Image-guided placement of long-term central venous catheters reduces complications and cost

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Abstract

BACKGROUND: The goals of this study were to evaluate the complication rate for intraoperative placement of a long-term central venous catheter (CVC) using intraoperative ultrasound (US) and fluoroscopy and to examine the feasibility for eliminating routine postprocedure chest X-ray.

METHODS: Retrospective data pertaining to operative insertion of long-term CVC were collected and the rate of procedural complications was determined.

RESULTS: From January 2008 to August 2013, 351 CVCs were placed via the internal jugular vein using US. Of these, 93% had a single, successful internal jugular vein insertion. The complications included 4 arterial sticks (1.14%). Starting in October 2012, postprocedure chest radiography (CXR) was eliminated in 170 cases, with no complications. A total of $29,750 in charges were deferred by CXR elimination.

CONCLUSIONS: This review supports the use of US for CVC placement with fluoroscopy in reducing the rate of procedural complications. Additionally, with fluoroscopic imaging, postprocedural CXR can be eliminated with associated healthcare savings.

More than 15 million central venous access cases are performed annually in the United States with associated rates of complications ranging from 5% to 19%.1,2 When ultrasound (US) guidance is used for central venous catheter (CVC) placement in the internal jugular vein (IJV), mechanical complications have been reported to be less than 5%.3–8 The most common complications that can occur include hematoma, arterial puncture, arteriovenous fistula, nerve injury, and pneumothorax.9 Incurring any of these complications can result in the need for additional invasive procedures and affect the overall morbidity.

Although most CVCs are temporary in nature and placed in intensive care or emergency room settings, there are other CVC types used for long-term care, such as those needed for chemotherapy or nutritional support. These CVCs are planned procedures and often take place in the operating room with sedation to implant the device. Numerous issues, such as patient anatomy, comorbidities, primary disease process, long-term durability of the catheter, and indications for placement, must be considered.

The modern literature now contains numerous guidelines based on research and safety data that recommends US guidance in the placement of CVC and as such was the primary consideration for undertaking a review of our center data.
The purpose of this study was to review the use of US for guidance by general surgeons when placing a CVC in patients for long-term venous access at our institution. The rate of complications associated with placement was collected and the associated use of fluoroscopy when compared with routine postprocedural radiography was evaluated.

Patients and Methods

Between January 2008 and August 2013, 351 patients underwent surgical placement of a long-term use CVC employing US and fluoroscopy. All procedures were performed by 2 surgeons at a single, university-based center. The majority of CVC placements were performed in an outpatient setting. The data extracted included patient demographics, procedure-related details, and outcome details, as indicated below.

The operative technique for placement of the CVC was similar between surgeons. The CVCs placed included PowerPort, Hickman, or HemoSplit (Bard Access Systems, Salt Lake City, UT). When appropriate, the anatomic site for CVC placement took into account patient diagnosis, such as previous or planned surgical treatment or radiation therapy. Patients were given either a general anesthetic or monitored anesthesia care sedation. US guidance using either the SiteRite (Bard Access Systems) or the SonoSite (FujiFilm, Bothell, WA) was used to obtain IJV access. Dynamic imaging US technique was used by both surgeon operators to visualize needle insertion into the vascular structure. Intraoperative fluoroscopy was used in all cases to confirm correct anatomic catheter placement.

Patient demographics and procedure-related details included the following: patient age, surgical time, number of insertion site attempts, final site of line placement, and early placement-related complications. The time for surgeon to place the CVC was 33 minutes, with an interquartile range of 16 minutes (n = 326).

Of the 351 cases, 93% (327) had a single, successful insertion via the IJV on the anatomic side originally attempted. The left IJV was the most common site employed with 51.3% of cases (180 of 351). There were 16 cases (4.6%) in which the initial IJV insertion was unsuccessful, requiring the subclavian vein site to be employed. Of these 16 cases, 13 were placed in the left subclavian after unsuccessful attempt made in the left IJV.

Of the entire group, there were no hemothoraces or pneumothoraces (either immediate or delayed), or hematoma, or significant bleeding events as a result of line placement. A total of 4 carotid artery punctures occurred, requiring only pressure to the site as treatment. Two of these were via the right IJV, with both successfully placed in the same anatomic site. This resulted in overall procedural complication rate of 1.14% when both US and intraoperative fluoroscopy was employed.

