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The *JMPT* is published as a print and online journal and thus takes more time to produce than if it were published online only. The benefit of having a journal that is both in print and online must be balanced with the need for timely publication. To improve our processes, we are instituting several mechanisms to reduce time to publication for the *JMPT*.

**Streamlining Through Electronic Processing**

Because we are dedicated to providing the most up-to-date scientific information for *JMPT* readers, we have instituted a new online manuscript submission and review process. Thus, we are no longer accepting manuscripts in paper format through the mail or by email. All submissions now go through the [www.mosby.com/JMPT](http://www.mosby.com/JMPT) web site (click on “Submit Manuscript”). This method of processing allows for timely manuscript handling and immediately dispenses with 1 month or more of added time related to mailing manuscripts, reviews, and correspondence by post.

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**Submission Prereview**

If a submission that does not belong in the journal enters the processing pipeline, it slows down manuscript processing for all other papers. Peer reviewers who review manuscripts that do not fit the mission of the journal or that do not conform to the instructions for authors may dedicate time reviewing projects that are not quite ready or inappropriate for the journal. This is not a good use of the talents of the reviewers and an inefficient way to run the journal. To ensure that only appropriate manuscripts are sent to *JMPT* reviewers, submitted manuscripts are prereviewed for relevance, appropriate submission format, and basic quality before sending out to peer review. Therefore, reasons for early rejection may include the following: the submission does not meet the requirements as stated in the instructions for authors, the work is of poor quality, or the topic is not relevant to the mission of the journal.

Once the decision that a manuscript is appropriate for submission has been made, it is then sent to peer review (a minimum of 2 reviewers for original research papers and most other paper categories). This process reduces the number of papers in the peer review pipeline, thus saving authors and reviewers time and anguish. Prescreening at submission dedicates time and resources to the manuscripts that fit the mission of the *JMPT* and ultimately speeds up processing.

**Publication Priority Hierarchy**

To decrease the time to publication for time-sensitive manuscripts and experimental research, a priority hierarchy is used to determine publication lineup. Manuscripts that rank higher on the hierarchy will be given higher priority and go to publication faster. Levels of evidence will be a primary factor in determining publication order. In addition to levels of evidence, potential impact on improving patient care will be considered. The decision for publication priority will be determined once a manuscript has been fully accepted and is made by the editor. This process will assist in getting manuscripts with greater impact to press more quickly.
RAPID REVIEW

We have instituted a rapid review process that speeds up the process of peer review and publication. Only manuscripts that are of very high quality and that have findings likely to affect practice immediately will be considered. Priority will be given to large clinical trials and meta-analyses.

Authors who feel that their research warrants rapid review should email the editor and submit justification regarding the merits of their manuscript to substantiate inclusion for rapid review. The editor of the JMPT will make the final decision regarding the suitability of a submission for rapid review and publication. If a manuscript is not accepted for rapid review, it may still be submitted through the regular submission process and timeline.

If a manuscript is accepted for rapid review, it will then be handled through an expedited peer review process for decision. The results may include acceptance, major revision, minor revision, or rejection. Inclusion in the rapid review process does not guarantee acceptance of the manuscript, neither does it promise rapid publication if accepted. Each decision and paper review will be done separately. All manuscripts that are selected for rapid review will be processed through full peer review.

The expedited review process will take approximately 15 business days. Authors will be notified about revisions no later than 5 weeks after manuscripts are initially received. Authors should return a revised manuscript within 2 weeks of notification. At this time, a decision will be made for acceptance or rejection. If the manuscript is accepted, it will be scheduled immediately for publication in the next available issue.

IN CONCLUSION

It is my hope that the procedures of electronic submission, submission prereview, publication priority hierarchy, and rapid review will continue to improve the quality and timeliness of manuscript publication for the JMPT. These processes and their results will be monitored and fine tuned as needed. Interestingly, we will only know if any of these processes make a difference once enough time has passed.
**Blood flow in the presence of posterior ponticles.**

Haynes et al (p. 323) present a pilot study in which they used Doppler ultrasound and magnetic resonance angiography to measure the amount of vertebral artery stenosis in patients with posterior ponticles.

**More than just back and neck pain.**

Leboeuf-Yde et al (p. 294) present findings from a variety of countries in which patients reported improvements of nonmusculoskeletal symptoms after chiropractic care.

**Compressive ulnar neuropathy at the elbow.**

Robertson and Saratsiotis (p. 345) provide a clinical review of the anatomy, etiology, and symptoms associated with compressive ulnar neuropathy at the elbow and discuss diagnosis and treatment of this condition.

**What do chiropractic students know about primary care?**

Sandefur et al (p. 336) compare the knowledge of primary care activities in a sample of chiropractic students with a sample of medical students.

**Can cervicothoracic angina be identified?**

Christensen et al (p. 303) complete a prospective trial to identify key factors in case history and palpation findings for identifying patients with musculoskeletal stable angina pectoris.

**Improving treatment outcomes in low back pain research?**

Kent et al (p. 312) provide findings that may help identify if clinician treatment choice influences the outcomes of randomized controlled trials of manual therapy for nonspecific low back pain.

**Continuing the vaccination debate.**

Busse et al (p. 367) offer a critical appraisal of common antivaccination arguments that are found in chiropractic and associated writings.

**Should we use plain films for pubic symphysis alignment?**

Ruch and Ruch (p. 330) perform an analysis of plain film radiography as a tool for measuring pubis symphysis misalignment.

**Potential contraindication with soft tissue calcification.**

Cagnie et al (p. 346) present a case report with abnormal findings in the course of the vertebral artery associated with an ossified hyoid apparatus and recommend caution when considering manipulation in these cases.

**Type II occipital-atlantoaxial rotatory subluxation.**

Tsai and Chou (p. 352) describe a case report of manipulation under anesthesia of a type II post-traumatic occipital-atlantoaxial rotatory subluxation in a 4-year-old girl.

**Do we have enough evidence?**

Budgell (p. 365) provides his insights into the current evidence base regarding the care of visceral conditions and offers some challenges to the research community.

**A model for presenting data.**

Evans (p. 374) proposes that survival analysis may offer an unambiguous method of presenting and comparing results of musculoskeletal therapy effectiveness studies.

**A patient presents with pain and dyspnea.**

Osterhouse et al (p. 356) provide a review of the clinical presentation, pathophysiology, and treatment options for patients with congestive heart failure.
Objective: To replicate a previous study of nonmusculoskeletal responses to chiropractic intervention and to establish whether such responses are influenced by the country of study, chiropractors’ attitudes, and information to patients, patients’ demographic profiles, and treatment regimens.

Methods: Information obtained through questionnaires by chiropractors and patients on return visit within 2 weeks of previous treatment from chiropractic practices in Canada, United States, Mexico, Hong-Kong, Japan, Australia, and South Africa. In all, 385 chiropractors collected valid data on 5607 patients. Spinal manipulation with or without additional therapy was the intervention provided by chiropractors. Outcome measures included self-reported improved non-musculoskeletal reactions (allergy, asthma, breathing, circulation, digestion, hearing, heart function, ringing in the ears, sinus problems, urination, and others).

Results: The results from the previous study were largely reproduced. Positive reactions were reported by 2% to 10% of all patients and by 3% to 27% of those who reported to have such problems. Most common were improved breathing (27%), digestion (26%), and circulation (21%). Some variables were identified that somewhat influenced the outcome: patients informed that such reactions may occur (odds ratio [OR] 1.5), treatment to the upper cervical spine (OR 1.4), treatment to lower thoracic spine (OR 1.3), and female sex (OR 1.3). However, these had a very small “explanatory” value (pseudo $R^2$ 3%).

Conclusion: A minority of patients with self-reported nonmusculoskeletal symptoms report definite improvement after chiropractic care, and very few report definite worsening. Future studies should use stringent criteria to investigate a possible treatment effect and concentrate on specific diagnostic subgroups such as digestive problems and tinnitus.

Key Indexing Terms: Chiropractic; Manipulation, Spinal; Visceral; Somatic; Survey

The possible link between spinal adjustments and changes in nonmusculoskeletal conditions has intrigued the chiropractic profession since the days of its founder, D.D. Palmer. Some have argued that spinal adjustments sometimes improve visceral conditions, whereas others claim that they only remove symptoms that mimic internal organ disease.

In a recent practice-based multicenter study, a pattern was identified of unexpected positive nonmusculoskeletal responses (N-MSRs) reported by patients after chiropractic
care. However, in that study, because there was no untreated control group, it was not possible to determine whether these responses were caused by the treatment, if they constituted mere signs of natural variation in the human physiology, or if they were figments of imagination.

To determine whether there is a causal link between the treatment and the symptom improvement, it would be necessary to conduct a number of randomized controlled trials. Such studies should include specific and valid outcome measures in relation to each N-MSR under scrutiny. This would be time consuming and expensive and not within the capability of most researchers at this time.

Therefore, to provide stronger data on the potential relationship between treatment and symptom improvement, a similar but expanded approach was taken to determine if the findings in the first study could be replicated in a much larger international sample. Additional objectives of the study were to establish whether N-MSRs were influenced by (a) the chiropractors’ attitudes to N-MSR and the information they gave to their patients on this subject, (b) patients’ demographic profiles (age, sex, education, and work status), and (c) treatment profiles (type of treatment provided, area treated, number of areas treated, and number of treatments over time).

**METHODS**

Through the initiative of an international chiropractic organization, the World Federation of Chiropractic, the means and manpower were made available to conduct an international multicenter study. The study design was nearly identical to the previous study except that it consisted of research teams from 7 different countries. A group of volunteer chiropractors (“research officers”) was selected, each to be responsible for 1 country (Hong-Kong, Japan, Mexico, South Africa, and United States) or for 1 study site (3 sites in Australia and 4 in Canada). In the end, 1 person from the Canadian Chiropractic Association assumed the task of collecting the data from the whole of Canada with each of the regions having a research officer.

Most of the research officers participated in 2 two-day workshops led by the chief investigator, one before the study commenced at which the research questions and study method were established, and the second before the data analysis commenced at which the strategy for data analysis was finalized and interpretation of potential study results was discussed.

Information to participants was standardized, and the data collection surveillance system was explained, systematized, and practiced as role play. A standard questionnaire was designed and translated into the relevant languages together with the information for all participants. The research officers were responsible for the translation and testing of these questionnaires.

The questionnaire consisted of 3 sections. The first part was filled out by the chiropractor with questions about his/her attitudes in relation to the importance of the “subluxation” and in relation to his/her information given to patients regarding N-MSRs. The second part was also filled out by the chiropractor relating to patients’ sex, age, reasons for current chiropractic management, present non-musculoskeletal complaints, time since last visit, number of visits over the last 3 months, patients’ use of medically prescribed drugs, types of care at last visit, and points of spinal contact at last visit. The third section was completed by the patient during the same visit and before the treatment was given and related to any changes in relation to a number of N-MSRs from the time of the last visit to the clinic until the present visit. The final 2 questions to the patient related to highest level of formal education and current employment status. A copy of the questionnaire is available from the first author on request.

Each research officer invited a number of chiropractors (“research aides”) in his country/area, who would supervise other chiropractors who then collected the data. If it was not possible to obtain a sufficient number of data-collecting chiropractors, the research aides themselves were, on their own or in collaboration with others, responsible for collecting the data. It was attempted to enlist 50 local chiropractors at each study site, each of whom would collect information on 10 to 20 patients. These chiropractors were selected on the basis of willingness to participate and constituted a convenience sample. Each research aide would be responsible for approximately 10 of these data-collecting chiropractors. The research officers at each site were responsible for the logistics of the study in their own country/area and reported back to the chief investigator who was responsible for the entire project. In the United States, data were collected using an already established practice-based research network with only 1 person being responsible for the logistics of the study.

The various research groups collected data at the different points in time, when each group had fulfilled their preliminary tasks, which included professional translation of questionnaires in non–English-speaking countries, recruitment and instruction of research assistants, and setting up a supervision system. The data were anonymous and therefore considered to be similar to a quality assurance project, with no need for acceptance from ethics committees or data registers.

The first project group delivered their data in September 2002 after having started in June, and the last group delivered their data in August 2003. The final number of research aides, data-collecting chiropractors, and patients collected per chiropractor differed from site to site, depending on the local resources.

Data in each country/research site were sent to the local research aides and then to the research officer who forwarded the collected material to the central office (chief
inclusion criteria for subjects in this study were that they were older than 18 years, understood the main language of the respective country, had received treatment within the immediate 2 weeks before being asked, and provided consent to participate in the study.

Analysis and Reporting of Data

Descriptive data were summarized for each variable for the entire sample and for each country. Estimates only, without confidence intervals (CIs), were used in the data presentation because of the large study sample. The proportion of patients who experienced N-MSRs was established for each nonmusculoskeletal condition (allergy, asthma, problems with breathing, circulation, digestion, hearing, heart, ringing in ears, sinus, urination, and vision). For analytical purposes, we categorized “definitely better” as a positive response, and all others, including “definitely worse,” “maybe worse,” no change,” “maybe better,” and “not relevant,” as negative. This division was selected to make the outcome measurement as stringent as possible in view of the imprecise method of data collection on this matter. In addition, the numbers of conditions reported as “definitely better” were added up for each individual to provide a sum variable with a possible range from 0 to 11. This variable was also dichotomized into “no definitely improved N-MSR” versus “at least 1 definitely improved N-MSR” and, in a post hoc analysis, dichotomized into “none or 1” versus “at least 2 definitely improved N-MSRs.”

Cross-tabulations were carried out on the entire study sample, studying the associations between the potential predictor variables and the dichotomized sum score for number of “definitely improved” N-MSR. In addition, a nested study was performed, including only those study subjects who were identified by their chiropractor as actually having a nonmusculoskeletal complaint. In this group, cross-tabulations were performed to investigate if specific treatment areas resulted in specific N-MSRs.

Despite the large study sample, the collected data were still considered to be rather imprecise. Nevertheless, because this report should be seen as hypothesis generating, we decided to report odds ratios (ORs) with their 95% CI, and P values were, generously, set at .05. However, the possibility of mass significance was considered in the data interpretation.

Finally, multivariable analyses were performed using a series of backward stepwise logistic regressions, including (a) dichotomized variables that were significantly associated with the outcome variable (≥2 N-MSR yes/no), (b) adding “research officer” as an independent variable, (c) controlling for the cluster effect in relation to treating chiropractor, and (d) controlling for the cluster effect of the “research officer.” This set of analyses was repeated, post hoc, using the ≥2 N-MSRs yes/no division. All analyses were performed using STATA 7 (Stata Corp, LP, College Station, Tex).

RESULTS

Participation in the Study

The number of chiropractors who collected data was 385, ranging from 15 in Hong Kong to 123 in Australia, and the number of patient questionnaires per country ranged from 276 in Hong Kong to 1855 in Australia. The total number of patient questionnaires returned to the central office was 6156, of which 549 were invalid mainly because they lacked information on the patients’ willingness to participate in the study, leaving 5607 for the analysis. The response rate could not be calculated because the numbers of chiropractors and patients who declined participation were not recorded.

Description of the Study Sample

Chiropractors. In all, 75% of the participating chiropractors believed that it was always or often “more important to correct a subluxation than to relieve a patient’s symptomatic complaint,” and 74% of chiropractors claimed to have—in the past 3 months—told all or most of their patients that “chiropractic adjustments might have nonmusculoskeletal effects on their bodies.” The same distribution of findings was noted when this variable was analyzed on the basis of patients. In other words, chiropractors with these characteristics had not provided a disproportionate number of patients for the study as compared with the others.

Patients. Overall descriptions of the patients (demography and complaints) and their treatment are found in Table 1A-C and briefly described below.

More than half of the patients in this study were women, in full-time employment or self-employed, and approximately four fifths were 25 to 64 years old, with an education ranging between high school and a bachelor’s degree (Table 1A).

The 2 most common reasons for the current chiropractic management were low back pain (60%) and neck problem (51%). The 2 least common reasons were “nonmusculoskeletal problem/type O оргanic” and dizziness (both 8%). The 3 most common nonmusculoskeletal complaints reported for patients by the chiropractor were problems with digestion (19%), problems with circulation (12%), and allergy (11%). The chiropractors reported that 69% of their patients took medically prescribed drugs (Table 1B).

Treatment. Over the past 3 months, 56% had attended 1 to 6 treatment visits, and the last visit took place within the past 8 days in three fourths of the patients (Table 1C). Four spinal areas were treated in at least half of the patients: These areas were, in order of frequency, occiput to C3, T1 to T6.
Outcome

When patients were asked if they had noticed any N-MSRs, most reported “not relevant” or “no change.” In all, 0.5% to 3% of all patients reported worsening (“definitely worse” or “maybe worse”), and 4% to 25% reported improvement (“definitely better” or “maybe better”) in relation to specific nonmusculoskeletal complaints. Patients not identified as having symptoms of nonmusculoskeletal complaints also reported changes in these conditions. Among those who were already known to have a musculoskeletal problem, 1% to 6% reported some degree of worsening, whereas 9% to 56% reported some degree of improvement, again in relation to specific nonmusculoskeletal complaints.

Improvement, in the remainder of the report, is defined as “definitely better” and ranged from 2% to 10%, for the whole study sample. Higher rates of improvement (3%-27%) were found among patients who initially were reported to have nonmusculoskeletal complaints (Table 2). Only a few patients (never exceeding 2%) reported becoming “definitely worse,” regardless of whether they initially reported symptoms.

Factors That May Explain Differences in the Reporting of Favorable Outcome

Country. The pattern of reported N-MSRs was similar across countries, when all patients were studied (Table 3). In the

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Table 1. Overall description of the participating patients (continued)

<table>
<thead>
<tr>
<th>C. Treatment pattern in % (n = 5607).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days since last treatment visit</td>
</tr>
<tr>
<td>0</td>
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<td>1</td>
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<td>2</td>
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<td>11</td>
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<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
</tbody>
</table>

---

Table 1.

A. Demographic description of all patients (%) (n = 5607).

| Sex | Male | 38 |
| Female | 60 |
| Missing | 2 |
| Age (y) | 18-24 | 9 |
| 25-44 | 43 |
| 45-64 | 36 |
| 65+ | 9 |
| Missing | 3 |

B. Description of patient complaints (reasons for current chiropractic management, any current nonmusculoskeletal problems) and any medically prescribed drugs presently taken by the patient (%) (n = 5607).

<table>
<thead>
<tr>
<th>Main reason for consultation (&gt;1 reply possible)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>29</td>
</tr>
<tr>
<td>Dizziness</td>
<td>8</td>
</tr>
<tr>
<td>Neck problem</td>
<td>51</td>
</tr>
<tr>
<td>Arm problem</td>
<td>12</td>
</tr>
<tr>
<td>Midback problem</td>
<td>30</td>
</tr>
<tr>
<td>Low back problem</td>
<td>60</td>
</tr>
<tr>
<td>Sciatica</td>
<td>16</td>
</tr>
<tr>
<td>Shoulder problem</td>
<td>21</td>
</tr>
<tr>
<td>Pelvic/Hip problem</td>
<td>23</td>
</tr>
<tr>
<td>Other extremity</td>
<td>12</td>
</tr>
<tr>
<td>Nonmusculoskeletal problem</td>
<td>8</td>
</tr>
<tr>
<td>Maintenance/wellness</td>
<td>16</td>
</tr>
<tr>
<td>Subluxation correction/management</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nonmusculoskeletal problems (&gt;1 reply possible)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Allergies</td>
<td>11</td>
</tr>
<tr>
<td>Asthma</td>
<td>5</td>
</tr>
<tr>
<td>Breathing</td>
<td>8</td>
</tr>
<tr>
<td>Circulation</td>
<td>12</td>
</tr>
<tr>
<td>Digestion</td>
<td>19</td>
</tr>
<tr>
<td>Hearing</td>
<td>4</td>
</tr>
<tr>
<td>Heart function</td>
<td>4</td>
</tr>
<tr>
<td>Ringing in the ears</td>
<td>5</td>
</tr>
<tr>
<td>Sinus problems</td>
<td>10</td>
</tr>
<tr>
<td>Urination</td>
<td>4</td>
</tr>
<tr>
<td>Vision</td>
<td>9</td>
</tr>
<tr>
<td>Drugs</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>69</td>
</tr>
<tr>
<td>No</td>
<td>27</td>
</tr>
<tr>
<td>Don’t know</td>
<td>4</td>
</tr>
</tbody>
</table>
much smaller group with previously reported nonmusculoskeletal symptoms, the pattern was more heterogeneous between countries. However, in many instances, the denominator (the number of patients who initially reported a complaint) was too small to produce meaningful information. Therefore, further analysis of these subgroups is not possible.

**Chiropractor.** At least 1 N-MSR was reported significantly more often by patients whose chiropractor believed it to be always/often (vs sometimes/never) more important to correct a subluxation than to relieve a patient’s symptomatic complaint (27% vs 19%). The OR was 1.5 (95% CI 1.3-1.8). This was also the case in patients whose chiropractors told all/most (vs some/none) of their patients that N-MSRs were possible (29% vs 18%; OR 1.8, 95% CI 1.6-2.1).

**Patient.** It was more common for women (28%) than for men (21%) to report at least 1 N-MSR (OR 1.4, 95% CI 1.2-1.6), but there were no significant differences in relation to age, type of education, or current work status. However, when the actual number of N-MSRs was taken into account (range 0-11), significant differences were found for work status ($P = .000$). A closer look at the spread of these data revealed no discernable pattern, and this information was therefore disregarded as being clinically irrelevant.

**Treatment.** There were no significant differences in the reporting of at least 1 N-MSR in relation to the number of areas treated, nor in relation to whether patients were treated with traditional adjustments, mechanically assisted adjustments, with mobilization, soft tissue treatment, or other methods. In relation to the number of visits over the past 3 months, a stepwise increase in the number of patients reporting at least 1 N-MSR was noted going from 14% (for 1 visit), 22% (for 2-3 visits), and 26% (for 4-11 visits) to 31% (for at least 12 visits) ($P = .000$). However, the number of reactions per patient did not increase with the number of visits.

Differences in outcomes were noted also in relation to the area treated. The upper cervical spine was most often associated with specific N-MSRs ($n = 4$), followed by the upper and lower thoracic regions ($n = 2$) and the pelvic/sacrum/coccyx area ($n = 1$) (Table 4). With 77 statistical tests performed in this part of the analysis and the $P$ value set at .05, several chance findings would be expected. According to the Bonferroni method to control for mass

| Table 2. Patients reporting definite improvement and definite worsening for each nonmusculoskeletal complaint, (a) in all patients ($n = 5607$) and (b) in patients who initially reported to have a nonmusculoskeletal complaint |
|---------------------------------|------------------|------------------|
| Nonmusculoskeletal complaint    | Definitely better (%) | Definitely worse (%) |
| | N = 5607 | (n for each complaint) | N = 5607 | (n for each complaint) |
| Allergies                       | 3 | 11 (638) | 2 (638) |
| Asthma                          | 2 | 17 (293) | 2 (293) |
| Breathing                       | 6 | 27 (460) | 1 (460) |
| Circulation                     | 10 | 21 (660) | 1 (660) |
| Digestion                       | 10 | 26 (1058) | 1 (1058) |
| Hearing                         | 2 | 13 (245) | 2 (245) |
| Heart function                  | 2 | 11 (244) | 1 (244) |
| Ringing in ears                 | 3 | 19 (312) | 1 (312) |
| Sinus problems                  | 3 | 3 (551) | 1 (551) |
| Urination                       | 6 | 10 (235) | 1 (235) |
| Vision                          | 3 | 13 (326) | 1 (326) |

| Table 3. Patients in each country reporting nonmusculoskeletal symptoms to be definitely better (%) |
|---------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
|                               | All patients     | Canada           | United States    | Mexico           | South Africa     | Australia        | Japan            | Hong Kong        |
| n                               | 5607             | 1375             | 339              | 744              | 459             | 1855            | 498             | 276             |
| Allergies                       | 3                | 3                | 4                | 5                | 1               | 3               | 1               | 2               |
| Asthma                          | 2                | 2                | 1                | 1                | 1               | 2               | 1               | 1               |
| Breathing                       | 6                | 8                | 4                | 11               | 4               | 7               | 3               | 4               |
| Circulation                     | 10               | 14               | 9                | 8                | 7               | 10              | 5               | 8               |
| Digestion                       | 10               | 11               | 7                | 16               | 8               | 10              | 8               | 4               |
| Hearing                         | 2                | 2                | <1               | 6                | 1               | 1               | 0               | 0               |
| Heart function                  | 2                | 3                | 1                | 4                | 1               | 2               | 2               | 1               |
| Ringing in ears                 | 3                | 3                | 2                | 4                | 3               | 3               | 3               | 1               |
| Sinus problems                  | 3                | 3                | 1                | 5                | 2               | 3               | 2               | 3               |
| Urination                       | 6                | 8                | 6                | 1                | 7               | 7               | 1               | 1               |
| Vision                          | 3                | 3                | 1                | 3                | 2               | 3               | 4               | 1               |
significance, statistical significance should therefore be set at <.0006 (.05 divided by the number of tests). None of the associations approached this stringent level.

There was considerable overlapping of treatment areas, so that patients who received treatment in 1 spinal region also received treatment in other areas. Unfortunately, there were too few patients who received single-area treatments only, which made it impossible to study the effect of treatment in specific anatomical areas.

**Multivariable analyses.** Multivariable analysis revealed weak ORs for those variables that remained in the model (female sex, chiropractor informs patient that a N-MSR is likely, larger number of treatment visits over the past 3 months, treatment of occiput to C3, and treatment of T1 to T6). These variables were found to “explain” altogether only a small proportion of the outcome, approximately 3%, with weak ORs, ranging from 1.1 to 1.5. Treatment of C4 to C7, T7 to T12, L1 to L5, the pelvic area, and “other treatment” failed to remain in the model.

Adding “research officer” to the model did not result in any obvious changes to the results nor did the extended model including a cluster control for “treating chiropractor.” However, when the first model was controlled for the potential cluster effect of “research officer,” 1 variable emerged (a borderline negative association between treatment of L1 to L5 and the outcome variable) (Table 5). The estimates were not obviously altered in the post hoc analysis, in which the cut point was set at 2 N-MSRs instead of at 1 N-MSR.

The number of patients who reported definite adverse reactions was too small to allow for any meaningful analysis.

**Answers to the Research Questions**

**Were the findings in the Swedish study replicated in the present study?**

As can be seen in Table 6, patients in both studies most often reported improved digestion (8% and 10%, respectively, in all patients). Seven percent of the Swedish patients versus 6% in the present study reported their breathing to be improved. However, both improved circulation (10%) and urination (6%) were more commonly reported in the present study than in the Swedish study (observed to be 2% in both cases). The results in the 2 studies were similar in relation to the paucity of reported improvement in relation to asthma, hearing, heart function, ringing in the ears, and vision. Thus, in relation to the 9 items that were tested in both studies, there was approximate agreement on 7.

In the Swedish study, there was a positive gradient for the number of reactions per patient in relation to the number of spinal areas treated, but no such pattern was found in the present study. Nonetheless, according to our study, there was a gradual increase in the number of reactions per patient in relation to the number of visits over the past 3 months. Thus, some type of dose-response was found in both studies.

**Were the findings similar across the participating countries?**
The outcome pattern was similar across countries, when all patients were studied (Table 3). The numbers of patients with known nonmusculoskeletal disorders were generally too small in the individual countries for statistical analysis.

**Were the findings affected by the chiropractors attitudes and information?** According to the final multivariable analysis, it would be somewhat easier to obtain reports of N-MSRs, if patients are informed that these are likely to occur. The OR was 1.5 (95% CI 1.2-1.9), and it was the strongest factor of those that remained in the final model.

**Were the findings affected by patients demographic background?** According to the final multivariable analysis, it was somewhat more common in women than in men to report at least 1 positive N-MSR, OR 1.3 (95% CI 1.1-1.5), whereas, for example, the level of education did not account for any of the difference.

**Were the findings affected by the treatment?** Treatment to the upper cervical spine and treatment to the upper half of the thoracic spine both resulted in relatively weak positive associations with reports of N-MSRs. The ORs were 1.4

---

### Table 4. Associations between area treated and positive nonmusculoskeletal reports (N-MSR) (n = 5607)

<table>
<thead>
<tr>
<th>Area treated</th>
<th>N-MSR</th>
<th>OR (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occiput-C3</td>
<td>Allergy</td>
<td>2.6 (1.4-5.0)</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td>Digestion</td>
<td>1.4 (1.0-1.9)</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>Hearing</td>
<td>3.8 (1.3-11.3)</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>Urination</td>
<td>4.1 (1.2-21.0)</td>
<td>.017</td>
</tr>
<tr>
<td>C4-C7 (including ribs)</td>
<td>None</td>
<td>1.7 (1.0-3.7)</td>
<td>.03</td>
</tr>
<tr>
<td>T7-T12 (including ribs)</td>
<td>Circulation</td>
<td>1.7 (1.2-2.6)</td>
<td>.007</td>
</tr>
<tr>
<td></td>
<td>Circulation</td>
<td>1.5 (1.0-2.2)</td>
<td>.031</td>
</tr>
<tr>
<td>L1-L5</td>
<td>Sinus</td>
<td>3.7 (1.4-10.0)</td>
<td>.005</td>
</tr>
<tr>
<td>Pelvis/sacrum/coccyx</td>
<td>Sinus</td>
<td>5.3 (1.2-23.3)</td>
<td>.013</td>
</tr>
</tbody>
</table>

---

### Table 5. Results of logistic regression, taking into account the possible clustering effect due to the research officers’ choice of participants (n = 5299)

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (female)</td>
<td>1.3</td>
<td>1.1-1.5</td>
</tr>
<tr>
<td>Subluxation important</td>
<td>1.3</td>
<td>0.9-1.8</td>
</tr>
<tr>
<td>N-MSRs likely</td>
<td>1.5</td>
<td>1.2-1.9</td>
</tr>
<tr>
<td>No. of visits last 3 mo*</td>
<td>1.1</td>
<td>1.1-1.2</td>
</tr>
<tr>
<td>Treatment occiput-C3</td>
<td>1.4</td>
<td>1.2-1.6</td>
</tr>
<tr>
<td>Treatment C4-C7</td>
<td>1.1</td>
<td>0.9-1.2</td>
</tr>
<tr>
<td>Treatment T1-T6</td>
<td>1.3</td>
<td>1.1-1.6</td>
</tr>
<tr>
<td>Treatment T7-T12</td>
<td>1.0</td>
<td>0.9-1.1</td>
</tr>
<tr>
<td>Treatment L1-L5</td>
<td>0.9</td>
<td>0.8-1.0</td>
</tr>
<tr>
<td>Treatment pelvis/sacrum/coccyx</td>
<td>2.0</td>
<td>0.8-1.2</td>
</tr>
<tr>
<td>Treatment other area</td>
<td>1.1</td>
<td>0.9-1.3</td>
</tr>
</tbody>
</table>

* Four categories, treated as a continuous variable in the analysis.
Table 6. Patients who reported positive nonmusculoskeletal reactions after chiropractic care in patients with or without known nonmusculoskeletal problems, in 2 different studies (%)

<table>
<thead>
<tr>
<th>Nonmusculoskeletal problem</th>
<th>Swedish study (N = 1506)</th>
<th>Present study (N = 5607)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allergy</td>
<td>*</td>
<td>3</td>
</tr>
<tr>
<td>Asthma</td>
<td>&lt;1</td>
<td>2</td>
</tr>
<tr>
<td>Breathing</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Circulation</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Digestion</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Hearing</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Heart function</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ringing in ears</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Sinus</td>
<td>*</td>
<td>3</td>
</tr>
<tr>
<td>Urination</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Vision</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

* No data available.

(95% CI 1.2-1.6) and 1.3 (95% CI 1.1-1.6), respectively. Moreover, the number of visits to the chiropractor over the last 3 months (as reported above) had a weak influence on the outcome, OR 1.1 (95% CI 1.1-1.2). However, the type of treatment, such as adjustment or mobilization, did not matter.

DISCUSSION

The reaction pattern in our international study was found to be similar across countries, and this pattern, in turn, was similar to the one identified in the previous Swedish study. These observations indicate either (1) that this is indeed a typical pattern of treatment effect that can be observed in chiropractic practice, (2) that this is how nonmuscular symptoms fluctuate as a function of being under care but not as a direct effect of care, (3) that this is how they fluctuate because they are under observation, or (4) that this is simply how nonmuscular symptoms fluctuate in the general population.

Furthermore, a number of variables were identified that may have an effect on the reporting of N-MSRs, although these “explained” an exceedingly small part of the variation (only 3%). These variables were, for example, sex and the spinal area treated. The ORs for reporting improved digestion, allergy, hearing, or urination ranged between 1.4 and 4.1 (Table 4) in patients treated (at least) in occiput to C3 versus those treated in any other area(s). It was also more likely that patients treated in the upper half of the thoracic spine reported improved symptoms in breathing and circulation (both ORs 1.7). Whether the latter reports actually describe N-MSRs as opposed to purely somatic symptoms is, however, uncertain. Problems with breathing, such as pain on inspiration, could be purely mechanical, and symptoms of diminished circulation are seen to occur with radicular problems of the upper limbs, commonly treated in the thoracocervical regions. Because most patients were treated in several spinal areas, it was impossible to investigate the outcome pattern for specific spinal areas in relation to specific conditions, such as the upper thoracic spine and hearing, as described by D.D. Palmer.

Patients who attended a larger number of visits over the past month were also more likely to report at least 1 N-MSR. There are 3 possible reasons for this: (1) several visits are likely to provide the chiropractor with more opportunities to influence the patient mentally, (2) several treatments may be needed to produce a physiological effect, and (3) a larger number of visits occur over a longer duration, giving a greater chance for nonmusculoskeletal symptoms to fluctuate spontaneously, as previously suggested.

Interestingly, in the multivariable analysis, the effect of “the number of visits”—variable on the reporting of N-MSRs—was not dependent on the 2 chiropractor-specific variables (“subluxation is important” and “information to patients that N-MSRs are likely to occur”). This indicates that the response observed in relation to the number of visits was not directly related to the amount of information received. Further data interpretation fails to strengthen the second possibility because the number of spinal areas treated is unrelated to the reporting of N-MSRs (contrary to the Swedish study). No conclusions can therefore be drawn on this issue.

Other variables examined in this study did not have an effect on the reported outcome. These variables were level of education, type of work, and type of treatment. The latter finding is interesting in that it shows that classical “spinal adjustments” are no more likely to be associated with N-MSRs than, for example, mobilization. The fact that there is no difference between treatment methods tends to weaken the “treatment effect” explanation and strengthens the alternative explanations as described above.

If we assume that all patients, identified in the study to have a nonmusculoskeletal problem, were able to accurately identify specific N-MSRs and if we also assume that those who reported a change in status did so as a result of the treatment, approximately one quarter of patients with breathing or digestive problems became definitely better, whereas only 1% became “definitely worse.” Approximately one fifth of those with circulation problems, ringing in the ears, or asthma reported definite improvement, and 2% or less became “definitely worse.” The proportions of definitely improved patients were approximately 10% or less for the other conditions studied in this study, with “definite” negative side effects never exceeding 2% (Table 2). If these assumptions are correct, it appears that chiropractic care for this type of conditions is only weakly to moderately successful but, at least, rarely harmful.

When interpreting the results of this study, it is important to keep in mind its weaknesses, including the potential for sampling bias (both of chiropractors and of patients),
uncertainty surrounding patients’ recall ability, problems with accurate description of variables in the questionnaire, and patients’ understanding of these, expectation bias that may have arisen before meeting the present chiropractor, and the possibility that N-MSRs may be missed if they require more than 2 weeks to manifest themselves or if patients are unable to identify these themselves. Another obvious limitation is the absence of a control group to compare the results against, which would be necessary to investigate treatment effects. It is therefore not possible to establish whether patients improved (or worsened) because of the treatment, despite the treatment or regardless of the treatment.

On the other hand, practice-based research is more likely to reflect everyday clinical practice than the procedures used and results obtained in “gold standard”-controlled clinical trials, in which highly selected clinicians and patients participate. Furthermore, the methodology adopted in this study makes it possible to obtain a large sample size at a relatively low cost, which allows for meaningful subanalysis through the use of internal control groups. This made it possible for us to test the influence of various factors that could be suspected to influence treatment outcome. These include information to patients regarding nonmusculoskeletal benefits of chiropractic care and the type and area of treatment.

An important quality issue in this type of study, with volunteer participants, is that of the study’s external validity. Our study participants consisted of a large proportion of chiropractors who believed firmly in the subluxation and in N-MSRs. It is not known if they are representative of the general chiropractic population. In fact, it is possible that chiropractors who elected to participate in this study were proponents of the concept under scrutiny. In a previous study of selected clinicians, the percentage of patients consulting their chiropractor for a nonmusculoskeletal complaint (10%) was approximately the same as in the present study (8%). A previous Australian practice-based study noted a change in digestive symptoms similar to our results. Furthermore, the fact that the outcome pattern in our study was so similar to that of the previous Swedish study, which was carried out among chiropractors generally without strong convictions concerning nonmusculoskeletal effects, is yet another argument in favor of the possibility that the patient profile in relation to N-MSRs is largely unaffected by the chiropractors’ beliefs and attitudes.

An additional method to investigate the external validity in studies in which particular characteristics of some clinicians can result in a nonrandom aggregation of patients with particular features is to control statistically for the “clustering effect.” In our study, such clustering effect could arise as a result of the research officers’ choice of participating chiropractors and also because of the individual chiropractors’ selection of patients. According to our results, the variable “treating chiropractor” did not remove any of the previously noted associations with the outcome variable, but the variable “research officer” did have the effect of removing the link between “subluxation” and the outcome variable. This means that at least some research officers invited chiropractic participants who were similar in their beliefs on the subluxation issue.

CONCLUSIONS

The findings in the present study were largely similar to those of the previous Swedish study. A minority of patients with self-reported nonmusculoskeletal symptoms report definite improvement after chiropractic care, and very few report definite worsening. Some factors relating to the chiropractor, the treatment, and the patient were found to be weakly associated with the outcome but these factors “explained” only a small fraction, approximately 3%, of the variance.

It is recommended that further research in this area would concentrate on specific disorders that are most likely to produce positive results, such as specifically identified subgroups of digestive problems or tinnitus, and that such research, whether purely experimental or clinical, use stringent research criteria such as random allocation, objective measurements, sham treatment, and observer blindness.

ACKNOWLEDGMENTS

The authors thank the chiropractors and patients throughout the world for their participation in this study. The authors acknowledge the administrative assistance provided by the World Federation of Chiropractic Canada and the Foundation for Chiropractic Education and Research, Dr Brian Budgell (Kyoto University, Japan) for editorial assistance, Ms Lien Ho (Canadian Chiropractic Association) for administrative assistance, Ms Karin Boulanger and Ms Lori Byrd for design and execution of the US branch of the study, and Dr Anthony Rosner (director of Research and Education, FCER) for his editorial comments.

REFERENCES


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**Sample mailing label**

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<th>This is your subscription account number</th>
<th>3-DIGIT 001</th>
</tr>
</thead>
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<td></td>
</tr>
<tr>
<td>J. H. DOE, MD</td>
<td></td>
</tr>
<tr>
<td>531 MAIN ST</td>
<td></td>
</tr>
<tr>
<td>CENTER CITY, NY 10001-001</td>
<td></td>
</tr>
</tbody>
</table>

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CERVICOTHORACIC ANGINA IDENTIFIED BY CASE HISTORY AND PALPATION FINDINGS IN PATIENTS WITH STABLE ANGINA PECTORIS

Henrik Wulff Christensen, DC, MD,a Werner Vach, PhD,b Anthony Gichangi, MSc,c Claus Manniche, MD, DMSca, Torben Haghfelt, MD, DMS cancel, and Poul Flemming HøiLund-Carlsen, MD, DMSc

ABSTRACT

Objective: To investigate the decision-making process of an experienced chiropractor in diagnosing noncardiac musculoskeletal chest pain of cervicothoracic angina in patients with stable angina pectoris, based on patient history and clinical examination. Secondly, to examine the possibility of obtaining an objective diagnostic rule tool for the identification of cervicothoracic angina and to validate the diagnosis of this disorder.

Methods: A nonrandomized prospective trial was performed at a university hospital. A total of 516 of 972 consecutive patients referred for coronary angiography because of known or suspected angina pectoris were asked to participate in the study. Of these, 275 gave informed consent to a standardized manual examination of their spine and thorax. Diagnoses of an experienced chiropractor on cervicothoracic angina patients. Myocardial perfusion imaging and coronary angiography were used for validation. A set of candidate variables from patient history and clinical examination were tested for their role in the decision-making process.

Results: Eighteen percent of the patients were diagnosed with cervicothoracic angina. Of these, 80% had normal myocardial perfusion compared to 50% of cervicothoracic angina–negative patients. The main determinants of the decision-making process could be identified.

