Ultrasound-guided central line insertion in children: how much radiation is really needed?

Sofia Vasconcelos-Castro[1], Beatriz Flor-de-Lima[1], and Miguel Soares-Oliveira[1]

[1]Centro Hospitalar Universitário de São João

June 22, 2020

Abstract

Background: A recent survey revealed that most pediatric surgeons use intraoperative fluoroscopy and routine postoperative chest radiography for catheter tip location in central line insertion. The aim of this study is to review all cases of ultrasound-guided central line insertion at a tertiary pediatric center and to evaluate the role of intraoperative fluoroscopy and postoperative chest radiography. Procedure: Retrospective data analysis of children submitted to percutaneous central line insertion under ultrasound control over a 2-year period. Data collected included: age, indication for central venous access, catheter type, usage of intraoperative fluoroscopy and postoperative chest radiography usage, complications, and whether chest radiography dictated any catheter-related intervention. Results: Fifty-five long-term central lines were successfully established. All patients had the catheter tip position confirmed either by intraoperative fluoroscopy (96%), chest radiography (85%) or both (82%). Catheter tip overlying the cardiac silhouette (right atrium) on chest radiography was reported in 4 cases; these findings led to no change in catheter positioning or other catheter-related intervention. There were no catheter-related complications. Conclusions: Percutaneous central line insertion under US-control was safe and effective. Postoperative chest radiography did not dictate any modification of catheter tip positioning after central line placement with ultrasound and fluoroscopic control, thus should not be used routinely.

Introduction

Central venous catheter (CVC) insertion remains a common procedure performed by pediatric surgeons. However, most guidelines for CVC insertion are designed for adult patients[1], resulting in a lack of standardized recommendations for the pediatric population.

A recent survey revealed that most pediatric surgeons use intraoperative fluoroscopy (IF) and routine postoperative chest radiography (CXR) for catheter tip location during/after central line insertion[2].

In an era of a growing concern with children's exposure to radiation, few authors have questioned the need for IF during CVC insertion[3], and others proposed that routine CXR may be unnecessary after uneventful central line insertion under IF control in children[4,5]. In 2016 Dalton et. al published a case series of 622 CVC placed under fluoroscopy: from 81% of patients who did not have postoperative CXR, none had adverse outcomes[5]. These findings, however, did not changed the current practice among pediatric surgeons in many centers[2].

The role of ultrasound (US) guidance for central line insertion has gained importance both in pediatric and adult patients due to higher success rates and fewer complications of cannulation when compared to the landmark technique[4]. Moreover, it has recently been suggested that US may also be useful in bedside detection of catheters' tip location and iatrogenic complications[6,7].

Tip malposition has been suggested as a possible cause of cardiac tamponade and arrhythmia, but evidence on that, particularly on pediatric patients, is still lacking[8,9].

The aim of this study is to review all cases of US-guided long-term CVC insertions in a Pediatric Surgery department over a 2-year period, and to evaluate the necessity of IF and postoperative CXR.

Methods

A retrospective study of data of all pediatric patients (aged 0 to 18 years-old) who underwent percutaneous central line insertion under US control in our department between January 2018 and December 2019 was conducted.

Individual patient data was obtained from electronic medical records. Data collected included patient's age, gender, weight (kilograms) and height (centimeters); indication for central line placement (oncology / nutritional / others); elected vein (left/right internal jugular, left/right subclavian, left/right femoral); history of previous catheter in the chosen vessel; type of central line (tunneled catheter, subcutaneous port, short-term); usage of IF; intraoperative complications; postoperative CXR; whether postoperative CXR dictated further intervention; and postoperative catheter-related complications.

Percutaneous central line insertion was done in all patients using a portable US device (Siemens Medical Solutions USA, Inc) equipped with a high-frequency linear array transducer, under general anesthesia. The procedure was done either by a senior surgeon or a resident under supervision. Preference was given to the right internal jugular vein; vascular US was done before draping in order to exclude intraluminal thrombus. Fluoroscopy was performed intraoperatively as per surgeon preference. Postoperative anterior-posterior inspiratory CXR was obtained after patients' discharge from the recovery room (few hours after the procedure).

Institutional review board approval was obtained. Collected data from patients is anonymized, so there were no ethical implications.

A limitation of this study is possible information bias: it is a retrospective study and data concerning clinical features was obtained from the clinical records.

Results

In the mentioned period, 54 patients underwent 70 CVC insertion under US control. Short-term CVCs were excluded from analysis (15 procedures). Therefore, the final study cohort comprehended 55 procedures in 45 patients (table 1).

The median age was 4 years-old (range 1 month - 17 years), and the majority of central accesses were required due to oncologic disease (84% of patients).

