Repositioning of central venous access devices using a high-flow flush technique - a clinical practice and cost review

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ABSTRACT
Background: Malpositioned central venous access device (CVAD) tip locations can cause significant mechanical and chemical vessel-related injuries and complications if left in inappropriate positions. The aim of this study is to determine the use of a high-flow flush technique (HFFT) in successful correction of malpositioned catheters into the lower superior vena cava or cavoatrial junction and provide a cost comparison to interventional/fluoroscopic-based repositioning.
Methods: This is a retrospective chart and radiographic review of all inserted CVADs found malpositioned between 1996-2014 in a multi-specialty 1000-bed tertiary trauma center in Sydney, Australia. 7450 CVADs placed by a nurse-led vascular access service were reviewed. Catheters repositioned pre-2010 were excluded owing to radiology repositioning interventions.
Results: There were 3996 peripherally inserted central catheters (PICCs) and 3454 centrally inserted central catheters (CICCs) placed. Seventy-four were malpositioned post-2010. Of these, 53 devices were repositioned using the studied technique; 86% (46/53) of catheters were successfully repositioned on the first HFFT attempt. There was supportive evidence that device insertion side is important in potential catheter malposition.
Conclusions: Clinical outcomes suggest that CICCs and PICCs may be successfully repositioned utilizing this technique, with no adverse events associated and a prospective cost saving benefit when compared to interventional-based repositioning procedures.
Keywords: Complications, Flushing, Malposition, Patient safety, Tip location, Thrombosis

Introduction

Centrally inserted central catheters (CICCs) and peripherally inserted central catheters (PICCs) are used extensively in many diverse patient populations in today’s current healthcare practices. The magnitude of parenteral infusions administered through these devices can be from relatively simple therapies, such as intravenous fluids and antibiotics, to more complex therapies such as parenteral nutrition, chemotherapy regimens and critical-care measures. With the large number of devices placed in any given institution today, the potential for device malposition is almost guaranteed at some point.

Placed by physicians and non-physicians alike, many of these devices have been reported widely throughout the literature with varying levels of successes. Operator skill, experience and outcomes, whilst always important, is not always synonymous with professional qualifications, and there have been well documented benefits regarding non-physician-based central venous access device (CVAD) placement services in terms of catheter-related complications and outcomes (1, 2). In particular, nurse-led CVAD placement has shown improvement in organizational efficiency through earlier catheter placement and patient follow-up, along with regular surveillance and consultation to clinicians on appropriateness of device selection, maintenance, troubleshooting and removal. Complications and infection risks were also greatly reduced in some studies (3, 4).

Implications

Complications such as arterial puncture, pneumothorax, hemothorax, bleeding, catheter malposition, vessel erosion, catheter fracture and embolism of the catheter are often widely described in literature after central venous cannulation.
Misplaced catheters have been reported in almost every possible anatomical position, including the arterial system, mediastinum, pleura, pericardium, trachea, esophagus, subarachnoid space, and other aberrant sites (5). The current ideal position for catheter tip location with the greatest safety profile in adults and children is the cavoatrial junction (CAJ) (6). Strong evidence supports correct tip location to aid in significant thrombosis risk reduction strategies (7, 8). CVAD tip location is supported internationally (Society of Interventional Radiology [SIR], Association of Anaesthetists of Great Britain and Ireland [AAGBI], Association for Vascular Access [AVA], Australia & New Zealand Intensive Care Society [ANZICS], European Society for Parenteral and Enteral Nutrition [ESPEN], Gli Accessi Venosi Centrali a Lungo Termine – Italy [GaVeCelt]) by current clinical practice guidelines, standards and recommendations.

Recent documentation of tracheo-azygos fistula (leading to patient death) after administration of a vesicant chemotherapy agent (rituximab) after a spontaneous malposition of an implanted central venous port was recently published (9). Additionally, Fernando et al (10) described malposition of a PICC in a 21-year-old who had a digital subtraction angiogram (DSA)-diagnosed thrombus in the left brachiocephalic vein (likely caused by the malpositioned left internal jugular CVAD (Fig. 1) prior to insertion of left basilic PICC for total parenteral nutrition (TPN). The catheter tip remained curled in upper superior vena cava (SVC) for 9 days without an attempt to reposition (Figs. 2 and 3).

The patient developed an azygos vein perforation after 10 days of a malpositioned PICC tip. This required chest drain insertion and drainage of 2 L of parenteral nutrition solution from the patient’s chest after biochemical confirmation of the collection fluid.