Conclusion: An experienced chiropractor could identify a subset of patients with angina pectoris as having cervicothoracic angina. Systematic manual palpation of the spine and thorax could be used as part of the clinical examination together with basic cardiological variables to screen patients with chest pain allowing for improvements in referral patterns for specialist opinion or angiography. (J Manipulative Physiol Ther 2005;28:303-311)

Key Indexing Terms: Angina Pectoris; Chiropractic; Decision Making

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According to current guidelines, angina pectoris (AP) is “[a] clinical syndrome characterized by discomfort in the chest, jaw, shoulder, back, or arm. It is typically aggravated by exertion or emotional stress and relieved by rest or nitroglycerin.” The term angina pectoris is usually confined to cases in whom the syndrome can be attributed to myocardial ischemia, although essentially similar symptoms can be caused by disorders of the esophagus, lungs, or musculoskeletal system. Reports suggest that about 50% of patients with chest pain and a negative coronary angiography (CAG) have esophageal reflux or motility disorder, and that 60% have evidence of breathing disorders and/or psychological abnormalities.

Chest wall tenderness has been observed in 69% of patients undergoing CAG. However, because of overlap of possible causes and lack of a generally accepted examination protocol, the diagnosis of musculoskeletal chest pain can be difficult to establish as can the concept of cause and effect when searching for an explanation of chest pain. Our group has previously reported on a standardized clinical examination protocol, including palpation of the cervical...
and thoracic spine, the chest wall, and thoracic paraspinal area, to assist in reaching a diagnosis of noncardiac chest pain originating from the musculoskeletal system.\textsuperscript{10,11} Up to 30\% of all patients catheterized for the investigation of chest pain have normal coronary anatomy.\textsuperscript{3} About three quarters of the patients continue to have residual chest pain with large socioeconomic consequences.\textsuperscript{3,12-15} Therefore, a search should be made for an alternative cause with related possibilities of treatment.

In the present investigation, this protocol, together with a detailed case history, was applied by an experienced chiropractor in patients with stable AP to diagnose cervicothoracic angina (CTA) (ie, chest discomfort originating from the cervical spine and the thorax). The aim was to investigate the decision-making process of the chiropractor and to identify the most important determinants from the patient history and clinical examination. In addition, we investigated the possibility of obtaining an objective and diagnostic rule tool for early identification of CTA in the clinical setting. Finally, we tested the validity of the chiropractor’s diagnosis.

\textbf{METHODS}

\textbf{Study Population}

This study was conducted as a substudy of the Myocardial Ischemic Logistic Evaluation Study (MILES) project,\textsuperscript{16} the objective of which was to compare the results of myocardial perfusion imaging (MPI) and CAG in a prospective series of patients referred to a tertiary hospital for CAG because of known or suspected stable AP. A total of 516 of 972 consecutive patients participated in the MILES study. This initial selection was made from the referral letter based on predetermined exclusion criteria ensuring a fairly well-defined population without too many concurrent diseases. Important exclusion criteria were age greater than 75 years, diabetes mellitus, accelerated catheterization, recent acute myocardial infarction, and ischemic heart disease already known to the cardiology department. All patients in the MILES study were interviewed and invited to participate in the present study. This study was approved by the local ethics review committee.

Of the 516 patients approached, 275 were included upon written consent. Patients who gave no written consent, had lack of compliance, previous thoracic surgery, no self-reported chest pain, inflammatory joint disease, malignant disease, apoplexia, and others were excluded from participating. As a result, 241 patients met one or more exclusion criteria and were not included in this study (Table 1). Baseline characteristics of the CTA population are shown in Table 2.

<table>
<thead>
<tr>
<th>Table 1. Exclusion criteria and their frequencies in 241 patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exclusion criteria</strong></td>
</tr>
<tr>
<td>Lack of compliance (withdrawal before the FUMU program)</td>
</tr>
<tr>
<td>No written consent</td>
</tr>
<tr>
<td>Previous surgery to the thorax</td>
</tr>
<tr>
<td>No self-reported chest pain, neck pain, or thoracic spinal pain</td>
</tr>
<tr>
<td>Inflammatory joint disease</td>
</tr>
<tr>
<td>Malignant disease</td>
</tr>
<tr>
<td>Apoplexia</td>
</tr>
<tr>
<td>Others</td>
</tr>
</tbody>
</table>

Some patients fulfilled more than 1 criterion.

\textbf{Patient Evaluation}

Each patient underwent the following procedures on a single day: (1) completion of questionnaires on health history, quality of life, and chest discomfort; and (2) case history and physical examination by a single physician. Patients were classified by the physician into 3 types of chest pain: typical angina, atypical angina, or noncardiac chest pain in accordance with the Danish guidelines\textsuperscript{17} and Diamond and Forrester.\textsuperscript{18} The physician also classified patients’ chest pain into 4 classes of severity according to the criteria given by the Canadian Cardiovascular Society (CCS).\textsuperscript{19} Consistent with the MILES study, MPI was carried out in all patients on the same day as the clinical examination, and CAG was undertaken in 262 patients within 6 months after MPI. The results of MPI were not communicated.

\textbf{Questionnaires}

All patients were given 2 sets of questionnaires by a laboratory technician not participating in the study including the SF-36 quality-of-life questionnaire\textsuperscript{20} and a questionnaire with intensity grading on an 11-point box scale\textsuperscript{21} of chest pain, thoracic spine pain, cervical spine pain, and shoulder arm pain. The questionnaires were filled out before the interview and physical examination, and returned to the laboratory technician.

\textbf{Physical Examination}

An experienced chiropractor (HWC) interviewed all patients using structured questionnaires throughout the study. The standardized examination protocol for the cervical spine and thorax was carried out as previously described.\textsuperscript{10,11} The following procedures were performed: (1) sitting motion palpation (MP) for end-play restriction at segments C4-T8 of the cervical and thoracic spine; (2) sitting palpation for tenderness of the anterior chest wall; (3) prone MP for joint-play restriction at segments T1-T8 of the spine; and (4) prone paraspinal palpation for tenderness at segments T1-T8.

\textbf{Myocardial Perfusion Imaging}

Single-photon emission computed tomographic imaging was performed using a same-day rest thallium-201/stress
technetium-99m sestamibi dual-isotope protocol initially introduced by Berman et al\textsuperscript{22} and adopted by our group as previously described for a 2-day protocol.\textsuperscript{23} Standard procedures for image interpretation included review of all scans by 2 experienced observers who were blinded to all other data including the result of CAG. Final segmental and overall image interpretation was achieved by consensus. Defects that were present at rest and remained unchanged during stress were considered as fixed. The appearance of new or worsening defects after stress was considered to be defect reversibility. The segmental scoring system used for this analysis included documentation of infarct (ie, fixed defects) or ischemia (ie, reversible or partially reversible defects) in the 3 main vascular territories.

**Coronary Angiography**

Selective coronary angiography was performed according to Judgkin using standard techniques in multiple views. For the purpose of this study, significant coronary stenoses were those with greater than or equal to 50% luminal diameter narrowing of an epicardial coronary artery.

### Table 2. Patient characteristics, medication, and results of myocardial perfusion imaging and coronary angiography

<table>
<thead>
<tr>
<th></th>
<th>CTA total (N = 275)</th>
<th>CTA positive (N = 50)</th>
<th>CTA negative (N = 225)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td>56.31 (9.26)</td>
<td>50.36 (9.14)</td>
<td>57.63 (8.78)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>81.24 (15.58)</td>
<td>82.02 (20.18)</td>
<td>81.08 (14.43)</td>
<td>.899</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.43 (12.50)</td>
<td>170.84 (18.68)</td>
<td>171.56 (10.74)</td>
<td>.765</td>
</tr>
<tr>
<td>BMI</td>
<td>27.08 (3.81)</td>
<td>26.39 (3.46)</td>
<td>27.22 (3.87)</td>
<td>.262</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>141.17 (16.64)</td>
<td>136.76 (17.81)</td>
<td>142.15 (6.25)</td>
<td>.009</td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>85.57 (9.12)</td>
<td>83.24 (7.90)</td>
<td>86.08 (9.32)</td>
<td>.025</td>
</tr>
<tr>
<td>Sex, % female</td>
<td>n = 104 (38%)</td>
<td>n = 22 (44%)</td>
<td>n = 82 (36%)</td>
<td>.337</td>
</tr>
<tr>
<td>Referred from GP</td>
<td>n = 135 (49%)</td>
<td>n = 38 (76%)</td>
<td>n = 97 (43%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>Medication</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>β-Blocker</td>
<td>n = 115 (42%)</td>
<td>n = 10 (20%)</td>
<td>n = 105 (47%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Ca\textsuperscript{2+}-antagonist</td>
<td>n = 64 (23%)</td>
<td>n = 7 (14%)</td>
<td>n = 57 (25%)</td>
<td>.998</td>
</tr>
<tr>
<td>ACE inhibitor</td>
<td>n = 40 (15%)</td>
<td>n = 2 (4%)</td>
<td>n = 38 (17%)</td>
<td>.015</td>
</tr>
<tr>
<td>Short-acting nitrates</td>
<td>n = 68 (25%)</td>
<td>n = 4 (8%)</td>
<td>n = 64 (28%)</td>
<td>.002</td>
</tr>
<tr>
<td>Long-lasting nitrates</td>
<td>n = 36 (13%)</td>
<td>n = 0 (0%)</td>
<td>n = 36 (16%)</td>
<td>.001</td>
</tr>
<tr>
<td>Magnyl</td>
<td>n = 157 (57%)</td>
<td>n = 15 (30%)</td>
<td>n = 142 (63%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Anticholesterol</td>
<td>n = 78 (28%)</td>
<td>n = 4 (8%)</td>
<td>n = 34 (33%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>Perfusion imaging</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>n = 151 (56%)</td>
<td>n = 40 (80%)</td>
<td>n = 111 (50%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Partially reversible defects</td>
<td>n = 33 (12%)</td>
<td>n = 1 (2%)</td>
<td>n = 32 (14%)</td>
<td></td>
</tr>
<tr>
<td>Reversable defects</td>
<td>n = 63 (23%)</td>
<td>n = 4 (8%)</td>
<td>n = 59 (27%)</td>
<td></td>
</tr>
<tr>
<td>Fixed defects</td>
<td>n = 25 (9%)</td>
<td>n = 5 (10%)</td>
<td>n = 20 (9%)</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Coronary angiography</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>n = 152 (59%)</td>
<td>n = 40 (91%)</td>
<td>n = 112 (52%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>1-vessel disease</td>
<td>n = 42 (16%)</td>
<td>n = 2 (5%)</td>
<td>n = 40 (19%)</td>
<td></td>
</tr>
<tr>
<td>2-vessel disease</td>
<td>n = 34 (13%)</td>
<td>n = 1 (2%)</td>
<td>n = 33 (15%)</td>
<td></td>
</tr>
<tr>
<td>3-vessel disease</td>
<td>n = 31 (12%)</td>
<td>n = 1 (2%)</td>
<td>n = 30 (14%)</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>16</td>
<td>6</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

BMI, Body mass index; BP, blood pressure; GP, general practice. Data are expressed as mean values (SD).

Clinical Decision-Making Process

The chiropractor was blind to the results of MPI and CAG. The case history and clinical examination were the basis for a decision made on the examination day of whether the patients were CTA-positive or CTA-negative.

Data Analysis

Before the analysis of the clinical data, we selected a number of candidate variables (Table 3) which we hypothesized as relevant for making the decision of CTA positivity. These variables were chosen from the case history questionnaire, the questionnaire on self-reported pain, and from interrogation and clinical examination including palpation findings.

The first step of the analysis was to compare the frequency of these variables in CTA-positive and CTA-negative patients. However, because many of the variables are correlated, it is difficult to judge the role of each single variable in the decision-making process. Furthermore, variables may have an influence on the clinical decision in certain subgroups, without showing a high discriminative
power in the whole population. To obtain further insight into
the decision-making process, we tried to reconstruct the
clinical decision-making process by serially selecting
variables with nearly unique discriminating power in the
sense that they allowed us to define a subgroup with almost
exclusively CTA-positive or CTA-negative diagnoses. In the
absence of such variables, we selected those variables with
maximal discriminative power in the sense of a minimal
$P$ value ($\chi^2$ test) and combined them into risk scores to
define according subgroups.

Descriptive statistics were applied to summarize charac-
teristics at baseline for each group, using percentages for
discrete variables and mean values and standard deviations
for continuous variables. Fisher’s exact test was used for
comparing binary or categorical variables and the Mann-
Whitney $U$ test for ordinal or continuous variables in 2
independent samples using the statistical package SPSS for
Windows, version 11 (SPSS Inc, Chicago, Ill). Odds ratios
(OR) were used to quantify associations. We used a 5%
significance level throughout.

RESULTS

Eighteen percent of patients ($n = 50$) had CTA. The CTA-
positive patients were significantly younger, had lower
blood pressure, were more often referred from general
practice than from local hospitals, and received less
medication than the CTA-negative patients (Table 2). Of
CTA-positive patients, 80% ($n = 40$) had a normal MPI
compared to 50% of CTA-negative patients ($P < .0001$).

Among CTA-positive patients, half ($n = 5$) of those with
abnormal perfusion had fixed defects in contrast to 18% ($n =
20$) in the CTA-negative group ($P = .031$). Correspondingly,
91% ($n = 40$) of CTA-positive patients and only 52% ($n =
115$) of CTA-negative patients were without significant
coronary artery disease ($P < .001$) (Table 2).

Pain Characteristics

The different types of pain appeared with similar
frequencies in the 2 groups, except for sharp pain, which
was more frequent among the CTA-positive patients, who
had their symptoms for a shorter time and with less
frequent attacks of longer duration. Provoking and
relieving factors were rare in both groups except for
physical activity, rest, psychic stress, and nitroglycerin.
Physical activity as provoking factor was significantly less
frequent in the CTA-positive group (Table 4). Noncardiac
chest pain and atypical AP were significantly more
frequent in the CTA-positive group (Table 5). There was
a significant trend for a generally higher CCS class in the
CTA-negative group ($P < .001$). Conversely, CTA-positive
patients more often have neck pain ($P < .001$), thoracic
spine pain ($P < .001$), and shoulder/arm pain ($P = .041$)
(Table 5). No differences were found with respect to the
pain intensities.

Palpation Findings

Chest wall tenderness, paraspinal tenderness, end-play,
and joint-play MP restrictions were significantly more
frequent among CTA-positive patients (Table 5). In Fig 1,
Transportation to the Clinical Decision-Making Process

(0.79-3.09). Segments C5 to C7 also had higher ORs.

We observed a tendency for higher ORs around segments T5 and spinal column examined by end-play and joint-play MP. We ORs are given for specific segmental restrictions of the patients

Table 4. Comparability on specific case history items for CTA patients

<table>
<thead>
<tr>
<th></th>
<th>CTA positive (N = 50)</th>
<th>CTA negative (N = 225)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you describe your symptoms?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squeezing/pressure-like</td>
<td>n = 41 (82%)</td>
<td>n = 203 (90%)</td>
<td>.134</td>
</tr>
<tr>
<td>Tenderness</td>
<td>n = 1 (2%)</td>
<td>n = 16 (7%)</td>
<td>.326</td>
</tr>
<tr>
<td>Sharp</td>
<td>n = 16 (32%)</td>
<td>n = 40 (18%)</td>
<td>.023</td>
</tr>
<tr>
<td>Well demarcated</td>
<td>n = 2 (4%)</td>
<td>n = 9 (4%)</td>
<td>.679</td>
</tr>
<tr>
<td>Diffuse</td>
<td>n = 6 (12%)</td>
<td>n = 18 (8%)</td>
<td>.255</td>
</tr>
<tr>
<td>Burning</td>
<td>n = 3 (6%)</td>
<td>n = 10 (4%)</td>
<td>.431</td>
</tr>
<tr>
<td>Prickly</td>
<td>n = 11 (22%)</td>
<td>n = 28 (12%)</td>
<td>.068</td>
</tr>
<tr>
<td>Other</td>
<td>n = 4 (8%)</td>
<td>n = 23 (10%)</td>
<td>.433</td>
</tr>
<tr>
<td>Duration of each attack?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10 min</td>
<td>n = 26 (52%)</td>
<td>n = 173 (77%)</td>
<td></td>
</tr>
<tr>
<td>10 min-1 h</td>
<td>n = 12 (24%)</td>
<td>n = 35 (16%)</td>
<td>.009</td>
</tr>
<tr>
<td>More than 1 h</td>
<td>n = 12 (24%)</td>
<td>n = 17 (7%)</td>
<td></td>
</tr>
<tr>
<td>Attacks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monthly</td>
<td>n = 24 (48%)</td>
<td>n = 61 (27%)</td>
<td></td>
</tr>
<tr>
<td>Weekly</td>
<td>n = 18 (36%)</td>
<td>n = 107 (48%)</td>
<td>.019</td>
</tr>
<tr>
<td>Daily</td>
<td>n = 8 (16%)</td>
<td>n = 57 (25%)</td>
<td></td>
</tr>
<tr>
<td>Symptoms for how long time?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 6 mo</td>
<td>n = 24 (48%)</td>
<td>n = 81 (36%)</td>
<td></td>
</tr>
<tr>
<td>6-24 mo</td>
<td>n = 16 (32%)</td>
<td>n = 108 (48%)</td>
<td>.034</td>
</tr>
<tr>
<td>&gt; 24 mo</td>
<td>n = 10 (20%)</td>
<td>n = 36 (16%)</td>
<td></td>
</tr>
<tr>
<td>Provoking factors</td>
<td>Physical activity precipitates</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>n = 25 (50%)</td>
<td>n = 190 (84%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Movement of the thorax</td>
<td>n = 4 (8%)</td>
<td>.060</td>
</tr>
<tr>
<td></td>
<td>Rest</td>
<td>n = 17 (34%)</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Sexual activity</td>
<td>n = 2 (4%)</td>
<td>.127</td>
</tr>
<tr>
<td></td>
<td>Sleep</td>
<td>n = 3 (6%)</td>
<td>.162</td>
</tr>
<tr>
<td></td>
<td>Leaning forward</td>
<td>n = 1 (2%)</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Swallowing</td>
<td>n = 0 (0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deep breath</td>
<td>n = 0 (0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eating</td>
<td>n = 1 (2%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold</td>
<td>n = 1 (2%)</td>
<td>.149</td>
</tr>
<tr>
<td></td>
<td>Psychic stress</td>
<td>n = 19 (38%)</td>
<td>.053</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>n = 9 (18%)</td>
<td>.230</td>
</tr>
<tr>
<td>Relieving factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rest</td>
<td>n = 23 (46%)</td>
<td>.016</td>
</tr>
<tr>
<td></td>
<td>Movement of the affected part</td>
<td>n = 2 (4%)</td>
<td>.614</td>
</tr>
<tr>
<td></td>
<td>Nitroglycerin</td>
<td>n = 9 (18%)</td>
<td>.008</td>
</tr>
<tr>
<td></td>
<td>Other antiangina</td>
<td>n = 1 (2%)</td>
<td>.217</td>
</tr>
<tr>
<td></td>
<td>Pain killers</td>
<td>n = 2 (4%)</td>
<td>.152</td>
</tr>
<tr>
<td></td>
<td>Tranquilizers</td>
<td>n = 2 (4%)</td>
<td>.033</td>
</tr>
<tr>
<td></td>
<td>Antiacid medicine</td>
<td>n = 0 (0)</td>
<td>1.000</td>
</tr>
</tbody>
</table>

ORs are given for specific segmental restrictions of the spinal column examined by end-play and joint-play MP. We observed a tendency for higher ORs around segments T5 and T6 (3.60-6.94) compared with the other thoracic segments (0.79-3.09). Segments C5 to C7 also had higher ORs.

Reconstruction of the Clinical Decision-Making Process

The first variable identified was a restriction at joint-play MP because this is a prerequisite for a musculoskeletal cause. All 50 CTA-positive patients were found among the 90 subjects who had a positive finding with joint-play MP (Fig 2), all of whom also had a restriction at end-play MP (Table 5). Among these 90 patients, noncardiac chest pain defined a subgroup of 18 patients, 17 of which were CTA-positive. In the remaining 72 patients, none of the candidate variables was able to define a subgroup with almost entirely CTA-positive or CTA-negative patients.

Twenty-seven variables were at least slightly associated with the diagnosis of CTA, 19 of these with a P value of .05. Highest significance was found for (a) CCS grade of angina (P = .00018); (b) presence of neck pain (P = .00048); (c) type of angina (P = .00020); (d) 4 palpation findings (P = .00064); and (e) spinal tenderness (P = .0013). Because type and grade of angina were highly associated, as were spinal tenderness and the number of positive palpation findings, it was not possible to analyze their joint effect. However, selecting any triple of variables from (a) or (c), (d) and (e), or (b), and analyzing their joint effect in a linear logistic model, we found that they all contributed significantly to the diagnosis. As seen in Fig 2 (score 1), if we used the combined presence of 3 such factors (ie, presence of neck pain + lowest CCS grade + 4 palpation findings) to define a risk score, we found that none of the 7 patients without any of these factors was CTA-positive, 2 of 21 with only 1 factor were CTA-positive, 12 of 23 with 2 factors were CTA-positive, and 19 of 21 with all 3 of these factors were CTA-positive.

Adding other factors to the aforementioned 3 factors in the logistic regression model one by one, the following factors showed a significant additional effect: diffuse chest pain (P = .04), number of chest pain attacks (P = .036), end-play MP T5/6 (P = .028), joint-play MP T5/6 (P = .010), and joint-play MP T6/7 (P = .014). However, a score based on all 8 variables did not improve the discrimination.

Looking at the subgroup of 23 subjects with 2 of the 3 factors being positive, we found 4 variables with a significant association and 1 with borderline significance: (1) chest pain described as sharp (P = .035), (2) chest pain relieved by rest (P = .049), (3) end-play MP T4/5 (P = .062), (4) end-play MP T5/6 (P = .016), (5) joint-play MP T5/6 (P = .035). Using these 5 factors to define a new score (score 2), we saw that absence of all defined the CTA-negative decision and presence of 3 of 5 factors was enough to diagnose CTA positivity.

The remaining 12 patients have 1 or 2 of these factors. However, in these 12 patients, we could still find borderline significance: thoracic spine pain (P = .079), neck pain (P = .079), shoulder/arm pain (P = .079), physical activity aggravation (P = .038), marital relation (P = .067), typical angina (P = .023), CCS 1 (P = .023), β-adrenergic blocker medication (P = .079), and joint-play MP T2/3 (P = .004). The last one allowed a nearly definite split: presence of this variable
indicated CTA positivity in 7 of 8 patients; absence indicated CTA negativity in 4 of 4 (Fig 2).

**DISCUSSION**

This appears to be the first study to systematically examine the combination of case history and palpation findings as a tool for identifying musculoskeletal causes of chest pain. In our sample of patients with stable AP, this approach resulted in a separation of nearly 1 of 5 patients with suspected noncardiac musculoskeletal chest pain (CTA-positive) and 4 of 5 patients (CTA-negative) who are more prone to having either AP (ie, angina caused by myocardial ischemia) or chest discomfort due to other reasons (Table 2). Separation could not be achieved by the use of single items from case history and clinical examination alone. By combining different items in a decision tree, we could nearly reconstruct the decision-making process illustrating the complexity of this kind of daily clinical practice (Fig 2).

The presence of chest pain was the same in the 2 groups with expected differences concerning type and severity of AP. More neck, thoracic, and shoulder arm pain were found in the CTA-positive group. Pain intensity seemed to have no discriminative power. Moreover, distinction could not be made from symptoms (pain on movement, deep breath, coughing pain) often regarded as characteristic for musculoskeletal chest pain.24,25 Chest pain precipitated by physical activity, lasting less than 10 minutes and relieved by rest and nitroglycerin, was found to be more common in the CTA-negative group. Accordingly, this group received more heart medication.

Reconstruction of the decision-making process suggested that joint-play and end-play MP findings together with traditional clinical classification of chest discomfort played a major role in the decision-making process. Among the candidate variables, the CCS class had a high discriminatory power for diagnosing CTA positivity \( (P = .000018) \). When patients were classified according to type of AP, variables such as medication or thoracic spine pain had little relevance. Interestingly, more patients in the CTA-positive group were referred from general practice, suggesting that a systematic manual palpation program might be useful for

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**Table 5.** Discrimination between the CTA groups at baseline in palpation findings, chest, neck, and thoracic pain, and cardiovascular classification

<table>
<thead>
<tr>
<th></th>
<th>CTA total (N = 275)</th>
<th>CTA positive (N = 50)</th>
<th>CTA negative (N = 225)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Palpation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest wall tenderness</td>
<td>214 (78)</td>
<td>49 (98)</td>
<td>165 (73)</td>
<td>.053</td>
</tr>
<tr>
<td>Paraspinal tenderness</td>
<td>133 (48)</td>
<td>48 (96)</td>
<td>85 (38)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>End-play motion palpation</td>
<td>160 (58)</td>
<td>50 (100)</td>
<td>110 (49)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Joint-play motion palpation</td>
<td>90 (33)</td>
<td>50 (100)</td>
<td>40 (18)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>Type of chest pain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noncardiac chest pain</td>
<td>39 (14)</td>
<td>17 (34)</td>
<td>22 (10)</td>
<td></td>
</tr>
<tr>
<td>Atypical angina</td>
<td>80 (29)</td>
<td>22 (44)</td>
<td>58 (26)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Typical angina</td>
<td>156 (57)</td>
<td>11 (22)</td>
<td>145 (64)</td>
<td></td>
</tr>
<tr>
<td><strong>CCS</strong></td>
<td>133 (48)</td>
<td>43 (86)</td>
<td>90 (40)</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>128 (47)</td>
<td>7 (14)</td>
<td>121 (54)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>14 (5)</td>
<td>0 (0)</td>
<td>14 (6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>III</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td><strong>Presence of chest pain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Today</td>
<td>159 (58)</td>
<td>31 (62)</td>
<td>128 (57)</td>
<td>.531</td>
</tr>
<tr>
<td>Pain past 14 d</td>
<td>249 (91)</td>
<td>44 (88)</td>
<td>205 (91)</td>
<td>.592</td>
</tr>
<tr>
<td><strong>Chest pain intensity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensity today</td>
<td>2.63 (1.61)</td>
<td>2.74 (1.29)</td>
<td>2.60 (1.69)</td>
<td>.283</td>
</tr>
<tr>
<td>Max. intensity past 14 d</td>
<td>4.29 (2.21)</td>
<td>4.14 (1.97)</td>
<td>4.32 (2.27)</td>
<td>.697</td>
</tr>
<tr>
<td>Average intensity past 14 d</td>
<td>3.36 (1.87)</td>
<td>2.91 (1.63)</td>
<td>3.46 (1.91)</td>
<td>.090</td>
</tr>
<tr>
<td>Presence of neck pain</td>
<td>106 (38)</td>
<td>37 (74)</td>
<td>69 (31)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Neck pain intensity</td>
<td>3.55 (1.99)</td>
<td>3.57 (1.89)</td>
<td>3.54 (2.06)</td>
<td>.713</td>
</tr>
<tr>
<td>Presence of thoracic pain</td>
<td>109 (40)</td>
<td>32 (64)</td>
<td>77 (34)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Thoracic pain intensity</td>
<td>3.45 (1.99)</td>
<td>3.19 (1.94)</td>
<td>3.56 (2.02)</td>
<td>.194</td>
</tr>
<tr>
<td>Presence of shoulder arm pain</td>
<td>144 (52)</td>
<td>33 (66)</td>
<td>111 (49)</td>
<td>.041</td>
</tr>
<tr>
<td>Shoulder arm pain intensity</td>
<td>3.80 (2.18)</td>
<td>3.61 (2.25)</td>
<td>3.86 (2.17)</td>
<td>.459</td>
</tr>
</tbody>
</table>

Values are absolute numbers and relative frequencies (in parentheses).

\( a \) Pain intensity data are expressed as mean values (SD) in patients reporting pain (ie, a rating scale value between 1 and 10 [1 is the lowest intensity]).
the general practitioner as a screening tool in these patients. Myocardial perfusion imaging categorized the population into those with normal and those with abnormal myocardial perfusion (Table 2). Eighty percent of the CTA-positive population had normal perfusion compared to 50% in the CTA-negative group. The 20% of CTA-positive patients with a perfusion abnormality were not necessarily misclassified, but might have had 2 diagnoses at the same time. Two of these 10 patients had indeed typical angina of CCS class 2 despite the CTA-positive diagnosis. Five other patients had irreversible ischemia possibly caused by previous undetected myocardial infarction. The fact that as many as half of the CTA-negative group had normal perfusion may indicate a conservative chiropractic diagnosis making or that reasons other than ischemic heart disease and musculoskeletal disorders may account for a sizable fraction of patients having chest pain.3,6,9,26 Similar relationships were found when patients were stratified according to catheterization results (Table 2).

Most previous studies were retrospective, often focusing on patients with a normal CAG.7,27 In an open study in patients with suspected AP but normal CAG, Wise et al7 applied limited palpation maneuvers on the spine and chest wall, and found that 69 of 100 patients had chest wall tenderness compared to 0 of 25 control patients with arthritis and no chest pain. Frobert et al27 did a blinded consecutive study on patients with AP and normal CAG, and found that patients had significantly more complaints of pain from the neck, chest, and thoracic spine, together with more pain radiating to the arms, than control individuals. Physical examination showed abnormal findings more frequently in patients localized to the anterior and posterior chest wall, spinal levels T1-T6, and the muscles of the neck and shoulder girdle.27 One prospective study compared positive palpation findings of chest wall tenderness in patients with normal CAG and abnormal CAG, and found no difference among the 2 groups.28 None of these observations is directly comparable to our results, but they support the view that musculoskeletal disorders are common in patients with chest pain.

**Clinical Decision-Making Process**

Presently, there exists no operational definition of chest pain originating from the musculoskeletal system. It has been suggested that the clinician rely on case history and aberrant movement of the thoracic spine to make a diagnosis, sometimes referred to as “the thoracic facet syndrome.”25,29,30 Apart from this, recognized textbooks state that among several differential diagnoses, musculoskeletal disorders may also account for conditions such as
dysfunction of the thoracic spine, intercostal myoses, and myositis, without providing a satisfactory explanation for their existence and thumb rules for their detection.1,25

Tables 4 and 5 show the discriminative power of different variables in distinguishing CTA-positive from CTA-negative patients. As many of these variables were correlated, it was difficult to judge the role of each single variable. In addition, variables that had an influence on the clinical decision in certain subgroups did not necessarily have a high discriminative power in all groups. Therefore, we reconstructed a decision tree, which, if simple and sufficiently accurate, might become useful outside the field of chiropractic. For the 6 patients violating our decision model, we identified some potential reasons. One patient was classified as CTA-negative despite noncardiac chest pain classification. The patient did not report cervical or thoracic spine pain within the last 14 days, suggesting that our time window for CTA positivity might have been too narrow. Two CTA-positive patients had only 1 of 3 factors in score 1. However, both had thoracic spine pain and restriction at joint-play and end-play MP evaluation indicating 2 competing conditions: ischemic heart disease and a musculoskeletal disorder. Two CTA-negative patients had a score 1 value of 3. One had a gastrointestinal disorder, and the other patient reported daily and constant pain—which makes a musculoskeletal diagnosis unlikely. Lastly, one CTA-negative patient with T2/T3-specific joint-play MP restriction had convincing cardiac symptoms (moderate dyspnea, CCS 2, and typical AP), which spoke against classifying the patient as CTA-positive.

Fig 2. The reconstructed decision tree. The diamonds show variables defining subgroups. The rectangles show the values defining subgroups and the numbers of the CTA-positive patients (left number) and total number of patients (right number) in this subgroup.

Our data did not apply to patients with recent onset of pain, whose symptoms may be more atypical. The present population was selected for catheterization at a university hospital, and, consequently, the discriminative value of certain criteria could be different in a wider clinical setting including those types of patients we excluded. Moreover, we did not consider other potential causes of chest pain and, therefore, could not allege CTA positivity to be the sole cause of chest discomfort in patients without perfusion abnormalities or coronary stenoses. However, we were able to identify a few candidate variables which, when added to certain palpation findings, identified almost all CTA-positive patients. To determine as to what degree patients can benefit from a positive CTA diagnosis, all CTA-positive patients were offered chiropractic treatment, the result of which shall be published elsewhere.

Conclusion

The results of this study suggest that an experienced chiropractor can fairly convincingly identify a subset of patients with angina pectoris as having CTA. Systematic manual palpation of the spine and thorax could be used as part of the clinical examination in combination with basic cardiological variables to screen patients with chest pain to allow for improvements in referral patterns for specialist opinion or angiography. The suggested decision tree may serve as an example of how to base the diagnosis of
noncardiac chest pain from the musculoskeletal system on a more objective and reproducible procedure, facilitating its use outside the field of chiropractic.

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REFERENCES

DOES CLINICIAN TREATMENT CHOICE IMPROVE THE OUTCOMES OF MANUAL THERAPY FOR NONSPECIFIC LOW BACK PAIN? A METAANALYSIS

Peter Kent, GradDip(ManipPhysio), a Darryn Marks, MManipPhysio, b Warrick Pearson, MManipPhysio, c and Jenny Keating, PhD d

ABSTRACT

Objective: The purpose of this study is to quantitatively compare outcomes for trials when treating clinicians did, or did not, have the discretion to decide on treatment technique.

Methods: CINAHL, EMBASE, MEDLINE, the Physiotherapy Evidence Database, the Cochrane Controlled Trials register, reference list searching, and citation tracking were investigated. Ten randomized controlled trials (RCTs) of mobilization and manipulation for nonspecific low back pain (NSLBP) met the inclusion criteria. The effectiveness of manual therapy with and without clinician technique choice was assessed using descriptive statistics and metaanalysis for the outcomes of pain and activity limitation.

Results: In approximately two thirds of the included RCTs, clinicians had choice of treatment technique. There were no systematic differences favoring results for RCTs that did allow clinician choice of treatment technique.

Conclusions: Few quality studies are available, and conclusions on the basis of these data need to be interpreted with caution. However, allowing clinicians to choose from a number of treatment techniques does not appear to have improved the outcomes of these RCTs that have investigated the effect of manual therapy for NSLBP. If tailoring manual therapy treatment to NSLBP patients does positively impact on patient outcomes, this is not yet systematically apparent.

(J Manipulative Physiol Ther 2005;28:312-322)

Key Indexing Terms: Low Back Pain; Treatment Outcome; Classification; Manual Therapy

Systematic reviews of the effectiveness of manual therapy for low back pain (LBP) have reached varying conclusions.1-6 The most recent systematic reviews have concluded that manual therapy offers some benefit over no intervention or sham intervention for LBP, but is no more effective than other therapies.7-11 These systematic reviews have summarized the findings of randomized controlled trials (RCTs). In the context of the widespread practice of manual therapy for LBP and anecdotal support for its use, Rosner12-14 has criticized both the generalizability of findings of manual therapy RCTs and the validity of conclusions of systematic reviews on the basis of summaries of these trials.

In approximately 80% of LBP presentations in primary care, the diagnostic label of “nonspecific LBP” (NSLBP) is currently thought to be the most accurate.15-17 Most primary-contact clinicians believe NSLBP is heterogenous (a number of subgroups), and treat NSLBP patients differently on the basis of that heterogeneity.18 If subgrouping does affect outcome and response to treatment, then NSLBP research that does not accommodate subgrouping may deliver a diluted estimate of treatment effects. If subjects belonging to one subgroup respond to a particular intervention (such as manual therapy), and those belonging to other subgroups do not, this may explain the prevalence of contradictory results in NSLBP research (because of differential sampling of these subgroups in heterogenous cohorts).19-23

If clinicians do not think that research has investigated cohorts that resemble the patients that they see, and if they think that interventions have been implemented in ways that do not resemble the ways in which they practice, they are
likely to remain reserved about adopting recommendations on the basis of that research. Clinicians may also perceive that the research effort is not serving them well. Furthermore, if particular interventions are effective only for specific LBP subgroups, this effectiveness could be masked in the outcomes of heterogeneous cohorts. This might lead to abandoning therapy that is effective for some people with the condition.

Accommodation for NSLBP heterogeneity could occur in the selection of subjects recruited into RCTs, and in the discretion regarding treatment technique selection that is delegated to participating clinicians. The differential selection of trial subjects on the basis of a clinical profile that indicates their probability of responding to manual therapy is constrained by the paucity of validated criteria on which to make this decision. Although there is evidence of better patient outcomes in acute LBP when making interventions on the basis of the Delitto subgrouping system, compared with clinical practice guideline-based interventions, those interventions were more than manual therapy and included exercise and traction. We are aware of only one paper that has developed an empirically based clinical prediction rule for responders to manual therapy. Flynn et al found that the presence of 4 of 5 variables (duration of symptoms <16 days, Fear Avoidance Beliefs Questionnaire work subscale <19, at least one hip with >35° of internal rotation, hypomobility in the lumbar spine, and no symptoms distal to the knee) increased the likelihood of success with spinal manipulation from 45% to 95% (positive likelihood ratio = 24.4). This prediction rule has been validated in a second sample but only for a single type of spinal manipulative technique.

The research aim of this quantitative systematic review was to test the hypothesis that RCTs of manual therapy for NSLBP show a greater therapeutic effect when participating clinicians have discretion regarding treatment selection.

**METHODS**

**Search Strategy**

Comprehensive electronic search strategies were used and are available on request from the first author. Searches were performed through August 2003 across the contents of the following databases: CINAHL, EMBASE, MEDLINE, the Physiotherapy Evidence Database (PEDro), and the Cochrane Controlled Trials register. The search also included checking the reference lists of retrieved papers and of systematic reviews of LBP RCTs, and tracking the citations of included papers. This process identified 288 relevant reports. The titles and abstracts were independently screened for suitability for inclusion by 2 reviewers.

After this screening, 65 full papers were retrieved and independently screened by 2 reviewers for suitability for inclusion. Several authors were contacted for additional information. Of these papers, 55 were excluded for the reasons shown in Appendix A. Finally, 10 RCTs met the inclusion criteria.

**Selection Criteria**

**Inclusion criteria.** Randomized controlled trials compared the effects of manual therapy (spinal manipulation or mobilization) to either a nontreatment control group or an alternative treatment. (Manipulative techniques were defined as techniques involving a high-velocity thrust, and mobilization techniques as low-velocity techniques.) Trial participants had to be older than 18 years with NSLBP of any duration. Trials were only included if the effects of manual therapy could be partitioned from the effects of other types of therapy and if continuous outcome data for change in pain and/or activity limitation (disability) were reported. Because of a lack of translation resources, only trials published in the English language were included.

**Exclusion criteria.** Trials of LBP were excluded for the following reasons: if associated with tumor, metastatic disease, systemic inflammatory conditions, infection, pregnancy, fracture, metabolic disorders, spondylolisthesis, or of LBP after surgery; data for NSLBP could not be discretely identified (eg, trials with combined results for back and neck complaints); manual therapy and comparison groups were significantly different for either pain or disability at baseline; there were insufficient data for a standardized mean difference (effect size) to be calculated for pain or activity limitation; or a PEDro quality rating of 3 or less.

**Quality Assessment**

Using the PEDro quality rating scale, one of the authors rated each paper and subsequently checked the rating of each item with the rating concluded by 2 independent PEDro raters. PEDro raters are trained and assessed in accurate determination of the methodological score. Thus, 3 independent quality assessment checks using PEDro criteria were applied to each paper. Data are available on the reliability of the PEDro rating scale. Reviewers were not blind to authors, institution, or journal. Appendix B shows the quality item rating for each of the included trials.

**Data Extraction**

Three reviewers independently extracted the following data from each paper using a standardized form: subject inclusion and exclusion criteria, number of subjects in each group, description of comparison interventions, frequency of intervention and follow-up, whether the clinicians were given treatment technique choice, outcome measures, and the data required to calculate effect sizes for all possible comparisons.

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**Appendix A:**

- Inclusion criteria:
  - Trials of LBP were excluded for the following reasons: if associated with tumor, metastatic disease, systemic inflammatory conditions, infection, pregnancy, fracture, metabolic disorders, spondylolisthesis, or of LBP after surgery; data for NSLBP could not be discretely identified (eg, trials with combined results for back and neck complaints); manual therapy and comparison groups were significantly different for either pain or disability at baseline; there were insufficient data for a standardized mean difference (effect size) to be calculated for pain or activity limitation; or a PEDro quality rating of 3 or less.

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The group means and SD were extracted for each comparison and each outcome measure (pain and activity limitation) if available. Group mean change scores were used when post-intervention means were not available.99

Where the SD was not provided, an estimate of the SD was calculated as either one quarter of the range of raw scores or one fifth of the scale width. Where only median scores were provided, these were used as a best estimate of mean scores.

All the included trials that measured the effects on pain used a Visual Analogue Scale (VAS). All the included trials measured activity limitation using one or more of the Oswestry Disability Questionnaire, Roland-Morris Disability Questionnaire, and SF-36 (Physical Function subscale) except for one trial that used the MacDonal Disability Questions. All of these assessment instruments attempt to measure the same underlying construct of activity limitation. Davidson and Keating have shown that the Oswestry Disability Questionnaire, Roland-Morris Disability Questionnaire, and SF-36 (Physical Function subscale) display comparable responsiveness. These instruments have also been shown to be moderately associated, with correlations ranging from approximately 0.6 to 0.8. For the purposes of this systematic review, data derived using any of these instruments was treated as being comparable. Where a trial used more than one measure of activity limitation, we preferentially used Oswestry scores. When some comparisons in an RCT report were for measures on which groups were not equal at baseline, these comparisons were not included in the analysis.

Because the included trials had postintervention assessments taken at varying periods, these were partitioned into short-term and long-term outcomes, using a method reported by Assendelft et al. Short term was arbitrarily defined as less than 3 weeks after the intervention. If a trial had multiple assessments during that period, the assessment closest to 3 weeks was used. Long term was defined as greater than 3 weeks after intervention, and the assessment closest to 3 months was used.