As shown in table 2, all accesses were placed in the internal jugular vein; 11 (20%) cases had a history of previous catheter placement in the selected vein. Tunneled catheters were the most common type of line used (61%).

IF was done in 96% (53/55) of cases.

Intraoperative complications occurred in 4 procedures (7%): arterial puncture (n=2), hematoma (n=1) and line malfunction (n=1); all CVCs were successfully established. In the case complicated by hematoma, there was a need for a second attempt in the contralateral internal jugular vein.

Postoperative CXR was obtained in the majority of cases (85%), including the two cases where IF was not used; of these 2 cases, although one CVC tip was in the cardiac silhouette, the other was seen in the superior vena cava (SVC). In 45 procedures (82%), both IF and CXR were obtained.

In the postoperative CXR, 4 CVC tips (4/47, 8%), were referred as overlying the cardiac silhouette (table 3). Most of them (3/4) had IF performed during the CVC insertion. Those 4 patients were stable and asymptomatic, and a decision not to change the catheter's position was made. There were no early postoperative complications.

While the CVC's were in place, and after a median follow-up of 6 months in those currently still in usage, there was no record of postoperative catheter-related complications, namely pneumothorax, hemothorax, catheter migration/dislodgement, thrombosis, pericardial effusion, cardiac tamponade or arrhythmias.

Discussion

Central venous access insertion remains a frequent procedure performed by pediatric surgeons. It is not risk-free, and mechanical complications such as pneumothorax and hemothorax may occur in 1.6% of children[10].

Catheter tip mispositioning is reported by some authors as occurring in up to 14% of the procedures[11], but debate continues regarding the best location for the final CVC tip position both in the adult and pediatric populations: it is generally assumed that a short CVC placed within the SVC is more prone to intravascular repositioning and thrombosis; whereas a catheter tip placed lower within the pericardium could potentially erode it and cause serious complications[12]. However, reports in the literature regarding CVC tip-related complications are almost nonexistent[13].

The ESPGHAN guidelines for vascular access in children, the only officially published recommendations for the pediatric population, recommend that the CVC tip should be placed in the SVC outside the pericardial sac in order to avoid pericardial effusion[14]. This recommendation is based on scarce reports of cardiac tamponade secondary to pericardial effusion in neonatal patients with catheter tip positioned inside the right atrium (RA)[15]. However, a review conducted in 2015 revealed that catheter-related cardiac tamponade in children is rare (<0.7/1000 procedures) and occurs mostly during CVC insertion (vessel/heart perforation after cannulation without US control, introduction of the stiff end of the guidewire instead of the J-tip, guidewire and/or dilator inserted far too deep, etc.) and are not related with the final position of the tip of the catheter[9]. Similarly, it has been largely assumed that a CVC inside the RA represents an increased risk of developing cardiac dysrhythmias. The majority of reports on arrhythmias associated with central lines in children state that those happen during the CVC insertion procedure, but there are no reports of children with cardiac dysrhythmias secondary to intracardiac CVC tip. In resemblance to CVC-related pericardial effusion, the only report on CVC-related tachycardia is on a neonatal group of 13 subjects who suffered cardiac arrhythmias either during CVC insertion or after catheter's tip migration[8].

Given the conflicting evidence, and as suggested by Perin and Scarpa in 2015, the current recommendation of tip positioning in the SVC or the SVC-RA in children is based in common sense and on a precautionary principle only[16]. Reports on vessel wall perforation have not been reported in adult patients over the last 20 years, and those on children seem to be related to vessel lesion during catheter insertion[9]. Moreover, as mentioned above, life threatening cardiac arrhythmias in children are only described during CVC insertion, and are usually detected and corrected intraoperatively by simple catheter withdrawal[12].

There are several methods for determining the final catheter tip location: either by anatomical landmarks, but also using the patients' height and body surface area[3,14,17,18]. Either IF, CXR, US and electrocardiography have been suggested as valid methods to determine final tip positioning[7,16,19]. However, considering that the tip commonly moves up and down for 2 cm during breathing, during movements of the arm, with change of body posture from supine to standing and with high-flow infusions[9], static evaluation becomes even more challenging in children in whom a 2 cm gap can make a difference in correct tip location.

Besides having a longer life expectancy, pediatric patients are up to 10 times more radio-sensitive than adults[20]. Moreover, lifetime radiation cancer risk is three times greater when exposure occurs in early childhood than it is after the age of 35[21]. So, it seems only logical that every effort should be made to reduce these children's exposure to radiation[22].