There were a total of 24 cases (6.8%) that required an additional attempted insertion site after failure of the initial IJV insertion. In 19 of these cases (79.1%), the IJV was cannulated but the wire could not be successfully passed into the central circulation. In 2 cases (8.3%), there was conversion to a second site because of arterial puncture. In

### Table 1 Descriptive demographic data

<table>
<thead>
<tr>
<th>Demographic data</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Body mass index (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>19.2–93.6</td>
<td>58.4%</td>
<td>15.9–57</td>
</tr>
<tr>
<td>Mean ± standard deviation</td>
<td>56.3 ± 14.8</td>
<td>Male</td>
<td>41.6%</td>
</tr>
<tr>
<td>Median (25th, 75th percentile)</td>
<td>58.4 (47, 67.2)</td>
<td>Body mass index (kg/m²)</td>
<td>28.8 (23, 33.4)</td>
</tr>
</tbody>
</table>

Results

Between January 2008 and August 2013, a total of 351 patients underwent US-guided CVC placement with the IJV as the initial attempted site. Table 1 lists descriptive information of the study population. Patient demographics included a mean age of 56.3 ± 14.8 (range 19 to 94) years, body mass index 28.8 ± 7.9 (range 16 to 57), and sex was 58.4% female. The preoperative American Society of Anesthesiologist score for 55.8% of the patients was greater than or equal to 3. Monitored anesthesia care with intravenous sedation was used in 85.5% of the cases, with the remaining 14% receiving a general anesthetic. The majority of cases (94.3%) had a PowerPort placed, with 4.6% having a Hickman catheter and the remaining 1.1% having a dialysis catheter placed. The median time for the surgeon to place the CVC was 33 minutes, with an interquartile range of 16 minutes (n = 326).

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1 case (4.2%), the IJV was unable to be cannulated because of difficult vascular anatomy, and for the remaining 2 cases (8.3%) the IJV could not be cannulated after multiple attempts. These 24 cases were not different with regards to sex, body mass index, or American Society of Anesthesiologist score than those that required a single site attempt. There was a trend for increased patient age in those who had more than one site, with a median age of 66.6 versus 58.1 years ($P = .067$).

Between October 2012 and August 2013, routine postprocedure CXRs were eliminated using intraoperative fluoroscopy alone to document correct line placement. Of the 176 patients reviewed, only 6 patients had a postprocedure CXR for the following specific indications: 2 patients for disease-related issues and 4 patients for an arterial stick, multiple site attempts, and subclavian vein placement. No delayed CXR was performed for symptoms and there were no cases of pneumothorax, hemothorax, or misplaced lines. Based on the elimination of the CXR in the remaining 170 patients, an estimated total of $29,750 in hospital charges was saved.

**Comments**

The evidence for the routine use of the US for central vein access is overwhelming. In 2001, an Agency for Healthcare Research and Quality Evidence Report recommended real-time dynamic US guidance for central venous catheterization because of evidence from multiple randomized controlled trials that showed decreased number of complications with US guidance. In 2011, a Cochrane review of US guidance for hemodialysis catheter insertion found a significantly reduced rate of catheter placement failure, time taken for successful catheterization, arterial puncture, and hematoma. The Third Sonography Outcomes Assessment Program Trial specifically studied the differences between static and dynamic US guidance. It found that static US guidance required less training than dynamic, but the dynamic method had improved rates of first attempt success and number of attempts.

US guidance also indirectly decreased the rate of catheter-related thrombosis because of decreased number of passes for cannulation. A high number of passes will disrupt the endothelial lining of the vessel, increasing the risk for catheter-related thrombosis. In a study comparing landmark-guided placement versus US-guided placement with a total of 3,951 long-term CVC placements, the US-guided method had a lower rate of CVC thrombosis and lower rate of catheter patency loss, rupture, or tip dislocation.

Placement of CVC is performed by multiple specialists including surgeons, nephrologists, intensivists, radiologists, etc.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>CVC</th>
<th>Successful IJV cannulation (%)</th>
<th>Pneumothorax (%)</th>
<th>Hematoma (%)</th>
<th>Arterial puncture (%)</th>
</tr>
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<tbody>
<tr>
<td>Denys</td>
<td>1993</td>
<td>928</td>
<td>100</td>
<td>0</td>
<td>3.3</td>
<td>3.9</td>
</tr>
<tr>
<td>Mey</td>
<td>2003</td>
<td>493</td>
<td>95.1</td>
<td>NR</td>
<td>4.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Oguzkurt</td>
<td>2005</td>
<td>220</td>
<td>100</td>
<td>0</td>
<td>.4</td>
<td>1.8</td>
</tr>
<tr>
<td>Karakitsos</td>
<td>2006</td>
<td>450</td>
<td>100</td>
<td>0</td>
<td>.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Cavanna</td>
<td>2010</td>
<td>1,978</td>
<td>99.1</td>
<td>0</td>
<td>.2</td>
<td>.3</td>
</tr>
<tr>
<td>Akoglu</td>
<td>2012</td>
<td>323</td>
<td>100</td>
<td>0</td>
<td>.3</td>
<td>.3</td>
</tr>
<tr>
<td>Si Jin Ahn</td>
<td>2012</td>
<td>1,254</td>
<td>99.9</td>
<td>NR</td>
<td>.24</td>
<td>.08</td>
</tr>
<tr>
<td>Presented series</td>
<td>2014</td>
<td>351</td>
<td>95.4</td>
<td>0</td>
<td>0</td>
<td>1.14</td>
</tr>
</tbody>
</table>

CVC = central venous catheter; IJV = internal jugular vein; NR = not reported.
and anesthesiologists, with each having their own level of experience with US guidance, preferred technique, and site of placement. Recent studies have suggested that the use of US did not decrease the complication rate when compared with landmark technique if the operator had performed less than 25 cannulations and that when operators took part in a standard training course, their total procedural time and time to puncture the IJV significantly improved over 8 catheter insertions. The complication rate of 3.97% was higher than multiple published results of US-guided CVC placement complications, yet still lower than the complication rate for landmark technique.