If trial clinicians were able to choose from a range of manual therapy techniques and had discretion regarding the spinal level(s) to which these techniques were applied, the option “treatment choice” was rated as “Yes.” If the trial did not meet both of these criteria, this option was rated “No.” During the search, selection, and data extraction phases, disagreements between reviewers were resolved through consensus negotiation.

Calculating Trial Effects

The mean and SD for each group, for each comparison, at each outcome period (if available), and for both outcome variables (if available) were entered into Cochrane Collaboration Revman (v4.2) software. This software was used to calculate effect sizes and perform (inverse variance) metaanalytic pooling. A random effects model was used for pooling because of the statistical heterogeneity of some data (Mantel-Haenszel method). Effect sizes were calculated using the difference between the mean of the experimental group and the mean of the control group, divided by the pooled SDs of both groups. Effect sizes were adjusted for small sample bias using the method recommended by Hedges and Olkin. An effect size is a unitless measure that allows comparison of effects across studies that have used different measurement tools. It is useful, for example, for comparing change in pain in 2 studies, one of which used an 8-point pain rating scale and the other that used a 100-mm VAS. Effect sizes from different studies can be statistically pooled to give a best estimate of the size of the effect of a particular intervention. In addition, comparisons can be made between the effect sizes of different interventions for the same condition. Cohen suggests that the following descriptors might be used as a guide to the magnitude of effect sizes: trivial (0.0), small (0.2), moderate (0.6), and large (1.2).

In some RCTs, outcomes for a single manual therapy group were compared to a number of other therapies. The differences in observed effects may not satisfy the statistical assumption of independence required for metaanalysis. To accommodate for this, the sample size of the manual therapy group used in the effect size calculator was divided by the number of comparisons that were made. Tests were made for significant differences (with 95% confidence) between the point estimates of pooled effect size where clinicians could or could not exercise discretion in treatment selection.

RESULTS

Study Characteristics

Appendix C shows the included trials, duration of symptoms at inception of trial, inclusion and exclusion criteria, sample sizes, intervention and control treatments, and outcome measures. Trials included clinicians from a number of professional disciplines, but there were too few trials to partition by profession. Clinicians were able to choose their preferred treatment in approximately two thirds (7/10) of the trials included in this review.

Quantitative Data Synthesis

Fig 1 shows the trials, the therapies that were compared, the effect sizes for each comparison, and the trial quality ratings. Trials are partitioned into those where clinicians could or could not exercise discretion in treatment selection. There was diversity present in the data available for the metaanalysis. Some trials compared manual therapy to no intervention or sham intervention, and some trials compared manual therapy to a variety of other interventions.
When these data were analyzed using only the studies that compared manual therapy to no intervention/sham intervention, there was a significant difference between the pooled estimates of effect size for short-term activity limitation (difference = 0.62 ± 0.47, z = 2.60, P = .00), in favor of the RCTs where clinicians did not have treatment technique choice. There were no significant differences between the pooled estimates of effect size for short-term pain and both long-term outcomes.

These data were reanalyzed using only the studies that compared manual therapy to other interventions. There was a significant difference between the pooled estimates of effect size for both short-term pain (difference = 0.51 ± 0.37, z = 2.04, P = .02) and short-term activity limitation (difference = 0.62 ± 0.47, z = 2.60, P = .00), in favor of the RCTs where clinicians did not have treatment technique choice. There were no significant differences between the pooled estimates of effect size for both long-term outcomes, and this was unchanged when the analysis was repeated without the outlier in the data provided by Herzog et al.84

Whether statistically significant or not, all of the pooled estimates of effect size favored the RCTs where clinicians did not have treatment technique choice. This held across all 4 analyses.

### DISCUSSION

There is insufficient data available to definitively quantify the effect of clinician treatment choice on the results of RCTs of manual therapy for LBP. This would require larger numbers of high quality RCTs with similar comparisons. Therefore, the results of this review should be interpreted with caution. This is particularly so in the long-term outcome comparisons because there was only one RCT available for inclusion in the “Yes-treatment choice” group. However, the...
limited data available do not provide support for a hypothesis that RCTs of manual therapy for NSLBP show a greater therapeutic effect when participating clinicians have discretion regarding treatment selection. If NSLBP is heterogeneous and tailoring manual therapy treatment to NSLBP subgroups does positively impact on patient outcomes, the outcomes of the RCTs in this review do not reflect this.

There could be a number of reasons for this result. It may be that tailoring manual therapy to NSLBP subgroups does positively impact on patient outcomes, but that there is insufficient consensus as to which subgroups respond to particular manual therapy interventions for consistent effects to become apparent across trials. Our survey data indicate little consensus within and between primary-contact professional disciplines regarding the specific signs and symptoms representative of putative NSLBP subgroups.115 This may have been compounded by the diversity of manual therapy techniques used in the RCTs included in this review.

Alternatively, it may be that tailoring treatment to NSLBP subgroups has limited impact on patient outcomes because patients respond similarly regardless of manual therapy technique. A recent RCT found that there was no difference in within-treatment–session change in pain and physical impairment depending on whether the mobilization technique used in NSLBP was “therapist selected” or “randomly selected.”116

If clinicians and researchers are to continue to investigate the effectiveness of manual therapy for NSLBP, there are a number of strategies that might enhance the research yield. One strategy would be for future RCTs to proceed only after there is consensus regarding appropriate outcome measures and time intervals for reassessment. This would facilitate comparisons between studies and improve confidence that pooling of data across studies is sensible. Another strategy would be for RCTs to commence when there is greater clarity regarding the clinical profiles of patients who are likely to respond to manual therapy.

Though not the primary aim of this study, it was noted that the preintervention inclusion and exclusion criteria of most of the included RCTs screened subjects only to ensure that they had NSLBP. In their inclusion criteria, Triano et al90 included “palpatory tenderness over facet joints”, and Andersson et al162 included “a lesion suitable for manipulation” as determined by osteopathic examination but using criteria not specified in the paper. These selection criteria could be refined using prospective inception cohort studies26.
that provide valid empirically based prediction rules for profiling patients’ likelihood of response to specific manual therapies. These studies can occur in a “signs and symptoms” paradigm, or in a pathoanatomically based paradigm. Ideally, prediction rules on the basis of prospective inception cohort studies will be retested in independent samples and will cover a range of manual therapy techniques.

Strengths and Weaknesses of this Review

Strengths of the current study are that the review search was comprehensive and quantitative analysis was performed. There are a number of weaknesses of the current study. The interventions studied are mostly a single form of intervention, and the clinical effects of manual therapy combined with other interventions were not investigated. The generalizability of these findings to clinical situations of combined therapy is unknown. Furthermore, there was diversity in the data used for this metaanalysis because of the heterogeneity of comparisons, time intervals, and activity limitation outcome measures. This reduces the clinical interpretability of the point estimates of pooled effect size. In addition, the literature search was restricted to studies published in the English language, so cultural bias and publication bias cannot be excluded. Lastly, there is a small number of RCTs included in this study because of requirement of high quality usable data. Some impact of the “stainless steel” law of systematic reviews, that is, “the more rigorous the review, the less evidence there will be that the intervention is effective,” cannot be excluded.

CONCLUSION

The limited available evidence does not suggest that allowing participating clinicians’ discretion regarding technique selection has improved outcomes in RCTs of manual therapy for NSLBP. If NSLBP is heterogenous and tailoring treatment to NSLBP subgroups does positively impact on patient outcomes, this is not yet systematically observable. This may be because of limitations in the design of previous RCTs or because tailoring manual therapy treatment to NSLBP subgroups actually has minimal effect on pain and activity limitation. A direction for future research is to select patients for manual therapy RCTs with a clinical profile that indicates a likelihood of responding to manual therapy. If such a clinical profile exists, it could be identified using prospective inception cohort studies.

REFERENCES


APPENDIX A. REASONS FOR EXCLUSION OF POTENTIAL PAPERS

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<td>Zylbergold80</td>
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</table>

A, The effects of manual therapy could not be partitioned from the effects of other types of therapy; B, not NSLBP; C, no measures of pain or activity limitation in a form suitable for calculation of effect size; D, groups not comparable at baseline.
### APPENDIX B. QUALITY ASSESSMENT (PEDRO RATING SCALE)

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<td>Licciardone et al, 87 6/10</td>
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<td>MacDonald and Bell, 88 5/10</td>
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<td>Pope et al, 89 6/10</td>
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<td>Triano et al, 90 6/10</td>
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<td>Waagen et al, 91 5/10</td>
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*ITT*, intention to treat.

*The item "eligibility criteria" relates to the generalizability of the RCT and is not included in the PEDro score.

### APPENDIX C. CHARACTERISTICS OF INCLUDED TRIALS

<table>
<thead>
<tr>
<th>RCT</th>
<th>Condition</th>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
<th>Intervention procedure (sample n)</th>
<th>Treatment choice (treatment frequency)</th>
<th>Control procedure and (sample n)</th>
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<tr>
<td>Andersson et al 82</td>
<td>NSLBP</td>
<td>Age, 20-59 y; manipulation warranted (osteopathic decision); duration, 3-26 wk</td>
<td>Nerve compression, systemic inflammatory conditions, scoliosis, serious medical illnesses, substance abuse, mental illness, pregnancy, litigation, workers' compensation, manipulated within 3 wk</td>
<td>Manipulation, muscle energy, counterstrain, articulation, myofascial release, plus 10-min back pain video (n = 83)</td>
<td>Yes—clinicians treating both groups could choose technique(s) (8 treatments over 12 wk)</td>
<td>Standard medical care (analgesics, NSAID, active but not manual physiotherapy, ultrasound, diathermy, hot/cold packs, corset, TENS plus 10-min back pain video) (n = 72)</td>
<td>ROM, SLR, pain 10-cm VAS, pain drawing, 6-point patient satisfaction scale, Roland-Morris Oswestry</td>
</tr>
<tr>
<td>Gibson et al 83</td>
<td>NSLBP</td>
<td>Duration, 8-52 wk</td>
<td>Nerve compression, inflammatory, metabolic or neoplastic spinal disease, spondylosis, spondylolisthesis, LBP medication other than analgesia</td>
<td>Manipulation, mobilization and soft tissue techniques (n = 41)</td>
<td>Yes—at clinician discretion (4 treatments over 4 wk)</td>
<td>(1) Short wave (n = 34), (2) detuned short wave (n = 34)</td>
<td>Daytime pain (100-mm VAS), nocturnal pain (100-mm VAS), No. of patients pain free, spinal tenderness (4-point scale), Lx flexion work status</td>
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<tr>
<td>Herzog et al 84</td>
<td>LBP and sacroiliac dysfunction</td>
<td>Age, 18-50 y; diagnosed independently as SIJ problem by 2 clinicians; onset unrelated to trauma; duration, &gt;4 wk</td>
<td>Extreme obesity, nonambulatory</td>
<td>Manipulative therapy (n = 16)</td>
<td>Yes—at clinician discretion (up to 10 treatments over 4 wk)</td>
<td>Back school (n = 13)</td>
<td>Pain VAS Gillet (SIJ ROM) score, Gait symmetry, Oswestry</td>
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<tr>
<td>Hsieh et al 85</td>
<td>NSLBP</td>
<td>Age, 18-55 y; self-reported good health; duration, 3-26 wk</td>
<td>Nerve compression, fracture, tumor infections, spondyloarthropathy, Not overweight (Davenport index), previous manipulative therapy for this episode, previous back surgery, heart pacemaker, compensation or insurance issues</td>
<td>Diversified chiropractic manipulation to lumbar spine and/or SIJ + hot pack (n = 26)</td>
<td>No—rotation manipulation only, but levels to be treated chosen by clinician (9 treatments over 3 wk)</td>
<td>(1) Gentle stroking massage + hot pack (n = 15), (2) corset (n = 12), (3) TMS (n = 10)</td>
<td>Oswestry, Roland-Morris</td>
</tr>
<tr>
<td>RCT</td>
<td>Condition</td>
<td>Inclusion criteria</td>
<td>Exclusion criteria</td>
<td>Intervention procedure (sample n)</td>
<td>Treatment choice (treatment frequency)</td>
<td>Control procedure and (sample n)</td>
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<tr>
<td>Hsieh et al</td>
<td>NSLBP</td>
<td>Age &gt;18 y; duration, 3-26 wk, or at least 8 wk pain free in preceding 28 wk</td>
<td>Specific back pain because of known pathology, lower limb neurological abnormalities, pregnancy, significant mental disorders, obesity, litigation, automobile injuries, work injuries, inappropriate illness behavior, anticoagulant therapy, lumbar surgery, previous manual therapy in current episode</td>
<td>Lumbosacral manipulation (n = 49)</td>
<td>Yes—at clinician discretion (3 treatments over 3 wk)</td>
<td>(1) Myofascial therapy (n = 51) (3 x wk for 3 wk), (2) back school (n = 48) (1 x wk for 3 wk)</td>
<td>Pain (10 cm) VAS Roland-Morris</td>
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<tr>
<td>Licciardone et al</td>
<td>NSLBP</td>
<td>Age, 21-69 y; duration &gt;3 mo</td>
<td>Nerve compression, pregnancy, specific back pain because of known pathology, workers compensation or litigation, lumbar surgery, previous manual therapy for current episode, previous attendance at trial site</td>
<td>Manipulative and soft-tissue techniques (high and low force) (n = 48)</td>
<td>Yes—at clinician discretion (7 treatments over 5 mo)</td>
<td>(1) Sham manual therapy, light touch, ROM activities (n = 23), (2) no treatment (n = 20)</td>
<td>Pain (10 cm) VAS, SF-36 physical function, global satisfaction</td>
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<tr>
<td>MacDonald and Bell</td>
<td>LBP and/or dorsal pain, plus asymmetrical restricted ROM</td>
<td>Age, 16-70 y; duration: 3 inception cohorts, 0-13 d, 14-28 d, &gt;28 d</td>
<td>Nerve compression, pregnancy, specific back pain because of known pathology, osteomalacia or osteoporosis, spondylolisthesis, transient patients, patients seeking other physical treatment of their condition</td>
<td>Manipulation, mobilization, massage, posture, and activity advice (n = 49)</td>
<td>Yes—at clinician discretion (treated twice weekly until self-rated recovery achieved or until 3 consecutive treatments without measurable recovery)</td>
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<td>Pope et al</td>
<td>NSLBP</td>
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<td>Nerve compression, fracture, tumor, infections, spondyloarthropathy, pregnancy, not overweight (Davenport index), previous manipulative therapy for this episode, previous back surgery, heart pacemaker, workers compensation or disability insurance issues</td>
<td>Manipulation (n = 70)</td>
<td>No—rotation manipulation only, but levels to be treated chosen by clinician (9 treatments over 3 wk)</td>
<td>(1) Massage (n = 37), (2) TMS (n = 28), (3) corset (n = 29)</td>
<td>Pain VAS, lumbar flexion, lumbar extension, mean voluntary, extension effort (%Change), Sorensen time (s), Sorensen slope</td>
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<td>Triano et al</td>
<td>LBP +/- nonradicular leg pain</td>
<td>Age &gt;17 y; palpatory tenderness over facet joints; duration, &gt;7 wk, or &gt;5 episodes within preceding 52 wk</td>
<td>Nerve compression, systemic disease potentially affecting musculoskeletal system, specific back pain because of known pathology, severe osteoporosis, patients receiving other treatment of LBP, workers compensation or pending litigation</td>
<td>Manipulation (n = 48)</td>
<td>No—rotation manipulation only, but levels to be treated chosen by clinician (12 treatments over 2 wk)</td>
<td>(1) High-velocity low force (mimic) (n = 42), (2) back education program (n = 43)</td>
<td>Pain VAS, Oswestry, ZUNG Scores, (only the back school comparison was used because the current authors could not be sure that the high-velocity low force mimic had no treatment effect) Pain VAS, Lumbar ROM, SLR, Average combined objective test results</td>
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<tr>
<td>Waagen et al</td>
<td>NSLBP</td>
<td>Age, 18-65 y; ambulatory LBP patients; duration, &gt;3 wk</td>
<td>Nerve compression, pregnancy, malingering, workers’ compensation, obesity, specific back pain because of known pathology, previous manipulative therapy</td>
<td>Manipulation (n = 9)</td>
<td>Yes—at clinician discretion (2-6 treatments over 2 wk)</td>
<td>Low-force sham adjustment (sacral PA pressure) and soft tissue massage (n = 8)</td>
<td>Low-force sham adjustment (sacral PA pressure) and soft tissue massage (n = 8)</td>
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TMS, Transcutaneous muscular stimulation; NSAID, nonsteroidal anti-inflammatory drug; TENS, transcutaneous electrical nerve stimulation; SIJ, sacroiliac joint; PA, posteroanterior.
Objective: To determine whether the presence of posterior ponticles markedly increases by 30% or more, the incidence of major rotational stenosis of vertebral arteries.

Methods: Doppler ultrasound studies were performed in 3 private chiropractic clinics and in the radiology department of a public hospital, and magnetic resonance angiography (MRA) studies were made in the latter location. Thirty-two chiropractic patients had Doppler velocimetry, and 16 of these patients had MRA scanning. The outcome measures included changes in Doppler velocimetry signals and MRA images indicative of marked rotational stenosis of vertebral arteries.

Results: All vertebral arteries from the 32 patients displayed no signs indicative of marked rotational stenosis.

Conclusion: The findings of this study show that the incidence of major rotational stenosis of vertebral arteries is not markedly increased by the presence of posterior ponticles. (J Manipulative Physiol Ther 2005;28:323-329)

Key Indexing Terms: Vertebral Artery; Cervical Vertebrae; Posterior Ponticle; Ultrasonography, Doppler; Magnetic Resonance Angiography; Chiropractic
calcification of the lower border of the posterior atlanto-occipital membrane. In support of this hypothesis, Taitz and Nathan\(^1\) observed that in the combined American white and African-American population groups they studied, there was a predominance of partial rings in the younger age group (ie, 10-30 years). Complete rings were more frequent in the older groups (30-80 years). They concluded that the partial bridge may be the precursor for the complete ring, which results from a degenerative process similar to osteophyte formation in the spine. However, this does not explain the occurrence of full rings in young children, in whom such a mechanism is unlikely, as observed by Lamberty and Zivanović.\(^2\) They proposed that the ponticulus posterior is a regressive evolutionary phenomenon based largely on repeated studies that have shown that these bony rings are a common feature in vertebrates, including primates. Hence, there is the possibility that the rings are congenital anomalies.

Lamberty and Zivanović\(^2\) suggested that the posterior ponticle can cause compression of the vertebral artery during cervical rotation. Gatterman\(^3\) proposed that this anomalous ring of bone could also be clinically significant for the practice of spinal manipulation, if it causes the vertebral artery to be compressed during rotational manipulations of the cervical spine.

A link between posterior ponticles and migraine was observed by Wight et al,\(^4\) who noted a significant over-representation of the ring in chiropractic patients presenting with migraine without aura (ie, visual or auditory disturbances). Gholker et al\(^5\) found that over a 7-year period, 10 children were shown to have had posterior circulation stroke due to vertebral artery dissection. Magnetic resonance angiography (MRA) was performed for 9 of the cases, and no gross anomaly of the vertebral arteries was detected. However, all 10 children had posterior ponticles, and of the 9 who had MRA performed, the dissections were located on the same side and close to the ponticles. It seems that no studies have been made on the possible effect posterior ponticles have on the frequency of rotational stenosis of vertebral arteries, which 2 studies have indicated is an independent risk factor for stroke in the vertebrobasilar territory.\(^6,7\)

The aim of this pilot study was to make a preliminary test of the hypothesis that the presence of posterior ponticles markedly increases the incidence of rotational stenosis of vertebral arteries among chiropractic patients. To test this hypothesis, the incidence of rotational stenosis of vertebral arteries for chiropractic patients with at least 1 posterior ponticle was compared with the reported incidence of rotational stenosis among chiropractic patients in general.

**METHODS**

**Participants**

Approximately 100 chiropractors practicing in Perth, Western Australia, were sent letters asking for their support in recruiting participants. The clinicians from 3 separate practices responded, and they were asked to invite patients who had posterior ponticles (particularly complete rings), as seen on their lateral cervical spine x-rays, to participate in the study. One author examined these radiographs to ensure that all of the participants who were recruited in the study did have posterior ponticles.

Patients from the clinics typically were white adults who had no serious debilitating illnesses and who came from all sections of the workforce. No participant had dizziness or other symptoms or signs of vertebrobasilar insufficiency. Over 300 invitations had been mailed out to the patients, and 32 patients volunteered. There were 17 men and 15 women whose ages ranged from 20 to 74 years (average 46 years, SD = 15.09). At the time of the study, the majority of the participants were relatively free from cervical symptoms. Three individuals had chronic neck pain that fluctuated from moderate to severe, but no one had any recent episodes of severe cervical pain and stiffness. All participants recruited for the studies were required to be able to rotate their heads to the midpoint (ie, approximately 45°) or beyond on at least 1 side. For the MRA part of the study, participants were excluded if they had any ferromagnetic implants that could be affected by the intense magnetic fields, were pregnant or had claustrophobia. There is a very confined space within the bore of a magnetic resonance imaging (MRI) scanner, where the patient is positioned for the examination, and so this would make it very uncomfortable for anyone having claustrophobia.

As many participants as possible were recruited. Before the study commencing, the authors calculated that a minimum sample size of 24 participants with posterior ponticles would be required. This would allow an analysis to detect statistical significance if there was a finding of 30% or more incidence of rotational stenosis, given that an
earlier study by Haynes\textsuperscript{8} found that chiropractic patients in general had an incidence of 5\%. The calculation was made using determination of sample size for differences in proportions without cross-classification and was verified by a statistician from the University of Western Australia Statistical Consulting Group. The authors anticipated that recruitment of participants could be difficult and so considered that, for statistical purposes only, a fairly large increase of incidence (eg, 30\%) of rotational stenosis could be tested for.

All 32 participants had Doppler velocimeter examination of their vertebral arteries, and from this group, 16 also had MRA studies done. The number of MRA scanning examinations was low because of limited access to the scanner, and exclusion criteria prevented 2 individuals from participating, one because of pregnancy and the other due to severe claustrophobia.

Ethics approval was granted by the University of Western Australia Human Research Ethics Committee, and in the case of the MRI/MRA studies, approval was also granted by the Human Research Ethics Committee of the Sir Charles Gairdner Hospital. Each participant provided their written informed consent to participate.

**Equipment**

A 4-MHz continuous-wave bidirectional Doppler velocimeter, the Huntleigh Super Dopplex II (Huntleigh, Cardiff, UK), operating on audio alone was used because of its ability to determine the direction of the blood flow, and a Siemens (Erlangen, Germany) Magnetom Vision Plus (version 3.1) 1.5-T MRI unit was used to take MRA images of the vertebral arteries.

A mercury sphygmomanometer was used to measure blood pressures, and the degree of head rotation was measured using a SpinT goniometer. A recent study\textsuperscript{9} indicated that the SpinT instrument is highly accurate in measuring cervical rotation that has concomitant lateral flexion, and the study also showed that it has very high interexaminer reliability. Like the cervical range of motion instrument, the SpinT goniometer is also worn on the head of the individual who sits for the examination.

**Procedure**

**Doppler velocimetry.** Doppler velocimeter examinations were performed with the subjects sitting. Insonation of the arteries was first made at the suboccipital portal, where the fourth curve of the atlantoaxial segment from the third part of the vertebral artery lies on the posterior arch of the atlas vertebra and winds around the articular process. The probe was first placed against the suboccipital region slightly posterior to the mastoid process. With the head in the neutral position, the probe was positioned to obtain the clearest vertebral artery signals possible. If the Doppler signals were not able to be located at this site, or the signals were markedly affected by the cervical rotation, the examination was made at the C2 level. Here, the probe can be orientated horizontally or slightly superiorly on the lateral aspect of the neck just below the tip of the C2 transverse process. The vertebral artery signal has a characteristic gradual reduction in diastolic flow that produces a soft “whooshing” sound. This helps differentiate the signal from the nearby occipital artery which displays a sharp drop in the diastolic flow that causes the sound to be harsher.\textsuperscript{10}

The participants were asked to slowly turn their head contralaterally (away from the side on which the probe was positioned) to the end range as far as they could do so comfortably, and the probe was moved slightly as required to maintain optimum signals. The degrees of rotation at which major changes in velocimeter signals occurred were measured by SpinT goniometry. During measurements made with the SpinT, the participants sat upright in a straight-backed chair, which was positioned in a corner of the room. Close to the left of the subject was a wall, which served as a reference surface for the T square of the SpinT during measurements of rotation. The participants were asked to brace their shoulders by pressing their hands against the wall that was in front of them. The aim of this was to prevent substitution movement by way of rotation of their trunk. The subjects were asked to slowly turn their head contralaterally to the end range (as far as they could do so comfortably), while allowing any natural concomitant lateral flexion to occur. The participants were allowed to move their head naturally in rotation to permit maximal ranges of motion, thereby potentially increasing the chances of rotational positional stenosis of the vertebral arteries.

The effects on the Doppler signals were recorded as follows: no change, markedly reduced signals, and major increases in signals. Signals were classified as being markedly reduced if normal signals in the neutral position developed a high resistance character (a loss of the low-pitched diastolic sound) and a lower amplitude or were lost completely during neck rotation, and also if weak signals in the neutral position were totally extinguished with rotation. Major increases in signals were defined by conspicuously higher amplitude and pitch. Velocimeter determination of blood flow persistence (ie, normality) during rotation was made if velocities were observed to be relatively unchanged with at least 1 examination at either the suboccipital or C2 levels. Results were considered to be positive for major decreases in signals if this was observed in all examinations of the artery at both portals.

**Magnetic resonance angiography.** A radiographer who was highly experienced in both MRI and MRA took scans according to a set protocol. MRI of the brain was performed, obtaining dual-echo fast spin echo proton density and T2-weighted axial slices, followed by sagittal T1-weighted slices of the whole brain. A T2-weighted sagittal sequence of the head and neck was also performed. MRA images of the brain and upper spine were also obtained in the axial
plane extending from the pons to the sixth cervical vertebra using a 2-dimensional (2D) time of flight (TOF) gradient echo sequence with suppression of venous flow.

However, all of the MRA-acquired data were reconstructed with a software program for maximum intensity projection to show the vessels in 3D observed from different spatial planes. Three MRA sequences were performed in different neck positions: neutral, full rotation to the right, and full rotation to the left, usually in the order of $60^\circ$ from the vertical. The acquisition technique used for the 2D TOF sequence is presented in Table 1.

The total examination time per subject was an average of 90 minutes' duration, with 1 short rest break between the cranial imaging and the MRA sequences. The subjects were placed in the scanner, and their head and neck positioned in the cradle, first in the neutral position, followed by full rotation left and then right. After the scans were made, the subjects had their blood pressure taken again while sitting.

Images of the atlantoaxial segment from the third part of the vertebral arteries in the neutral position were observed and classified according to the amount of curvature of the 4 component curves. With rotation, the images of the vertebral arteries that were obtained were evaluated in terms of changes in the overall shape of the atlantoaxial curves of the artery, the density, and the luminal dimensions. We used the same grading system for stenosis that Weintraub and Khoury\textsuperscript{7} had used, which had been found to have high interexaminer reliability ($k = 0.75$), in their study of vertebral arteries during cervical rotation (Table 2). Blood flow studies using MRA were attempted but were not possible due to technical difficulties.

### Data Analysis

To determine whether Doppler signals were more likely to be affected by cervical rotation in the group of patients with posterior ponticles, the incidence was compared with chiropractic patients generally. An earlier study\textsuperscript{8} found that 5% of vertebral arteries from chiropractic patients exhibited rotational stenosis. The statistic that the authors used was Fisher exact test for differences in proportions, and the confidence interval set at 95%. A 2-sample $t$ test was used to ascertain whether there were any differences between the ponticle group and a subset of general patients in terms of active cervical rotation and blood pressures, and the level of significance was set at 95%.

### RESULTS

Of 32 participants, there were 26 individuals (81.2%) who displayed full posterior ponticles on their lateral cervical films and 6 (18.8%) who had partial rings. One participant clearly had 2 full posterior ponticles, as observed on the lateral x-rays by 1 of the authors. It is likely that these 2 full ponticles were imaged due to some rotation of the head at the time the radiograph was taken. For the whole sample, the average amount of rotation to the left was $65^\circ$.

### Table 1. Acquisition technique used for the 2D TOF sequence

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<td>TR</td>
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</tr>
<tr>
<td>TE</td>
<td>9 ms</td>
</tr>
<tr>
<td>Flip angle</td>
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</tr>
<tr>
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<tr>
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<td>Matrix</td>
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<td>FOV</td>
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<td>No. of excitations</td>
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<tr>
<td>Scan time</td>
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</tbody>
</table>

### Table 2. Grading system for stenosis based on the study by Weintraub and Khoury\textsuperscript{7}

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Well-visualized vessels in all views</td>
</tr>
<tr>
<td>2</td>
<td>Decrease in density with dynamic positions at atlantoaxial segment</td>
</tr>
<tr>
<td>3</td>
<td>Decrease in density of the artery at atlantoaxial segment</td>
</tr>
<tr>
<td>4</td>
<td>No flow (occlusion) with dynamic positioning</td>
</tr>
</tbody>
</table>

Fig 2. A 3D TOF MRA image of a right vertebral artery from a patient with a full posterior ponticle. A. Neutral position. B. Full left rotation. Note the straightening of the atlantoaxial curve of the vertebral artery but that there is no evidence of stenosis.
(SD = 8.1), and to the right, it was 71° (SD = 11.5). Blood pressures for the entire group averaged 135/86 mm Hg (SD = 21.2/15.0).

While in the neutral position, all the vertebral arteries had normal Doppler signals, and MRA also revealed no abnormality. None of the 64 vertebral arteries from the participants examined with Doppler velocimetry displayed any marked changes in the audio Doppler signals during contralateral cervical rotation. The MRA studies found that there were no changes in image density or luminal diameter changes indicative of stenosis that occurred during contralateral or ipsilateral cervical rotation (Fig 2). Hence, there was complete agreement of the Doppler velocimeter and MRA findings among the 16 participants who had both types of examinations. Straightening of at least 1 part of the atlantoaxial curves was observed in all the cases.

**DISCUSSION**

The present study indicates that rotational stenosis of vertebral arteries among posterior ponticle patients occurred less frequently (0%) than the 5% that was observed in the study by Haynes for chiropractic patients in general. However, this difference was not statistically significant ($P = .3938$). What can be deduced from the results is that they do not support the hypothesis that the presence of posterior ponticles greatly increases the incidence of rotational stenosis of vertebral arteries among chiropractic patients with a history of spinal complaints.

The perfect agreement between the Doppler technique and MRA in assessing vertebral artery patency in the neutral position and with full contralateral cervical rotation provides further evidence supporting the validity of the former. Previous studies that compared Doppler velocimetry of vertebral arteries with arteriography indicated that Doppler had high sensitivity and specificity in examining the patency of vertebral arteries with the head in the neutral position.$^{11-14}$ Another study$^{15}$ that compared Doppler velocimetry with color duplex sonography indicated that the former had high validity ($k = 1.00$) in determining rotational stenosis of vertebral arteries. Haynes et al$^{16}$ found that the Doppler technique also displayed high interexaminer reliability ($k = 0.68$).

It should be noted that the group of ponticle patients had averaged similar cervical rotation, left (65°) and right (71°), to the average rotation, left (65°) and right (72°), found in the subset of general chiropractic patients who had duplex ultrasonography scanning studies made in the paper by Haynes and Milne.$^{17}$ This means that the lack of evidence concerning overrepresentation of rotational stenosis in the ponticle group is unable to be explained as being due to this group having less cervical rotation than the general chiropractic patient group. Even if there had been a difference in overall cervical rotation, the main movement that affects vertebral arteries is atlantoaxial rotation, which according to Dvorak et al$^{18}$ does not decrease with age as does general neck rotation. This means that even if the gross cervical rotations were different, the atlantoaxial rotations may have been the same.

The ponticle patient group exhibited a higher average blood pressure (134/86 mm Hg) than the general chiropractic group (121/78 mm Hg) in the study by Haynes and Milne$^{17}$, the difference between the systolic blood pressures being statistically significant ($P = .023$) but was not significant for the differences in the diastolic pressures ($P = .63$). There were only 20 patients in the group who were examined with duplex sonography by Haynes and Milne,$^{17}$ which means that their blood pressures may not have been representative for the whole of the chiropractic patients in general. With the available data, it seems that it would be difficult to determine whether the blood pressures were really higher for the ponticle group. If there had definitely been this difference, perhaps then the effects of the posterior ponticles would have been reduced by the higher intramural pressures. The modeling studies by Haynes et al$^{19}$ showed that indentation of the model artery from localized compression was reduced with higher intramural pressures, but they also indicated that the higher pressures failed to prevent the indentation when the vessel was compressed. This means that even if there had been higher blood pressures in the ponticle group, this would not have been sufficient to completely counter the localized compression from a posterior ponticle. The MRA scans provided no evidence of even minor compression of the arteries at any point along their course, which indicates that blood pressures most likely had little or no effect on the results of the present study.

From the 32 participants there may have been more than 33 ponticles that were observed on the lateral cervical spine radiographs, which would have given the study more statistical power. There is the possibility that a second ring could be superimposed on the one that is visualized on the radiograph and thereby is hidden on the film. In addition, there is evidence that the radiologically reported incidences of posterior ponticles are considerably lower than that of cadaveric studies,$^{2,20,21}$; for example, there was a 33% incidence for cadaveric studies and 13.64% for radiographic examinations.

Another factor to be considered is that, according to Lamberty and Zivanović,$^{2}$ whenever there is a bony ring, either complete or incomplete on 1 side only, there is always a deeper groove than usual on the other side. If this groove is deep enough, bone from the posterior arch could contact the rear of the vertebral artery at this level. Such contact would be similar to that made by a posterior ponticle, especially during contralateral cervical rotation, where the atlas transverse process is drawn forward relative to the artery (ie, the back of the bony ring or deep groove would have been drawn forward). However, the biomechanical
rationale for the mechanical effects of posterior ponticles has not been shown. It seems unlikely that there would be much movement of the vertebral artery between the arcuate foramen and the transverse foramen, there being no joint for movement to occur between these 2 locations. It would be expected that this section of the vertebral artery would move en bloc with the atlas during rotation, especially considering that the adventitia of the vertebral artery is often adherent to the periosteum of the cervical vertebra when the two come in close contact.22

Conceivably, tensions on the atlantoaxial segment from the third part of the vertebral artery during contralateral rotation could be translated to the portion of the vessel lying on the posterior arch of the atlas. Taitz and Nathan1 suggested that if the arcuate foramen was small, this movement of the artery could be restricted, causing mechanical stresses to the arterial wall. However, it is likely that translational movement of the artery at this level would normally be limited by its adhesion directly to the periosteum of the atlas or via a plexus of veins that surround the artery.22 Furthermore, vertebral arteries that have particularly tortuous courses can cause erosion of bone in the lateral aspects of the bodies of cervical vertebrae.23 Hence, vertebral arteries can shape the bone that is close to them, and it would be likely that the pulsatile forces of the arteries within a foramina would keep the aperture to at least the diameter of the artery.

Typically, vertebral arteries fit snugly in the transverse foramen,22 and usually, this causes no major mechanical stresses to the vessels during neck movement. If posterior ponticles can be thought of as forming an accessory foramen, there seems to be little reason to expect that the bony rings would cause any greater mechanical stresses to vertebral arteries than a typical transverse foramen. This is particularly so when there is no relative movement between the posterior ponticle and the atlas transverse process.

There appears to be little evidence that posterior ponticles place extra mechanical stresses on vertebral arteries. The present study was confined to examining adults because of ethical considerations, so the results should not be extrapolated to children. Maybe there is another explanation for the finding of an association of vertebral artery dissection and posterior ponticles in the case study of 9 children. The hypothesis that the presence of posterior ponticles markedly increases the incidence of rotational stenosis of vertebral arteries among patients with a history of spinal complaints was not supported by the findings of this pilot study. Replication studies should be made, and the results from those studies pooled with those from the present study. This would help generate a larger sample size to enable better statistical analysis for differences between ponticle patients and chiropractic patients in general.

CONCLUSION

The study by Guillon et al25 showed that internal carotid arteries that had healed after arterial dissection had greater changes in the diameter with each pulse than those from matched controls. This suggests that arteriopathy associated with arterial dissection affects the arterial wall in such a way that it can lead to a greater distension with each pulse. If this was to occur with vertebral arteries, extra distension of the vessel in the region of the atlas posterior arch could transmit more force to the lower margin of the posterior atlanto-occipital membrane, causing reactive sclerosis of this structure. As the arteriopathy gradually worsened, the posterior ponticle would become more pronounced. Arterial dissection may occur as a natural progression of the arteriopathy and could be hastened by pressure of the artery against the posterior ponticle. In these cases, it could be that the artery, with its arteriopathy, contributes to the formation of the bony ring. Perhaps in some instances, a full posterior ponticle in a young child can be an indicator of an arteriopathy that is affecting the vertebral artery at that level.

ACKNOWLEDGMENTS

The authors thank Drs Peter Bryner, Miriam Minty, and Paul Stearker from the Burswood Health Professionals; Dr Gordon Benz from the Kwinana Chiropractic Clinic; and Dr Terrence Haynes from the Midland Chiropractic Clinic for help in recruiting participants for this study.

REFERENCES


AN ANALYSIS OF PUBIS SYMPHYSIS MISALIGNMENT USING PLAIN FILM RADIOGRAPHY

William J. Ruch, DC, a and Brandy Mychals Ruch, DC b

ABSTRACT

Objective: To show, using a laboratory model, the inherent problems and test the validity of viewing actual pubis symphysis misalignment via plain film radiography in humans.

Study Design: In vitro experiment of pubic bone and pubis symphysis model alignment as determined through projected imaging with collimated light.

Results: The shadows cast by plastic models did not accurately reflect the physical reality. The image representations of the pubic bones with significant misalignment appeared as “normal.” Some of the misalignments were viewed in the exact opposite alignment on the projected image as compared with the physical reality.

Conclusions: This study provides evidence that misalignment of the pubic bones cannot be reliably viewed on a standard anteroposterior lumbopelvic radiograph. The results show the potential for missed diagnoses of clinical significance. Additional research on pelvic joint dysfunction and imaging problems is needed. (J Manipulative Physiol Ther 2005;28:330-335)

Key Indexing Terms: Pubic Symphysis; Radiography; Pelvic Bones; Injury; Chiropractic

The purpose of this study was to examine radiographic reliability of pubic symphysis misalignment with consideration of its potential role in low back pain and/or pelvic pain. The rationale for this study was obtained considering the frequent discussion regarding the etiology of low back pain coupled with the scarcity of scientific literature examining the role of pelvic girdle misalignments. In addition, the following considerations were made in evaluating the potential value of this study.

ANATOMICAL CONSIDERATIONS

In instances where pelvic girdle instability is considered, the pubic symphysis is seen as less responsible for low back pain than the sacroiliac joints. A more complete analysis of the 3-bone 3-joint complex that makes up the pelvic girdle shows the pubic symphysis’ immense influence over the entire musculoskeletal system. This is specifically illustrated by the bulk of the body’s muscle mass attached directly to the pelvic bones, the fact that the pelvis supports and has attached to it the large trunk and leg muscles. When joint misalignment and ligament instability are present, it can initiate reflexive guarding of the tissues involved.

A more careful examination of the pubic bones points to the mechanical and physiological importance of this pelvic joint. The 2 pelvic bones are connected by the pubic symphysis, an avascular fibrocartilaginous disk. This disk is composed of the same properties as the avascular fibrocartilaginous intervertebral disks in the spine. Anatomical evidence points to movement initiating imbibition as the sustaining nutritional force for the life of this tissue. Limited background research shows that a separation of 2 cm in the x-axis (Fig 1A and B) will cause severe patient distress and loss of ambulation referred to as an open-book dislocation. However, despite the research and basic anatomical considerations, this joint structure, its biomechanics, and potential injury are ignored in current clinical practice and treatment recommendations.

There is an expanding body of research that shows how 2-dimensional imaging of an irregular 3-dimensional object on a plane surface creates projection errors. One possible reason the pelvis is neglected when diagnosing injury is due to the fact that imaging makes the radiograph look normal when it is clearly misaligned in anatomical reality (Fig 2). A review of the literature illustrates that this has been known for some time. The pubic bones are not included in most anteroposterior (AP) radiographs, and use of radiographic techniques to show symphysis pubis subluxation or insta-
bility is not commonly found in clinical practice. Severe symptoms involving pelvic instability with radiographic analysis of sacroiliac joint dislocation will frequently be referred to as only the appearance of dislocation at the pubis symphysis.” The normal motion of the pubis symphysis is very small when compared with other joints with only 2 mm of displacement considered normal. A separation of 3 mm or more is pathological and should be considered a subluxation in the static evaluation (Fig 1A and B).

The question that this study investigates is: can displaced pubic bones be seen on plain film AP radiographs?