In our study, we showed that postoperative CXR resulted in no change in the management of any patient after US-guided central line placement. This is a strong evidence that this exam could be omitted, as previously suggested by others[5,10,23]. In addition, intracardiac tip positioning determined by CXR was reported in 4 cases (in 3 cases IF did not prevent this mispositioning), but in all these patients the central line was maintained and used fully, with no record of complications. Again, CXR did not alter the course of any of

these patients.

A recent survey revealed that the majority of pediatric surgeons still use IF and postoperative CXR to evaluate the final catheter tip position[2]. However, in light of the existing data regarding almost nonexistent CVC tip-related complications (apart from newborns), the difficulty in interpreting static imaging, and concerns regarding children's exposure to radiation, this practice should be questioned.

Nowadays the superiority of US-guided central line placement is well established: when compared to the landmark technique, US-guided procedures are associated with higher first insertion attempt success rate, fewer procedural complications, higher overall successful cannulation rate, shorter operative times and reduced costs[4,14,24]. Our study reinforces the efficacy and safety of US: all but one cannulation was successful in the first attempt, there were only records of 3 intraoperative minor complications related to puncture (2 arterial punctures and 1 venous hematoma), and there were no postoperative complications (such as pneumothorax, hemothorax or cardiac tamponade).

Recently, there are promising reports on the usage of US both to verify CVC tip position and to recognize postoperative complications such as pneumothorax and hemothorax[6,7,11].

Conclusions

Percutaneous central vein insertion under US-control is safe and effective.

Intraoperative fluoroscopy, although important for tip final position confirmation, did not prevent mispositioning.

Postoperative chest radiography did not dictate any modification of catheter tip positioning after central line placement under ultrasound-control and intraoperative fluoroscopy, and so should not be used routinely.

Central vein cannulation under US-control may become the preferred method for central line insertion with no need for further image-control procedures, but more studies are needed.

Conflict of Interest Statement

No conflicts to declare.

Acknowledgments

Thank you to Professor Tiago Henriques-Coelho, for his forever inspiring spirit.

References

1. Sousa B, Furlanetto J, Hutka M, et al. Central venous access in oncology: ESMO Clinical Practice Guidelines. *Annals of oncology : official journal of the European Society for Medical Oncology.* 2015;26 Suppl 5:v152-168. doi: 10.1093/annonc/mdv296

2. Cunningham AJ, Krishnaswami S, Radu S, Hamilton NA. Contemporary postoperative imaging practices among pediatric surgeons for image-guided central venous line placement: A survey of the American Pediatric Surgical Association. *Journal of pediatric surgery.*2020;55(6):1123-1126. doi: 10.1016/j.jpedsurg.2020.02.039

3. Dore M, Barrena S, Triana Junco P, Sánchez Galán A, Jimenez Gomez J, Martinez L. Is Intraoperative Fluoroscopy Necessary for Central Venous Port System Placement in Children? *European journal of pediatric surgery : official journal of Austrian Association of Pediatric Surgery [et al] = Zeitschrift fur Kinderchirurgie.* 2019;29(1):108-112. doi: 10.1055/s-0038-1675773

4. Bowen ME, Mone MC, Nelson EW, Scaife CL. Image-guided placement of long-term central venous catheters reduces complications and cost.*American journal of surgery.* 2014;208(6):937-941; discussion 941. doi: 10.1016/j.amjsurg.2014.08.005

5. Dalton BG, Gonzalez KW, Keirsy MC, Rivard DC, St Peter SD. Chest radiograph after fluoroscopic guided line placement: No longer necessary. *Journal of pediatric surgery.* 2016;51(9):1490-1491. doi:

10.1016/j.jpedsurg.2016.02.003

6. Smit JM, Raadsen R, Blans MJ, Petjak M, Van de Ven PM, Tuinman PR. Bedside ultrasound to detect central venous catheter misplacement and associated iatrogenic complications: a systematic review and meta-analysis. *Critical care (London, England).* 2018;22(1):65. doi: 10.1186/s13054-018-1989-x

7. Zaghloul N, Watkins L, Choi-Rosen J, Perveen S, Kurepa D. The superiority of point of care ultrasound in localizing central venous line tip position over time. *European journal of pediatrics.*2019;178(2):173-179. doi: 10.1007/s00431-018-3269-9

8. Amer A, Broadbent RS, Edmonds L, Wheeler BJ. Central Venous Catheter-Related Tachycardia in the Newborn: Case Report and Literature Review. *Case reports in medicine.* 2016;2016:6206358. doi: 10.1155/2016/6206358

9. Pittiruti M, Lamperti M. Late cardiac tamponade in adults secondary to tip position in the right atrium: an urban legend? A systematic review of the literature. *Journal of cardiothoracic and vascular anesthesia.* 2015;29(2):491-495. doi: 10.1053/j.jvca.2014.05.020

