Clinical Study

Impact of imaging guidelines on X-ray use among American provider network chiropractors: interrupted time series analysis

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Abstract

BACKGROUND CONTEXT: Overuse and misuse of spine X-ray imaging for nonspecific back and neck pain persists among chiropractors. Distribution of educational materials among physicians results in small-to-modest improvements in appropriate care, such as ordering spine X-ray studies, but little is known about its impact among North American chiropractors.

PURPOSE: To evaluate the impact of web-based dissemination of a diagnostic imaging guideline on the use of spine X-ray images among chiropractors.

STUDY DESIGN/SETTING: Quasi-experimental design that used interrupted time series to evaluate the effect of guidelines dissemination on spine X-ray imaging claims by chiropractors enlisted in managed care network in the United States.

PATIENT SAMPLE: Consecutive adult patients consulting for complaints of spine disorders.

OUTCOME MEASURES: A change in level (the mean number of spine X-ray imaging claims per month immediately after the introduction of the guidelines), change in trend (any differences between pre-intervention and post-intervention slopes), estimation of monthly average intervention effect after the intervention.

METHODS: The imaging guideline was disseminated online in April 2008. Administrative claims data were extracted between January 2006 and December 2010. Segmented regression analysis with autoregressive error was used to estimate the impact of guideline recommendations on the rate of spine X-ray studies. Sensitivity analysis considered the effect of two additional quality improvement strategies, a policy change and an education intervention.

RESULTS: Time series analysis revealed a significant change in the level of spine X-ray study ordering weeks after introduction of the guidelines (β = 0.01; 95% confidence interval = (–0.01, –0.002; p = .01), but no change in trend of the regression lines. The monthly mean rate of spine X-ray studies within 5 days of initial visit per new patient exams decreased by 10 per 1000.
a 5.26% relative decrease after guideline dissemination. Controlling for two quality improvement strategies did not change the results.

CONCLUSIONS: Web-based guideline dissemination was associated with an immediate reduction in spine X-ray imaging claims. Sensitivity analysis suggests our results are robust. This passive strategy is likely cost-effective in a chiropractic network setting. © 2014 Elsevier Inc. All rights reserved.

Keywords: Chiropractors; Health care; Primary care; Quality assurance; Test ordering; X-rays; Utilization

Introduction

Poor-quality care, including overuse and misuse of imaging for spine disorders, has been reported in the medical [1,2] and chiropractic literature [3,4]. Overuse may be defined as patients receiving unnecessary tests or procedures with associated risks and side effects, whereas misuse are mistakes that can harm people [5]. Spine X-ray studies are of little clinical use in the absence of clinical indicators of potentially serious pathology requiring specialist referral or urgent surgical intervention (red flags) [6,7]. The yield of a positive finding associated with risks and side effects, whereas misuse are mistakes that can harm people [5]. Spine X-ray studies are of little clinical use in the absence of clinical indicators of potentially serious pathology requiring specialist referral or urgent surgical intervention (red flags) [6,7]. The yield of a positive finding

Distribution of printed educational material (PEM), including the posting of guidelines on the web, is a widely used passive dissemination strategy to improve knowledge, awareness, attitudes, skills, professional practice, and patient outcomes [23]. High-quality reviews suggested distribution of PEM was effective for improving physician ordering X-ray studies for low back pain [24,25] and other musculoskeletal conditions [24,25]. However, little is known about the impact of dissemination of diagnostic imaging guidelines for spine X-ray study ordering behavior among chiropractors in the US setting [22]. To our knowledge, this is the first study to use a large database that reflects real-world chiropractic care delivery to assess the impact of a guideline dissemination strategy. We undertook an interrupted time series (ITS) to assess the impact of web-based dissemination of a spine imaging guideline on spine X-ray image claim rates among chiropractors enlisted with the American Specialty Network (ASH), a large chiropractic provider network (PN) in the United States.

Methods

Design

We performed a retrospective, quasiexperimental design using segmented regression analysis of ITS data to assess the significance of changes in level and slope of the regression lines before and after the introduction of a spine imaging guideline [26,27]. ITS design allows for the statistical investigation of potential biases in the estimate of effect of the intervention and is widely regarded as the strongest quasiexperimental design for causal inference guideline [26]. These potential biases include: secular trend, seasonal effects, duration of the intervention, random fluctuations, and autocorrelation [28].