**METHODS**

The problem of imaging the pelvis is further complicated by the variety of pelvic tilt found in the individual human form (Fig 3). It was necessary to create an “in inferior pubic line” via evaluation of the lateral lumbo pelvic radiograph to reach a determination of the angle of the pubic bones to the central ray in an AP lumbo pelvic
radiograph. This was accomplished by identifying and scribing the inferior aspect of the pubic bones. Then a horizontal line was used to orientate the inferior pubic line and the end ranges of the pelvic tilt between the anterior and posterior positions. Fifteen degrees represents the extreme anterior tilt orientation often found in the female pelvis, and 55° was the extreme posterior tilt position often represented in the male pelvis (Fig 3).17-19

Study Design

Two objects of similar size and shape to a pubic bone (Fig 4) were connected with a small piece of acrylic to form a model of the pubic symphysis. Four models were made with various alignments. The first, labeled Z 0/Y 0, was correctly aligned in the Z and Y planes (Fig 5). The second, labeled Z 1 cm/Y 1 cm, was misaligned by 1 cm anteriorly in the Z plane and 1 cm superiorly in the Y plane (Fig 6). The third, labeled Z 0.6 cm/Y 2 cm, was misaligned by 0.6 cm posteriorly in the Z plane and 2 cm superiorly in the Y plane (Fig 7). The fourth was labeled Z 1.5 cm/Y 0 and was misaligned by 1.5 cm anteriorly in the Z plane and was correctly aligned in the Y plane (Fig 8).

The models were suspended 9 in toward the front of a vertical white surface and 7 in below the center of a 90-W lamp located 40 in away from the vertical surface and collimated in similar fashion of an AP lumbopelvic radiograph to model this x-ray view (Fig 9). Collimation was performed by using cardboard with a cutout opening of 7/8 × 1 1/4 in, 16 in above the desk surface.

Each model was photographed 5 times. One photograph was taken to show the actual physical misalignment and 4 times in the projected image shadow tilted at 15°, 30°, 45°, and 55° to represent the variations of normal pelvic tilt in human anatomy.
RESULTS

The shadows cast by the models in positions similar to a standing AP lumbopelvic radiograph were not an accurate representation of the 3-dimensional models. In some cases, the actual misalignment would appear as a straight line on the projected image (Fig 7E) or in the exact opposite impression on the projected image (Fig 8C). Fig 5 illustrates the normal or aligned model. Fig 5B to E are the projected image of the aligned models that show the changes of tilt positions and consistent shadow images. Fig 6A is displaced by 1 cm in both the Z and Y planes, on the left side of the model. Note that the illusion in Fig 6B to E projected images that show the left side as inferior. Fig 6B in the 15° orientation correctly illustrates the anterior or Z-plane misalignment, but incorrectly appears to be inferior in the Y plane. Fig 6C represents the 30° pelvic tilt. This mock radiographic view shows slight Y displacement on the wrong side. In Fig 6D, the left side appears inferior when it is physically superior, and Fig 6E is incorrectly appearing to look aligned.

In Fig 7A, the model has been misaligned on the right at 2 cm superiority in the Y plane and 0.6 cm anteriorly in the Z plane. In Fig 7B, the expected inferior appearance of the anterior Z displacement is visible on the right side, but what is not seen is the 2-cm displacement in the Y plane. The Fig 7C shadow incorrectly appears as a straight line at 30°, obscuring all misalignments, a clear false-negative reading. Fig 7D is set in the 45° pelvic tilt and shows some of the right side superior displacement in the Y plane, but does not illustrate the Z-plane displacement. Fig 7E represents more of the misalignment pattern but still does not show the true physical reality. Fig 8A is a 1.5-cm misalignment in the Z plane, representing what would be clinically determined to be a luxation because the objects are only

Fig 7. A. This model has a small 0.6-cm Z-plane displacement but a large 2-cm displacement in the Y plane. B. The right side has the 0.6-cm +Z displacement as well as the 2-cm +Y displacement. Only the +Z displacement is seen, but as an inferior displacement. C. This looks similar to Fig 3C, aligned. D. At 45° the right side is beginning to appear slightly superior. E. The 55° position has the right side with greater superior displacement.

Fig 8. A. This model has a 1.5-cm +Z displacement of the right side. B. The 15° angle makes the right side appear inferior. Note the appearance of the complete slip or luxation in the Y plane (C, D, and E) all have the right side appearing in the inferior position. The −Z position of the left side appears as a +Y displacement.
The model is constructed to have the right side anterior in the Z plane. In Fig 8B to E, the mock radiographs all incorrectly appear to be inferior on the right.

**DISCUSSION**

The inconsistency in the projected images versus the actual physical misalignments correlates with our clinical observations of treating pubic symphysis misalignment over the past 16 years. In the clinical setting, pubic symphysis examination including palpation and functional assessment will often not match the standard AP lumbo-pelvic radiograph. According to clinical observation, the more anterior the pelvic tilt, then the more likely a superior misalignment in the Y plane will appear incorrectly as an inferior misalignment on projected image. The experiment verifies this clinical observation and allows the hypothesis that it is the Z-plane displacement that obscures the Y plane and creates this projection error. In addition, 7 years of human cadaver dissection also produced findings of pubis symphysis misalignment that would not be accurately shown on radiographs.

Fig 9. Diagram of imaging apparatus (not to scale). View represents a midsagittal section as viewed from the “patient’s” right side. This shows the relationship of the x-ray source, target structures, and x-ray film. Note that although the recording camera is positioned slightly below the “target,” the shadow and x-ray image are 2-dimensional and are therefore accurately represented in the photographs, although the image of the target itself is subject to parallax (and depth-of-field focusing limitations). The camera is in fact at the same level as the shadow. That this is below the level of the target verifies the distortion of both the position and shape of the target structure introduced by the point-source nature of the x-ray, and its position relative to any particular structure. This physical distortion is complicated by a psychological distortion—we tend to view the x-ray image from the viewpoint of the recording camera, when in fact, the image must be interpreted as if viewed from the light source. Dimensions are average figures derived from recent analyses of x-ray imaging and are based on the standard technique of positioning the central ray of the x-ray source at the level of L4. Images were projected using a collimated light source to simulate the point-source characteristics of typical x-ray equipment.

It is apparent that imaging of the pubic bones can be complicated and misleading. These findings may have clinical significance for any practitioner attempting to accurately assess pelvic girdle dysfunction and potential misalignment. The inability to correctly assess pubis symphysis misalignment via radiograph could lead to inaccurate diagnosis and treatment by practitioners unaware of this phenomenon.

It is interesting to note that there were many false-negative findings (the misalignment appeared normal) on the projected images. However, although misalignments were often inaccurately represented, there were not any false-positive findings (a correctly aligned model appearing misaligned on the projected image). The rotation in the X plane was not considered in this experiment but would add even more complexity to the problem.

**CONCLUSION**

This study suggests that significant displacement patterns of the pubic bones may not be accurately visualized on plain radiographs, specifically the AP lumbo-pelvic view. This suggests that use of x-ray analysis alone in determining clinically significant subluxation or misalignment patterns of the pelvis may not be sufficient for accurate diagnosis. It is possible that new methods need to be explored to evaluate imaging of the pelvic girdle. We are in need of a more
expansive body of research on pelvic joint dysfunction and the inherent imaging problems presented.

ACKNOWLEDGMENTS

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REFERENCES

Assessment of Knowledge of Primary Care Activities in a Sample of Medical and Chiropractic Students

Ruth Sandefur, DC, PhD, a Theresa A. Febbo, DC, b and Ronald L. Rupert, MS, DC c

Abstract

Objective: To examine the influence of chiropractic education on knowledge of primary care tasks. Scores received on a test of knowledge of primary care tasks were compared between 3 samples of chiropractic students and 1 small sample of medical students.

Data Sources: The taxonomy of primary care tasks that was previously published provided the basis for test items used in this study. A team of test writers prepared an evaluation instrument that was administered to final-term chiropractic students at 3 colleges and to a small sample of medical students as they were entering their residency programs.

Results: The chiropractic students scored below the medical students on the primary care examination in every area except musculoskeletal conditions. Chiropractic students scored higher than medical students on the musculoskeletal portion of the examination.

Conclusions: In this sample, chiropractic students performed almost as well as medical students on a test that was designed to measure knowledge of primary care tasks. If the premise is accepted that medical school is the gold standard of primary care instruction, that chiropractic students fared almost as well as medical students is noteworthy. (J Manipulative Physiol Ther 2005;28:336-344)

Key Indexing Terms: Chiropractic; Primary Care; Education, Medical; Education, Professional

There is a spirited and often passionate debate within the chiropractic profession regarding the ability, or even the appropriateness, of chiropractors to fill the role of primary care providers. From a practical standpoint, being a primary care provider opens doors to systems of reimbursement that otherwise are not approachable. This may help explain the passion often associated with the “to be or not to be” a primary care provider question. There is the view that doctors of chiropractic (DCs) fail to qualify as primary care physicians, but this does not provide the necessary documentation that they indeed fill that role.

Perhaps one problem surrounding this issue is the elusiveness of the concept and the fact that primary care is difficult to define in absolute terms. According to Kranz, the difficulty in establishing a widely accepted definition of primary care has made the accumulation of data that can be used to measure primary care challenging. The establishment of a taxonomy of primary care tasks reported in a previous study may be a first step in providing tools for this purpose.

Historically, chiropractors have devoted a good deal of their internal resources to survival. Antitrust litigation, college accreditation, and practitioner autonomy have mitigated resources and the focus of professional efforts. Major strides were made when the chiropractic college accrediting agency, the Council on Chiropractic Education, was officially recognized in 1974 by the US Office of Education. This recognition was the culmination of years of work involving chiropractic organizations. Because of the accreditation of chiropractic institutions by the Council on Chiropractic Education, educational rigor and faculty credentials have been elevated. Professional efforts became focused when members of the profession involved in developing a research infrastructure had the foresight to see

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a need for future preparedness. As a result, a cadre of highly trained scientific researchers has emerged. On many levels, chiropractors have assumed regulatory responsibility. The Mercy Guidelines document is a notable example.

Questions have been raised about the role of chiropractic in health care, acknowledging the established benefits of spinal manipulation for low-back and neck pain, but conceding few other areas of potential health benefits. Appeals have been made that chiropractors are qualified to offer certain aspects of primary care. Proponents of chiropractors serving as primary care providers usually offer caveats, such as (1) improve the education of chiropractic students to better prepare them for primary care practice; (2) serve as a member of a primary care team in a multi-disciplinary setting; and (3) offer primary care in the context of prevention and wellness care. On the issue of state laws and their impact upon the practice of chiropractic, there are no data on the effect of scope of practice restrictions and the ability of chiropractors to deliver primary care services.20

With regard to practicing chiropractors, a discrepancy exists between how most chiropractors see themselves and how they actually practice. As pointed out in a survey of the practitioners listed in the National Directory of Chiropractic 1993-1994 edition, 90.4% answered “yes” to the question, “Do you consider yourself a primary care practitioner?” Evidence to support this contention is sparse. In a survey of North American chiropractors with 687 respondents conducted by McDonald et al., data were collected on various aspects of chiropractic practice. Although the specific question addressing attitudes about primary care was not asked in this survey, it is not unreasonable to make inferences based on survey responses. The question “Should the adjustment be limited to musculoskeletal conditions?” was answered “no” by (89.8%) of those surveyed. Respondents clearly do not want to be limited to treating only musculoskeletal conditions. Another related finding of this survey is that 93.6% reported that they offer “wellness” care in their practices.

Although chiropractors continue to debate the pros and cons of being primary care providers, and although chiropractic educators are striving to meet the challenge of training primary care physicians, patients tend to seek chiropractic care largely for neuromusculoskeletal conditions. A survey of chiropractic practice patterns from 1985 through 1991 at 5 US sites and 1 Canadian site showed that 68% of the care provided by chiropractors was for low-back pain. A later report stated that 70% of patients who visited chiropractors had consulted the chiropractor for back or neck pain. Of this sample, only 6% of the visits were for conditions that were not musculoskeletal in nature.

With regard to primary care, the public has little to help them determine whether the chiropractor they plan to visit for back pain can also diagnose and treat their reflux disease. For chiropractors to enjoy a wider traditional covenant, the competence of graduates in primary care activities must be established. It is also useful to determine how well chiropractic graduates score on tests that compare them to medical counterparts on knowledge about primary care activities. This research was undertaken with that aim in mind.

In a previous study, the curricula of selected medical schools and chiropractic schools were compared. The authors concluded that in the basic sciences, chiropractic and medical curricula are quite similar. The biggest difference existed in the clinical practice portion of the curriculum where medical school exceeded chiropractic institutions in the number of hours offered. Among other recommendations advanced was that the quality of educational programs be explored. In a study addressing physician’s perceptions of their ability to provide high-quality care in a managed care system, it was notable that in each category polled, the primary care providers scored themselves higher than specialists in being able to offer quality services to their patients. This study takes a small, first step by evaluating knowledge of chiropractic students compared with medical students on knowledge of primary care activities.

The debate over the role chiropractic will play in primary care will no doubt continue for a long while and, in the meantime, the Council on Chiropractic Education has mandated that chiropractic institutions “educate and train a competent doctor of chiropractic who will provide quality patient care and serve as a primary care physician” as a requirement for accreditation. Chiropractic institutions, coveting accreditation, strive to meet these standards and, despite philosophical objections that some academic leaders may have, include in their curricula requisite numbers of courses in pathology and diagnosis. This study, rather than engaging in the ongoing primary care debate that previously has been extensively reviewed, approached the subject from a pragmatic standpoint and simply asked the question, “How well do our institutions train students in knowledge of primary care activities?”

Table 1. Primary care major categories

<table>
<thead>
<tr>
<th>Major categories</th>
<th>Examples of activities involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Information gathering</td>
<td>Physical examination, history, other examination procedures</td>
</tr>
<tr>
<td>2. Screening and prevention</td>
<td>Providing screening activities, counseling and prevention</td>
</tr>
<tr>
<td>3. Other diagnostic procedures</td>
<td>Drawing blood, obtaining samples, dressing changes, biopsies</td>
</tr>
<tr>
<td>4. Counseling/education</td>
<td>Nutritional advice, stress, death and dying issues, family planning</td>
</tr>
<tr>
<td>5. Management of acute and chronic conditions</td>
<td>Subcategories of major body systems and relevant disorders</td>
</tr>
<tr>
<td>6. Special populations</td>
<td>Frail elderly, pregnant females, nursing home patients</td>
</tr>
<tr>
<td>7. Other primary activities</td>
<td>Coordination of care, community activities and services</td>
</tr>
<tr>
<td>8. Counseling on complementary care</td>
<td>Counseling activities, referrals to other providers</td>
</tr>
</tbody>
</table>
In 2001, a publication reported on a study that asked 2 panels of experts to identify tasks performed by health-care providers that were considered to be “primary care activities.” In addition, these panels considered the potential role of chiropractors to provide primary care services. This report is a follow-up and expansion on previously published work that established a taxonomy of primary care activities and examined the potential role for chiropractors to provide primary care services. The purpose of the present study was to evaluate the ability of chiropractic students to correctly respond to questions formulated around the identified primary care tasks.

**METHODS**

A committee composed of full-time faculty members at a chiropractic college constructed a test to be used to evaluate the previously identified primary care activities. The committee was composed of 2 DCs who also hold bachelor’s degrees, 1 DC with a diplomate in radiology, a DC enrolled in the final year of a radiology residency program, and 2 MDs. The test was constructed based upon a collapsed task list derived from the original list of 175 items. The original task list had been divided into 8 categories by the expert panels (Table 1). The shortened list resulting from criteria established by the present study contained 52 items that the former expert panel had scored highest on “frequency” and “importance” rankings (Table 2).

Members of the 6-person team were requested to write items from an assigned series of topics chosen from among the 52 primary care tasks. After completion of assignments, team members convened in a series of meetings to consider

### Table 2. List of primary care tasks scoring highest on frequency and importance

<table>
<thead>
<tr>
<th>Task list</th>
<th>Frequency score</th>
<th>Importance score</th>
<th>Total score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information gathering</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment of the necessity for care</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Complete or focused physical examination</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Complete or focused health history</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Mental status examination</td>
<td>10</td>
<td>8.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Focused examination for the management of acute or chronic conditions</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Documenting final medical assessment</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Documenting plan of care</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Triaging</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Evaluation of undifferentiated problems</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Disposition of undifferentiated problems</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Screening/prevention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Providing appropriate screening measures</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Interpreting results of screening</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Counseling regarding screening</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Other diagnostic procedures/techniques</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drawing blood for samples</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Obtaining urine samples</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Reviewing radiographic reports</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Ergonomics and workplace safety</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Counseling/education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol/substance abuse</td>
<td>9.5</td>
<td>10</td>
<td>19.5</td>
</tr>
<tr>
<td>Smoking cessation</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Diet/nutrition</td>
<td>10</td>
<td>9.5</td>
<td>19.5</td>
</tr>
<tr>
<td>Stress management</td>
<td>10</td>
<td>8.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Prescriptions and polypharmacy</td>
<td>9.5</td>
<td>9.5</td>
<td>19</td>
</tr>
<tr>
<td>Helping patients make choices</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Safety</td>
<td>9.5</td>
<td>9.5</td>
<td>19</td>
</tr>
<tr>
<td>Disease education</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Fitness and exercise</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

**Table 2. (continued)**

<table>
<thead>
<tr>
<th>Task list</th>
<th>Frequency score</th>
<th>Importance score</th>
<th>Total score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management of acute and chronic conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prescribing appropriate medications*</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Injuries/trauma</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor trauma</td>
<td>10</td>
<td>8.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Sprains/strains</td>
<td>10</td>
<td>8.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back and neck pain/strain</td>
<td>10</td>
<td>8.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Repetitive stress injury</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Genitourinary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear, nose, and throat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ophthalmologic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dermatologic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infectious</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neurological</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest pain</td>
<td>9.5</td>
<td>9.5</td>
<td>19</td>
</tr>
<tr>
<td>Hypertension</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Endocrine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Pulmonary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emphysema</td>
<td>9.5</td>
<td>9.5</td>
<td>19</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Behavioral</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hematologic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special populations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional/support or frail elderly</td>
<td>9.5</td>
<td>9.5</td>
<td>19</td>
</tr>
<tr>
<td>Pregnancy-related care</td>
<td>9</td>
<td>10</td>
<td>19</td>
</tr>
</tbody>
</table>

*Outside scope of chiropractic practice.
Each submitted question. Each item was projected onto an overhead screen and a group determination was made whether to accept the question, edit the question to make it acceptable, or to reject it. This process resulted in a 100-item multiple-choice examination. The test was divided into two 50-item examinations to meet testing time limitations imposed by the study.

The examination was pilot-tested with a sample of chiropractic students to perform reliability testing. Both versions of the examination were found to be reliable upon split-half reliability testing. Test version A was accepted for use in this study. It was administered to final-year chiropractic college students at 3 major institutions. The purpose of the study was explained to all subjects, who also read and signed an informed consent statement. Their participation was clearly indicated as voluntary. Anonymity was assured for individuals and the institutions represented.

Collapsing the 175-item task list into a more manageable number, 52, was done by selecting only those items that scored highest by the panel on “frequency of performance” and “importance to perform.” A composite score of 20 was the highest possible rating given by the panel. For this report, a composite score of 18.5 or above was necessary to be included in the task list. The resulting 100-item instrument was divided into two 50-item tests. Each was found to be reliable upon split-half reliability testing. Only 1 of the 50-item examinations was used in this study because of a sample size too small to adequately evaluate 2 test instruments. Examination version A was selected for this study, and it is suggested that in future studies, examination version B is also available for use.

The previous study, published in 2001,8 that was used as the basis for test items in the present study investigated the role of chiropractors in primary care activities. Two expert panels were convened and participated in a consensus process aimed at identifying and categorizing primary care activities. A stated goal was the enumeration of primary care activities that are common between chiropractors and other health-care professionals. The outcome of the 2 consensus panels was identification of 8 major categories. Of the 8 major categories, the category of “management of acute and chronic illnesses” was further divided into 15 subcategories (eg, injuries and trauma, musculoskeletal, genitourinary, ears, nose, and throat, ophthalmology, dermatology, infectious diseases, neurology, cardiovascular, endocrine, pulmonary, gastrointestinal, psychiatric, hematological, and special populations).

Table 3. Raw and percentage scores of all test groups

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Combined 1 to 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td>21</td>
<td>22</td>
<td>79</td>
<td>122</td>
</tr>
<tr>
<td>Raw scores</td>
<td>32.7</td>
<td>28</td>
<td>32.1</td>
<td>31.4</td>
</tr>
<tr>
<td>% Scores</td>
<td>65.4</td>
<td>56</td>
<td>64.2</td>
<td>62.8</td>
</tr>
<tr>
<td>SD</td>
<td>4.6</td>
<td>5</td>
<td>4.4</td>
<td>4.7</td>
</tr>
</tbody>
</table>

The present project was designed to assess knowledge of primary care activities in a population of chiropractic students who were about to graduate. Test items were constructed at the level of synthesis and analysis using Bloom’s taxonomy of learning.28 Testing in this manner has been shown to, “develop a more deeply oriented learning strategy,” rather than one of rote memorization, which develops when students are tested on simple basic facts.29 The results obtained from this sample were later compared with a small number of graduate medical students as they were entering their residencies.

RESULTS

Table 3 shows the average number of correct answers out of 50 questions attained by each of the 4 groups. Groups 1 through 3 are the students from the 3 different chiropractic institutions, and group 4 is the medical student sample. The combined group includes the average of the 3 chiropractic student groups. Percentage scores indicate that the percentage of correct answers for each of the chiropractic groups is below passing based on 70% as a passing score.

The medical students scored higher on questions regarding each component of primary care activities than the chiropractic students except for the set of data identified as “musculoskeletal.” For this data set, each of the chiropractic groups scored higher than the medical group. The medical group scored lower on the neuromusculoskeletal test items than would be expected based on _χ²_ statistical tests (Table 4).

The average percentage of correct answers for each of the major categories is presented in Table 5. The average percentage of correct answers for each group on the subcategories under the major heading “management of acute and chronic conditions” is presented in Table 6. Looking more closely at the group scores on test items as shown in Table 6, one can see that some wide variances in average scores occur. Two of the chiropractic groups scored only slightly above 50%, and the other chiropractic group scored only one percentage point above “passing” on these same items. For several subcategories, outlier group scores appear. For example, group 2 scored very low on genitourinary and cardiovascular items. For several of the subcategories, no group, including the medical group, scored on the average above passing. These subcategories include ophthalmology, endocrine, and special populations. Subcategories in which chiropractic students all scored low but medical students
Tables 5, 6, and 7.

Table 5. Percentage scores of all students on 5 major categories of primary care tasks

<table>
<thead>
<tr>
<th>Primary care activities</th>
<th>Information gathering (% correct)</th>
<th>Screening and prevention (% correct)</th>
<th>Other diagnostic procedures (% correct)</th>
<th>Counseling and education (% correct)</th>
<th>Management of acute/chronic conditions (% correct)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>60.12</td>
<td>35.72</td>
<td>66.94</td>
<td>69.05</td>
<td>65.71</td>
</tr>
<tr>
<td>Group 2</td>
<td>57.04</td>
<td>27.09</td>
<td>57.64</td>
<td>75.00</td>
<td>57.04</td>
</tr>
<tr>
<td>Group 3</td>
<td>64.72</td>
<td>38.93</td>
<td>65.83</td>
<td>87.75</td>
<td>64.69</td>
</tr>
<tr>
<td>Group 4</td>
<td>76.64</td>
<td>63.10</td>
<td>74.34</td>
<td>95.24</td>
<td>73.01</td>
</tr>
</tbody>
</table>

Table 6. Percentage correct answers for subcategories of management of acute and chronic conditions

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injuries and trauma</td>
<td>57.14</td>
<td>87.5</td>
<td>96.2</td>
<td>95.24</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>71.04</td>
<td>56.95</td>
<td>54.75</td>
<td>48.02</td>
</tr>
<tr>
<td>Genitourinary</td>
<td>53.97</td>
<td>37.5</td>
<td>66.25</td>
<td>90.48</td>
</tr>
<tr>
<td>Ophthalmologic</td>
<td>58.73</td>
<td>44.45</td>
<td>52.32</td>
<td>63.5</td>
</tr>
<tr>
<td>Ears, nose, and throat</td>
<td>69.05</td>
<td>59.03</td>
<td>71.73</td>
<td>87.31</td>
</tr>
<tr>
<td>Dermatologic</td>
<td>89.53</td>
<td>67.5</td>
<td>83.55</td>
<td>97.15</td>
</tr>
<tr>
<td>Infectious disease</td>
<td>88.1</td>
<td>79.17</td>
<td>86.08</td>
<td>98.81</td>
</tr>
<tr>
<td>Neurological</td>
<td>78.1</td>
<td>61.67</td>
<td>78.99</td>
<td>82.86</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>53.97</td>
<td>37.5</td>
<td>66.25</td>
<td>90.48</td>
</tr>
<tr>
<td>Endocrine</td>
<td>53.97</td>
<td>52.09</td>
<td>53.17</td>
<td>69.85</td>
</tr>
<tr>
<td>Pulmonary</td>
<td>73.02</td>
<td>69.44</td>
<td>81.02</td>
<td>92.07</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>53.18</td>
<td>52.78</td>
<td>59.29</td>
<td>72.21</td>
</tr>
<tr>
<td>Behavioral</td>
<td>69.05</td>
<td>75</td>
<td>87.75</td>
<td>95.24</td>
</tr>
<tr>
<td>Hematologic</td>
<td>60</td>
<td>61.67</td>
<td>69.62</td>
<td>78.1</td>
</tr>
<tr>
<td>Special populations</td>
<td>35.72</td>
<td>20.94</td>
<td>38.61</td>
<td>64.29</td>
</tr>
</tbody>
</table>

Table 7. Absolute differences between individual group mean values (t2)

<table>
<thead>
<tr>
<th></th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>4.9* (0.20)</td>
<td>0.6 (0.01)</td>
<td>4.0* (0.21)</td>
</tr>
<tr>
<td>Group 2</td>
<td>4.3* (0.30)</td>
<td>8.9** (0.55)</td>
<td></td>
</tr>
<tr>
<td>Group 3</td>
<td>4.6* (0.41)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion

Despite the limitations imposed by study design, sampling methods, sample size, and test format, which all have been addressed elsewhere, the results obtained have provided some interesting information. These data will be provided to the administrators of the colleges participating in this project. Chiropractic educators may wish to provide feedback to those who supervise the instruction in the areas identified as weak. Claims about the usefulness of these data for chiropractic educators, however, must be tempered in light of the small number of questions addressing each subject area. The problem associated with attempting to address 52 identified tasks with a 50-item evaluation instrument is obvious. For the medical students and their performance on the musculoskeletal questions, medical educators have previously acknowledged the need to better prepare graduates in this area of study.

An additional caveat with regard to these data is that neither the study design nor the subject population met parametric assumptions considered necessary for the proper application of statistical tests. The student sample was a nonrandomized convenience sample. It cannot be claimed that the groups were obtained from the same population because of the differences in their educational programs. The statistical results were presented only to provide an additional way to view the results.

There are factors that may have affected the performance of chiropractic students on a test of primary care tasks. One of those factors is that of personal bias. If the student does not value primary care, they may not score well on a test designed to assess that knowledge. In addition, there is a vocal segment of the chiropractic profession that embraces the subluxation complex, the sine qua non of chiropractic, to the exclusion of all other considerations. This faction seems to deplore traditional diagnostic methods. They are able to exert influence on chiropractic students through on-campus organizations and outside-of-campus seminars. They often disparage the study of subjects not directly related to the subluxation complex. Students thus influenced may score poorly on tests designed to evaluate primary care knowledge.

Because the range of average scores for all of the students tested was between 56% and 73%, the difficulty level of the examination is called into question. As previously stated, the examination was found to be reliable upon split-half reliability testing. The issue of validity was addressed by sending copies of the test to members of the original expert panels soliciting their opinions as to the appropriateness of the test questions in addressing primary care tasks. Although the results of this inquiry were not unanimous, and several...
panel members expressed concerns about some of the test items, most responders agreed that the test adequately covered the primary care tasks. The majority attested to the appropriateness of the examination. The results obtained in this study suggest, however, that the test may be difficult. That consideration aside, the medical students scored higher than the 3 chiropractic groups. At this point, it should be explained that the medical student sample was obtained just as they entered their residency programs. These students most likely would have fared better on the examination had it been administered after their residency training. The timing of evaluation selected for this study was to provide a more logical comparison with the chiropractic students who were completing a 4-year program of study.

Although this study used a standard testing format to examine the issue of how well students performed on an evaluation of knowledge of primary care tasks, it is acknowledged that, “primary care is a way of delivering health care,” and not a body of knowledge.19 The World Health Organization has long advocated the coordinator aspect of primary care, wherein the physician takes into account the patients’ cultural, social, and economic circumstances.31 The National Academy of Sciences has developed a definition of primary care that describes accessibility and coordination of services as important components to that practice.3 Obviously, as some have pointed out, chiropractors have significant deterrents to being primary care practitioners in the usual sense of the term.2,20,32 Chiropractors do not manage infectious diseases nor are they in a position to “manage 90% of the problems arising in the served population without referral.”2,24 According to data published in the Job Analysis of Chiropractic, 2000, only 5.2% of chiropractors have staff privileges at a medical or osteopathic facility, indicating that it may be difficult to meet the “continuous” aspect of primary care as defined by the Institute of Medicine.33

Nevertheless, many chiropractors consider themselves to be primary care providers.4,15 To be relegated to the role of neuromusculoskeletal practitioner is offensive to some chiropractors, who suggest that to accept that role would deprive the public of the potential benefits chiropractic may be able to offer patients with nonneuromusculoskeletal conditions. Those with a more pragmatic approach2,24 suggest that the benefits to be gained through chiropractic will occur even if treatment is provided for a neuromusculoskeletal complaint. Pragmatists say that the acceptance of chiropractic into the health-care system will be met with fewer objections if that entry is as a neuromusculoskeletal specialist.24

Previous data suggest that chiropractors do well with regard to patient satisfaction and perceived patient participation.23,34 Patients seek alternative therapies and are looking for practitioners well versed in wellness and prevention.18,35 Indeed, a burgeoning class of entrepreneurial physicians (eg, Drs Andrew Weil and Deepak Chopra) has capitalized on the momentum. People want options or “alternatives.”36 Chiropractic care positively correlates with a lower number of hospital stays, fewer nursing home days, and fewer visits to physicians in a population of geriatric patients.37 The geriatric population is particularly challenging because many of their problems are longstanding. Therefore, it is not unreasonable to hypothesize that younger people might expect even higher positive health indicators with regular chiropractic care. According to a survey by Hawk and Dusio,4 a large segment of practicing chiropractors consider themselves to be wellness care practitioners. A number of chiropractors have expressed the view that chiropractic is positioned favorably to fill the wellness care model.17,19,37

Flexibility in maintaining a focus different than that of the typical medical primary care provider would, as many have argued,17,19 be more in keeping with the social milieu and the public’s interest in health and wellness. In the 21st century, the focus will be on prevention and maintenance of function rather than cure.38 The bandwagon of alternative care, however, may not offer a smooth ride. One author18 warns that the desire of the public to seek alternative care may result in the medical profession seeking to be the sole provider of these services. “Notice,” Jusino18 warns, “that it is the therapies and not the practitioners that they intend to incorporate into their system.”

Medical educators have reported strategies used to bolster the number of medical students entering a primary care specialty.38 With the goal of increasing generalist practitioners, adequate interaction between medical students and role models among faculty well versed in generalist specialties became a priority.39 Furthermore, recommendations were made,39 whereby faculty members were to “cease deprecating careers in primary care specialties.” Studies show that attitudes of faculty members have significant influence on institutional reform and on increasing the numbers of generalist graduates.40

The physician workforce has shifted dramatically in terms of specialty composition over the past few decades. For example, between 1965 and 1992, the total number of physicians increased 65%. During this time, the number of specialists per 100,000 rose 121%, whereas the numbers of primary care physicians increased by only 13%.40 By 1998, more than two thirds of the practicing physicians in the United States were specialists.41 As a result of the demand for primary care by managed care organizations and the disproportionate growth of the specialty workforce, policymakers began to focus on a goal to have 50% of all medical school graduates choose primary care careers.42 The Council on Graduate Medical Education established the objective and medical schools targeted increases in the selection of primary care residencies by postgraduates. The targeted selection process was apparently successful, and there was a shift in the other direction. From 1992 to 1997, the percentage of medical school graduates who chose primary care residencies rose from 14.6% to 39.6%.41

As society became more complex and the uninsured and underserved segment increased, trust in the health-care
professions declined. In the United States, this situation has become progressively worse and is complicated by perhaps the most confusing system of health-care reimbursement in the world. As Hawk\textsuperscript{17} states, “The U.S. system of health care is characterized by the highest costs and lowest consumer satisfaction of any developed country.” Although our per-capita spending dwarfs any other nation, our performance with regard to health care is modest.\textsuperscript{31}

At the end of the 20th century, the United States ranked 37th among nations by measures of health-care quality, relevance, and cost-effectiveness.\textsuperscript{31} Furthermore, more than 22 million US citizens have inadequate access to primary care.\textsuperscript{3,40} This situation has made it difficult, if not impossible, for American medical educators to live up to the social contract. Having acknowledged this, many medical educators maintain that the training of the generalist as opposed to the specialist physician is crucial to the evolving health-care system.\textsuperscript{3,14-36} Equal access of patients to health care has been further compromised by increased numbers of specialists.\textsuperscript{3} Perhaps if chiropractors were prepared to offer primary care services, this would contribute to balancing the distribution of health-care providers.\textsuperscript{15,18}

As was made clear in the October 1993-1994 joint meeting of the World Health Organization and the Educational Commission for Foreign Medical Graduates in Geneva Switzerland, self-assessment of medical schools is a good beginning step toward ensuring quality in medical education.\textsuperscript{57} It is proposed that the test used in this study might serve as a tool for self-assessment in chiropractic colleges. There are, however, limits to the information to be gained from this tool. Clearly, this test takes into consideration the assertion of Greenlick\textsuperscript{48} that, “little or no accounting for the preexisting characteristics, interests, and career plans of students and residents across schools and programs.”

Career choices have been studied in medical education. Factors affecting medical students’ choices of a career in primary care over medical specialties were examined.\textsuperscript{41,49} Often the individual decides long before he or she matriculates in medical school how they are going to practice.\textsuperscript{40} Indeed, these preconceived practice preferences actually preempt any specific training that is later encountered.\textsuperscript{40} The importance of interest in family medicine versus durability of that interest throughout the educational period has been studied. When this predictor variable was examined, initial interest was more highly related to practice patterns than the content of the medical education.\textsuperscript{50} If this example holds for chiropractic students, one could speculate that students who enter chiropractic college, having already decided to relegate primary care activities to a secondary position, are not likely to alter their eventual practice patterns regardless of what they are exposed to during their professional education.

Many groups are stakeholders in the quality of health-care education. Students, licensing boards, local health organizations, third-party pay groups, and patients are all concerned with provider education and how limited or general is their scope of knowledge. In this social accountability, Retchin et al\textsuperscript{51} have stated, “for any learned profession there are but two alternatives for establishing standards of practice and education. Responsibility can be assumed by the organized profession through a voluntarily accepted self discipline, or by society as a whole, operating through government.” If the profession does not take responsibility, society will demand the vacuum be filled and government will provide outside regulation.\textsuperscript{43,52} Acceptance of this responsibility both reassures the public that the profession warrants trust and obviates a subordinate relationship likely to develop because of outside regulation.\textsuperscript{3,53}

In the future, it may be determined that the best role for chiropractors is that of portal of entry providers with the ability to differentially diagnose, but with a focus on structural and functional wellness not addressed by the typical primary care provider. As Seater\textsuperscript{53} has suggested, “both chiropractors and consumers might prefer that chiropractors not be primary care providers in the usual sense of the term.” Gatterman\textsuperscript{54} has called for a patient-centered paradigm for chiropractic education, research, and practice. The proposed patient-centered approach includes wellness concepts embedded within a broader framework encompassing social, environmental, and individual concerns.

The challenge for the chiropractic profession is to take on the issue of primary care with a sophistication that allows a clear perception of the complexities involved. Declarations by chiropractors that they “are primary care providers” must be balanced with supporting data.\textsuperscript{33} Surveys by chiropractors and leaders in the profession\textsuperscript{55} will not suffice without data on the readiness of graduates to provide these services. The determination regarding whether DCs are qualified to provide primary care should be predicated upon data indicating that students performed well on examinations such as the one used in this study. The social contract and the accountability aspect of the practice of primary care depend upon grass roots efforts by chiropractic educators to both widen the practice covenant and to expand the collective consciousness regarding primary care without individual or professional bias.\textsuperscript{15} This project is an example of an educational assessment that was funded by a professional organization. In other venues, the profession is providing the accountability that the public demands and deserves.

Because the test instrument used in this study showed reliability, educational institutions could implement the test to evaluate internal effectiveness of their programs. It could be argued that a pen-and-paper, multiple-choice examination is not adequate to evaluate knowledge about primary care tasks. Admittedly, this type of test is not the best evaluation tool. It has been suggested that evaluation methods in medical education have not kept up with progress made on the delivery side of the equation.\textsuperscript{56} It should be pointed out, however, that a major portion of the
examinations used to determine whether a chiropractor will receive licensure remains this type of test.

CONCLUSION

The test designed for this study assessed how a sample of chiropractic students compare with medical students in knowledge about primary care activities. The chiropractic test takers scored below their medical counterparts, but not by much. Considering the emphasis on primary care within medical education over the past few decades and the ambiguity with which the chiropractic profession has approached primary care, the fact that chiropractic students scored almost as well as medical students is noteworthy. A follow-up to this study using a clinical competency practical examination constructed around the identified primary care tasks should be undertaken.

ACKNOWLEDGMENTS

The authors acknowledge the assistance with statistical computations provided by Howard Petersen, MA, MS, DC, and David Deupree, PhD.

REFERENCES

LITERATURE REVIEW

A REVIEW OF COMPRESSION Ulnar Neuropathy at the Elbow

Chad Robertson, BKin,a and John Saratsiotis, DCb

ABSTRACT

Objective: To review the anatomy, etiology, and symptoms associated with compressive ulnar neuropathy at the elbow and to discuss the diagnosis and treatment of this condition.

Data Source: The following were searched for information relevant to cubital tunnel syndrome: MEDLINE, WorldCat, and Index to Chiropractic Literature.

Results: Cubital tunnel syndrome is the second most common nerve compression syndrome of the upper extremity. Clinical features of this syndrome are described along with electrodiagnostic techniques that can be used to provide evidence concerning the probable location, character, and severity of the lesion affecting the ulnar nerve. Conservative treatment of cubital tunnel syndrome is recommended for patients with intermittent symptoms and without changes in cutaneous sensation or muscle atrophy.

Conclusion: A definitive diagnosis can best be made using clinical tests along with nerve conduction studies and electromyography, conservative treatment can be effective in treating this neuropathy in mild cases; in moderate or severe cases, surgery may be necessary. (J Manipulative Physiol Ther 2005;28:345.e1-345.e18)

Key Indexing Terms: Cubital Tunnel Syndrome; Ulnar Neuropathies; Chiropractic; Nerve Conduction; Rehabilitation

Cubital tunnel syndrome is the most common form of ulnar nerve entrapment and the second most common entrapment neuropathy of the upper extremity.1,2 This is a condition that is often undiagnosed or misdiagnosed. Entrapment of the ulnar nerve has been recognized for more than 100 years3; however, the term “cubital tunnel syndrome” has been described more recently by Feindel and Stratford.4 Initially, the term “cubital tunnel” was closely associated with the arcuate ligament of Osborne, which forms the roof of the bony retrocondylar groove of the medial epicondyle. Over the years, the term has been broadened to encompass ulnar nerve entrapment and compromise to the intraneural microcirculation at the following sites: (1) the distal length of the medial intermuscular septum; (2) proximally, the leading edge of the arcade of Struthers; (3) the arcuate ligament of Osborne; and (4) the aponeurosis/confluence of the 2 heads of the flexor carpi ulnaris.

Diagnosis is based on signs, symptoms, orthopedic testing, and electrodiagnostic studies. Based on the latter criteria, along with a thorough patient history and physical examination, an appropriate treatment plan can be designed for the patient. Signs and symptoms of cubital tunnel syndrome can include both motor and sensory abnormalities involving the ulnar nerve distribution over the forearm and hand.5 Tinel sign and the elbow flexion test are both useful orthopedic tests for diagnosing cubital tunnel syndrome.6 Electrodiagnostic studies can be helpful in confirming a diagnosis, quantifying the severity of the lesion, and identifying the exact site of ulnar nerve compression. Many cases of cubital tunnel syndrome can be treated non-operatively. However, some of the more severe cases require surgical treatment to alleviate the syndrome and prevent deterioration of neurological function. Surgical options include simple decompression,7 medial epicondylectomy,8 anterior subcutaneous transposition,9 anterior

a Private practice of chiropractic.
b Private practice of chiropractic.
Sources of support: none.
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0161-4754/$30.00
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intramuscular transposition, and anterior submuscular transposition. This article presents a synthesis of the literature addressing issues related to ulnar neuropathy at the elbow. The focus includes anatomy, etiology, symptoms, diagnosis, and treatment.