In this case, the PICC was removed and the patient recovered and was discharged without serious consequence (10). This, however, highlights the importance of regular radiographic checks of CVADs for potential secondary spontaneous tip malposition, as occurrence is possibly more frequent than actually estimated. Even relatively simple changes in intrathoracic pressure, such as sneezing, coughing and vomiting can contribute to catheter malposition and should be taken into consideration if the patient has a CVAD in situ.

Other risk factors for secondary CVAD migration is movement of the catheter with changes in arm or body position. PICCs inserted in an abducted arm have been shown to migrate caudally by an average of 2 cm in adduction (11). Cranial migration can be caused by changing from a supine to standing position. There have also been reports of catheter malposition due to severe lower airways distortion (12).

To prevent the rare (13), but potentially lethal complication of cardiac tamponade, the catheter tip should ideally lie proximal to the boundaries of the pericardial sac; however, too proximal placement of the tip greatly increases the risk of thrombosis (5). Other parenteral infusions, as mentioned earlier, require greater hemodilution for successful longer-term administration and a greater reduction of potential intimal damage. Placing the CVAD tip in a vessel other than the distal SVC or the proximity of the CAJ increases the risks of catheter wedging, intimal erosion and/or perforation of vessel walls, local venous thrombosis, catheter dysfunction (6), and cranial retrograde injection, in which the infusate is directed to the head instead of the central circulation (14). The more recent benefits in the use of electrocardiogram (ECG) and doppler-based (15, 16) tip navigating technologies have also reduced the incidence of primary catheter tip malposition in both CICCs and PICCs in adult and pediatric populations (17-20).
and is gaining wider acceptance within the device-inserting communities worldwide.

Malpositioning of CVADs has been described in abundance throughout previously published literature, and spontaneous correction of devices, even in infants, has been described to occur within the first 24 hours of diagnosed malposition (21). However, many techniques still require the assistance of the interventional radiology (IR) department, which is potentially costly in terms of delays in patient therapy, expensive additional product use, as well as associated costs per fluoroscopy procedures.

Methods

A retrospective database, chart and radiographic review of all CVADs with a malposition tip was performed between 1996-2014. These devices were highlighted through a Microsoft Access™ database query of all CVADs inserted by a nurse-led vascular access service at a 1000-bed multi-specialty university hospital. The study reviewed all secondary catheter malpositioning (noted on the post-insertion chest x-ray [CXR] through digital diagnostic imaging to determine if a high-flow flush technique [HFFT] showed clinical benefit in manipulating the catheter into position without the need for interventional or invasive medical procedures. This process allowed comparison of possible cost implications with other current methods of CVAD repositioning (interventional radiology/fluoroscopy). The HFFT technique can be described as a rapid manual flush using 10- to 20-cc 0.9% sterile sodium chloride, aseptically administered through the catheter via the distal lumen (to demonstrate the HFFT see Video 1 - Courtesy of Dr. J. LeDonne - showing flushing technique and a side-by-side video of catheter movement recorded under fluoroscopic conditions. The video is available online as Supplementary material at www.vascular-access.info). The patient is placed in a high Fowlers position (when the head of the bed needs to be elevated as high as possible). The upper half of the patient’s body is between 60 degrees and 90 degrees in relation to the lower half of their body and is encouraged to perform several deep coughs prior to the administration of the flush. Natural changes in intrathoracic pressure allows for catheter movement within the vessel due to changes in vessel size and flow dynamics. This process is repeated for every flush attempt.

Discovery of a malposition, when not using navigational and tip positioning techniques, can often be frustrating for the inserting proceduralist during the post-insertion x-ray review period. The process of either repeating the insertion, moving to an alternate insertion site, thus risking potential iatrogenic complications, or performing a guidewire or catheter exchange itself, is challenging in terms of clinician time management, considering the number of other competing healthcare-related tasks for the proceduralist. The influence of malpositioned catheters has significant effect on clinician workflow and efficiency, which can add to the significant costs associated with vascular access. Some examples of catheter malposition and repositioning are shown in Figures 4 to 8.