Setting

The PN provides complementary health care networks for health plans across the United States and includes more than 15,000 chiropractors from 50 states [29].

Participants

Contracted providers who received payment for at least one claim submitted between 2006 and 2010 for consecutive adult patients consulting for complaints of spine disorders were identified from the PN administrative databases.

Interventions

The primary intervention was the introduction of the Diagnostic Imaging Guidelines [19]. These open access guidelines were first published in the Journal of Manipulative and Physiological Therapeutics in January 2008 [19]. In March 2008, the guidelines were posted on the National Guideline Clearinghouse [30], and the PN updated their
web-based diagnostic imaging guidelines accordingly in May 2008. Consequently, the intervention is considered as occurring on April 1, 2008. Table 1 provides a description of the delivery of the intervention with the corresponding periods.

**Associated quality-improvement (QI) initiatives**

The PN clinical staff retrospectively identified QI initiatives to improve appropriate use of spine radiographs. The PN assigned chiropractors to one of six levels (provider tier system) on the basis of service use, including X-ray image ordering practice, and quality data. Each level defines the point at which medical necessity review is applied. Two QI strategies were targeted at more frequent radiograph users during the study period: (1) a policy change introduced across the network in December 2006, and (2) an educational intervention delivered in September 2007 in the state of Georgia (Table 1).

**Data sources**

Data were extracted between January 1, 2006 and December 31, 2010 from the ASH administrative claims database. The database contains claims data for billed services submitted by the PN contracted practitioners. Data were extracted for consecutive patients older than the age of 18 who were treated for complaints of neck, back, or low back pain. Duplicate claims submissions and Medicare contracts were excluded. Diagnostic and procedure codes used are classified under the International Classification of Disease, Ninth Revision [31] and the Current Procedural Terminology, Fourth Edition [32].

The following complete datasets were extracted each month at the care provider level for patients consulting for spinal complaints during the study period: (1) number of “unique” patients defined as insured individuals using chiropractic services for which there was at least one allowed paid service during the reporting period; (2) number of “new patient exams” claims for complaints of spinal disorders; and (3) spine X-ray study ordering claims data (cervical, thoracic, lumbar, and full spine X-ray images) were extracted for the entire study period and if ordered within 5 days of a billed initial patient visit. Each service for a radiographic examination as identified by the applicable Current Procedural Terminology code was counted as an X-ray study. PN officials routinely assess billing patterns and audit chiropractors to ensure billing accuracy. In addition, reliability of data extraction process were assessed by two study investigators on two occasions (February and June 2011) at the PN headquarters in San Diego by comparing randomly selected cases with the original dataset.

**Outcome measures**

The primary measure was a change in level or the mean number of spine X-ray imaging claims ordered within five days of initial patient visit per 1,000 new patient exams per month immediately after the introduction of the guidelines, and any differences between preintervention and postintervention trends. A third outcome of ITS analysis is the estimation of monthly average intervention effect after the intervention [26,27].

**Ethics**

A data use agreement was signed by involved parties and ethics approval was granted by the Ottawa Health Research Ethics Boards.

**Data analysis and management**

Encrypted data were downloaded into an Excel file, transposed into a 60-month observation period, and converted using SAS statistical software (version 9.2) in July 2011. A two-sided \( p < .05 \) was considered statistically significant, and analyses were performed using SAS enterprise guide (version 4.2). We estimated changes in level and trend for the dissemination of the guidelines and conducted sensitivity analyses on the PN QI strategies (Supplementary
file 1). The Durbin-Watson (dw) statistic was used to test for autocorrelation. The dw statistic detected no evidence of autocorrelation (dw = 1.95, p = .99). Nonetheless, because time series data typically are auto-correlated, we undertook a conservative approach and used regression analysis with autoregressive errors.