10. Janik JE, Cothren CC, Janik JS, et al. Is a routine chest x-ray necessary for children after fluoroscopically assisted central venous access? *Journal of pediatric surgery.* 2003;38(8):1199-1202. doi: 10.1016/s0022-3468(03)00267-7

11. Oliveira L, Pilz L, Tognolo CM, et al. Comparison between ultrasonography and X-ray as evaluation methods of central venous catheter positioning and their complications in pediatrics.*Pediatric surgery international.* 2020;36(5):563-568. doi: 10.1007/s00383-020-04642-y

12. Jamshidi R. Central venous catheters: Indications, techniques, and complications. *Seminars in pediatric surgery.* 2019;28(1):26-32. doi: 10.1053/j.sempedsurg.2019.01.005

13. Roldan CJ, Paniagua L. Central Venous Catheter Intravascular Malpositioning: Causes, Prevention, Diagnosis, and Correction. *The western journal of emergency medicine.* 2015;16(5):658-664. doi: 10.5811/westjem.2015.7.26248

14. Kolaček S, Puntis JWL, Hojsak I. ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition: Venous access. *Clinical nutrition (Edinburgh, Scotland).* 2018;37(6 Pt B):2379-2391. doi: 10.1016/j.clnu.2018.06.952

15. Weil BR, Ladd AP, Yoder K. Pericardial effusion and cardiac tamponade associated with central venous catheters in children: an uncommon but serious and treatable condition. *Journal of pediatric surgery.* 2010;45(8):1687-1692. doi: 10.1016/j.jpedsurg.2009.11.006

16. Perin G, Scarpa MG. Defining central venous line position in children: tips for the tip. *The journal of vascular access.*2015;16(2):77-86. doi: 10.5301/jva.5000285

17. Andropoulos DB, Bent ST, Skjonsby B, Stayer SA. The optimal length of insertion of central venous catheters for pediatric patients.*Anesthesia and analgesia.* 2001;93(4):883-886. doi: 10.1097/00000539-200110000-00016

18. Witthayapraphakorn L, Khositseth A, Jiraviwatana T, et al. Appropriate length and position of the central venous catheter insertion via right internal jugular vein in children. *Indian pediatrics.*2013;50(8):749-752. doi: 10.1007/s13312-013-0217-7

19. Simon L, Teboul A, Gwinner N, Boulay G, Cerceau-Delaporte S, Hamza J. Central venous catheter placement in children: evaluation of electrocardiography using J-wire. *Paediatric anaesthesia.*1999;9(6):501-504. doi: 10.1046/j.1460-9592.1999.00422.x

20. Linet MS, Kim KP, Rajaraman P. Children's exposure to diagnostic medical radiation and cancer risk: epidemiologic and dosimetric considerations. *Pediatric radiology.* 2009;39 Suppl 1(Suppl 1):S4-26. doi: 10.1007/s00247-008-1026-3

21. Royal HD. Effects of low level radiation-what's new? *Seminars in nuclear medicine.* 2008;38(5):392-402. doi: 10.1053/j.semnuclmed.2008.05.006

22. Strauss KJ, Kaste SC. The ALARA (as low as reasonably achievable) concept in pediatric interventional and fluoroscopic imaging: striving to keep radiation doses as low as possible during fluoroscopy of pediatric patients–a white paper executive summary. *Radiology.*2006;240(3):621-622. doi: 10.1148/radiol.2403060698

23. Cunningham AJ, Haag MB, McClellan KV, Krishnaswami S, Hamilton NA. Routine Chest Radiographs in Children After Image-Guided Central Lines Offer Little Diagnostic Value. *The Journal of surgical research.*2020;247:234-240. doi: 10.1016/j.jss.2019.10.019

24. Criss CN, Gadepalli SK, Matusko N, Jarboe MD. Ultrasound guidance improves safety and efficiency of central line placements. *Journal of pediatric surgery.* 2019;54(8):1675-1679. doi: 10.1016/j.jpedsurg.2018.08.039

Hosted file

`Table 1.docx` available at https://authorea.com/users/335762/articles/461567-ultrasound-guided-central-line-insertion-in-children-how-much-radiation-is-really-needed

Hosted file

`Table 2.docx` available at https://authorea.com/users/335762/articles/461567-ultrasound-guided-central-line-insertion-in-children-how-much-radiation-is-really-needed

Hosted file

`Table 3.docx` available at https://authorea.com/users/335762/articles/461567-ultrasound-guided-central-line-insertion-in-children-how-much-radiation-is-really-needed