Results

A total of 7450 polyurethane CVADs (ranging in size from 4, 5 or 7 French) were inserted during the review period (1996-2014). PICCs had a slightly higher number of insertions (3996) compared to CICCs (3454). The total number of catheters found to be malpositioned totaled 91/7450 (1.2%). Catheters were reviewed in two groups, pre- or post-2010, as the pre-group (17/91) were all rewired or exchanged. All post-2010 catheters (74/91) were attempted for repositioning using a HFFT. HFFT successfully repositioned 53/74 (71.6%), and 21/74 (28.4%) catheters could not be repositioned (Tabs. I and II).
Results of this study show most PICCs and CICCs were successfully repositioned using a HFFT on the first attempt (86.8%). Possible limitations for successful repositioning with CICCs may be due to catheter rigidity in relation to catheter French size and anatomical insertion side. Previously reported literature demonstrates that left-sided placements are more prone to malposition (5). In this dataset, it was demonstrated that 30 (58.5%) devices were inserted on the left side, highlighting a greater chance of malposition, as opposed to 20 (41.5%) on the right side (see Tab. III), supporting that malpositioned catheters from the left side are often due to the tortuous pathway (5).

Table IV shows the number of HFFT attempts to reposition device based on vessel/side of insertion.

A recent study in a US cancer-designated institute demonstrated 68% success on application of a flushing protocol by a vascular access team using a simultaneous rapid saline flush technique (SRSFT) (22). In addition, the use of the SRSFT showed a cost savings of up to 90% compared with traditional interventional repositioning procedures. This study also highlighted a low correction rate for double-lumen catheters and situations in which CVAD tips had curled or migrated into smaller veins, such as the azygos and mammary vessels (22); however, it did not specify catheter French size. Other previously documented success rates of adjusted malpositioned PICCs have been reported at 77%
TABLE I - Catheter types and malposition rate

<table>
<thead>
<tr>
<th>CVADs (n = 7450)</th>
<th>Total CVADs</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>PICC %</td>
<td>3996</td>
<td>53.6</td>
</tr>
<tr>
<td>CICC %</td>
<td>3454</td>
<td>46.4</td>
</tr>
<tr>
<td>Malpositioned catheters %</td>
<td>91 (1.2)</td>
<td></td>
</tr>
<tr>
<td>PICC %</td>
<td>86 (94.5)</td>
<td></td>
</tr>
<tr>
<td>CICC %</td>
<td>5 (5.5)</td>
<td></td>
</tr>
</tbody>
</table>

CVADs = central venous access devices; PICC = peripherally inserted central catheter; CICC = centrally inserted central catheter.

TABLE II - Pre- and post-2010 catheter malposition data

<table>
<thead>
<tr>
<th>CVADs (n = 91)</th>
<th>Pre-2010 (rewired/exchanged) %</th>
<th>Post-2010 %</th>
<th>Rewired/exchanged %</th>
<th>Total HFFT performed %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17 (18.7)</td>
<td>74 (81.3)</td>
<td>21 (28.4)</td>
<td>53 (71.6)</td>
</tr>
</tbody>
</table>

CVADs = central venous access devices; HFFT = high flow flush technique.

TABLE III - Catheter malposition based on side of insertion

<table>
<thead>
<tr>
<th>Malposition vessel n (%)</th>
<th>L) Basilic (PICCs)</th>
<th>R) Basilic (PICCs)</th>
<th>R) Axillary (CICC)</th>
<th>L) Internal jugular (CICC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 (56.6)</td>
<td>20 (37.7)</td>
<td>2 (3.8)</td>
<td>1 (1.9)</td>
</tr>
</tbody>
</table>

PICCs = peripherally inserted central catheters; CICC = centrally inserted central catheter.

Conclusion

Malpositioned catheters that are often considered clinically dubious are generally removed or replaced (potentially after some delay). In some instances, these malpositioned devices can be inappropriately left in place, putting the patient at serious risk of venous thrombosis from vessel injury to more serious complications. This little-known procedure is based on an old maneuver, occasionally adopted in clinical practice—yet it is rarely described in the literature.

This study shows hopeful signs that the use of HFFT demonstrates a suitable and potentially safe and cost-efficient process to reposition CVADs found during the post-insertion review process. This study demonstrated a reduction of potential radiological interventions required to reposition the catheter. This saved considerable time, particularly in patient treatment delays, as well as a relative cost saving compared to more invasive interventions.

Non-invasive techniques, such as HFFT or SRSFT (22) help optimize repositioning of vascular access devices when performed by appropriately trained vascular access teams and other specialist clinicians knowledgeable in this technique. Adding to this is the importance of ECG for catheter tip positioning during the insertion process, which would potentially reduce any primary catheter malposition.