Table 1
Description of the delivery of the primary intervention (guidelines dissemination) and the PN quality improvement strategies, and corresponding periods

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preintervention</td>
<td></td>
<td>January 1, 2006 - March 31, 2008 (28 months)</td>
</tr>
<tr>
<td>Primary intervention</td>
<td>Web-based guideline dissemination</td>
<td>April 1, 2008 (Month 29)</td>
</tr>
<tr>
<td>Postintervention</td>
<td></td>
<td>April 1, 2008 - December 31, 2010 (32 months)</td>
</tr>
<tr>
<td>Provider Network quality improvement initiatives</td>
<td>New providers: Tier* 2 credentialing process was implemented by the PN in March 2006, enabling the PN to accept applicants with high X-ray imaging use while maintaining quality oversight. These chiropractors received an educational packet (notification letter, description of tier 2 requirements, and PN X-ray imaging guidelines), followed by an educational phone call and three educational letters over their first 12 months.</td>
<td>December, 2006 (Month 12)</td>
</tr>
<tr>
<td></td>
<td>Existing providers: In December 2006, the PN implemented a program focused on contracted chiropractors with high X-ray rates. On annual review, providers exceeding the revised parameters (spine x-ray rates&gt;60% and/or full spine X-ray image rates&gt;5%) were assigned to tier 2. Under tier 2, all X-ray study services required medical necessity review before submitting X-ray imaging claims for reimbursement.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Educational intervention in Georgia state</td>
<td>Education letter sent to all Georgia providers whose X-ray imaging use rate was equal or greater than 60% Phone outreach educational calls to providers seeing a minimum of 10 patients and X-ray imaging utilization was greater than 60% (not already in tier 2)</td>
</tr>
</tbody>
</table>

DIGASD, Diagnostic Imaging Guideline for Adult Spine Disorders; NCG, National Guideline Clearinghouse; PN, provider network.

* Provider tier: As part of a quality improvement initiative implemented in 2005, PN assigned chiropractors to one of six levels (provider tier) on the basis of service use, including X-ray study ordering practice, and quality data. Each level defines the number of patient visits and services permitted before verification of medical necessity is required. Provider tier ranges from having to submit documentation for medical necessity verification for all services after the first visit (tier 1) to no medical necessity verification (tier 6). Providers can move up or down in tier level on an annual basis based on compliance with both quantitative and qualitative criteria.
Primary analysis

Estimating changes in level and trend for the dissemination of the guidelines

To determine the expected mean number of the dependent variable following exposure to the intervention, three variables were entered into the time series model: (1) a time variable; (2) an indicator variable to differentiate between pre- and postguideline publication period; and (3) a postintervention term. The autoregressive error structure (\(v_t\)) represents the random variability not explained by the model. We specified the following linear regression model:

\[
Y_t = \beta_0 + (\beta_1 \times Time_t) + (\beta_2 \times Intervention_t) + (\beta_3 \\
\times Time, after Intervention_t) + v_t (error term)
\]  

(1)

Intervention effects

Three outcomes in the ITS analysis are: first, change in level immediately after the intervention; second, difference between preintervention and postintervention slopes; and third, the estimation of monthly average intervention effect after the intervention [27,33,34]. To estimate the intervention effect across PN providers, the expected results from regression equation 1 at month 60, which is 32 months after the CPGs were disseminated, is expressed as [27,34]:

\[
\hat{Y}_{60\text{(with CPGs)}} = \hat{\beta}_0 + \hat{\beta}_1 \times 60 + \hat{\beta}_2 + \hat{\beta}_3 \times 32
\]  

(2)

The following expresses regression equation 1 at month 60 without the CPGs not been disseminated (ie, without any postintervention effect in the model):

\[
\hat{Y}_{60\text{(without CPGs)}} = \hat{\beta}_0 + \hat{\beta}_1 \times 60
\]  

(3)

Intervention effects may be expressed as the absolute intervention effect: \(\hat{Y}_{60\text{(with CPGs)}} - \hat{Y}_{60\text{(without CPGs)}} = \hat{\beta}_2 + \hat{\beta}_3 \times 32\), or as the relative change in outcome associated with the CPGs, expressed as percentage increase or decrease:

\[
\frac{\hat{Y}_{60\text{(with CPGs)}} - \hat{Y}_{60\text{(without CPGs)}}}{\hat{Y}_{60\text{(without CPGs})}} \times 100.
\]