**METHODS**

A MEDLINE search was conducted. The medical subject headings (MeSH) included the following terms: ulnar nerve, nerve compression syndrome, electrodiagnosis, elbow, cubital tunnel syndrome, ulnar neuropathy, rehabilitation, and ulnar nerve treatment. Other search engines included WorldCat (books) and Index to Chiropractic Literature. Articles and books included in this review had to be peer-reviewed journal articles, written by experts in the field, and have clear methodology. The search generated 354 articles and books that were relevant to this review. The abstracts and books were reviewed, and 88 articles and books were ultimately used. From these retrieved 88 articles and books, their respective bibliographies were examined, and an additional 15 entries were found to be pertinent and of value to this review. In total, 101 articles and texts were used for this review.

**DISCUSSION**

**Anatomy**

The ulnar nerve arises as a terminal branch of the medial cord of the brachial plexus consisting of C8 and T1 (occasionally C7) nerve root levels and descends along the upper arm until the middle and distal third of the humerus, where it pierces the medial intermuscular septum at the border of the triceps and brachialis muscles and enters the posterior compartment of the arm (Fig 1). The medial intermuscular septum traverses from the coracobrachialis muscle to the medial epicondyle of the humerus.

Following its course through the intermuscular septum, the nerve travels subcutaneously from the extensor compartment of the arm to the flexor compartment of the forearm via the medial epicondylar groove of the distal humerus. As the ulnar nerve exits the epicondylar groove, it runs between the aponeurosis surrounding the 2 heads of the flexor carpi ulnaris. This aponeurotic bridge stretches approximately...
5 mm for each 45° of elbow flexion, thus closing down and narrowing the cubital tunnel (Fig 2). The flexor carpi ulnaris aponeurosis blends with a dense aponerotic band, the arcuate ligament of Osborne. The arcuate ligament of Osborne joins the medial epicondyle of the humerus and the olecranon process, forming the roof of the cubital tunnel, whereas the floor of the tunnel is formed by the medial collateral ligament and elbow joint capsule. During elbow flexion, the medial collateral ligament bulges inward, further narrowing the cubital tunnel space.12

Distal to the cubital tunnel, the ulnar nerve exits through the deep flexor-pronator muscle group of the forearm, giving off small branches supplying the flexor carpi ulnaris and the ulnar half of the flexor digitorum profundus muscles. The ulnar nerve further subdivides into 2 cutaneous branches: a dorsal cutaneous branch supplying the dorsal ulnar side of the hand and the fourth and fifth digits, and a palmar cutaneous branch supplying the ulnar side of the palm. At the level of the wrist, the palmar trunk of the ulnar nerve bifurcates into a superficial and deep branch. The superficial branch of the ulnar nerve innervates the palmaris brevis, the skin over the hypothenar eminence, and then further divides into digital branches to supply the palmar surface of the little finger and adjacent side of the ring finger. The deep branch of the ulnar nerve passes between the abductor digiti minimi and flexor digiti minimi muscles to innervate the hypothenar eminence, third and fourth lumbricals, all interossei muscles, adductor pollicis, and deep head of the flexor pollicis brevis.

**Etiology**

One of the most common etiological factors in ulnar neuropathy at the elbow involves compression of the nerve due to entrapment. There are 4 sites where the ulnar nerve is frequently vulnerable to compression. These include (1) the arcade of Struthers (medial intermuscular septum), (2) the ulnar groove, (3) the humeroulnar arcade (or cubital tunnel), and (4) the exit point between the 2 heads of flexor carpi ulnaris.13 From these locations, the most common are lesions at the ulnar groove and humeroulnar arcade.14

The first potential site of compression/entrapment around the elbow is found 8 to 10 cm proximal to the medial epicondyle, also known as the arcade of Struthers. This is a thick fascial band running from the medial head of the triceps to the medial intermuscular septum.14,15 Consequently, the nerve becomes entrapped between a muscular structure and a ligamentous sheath.

Various reasons exist for lesions occurring to the ulnar nerve within the ulnar groove and cubital tunnel including external trauma, pressure, bony or scar impingement, irregularities in muscles, congenital abnormalities such as combinations of cubitus valgus and anterior dislocation of the head of the radius, and sometimes soft tissue mass lesions.14 Acute trauma results from blows/lacerations that occasionally result in dislocation or fracture that can injure the nerve directly or through posttraumatic fibrosis and scarring.14 In addition, the summation of multiple, repetitive episodes of microtrauma can also lead to fibrosis and nerve constriction. This etiological factor in ulnar neuropathy has been evident in baseball pitchers, assembly line workers, violinists, and occupations that involve hammering, shoveling, and/or lifting.16-18

Because the ulnar nerve is located superficially and is unprotected as it passes along the condylar groove, it is particularly susceptible to external pressure. Shallowness of the condylar groove can predispose the nerve to external trauma and pressure. Multiple instances of minor pressure can lead to ulnar neuropathies. Examples include leaning one’s elbows on hard chair arms such as wheelchairs, prolonged use of the telephone when leaning on a hard surfaced desk, and resting the elbow on car window frames (truck/taxi drivers, or individuals on long journeys).14 Occupations involving use of vibrating tools are also at risk for developing cubital tunnel. In a study conducted by Kakosy,15 through neurological and electrophysiological examination of individuals exposed to hand-arm vibrations, approximately 43% of the subjects had symptoms indicative of cubital tunnel syndrome. The study concluded that hand-arm vibration tools can potentially lead to ulnar neuropathy at the elbow.

The bony injuries that lead to the development of ulnar neuropathies include supracondylar fracture and fracture of the medial epicondyle, both of which can lead to a valgus deformity.14 After abnormal healing, the ulnar nerve can be less protected in the condylar groove and is more susceptible to external pressure. The presence of osteophytes (eg, osteoarthritis or Paget disease) at the elbow can lead to the development of cubital tunnel syndrome.20,21 Taniguchi et al22 showed that calcium pyrophosphate dihydrate crystal deposition disease is associated with cubital tunnel syndrome. In this study, calcification of the collateral ligaments, synovium, and hyaline cartilage of elbow joint was examined. In the subjects of this particular study,23 arthropathic changes had resulted in ulnar nerve compression in the medial edge of the coronoid process at the site of insertion of the medial collateral ligament. The nerve can also be hard-pressed by a displaced triceps muscle or anconeus epitrochlearis. The nerve can often be stretched over a bony callus or by the abnormal angle of the elbow joint.

Soft tissue masses such as ganglia, lipomas, fibrolipomas, and epidermoid cysts can compress the ulnar nerve as it lies in the condylar groove or within the cubital tunnel.16 Other types of masses such as thickened synovium in patients with rheumatoid arthritis, giant cell tumors, synovial cysts, and tophaceous gout can press on the ulnar nerve.24,25

Compression of the ulnar nerve under the edge of the flexor carpi ulnaris aponeurosis can also result in ulnar nerve neuropathies. The aponeurosis can be thick and fibrotic, and by flexing the elbow, the aponeurosis tightens, further constricting the cubital tunnel space. This, in turn,
compresses the ulnar nerve. The entrapment site is located 5 to 7 cm distal to the medial epicondyle.\textsuperscript{14}

Finally, flexion of the elbow for prolonged periods can also lead to ulnar neuropathies at the elbow (eg, immobilization of an arm following fracture, or dislocation of upper arm or shoulder). Prolonged elbow flexion puts a tremendous stretch on the nerve and simultaneously changes the diameter of the nerve, compressing it. There are various occupations and activities that require prolonged elbow flexion. Sleeping is one activity that examiners may fail to recognize as a cause of symptoms. Studies have shown that sleeping with one or both arms in the flexed position can prove to be damaging to the nerve.\textsuperscript{23,24}

**Signs and Symptoms**

Symptoms of cubital tunnel may start insidiously or acutely, the latter being more common with trauma. The clinical symptoms relate to the mixed sensory and motor neural fibers of this nerve in early disease. The patient generally has paresthesias radiating distally in the hand over the fifth finger and ulnar aspect of the fourth finger. Paresthesias are usually related to activity and sometimes coupled with pain in the medial aspect of the elbow, which may extend distally or proximally, due to overuse of forearm flexors such as the flexor carpi ulnaris. Paresthesias have a tendency to be more pronounced at night as a result of flexion of the elbow while sleeping.\textsuperscript{18}

Symptoms progress from mild intermittent numbness induced with elbow flexion to constant anesthesia.\textsuperscript{15} Pain and tenderness over the medial epicondyle and cubital tunnel may be present with proximal or distal extension of the elbow. Weakness of ulnar nerve–innervated intrinsic hand muscles can also be seen at this time. This symptom observed alone may be more likely because of the improper functioning of the C8 and T1 nerve roots.\textsuperscript{15,24} The flexor carpi ulnaris and the ulnar half of the flexor digitorum profundus are usually not affected. Weakness starts with clumsiness and loss of dexterity of the hand, with progression to weakness of grip and pinch (Froment sign) (Fig 3). Atrophy of the intrinsic hand muscles, as well as “clawing” of the fourth and fifth fingers is an indication of advanced motor loss. This latter classic sign, better known as “claw hand,” “benediction posture,” or “main en griffe,” is produced by the hyperextension of the metacarpophalangeal joints of the fourth and fifth digits and flexion of the interphalangeal joints, because their interossei and lumbrical muscles are paralyzed. Consequently, the patient cannot flex the metacarpophalangeal joints or extend the interphalangeal joints. Because of this phenomenon, patients with ulnar nerve injury are likely to have difficulty in making a fist.

**Diagnosis**

Diagnosis of cubital tunnel syndrome is often overlooked or misdiagnosed by many doctors. A thorough physical examination can assist the examiner in determining the appropriate diagnosis. Tables 1 and 2 list some of the common motor and sensory examinations performed by health-care professionals for diagnosing cubital tunnel syndrome.

**Differential Diagnosis**

Table 3 lists the conditions that are commonly confused with cubital tunnel syndrome and physical examination differences that can help distinguish the cause of symptoms.

**The Use of Electrodiagnostics in the Diagnosis of Cubital Tunnel Syndrome**

Electrodiagnostic testing can be used to evaluate suspected ulnar neuropathy at the elbow (Table 4). Several studies have suggested that electrodiagnostic testing can markedly improve diagnostic accuracy by mapping out the exact location of pathological compression of the ulnar nerve, thus providing a relatively early diagnosis of cubital tunnel syndrome in patients who have symptoms suggestive of ulnar nerve lesions but who have few, if any, confirmatory clinical signs.\textsuperscript{26-28} With the presence of nerve lesions, electromyography (EMG) and nerve conduction velocity (NCV) examinations can define the type of pathology, distinguishing axonal degeneration, segmental demyelination, and abnormal nerve irritability from one another.\textsuperscript{29} Such information will provide valuable clues as to the etiology and, more importantly, treatment of the neuropathy.\textsuperscript{30}

Various researchers have studied the use of electrodiagnostics to evaluate suspected ulnar neuropathy. Accordingly, there have been differences in the technique and criteria used to determine if there is an abnormality present in the ulnar nerve.\textsuperscript{28,31-34} The parameters that have been used include the following: (1) motor and sensory examination and NCV of the elbow segment; (2) comparison of the elbow segment velocity to that of an adjacent nerve segment; (3) measurement of a latency from the elbow to the wrist or from the elbow to the flexor carpi ulnaris or flexor digito-
Table 1. Testing for ulnar motor function

<table>
<thead>
<tr>
<th>Positive test for ulnar paralysis</th>
<th>Muscle(s) tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inability to flex distal interphalangeal joint of little finger</td>
<td>Flexor digitorum profundus</td>
</tr>
<tr>
<td>Absence of dimpling along ulnar border with forceful abduction of little finger</td>
<td>Palmaris brevis (abductor brevis)</td>
</tr>
<tr>
<td>Inability to oppose little finger to thumb at 180°</td>
<td>Fifth abductor digiti, fifth opponens digitii, fifth flexor digitii, (abductor pollicis)</td>
</tr>
<tr>
<td>Inability to adduct extended little finger to ring finger</td>
<td>Third volar interosseous</td>
</tr>
<tr>
<td>Inability to flex 5th metacarpophalangeal joint to 90° with interphalangeal joints extended</td>
<td>Fourth lumbrical</td>
</tr>
<tr>
<td>Inability to abduct extended middle finger in radial and ulnar directions with hand flat</td>
<td>Second and third interossei</td>
</tr>
<tr>
<td>Inability to forcibly abduct and adduct fingers away from and toward extended middle finger with flat hand</td>
<td>Fifth abductor digitii, first and second dorsal interossei, first and second volar interossei</td>
</tr>
<tr>
<td>Inability to cross flexed middle finger dorsally over extended index finger (crossed-finger test)</td>
<td>First volar interosseous, second dorsal interosseous</td>
</tr>
<tr>
<td>Full flexion of thumb interphalangeal joint on forced grasp (adduction) against radial border of index finger (Froment test)</td>
<td>Adductor pollicis, first dorsal interosseous, ulnar part of flexor pollicis brevis</td>
</tr>
<tr>
<td>Inability to make good “O” with opposed thumb and index finger</td>
<td>Adductor pollicis</td>
</tr>
<tr>
<td>Inability to “scrape” extended thumb ulnar-ward across palm to base of little finger</td>
<td>Adductor pollicis</td>
</tr>
<tr>
<td>Inability to forcibly abduct extended index away from middle finger</td>
<td>First dorsal interosseous</td>
</tr>
<tr>
<td>Inability to bring tips of extended ulnar 4 digits together into cone</td>
<td>Fifth opponens digitii, first and third volar interossei, adductor pollicis</td>
</tr>
<tr>
<td>Extension of fingers leads to abduction of fifth digit (Wartenberg sign)</td>
<td>All interossei</td>
</tr>
<tr>
<td>Touch thumb to fifth digit does not result in a rounded cup shaped contour of the palm</td>
<td>Opponens digitii minimi</td>
</tr>
<tr>
<td>Wrist is drawn to the radial side when the wrist is held in a flexed position</td>
<td>Flexor carpi ulnaris</td>
</tr>
<tr>
<td>Hold paper between ring finger and middle finger, there is an abnormal flexion of the metacarpophalangeal joint (finger flexion test)</td>
<td>All interossei</td>
</tr>
</tbody>
</table>


Table 2. Testing for ulnar sensory function

<table>
<thead>
<tr>
<th>Sensory test (ulnar)</th>
<th>Positive finding for ulnar neuropathy at elbow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tap the ulnar nerve at the medial epicondylar groove</td>
<td>Electrical shock sensation radiating to the fourth and fifth digits (Tinel sign)</td>
</tr>
<tr>
<td>Apply pressure for 60 seconds over the ulnar nerve just proximal to the cubital tunnel with the elbow flexed at 20° with the forearm supinated (pressure provocative test)</td>
<td>Tingling, numbness, paresthesias sensation radiates down to the 4th and 5th digits</td>
</tr>
<tr>
<td>Elbow is placed in maximal flexion with full supination and wrist is kept in the neutral position (elbow flexion test)</td>
<td>Tingling, numbness, paresthesias felt along the ulnar nerve distribution</td>
</tr>
<tr>
<td>Elbow is placed in maximal flexion, and while in this position, pressure is placed on the ulnar nerve just proximal to the cubital tunnel (combined pressure and provocative test)</td>
<td>Tingling, numbness, paresthesias felt along the ulnar nerve distribution. This is the most sensitive provocative test in the diagnosis of cubital tunnel syndrome</td>
</tr>
<tr>
<td>Semmes-Weinstein monofilament testing</td>
<td>Loss or diminished sensation to fourth and fifth digits</td>
</tr>
<tr>
<td>Test ulnar aspect of dorsum of hand, fourth and fifth digits</td>
<td>Decreased sensation implies lesion of the ulnar nerve is above the level of the wrist</td>
</tr>
<tr>
<td>Test hypothenar eminence</td>
<td>Diminished sensation</td>
</tr>
<tr>
<td>Palpation of the area just proximal to the medial epicondyle</td>
<td>Tenderness in the area which indicative that the arcade of Struthers is compressing the ulnar nerve</td>
</tr>
<tr>
<td>Static 2-point and vibratory discrimination test</td>
<td>Diminished sensation along the ulnar nerve distribution of the hand</td>
</tr>
</tbody>
</table>

rum profundus; (4) change in the size or configuration of the compound muscle action potential (CMAP) or sensory nerve action potential (SNAP) evoked both proximal and distal to the elbow; and (5) the pattern of needle examination (EMG) abnormalities in ulnar nerve–supplied muscles.

Motor nerve conduction studies. A patient with a suspected compression of the ulnar nerve at the elbow will have a stimulating cathode applied to 4 different points along the course of the ulnar nerve. The 4 standard points of stimulation are at the wrist, distal to the elbow, proximal to the elbow, and in the axilla. The CMAP is recorded from one of the muscles innervated by the ulnar nerve; thus, the recordings will only assess the axons innervating that specific muscle. Obtaining a recording, most commonly, from the hypothenar muscles can test for ulnar motor nerve conduction. However, a recording electrode placed on the hypothenar muscles will not detect selective damage to the axons innervating either the flexor carpi ulnaris or first dorsal interosseous. Therefore, a recording electrode should be placed over the first dorsal interosseous and the
flexor carpi ulnaris muscles because they can be differentially affected. The conduction velocity of the ulnar nerve is measured by comparing the differences in the distance and latency between sites of stimulation. Chronic compression of the ulnar nerve at the cubital tunnel will produce a localized narrowing of the axons distal to the cubital tunnel causing a slowing of conduction. Generally, this slowing of conduction is localized to the elbow, but in longstanding ulnar neuropathies, it may extend distally.

During this procedure, it has been advocated that the elbow be kept in a “moderately flexed” position, specifically, 70° to 90° from the horizontal. Moderate flexion provides the greatest correlation between surface skin measurement and true nerve length. In elbow extension, the skin distance is falsely short compared with true nerve length, causing spurious and artifactual conduction slowing. In addition, the length of an ulnar nerve segment used is important in the ability of a nerve conduction study to localize the site of compression. A 10- to 12-cm distance between stimulation above and below the elbow is used. Very-short-length segments are subject to a considerable amount of error in calculating conduction velocity because of inaccuracies in

**Table 3. Clinical differentiating factors in suspected ulnar neuropathy**

<table>
<thead>
<tr>
<th></th>
<th>UNW</th>
<th>UNE</th>
<th>Medial cord</th>
<th>Lower trunk</th>
<th>C8 to T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weakness of the interossei</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Weakness of the hypothenar muscles</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Weakness of the third and fourth lumbricals</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Weakness of distal finger flexion of the little and ring fingers</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Weakness of thumb abduction</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Weakness of thumb flexion</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Weakness of index finger extension</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sensory loss of the volar medial hand, little finger, and medial ring finger</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sensory loss of the dorsal medial hand, dorsal little finger, and ring finger</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sensory loss of the medial forearm</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tinel sign at the elbow</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

X, May be present; UNW, ulnar neuropathy at the wrist; UNE, ulnar neuropathy across the elbow.


**Table 4. Electromyographic and nerve conduction study abnormalities localizing the lesion site in suspected ulnar neuropathy**

<table>
<thead>
<tr>
<th></th>
<th>UNW</th>
<th>UNE</th>
<th>Medial cord</th>
<th>Lower trunk</th>
<th>C8 to T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMG results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First dorsal interosseous</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Abductor digiti minimi</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Flexor digitorum profundus (digits 4 and 5)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Flexor carpi ulnaris</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Abductor pollicis brevis</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Flexor pollicis longus</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Extensor indicis proprius</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cervical paraspinal muscles</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nerve conduction study results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulnar digit 5 SNAP</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Dorsal ulnar cutaneous SNAP</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Medial antebrachial cutaneous SNAP</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Decreased Ulnar CMAP</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Decreased Median CMAP</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Conduction block/slowing of ulnar nerve across elbow</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

X, May be abnormal; UNW, ulnar neuropathy at the wrist; UNE, ulnar neuropathy across the elbow.

measuring latency and distance. Studying long-length nerve segments may mask focal slowing by including lengths of a normally conducting nerve. Ulnar nerve compression can be located at the elbow by using 2 criteria: (1) an absolute motor NCV from above the elbow to below the elbow of less than 50 m/s or (2) slowing of greater than 10 m/s in the above-the-elbow to below-the-elbow segment compared with the below-the-elbow to wrist segment (Fig 4).

In general, focal compressive entrapment neuropathies, such as cubital tunnel syndrome, can damage Schwann cells and cause focal demyelination. Demyelination can contribute to a significant reduction in the conduction velocity of an affected nerve. If the Schwann cells are damaged severely enough, as can occur with chronic compression of the ulnar nerve, action potentials may not propagate past the damaged region, resulting in a condition known as a “conduction block.” Conduction block at the elbow may be associated with focal slowing, due to marked axonal stenosis distal to the elbow, which can contribute to a slowing in the ulnar NCV. Slowing of NCV is directly proportional to the duration and severity of the compression.

Quantification of the area and amplitude of the CMAP are important; they are proportional to the number of muscle fibers activated and provide an estimate of the amount of functioning present in the tested nerve and muscle. On proximal stimulation of a compressed ulnar nerve at the elbow, there is a gradual reduction in the amplitude of the evoked response potential by 30% or more because of dispersion and increased duration of the response. However, the area of the evoked response stays relatively constant. The amplitude of the CMAP decreases as the synchrony of discharge of the contributing motor units decreases. If all axons conduct at the same velocity, the amplitude remains unchanged, but because they differ, slower conducting axons activate the muscle progressively later with more proximal stimulation. Because of this effect, the CMAP becomes longer and lower. If there is any reduction in the area of the CMAP at proximal sites of stimulation, it will be much less than the reduction in the amplitude, which results from the cancellation of negative components (ie, overlapping of positive components). A drop in amplitude of more than 20% across the elbow or an abrupt drop in conduction velocity likely represents a conduction block and possibly temporal dispersion indicative of focal demyelination.

In assessing amplitude reduction, the examiner must make sure that a “Martin-Gruber anastomosis” is not present. In this normal variation, some of the motor fibers destined for ulnar hand muscles travel with the median nerve at the elbow, cross over to the ulnar nerve in the forearm, and come into the hand via the ulnar nerve through the Guyon canal. Such crossover will lead to a larger ulnar muscle action potential from the wrist than from the elbow and might, therefore, produce a false amplitude reduction, better known as a “pseudoconduction block.”

**Sensory and mixed conduction studies.** Sensory and mixed ulnar nerve conduction across the elbow may increase the yield of identifying focal slowing in patients with ulnar nerve entrapment at the elbow. Sensory conduction studies can be done either orthodromically and/or antidromically because the conduction velocity of the axons is the same in both directions. Stimulating the dorsal ulnar cutaneous nerve just below the ulnar styloid while recording an orthodromic SNAP can be done at one of the following sites: in the dorsal web between the fourth and fifth digits, the wrist, below the elbow, and above the elbow. On the other hand, an antidromic SNAP can be recorded over the fifth digit while stimulation can be applied over a mixed nerve at the following locations: the wrist, below the elbow, and above the elbow. The easiest and most reliable distal SNAP recordings for the ulnar nerve are obtained by orthodromic stimulation of its axons. Similarly, a mixed nerve potential can be recorded below and above the elbow by stimulating the mixed nerve at the wrist.

There are several parameters in sensory conduction studies that can be useful in identifying the location of the compression of the ulnar nerve at the elbow. The nerve action potential is used to measure the amplitude, area, latency, conduction velocity, area, and amplitude, but are more difficult to measure because of configuration changes and small size. The amplitude and area of the SNAP provide information about the number of functioning axons and their respective sizes. Criteria for an abnormally low ulnar SNAP
amplitude include an amplitude that is either less than 10 mV or less than 50% of the amplitude of the asymptomatic limb.\textsuperscript{45,46} Low ulnar SNAP values seen in entrapment neuropathies, such as cubital tunnel syndrome, can be attributed to temporal dispersion, conduction block, severe axonal stenosis, and significant loss of large myelinated axons by focal demyelination.\textsuperscript{34,37,46} Conduction block, which is associated with entrapment neuropathies, is caused by processes that may also cause a loss of large myelinated axonal fibers and severe axonal stenosis seen in cubital tunnel syndrome resulting in a low SNAP amplitude in conjunction with a prolonged distal latency. A slowing of the SNAP across the elbow is another hallmark of ulnar nerve entrapment at the elbow. The reduced conduction velocity is because of a significant loss of large, myelinated, rapidly conducting fibers that also produce most of the SNAP amplitude.\textsuperscript{46}

**Inching technique.** An inching technique can be used to identify the exact location of the pathological compression of the ulnar nerve, which is imperative in determining the treatment protocol that should be used. Inching is performed by marking off 1-cm increments from 4 cm below the elbow to 6 cm above the elbow. The ulnar nerve is then stimulated using a submaximal current (10% to 25% supramaximal) while recording the activity of the abductor digiti minimi.\textsuperscript{45} An abrupt increase in latency of more than 0.4 to 0.5 msec and/or drop in amplitude of CMAP implies focal slowing. The inching technique has the potential to locate the site of entrapment of the ulnar nerve at any one of the following locations: (1) proximal leading edge of the arcade of Struthers; (2) distal length of the medial intermuscular septum; (3) entire arcade of Struthers, transversely attaching the deep fascia of the distal triceps and its tendon of insertion to the medial intermuscular septum; (4) Osborne ligament, forming the roof of the bony retrocondylar groove; (5) fascial origin of the flexor digitorum superficialis of the ring finger; and (6) confluence of the 2 heads of the flexor carpi ulnaris.

**Needle EMG.** Needle electrode examination can be used in concert with nerve conduction studies to establish the severity and location of the compression of the ulnar nerve. The needle examination should check the following muscles for abnormalities: first dorsal interosseus, hypothenar muscles, abductor pollicis brevis, flexor digitorum profundus (digits 4 or 5), and flexor carpi ulnaris. If ulnar nerve–innervated muscles are abnormal, the examination should be extended to include non–ulnar nerve (C8 nerve root/medial cord/lower trunk)–innervated muscles to exclude a brachial plexopathy as well as the cervical paraspinal musculature to exclude radiculopathy. A compressed ulnar nerve characterized by a conduction block may show reduced motor unit potential recruitment. Where the axonal interruption occurs, positive sharp waves and fibrillations can be observed. The presence of abnormalities in the flexor carpi ulnaris or in the flexor digitorum profundus indicates a compression at or proximal to the elbow. On occasion, the flexor carpi ulnaris receives its innervation above the elbow. Thus, denervation of the flexor carpi ulnaris may be caused by a more proximal compression such as at the arcade of Struthers and/or medial intermuscular septum. In some cases, the flexor carpi ulnaris may be spared even when the ulnar division of the flexor digitorum profundus (digits 4 and 5) is abnormal. If significant axonal loss has occurred, with subsequent reinnervation taking place, polyphasic motor unit potentials with moment-to-moment variation in shape will be observed.\textsuperscript{47} In fact, increases in motor units action potential duration and amplitude indicate that reinnervation has already taken place.\textsuperscript{39,47}

**Conservative Treatment and Rehabilitation**

Once the location and severity of the neuropathy has been correctly determined, a treatment protocol can be established. In the cases where the symptoms are mild to moderate, conservative treatment can be administered.\textsuperscript{48-50} As Dellon et al\textsuperscript{50} reported in their study, conservative treatment proved to be beneficial in approximately 90% of patients in their study with mild symptoms. In the same study, 38% of patients with moderate symptoms were treated effectively using nonoperative methods. Thus, it appears that resolution of symptoms when using nonoperative treatment methods is inversely proportional to the severity of the condition at initiation of treatment.

In treating cubital tunnel syndrome, the goal of conservative treatment is 2-fold: to eliminate, or reduce, the frequency of external compression on the nerve and to minimize flexion at the elbow joint. This will consequently alleviate some of the stresses placed on the ulnar nerve because of its compromising position. Before any conservative treatment takes place, it is important to realize that for a conservative care, or any type of treatment, to be successful, the patient and the health-care professional must work together as a team.\textsuperscript{51} The patient must ensure that instructions provided by the health-care professional are understood and adhered to. Patient education is critical. The patient should not only understand what his or her problem entails, but should be aware of the details of their treatment. By truly understanding the condition and the path the care provider is taking for treatment, patients are more likely to be compliant in adhering to the treatment protocol to protect the damaged nerve.

Before engaging in nonoperative treatment and rehabilitation, ligamentous laxity or obvious skeletal valgus deformity of the elbow that compromise the neural structures on the medial aspect of the elbow must be ruled out. There are 4 stages to nonoperative rehabilitation of ulnar neuropathy at the elbow: (1) reduction of overload, pain, and inflammation; (2) promotion of total arm strength and normal joint arthrokinematics; (3) interval return to full activity; and (4) maintenance.

**Stage 1: Reduction of overload, pain, and inflammation.** Reduction of pain and inflammation is imperative before other
significant range-of-motion or strengthening procedures are used. With respect to acute symptoms attributable to nerve injury, rest is essential. Rest decreases the inflammatory response around the nerve, as well as any eventual swelling, and may lead to resolution of symptoms. This can be accomplished with the help of a splint. In the acute inflammatory phase, a resting splint is used initially to rest the inflamed tissues to allow healing to begin. The splint’s purpose is to position the ulnar nerve in the position of least pressure, to help promote healing. The key to splint design is to immobilize only the joints directly involved with the inflamed tissue, thereby preventing weakness and stiffness of nearby joints and allowing the greatest function.

Night splints are an excellent method of minimizing elbow flexion during sleep. Night splinting is important because many individuals may inadvertently flex their elbows while sleeping. Splinting will minimize elbow flexion during sleep and sleeping prone with the arm curled around the pillow. Such splinting is important even if the patient is not experiencing any paresthesias at night. There is some discrepancy as to the angle of flexion during splinting. Nevertheless, it appears that splinting at night should occur with the elbow fixed between 30° and 45°. Additional methods of protecting the elbow at night include positioning a pillow between the patient’s trunk and affected extremity, reversing an elbow pad to cover the antecubital fossa, or using a towel wrapped in a figure-of-eight around the elbow to restrict elbow flexion.

Only in severe cases of cubital tunnel syndrome is daytime splinting advised. The patient is usually fitted with a thermosensitive molded plastic splint that will ensure elbow immobilization during the day. Idler recommends applying the splint over the anterior aspect of the arm, positioning the elbow at 40° to 60°, and assuring that the straps do not cross the ulnar nerve at the cubital tunnel. The problem with daytime splinting is that it hinders the patient from freely doing various occupational and recreational activities. Consequently, because it is so inconvenient, if no improvement is evident within the first 3 to 4 weeks of this type of treatment, other options should be considered.

To protect the ulnar nerve from external pressures and frequent flexion posturing, there are several potentially effective solutions. The patient can be given an elbow pad that can be worn over the posterior medial aspect of the elbow to protect the ulnar nerve from direct pressure or trauma during the day. In the work environment, placing a pillow beneath the elbow at the desk will reduce external pressure on the nerve. The patient should avoid resting the elbows on hard surfaces. When sitting, arms are not to be crossed, but rather the forearm of the symptomatic arm should rest supinated on the thigh. If extensive reading is done, a bookstand should be used, as well as adjusting the angle and height of the keyboard so that the elbows do not rest directly on the desk or chair. Furthermore, for patients whose occupation involves spending long hours on the telephone (eg, secretaries, receptionists, operators), the telephone should be held by the unaffected extremity or a headset can be used as an effective alternative.

Some health professionals suggest the use of nonsteroidal anti-inflammatory drugs, whereas others feel that these drugs have no clinical efficacy in treating this condition. In addition, use of steroidal injections for patients with cubital tunnel syndrome has been administered in the past; however, prolonged corticosteroid use has various negative side effects. In a recent study conducted by Hong et al, splinting alone was compared with applying a local steroid injection in addition to splinting. The results showed that the addition of a steroid injection did not provide further benefit in the treatment of cubital tunnel syndrome. The splint application alone proved adequate in the improvement of symptoms and ulnar nerve conduction across the elbow. Furthermore, injection of a corticosteroid solution locally could possibly result in an intraneural injection or even a subcutaneous atrophy with fatty tissue necrosis.

Treatment modalities for the reduction of pain and inflammation includes ice, ultrasound, and pulsed signal therapy, which are further discussed below. The region of modality application is generally directed over the most affected areas subjectively reported by the patient, as well as any area of palpable tenderness found during initial examination.

In the early part of immobilization, when pain and inflammation are at their greatest, icing or ice massage is recommended to the elbow area. During this period, which can be from 10 days to 6 weeks depending on the severity, patients are instructed to remove their splints twice daily to perform gentle passive range of motion exercises to the immobilized elbow joint to prevent stiffness and loss of range of motion. Although mobilization is recommended at this early stage of treatment, myofascial work should not be performed if inflammation is still present. The purpose of treatment during this first stage of treatment is to decrease some of the inflammation present. Myofascial work, particularly aggressive techniques, can hinder effective treatment of this condition. For this reason, myofascial work should be implemented in the third stage of treatment (see stage 3).

Ultrasound has shown effectiveness in chronic overuse syndromes, such as lateral epicondylitis, owing to its nonthermal effects, which include both cavitation and microstreaming. Consequently, ultrasound may be beneficial in treating various other chronic overuse syndromes, such as cubital tunnel syndrome. Furthermore, it has been suggested that ultrasound can affect nerve conduction in normal nervous tissue and healing in damaged nerves. A continuous beam of ultrasound can increase the sensory and motor conduction rate of a nerve, provided that the treatment took place under a low intensity and appropriate frequency.
Before administering ultrasound therapy, there are a number of factors that must be taken into consideration for the treatment to be effective. These factors include frequency, intensity, pulse regimen, duration, length, and frequency of treatment. In an experiment conducted by Hong et al, it was shown that an intensity of 0.5 W/cm² and a frequency of 1.0 MHz increased the recovery rate of a compressed nerve in contrast to a dose of 1.0 W/cm² of intensity with the same frequency, which slowed down the nerve’s recovery rate. It has been suggested that if the intensity dose is too high, ultrasound can have damaging and proinflammatory effects. In addition, an appropriate coupling medium (eg, water, mineral oil, gel) is required to avoid any reflection of the ultrasonic energy at the air-tissue interface. When working with the elbow, if the elbow cannot be comfortably immersed in water, usually a water balloon can be used instead as the coupling medium. It is important to fill the balloon with degassed water (no air bubbles) followed by a thorough coating of the balloon with a gel coupling medium and firmly applying the balloon against the skin ensuring no air pockets are present.

Pulsed signal therapy is a noninvasive medical technology that involves directing a series of magnetic pulses through injured tissue and has been used to treat osteoarthritis, meniscus degeneration, injuries to the anterior cruciate ligament, neck whiplash syndrome, Achilles tendon injuries, and soft tissue injuries such as carpal tunnel syndrome. According to experimental data by Lin et al, pulsed electromagnetic fields can enhance blood flow at the area of injury. Because cubital tunnel syndrome does encompass a decrease in the neural microcirculation, theoretically, an increase in blood flow to the area may increase stimulation of the healing process. Patients who have not responded well to other conservative forms of therapy may consider pulsed signal therapy as an alternate choice.

Clinical signs that indicate the ineffectiveness of therapeutic modalities are (1) continued pain at rest or with light activity, (2) inability to tolerate light stretching/range-of-motion exercise, and (3) continued inability to perform submaximal exercises to increase strength. If the above signs are present after a 2- to 3-week period of initial modality application, the clinician should consider reevaluating the patient and/or modifying the treatment plan.

**Stage 2: Promotion of total arm strength and normal joint arthrokinematics.** Weaning from the supportive splints begins when immobilization has accomplished the goals of reducing inflammation and pain proximal and distal to the medial epicondyle. The patient removes the splints initially for submaximal exercise sessions. Gradually, the splint is removed for light daily activities in addition to exercise sessions, then progressing to night wear, and finally to splint wear as needed to prevent pain with strenuous activity.

Integration of range of motion and general upper extremity flexibility is gradually performed during the initial stage of rehabilitation. Aggressive end-range passive stretching and mobilization are not indicated at this time. Maintenance of pain-free elbow, forearm, wrist, and finger motion is the goal in this stage. In addition, stretching the shoulder musculature is applied to prevent loss of range of motion in the proximal structures, especially during this period of either modified activity or rest. Mobilization and passive stretching are also performed to normalize length tension relationships of the flexor/pronator musculature and promote the reattainment of elbow extension (ie, the position of osseous congruency and stability).

Aggressive stretching is not advocated during this period of the rehabilitation program. If the injured elbow exhibits a significant range of motion limitation compared with the uninjured elbow, joint distraction and mobilization to enhance ulnohumeral extension are recommended during this stage. Placing the elbow in a greater amount of extension with subsequent distraction application will be limited by tension in the anterior capsule and anterior ligamentous structures, resistance of the flexor muscles, and the tip of the olecranon entering the olecranon fossa but will enhance elbow extension range of motion.

A technique for posterior gliding of the ulna on the humerus may also be used to increase extension range of motion. The edge of the treatment plinth or rubber edge can be used as a fulcrum for the distal aspect of the humerus as the clinician glides the ulna in a posterior direction relative to the humerus. The amount of elbow extension range of motion used during mobilization dictates the amount of stress imparted to the anterior capsular structures. The 30° angulated alignment of the distal humerus and sigmoid notch is an important anatomical relationship for the clinician to understand to ensure proper direction of force application during mobilization. Medial and lateral gliding of the ulna relative to the humerus is reported as the mobilization of choice to increase overall joint play necessary for full elbow extension range of motion. This technique should be used with caution in the throwing athlete and only performed in the presence of significant joint hypomobility because of possible stresses imparted to the ulnar collateral ligament complex. A true medial and lateral gliding motion of the ulna on the humerus with the forearm supinated is performed with either a varus or valgus movement. Stabilization of the distal humerus is performed by grasping both humeral epicondyles with the olecranon supported in the palm of the clinician’s stabilizing hand. Varying degrees of elbow extension and flexion are recommended, with application of this mobilization technique near the current limits of elbow extension.

However, in most cases of overuse injury, only active assisted and passive stretching of the elbow, forearm, and wrist using intensities well tolerated by the patient are necessary to return to normal bilaterally symmetrical motion to the injured extremity. Active assisted and passive stretching, using several repetitions and hold duration of 15 to 30 seconds, are indicated to produce a plastic deformation.
of the muscle tendon unit. A supine patient position is recommended to enhance the clinician’s ability to perform combined patterns of elbow, forearm, wrist, and finger movements relative to the glenohumeral joint and trunk.

Submaximal strengthening exercises are introduced as signs and symptoms allow. A firm handshake can be used as a criterion for determining whether a patient is ready for early exercise in the treatment program. The initial goal of rehabilitation, with respect to the muscle tendon unit, is the promotion of muscular endurance and improved resistance to repetitive stress. To accomplish this goal, extremely low or no resistance is used with high repetition formats of 20 to 40 per set. Such high resistance have 2 important effects; first, it promotes local muscular endurance, and second, it provides a vascular response to the exercising tissues. Total arm strength exercises are used for the scapulothoracic and scapulohumeral musculature, with resistance applied in a manner that does not either produce undue valgus stress or attenuate the ulnar nerve. Isokinetic exercises are used later in this second rehabilitation stage.

Progression to resistive exercise from the initial stage of isometrics and manual resistance is recommended during the second stage. The modes of resistive exercise followed in the rehabilitation of overuse injuries, as outlined by Davies, are multiple-angle isometrics, manual-resistance isotonics, isotonics (concentric and eccentric emphasis), and finally isokinetics. A low-resistance, high-repetition format is used to increase not only strength but local muscular endurance as well. Strengthening exercises for the proximal aspect of the upper extremity kinetic chain are added during this stage. Rotator cuff strengthening exercises are used to promote proximal muscular balance and strength.

Additional exercises using low resistance levels and multiple repetitions are used during this stage of rehabilitation. Surgical tubing is used for concentric and eccentric muscular strengthening of the elbow flexors and elbow extensors. Exercises involving the upper extremity where the distal member of the extremity is fixed during exercise (known as a “closed-chain” state) are also used during this stage. The extremity is placed so that the elbow is in a comfortably extended position over a large, inflatable ball, with the extremity bearing progressive amounts of weight into the ball. As with any closed-chain exercise, this position causes co-contraction of the musculature surrounding multiple joints via multiple joint axes. Clockwise and counterclockwise circles of various sizes are performed by the patient, as well as crosslike patterns and diagonals.

The use of plyometric exercises is recommended in the later stages of total arm strength phase of rehabilitation. These exercises are characterized by an eccentric contraction of a muscle followed immediately by a concentric contraction of the same muscle group. The concept or principle behind the plyometric exercise is that stretching of the series elastic components of the muscle and activation of the stretch reflex from the eccentric muscular contraction during the lengthening phase of the exercise enhances the subsequent concentric or shortening response of the muscle.

**Stage 3: Interval return to full activity.** Evaluation of the patient for a return to full activity includes specific assessment of upper extremity range of motion and strength. A full pain-free range of motion in the elbow, forearm, and wrist is required before the patient can be considered an optimal candidate for return to full activity. Assessment of strength using isokinetics, if available, or manual muscle testing is also recommended in the comprehensive evaluation. Appropriate levels of strength compared bilaterally, as well as normal balance of the unilateral muscle ratios, are expected before a functional return is recommended. A handgrip dynamometer is also used as a gross strength measure for bilateral comparison. Generally, a greater emphasis is placed on isokinetic test results as opposed to either handgrip dynamometers or manual assessment because of the dynamic nature of the isokinetic test and degree of objectivity. Competitive athletes should rehabilitate the previously injured elbow at a high-speed contractile activity before returning to competition.