The abundance of guidelines surrounding US-guided CVC placement was the motivation for our review of US use with placement of a CVC for long-term use. A 93% successful cannulation on the first pass and 4.6% failure rate are consistent with results reported in prior studies. The reasons for inability to cannulate the IJV on the first pass were related to issues commonly seen in other studies such as aberrant anatomy or the inability to direct the catheter into the central circulation. The complication rate, 1.14% also compares to the complication rate within larger, published studies (Table 2).

US is a proven method for reducing the incidence of complications at a marginal cost compared with the cost of managing complications. This is particularly important with the pressure to adopt a system of “never” events and bundle payments for procedures.

In our review, the rate of complications from CVC placement was approximately 1%, leading to a question as to the need for routine postprocedural CXR. It has been previously reported that when intraoperative fluoroscopy is used, the incidence of problems found on CXR is 1%. Based on these data and our experience, a safety and cost analysis of eliminating routine CXR was added to this review.

Prior studies have supported elimination of postprocedure radiography in US-guided, fluoroscopy-assisted CVC placement. The rate of complications detected by routine CXR after CVC placement was found to be 7% to 3.6%, including a rate of pneumothorax of 0% to 35%. In a study examining the utility of CXR in the critical care population, risk factors for pneumothorax or arterial puncture included surgeons’ judgment as to the difficulty of the procedure and multiple needed passes. Several studies have also documented a very low incidence of line malposition or complications requiring intervention especially in asymptomatic patients.

Overall, obtaining routine postprocedure CXR has a low likelihood of changing management; therefore, eliminating routine postprocedure CXR results in cost reduction with negligible effect on patient safety. In less than a year, a total of $29,750 in hospital charges were saved, not including indirect cost savings such as decreased turnover time in same day surgery, better utilization of staff time, and decreased exposure to radiation for patients and staff.

The study has the usual limitations of a retrospective review. In addition, the data comes from a single institution and 2 surgeons with significant levels of experience with CVC placement. Nonetheless, this review does confirm that US guidance is effective in reducing the complications of long-term CVC placement and the routine use of postplacement CXR can be safely eliminated. Given that this is a population at high risk for infection with often limited access sites, the responsibility is with the practitioner to maximize the accuracy for correct placement and minimize the risk for complications.

Conclusions

US has been confirmed to be a low cost effective measure in decreasing complication rate and increasing efficiency of CVC placement. In addition, when CVCs are placed with fluoroscopic guidance, routine postprocedure CXR can be safely eliminated at significant cost savings. The intelligent use of healthcare resources dictates combining technology resources with best practice measures to optimize patient outcomes.

References

Discussion

**Discussant:** Dr Scott Petersen (Phoenix, AZ): The issue of charges versus costs. It looks like your institution charges around $175 for a chest x-ray, but what's the real cost? Also, does a chest x-ray give a patient a significant dose of radiation?

**Dr Megan Bowen:** There is quite a difference between the charge and reimbursement. My institution charges $175 for a chest x-ray and they receive approximately one seventh of this charge. However, if obtaining a chest x-ray does not change management, then we should question whether the chest x-ray should be performed. A chest x-ray does not give us a significant amount of radiation. The total radiation from a chest x-ray is .1 millisieverts, and this is equivalent to the amount of radiation received from the environment over a 10 day period.

**Dr Brock Bordelon** (Colorado Springs, CO): I would like to make a comment about routine use of fluoroscopy, which I think is real important. But if you're going to skip the post-operative chest x-ray, I want to know whether or not you routinely use image capture and print the image. The older I get, the more time I spend around attorneys, if it's not shown or written, it wasn't done. Our orthopedic colleagues have, for years, done that, take an image, put it in the chart. That way, they avoid the postoperative x-ray. Is that part of your routine?

**Dr Megan Bowen:** Yes, it is part of our routine. We use the image capture on fluoroscopy. It is then saved and available to view in our electronic medical record. Also, the surgeons that do the port placements dictate in their operative report that they viewed the fluoroscopic image and interpreted it.

**Dr Shanu Kothari** (Lacrosse, WI): Could you clarify for me, when you say it’s two surgeons that did this, who was actually putting the needle in? Is this in a training program, were there residents involved, or was every needle stick done by the two attendings?

**Dr Megan Bowen:** This is a training program. Residents were involved in the placement of these long-term central venous catheters. They were supervised by one of two surgeons that routinely place long-term central venous catheters.