Sensitivity analysis

Estimating changes in level and trend for the PN quality improvement strategies

To control for changes in level and trend of the series that are caused by reasons other than the release of the Diagnostic Imaging Guidelines, we conducted separate time series by adding the PN QI strategies as a change point in the segmented regression analysis of ITS, along with the primary intervention disseminated at month 29. The model with two point changes was as follows [27]:

\[
Y_t = \beta_0 + (\beta_1 \times Time_t) + (\beta_2 \times Intervention_t) + (\beta_3 \\
\times Time, after Intervention_t) + (\beta_4 \times QI strategy_t) + \\
+ (\beta_5 \times Time, after QI strategy_t) + v_t (error term)
\]  

(4)

We first conducted a time series analysis adding the policy change implemented across the PN at month 12 (Fig. 1). We performed a separate analysis using data for the state of Georgia only, adding both QI strategies, the policy change at month 12 and an educational intervention at month 21 (Fig. 2).

Results

During the 5-year period, more than 605,500 new patient examination claims were made for 4,554,362 patients. Spine X-ray imaging use claims decreased steadily during the 5-year period, with a mean of 248.2 (95% confidence interval [95% CI] 247.9–248.5) spine X-ray imaging claims per 1,000 new patient exams per month before, and 203.3 per 1,000 (95% CI 202.9–203.6) after guidelines dissemination (Table 2).

Primary analysis: guidelines dissemination

Visual inspection suggests a downward trend in use of spine x-ray claims throughout the study period, with an abrupt level change occurring soon after the intervention at around month 29 (Fig. 1). The coefficients, associated 95% CIs, and significance level for each variable are presented in Table 3. At the beginning of the observation period, chiropractors claimed for average 265 of 1,000 spine X-ray studies within 5 days of initial visit per new patient exams per month. A small but significant level change in the mean number of spine X-ray imaging claims per new patient exams per month (about 10 per 1,000) was observed immediately after the guidelines were released (−0.0104, 95% CI −0.0182, −0.0026, p=.0114). There was a significant overall decrease in the rate of spine X-ray study claims over the study period (p<.0001), but the rate of decrease did not appear to change after the intervention (p=.8536).

After stepwise elimination of nonsignificant terms, the most parsimonious model contained only the intercept, the baseline trend, and the level change in the mean number of spine X-ray imaging claims after guidelines release (−0.0103, 95% CI = −0.0180, −0.0026; p=.0109).

Using results in Table 3, we estimated that at 60 months, PN chiropractors claimed for 186 spine X-ray images per 1,000 new patient exams per month. Had the CPGs not been introduced, the mean monthly rate of spine X-ray imaging claims per new patient examinations would have been 196 per 1,000. Thus, the average rate of spine X-ray imaging claims per new patient examinations per month decreased
by 10 spine X-ray images per 1,000 (the absolute intervention effect), or 5.26% after the CPGs were disseminated, compared with what it would have been without the CPGs (a relative percentage decrease).

**Sensitivity analysis: PN QI strategies**

A significant level change remained after controlling for PN QI strategies across the network (Fig. 1) and in Georgia State (Fig. 2).

**Discussion**

Segmented regression analysis of a 5-year ITS showed that web-based dissemination of a diagnostic imaging guideline among a large group of chiropractors in a PN setting was associated with a significant change in level (step) but not trend in X-ray imaging claims. The change in level remained significant after we controlled for previous PN quality improvement strategies targeting high X-ray imaging users, suggesting our findings were not caused by relevant factors we were able to measure. We also observed an underlying secular reduction in X-ray imaging claims during the study period. Such downward trend has been observed over the past decades among chiropractors in North America [3,35–37] and overseas [38,39].