Manual soft tissue techniques such as active-release technique, nerve gliding, Nimmo technique, and scar modification can be helpful if performed by a therapist trained in these specific techniques. Constant repetitive motions can result in the formation of fibrous adhesions among muscles, fascia, and peripheral nerves. Consequently, such techniques were developed to treat and resolve repetitive strain injuries. These methods of treatment consist of applying both manual pressure and tension directly over an adhesion site. Although these soft tissue techniques can prove to be painful at times, application of heavy pressure promotes the healing process to a greater degree than light or moderate pressure. However, it is important to respect the patient’s pain threshold. Excessive pain will cause the patient to become tense, contract the muscle further, leading to an ineffective treatment. Furthermore, such soft tissue techniques should not be used directly over neurovascular structures because of the constant deep pressure applied, which may result in bruising. Thus, this method of treatment might not be appropriate for some of the entrapment sites; however, it may prove effective for other entrapment sites of the nerve at the elbow such as its exit point between the 2 heads of flexor carpi ulnaris or other musculotendinous causes of entrapment.

**Stage 4: Maintenance.** The goals in the maintenance phase are to continue to increase the strength, power, and endurance of the upper extremity musculature by initiating an interval training program (phase 1) specific to the individual’s sport or activity, while subsequently continuing to emphasize strengthening of the elbow and wrist. The type of interval return program designed is specific to the activity the individual is involved in. Consequently, the program will vary from one activity, or sport, to the next.
An interval throwing program is designed to gradually return motion, strength, and confidence in the throwing arm of a baseball player after injury or surgery by slowly progressing through graduated throwing distances. Furthermore, the interval throwing program is designed so that each level is achieved without pain or complication before the next level is started. This sets up a progression where a goal must be achieved before advancement. Because of this design, the interval throwing program may be used for different levels of skill and abilities, from those in high school to those in professional levels. The critical factor although is throwing mechanics. Regardless of the level of competition of the athlete, proper throwing mechanics through the program must be followed at all times. Simultaneously, the athlete should be supplementing the interval throwing program with both stretching and strengthening routines. Throwing involves all muscles in the body; thus, all muscle groups should be stretched before throwing. This should be done in a systematic fashion beginning with the legs and including the trunk, back, neck, and arms.

Continuation of conservative treatment should take place even after symptoms have subsided. There is some speculation as to how long conservative treatment should be adhered to ranging from a minimum of 90 days to up to 1 year. Nevertheless, if there is a continual ulnar nerve instability, distal neural symptoms, and/or pain that limits performance despite a comprehensive nonoperative rehabilitation program, the patient is most likely a candidate for surgical intervention.

Surgical Treatment of Cubital Tunnel Syndrome

If the patient’s symptoms become persistent and accompanied with muscle atrophy and sensory changes, surgical treatment should become a consideration. The basis for choosing a surgical technique must relate to (1) the pathophysiology of the compression of the ulnar nerve at the elbow, (2) an understanding of the etiology of the ulnar nerve compression in the patient’s particular case, and (3) the potential drawbacks of the various operative procedures.

Many surgical procedures are advocated for the treatment of cubital tunnel syndrome, including simple decompression, anterior transposition (subcutaneous, submuscular, intramuscular), and medial epicondylectomy. Surgical treatment of patients with cubital tunnel syndrome with no obvious associated pathology are governed by the following principles: (1) release all possible sites of compression; (2) preserve the vascularity of the ulnar nerve at the elbow; (3) allow early mobilization of the elbow; and (4) if the nerve subluxates during surgery, then perform a medial epicondylectomy.

Simple decompression. Simple decompression of the ulnar nerve employs the use of a longitudinal incision approximately 6 to 8 cm long just anterior to the medial epicondyle. The medial epicondyle is exposed, allowing identification of the ulnar nerve proximally. The nerve is released proximally as it passes through the medial intermuscular septum. A portion of the medial intermuscular septum is released from its attachment to the medial epicondyle to prevent kinking or compression of the ulnar nerve in elbow flexion. The cubital tunnel retinaculum and flexor carpi ulnaris aponeurosis is divided, which allows for simple decompression of the ulnar nerve at the elbow. There is commonly a second constricting fascial band deep within the substance of the flexor carpi ulnaris, 1 to 2 cm distal to the proximal fibrous arcade that must be released. Next, the portion of the ulnar nerve under the medial epicondyle is frequently compressed and must be released by dissecting it free from the overlying aponeurosis (Fig 5).

Postoperative subluxation of the ulnar nerve over the medial epicondyle with full passive elbow flexion has been reported as a statistically significant cause of failure of simple decompression of the ulnar nerve. The ligamentous band between the epicondyle and the olecranon should not be released. If this ligament is cut, the ulnar nerve should not be released from its posterior attachments to avoid sub-

Fig 5. Simple decompression. Reprinted with permission from Kleinman.
sequent subluxation. If the ulnar nerve continues to be compressed or subluxated over the medial epicondyle during passive elbow flexion, the remainder of the cubital tunnel is released and a medial epicondylectomy is performed. There have been some surgical modifications made to cubital tunnel decompression procedures, such as the use of endoscopic assistance, which allows the surgeon to visualize the ulnar nerve in relation to its potential sites of compression.

Simple cubital tunnel decompression has numerous associated advantages. The relative simplicity, safety, and predictability of the procedure allows postoperative rehabilitation to begin immediately, inevitably resulting in an average “return-to-work interval” of 20 workdays. This is less than one third that reported for anterior transposition, and it does not disturb the vascularity of the ulnar nerve as much as anterior transposition. Finally, in situ decompression avoids subluxation of the ulnar nerve as is frequently seen after simple release.

Disadvantages associated with simple decompression include the predisposition of the ulnar nerve to recurrent dislocation after extensive release and a high recurrence rate when the surgeon cannot locate the site of compression. In addition, this method does not deal with nerve compression resulting from lesions underlying the ulnar nerve such as ganglion, severe cubitus valgus, bone fragment, or osteophyte. Recently, it has been reported by Gelberman et al that simple release of the aponeurotic roof of the cubital tunnel does not modify the increase of intraneural pressure induced by elbow flexion. Simple decompression is best suited for the following patients: ones that exhibit mild symptoms due to a mild compression of the ulnar nerve; patients with preoperative evidence of subluxation of the ulnar nerve; and patients with abnormal electrodiagnostic studies defined by the inching technique, but with normal or only mildly abnormal nerve conduction velocities across the 10-cm elbow segment.

**Anterior transposition.** Anterior transposition surgical procedures can be grouped into 3 classes, depending on the location of the transposed ulnar nerve: subcutaneous anterior transposition, submuscular anterior transposition, and intramuscular anterior transposition. All transpositions remove the ulnar nerve from the compressive effects of the ulnar groove and cubital tunnel retinaculum, and by placing it anterior to the axis of motion of the elbow, they decrease tension and pressure on the nerve during flexion.

Disadvantages of anterior transposition of the ulnar nerve include the risk of denervating the flexor carpi ulnaris muscle and disruption of the nerve vasculature during dissection. Potential complications that may arise when moving the ulnar nerve away from its natural bed include symptoms produced with elbow extension, subluxation back to the original position, fascial slings causing new sites of entrapments, kinking of the ulnar nerve proximally and distally, scarring in the muscle channel, injury to the flexor carpi ulnaris motor branches, perineural fibrosis from transfer to a relatively hypovascular bed, perineural fibrosis from intraneural injury, devascularization of the ulnar nerve, and elbow contracture from immobilization. The worst of all complications is the failed submuscular transposition, in which there is often an extraordinary degree of fibrosis with resultant severe and permanent neurological defect. Immobilization, together with transposition, may result in new compression sites. In addition, elbow contracture may occur following elbow immobilization. Patients with longstanding cubital tunnel syndrome, pronounced symptoms, posttraumatic conditions of the elbow, a subluxating ulnar nerve, scarring around the nerve, space occupying lesions, or those with no obvious site of compression at the time of the surgery are better served by procedures that transpose the ulnar nerve.

**Subcutaneous transposition.** Subcutaneous transposition of the ulnar nerve was first described by Curtis in 1998 as releasing the ulnar nerve from all potential sites of entrapment and moving it anterior to the motion axis of the elbow, thereby relieving tension. Anterior subcutaneous transposition of the ulnar nerve consists of a longitudinal incision made posterior to the medial epicondyle extending several centimeters proximal and distal to the condyle. The ulnar nerve generally is identified where it enters the cubital tunnel and is dissected from the cubital tunnel and from between the humeral and ulnar heads of the flexor carpi ulnaris. This is accomplished by splitting the flexor carpi ulnaris aponeurosis, which allows the freeing of the ulnar nerve from the epicondyle. The mobilized ulnar nerve is transposed superficially to the flexor pronator muscle. Maintaining the ulnar nerve in the anteriorly transposed position is essential in this surgical procedure. In fact, some surgeons advocate using a fasciodermal sling to maintain the transposed anterior position of the ulnar nerve preventing it from falling back posteriorly. The most common approach in creating a fascial sling is to suture the subcutaneous layer directly to the flexor-pronator fascia, medially to the transposed nerve, using 2 or 3 absorbable sutures (Fig 6).
Failures in subcutaneous transposition have most commonly resulted from incomplete immobilization, therefore, it is imperative that the elbow be held in a slightly flexed position for approximately 14 to 21 days to allow for healing to take place. However, immediate mobilization of the ulnar nerve has been shown to significantly reduce the period in which the patient returns to work, thus, periodically, it would be beneficial to put the elbow through a pain-free range of motion. Subcutaneous transposition of the ulnar nerve with fasciodermal slings has shown to lead to a higher degree of patient satisfaction and relief of symptoms.

Subcutaneous transposition avoids detaching the flexor pronator muscle from its origin, thus placing it at a distinct surgical advantage over submuscular transposition for the throwing athlete. Risks specific to subcutaneous transposition include devascularization of the ulnar nerve, potential creation of other areas of impingement by altering the course of the ulnar nerve, possible subluxation of the ulnar nerve behind the medial epicondyle causing a recurrence of symptoms, the surgical incision may damage the posterior branch of the medial antebrachial cutaneous nerve leading to further distressful or painful paresthesias. Submuscular transposition was first described in 1942 by Learmonth and involves an incision centered over the cubital tunnel between the medial epicondyle and the olecranon process. The ulnar nerve is identified proximal to the cubital tunnel, and is traced proximally to the arcade of Struthers. Distally, the nerve is dissected between the 2 heads of the flexor carpi ulnaris muscle. It is very important to preserve the perineural vascular network to minimize devascularization of the nerve when it is transposed to its new position. Distal to the cubital tunnel, motor branches supply the flexor carpi ulnaris and flexor digitorum profundus muscles and must be preserved. If these come under undue tension during anterior transposition, intraneural dissection is used to facilitate anterior transposition. The medial intermuscular septum should be excised to prevent subsequent kinking of the ulnar nerve in its new position. In the proximal extent of the incision, the ulnar nerve pierces the medial intermuscular septum. The fascial band must be identified and released to prevent subsequent compression of the nerve. Approximately 1 cm distal to the medial epicondyle, the flexor-pronator muscle is divided and the ulnar nerve is then transposed anteriorly to rest adjacent and parallel to the median nerve. When the ulnar nerve is transposed anteriorly, the flexor pronator muscle is dissected from the medial epicondyle, allowing the nerve to be placed beneath the flexor pronator muscle. The flexor-pronator muscle origin is then repaired. Postoperatively, the elbow is held in a flexed and pronated position for 3 weeks, allowing the flexor pronator muscle to heal completely. However, Siegel encourages early range of motion of the elbow and forearm within a few days of the surgery. Strengthening of the forearm muscles should begin approximately 6 weeks after surgery (Fig 7).

The advantages of submuscular transposition include removal of all potential entrapment structures and ability to place the ulnar nerve in a well-vascularized intermuscular bed, to prevent the ulnar nerve from undergoing kinking at the point where the nerve enters the flexor carpi ulnaris, to prevent the ulnar nerve from drifting, and to protect from external compression. The disadvantages of this procedure are medial epicondyliitis, a longer recovery time because of healing of the flexor pronator origin, and possible nerve entrapment by a reattached muscle mass. Flexion contracture is a rare complication following cubital tunnel surgery but when it does occur, it usually follows submuscular transposition. Intramuscular transposition. In intramuscular transposition, the ulnar nerve is placed in a tunnel inside the flexor-pronator muscle and was first described by Adson in 1918. This surgical procedure consists of transposing the ulnar nerve anteriorly and forming an intramuscular bed using a 5- to 10-mm-deep incision along the flexor-pronator muscle just distal to the medial epicondyle in line with the transposed ulnar nerve. The ulnar nerve is identified proximally, posterior to the medial intermuscular septum, and distally, through the fascia overlying the 2 heads of the flexor carpi ulnaris. The ulnar nerve is followed distally beneath the flexor carpi ulnaris to ensure its free mobility. Failure to release the fibrous deep flexor-pronator aponeurosis between the ring finger superficialis muscle belly and the

Fig 7. Submuscular anterior transposition. Reprinted with permission from Kleinman.
The flexor carpi ulnaris may result in ulnar nerve compression in its transposed position.93,94 The proximal border of the pronator teres fascia and medial intermuscular septum from the middle of the humerus to the elbow are excised so that the ulnar nerve can be transposed anteriorly. After the ulnar nerve has been transposed inside the flexor pronator muscle, the fascia is closed avoiding any constriction or epineural adherence. This closure is easiest with the elbow held in a slightly flexed position and the forearm pronated at 45°.96

After surgery, the arm is kept in a long dressing, with the elbow fixed at 90° and forearm in midpronation for 3 weeks. Active range of motion begins at 3 weeks, whereas passive range of motion, if needed, is begun at 6 weeks, along with strengthening programs. Most patients with jobs that require manual labor are able to return to work at 8 weeks and resume full activity without restrictions by 10 weeks.10

Reported surgical failure in the intramuscular transposition has been attributed to either adhesion formation between the ulnar nerve and other fibrous anatomical structures around the elbow (remote from the intramuscular site) or to dense scarring10,94,96 (Fig 8).

Medial epicondylectomy. This surgical technique was first described in 1950 by King and Morgan.98 Medial epicondylectomy removes the major mechanical compressive factor in the cubital tunnel and allows anterior transposition of the ulnar nerve with considerably less dissection of the nerve than is required in the standard anterior transposition.8 An incision 12 to 15 cm long is made centered over the medial humeral epicondyle. The superficial surface of the ulnar nerve is exposed by incising the fascia and dividing the arcade ligament. The origins of the flexor carpi ulnaris are identified and the arcade is incised at the cubital tunnel. The entire medial epicondyle is then excised after the flexor pronator origin is detached from the epicondyle and is reflected distally. The medial intermuscular septum is excised for a few centimeters proximally.99 The epicondyle is then removed by aligning a 2.5-cm osteotome along the medial margin of the trochlea, which provides a useful natural guide. After removal of the epicondyle, the margins are smoothed with a rongeur and the raw cancellous surface is covered with bone wax. Removing the medial epicondyle excises the major bony block causing compression of the ulnar nerve, allowing it to migrate anteriorly without the necessity for its increased dissection and mobilization required for anterior transposition. The flexor pronator origin is reattached with the elbow in extension by closing the soft tissue envelope that previously enclosed the epicondyle, allowing the nerve to slide anteriorly in a superficial position. If any tension remains in the ulnar nerve after moving the elbow through a range of motion, the aponeurosis of the flexor carpi ulnaris must be divided further distally. A subcuticular closure is done and a soft compressive dressing is applied. No splint is required and early active motion is encouraged14,100 (Fig 9).

The major advantage of medial epicondylectomy is that it requires less dissection and mobilization. Therefore, there is a better preservation of blood supply to the ulnar nerve when compared with anterior transposition. Medial epicondylectomy has numerous other advantages associated with it such as complete release or removal of constraining structures (including the arcade of Struthers, roof of the cubital tunnel, fascia overlying the heads of the flexor carpi ulnaris, and the medial epicondyle), more thorough decompression than simple in situ release, support of early postoperative elbow mobilization, which leads to a faster recovery, and preservation of small proximal nerve branches that might be sacrificed in anterior transposition procedures.99

Numerous potential problems that have been reported in using medial epicondylectomy in treating compression of the ulnar nerve at the elbow include tenderness at the osteotomy site, weakness in pronation and flexion seen in the postoperative period, and medial instability of the elbow caused by operative injury to the medial collateral ligament and medial epicondylitis.5,101 This procedure should not be considered for athletes who engage in throwing motions,
such as baseball, because it allows greater anterior migration of the ulnar nerve with elbow flexion, which could be detrimental to the integrity of the nerve.

**Postoperative rehabilitation.** The patient is immobilized in a posterior splint or hinged elbow brace to allow the soft tissues to heal and to provide limited motion of the elbow in a safe and neutral range of motion. During the first postoperative week, the patient’s brace is set from −30° of extension to 100° of elbow flexion. Selective distal range of motion is performed into forearm pronation and wrist flexion, with guarded wrist extension and forearm supination to protect the flexor-pronator origin. Gentle isometric exercises with extremely light resistance levels are applied to prevent disuse atrophy. Foam balls or putty squeezing are also used.

During week 2, range of motion is progressed to −15° of elbow extension and 120° of elbow flexion. Gentle manual resistance and distal strengthening patterns, using little or no weight, are applied as tolerated. During week 3, the immobilizer is opened to allow full range of motion with continued use of light isotonic strengthening using patterns identical to those presented for nonoperative rehabilitation of ulnar neuropathy. Range of motion of the glenohumeral joint continues throughout the rehabilitation to prevent contractures from disuse. During week 6, isotonic shoulder and scapular strengthening exercises are introduced, with resistance being applied proximal to the elbow to prevent excessive stress across the elbow.

Isokinetic wrist and forearm exercise is initiated at 10 weeks with progression to interval sport/activity return programs by week 12. An isokinetic evaluation is performed at this time to formally assess strength of the wrist and forearm musculature. A shoulder isokinetic evaluation is also performed to assess more proximally the relative strength and balance of strength before performing interval sport/activity return programs.

**CONCLUSION**

This article has provided a review of the anatomy, etiology, and symptoms associated with compressive ulnar neuropathy at the elbow. A definitive diagnosis can best be made using clinical tests to assess for ulnar motor and sensory functions along with nerve conduction studies and EMG used as an adjunct to the clinical diagnosis. Conservative treatment of cubital tunnel syndrome is recommended for patients with intermittent symptoms and without changes in cutaneous sensation or muscle atrophy. If symptoms become persistent accompanied with muscle atrophy and sensory changes, surgical treatment should be considered.

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CASE REPORTS

A CASE OF ABNORMAL FINDINGS IN THE COURSE OF THE VERTEBRAL ARTERY ASSOCIATED WITH AN OSSIFIED HYOID APPARATUS. A CONTRAINDICATION FOR MANIPULATION OF THE CERVICAL SPINE?

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ABSTRACT

Objective: To describe a case of a simultaneous occurrence of an ossified stylohyoid ligament in a 56-year-old male cadaver and anomalies of the vertebral artery, and to consider the clinical implications for manipulative therapists.

Intervention and Outcome: Dissection showed a simultaneous occurrence of complete developmental ossification of the left hyoid apparatus, variants of the vertebral artery, and a left superior vena cava in a 56-year-old male cadaver.

Discussion: Developmental variants, posttraumatic and degenerative changes of the hyoid apparatus may result in variable degrees of ossification or calcification.

Conclusion: This unusual disorder should be considered in the differential diagnosis of facial and neck pain especially within the scope of manipulation of the upper cervical spine. Cervical spine manipulation may exacerbate existing pathological conditions of the styloloid apparatus, thereby irritating neurovascular structures, and induce a fracture. Developmental ossification of this apparatus might be associated with anomalies in the atlantic section of the vertebral artery which make the patient more susceptible to vertebrobasilar insufficiency. We conclude that extreme care should be taken in the presence of such an ossification to avoid trauma to the stylohyoid apparatus and maybe even because of increased vertebrobasilar risk. (J Manipulative Physiol Ther 2005;28:346-351)

Key Indexing Terms: Hyoid Bone; Neck Muscles; Vertebral Artery; Vena Cava, Superior; Cervical Vertebrae; Manipulation, Spinal

The styloid process is a site of muscle attachment and an important landmark on skulls.1 The stylohyoid ligament connects the styloid process with the lesser horn of the hyoid bone. These elements are seldom included in clinical evaluation by therapists focusing on the musculoskeletal apparatus.2 Developmental (congenital), posttraumatic and degenerative changes frequently result in a variable degree of ossification and/or calcification of this ligament, ranging from discrete calcifications near the lesser horn to complete ossification.3,4 This clinical phenomenon is normally benign and asymptomatic, but a number of patients, generally older than 40 years, complain of vague symptoms such as irradiating pharyngeal pain, earache, headache, cervical pain, and painful restrictions of the movements of head and neck.5-9 The latter, in particular, may be mistaken for symptoms of cervical spine pathologies and patients may therefore initially seek help from manipulative therapists. In addition, ossification of the stylohyoid ligament is often
associated with malformations of the odontoid process of the C2 vertebra and the atlanto-occipital joint, also resulting in neck complaints.10

Ossification of this apparatus may therefore have clinical implications for therapists who use manipulation, and a correct diagnosis is of great importance within the scope of spinal manipulation of the upper cervical spine. Johnson et al11 hypothesize, on the basis of 2 cases, that congenital ossification of the stylohyoid apparatus might be associated with anomalies in the atlanto section of the vertebral artery. If this is the case, an ossified stylohyoid ligament should be considered as an exclusion criterion for cervical spine manipulation.

We report a case of a simultaneous occurrence of an ossified stylohyoid ligament and anomalies of the vertebral artery and consider the clinical implications for manipulative therapists.

CASE REPORT

The present report deals with a male cadaver, dissected in the Department of Anatomy, Ghent University. The cadaver, from a 56-year-old man at time of death, had a completely ossified left stylohyoid ligament articulating with the styloid process through a synovial joint (Fig 1).

The vertebral artery originated from the aortic arch between the left carotid artery and the left subclavian artery (Fig 2) and entered the transverse foramen of the fifth instead of the sixth cervical vertebra. This artery also had a noticeably abnormal course at the atlanto-axial level, where the left vertebral loop was totally absent and thus was in close contact with the left lateral atlanto-axial joint. The diameter of the left vertebral artery was much smaller than the right vertebral artery (Fig 3).

There was also a left superior vena cava (LSVC), which was a persistent left precardinal vein, draining the left internal jugular and subclavian veins. This vein passed ventral to the hilus of the left lung, to reach the atrioventricular sulcus. It then ran to the right in this sulcus as a distended coronary sinus to empty in the right atrium. The right superior vena cava had a normal course. There was no anastomotic left brachiocephalic vein between the 2 venae cavae. There was a scalenus minimus muscle inserting on the first rib, between the subclavian artery and the brachial plexus.
DISCUSSION

Stylohyoid Ligament

The styloid process and the stylohyoid ligament are derived from the second branchial arch. These structures are first formed in cartilage from neural crest origin. The cartilage of the styloid process ossifies whereas the epihyal cartilage, which connects the styloid process and the hyoid bone, is usually reabsorbed. The stylohyoid ligament is formed from the remnants of the epihyal cartilage, also known as Reichert cartilage. It develops between days 45 and 49 (Fig 4).

The cause of an ossification of the stylohyoid ligament is unclear. Steinman has proposed 3 theories that could explain the ossification. Congenital ossification of the stylohyoid ligament may be attributed to the persistence of a cartilaginous element, the epihyal cartilage, which may grow abnormally and be converted to bone. As a result, the stylohyoid ligament may become partially or even completely ossified resulting in 1 or 2 stylohyoid bones. Between the different ossified structures, synchondroses and true synovial joints may develop.

Reactive changes could be due to stimulation of the still growing ossification centers of the styloid process, resulting in hyperplasia or excessive length of the process. Reactive metaplasia is another possibility. In this case, osseus centers within the stylohyoid ligament are stimulated and start ossifying, thereby joining the stylohyoid apparatus into a stiff inelastic cord to the styloid process. Tonsillectomy was initially recognized as a traumatic trigger of hyperplasia or metaplasia, but other trauma and recurrent or chronic inflammation could also induce these changes.

Changes are also seen in degenerative rheumatologic conditions such as diffuse idiopathic skeletal hyperostosis and in osteoarthrosis of the cervical spine. With the aging process, as soft tissues lose their elasticity, a localized inflammatory reaction causes a tendonitis at the junction of the ligament and the lesser horn. The ligament stiffens and the inflammatory response of associated tissues causes the symptoms.

According to their etiology, Camarda classified cervicopharyngeal pain related to the stylohyoid apparatus into 3 distinct entities. A diagnosis of Eagle’s syndrome is applied to symptomatic patients in whom elongated, ossified styloid processes develop within a period posttraumatically. Clinically, Eagle’s syndrome is divided into 2 subtypes. The classic stylohyoid syndrome, almost always after tonsillectomy, is characterized by dull and persistent, pharyngeal pain, radiating to the mastoid region, accompanied occasionally by dysphagia and painful swallowing, foreign body sensation, as much as facial and/or cervical pain. The stylocarotid syndrome is characterized by cervical pain, provoked and aggravated by rotation and compression of the neck and the occurrence of recurrent syncope, exacerbated by certain movements, due to compression of the carotid artery and the glomus caroticum.

Vertebral Artery

The development of vertebral arteries takes place between days 33 and 55 of intrauterine life. The vertebral artery is formed by the development of longitudinal anastomoses that link the 7 cervical intersegmental arteries. The intersegmental arteries soon obliterate and disappear, except for the segment of the seventh intersegmental artery, which becomes the subclavian artery and which includes the point of origin of the vertebral artery in adults.

In approximately 2.5% of the population, the anastomosis between the sixth and seventh intersegmental arteries does not develop on the left side and the sixth intersegmental artery persists. In this event the left vertebral artery originates from the aortic arch between the left common carotid and subclavian arteries. When the vertebral artery originates from the aortic arch, it usually enters the transverse foramen of the fourth or fifth cervical vertebra rather than the sixth.
Normally, from the third cervical vertebra onward, the artery undergoes a more lateral course to reach the transverse foramen of the axis. As it leaves the foramen the artery inclines further laterally and then bends upward to reach the transverse foramen of the atlas. After emerging from the transverse foramen of the atlas, the vertebral artery turns posteriorly and then medially around the lateral mass. After piercing the dural sac, it then runs anterosuperiorly to unite with its heterolateral counterpart to form the basilar artery. In the present case the transverse foramen of the C2 vertebra was not angulated and only slightly oblique. The transverse process of the C1 vertebra seemed shorter than we would normally expect, so the artery ran in close contact with the capsule of the lateral C1 through C2 joint from which it was difficult to separate by dissection.

Superior Vena Cava

In the very early stages of the development of the venous system, the main veins are arranged in the shape of the letter “H”: a left and a right precardinal and a left and a right postcardinal vein. On each side, pre- and postcardinal veins join to form a short common cardinal vein which enters the horizontal sinus venosus at the dorsal side of the primitive heart. The precardinal veins drain the head, neck, and upper extremities and become the jugular and subclavian systems. An anastomosis between the left and right precardinal veins develops around day 50 and becomes the left brachiocephalic vein. In approximately 0.4% of the population the anastomosis between left and right precardinal veins does not develop or remains hypotrophic and the left precardinal vein remains open, resulting in a normal right superior vena and a LSVC, draining into the coronary sinus (Fig 6).

**Clinical Implications**

Damage to the vertebral artery is the most feared complication after manipulation of the cervical spine. Other complications are seldom considered in literature. The present case, as well as case descriptions by Johnson et al, report on the simultaneous occurrence of an ossified stylohyoid ligament and anomalies of the vertebral artery. The question arises as to whether this combination is a common phenomenon or a mere coincidence. If this link can be established, the discovery of an ossified stylohyoid ligament would be a warning for potential arterial abnormalities.

The stylohyoid ligament is formed from the remnants of the Reichert cartilages. It develops between days 45 and 49. The earliest development of the vertebral arteries is apparent in the embryo at the 7-mm stage (day 33) and is usually completed by the 14- to 17-mm stage (day 54).
The formation of the left brachiocephalic vein takes place around the 50th day, soon followed by the obliteration of the left precardinal vein. Given the embryologic time table, it could be argued that some aberrant developments around the 50th day suggest a probable link between the observed anomalies.

The fact that, in the present anatomic description as well as in the unilateral case of Johnson, the vascular anomalies occurred on the same side as the ossification adds to the hypothesis of a consistent link. However, given the embryologic development, an aberrant development of the brachiocephalic vein with concomitant aberration of the right venous system is quite different and more exceptional.

This assumption may have clinical implications for therapists performing spinal manipulations in the cervical region. The normal loop at the atlanto-axial level, which is thought to protect the artery during rotational movements, is deficient in the described cases. Subjects with loop deficiencies may be more susceptible to disturbances in blood flow, resulting in verteobasilar insufficiency.

As a consequence, it seems worthwhile to increase the number of observations to confirm or deny the hypothetical link. If the link between deficient arterial loops and ossified stylohyoid ligaments is consistent, the ossified stylohyoid ligament, which is well visible on radiographs, should be considered as an exclusion criterion for cervical spine manipulations.

Other complications are attributable to the ossified stylohyoid ligament itself. Besides the relatively rare congenital complete ossification, posttraumatic changes are much more frequent. Potential problems can arise in the presence of trauma, such as whiplash. Because manual therapy is the treatment of choice for these types of cervical trauma, it is important that the therapist be knowledgeable about this syndrome. The therapist should be attentive in examining the routine lateral skull view and panoramic radiographs during diagnosis. The stylohyoid ligament can be injured and because these ligaments have a high collagen content, they do not stretch, but rather permanently elongate. Cervical spine manipulation or end-range mobilization can prolong irritation and inflammation in the compromised soft tissues surrounding the calcified stylohyoid structures. The therapist who initiates treatment blindly may unwittingly exacerbate the ossification of the stylohyoid ligament.

Once established, posttraumatic ossifications, especially those resulting in elongation of the styloid process, may induce a type II Eagle syndrome, through mechanical irritation of the neurovascular complex. The syncopes associated with this syndrome resemble drop attacks and hence should be considered as a contraindication. The worst case scenario for the uninformed or unsuspecting manipulator is the risk that this calcified pencil-shaped structure could damage the vital proximate vascular structures during the thrusts with devastating consequences.

Finally, ossified stylohyoid ligaments and elongated styloid processes may fracture with or without an obvious traumatic incident. With sudden jerking of the head, such as a thrust during a manipulation, a fracture of the ossified stylohyoid ligament can occur, and a nonunion may develop because of continuous micromovement of the hyoid bone. The proliferation of granulation tissue in the region of the nonunion could then cause pressure on the surrounding structures, resulting in pain in that area.

As the stylohyoid ligament is also connected to the angle of the mandible through a mandibu-stylohyoid ligament, regional rotational techniques grasping the mandible can transmit traction onto the stylohyoid apparatus and fracture ossified elements. Such a fracture causes heavy disabilities and pain and may require surgery.

Cervical spine manipulation may exacerbate existing pathological conditions of the stylohyoid apparatus, thereby irritating neurovascular structures, but can also induce a fracture. Considering this, caution should be exercised and forceful manipulations should be avoided in the case of an ossified stylohyoid ligament or elongated styloid process.

**CONCLUSION**

Developmental variants, posttraumatic and degenerative changes can result in a variable degree of ossification or calcification of the stylohyoid apparatus. Pathologic examination of this apparatus is seldom included in the clinical assessment by manipulative therapists, but it is of great importance to diagnose within the scope of manipulation of the upper cervical spine. It is hypothesized that congenital ossification of the stylohyoid apparatus might be associated with anomalies in the atlantic section of the vertebral artery which make the patient more susceptible to verteobasilar insufficiency. More observations are required to confirm this link. The practitioner should be attentive in examining the routine lateral x-rays of the cervical spine to substantiate the clinical diagnosis of an ossified stylohyoid apparatus.

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A Case Report of Manipulation Under Anesthesia of Posttraumatic Type II Occipital-Atlantoaxial Rotatory Subluxation in a 4-Year-Old Girl

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Abstract

Objective: To discuss a case of occipital-atlantoaxial rotatory subluxation successfully treated with manipulation under general anesthesia.

Clinical Features: A 4-year-old girl presented to the Taichung Veterans General Hospital with acute torticollis and neck stiffness for 1 week after she had fallen. Although some nonsteroidal anti-inflammatory drugs had been prescribed for her, her neck still tilted to the right side and her chin inclined to the left side. There were no neurological signs, no significant pain if she did not move her neck and head, and no muscular hypertonicity. There was painful guarding in the right sternocleidomastoid muscle when manipulation was attempted. Three-dimensional computer tomography revealed uneven joint space between the C1 anterior arch and odontoid process and confirmed a type II atlantoaxial rotatory subluxation.

Intervention and Outcome: Manipulation under anesthesia was performed by a medical doctor trained in manual therapy. The low-velocity, right rotational manipulation applied to the occiput included axial traction. The neck symptoms were relieved immediately after treatment.

Conclusion: Under general anesthesia, manipulation may be a good method for treating noncomplicated type II atlantoaxial rotatory subluxation. Additional investigations may be necessary to evaluate the treatment effect.

Key Indexing Terms: Atlantoaxial Joint; Rotatory Subluxation; Manipulation; Spinal

Sudden onset of acute torticollis is a rare condition in children. One possible cause is atlantoaxial rotatory subluxation. The common clinical characteristic is the patient presenting with the head tilted to one side and rotated to the other side, the so-called cock robin position. Ligament laxity secondary to minor trauma, or a preceding history of upper respiratory infection, has been reported to be the etiology. Treatment options include medication, traction, manipulation, bracing, or operation, but it usually takes several weeks for symptoms to resolve. We present this case treated successfully with manipulation under general anesthesia and with immediate relief after this maneuver, and then review our other 3 cases.

Case Report

A 4-year-old girl presented to the Taichung Veterans General Hospital with neck stiffness, and her head was tilted to the right for 1 week after she fell down on a playground. She had taken some nonsteroidal anti-inflammatory drugs, but the symptoms remained. Observation showed that her head tilted 30° to the right and rotation 10° to the left. Her active range of motion was less than 10° in rotation and lateral bending. Palpation showed the atlas in a right rotated position with left border posterior. The axis spinous process was in a relatively neutral position. Muscle guarding was found in the paraspinal C1-2 muscles when mobilization of the C1-2 joints was attempted. There were no neurological signs, no fever, no significant pain, and no muscular hypertonicity, but there was some painful guarding in the right sternocleidomastoid muscle when manipulation was attempted. This pain guarding of the neck muscles
made the child irritable and uncooperative and impeded manipulation. According to previous experience with such cases, atlantoaxial rotatory subluxation was the first diagnostic impression.

Plain film radiographs for her neck were not taken because of our first diagnostic impression. Instead, a traditional computed tomography (CT) scan was taken and showed uneven joint space between the C1 anterior arch and odontoid process and a left rotated atlas (Fig 1). Three-dimensional CT scan was done; the bony structure of the occipital-atlantoaxial rotatory subluxation was reconstructed. The posterior view showed the atlas tilted about 12° to the right side (Fig 2). The top view showed the atlas in a unilateral left-rotated position, with uneven space between the odontoid process and anterior arch of C1; the occiput was in a left-rotated position of about 75° (Fig 3). According to the classification of Fielding and Hawkins,8 the diagnosis of this patient was atlantoaxial rotatory subluxation type II.

Consent to proceed with treatment was obtained from the patient’s parents. An anesthesiologist was consulted for general anesthesia, and a muscle relaxant was given. The anesthesia was delivered through a mask; thus, no endotracheal tube was inserted. The manipulation procedure was performed in the operating room by the primary author who has a specialty of physical medicine and rehabilitation and was trained by the chief of department who learned manipulative skills from Cyriax.

The patient was placed in a supine position, with some occipital traction vector. With the left index finger fixing on the left C2 articular pillar, a gentle rotary manipulation was given to the right side. Passive stretching of the right neck muscles and mobilization manipulation of the cervical spine were done after this manipulation. The symptoms were relieved immediately after this maneuver. Three months later, a follow-up examination showed normal
alignment of her upper cervical spine, and no other problems were found.

**DISCUSSION**

Atlantoaxial rotatory subluxation is a rare condition that usually occurs in children. The estimated frequency of this disorder is approximately 200 cases per year in the United States. The typical manifestations are acute onset of head stiffness and pain, with the head tilting to one side and rotating to the other side, or a "cock-robin" position. Ligament laxity secondary to trauma, or a preceding upper respiratory infection history, has been reported.

In noncomplicated cases, no treatment for immediate relief has been reported. Chiropractic correction of atlantoaxial rotatory fixation was reported by Knutson in 1996, but the treatment course required 12 visits and lasted 2.5 months. While under general anesthesia, our case showed relief immediately after the manipulative procedure.

Manipulation under general anesthesia was used in this case because the neck muscles are usually very tight due to guarding, and poor cooperation of the children is usually encountered when traditional manipulation is performed. Under general anesthesia, with muscle relaxant given, there was no resistance to manipulation.

This is the fourth case of atlantoaxial subluxation we have treated successfully with manipulation in the past 3 years. The 3 earlier cases were all boys. One incurred atlantoaxial subluxation after he fell down while playing basketball; the other 2 boys incurred this problem after falling asleep. No trauma history and no upper respiratory tract infection signs were noted. Of these 3 boys, 2 were successfully treated with under-anesthesia manipulation. The other one improved completely 3 days later after one session of manipulation (not under anesthesia) to C0-C1-C2 while he was waiting for under-anesthesia manipulation.

The rationale for manipulation under anesthesia for these patients was that children were usually uncooperative and cried during the manipulation procedure. Questions raised included the following: What is the time interval that patients should receive manipulative management? When should patients seek a second opinion (surgery, continuous traction, chiropractic) if manipulation failed? After searching MEDLINE, we found no standard and effective treatment method (including manipulation) for atlantoaxial rotatory subluxation. Given the lack of treatment guidance for manipulation in such cases, there is still no evidence for the effectiveness of manipulation. For the above reasons, the first author informed the patients' guardians that the treatment procedure was based on his successful previous experience. However, more cases and clinical investigations are necessary to provide more evidence.

This case demonstrates a subluxation of the atlanto-occipital articulation joints that was combined with atlantoaxial rotatory subluxation. Initially, this case was thought to be only another case of simple atlantoaxial rotatory subluxation. Because of previous experience with managing such a case, a 3-dimensional (3D) CT scan was arranged directly rather than plain film first. The magnitude of subluxation disclosed in the 3D CT scan was an unanticipated finding (Fig 3). It is unknown how many chiropractors or physicians could identify this structural change by manual palpation alone. It is a challenge to perform manipulation for the magnitude of displacement by image findings. We cannot compare the plain film findings in this case with our other cases, which might be a limitation in this report.

For the anesthesia, the procedure was performed by an anesthesiologist specialist; no endotracheal tube was used, only a mask. Manipulation was done after the patient fell asleep and the manipulation procedure lasted only 2 to 3 minutes. The anesthesia procedure lasted no more than 10 minutes. During anesthesia administration, respiration, blood pressure, oximeter, and electrocardiogram were monitored to make sure the patient was in a stable condition. As the duration of this procedure is short, and monitored by an anesthesiologist specialist, it appears that the risk due to anesthesia is low.

In comparison of the cost between CT scans and plain film in Taiwan, CT scan costs about NT$5000 (about US$140), whereas plain film radiography (including posterior-anterior view, lateral view, and open-mouth view) costs about NT$800 (about US$23). These are all paid by health insurance.

Plain firm radiographs (including open-mouth view, posterior-anterior views, and lateral views) are usually suggested as the first tool for evaluating the neck condition when atlantoaxial rotatory subluxation is considered. In our prior cases, plain firm were arranged first, but little information was obtained. With these 3 plain views, a distance discrepancy between the dens and the lateral masses of atlas in the open-mouth view can only give us impressions of atlantoaxial rotatory subluxation. In this case, we did not order plain films but 3D CT scans instead. The bony structure can be presented clearly after image reconstruction for premanipulation evaluation (Figs 2 and 3).

Using the classification system of Fielding and Hawkins, this case presented as a unilateral anterior rotation, and the dens had deviated to the left side; type II atlantoaxial rotatory subluxation was the impression. The other 3 cases were also type II. According to the Fielding and Hawkins classification, type I injury is a rotatory displacement with less than 3 mm anterior displacement of the atlas, implying an intact transverse ligament; type II injury has anterior displacement of C1 on C2 of 3 to 5 mm with some deficiency of the transverse ligament; type III
injury has greater than 5 mm of anterior displacement; type IV injury has posterior displacement of C1 on C2.

The positional change of the occiput was not mentioned in previously published literature on atlantoaxial rotatory subluxation. The atlanto-occipital articulation joins the elliptic and convex occipital condyles with the superior articular cavities of the atlas. In Fig 3, subluxation of the atlanto-occipital articulation can be found. Occipital atlantoaxial rotatory subluxation may be a more proper diagnosis for this rare disorder.

