ORIGINAL ARTICLE

ULTRASOUND-GUIDED CENTRAL LINE INSERTION IN CHILDREN: HOW MUCH IMAGING IS REALLY NEEDED?

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Abstract

Introduction: *A recent survey revealed that most pediatric surgeons use intraoperative fluoroscopy and routine postoperative chest radiography for catheter tip location in central line placement. The aim of this study is to review all cases of ultrasound-guided central line placements and to evaluate the role of postoperative chest radiography.*

Methods: *Retrospective data analysis of children submitted to percutaneous central line insertion under ultrasound control over a 2-year period in a pediatric surgery department. Data collected included: age, indication for central venous access, catheter type, usage of intraoperative fluoroscopy and postoperative chest radiography, complications, and whether chest radiography dictated any catheter-related intervention.*

Results: *Fifty-five long-term central lines were successfully established in children aged between 1 month and 17 years. 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 is safe and effective even in small children. Postoperative chest radiography did not dictate any modification of catheter tip positioning after central line placement with ultrasound and fluoroscopic control or identified any other complication, thus should not be used routinely.*

Keywords: *pediatrics, central line, ultrasound, chest radiography*

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 paucity 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 placement [2]. In an era of a growing concern with children's exposure to radiation, few authors proposed that routine CXR may be expendable after uneventful central line insertion under IF control in children[3-5].

The role of ultrasound (US) guidance for central line insertion has gained importance first in adults and then in the pediatric population due to higher success rates and

fewer complications of cannulation when compared to the landmark technique [3].

Tip malposition has been suggested as a possible cause of cardiac tamponade and arrhythmia, but evidence on that, particularly on pediatric patients, is scarce [6, 7].

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, to evaluate the technique's efficacy and safety and to determine the value of postoperative CXR.

MATERIALS AND 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 (cm); indication for central line placement (oncology / nutritional / others); selected vein (left/right internal jugular); 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 US (7.5 MHz linear array transducer; Siemens Medical Solutions USA, Inc) control 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. The chosen vein is identified and then punctured under ultrasound vision just above the clavicle, observing the tip of the needle within the vessel lumen. A guidewire is then passed. A dilator with peel-away sheath is passed over the guidewire using a Seldinger technique. Finally, the guidewire is removed, and the catheter passed via the peel away sheath to its final position. Fluoroscopy was performed intraoperatively as per surgeon preference. Central catheters were tunneled subcutaneously to the anterior chest. Totally implantable venous access devices were secured to the pectoral fascia in a subcutaneous pocket with three to four nonabsorbable sutures. Postoperative anterior-posterior inspiratory CXR was obtained after patients' discharge from the recovery room (a 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

Table 1 **Patients' demographics**

	Total (n=55)
Age, years (median, range and [IQR])	4 [0.1-17.8] [1.7;11.5]
Male gender, No. (%)	36 (65)
Weight (kg) (median, range and [IQR])	18 [4-93] [11;37]
Height (cm) (median, range and [IQR])	129 [66-184] [90;160]
BMI (kg/m2) (median, range and [IQR])	17 [13-31] [15.1;18.2]
Indication for central line, No. (%)	
Oncology	46 (84)
Nutrition	6 (11)
Others	3 (5)

BMI, body mass index; IQR, interquartile range.

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). Eleven patients weighted 10kg or less (table 2).

As shown in table 3, 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 cases complicated by hematoma and line malfunction, there was a need for a second attempt in the contralateral internal jugular vein.

Postoperative CXR was obtained in the majority of cases (84%), 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 44 procedures (80%), both IF and CXR were obtained.

In the postoperative CXR, 4 CVC tips (4/47, 8%), were referred as overlying the cardiac silhouette (table 4). 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 immediate postoperative complications.

While the CVC's were in place, and after a median follow-up of 8 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 complications such as pneumothorax and hemothorax may occur in 1.6% of children [8].

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[3,9,10]. These advantages have also been demonstrated in small children [11, 12]. Our series reinforces the efficacy and safety of this procedure in children, even in those with 10kg or less: all but one cannulation was successful in the first attempt; there were only 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).

There are promising reports on the usage of US both to verify CVC tip position and to monitor postoperative complications such as pneumothorax and hemothorax[13-15]. However, a recent survey revealed that the majority of pediatric surgeons still rely on postoperative CXR to identify postoperative technical complications and to evaluate the final catheter tip position[2]. In our cohort, 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. In fact, some authors [4,5,8] have previously suggested this attitude: in 2003, Janik et. al suggested that postoperative CXR should only be done in symptomatic patients after central line placement using IF[8]. More recently, Cunningham et. al compared patients in whom postoperative CXR was routinely performed with those evaluated only if clinically adequate, and they concluded that postoperative CXR adds minimal value in diagnosing severe complications after CVC insertion guided by US, IF or both [4].