To our knowledge, this is the first study to document, with a strong quasi-experimental design, a decrease in spine X-ray imaging claims after web-based dissemination of PEMs among chiropractors enlisted in a PN. Our results concur with the recent updated Cochrane review that suggests PEMs generally are effective strategies for improving process of care among physicians and result in small to modest improvements [40]. Giguère’s review included 45 studies comprising 14 randomized controlled trials and 31 ITS studies [40]. For randomized controlled trials, the median absolute improvement in continuous professional practice outcomes was 0.13 SMD (range from −0.16 to +0.36) when PEMs were compared with no intervention. Results for ITS studies were consistent across studies and support the aforementioned conclusions (standardized median change in level of 1.69, range from −6.96 to +14.26). Only three studies included nonphysicians (nurses, pharmacists, or psychologists), and mode of delivery of PEMs rarely consisted of web-based dissemination. A recent randomized trial in the United Kingdom showed that posted PEM can shift chiropractors’, osteopaths’, and physiotherapists’ beliefs and self-reported behavior toward treatments more in line with guideline recommendations [41]. However, the trial did not include recommendations for lumbar X-ray studies and had a short follow-up.

**Implications for research**

Although the evidence-based movement is now prominent in allopathic medicine, this approach to clinical
practice has been a much slower process in chiropractic [42]. Although there is a substantial evidence base focusing on changing physician practice (eg, improving prescribing and medicines use) [43], the applicability of this research to chiropractic is uncertain given the differences in practitioners’ training and practice patterns [44,45]. To date, there has been little knowledge translation research in chiropractic. We are aware of only one (ongoing) cluster trial enrolling practitioners in one of the largest PN across the United States, and a long study period (this study had 60 time point observations and no autocorrelation was found), some limitations must be considered. First, determinants of health-care insurance coverage, were not available for analysis. Second, appropriateness of X-ray imaging ordering cannot be addressed as the available administrative data lacked detailed clinical information such as presence of red flags, specific diagnosis, and disease severity. Third, providers could have ordered X-ray images without submitting claims for them. Fourth, it is unclear if other tests were being substituted for undergoing X-ray studies such as magnetic resonance imaging.

The biggest threat to time series analysis is an event occurring at the same time as the intervention producing

**Implications for practice and policy makers**

Chiropractic care and complementary and alternative medicine are increasingly being used [47] and integrated into group practice organizations and mainstream health care [48] with significant potential economic benefits [49]. Further integration of complementary and alternative medicine, however, should be founded on sound evidence-based principles of quality health care delivery [48].

Although a formal cost analysis was not conducted, web-based dissemination of these imaging guidelines appeared to be cost-effective. Developing the Diagnostic Imaging Guidelines for Adult Spine Disorders and web posting in three open sources cost less than 45,000 USD. Considering an average of 9,553 new patient exams were performed each month across ASH network after guidelines were disseminated, we estimate a reduction of 3,056 X-ray imaging series over the study period (10 fewer spine X-ray images/1,000 new patient examinations×9,553 new patients exams/month×32 months). This would translate in direct savings to the PN on the order of $152,848 USD during the 32-month period (average of $50,00/spine X-ray images). Furthermore, the observed 5% decrease in the rate of ordering X-ray studies also resulted in less patient ionizing radiation exposure [9–11], and possibly reduced inefficient and potentially inappropriate invasive diagnosis and subsequent treatment [12,14,50]. Such issues are likely significant both at the clinical and the population health level [10,51].

Policy makers within a PN setting should consider web-based dissemination of evidence-based guidelines as an initial step to reduce knowledge-practice gap. Greater effects may be achieved through active dissemination strategies [52].

**Limitations**

Although our study had a number of strengths, including use of a strong quasiexperimental design, a large sample size, inclusion of consecutive patient encounters with chiropractors enlisted in one of the largest PN across the United States, and a long study period (this study had 60 time point observations and no autocorrelation was found), some limitations must be considered. First, determinants of health care use, including patient health status and extent of health-care insurance coverage, were not available for analysis. Second, appropriateness of X-ray imaging ordering cannot be addressed as the available administrative data lacked detailed clinical information such as presence of red flags, specific diagnosis, and disease severity. Third, providers could have ordered X-ray images without submitting claims for them. Fourth, it is unclear if other tests were being substituted for undergoing X-ray studies such as magnetic resonance imaging.