Ongoing research is still essential to evaluate the success of CVAD repositioning using the HFFT in comparison to radiological imaging to reposition the 132 malpositioned catheters, catheter exchange was performed in 76 of the 132 (58%), repositioning in 48 (36%), spontaneous correction occurred in 7 (5%) and one resulted in catheter removal (1%). While most repositions were performed using a guide-wire procedure, there was only a 64% success rate described when performed at the patient’s bedside (24).

The repositioning cost of a catheter utilizing the HFFT was noted to be significantly reduced if the PICC was successfully repositioned on the first flush ($47.62), in comparison to interventional repositioning ($337.20), an overall 86% cost saving (Tab. V). Even performing a bedside rewiring/catheter exchange ($200.55), costs were still significantly reduced, with a savings of $136.65 (40.5%). As the number of HFFT attempts rose, the costs increased, due to additional use of portable CXR to verify each HFFT attempt. However, the costs were still less than implementing fluoroscopic interventions. There was virtually no cost difference ($0.06) when using either prefilled saline syringes or assembled sterile flushing supplies (Tab. VI).
Repositioning of central venous access devices

Table V - Cost differences between IR reposition, bedside rewire and HFFT (%AU)

<table>
<thead>
<tr>
<th>Procedural item costs (2014)</th>
<th>Procedure cost</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoroscopic PICC repositioning</td>
<td>$337.20</td>
<td>$337.20</td>
</tr>
<tr>
<td>Bedside rewiring/exchange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replacement PICC</td>
<td>$138.90</td>
<td>-</td>
</tr>
<tr>
<td>0.032&quot; guidewire</td>
<td>$14.50</td>
<td>-</td>
</tr>
<tr>
<td>Repeat CXR</td>
<td>$47.15</td>
<td>-</td>
</tr>
<tr>
<td>Cost for bedside replacement</td>
<td>$200.55</td>
<td>$136.65</td>
</tr>
<tr>
<td>Use of HFFT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st HFFT (prefilled)</td>
<td>$0.53</td>
<td>-</td>
</tr>
<tr>
<td>Repeat CXR</td>
<td>$47.15</td>
<td>-</td>
</tr>
<tr>
<td>Cost of HFFT</td>
<td>$47.68</td>
<td>$289.52</td>
</tr>
</tbody>
</table>

IR = interventional radiology; HFFT = high flow flush technique; PICC = peripherally inserted central catheter; CXR = chest x-ray.

Table VI - Procedural item costs (%AU) comparing plain and pre-filled syringes

<table>
<thead>
<tr>
<th>Individual item costs</th>
<th>HFFT CXR 0.9% Sodium chloride (10 cc)</th>
<th>Blunt needle</th>
<th>Syringe</th>
<th>CHG/IPA swab</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain syringe</td>
<td>1</td>
<td>$47.15</td>
<td>$0.23</td>
<td>$0.10</td>
<td>$0.02</td>
</tr>
<tr>
<td>2</td>
<td>$94.30</td>
<td>$0.46</td>
<td>$0.20</td>
<td>$0.04</td>
<td>$0.24</td>
</tr>
<tr>
<td>3</td>
<td>$141.45</td>
<td>$0.69</td>
<td>$0.30</td>
<td>$0.06</td>
<td>$0.36</td>
</tr>
<tr>
<td>Prefilled syringe</td>
<td>1</td>
<td>$47.15</td>
<td>-</td>
<td>-</td>
<td>$0.41</td>
</tr>
<tr>
<td>2</td>
<td>$94.30</td>
<td>-</td>
<td>-</td>
<td>$0.82</td>
<td>$0.24</td>
</tr>
<tr>
<td>3</td>
<td>$141.45</td>
<td>-</td>
<td>-</td>
<td>$1.23</td>
<td>$0.36</td>
</tr>
</tbody>
</table>

HFFT = high flow flush technique; CXR = chest x-ray; CHG = chlorhexidine gluconate; IPA = isopropyl alcohol.

to bedside over-wire catheter exchanges and interventional or fluoroscopic repositioning. This straightforward practice-based evidence indicates that this procedure is a relatively safe, cost-efficient intervention to undertake catheter repositioning with minimal delay to patients’ prescribed therapies within either an inpatient or outpatient settings.

Disclosures

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8. Chopra V, OHor JC, Rogers MA, Maki DG, Safdar N. The risk of bloodstream infection associated with peripherally inserted