CONCLUSION

Occipital-atlantoaxial rotatory subluxation is a rare, more complex condition than atlantoaxial rotatory subluxation. With a 3D CT scan, a precise structural diagnosis of the upper cervical spine can be obtained before performing manipulation. Using traditional manipulation, the resistance of ligaments and guarding muscles may be difficult to overcome in children. Under general anesthesia, the resistance of ligaments and muscles in the upper neck is reduced, and manipulation is easy to perform. Precise structural diagnosis of the spine and careful manipulation may be a good method for treating a type II occipital-atlantoaxial rotatory subluxation.

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CONGESTIVE HEART FAILURE: A REVIEW AND CASE REPORT FROM A CHIROPRACTIC TEACHING CLINIC

Melanie D. Osterhouse, DC, a Norman W. Kettner, DC, b and Ron Boesch, DC c

ABSTRACT

Objective: To discuss the case of a 62-year-old woman with congestive heart failure (CHF), precipitated by a previous arteriovenous malformation, and to review the clinical presentation, pathophysiology, and treatment options for patients with CHF.

Clinical Features: The patient complained of pain, rapid weight gain, and shortness of breath. The index event for this patient was known to be an arteriovenous malformation. Biventricular cardiomegaly with pulmonary venous hypertension was evident on chest radiographs.

Intervention and Outcome: The patient received both medical care (drug therapy) and chiropractic care (manipulation and soft tissue techniques to alleviate symptoms and discomfort).

Conclusion: Patients with known and undiagnosed CHF may visit the chiropractic physician; thus, knowledge of comprehensive care, differential diagnosis, and continuity of care are important. Chiropractic management may be helpful in alleviating patient discomfort. Further clinical investigations may help to clarify the role of complementary and alternative care in the diagnosis and treatment of CHF. (J Manipulative Physiol Ther 2005;28:356-364)

Key Indexing Terms: Heart Failure; Congestive; Myocardial Infarction; Hypertension; Chiropractic

Heart failure is a leading killer, affecting 1% of people aged 50 to 60 years and 10% of people in their 80s, for a total of 4.9 million Americans. In the United States, 400,000 new cases are diagnosed each year. In 1993, the cost of treating heart failure patients was approximately US$10 billion, with each individual case costing approximately US$20,000 per year. African Americans have a 40% higher mortality rate from heart failure than Caucasians, and men have a 25% higher mortality rate than women. Heart failure accounts for approximately 250,000 deaths per year and is the most frequent cause of hospitalization in the elderly. The median survival after the diagnosis of heart failure is 1.37 years for men and 2.48 years for women. Only 50% of cases are initially diagnosed correctly. Due to the clinical magnitude of heart failure and the low rate of accurate diagnosis, it is our intent to offer chiropractic physicians a review of the diagnosis, pathophysiology, and range of treatment options for the patient with heart failure. We present a patient with chronic heart failure seen at a chiropractic teaching clinic.

CASE REPORT

A 62-year-old white woman presented with unrelenting right-sided neck and shoulder pain of 6 months duration. The pain was characterized as sharp and numbing with radiation into the right hand. Within 12 days of the initial visit, she had gained 8 lb and was exhibiting labored respiration.

Significant patient history included previous diagnoses of cardiomyopathy, type II diabetes mellitus, hypertension, and arthritis. She had a surgical history of a pulmonary arteriovenous malformation (AVM) that was excised 3 years prior. Her presurgical computed tomography (CT) from 3 years prior showed 4-chamber heart enlargement (Fig 1). A lobular, serpentine, abnormal soft tissue mass was seen in the left paraspinous region. The mass enhanced identical to the aorta, which was consistent with AVM (Fig 2).

Chest radiography done at our institution revealed biventricular cardiomegaly with pulmonary venous hypertension (Fig 3). Surgical sutures were seen posteriorly on the lateral radiograph, consistent with the AVM excision. A follow-up CT of the chest, cervical spine, and abdomen was obtained. Moderate, but stable, cardiomegaly with a small pericardial effusion was noted on the chest CT. Diffuse degenerative spondylosis was confirmed throughout the
cervical spine based on the cervical CT. The abdominal CT revealed hepatomegaly that was suggestive of hepatic congestion from cor pulmonale or early cirrhosis and a separate finding of a gallstone. Her findings were also consistent with congestive heart failure (CHF).

She underwent medical care with diuretics and anti-inflammatory and antihypertensive medications. Concurrent chiropractic management was undertaken. Cervical spine manipulation and postisometric relaxation techniques were used and alleviated much of the patient’s neck and shoulder symptoms.

DISCUSSION

Pathophysiology

Heart failure exists when cellular respiration becomes impaired because the heart cannot pump enough blood to support the metabolic demands of the body. The initial signs and symptoms of heart failure include dyspnea, cough, nocturia, mental disturbances, anxiety, and generalized fatigue. Peripheral edema of cardiac origin may be present which is symmetric and worse in the evening. Edema is detected when the extracellular volume exceeds 5 L. With time, gastrointestinal symptoms emerge, such as abdominal bloating, anorexia, and fullness in the right upper quadrant. Eventually, cardiac cachexia may arise secondary to protein loss from enteropathy and increased cytokine levels.

Pathophysiological theories of heart failure include the hemodynamic theory and the neurohumoral theory. In recent years, the hemodynamic theory has been replaced by the neurohumoral theory. The hemodynamic theory states that impaired hemodynamics, as characterized by low cardiac output, compensatory vasoconstriction, and compensatory sodium and water retention, create a vicious cycle eventually leading to the patient’s demise. These altered hemodynamics result in the symptoms of cardiac failure but do not represent the whole story, as evidenced by the long-term failure of the pharmacological regimens seeking to normalize hemodynamic status. These drugs include positive inotropes, peripheral vasodilators, and diuretics.

The neurohumoral theory states that heart failure is initiated and perpetuated by the activation of endogenous neurohormones and cytokines as a consequence of an “index event.” This “index event” may represent an acute injury to the heart or genetic mutation. The process of heart failure is now defined as the development and progression of left ventricle myocardial remodeling. The neurohumoral
theory evolved from the introduction of angiotensin-converting enzyme inhibitors (ACEIs) in the 1980s. This drug was the only intervention that improved symptoms while prolonging life. Not only did ACEIs affect hemodynamics by acting both as a diuretic and vasodilator, but it also protected against endothelial dysfunction and suppressed the adverse remodeling of the cardiac and vascular walls. Coronary endothelial dysfunction is known to stimulate vasoconstriction, smooth muscle proliferation, increased lipid deposition, and thrombosis, thus explaining in part the exercise intolerance seen in heart failure. Coronary endothelial dysfunction is known to stimulate vasoconstriction, smooth muscle proliferation, increased lipid deposition, and thrombosis, thus explaining in part the exercise intolerance seen in heart failure.4

Heart failure is also known to activate myocardial collagenases or matrix metalloproteinases by the alteration of myocardial tissue oxidation-reduction states. The result is loss of the interstitial supporting structure. The increase in cardiac mass is a result of reactive fibrosis, myocyte hypertrophy, and altered cytoskeletal structure within the cardiomyocyte.5

More recently, excessive cytokine activity has been noted in chronic heart failure. Cytokines act at short distances in a paracrine or autocrine manner. The 2 cytokines associated with heart failure are endothelin, which is a vasoconstrictor, and the proinflammatory vasosuppressor cytokine, tumor necrosis factor (TNF).4 TNF produces myocyte hypertrophy and apoptosis.5 The major source of cytokines may be the heart itself. TNF mRNA and protein have been found in the failing heart but not in normal hearts. Cytokines most likely perpetuate heart failure but do not initiate the condition.

Elevated neurohormone production possibly evolves for the short-term stabilization of dehydration or other causes of reduced cardiac output. Prolonged states of neurohormonal activation, however, result in progression of left ventricle remodeling.5 There is overlapping of neurohumoral imbalance, endothelial dysfunction, and elevated cytokine expression resulting in the initiation and progression of chronic heart failure.4 The chronic heart failure starts with an “index event” causing structural remodeling and leading to the clinical syndrome of heart failure.5

The “index event” can be any disease that leads to heart failure (Fig 4). The indexing event seen in this case report was an AVM. Myocardial infarction leads to the loss of contractile tissue that is replaced by fibrosis.5

Hypertension is the most common risk factor for heart failure. Stage 2 hypertension doubles the risk of developing

Noncompliance with a low-salt diet or medical regimen
Uncontrolled hypertension
Myocardial infarction
Arteriovenous malformation
Cardiac arrhythmias
Systemic illness (any infection can precipitate congestive heart failure)
High-output states (thyrotoxicosis, anemia, renal disease, arteriovenous fistula, Paget disease, beriberi, Kaposi sarcoma)
Administration of cardiodepressants if systolic congestive heart failure (β-blockers, disopyramide, first-generation calcium blockers such as verapamil, doxorubicin, or cyclophosphamide)
Administration of salt-retaining drugs (NSAIDs, estrogen, androgen, corticosteroids)
Environmental stress, such as exposure to extreme cold or heat
Emotional stress
Pulmonary embolus

Based on information from Ref. [6].

Fig 4. Index events precipitating CHF. NSAIDs, Nonsteroidal anti-inflammatory drugs.
heart failure in patients aged 60 to 70 years. Risk factors include increased heart rate, advanced age, insulin resistance, glucose intolerance, elevated blood lipids, left ventricle hypertrophy, obesity, and cigarette smoking. Diabetes is found in 1 of 4 to 1 of 3 of patients with CHF, and diabetes increases the risk of CHF in post–myocardial infarction patients. With increasing age, vascular stiffness results from thickening of the media and adventitia. The stiffness is due to myocyte loss, delayed relaxation, and calcium-uptake abnormalities. This thickening causes increased afterload culminating in left ventricle hypertrophy.

The clinical syndrome of heart failure may include myocardial energy starvation and salt and water retention. Arterial remodeling diminishes coronary vessel size and contributes to the energy starvation of heart failure. With decreases in cardiac output, arterial blood volume is reduced, which stimulates the sympathetic nervous system and the renin-angiotensin-aldosterone cycle. The result is reduced renal blood flow. Thus, the kidneys retain salt and water to restore perfusion, resulting in congestion and edema.

The transition from this compensated hypertrophy to heart failure occurs when myocytes lose the ability to normally maintain calcium ion homeostasis. Heart failure is accompanied by a decreased amount of calcium ion release from the sarcoplasmic reticulum. Houser et al propose that the sarcoplasmic reticulum calcium ion release does not offset the frequency-dependent excitation-contraction (EC) coupling refractoriness. These abnormal levels of sarcoplasmic reticulum calcium thus produce the EC coupling defects of the failing myocyte. Therefore, abnormal EC coupling contributes to the dysfunctional calcium handling in heart failure. Treatment approaches that improve calcium ion homeostasis may prevent heart failure onset.

Clinical Diagnosis

Physical findings associated with congestive failure may include a weak thready pulse and pulsus alternans that suggests diminished left ventricle function. Cheyne-Stokes respiration and tachycardia are common. Tachycardia is the body’s attempt at maintaining adequate cardiac output. Beyond these vital signs, findings of congestion include jugular veins that show central venous pressure elevation or paradoxical inspiratory venous pressure rise, known as the Kussmaul sign. This test for jugular venous distention is 90% specific but only 30% sensitive for elevated left ventricular filling. Valsalva maneuver is 91% specific and 69% sensitive for detecting left ventricle dysfunction.

The New York Heart Association (NYHA) functional classification of dyspnea is graded I to IV for left ventricular heart failure (Fig 5). On cardiac examination, the point of maximal impulse may be displaced laterally and downward, indicating cardiomegaly. This patient showed cardiomegaly. Gallop rhythm is a reliable sign of a failing ventricle, especially the quadruple rhythm or summation gallop. A third heart sound is 99% sensitive but only 24% specific for heart failure. Electrocardiography (ECG) may reveal atrial and ventricular arrhythmias that are not specific for heart failure, nonetheless a common finding. Pulmonary examination may show evidence of rales and pleural effusion. Right-sided heart failure may be manifested by the presence of hepatojugular reflex indicating congestive hepatomegaly.

Diagnostic Imaging

After a physical examination suggestive of congestive failure, chest radiography should be obtained. Radiographic findings of heart failure may include cardiomegaly, cephalization of vessels, hilar haze, and interstitial edema. Cardiomegaly is determined by a cardiothoracic ratio greater than 0.50 on the posteroanterior projection. However, the finding of an elevated diaphragm, apical fat pad, and even anteroposterior expiratory films may mimic cardiomegaly.

Cardiomegaly is sensitive for determining the setting of decreased ejection fraction. Patients with diastolic failure may have a normal heart size, thus differentiating diastolic from systolic failure. The normal heart size in diastolic failure is due to the inability of the ventricles to dilate normally during diastole. The heart is often imaged in diastole because it is the longest phase of the cardiac cycle. Therefore, the heart size appears normal. These patients have little, if any, systolic impairment to create cardiomegaly. Forty to 50% of the elderly with heart failure have the diastolic variety. The radiographic findings of cephalization and hilar haze are more sensitive than cardiomegaly at determining increased preload. Cephalization occurs when the pulmonary venous pressure rises as a result of elevated

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Fig 5. Classification of dyspnea.

I Patients who have no symptoms
II Patients with dyspnea or fatigue with moderate exertion
III Patients who have dyspnea or fatigue
IV Patients who have dyspnea or fatigue at rest and with mild exertion

Based on information from Ref. [6]
left ventricular preload. Dilated upper lobe pulmonary veins and constricted lower lobe veins are then noted. Cephalization is also known as vascular redistribution, flow shift, flow inversion, or pulmonary venous hypertension.

Interstitial edema is radiographically represented by linear densities known as Kerley lines or by hilar haze known as the butterfly pattern. Lastly, the plain film is helpful in identifying pleural effusion resulting from heart failure. Badgett determined that the chest radiograph is only reliable when excluding or confirming increased preload or systolic dysfunction in patients with high or low prevalence of heart disease. The chest radiograph should be used then in conjunction with a comprehensive history, targeted physical examination, and confirmatory tests for an accurate diagnosis.

CHF testing frequently includes use of ECG. It is not specific, however, for heart failure. Atrial andventricularrhythmias are common to heart failure and can be detected by ECG. Prolonged QRS duration has been correlated with decreased ejection fraction. Echocardiography is more useful, and an ECG is simultaneously performed. The transthoracic 2-dimensional echocardiograph with Doppler flow assesses the left ventricle size, mass, and function.

Echocardiography is currently the method of choice for anatomic cardiac characterization in most clinics and hospitals. M-mode and 2-dimensional echocardiography are used to evaluate left ventricular functional impairment. The echocardiograph will display left ventricular enlargement, increased end-diastolic and systolic volumes, and reduced myocardial fractional shortening and calculate ventricular ejection fraction. Due to the diminished left ventricular compliance and elevated left ventricular end-diastolic pressure, mitral valve motion may be abnormal.

Stress echocardiography performed using low-dose dobutamine, as well as positron emission tomography (PET) and thallium 201 radionuclide scanning can identify hibernation. Hibernation is cardiac dysfunction that is reversible and occurs during ischemia. Identification of hibernation helps to determine suitable candidates for surgery that can provide improved ejection fraction and other measures of left ventricular function. Echocardiography is portable, making it convenient. However, echocardiography is operator-dependent, and its acoustic window limitations constrain the field of view. Precise cardiac chamber size cannot be determined due to the arbitrary scan planes that result from contour variation of the chest wall. Emerging cardiac imaging techniques include magnetic resonance imaging (MRI) and CT. They provide exquisite detail of the cardiac chambers and pericardium and a look at integrated cardiorespiratory systems.

Cardiac MRI evaluates cardiac function by cine gradient-echo imaging of the ventricles. Cardiac wall motion, ventricular volumes, and flow analysis can be assessed. The flow analysis assesses cardiac function by measuring velocity and flow during the cardiac cycle. Ventricular volumes are obtained using Simpson’s rule. The ventricular area is measured for each slice and then multiplied by the combined slice and gap thickness that represents each slice volume. Ventricular volume is the sum of the slice volumes. End-diastole and end-systole volumes can be used to calculate stroke volume, ejection fraction, regurgitant fractions, and shunts. Data points acquired throughout the cardiac cycle can be used to generate volume-time curves to detect diastolic filling or systolic ejection dysfunction.

Dilated cardiomyopathy has been shown with MRI to display heterogeneity in the wall thickness with thinning of the apical myocardium and posterior septum. Change in myocardial thickness for dilated cardiomyopathy is reversed from normal, with thickness decreasing through the antero-lateral wall from base to apex. More advanced tools allow for real-time MR fluoroscopy, myocardial perfusion, myocardial tagging, and myocardial viability.

Cardiac MRI also has relevant limitations. MRI has many contraindications, including pacemaker, implanted defibrillator, Swan-Ganz catheter, recent coronary artery stenting, and cardiac arrhythmias that significantly impair cardiac imaging. A high-performance MRI system is costly but necessary to enable cine gradient-echo imaging and 3-dimensional contrast-enhanced MRA with acquisition times of less than 25 seconds (1 breath-hold). MRI sequences are also time-intensive, highly motion-sensitive, and subject to artifacts that degrade image quality.

Ultrafast electron beam CT (EBCT) shows structural abnormalities and areas of decreased cardiac contractility. Ventricular volume measurements provide accurate calculations for stroke volume and ejection fraction of both right and left ventricles. Ultrafast EBCT is performed by magnetically focusing and deflecting an electron beam. It replaces tube rotation used in conventional CT scanning. The electron beam hits fixed tungsten target rings resulting in a collimated fan beam of radiation which allows extremely short imaging times of 50 milliseconds. This imaging time is fast enough to study ventricular function. However, unlike MRI, EBCT produces individual images rather than composite images. Multiple factors inhibit the widespread use of ultrafast EBCT imaging. Ultrafast EBCT scanners are not readily available. In addition, an examination results in a relatively large radiation dose of approximately 0.05 Gy (5 rad). Lastly, intravenous contrast may exclude patients with allergies or renal disease.

The state-of-the-art CT is the multidetector row computed tomographic scanner. This 16-section scanner emerged in 2001 and has the advantage over its imaging counterparts by being faster with improved temporal resolution and better spatial resolution in the transverse plane. The image is isotropic, meaning that the resolution is equally adequate in the sagittal, coronal, and axial planes; therefore, there is no preferred plane for image reconstruction. The 16-section scanner even has an advantage over MRI. MRI requires the examiner to choose the plane of
imaging before data acquisition, whereas this type of CT scanner allows for the optimal plane to be chosen after the examination. This new generation of scanner works by allowing simultaneous acquisition of up to 16-submillimeter sections with gantry rotation times of less than 0.5 seconds. Currently, the technology is being used for visualization of plaqued coronary artery branches or coronary stents (Fig 6). This technique may become the preferred modality for cardiac imaging.16,17

With the continued development of new agents and instrumentation, nuclear medicine has its role in the analysis of heart disease.18 Nuclear cardiology is used for heart disease screening, prognosis evaluation, and myocardial viability.19 Patients with significant myocardial viability may benefit from revascularization rather than medical therapy.20 Those patients with predominantly scar tissue may require heart transplantation and are not candidates for revascularization.21 The most sensitive nuclear modalities for assessment of viability are thallium 201 and 18-fluorodeoxyglucose (FDG)–PET.20 FDG-PET identifies patients who will show improvement of left ventricle function, relief from heart failure symptoms, and improved long-term prognosis when revascularization is used. However, PET is not readily available; therefore, a less expensive nuclear imaging technology, single photon emission CT is often used for FDG imaging. PET and single photon emission CT have been shown to demonstrate good agreement.21 Cavitary tomoscintigraphy directly evaluates ejection fraction and volumes in both ventricles and will most likely replace traditional isotopic angiography.20

Catheter angiography is rarely indicated for ventricular assessment. However, this imaging technique does evaluate systolic function if noninvasive studies are inadequate.22 Radionuclide angiography provides quantitative measurement of the left ventricle ejection fraction and regional wall motion.1 Coronary arteriography is required if revascularization is contemplated for treatment. Arteriography determines the severity and extent of coronary artery disease. The most invasive procedure that may be indicated is the endomyocardial biopsy. It may determine the cause of cardiomyopathy.22

Clinical Laboratory

Laboratory evaluation is valuable in the diagnosis of heart failure. Patients already diagnosed with heart failure should undergo a thyroid panel to rule out hypothyroidism or hyperthyroidism as a cause. Severe anemia may also cause heart failure. More importantly, anemia should be ruled out because it worsens existing heart failure.1 Plasma atrial natriuretic peptide levels are elevated in response to increased intra-atrial pressure, and the failing ventricle will secrete brain natriuretic peptide (BNP).

B-type natriuretic peptide, brain natriuretic peptide, or BNP, is a cardiac neurohormone secreted in response to increased ventricular volume and pressure. This peptide is known to increase in proportion to the severity of heart failure. BNP levels correlate with the following: left ventricle end-diastolic pressure, pulmonary artery wedge pressure and atrial pressure, ventricular systolic and diastolic dysfunction, and left ventricle hypertrophy. This test is a fluorescent immunoassay that quantitatively measures BNP levels in whole blood or plasma specimens. Sensitivity ranges from 85% to 97% and specificity from 84% to 92%. The negative predictive value is greater than 95%; therefore, a normal BNP level can help to rule out heart failure. The range of values is from 0 to 3500 pg/mL, with the most accepted upper limit of normal at 100 pg/mL. Values higher than 100 pg/mL suggest a diagnosis of heart failure. Depending on the severity of heart failure, BNP values can be elevated 25 times higher than in normal individuals. Right ventricular dysfunction will also have elevated BNP values but not to the same extent as left ventricular dysfunction.23 Multiple applications of natriuretic peptide are reported, ranging from screening to monitoring treatment (Fig 7).

Treatment

Growth hormone is 1 therapy that helps maintain normal cardiac structure and function. Growth hormone deficiency reduces the growth rate of the heart muscle, impairs cardiac performance, and negatively impacts myocardial contractility. Studies have shown that administering growth
hormone may improve contractility, induce myocyte hypertrophy, and improve the metabolic efficiency of the heart. Other studies have disputed these results. The difference may be the result of acquired growth hormone resistance that occurs in heart failure patients, especially those with cardiac cachexia. After testing the patient for resistance, growth hormone may be a suitable treatment option for heart failure.24

Other pharmacological treatments include the use of ACEIs in conjunction with diuretics and digitalis. As previously discussed, the neurohormone blockers prevent progression of heart failure, whereas diuretics control the signs and symptoms of congestion.5 However, ACEIs act on the renin-angiotensin-aldosterone system but are less effective in the elderly and obese who carry low levels of renin. Calcium antagonists are more effective for patients with low levels of renin. Autonomic responses are pharmacological targets. α1-Adrenoceptor blockers decrease peripheral resistance and reduce afterload, helping to reduce left ventricle hypertrophy. β1-Adrenoceptor antagonists reduce heart rate and cardiac output that improves exercise tolerance and reduces the recurrence rate of myocardial infarctions.17 The future of drug therapy will likely focus on adrenergic β-blockers, angiotensin II receptor blockers, ACEIs, endothelin inhibitors, TNF-α blockers, and drugs designed to increase plasma concentrations of counterregulatory atrial natriuretic peptides.15

New surgical techniques are on the horizon for heart failure treatment. Dr Randas J. Batista introduced surgical ventriculoplasty, where segments of still viable but abnormally functioning myocardium of the left ventricle are resected. This procedure has been shown to increase the cardiac ejection fraction.4,24 Several hundred cases of end-stage dilated cardiomyopathy have been successfully treated with the Batista procedure.4 Alas, the only effective proven treatment to date for end-stage heart failure is heart transplantation.24 Heart transplantation has a long-term survival rate of 92.7%, 81.3%, 79.3%, 80%, and 23% at 30 days, 1 year, 4 years, 10 years, and 19 years, respectively.25-28

Based on information from Ref. [7].

**Fig 7. Uses of natriuretic peptides.**

Nonpharmacological therapies are also disease modifying and could be administered by chiropractic physicians in conjunction and as a complement to drugs and surgery in patients with CHF. A comprehensive holistic approach is patient-centered and beneficial. The congestive failure patient should be coached on dietary changes. The renal response to reduced cardiac output is the retention of sodium; therefore, sodium intake should be restricted to 3 g/dL. This level of sodium restriction can be obtained by reducing foods with high sodium content, such as canned foods and packaged luncheon meats. For severe volume overload, sodium intake should be reduced to less than 2 g to improve the effectiveness of diuretics. The patient should be advised of the potential harm in using salt substitutes high in potassium while using drugs that elevate potassium levels such as potassium-sparing diuretics, ACEIs, or renal insufficiency. Another necessary dietary change is to limit fluid intake in sodium-restricted patients. Fluid should be limited to less than 2 L/d in hyponatremic patients and those with severe volume overload.29

The patient’s lifestyle must also be monitored. Alcohol is a cardiotoxin; its consumption is ill-advised. Alcohol should also be discouraged because of its myocardial depressant effect. Weight control is also necessary. The cardiac workload is increased in obesity even in the absence of hypertension. Nearly half of obese patients with sudden cardiac death have severe dilated cardiomyopathy. Clinicians should moderately restrict caloric intake and encourage exercise training to ensure a gradual weight loss.29 Not only can an exercise regimen help with weight control, it can also have positive effects on cardiac functional capacity by improving endothelial function. However, the cardiac improvement is only maintained with a continuous exercise program, and all values are lost after 3 weeks of inactivity. Previous studies have shown that exercise decreases mortality by 25% (at a 3-year follow-up), increases the return-to-work rate, and may reduce patient cost due to reduced hospitalization.30 Lastly, nearly half of patients with heart failure die of ischemic events; thus, lifestyle changes to
reduce coronary artery disease are essential. For example, adjust fat intake to control lipid levels and recommend cessation programs for smokers.  

Supplements may also be helpful for heart failure. Thiamine is often deficient in patients on high doses of diuretics. Coenzyme Q is important in mitochondrial energy transfer and has been shown to reduce hospitalizations in the heart failure patient. Vitamin E (400-800 IU) and purple grape juice are antioxidants which may reduce lipid peroxidation that leads to atherosclerosis. Vitamin C potentiates the antioxidant effect of vitamin E. Magnesium may be needed in those on diuretics that induce magnesium loss. A recent study revealed that Crataegus extract WS 1442 may be a safe and effective alternative to the conventional treatment of mild heart failure (NYHA class II). This extract is made from hawthorn leaves with flowers standardized to a constant content of oligomeric procyanidines. The pharmacological outcome is to produce a positive inotropic effect on the left ventricular muscle of terminally failing hearts, also acting as an antioxidant and demonstrating damage-preventing properties. The cardiac muscle underwent increased force of contraction with Crataegus allowing for improvements in physical exercise tolerance.

Acupuncture may help to improve the prognosis of advanced heart failure patients. In heart failure, the sympathetic nerve activity of muscle is increased. There is an indirect relationship between the amount of sympathetic nerve activity and prognosis with higher activation resulting in the worst prognosis. Acupuncture has been found to create a sympathomodulatory effect with greater effects being found in diseased subjects compared with healthy subjects. The mechanism of this response is presumed to result from endogenous opioids in the central nervous system. Myocardial ischemia can be reduced in as little as 30 minutes after electroacupuncture.

Spinal manipulation, in addition to its somatic benefits, may favorably modulate the autonomic and neuroendocrine imbalance of CHF and improve stress coping in this chronic illness. Validation of its role awaits scientific scrutiny.

**CONCLUSION**

Comprehensive care, differential diagnosis, and continuity of care are important aspects of primary care. These principles are emphasized in the chiropractic clinical curricula and delivered through chiropractic patient management. This case report also typifies the application of primary care principles in a chiropractic teaching clinic. Holistic care delivered with compassion but guided by rigorous science is in the best interest of the patient. A clinical trial using a multidisciplinary team could further clarify the role of complementary and alternative care in the diagnosis and treatment of CHF. It is our hope that this report stimulates research in this critically important area of patient care.

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A large body of credible clinical evidence more than adequately vindicates the use of spinal manipulation in the treatment of a range of musculoskeletal disorders. Furthermore, even in the absence of a robust physiological explanation, health professionals of whatever ilk can generally accept that a prudently applied force might alter the behavior of a joint and thereby provide at least some relief of musculoskeletal symptoms.

On the other hand, the use of spinal manipulation in the management of patients with visceral disorders is a highly politicized and emotive issue. Although it appears that many chiropractic practitioners are comfortable with the concept of using spinal manipulation to address a subset of visceral disorders, there is also recognition that care of non-musculoskeletal complaints may alienate other health professions and threaten the credibility of the chiropractic profession in the public eye.

With the growing influence of evidence-based care, it is expected that questions concerning the appropriate matching of clinical techniques and patient cohorts would be illuminated increasingly by reference to scientific evidence. Unfortunately, few original data articles address nonmusculoskeletal responses to chiropractic care.

A fairly recent and comprehensive survey of original data articles has reported papers describing the use of spinal manipulation in the treatment of only 39 visceral disorders. In 27 of 39 instances, the use of spinal manipulative therapy to treat a particular visceral disorder was supported by a single paper. Fifteen of these 27 papers referred to a single patient. Hence, for 15 of 39 disorders cited in the literature, the use of spinal manipulation was supported by experience with a single patient. The majority of articles were in support of only 6 complaints: 8 papers concerned visual deficits, 6 papers referred to chronic pelvic pain and dysmenorrhea, and 4 different papers focused on asthma, enuresis, and premenstrual syndrome. Particular authors or groups of authors dominated certain topics, suggesting that the numerical distribution of papers according to disease reflected the interests of the authors rather than the prevalence of the conditions or their importance in chiropractic practice.

Currently, very little primary data are available concerning clinical outcomes, and such studies that do exist are generally of a poor quality. At this point, it would be difficult to advocate based on evidence alone, anything beyond the experimental use of spinal manipulation in the treatment of perhaps 1 or 2 nonmusculoskeletal complaints.

The paper by Leboeuf-Yde et al in this issue of the JMPT (June 2005) draws attention to a serious and additional concern about the integrity of our body of knowledge concerning nonmusculoskeletal responses to spinal manipulation. Are clinical trials justifiable at this time, given our very limited epidemiological data?

Whereas chiropractic management of nonmusculoskeletal disorders may have been an important component of chiropractic practice in our past, it is a trivial portion of modern practice. It represents no more than a few percent of new patient presentations, without addressing whether the practitioner chooses to take on a given case and is able to achieve useful results. We have scarce information about which complaints patients actually seek care for and which complaints appear to respond in the real-world setting.

In the absence of epidemiological studies indicating what conditions chiropractors treat, regardless of reported outcomes, it is reasonable to question whether it is currently rational and economically justifiable to conduct...
clinical trials. The results of Leboeuf-Yde et al are not consistent with an earlier literature review, which would seem to have suggested a more likely role for chiropractic in the management of visual and gynecologic complaints, or even asthma. Instead, Leboeuf-Yde’s analysis, based on a sample of almost 6000 patient questionnaires, suggests that digestive and general respiratory difficulties might provide more fertile ground for investigation. On this point, however, the authors take pains to point out that their study indicates associations between treatment and changes in symptoms. Notwithstanding the term “nonmusculoskeletal responses,” this study was not designed to determine, nor is there any implication of, cause and effect.

On this basis, certain past and ongoing high-profile investigations may provide clinical answers for which there were no real-world clinical questions. If, instead of investing limited research funds in politically attractive clinical trials, we had instead funded less emotive groundwork epidemiology, we might be further ahead. It is probably fair to describe the current approach to investigating chiropractic management of visceral disorders as “backward.” This applies not just to clinical studies, but also to the neglect of basic physiological investigations.

Although it may seem expedient to fund research that proves chiropractic “works” for this or that clinical entity, we need to outgrow our folk medicine mentality and start to ask how and why chiropractic works, and when it does. Would it harm chiropractic to make a few contributions to the common body of knowledge of all of the health sciences? In addition, would it harm chiropractic to ask honest questions about what we do not know, instead of trying to prove what we think we know? Is not the chiropractic management of patients with visceral disorders important enough to approach with honesty?

Congratulations to Leboeuf-Yde et al for a very unsexy paper, which provides a basis on which to propose future clinical studies with intelligence and integrity.

REFERENCES

Chiropractic Antivaccination Arguments

Jason W. Busse, DC, MSc,a Lon Morgan, DC,b and James B. Campbell, PhDc

From its inception in the late 19th century, the chiropractic profession has seen itself as offering distinct services from allopathic medicine.1,2 Chiropractic’s unique approach necessitated justification, which was provided by the formulation by the founder, DD Palmer, of a novel theory of disease (or “dis-ease”) that centered on lesions of the nervous system (subluxations). The central tenet of early chiropractic theory was that most, if not all, disease was the result of such lesions.3 As a result, immunization, which is based on the concept that infectious disease processes arise from external challenge, was seen as unnecessary and any associated risks as unacceptable.1,4

The extent to which anti-immunization views perpetuate the modern-day chiropractic profession is uncertain. The official 2002 policy of the American Chiropractic Association regarding vaccination reads as follows:

Resolved, that the ACA recognize and advise the public that: Since the scientific community acknowledges that the use of vaccines is not without risk, the American Chiropractic Association supports each individual’s right to freedom of choice in his/her own health care based on an informed awareness of the benefits and possible adverse effects of vaccination.

The ACA is supportive of a conscience clause or waiver in compulsory vaccination laws thereby maintaining an individual’s right to freedom of choice in health care matters and providing an alternative/elective course of action regarding vaccination. (http://www.acatoday.com/pdf/2002_aca_policies.pdf)

The policy of the International Chiropractic Association is practically identical. By such noncommittal statements, both associations have distanced themselves from any official recognition of vaccination as an effective public health procedure. Although neither formally rejects vaccination, each emphasizes the risk aspect. The official policy statement of the Canadian Chiropractic Association is supportive of vaccination, stating, “The CCA accepts vaccination as a cost-effective and clinically efficient public health preventive procedure for certain viral and microbial diseases, as demonstrated by the scientific community” (Policy Manual; Motion 2139/93).

One might presume, therefore, that the Canadian chiropractic profession maintains a similar perspective on vaccination. Nevertheless, a recent survey of 621 students (75.2% response rate) attending the Canadian Memorial Chiropractic College (CMCC), the only English-language chiropractic college in Canada, found that approximately 29% of students graduated in the year 2000 with antivaccination attitudes, 40% being supportive of vaccination, with 31% unsure.5 Further, a 2002 survey of Alberta (Canada) chiropractors, many of whom will have graduated from CMCC, found that 27.2% advised patients against vaccinating themselves or their children.6

The antivaccination stance of some chiropractic organizations, and the writings and other activities of certain chiropractors,7-13 have placed the profession as a whole under scrutiny.5,6,14-22 It is therefore appropriate to consider whether or not there is any justification for such a stance. Although most public health authorities would agree that vaccination constitutes one of the most cost-effective infectious disease control measures of the last century, few, if any, would argue that there are no problems associated with their use.23 Concerns about vaccine safety and efficacy are valid issues which continue to be addressed by public health experts in many countries. Nevertheless, in evaluating these concerns within the context of a vaccination program, it is essential that the risks and benefits be given the appropriate weight. Whether or not the curricula of most chiropractic colleges provide the necessary instruction to permit their graduates to provide this is questionable. In Ontario, the chiropractic profession is regulated under the Regulated Health Professions Act (1991) and the Chiropractic Act of 1991. With regard to vaccination issues, the Ontario Chiropractic College recently approved a standard of practice requiring its members to refrain from discussing these issues with their patients and the general public, on the basis that immunization/vaccination is

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outside their scope of practice. Contravention of this ruling may result in fines or even imprisonment (http://www.cco.on.ca/standard_of_practice_s-015.htm).

It is certainly the case that most chiropractic writings on vaccination focus almost exclusively on the negative aspects, either ignoring the huge amount of evidence supporting the benefits of vaccination or summarily dismissing this as “bad science” or government/industrial propaganda.\(^\text{17}\) Such an approach, however, is akin to describing the airline industry entirely on the basis of flight delays, lost luggage, and air crashes.

In this article, we offer a critical appraisal of published statements and consider some of the more common anti-vaccination arguments in chiropractic and associated writings. We have also provided a brief discussion on historical chiropractic philosophy in an attempt to explore why certain chiropractors continue to promulgate such arguments.

**DISCUSSION**

**Antivaccination Arguments**

In almost all cases, antivaccination writings by chiropractors have appeared in non–peer-reviewed magazines or newspapers, or in paid advertisements.\(^\text{17}\) Consequently, most of these writings have not been subjected to the critical editorial process undergone by peer-reviewed articles in reputable journals. Few appear in any of the major medico-scientific databases. Our main sources, therefore, have been chiropractic trade journals, web sites, and local newspapers. We have elected to focus on a Letter to the Editor of the *Burlington Post* (Ontario, Canada) (May 12, 1999), written by a chiropractor and clearly advocating against immunization programs. The following are excerpts from this single letter, but we feel they illustrate claims that commonly recur in antivaccination chiropractic writings.

**Statement 1.** “Catherine Diodati, Ontario’s own vaccine researcher, has just completed a study on the biomedical ethics of vaccination…[she] feels vaccination has little to do with health care and everything to do with wealth care — and not yours or mine!”

Whether or not Diodati made these claims is not the major issue; however, the chiropractor writer is claiming that a noted public health expert is making a statement that would be a matter of grave concern to the general reader. But can Diodati be considered a noted public health expert? An examination of her background is instructive. Diodati holds a Master of Arts degree, University of Windsor, Ontario, Canada (1998), in which, according to a curriculum vitae posted on the Internet (http://www.freyurko.bizland.com/diodatcv.html), her primary areas of study were theology, theodicy, philosophy and ethics. The study referred to above is a privately published book entitled *Immunization. Health, Ethics, Law and Health*,\(^\text{24}\) based on her Master’s dissertation, which provides the statement that her interest in vaccines started after her child was (allegedly) vaccine injured. As far as we know, Diodati is not affiliated with any academic or private research institution involved in vaccine research. A MEDLINE search revealed only 1 publication by her, in 2002. She is the coauthor of a short article in *Medical Hypotheses* which suggests that vaccinating postpartum women with measles, mumps, and rubella (MMR) vaccine may cause autism in their children through breastfeeding.\(^\text{25}\) Although this might be a valid subject for a hypothesis, the premise is seriously compromised by having its basis in the responses of 62 self-selected women who completed a questionnaire posted on the Internet, the results of which were not published in any peer-reviewed journal. A recent systematic review has rigorously examined this topic and found no association between autistic spectrum disorder and the MMR vaccine.\(^\text{26}\) In reality, it seems that, contrary to being “Ontario’s own vaccine researcher,” Ms Diodati has attained expert status only in the eyes of certain lay organizations and others such as chiropractors and chiropractic organizations that invite her to speak on the dangers of immunization.

**Statement 2.** “proponents of vaccination, feel it is vaccination programs which have caused a decrease in the number of communicable diseases seen. This view is old and outdated. Current scientific research indicates that these diseases were beginning to decline long before the advent of vaccination. The reason for their decline is based on new sanitation protocols, cleanliness, better diet and nutrition, etc, not vaccination.”

Indeed, certain chiropractors have published articles that seemingly present evidence to substantiate the view that “diseases were beginning to decline long before the advent of vaccination.” An example of this is found in an article by Lanfranchi\(^\text{27}\) in the *ICA International Review of Chiropractic*. In it, he provides a figure giving evidence for this argument, and he even goes as far as to suggest that “mathematical modeling suggests recrudescence (sic) of measles in 1990-2010.” He claims to have obtained the data to plot the graph, starting from 1850, from the US Government’s Centers for Disease Control and Prevention (CDC, Atlanta, Ga) which, in reality, has such statistical data only from 1940 onward (personal communication; July 19, 2001). The most recent published findings by the CDC\(^\text{28}\) reported “no endemic measles virus is circulating in the United States,” and emphasized that, “…maintaining immunity through high vaccination coverage levels is essential to limit the spread of measles from imported cases.”

When Lanfranchi\(^\text{27}\) was contacted for clarification of this matter (RG Lanfranchi, written communication; Sept 7, 2001), he admitted that the statistics for the graph were not actually obtained from the CDC but were from a lecture
presented at the “New York Chiropractic College back in the early 1990’s.” Attempts to contact the purported author of this lecture were unsuccessful. The conclusion is that Lanfranchi may have misrepresented the source of this data in his article, and that the validity of the data is uncertain.

The statement that communicable diseases were on the decline long before the advent of vaccines is an example of selective information. There is little doubt that advances in medical treatments and increased standards of hygiene and nutrition have contributed greatly to the control of communicable diseases. Diseases, such as measles, are more severe in malnourished individuals. Improved sanitation has been a major factor in the control of cholera and other infectious agents that make use of a fecal-oral route of transmission. Antibiotics have greatly reduced the high rates of morbidity and mortality previously associated with many enteric and respiratory bacterial infections. Nevertheless, this is only part of the story, as the following examples show. Although improvements in sanitation during the first half of the 20th century reduced the number of polioviral infections, these actually contributed to the increased incidence of paralytic poliomyelitis. Improved sanitation resulted in later first exposures to the virus, with a corresponding increase in pathogenicity. However, the almost complete global eradication of wild poliovirus, even from countries with primitive sanitation and poor nutritional standards, can only be attributed to the massive vaccination campaigns. Invasive disease due to Haemophilus influenzae (ie, meningitis) was prevalent until the early 1990s when an H influenzae (type b) vaccine (Hib) was developed. Before vaccine licensure, an average of 20 000 cases occurred each year in the United States; in 2000, there were only 55 cases. It may be unreasonable to presume that this dramatic change was due, for example, to improvements in sanitation and diet since 1990.