Catheter tip mispositioning is reported by some authors as occurring in up to 14% of the procedures[13], but debate continues regarding the best location for the final CVC tip location 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 cause pericardial effusion or arrythmias [16]. However, reports in literature regarding CVC complications related to final tip positioning are almost nonexistent [17]. A review conducted in 2015 revealed that catheter-related cardiac tamponade in children is rare (<0.7/1000 procedures, with the majority of cases reported in infants younger than 1 year of age), that it 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 and guidewire and/or dilator inserted far too deep) and is not related with the final

Table 2 **Patients with 10kg or less**

Weight (kg)	Vein	CVC type	IF?	Postoperative CXR?	CVC's tip location on CXR	CVC-related complications
8	RIJ	Port	Yes	Yes	SVC-RA	No
4	LIJ	Tunneled	Yes	Yes	SVC-RA	No
4	RIJ	Tunneled	Yes	No	n/a	No
9	RIJ	Tunneled	Yes	Yes	SVC-RA	No
9	RIJ	Tunneled	Yes	Yes	SVC-RA	No
9	RIJ	Port	Yes	Yes	RA	No
8	RIJ	Port	Yes	Yes	SVC	No
7	RIJ	Tunneled	Yes	No	n/a	No
6	RIJ	Tunneled	Yes	Yes	SVC	No
10	RIJ	Tunneled	Yes	No	n/a	No
8	RIJ	Tunneled	Yes	No	n/a	No

CXR, chest radiography; LIJ, left internal jugular; n/a, not applicable; RA, right atrium; RIJ, right internal jugular; SVC, superior vena cava; SVC-RA, superior vena cava and right atrium transition

Table 3 **Procedures' summary**

	No. (%)
Vein selected	
Right internal jugular	42 (76)
Left internal jugular	13 (24)
Type of central line	
Tunneled catheter	34 (62)
Subcutaneous port	21 (38)
Usage of intraoperative fluoroscopy	53 (96)
Intraoperative complications	4 (7)
Postoperative CXR	47 (85)
Re-intervention after CXR	0 (0)
Postoperative catheter-related complications	0 (0)

CXR, chest radiography

position of the tip of the catheter[7]. Moreover, reports on vessel wall perforation have not been reported in adults over the last 20 years, and those reported on children seem to be directed related to vessel lesion during the procedure of catheter insertion[7]. Similarly, the majority of arrhythmias associated with central lines in children are reported to occur during the CVC insertion procedure, and there are no reports of children with cardiac dysrhythmias secondary to intracardiac CVC tip. In resemblance to CVC-related cardiac tamponade, 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[6].

Given this conflicting evidence, and as suggested by Perin and Scarpa in 2015, the current recommendation of tip positioning in the SVC or in the SVC-RA in children is based in common sense and on a precautionary principle only[18]. As shown in table 4, intracardiac tip positioning determined by CXR was reported in 4 cases of this cohort (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 complication.

Static determination of the final catheter tip location has several pitfalls: the CVC 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[7]. Three of the 4 patients with reported intracardiac CVC tip on postoperative CXR had an IF performed during the CVC insertion that did not prevent this. This may be explained by the CVC tip physiologic motion (with breathing movements).

When compared to adults, besides having a longer life expectancy, pediatric patients receive higher radiation doses: their organs and tissues are smaller and thinner, and organs are closer together; this way, scattered radiation from the primary beam can reach adjacent organs and tissues more easily in children than in adults[19]. Moreover, lifetime radiation cancer risk is three times greater when exposure occurs in early childhood than it is after the age of 35[20].

According to all the presented data and to reduce children's exposure to unnecessary radiation, we advocate that postoperative CXR should not be performed routinely but only when clinically adequate; and the evaluation of the final CVC tip location is essential in neonatal patients only. Moreover, static imaging should not be the preferred method to determine the final CVC tip location.

CONCLUSIONS

Percutaneous central vein insertion under US-control is safe and effective in pediatric patients, even in small children.

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.

Table 4 **Patients' with mispositioned CVC on CXR**

	Age, Gender	Vein	CVC type	IF?	CVC's tip location on CXR	Duration of CVC utilization	CVC-related complications
1	4y, F	RIJ	Port	Yes	RA	Still in usage	No
2	1y, M	RIJ	Tunneled	Yes	RA	2y *	No
3	6m, F	RIJ	Port	Yes	RA	Still in usage	No
4	1, M	RIJ	Tunneled	No	RA	1m *	No

** accidental CVC removal; F, female; M, male; m, months; RA, right atrium; RIJ, right internal jugular; y, years.*

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