The biggest threat to time series analysis is an event occurring at the same time as the intervention producing

| Table 2 |
| Mean monthly number of new patient examinations, spine X-ray studies within 5 days of initial examination, and rate of spine X-ray studies within 5 days per 1,000 new patient examinations before and after the intervention among provider network chiropractors in the United States |
| New patient examinations* | | |
| Mean per month (MD) | 10,708.6 (1,040.7) | 9,552.8 (817.1) |
| Spine X-ray studies within 5 days of initial examination | | |
| Mean per month (CI) | 2662.1 (2,677.0–2,787.6) | 1945.2 (1,945.16–2,029.4) |
| Mean monthly rate of spine X-ray studies within 5 days per 1,000 new patient exams | | |
| Mean per month (CI) | 248.22 (247.93–248.51) | 203.29 (202.99–203.59) |

CI, confidence interval; CPG, clinical practice guideline; SD, standard deviation.

* New patient exams: Patient between age 18 and 65 years with chief complaints of neck, thoracic, or low back pain during the study period 2006–2010.

| Table 3 |
| Parameter estimates, CIs, and p values from the full and most parsimonious segmented regression models predicting mean monthly numbers of spine X-ray studies within 5 days of initial visit per new patient exams across provider network over time |
| Guidelines dissemination | Coefficient (95% CI) | p Value |
| Full segmented regression model | | |
| Intercept B0 | 0.2645 (0.2586, 0.2701) | <.0001 |
| Baseline trend B1 | −0.0011 (−0.0015, −0.0008) | <.0001 |
| Level change after guidelines release B2 | −0.0104 (−0.0182, −0.0026) | .0114 |
| Trend change after guidelines release B3 | −0.00004 (−0.0005, 0.0004) | .8536 |
| Most parsimonious segmented regression model | | |
| Intercept B0 | 0.2649 (0.2606, 0.2692) | <.0001 |
| Baseline trend B1 | −0.0012 (−0.0014, −0.0009) | <.0001 |
| Level change after guidelines release B2 | −0.0103 (−0.0179, −0.0026) | .0109 |

CI, confidence interval.
a similar effect (ie, history) [26,53]. Although a number of national guidelines on back pain were released or updated during the study period [20,21], CPGs made available in 2008 were in Finnish [54] or housed under the National Health Service in the UK [55], a website unlikely to be frequently visited by US chiropractors. One other notable event was the online release of a chiropractic imaging guideline at the end of 2007 [16]. History is not plausible, however, because this chiropractic guideline promoted the routine use of spine X-ray imaging, a behavior in the opposite direction of the Diagnostic Imaging Guideline, which consistently recommends not using X-ray imaging in the absence of red flags. A second common threat to time series analysis is a change in the composition of the study population. This seems unlikely because: (1) there was no atypical change in the mean number of providers per month in the adjacent months before and after the intervention; (2) there are no compelling reasons why patient characteristics, severity of presenting complaints, and co-morbidity would change when CPGs were disseminated; and (3) it seems improbable that such a large number of providers would stop using their X-ray equipment in response to the dissemination of the guidelines. Two other common threats to time series analysis are seasonality and testing effect. No important seasonality (cyclical variation) was expected, and inclusion of 60 data points likely captured potential seasonal variations in the pre- and post-intervention periods. Lastly, testing effect is unlikely as there was no change in the way claims were recorded during the study period.

Conclusions

Web-based dissemination of diagnostic imaging guidelines was associated with a reduction in the X-ray imaging claims by chiropractors enlisted with a large network of providers in the United States. Passive guidelines dissemination appeared to be a simple, cost-effective strategy in this setting to improve X-ray study ordering rates. More research is needed to find more efficient guideline dissemination strategies. Interventions aiming to further reduce X-ray imaging utilization should identify barriers to change and target high users in identified geographical areas, and aim to clarify the effect of a provider tier system on X-ray imaging ordering practice in a managed system.

Appendix

Supplementary material

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.spinee.2013.08.051.

References

[23] Bero L, Grilli R, Grimshaw J, et al. Closing the gap between research and practice: an overview of systematic reviews of interventions to promote the implementation of research findings. The