Statement 3. “One of the great concerns is there has been a drastic increase in the numbers of autoimmune diseases seen: everything from diabetes to asthma, autism, Crohn’s disease, AIDS, cancer, etc. Many in the scientific community are convinced vaccination is to blame. A vast number of research studies have been done to prove this point.”

It is, of course, easy to make sweeping, unsubstantiated claims such as in the last 2 sentences. But are there really “vast numbers of studies” that prove this point? We can cite a few that provide questionable, although avidly quoted, support for them. An example is contained in a front-page headline in Dynamic Chiropractic (March 20, 2000) which read: “Do DPT and Tetanus Vaccinations Cause Asthma? New Study Shows Vaccinated Children Twice as Likely to Get Asthma and Other Allergy-Related Symptoms.”

This statement referred to a study reported in the Journal of Manipulative and Physiological Therapeutics which compared 13 328 infants, children, and adolescents who reported being vaccinated with diphtheria-pertussis-tetanus (DPT) or tetanus to 284 who reported not being vaccinated. Within these respective groups, 5843 of 13 328 had shot records documenting their positive DPT or tetanus vaccination status and only 22 of 284 had records available to attest to their nonvaccination status. Studies that use small groups, however, carry a substantial risk of false-positive or false-negative results. This can be illustrated by presenting the data with a point estimate of the effect, such as an odds ratio, and a measure of precision, such as a confidence interval (CI). In the Hurwitz and Morgenstern study, the adjusted odds ratio of asthma among the vaccinated subjects was reported as 2.00 (vaccinated subjects twice as likely to have asthma vs unvaccinated) with a 95% CI of 0.59 (a reduction of 41%) to 6.74 (an increase of 574%). Consequently, although the odds ratio is 2, the results rule out neither a substantial decrease in the risk of asthma nor a substantial increase in the risk of asthma for vaccinated subjects because the CI crosses over “1.” The Dynamic Chiropractic headline claim, therefore, cannot be justified.

No vaccine is 100% safe or 100% effective, and this is true of any health care intervention. However, opponents of vaccination frequently emphasize or exaggerate the adverse effects of vaccines, but fail to consider the consequences of compromised vaccination programs. Furthermore, although it is true that a number of published studies have implicated vaccines in certain disorders, these have generally not held up under investigative scrutiny. For example, an oft-quoted 1998 study of 12 children by Wakefield et al suggested a link between MMR vaccination and the development of autism. What antivaccinationists may fail to note is that larger trials have failed to confirm these findings, and that “serious allegations of research misconduct” have been made with regard to the Wakefield article. Indeed, 10 of Wakefield’s 11 coauthors published an official retraction. There are numerous studies that have found no association between vaccines and asthma, diabetes, cancer, autism, AIDS, epilepsy, Crohn’s disease, etc.

Statement 4. “In light of this, many experts, among them Dr. Viera [sic] Schreiber [sic], probably the single most recognized vaccine expert, now view the current vaccination program as human experimentation, which has been outlawed by the Helsinki Accord at the end of the Second World War.”

Again, one might question the qualifications, and numbers, of the “many experts” the writer claims to hold these extreme views. And is there any justification for the statement that Scheibner is “probably the single most recognized vaccine expert”? For more than a decade, she has been an outspoken antivaccination activist and is the author of the book Vaccination: 100 Years of Orthodox Research Shows that Vaccines Represent a Medical Assault


Statement 3. “One of the great concerns is there has been a drastic increase in the numbers of autoimmune diseases seen: everything from diabetes to asthma, autism, Crohn’s disease, AIDS, cancer, etc. Many in the scientific community are convinced vaccination is to blame. A vast number of research studies have been done to prove this point.”

It is, of course, easy to make sweeping, unsubstantiated claims such as in the last 2 sentences. But are there really “vast numbers of studies” that prove this point? We can cite a few that provide questionable, although avidly quoted, support for them. An example is contained in a front-page headline in Dynamic Chiropractic (March 20, 2000) which read: “Do DPT and Tetanus Vaccinations Cause Asthma? New Study Shows Vaccinated Children Twice as Likely to Get Asthma and Other Allergy-Related Symptoms.”

This statement referred to a study reported in the Journal of Manipulative and Physiological Therapeutics which compared 13 328 infants, children, and adolescents who reported being vaccinated with diphtheria-pertussis-tetanus (DPT) or tetanus to 284 who reported not being vaccinated. Within these respective groups, 5843 of 13 328 had shot records documenting their positive DPT or tetanus vaccination status and only 22 of 284 had records available to attest to their nonvaccination status. Studies that use small groups, however, carry a substantial risk of false-positive or false-negative results. This can be illustrated by presenting the data with a point estimate of the effect, such as an odds ratio, and a measure of precision, such as a confidence interval (CI). In the Hurwitz and Morgenstern study, the adjusted odds ratio of asthma among the vaccinated subjects was reported as 2.00 (vaccinated subjects twice as likely to have asthma vs unvaccinated) with a 95% CI of 0.59 (a reduction of 41%) to 6.74 (an increase of 574%). Consequently, although the odds ratio is 2, the results rule out neither a substantial decrease in the risk of asthma nor a substantial increase in the risk of asthma for vaccinated subjects because the CI crosses over “1.” The Dynamic Chiropractic headline claim, therefore, cannot be justified.

No vaccine is 100% safe or 100% effective, and this is true of any health care intervention. However, opponents of vaccination frequently emphasize or exaggerate the adverse effects of vaccines, but fail to consider the consequences of compromised vaccination programs. Furthermore, although it is true that a number of published studies have implicated vaccines in certain disorders, these have generally not held up under investigative scrutiny. For example, an oft-quoted 1998 study of 12 children by Wakefield et al suggested a link between MMR vaccination and the development of autism. What antivaccinationists may fail to note is that larger trials have failed to confirm these findings, and that “serious allegations of research misconduct” have been made with regard to the Wakefield article. Indeed, 10 of Wakefield’s 11 coauthors published an official retraction. There are numerous studies that have found no association between vaccines and asthma, diabetes, cancer, autism, AIDS, epilepsy, Crohn’s disease, etc.

Statement 4. “In light of this, many experts, among them Dr. Viera [sic] Schreiber [sic], probably the single most recognized vaccine expert, now view the current vaccination program as human experimentation, which has been outlawed by the Helsinki Accord at the end of the Second World War.”

Again, one might question the qualifications, and numbers, of the “many experts” the writer claims to hold these extreme views. And is there any justification for the statement that Scheibner is “probably the single most recognized vaccine expert”? For more than a decade, she has been an outspoken antivaccination activist and is the author of the book Vaccination: 100 Years of Orthodox Research Shows that Vaccines Represent a Medical Assault
on the Immune System.\textsuperscript{59} Her extreme antivaccination bias is apparent by her claim in a number of articles to have,\textsuperscript{60,61} “…studied 60,000 pages of medical literature on vaccines and vaccinations” while finding “no evidence of [their] effectiveness or safety.”

As an antivaccination spokesperson, Scheibner’s published academic affiliation(s) are unclear, other than being a “retired Principal Research Scientist in Australia”\textsuperscript{60,61} with “90 papers in refereed scientific journals.”\textsuperscript{60} By her own admission, her formal training in health-related sciences has been limited to the study of human biology at university and a “year of medicine”.\textsuperscript{52} Indeed, her doctorate is not in health-related science. As Viera Scheibnerová she was a member of the Department of Geology, Comenius University, Bratislava, before moving to Australia and the Geological Survey of New South Wales. Her publications in scientific journals appear to be limited to geology/paleontology. A recent search of MEDLINE (1966-December 2004) came up negative for ‘Scheibnerová V’ and with 2 entries for ‘Scheibner V’ as the fourth of 5 authors of a study on the incidence of apnea in rats\textsuperscript{63} and as the author of an unedited letter\textsuperscript{62} responding to an article criticizing her position on vaccination.\textsuperscript{64} Her contribution to the animal study appears to be related to the use of Cotwatch, a breathing monitor developed by her (late) husband that provided the original stimulus for her interest in sudden infant death syndrome (SIDS) or cot death.\textsuperscript{65}

Scheibner’s work is commonly cited to support anti-vaccination arguments put forth by chiropractors. For example, one of us (LM) published what we consider to be a balanced (but nevertheless clearly provaccination) article on pertussis immunization\textsuperscript{65} in the Journal of the Canadian Chiropractic Association. Of 9 published letters responding to this article, 7 were strongly antagonistic. The following excerpts from 4 letters provide examples:

Dr. Morgan’s acknowledgement of the division in chiropractic on issues of immunization is quite correct. However, his implication that those who oppose it [vaccination] lack scientific support for their logic is both arrogant and short-sighted. Does he think he is the only chiropractor alive who takes the time to become informed on this controversial health issue? Dr. Vera \textsuperscript{sic} Scheibner PhD…has produced the most comprehensive scientific search on the subject. The basic conclusion of this search is that inoculations are dangerous and ineffective, moreover that proponents of vaccination often misrepresent the results of trials and tests. …\textsuperscript{66}

It is said that the worst enemy is the enemy from within. Dr Morgan has certainly spent a lot of time and effort in his research to reach his opinion supporting the pertussis vaccine and to criticize the chiropractic profession… Dr. Vera \textsuperscript{sic} Scheibner PhD, an independent researcher…observed a relationship between the DPT vaccine and conditions such as leukemia, diabetes, asthma and SIDS.\textsuperscript{67}

I can hardly believe that someone who has gone through the trouble of compiling information on this subject has managed to ignore or omit all the studies and papers showing that the pertussis vaccine is not safe. …He has failed to look at Dr. Vera \textsuperscript{sic} Scheibner’s substantial work on the subject.\textsuperscript{58}

I think I understand why the JCCA is always presenting an allopathic model of chiropractic, rather than the vitalistic model, but the inclusion of a pro-immunization article is going too far. …I suggest you commission Barbara Loe Fisher, Harris Coulter or Vera \textsuperscript{sic} Scheibner to present the other side of the immunization story.\textsuperscript{69}

Despite persistent references by antivaccination chiropractors to the “extensive work” of Scheibner, the authors are not aware whether she has published her antivaccination arguments formally in any mainstream peer-reviewed scientific or medical journal (apart from the unedited letter in Vaccine).\textsuperscript{62} It may be possible that many of her arguments do not hold up under scrutiny and, consequently, would not be acceptable for publication in any of these. For example, one of Scheibner’s claims is that pertussis vaccination of infants is a major cause of SIDS, and, as evidence, she cites the situation in Japan in 1975 after a shift in the age of pertussis (DPT) immunization from 3-5 months to 2 years.\textsuperscript{70} To quote from page 43 of her book,\textsuperscript{59} “When Japan moved the vaccination age to two years, the entity of cot death in that country disappeared [Cherry et al (1988)], while the amount of adverse reactions in 2-year-olds remained the same or increased.” The author continues on pages 62 to 63 that,\textsuperscript{59} “The seeming and widely perpetuated dilemma ‘is there or is there not a causal relationship between DPT injections and cot death’ has, quite adequately and indeed without a shadow of a doubt, been resolved by the Japanese experience with cot death.”

This, however, is not an accurate representation of the facts. Scheibner’s quotation of Cherry et al\textsuperscript{71} actually referred to data of Noble et al\textsuperscript{70} based on claims paid by the Japanese national vaccine compensation system. What happened was that, after the shift in minimum age of pertussis immunization to 2 years, no further claims were made through the national compensation system, which is a completely different issue from the incidence of cot deaths. Sudden infant death syndrome occurs primarily in babies between the ages of 2 and 4 months; consequently, with no DPT vaccinations being given at this age, there could\textsuperscript{72} be no Japanese claims for vaccine-related sudden deaths. Indeed, the incidence of SIDS in Japan has even been reported to have increased after this time,\textsuperscript{72} although a greater awareness of SIDS among Japanese pathologists and changes in reporting may have contributed to these elevated figures.

Scheibner also ignores the evidence against a causal relationship between DPT inoculations and SIDS and other temporally associated major adverse events discussed by Cherry et al.\textsuperscript{71} She states on page xv that,\textsuperscript{59} “There is no evidence whatsoever that vaccines of any kind—but especially those against childhood diseases—are effective in preventing the infectious diseases they are supposed to prevent.” However, she makes no mention that, after implementation of the later vaccination schedule, the incidence of pertussis in Japan increased dramatically.\textsuperscript{70,73} These are only some examples of her selective omissions of facts; however, Basser\textsuperscript{74} has conducted a detailed analysis of the accuracy of reporting in her book. One of his
conclusions is that Scheibner is74 “At best sloppy, and at worst blatantly dishonest.” He provides numerous examples to justify his analysis.74

There appears to be a relatively small number of chiropractic (and chiropractic-associated) authors who continue to disseminate antivaccination views.7,13,61 Their arguments may appear to be valid until supporting references and data are investigated further. One common occurrence, documented above, is the use of questionable sources as the basis for antivaccination arguments.

We hope that this article may stimulate some practitioners to examine critically the sources of their information. However, it may be unlikely that any measure of critical analysis will serve to sway many confirmed antivaccination chiropractors from their position, in that their views on immunization may not be based on evidence, or open to scientific scrutiny, but rather on the demands of their faith/belief system/philosophy.14,75,76 To quote Nelson75:

I long ago ceased being embarrassed by the excesses, idiosyncrasies and quirks of my colleagues. In fact I rather enjoyed collecting the most egregious examples of chiro-babble…. My sense of amusement [however]…has vanished primarily because of a growing awareness that: a) the number of chiropractors who are animated by 19th century pseudo-science seems to be growing rather than shrinking, and b) these chiropractors will abandon their philosophy when hell freezes over.

He also states,76 “If you peel away all the arguments about the safety and effectiveness of immunizations, you will find at the core of this debate, chiropractic philosophy.”

It is therefore informative to briefly review aspects of historical chiropractic philosophy as may relate to current views on vaccination.

### Chiropractic Philosophy

Chiropractic was founded by David D. Palmer and developed by his son Bartlett Joshua (BJ). The Palmers held that infectious disease was the result of spinal subluxations, and BJ in particular wrote extensively about how infectious diseases and other ailments (including cancers) can readily be cured by removal of the subluxation. For example, BJ wrote in 19091:

Chiropractors have found in every disease that is supposed to be contagious, a cause in the spine. In the spinal column we will find a subluxation that corresponds to every type of disease. If we had one hundred cases of small-pox, I can prove to you where, in one, you will find a subluxation and you will find the same condition in the other ninety-nine. I adjust one and return his functions to normal and you could do the same with the other ninety-nine.

Although sometimes referred to as “chiropractic philosophy,” the doctrines originally espoused by the Palmers and maintained by modern fundamentalist chiropractors cannot be considered to constitute a true philosophy in that they are not subject to change. It is more correct to categorize historical chiropractic philosophy as a belief system, in that any true philosophy should be dynamic and is accountable to a methodological pursuit of knowledge.

The historical belief system of chiropractic, as advocated by the Palmers, does not allow for the acceptance of vaccination. According to DD Palmer4:

It is the very height of absurdity to strive to ‘protect’ any person from smallpox or any other malady by inoculating them with a filthy animal poison…No one will ever pollute the blood of any member of my family unless he cares to walk over my dead body to perform such an operation.

Historical chiropractic belief systems provide a number of benefits, however, including simplistic answers to complex problems and provision of a “unique” service among health care providers resulting in decreased competition. Because fundamentalist practitioners do not “cure” or “treat” conditions aside from subluxations, which may or may not be symptomatic, treatment frequency and duration are entirely determined by the practitioner. Consequently, the result of adhering to a belief system of practice that can be applied rapidly, and administered to each and every presenting patient on an ongoing, and often frequent, basis, has obvious financial implications. This scenario may offer some insight as to why some chiropractors adopt historical belief systems that entail negative views toward vaccination. As written by a third-year chiropractic student at CMCC,77 “I feel that chiropractic in Canada needs to go more towards a philosophical subluxation approach or we may no longer exist as a separate health profession. There is too much competition for patients at the evidence-based end of things.”

### Conclusion

The chiropractic antivaccination position was established by DD Palmer by likening vaccines to “filthy animal poisons.”4 Palmer’s views resulted not from any objective analysis of scientific data, but from a rejection of anything he perceived to be associated with the medical profession of the day.17 His anti-immunization position was a narrowly dogmatic one that did not allow for scientific advancements or the introduction of new data. In the face of now overwhelming evidence to show that vaccination is an effective public health procedure, Palmer’s modern followers have turned to whatever sources they can to support chiropractic’s archaic anti-immunization position. However, our preliminary discussion suggests that current chiropractic anti-immunization arguments rely heavily on biased and selective misrepresentations, or omissions, of the scientific literature by a small group of authors whose credibility as authorities on vaccination remains questionable. Opposition to immunization by some in chiropractic may be purely “philosophical,” not scientific; nevertheless, this does not justify the dissemination of innuendo, half-truths, and false information to support this position.
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The Use of Survival Analysis for the Evaluation of Musculoskeletal Therapy

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Survival analysis is seldom used in studies of the effectiveness of musculoskeletal therapy. Most clinical studies of musculoskeletal therapy use parametric statistical methods such as analysis of variance (ANOVA) to illustrate the effects of treatment on outcomes. Nonparametric techniques of analysis such as survival analysis are less frequently used.

Survival analysis has a number of advantages that make a research design a better choice than ANOVA for clinical evaluation studies. Among these advantages are that survival analysis uses a patient-specific response as an output measure whereas ANOVA requires the valid generation of a group mean response. Comparison of the results of studies is clear and unambiguous with survival analysis, which produces a survival function that represents the effect of treatment over the entire course of the study. Comparison of the results of studies is difficult with ANOVA, which produces estimates of effectiveness at a few discrete points during the study. Survival analysis is “distribution free” and enables the direct analysis of highly skewed distributions that are commonly encountered in studies where patients respond as individuals to treatment and do not require data transformations to meet the underlying assumptions of parametric statistical methods such as ANOVA. Lastly, survival analysis incorporates a method of explicitly dealing with the problem of incomplete observations, which is not available in ANOVA.

Analysis of variance is used to study the mean values of 2 populations, often the distribution of some measure of response to treatment. Analysis of variance is termed a parametric method of analysis because it depends on the calculation of parameters of the distribution of measures of interest such as the mean and standard deviation. Analysis of variance is based on the mathematical concept of least squares. The least squares formulation requires that each incidence of the measure of response be subtracted from the mean value of all scores obtained from the population. The theorems underpinning the use of the least squares formulation assume that the distributions from which the measure of response is drawn are symmetric (in fact, normal), and that the measures selected of those measures is normal, and that the measures selected validly reflect the state or condition under study.

Because patients respond as individuals to clinical intervention, not all patients will achieve the same level of response at a given time after the initiation of treatment. Therefore, when using ANOVA, some estimate of group response must be constructed to enable changes in average patient response to be analyzed. The most commonly used measure of therapeutic effectiveness is the visual analogue scale (VAS). The VAS, combined with research designs using statistical methodology on the basis of the least squares formulation such as ANOVA and regression analysis where each VAS score is subtracted from the mean value of all scores as part of the analysis, presents immediate problems. An initial pain intensity score on the VAS of 100 for one individual and a VAS of 20 for a second individual may be elicited by the same experimental pain stimulus. Because the VAS is a measure of pain intensity specific to an individual, with possibly different meaning for each individual, the addition of 2 VAS scores, a requirement for the construction of a mean score, may not be valid. Survival analysis does not depend on the construction of a valid mean value of the subjects’ responses. This frees the analysis of the need for normality in the distribution of responses because the analysis is not dependent on knowing the mean response.

A second problem with musculoskeletal studies using the VAS and ANOVA is that comparison of the results of studies is problematic. It is not clear that a change in a mean VAS score of any specific magnitude in one study has any valid relationship to another study or clinical significance in itself. This is especially true when the length of the studies is different. Because the results of survival analysis are presented in the form of a survival function that represents the probability of achieving the event of interest at any point during the study, the results of one study are more easily compared to another. One simply compares the survival functions generated by both studies. Parameters of the resulting survival function, such as the time for 50% of the patients to reach a pain-free state, may be of assistance in comparison of the results as well.
Survival analysis is a powerful means of illustrating and analyzing the course of patient progress while undergoing therapy that is “distribution free.” That is, the distribution from which the measure of response is drawn is not assumed to be normal. In fact, no assumption regarding the distribution need be made. This enables highly skewed distributions such as those associated with time-to-event data to be directly analyzed without the use of data transformations to normalize the data before analysis, as would be required with ANOVA. Time-to-event data are normally highly skewed, with most responses occurring in the initial stages of the study, and with a long tail to the right of the interval containing most responses. The results of survival analysis comprise an estimate of the probability of occurrence of an event of interest (eg, the relief of pain in musculoskeletal studies) in the study population as the course of treatment proceeds. Simultaneous analysis of 2 or more treatment protocols is used to analyze and illustrate differences in treatment effect.

Although not frequently used in musculoskeletal studies, survival analysis has seen extensive use in almost all other areas of medical research. Examples of the use of survival analysis include time to the discontinuation of the use of an intrauterine device, prognosis for women with breast cancer, survival of patients with multiple myeloma, comparison of 2 treatments for prostate cancer, remission duration for acute leukemia, time to infection of patients with kidney dialysis, time to infection for patients with burn, time to first use of marijuana, and so on. In all of these examples, the research question is formulated as a “time to an event.” That is, the question of interest is, “How long does it take to achieve the desired result?” An intuitive way of posing the research question in musculoskeletal research is, “How long does it take for the patient to get better?” or “Do patients get better faster under treatment A or under treatment B?” Because survival analysis was invented specifically to deal with time-to-event problems, it is not clear why survival analysis has not found wider application in musculoskeletal research.

One possible reason might be that musculoskeletal therapies do not always achieve a clear end-point such as the pain-free state. Why this is so is not clear. Waddell characterizes low back pain as a benign and self-limiting condition characterized by recovery in approximately 6 weeks independent of the administration or type of treatment. That is, most individuals with the condition do not seek treatment, and of those that do, most (80%-90%) recover in approximately 6 weeks. If the results obtained in clinical trials of musculoskeletal therapy do not achieve clear-cut end points, it may be that the output measure is flawed, the research design is inadequate, the method of therapeutic intervention is not effective or actually interferes with the natural course of recovery, or the trial is simply not continued for sufficient time to allow the participants to achieve pain resolution.

No single statistical methodology will be appropriate for all formulations of all research questions relating to the evaluation of musculoskeletal therapy, but when the research design is formulated as a time to a specific event such as the time to resolution of pain under a particular mode of musculoskeletal therapy, then the researcher should consider survival analysis. Selection of one method of analysis for a study does not exclude the use of other analyses where appropriate. For example, the use of survival analysis using the no-pain end of a pain relief scale does not preclude using regression analysis or ANOVA using the graded response provided by pain relief scores to examine other aspects of the study that are important to the researcher such as the variation of patient response with age, sex, body mass index, or other covariates.

Survival analysis may be used to directly examine the effect of covariates such as age, sex, and the like, by grouping. For example, separate analyses may be conducted to compare the response to treatment of males vs females or the influence of age by binning or grouping. However, these techniques can quickly become cumbersome and the field of survival analysis has developed its own approach to the analysis of both variates and factors that may affect the outcome of survival times. This approach is referred to as the proportional hazards model. Originally proposed by Cox in 1972, it is also known as the Cox regression model.

One factor that may explain the relative neglect of survival analysis in musculoskeletal research may be that researchers are simply not familiar with the technique. The first step in research design is to define the research question to be examined by the study. After that initial crucial step, the measures that will best describe the independent and dependent variables are chosen. The final step is choosing the method or methods of analysis that enable the researcher to most clearly reject the research hypotheses posed by the study. The development of a final research design is complex and interactive, initial decisions being revised as the design progresses. The overall process is influenced by the researcher’s knowledge of and familiarity with specific methods of analysis. If the researcher is not aware of a specific methodology of analysis, then making an informed choice of analysis technique is not possible. This paper proposes that research designs for the evaluation of musculoskeletal therapy using a time-to-event model in which the event is defined as the resolution of pain (the pain-free state) are not only possible but also productive and addresses the issue of informed choice by introducing researchers and potential researchers to the methodology of survival analysis.

**DISCUSSION**

**Calculation of Survival Analysis**

In addressing the problem of evaluating the effectiveness of multiple impulse therapy, the basic question is, “How long
does it take for the patient to get better?" We have defined “get better” as the time at which the patient reports that she or he has reached the pain-free state. The analysis used to answer this question is referred to as a product limit estimate, survival analysis, or Kaplan-Meier survival analysis. This procedure is referred to as a survival analysis because a common early use was the determination of how long it takes for someone to die. That is, given a population of individuals, what is the frequency of occurrence of the event (in this case, death) in the population as a function of time? Now, the “frequency of occurrence” of an event sounds suspiciously like a probability. In fact, the concept of probability defined as the probability of an event (an event is defined as any set of outcomes of interest) is the relative frequency of the event over an indefinitely large (or infinite) number of trials.

Because there would never be enough time and/or money to conduct indefinitely large trials, probability analyses are termed probability estimates. It is assumed that the larger the trial, the closer the results of the analysis will be to the true frequency of occurrence of the event in the population under study. Survival analysis is indeed a form of probability analysis, and the key to understanding these types of analyses lies in the concept of conditional probability.

Because the progress of each of the patients in the study is followed, after some number of visits, which are associated with the number of days since treatment was initiated, some patients have reached the state of no pain, which is the event of interest of our study. At the start of the study, all patients were in pain. Therefore, the probability that the patients were in pain at the start of the study was equal to 1 and was calculated as the number of patients in pain divided by the number of patients in the study. This proportion is the unconditional probability of the patients having pain at the start of the study. As the study progressed, some patients reached the pain-free state. When the first patient reached the pain-free state, the number of patients in pain has changed compared to the number of patients in pain at the beginning of the study. The effect of this change can be represented as the difference between the initial proportion of patients in pain and the proportion of patients that have reached the pain-free state. This difference can be represented as

\[ \frac{n_0 - 1}{n_0} \]  

where \( n_0 \) equals the number of patients in pain at the beginning of the study and 1 is the number of patients that reached the pain-free state. The proportion \( 1/n_0 \) represents the change in the initial proportion of patients in pain at the beginning of the study caused by the fact that one patient has reached the pain-free state.

This modified proportion is referred to as the conditional probability of the patients remaining in the study having pain, that is, the probability that a patient will be in pain given the fact that one patient has recovered from pain.

The formula for calculating the probability of patients having pain as the study progresses over time may be generalized from Eq. (1). The ratio \( n_0/n_0 \), which represents the proportion of patients in pain at the beginning of the study (all patients are in pain at the beginning of the study), may be set to 1 and does not change as the study progresses. The proportion \( 1/n_0 \) may be modified to represent the effect of additional patients reaching the pain-free state by setting 1 in the proportion to the variable \( e_i \), where \( e_i \) is the number of patients who have attained the pain-free state (ie, the number of events of interest when the patients’ progress is observed) between the time \( t_{i-1} \) and \( t_i \) when the conditional probability is calculated. Using statistical notation to represent the conditional probability at time \( t_i \) yields the relationship in the following equation:

\[ Pr[ \text{pain at } t_i | \text{pain at } t_{i-1}] = 1 - e_i/(n_{i-1}) \]  

where \( Pr[\text{pain at } t_i | \text{pain at } t_{i-1}] \) equals the conditional probability of a patient having pain at time \( t_i \) given the probability of a patient having pain at the prior sample time \( t_{i-1} \); \( e_i \) is the number of patients that reached a pain-free state between the \( t_{i-1} \) and \( t_i \); \( n_{i-1} \) equals the number of patients still in pain at time \( t_{i-1} \).

Being able to compute the conditional probability of getting to the pain-free state at each point in time is relatively straightforward but is only the first step. Of greater interest is the unconditional probability of attaining the pain-free state after some treatment time. That is, what is the probability of a patient being in pain after 7 days of treatment using multiple impulse therapy? To compute this probability, we first need to review the relationship between conditional and unconditional probability.

One of the major assumptions of simple survival analysis procedures such as the one described here is that the events of interest are independent. That is, the occurrence of one event does not influence the occurrence of a second event of the same type. This means that if one patient reaches the pain-free state, that patient has no effect on other patients’ achievement of the pain-free state. One could postulate that patients might be influenced by the progress of other patients if, for instance, a chart of each patient’s progress was posted in view of all patients and patient progress became a competition. Although this may indeed be a good idea, it would complicate the analysis (and confound researchers). However, no such coupling of patient progress is normally allowed, and the assumption of independence is assumed to be valid. Under the assumption of independence, the relationship between unconditional and conditional probability is represented in the following equation:

\[ Pr(B) = Pr(B|A) \times Pr(A) + Pr(B|A) \times Pr(A) \]  

where \( Pr(B) \) is the unconditional probability of the event B, \( Pr(B|A) \) is the conditional probability of event B given that event A has occurred, \( Pr(A) \) is the unconditional probability.
of the event A, \( \Pr(B|A) \) is the conditional probability of event B given that event A has not occurred, and \( \Pr(A) \) is the unconditional probability of A not occurring.

Now, our interest is in determining the unconditional probability of a patient being in pain at time \( t_i \), and we already know the conditional probability of the patient being in pain at time \( t_i \). Eq. (3) may be used to express this relationship as the following equation:

\[
\Pr[\text{pain at } t_i] = \Pr[\text{pain at } t_i | \text{pain at } t_{i-1}] \\
\times \Pr[\text{pain at } t_{i-1}] \\
+ \Pr[\text{pain at } t_i | \text{no pain at } t_{i-1}] \\
\times \Pr[\text{no pain at } t_{i-1}] 
\]

(4)

where \( \Pr[\text{pain at } t_i] \) is the unconditional probability of a patient being in pain at time \( t_i \), \( \Pr[\text{pain at } t_i | \text{pain at } t_{i-1}] \) is the conditional probability of a patient being in pain at \( t_i \) given that the patient was in pain at \( t_{i-1} \), \( \Pr[\text{pain at } t_{i-1}] \) is the unconditional probability that a patient will be in pain at \( t_{i-1} \), \( \Pr[\text{pain at } t_i | \text{no pain at } t_{i-1}] \) is the conditional probability of a patient being in pain at \( t_i \) given that the patient was not in pain at \( t_{i-1} \), and \( \Pr[\text{no pain at } t_{i-1}] \) is the unconditional probability of a patient being in pain at time \( t_{i-1} \).

Because the unconditional probability of a patient being in pain at time \( t_i \) given that the patient was not in pain at time \( t_{i-1} \) is equal to 0 (the patient is already out of pain and therefore no longer has any chance of being in pain), Eq. (4) reduces to the following equation:

\[
\Pr[\text{pain at } t_i] = \Pr[\text{pain at } t_i | \text{pain at } t_{i-1}] \\
\times \Pr[\text{pain at } t_{i-1}] 
\]

(5)

Now, we still cannot calculate the unconditional probability of the patient being in pain at time \( t_i \) because the unconditional probability of pain at time \( t_{i-1} \) is not known. However, we can express the unconditional probability of pain at time \( t_{i-1} \) in terms of the conditional probability at time \( t_{i-1} \) and the unconditional probability of pain at the previous time \( t_{i-2} \). This still does not allow us to solve the problem, because the unconditional probability at time \( t_{i-2} \) is not known. However, by continuing to express each unknown unconditional probability in terms of a conditional probability and the unconditional probability at the previous time, we eventually arrive at the start of the study. This process leaves only one unconditional probability in the calculation, that unconditional probability is the probability of the patients being in pain at the start of the study, which, unless we recruited pain-free patients, is equal to 1. The unconditional probability at time \( t_i \) may now be computed because we have expressed its calculation in terms of conditional probabilities at each previous time in the study and the unconditional probability at the start of the study.

Fig 1. Results of Kaplan-Meier survival analysis of patient response to physical therapy and “no treatment” replotted from van den Hoogen et al.

All of these values are known. The following equation describes this calculation:

\[
\Pr[\text{pain at } t_i] = \prod_{j=1}^{i} \left(1 - \left(e_j/n_j\right)\right) 
\]

(6)

where the symbol \( \prod \) represents the multiplication of all the conditional probabilities starting at \( t_i \) and continuing until the point in time at which the first patient reached the pain-free state (because the unconditional probability of pain at the beginning of the study is 1, its multiplication may be omitted).

Up until this point, we have assumed that all of the patients in the study were “well behaved” in the sense that all patients participated in the study until, at some point, each patient achieved a pain-free state. If this were the case, then the analysis described above is appropriate for the determination of the probability of pain at each point in the study. However, not all patients are well behaved. Some may decide to leave care because they move from the area, some may become discouraged with their progress and leave, some may become pain-free and leave without reporting that fact, and some may not respond to the treatment. How do we handle these pesky patients who perversely pollute our data?

Kaplan and Meier independently developed a methodology designed to address this issue. The authors of the 1958 paper23 titled “Nonparametric estimation from incomplete observations” that describes the Kaplan-Meier estimate and provides the answer to this question never met in person! Each author independently invented the analysis,
submitted a paper for publication to the same journal, and collaborated by mail to finalize the journal article! The importance of this methodology to investigators is suggested by the fact that it is number 2 on the list of most cited ever papers in mathematics, statistics, and computer science.24

The solution provided by the Kaplan-Meier analysis involves first classifying all of the patients in the study according to whether they are well behaved or not. In Kaplan-Meier terminology, those patients who are well behaved are classified as “uncensored,” and all other patients are classified as “censored.” Uncensored patients are handled exactly as described above; that is, the calculation of the conditional probability is exactly as described. When a censored patient leaves the study sample for any reason, the time at which they departed is noted and the calculation of the conditional probability is changed by removing that patient from the denominator of the proportion $e_j/n_j$. That is, $n_j$ is reduced by 1 whereas $e_j$ is unchanged, unless a patient simultaneously achieved the “pain-free” state.19

When comparing 2 methods of treatment, 2 separate survival analyses are computed. Visual comparison of the 2 results will reveal differences in the rate of patient response of the 2 methods as well as differences in their effectiveness.19 Statistical tests such as the log-rank or Wilcoxon are available to determine the likelihood that the observed results are due to chance. Both tests are variations of the $\chi^2$ statistic. The log-rank test emphasizes the differences between the 2 results observed later in the experiment, whereas the Wilcoxon emphasizes the differences early in the analysis.18

Fortunately for the researcher, the tedious manual calculations required for completion of a Kaplan-Meier analysis are now available in commercial statistical software. In addition to MedCalc25 used by Evans et al,15 Peltz and Klein26 have authored a comparison of 3 commercially available statistical software packages that all contain survival analysis capability.

### Examples of Survival Analysis in Musculoskeletal Research

The work of van den Hoogen et al27 provides an excellent example of Kaplan-Meier survival analysis applied to the study of patients who have nonspecific low back pain. All of the subjects in the study sought care from multiple clinics and multiple care providers (medical practitioners) in The Netherlands. The results of the study are shown in Fig 1. The upper curve represents the progress of those patients who were referred to physical therapy. The lower curve represents the progress of those patients who received no specific care other than analgesics and standard medical recommendations such as bed rest or limitations of activity. It is obvious that those patients who were not referred to physical therapy fared better than those who were referred to physical therapy. van den Hoogen et al speculate that those patients referred to physical therapy may have had a more serious back pain than those patients who received no special treatment. Another possible explanation might be that the natural recovery process was interfered with by physical therapy. In any case, the

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1 Fig 2. Results of Kaplan-Meier survival analysis of patient response to multiple impulse therapy. MIT, Multiple impulse therapy.

2 Fig 3. A sample comparison of Kaplan-Meier survival analysis results.
difference in the response of the 2 patient groups is clear. Methods for testing the likelihood that the observed differences are due to chance, such as the log-rank test, are available. A second example of survival analysis may be found in a study of the effectiveness of multiple impulse therapy for nonspecific low back pain. The results of this study are presented in Fig 2. The 2 sets of experimental points represent the estimate of the upper and lower bounds of the results. The bounds resulted from the method of measuring the output variable. Each patient was asked to score his or her pain relief at the beginning of each visit. A patient who reached the no-pain state at the beginning of the visit did so somewhere between the last visit and the current visit. The upper and lower bounds represent the spread between the visit, at which the no-pain score was achieved, and the previous visit.

Can the results of these 2 studies be compared using survival analysis? The results of both studies have been cast into what we will refer to as probability space and therefore share the same dimensions: the probability that a patient will be in pain and time. The result of such a comparison is shown in Fig 3. Qualifications of the comparison include that the patients in both studies are similar on important dimensions such as patient complaint, distribution of patient characteristics, which apply to the comparison of results obtained with any method of analysis.

Comparison of different methods and techniques of musculoskeletal therapy in the manner illustrated in Fig 3 is unlikely to result in clinicians ceasing to refer patients to physical therapists or physical therapists adopting other techniques of therapy. The comparison of these 2 studies, although provocative in that it would appear from the comparison that both multiple impulse and osteopathic therapy are more effective than physical therapy, is not definitive.

However, if these results are supported by well-designed clinical trials, such comparisons may result in a reevaluation of and/or development of more effective therapeutic techniques. The results of all published studies of musculoskeletal therapeutic techniques are formally and informally compared by clinicians, researchers, administrators, third party payers, and patients independent of the format in which they are presented. Survival analysis may enable the formal comparison of the results of studies of therapeutic effectiveness in a straightforward and unambiguous format.

**CONCLUSION**

Kaplan-Meier survival analysis techniques may provide a simple yet powerful means of visually observing the course of treatment of patients under therapy for musculoskeletal complaints such as low back pain. In addition, survival analysis may be useful as an unambiguous means of comparing study results of different musculoskeletal techniques. Further investigation into these methods should be performed.

**REFERENCES**

To the Editor:

Beck et al. in their recent article fail to provide sound evidence that chiropractors need their own set of radiography guidelines, “not medical guidelines,” nor do they provide valid evidence to justify the use of full spine radiography in 84% of patients who present to the outpatient clinic at the New Zealand Chiropractic College.

In their article, the authors found that 68% of patients presenting for chiropractic care who had full spine radiography had significant anomalies. They suggest that this finding may have implication for chiropractic treatment.

However, the likelihood of detecting an anomaly on a radiograph is unimportant unless it has clinical relevance. To have clinical relevance, the anomaly should, first, provide information beyond that obtained during history taking and physical examination; secondly, its presence should significantly alter patient management; and thirdly, the alteration in management should be associated with a benefit to the patient (improved outcome).

When examining the 68% of patients who were found to have anomalies (their Table 1), more than 75% of patients had anomalies that lack sufficient evidence of their clinical relevance such as transition segments, blocked vertebrae, nonunion, spina bifida occulta, mild scoliosis, and facet tropism. There is no convincing evidence that these anomalies are contraindications to spinal manipulative therapy. Furthermore, there is no evidence that their presence alters patient management or that altering management (spinal manipulative therapy) will result in improved patient outcomes.

The remaining patients had clinically relevant pathologic conditions of low prevalence that are either found among high-risk groups or are incidental findings. High-risk patients can usually be identified by the presence of red flags during history taking and physical examination. As for the unsuspecting pathologies, these are relatively uncommon and there is no evidence to justify using full spine radiography to screen for these conditions.

In conclusion, most patients in this sample had anomalies of no proven clinical relevance. Selective criteria based on the presence of clinical indicators (red flags) have been shown to be highly sensitive in ruling out most of the remaining clinically relevant conditions.

The chiropractic profession urgently needs to critically appraise its current use of radiography. In addition to clinical relevance, the potential risks of routine spinal radiography must be considered. In the United States, approximately 5700 cancer cases a year are attributed to diagnostic x-rays. In the sample of Beck et al. of 847 full spine radiographs, most patients are younger than 40 years. The cells in young individuals, particularly the reproductive tissues, are most susceptible to mutation from ionizing radiation. The concern for inappropriate use of radiography by chiropractors in The Netherlands prompted the government to prohibit chiropractors from owning any further x-ray equipment.

For the sake of patient safety, professional responsibility, and credibility within the scientific community, the chiropractic profession must take it upon itself to reduce unnecessary radiography or they may find that someone else will do it for them.

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REFERENCES


RESPONSE TO THE LETTER TO THE EDITOR

In Response:

We would like to thank the writer for his insightful comments. We would like to address the pertinent remarks in this letter. Firstly, it was never our purpose to provide sound evidence that chiropractors need their own set of radiography guidelines. We hope that through analysis of this type of data, we can supply some evidence for the myriad of controversial questions surrounding the issue.
suggest that some constructive dialogue in this area is long overdue and that if we fail to establish our own guidelines, should this be appropriate, other agencies will do it, possibly without our input.

The full spine radiographs that were used in this study were taken in accordance with the Standards of Practice Guidelines clause 4.3.1 of the New Zealand Chiropractic Board. It is our understanding that these standards are currently under review.

We agree with the author and state in our discussion that some of the anomalies that were included may not alter the adjustive strategies or procedures that chiropractors may decide to use. However, there is enough disagreement in the literature (as referenced in our article) over the clinical relevance of the occurrence of these anomalies to warrant some investigation into the clinical utility of full spine x-rays before we arrive at the conclusion that they are unjustified. In other words, there is no evidence that we are aware of that concludes that altering patient management in the presence of the anomalies that we reported on does not result in improved patient outcomes.

We welcome the discussion that this topic will hopefully generate and have reported these findings in an attempt to generate more dialogue and investigation in this very important area.

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