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Research Article

Evaluating Complications of Cuffed Tunneled Central Venous Catheters in Pediatric Patients: A Systematic Review

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Abstract

Introduction: Cuffed Tunneled Central Venous Catheters (ctCVCs) are widely used in pediatric patients for chemotherapy, nutrition, dialysis, and antibiotics. While prior reviews have examined various catheter complications, a focused review on ctCVC safety in children is lacking. Thus, the objective of this systematic review is to evaluate the immediate and long-term complications of ctCVC sites in pediatric patients.

Methods: A systematic review of original research studies reporting the use of ctCVCs in patients < 18 years of age was performed. Inclusion criteria were papers published in English, since 2000, involving ctCVCs, and including only the pediatric population (< 18). Descriptive data analysis was performed across key themes based on the research questions. Study quality was evaluated using the Mixed Methods Appraisal Tool.

Results: Of the 738 studies identified through database searches, six studies met final criteria for inclusion. Studies included a total of 1,581 patients with a total of 1,713 ctCVCs placed. Average age was 2.2 years and 52.3% were male. Of the 1,713 ctCVCs placed, 1,660 were placed in the internal jugular vein (96.9%), 48 were placed in the femoral vein (2.8%), two were placed in the subclavian vein (.12%), and three were placed in another vein (.18%). Average duration of IJ insertions was 179.1 days while average duration of femoral insertions was 24 days. There were a total of 320 long term complications associated with IJ insertion (19%). There were a total of eight long term complications associated with femoral insertion (17%).

Conclusion: IJ vein remains the predominant site for ctCVC placement in pediatric patients. However, our review highlights the potential benefits of femoral access, particularly in terms of safety profile during placement. These findings emphasize the need for continued research to optimize ctCVC site selection and improve patient outcomes.

Introduction

Ensuring dependable vascular access in pediatric patients, particularly ill neonates, provides many challenges due to the small and delicate nature of their peripheral vasculature [1]. To establish temporary venous access in this population, Peripheral Intravenous Lines (PIVs), Umbilical Venous Catheters (UVCs), and Percutaneously Inserted Central Venous Catheters (PICCs) are commonly utilized [2]. Oftentimes, pediatric patients with chronic illnesses require long-term medications and infusions. These substances can irritate veins, thus current guidelines recommend administration via a Central Venous Access Device (CVAD) to protect the patient's peripheral veins and improve long term outcomes [3]. Placement of Cuffed Tunneled Central Venous Catheters (ctCVCs) is a routine procedure performed by pediatric surgeons. ctCVCs differ from PICCs in that they travel under the skin away from the point of entry into the vein before exiting the skin [4]. Additionally the cuff allows for internal fixation as tissue ingrowth takes place thus providing a theoretical antimicrobial

barrier and improved mechanical stability [4]. Common indications for ctCVC insertion include chemotherapy, parental nutrition, hemodialysis, and antibiotic administration [5]. Popular ctCVCs include Broviacs, Hickmans, Groshongs, and Permcaths [5]. Prior systematic reviews have explored complications associated with different catheter types and insertion techniques, including comparisons between peripheral arm ports and central chest ports [6], multiple versus single lumen umbilical venous catheters [7], and the efficacy of ultrasound-guided cannulation [8]. While reviews have investigated the relationship between tunneled central venous catheter locations and complication rates [4], a comprehensive systematic review specifically examining the safety of ctCVC sites in children has not been conducted. The objective of this systematic review is to evaluate the immediate and long-term complications of ctCVC sites in pediatric patients.

Methods

A systematic review of original research studies reporting the use of ctCVCs in patients < 18 years of age was performed. Our research question was as follows: How do the immediate and long term complication rates of ctCVCs compare depending on insertion site? This review follows the methodological framework for systematic reviews and is reported in alignment with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Figure 1) [9]. MeSH terms and keywords were used to construct a systematic search involving the following databases: PubMed, Embase, Web of Science, Cochrane, and CINAHL (Table 1). Inclusion criteria were randomized control trials or cohort studies published in English, since 2000, involving ctCVCs, and including only the pediatric population (< 18 years of age). Exclusion criteria included systematic reviews or case reports, unpublished studies including conference proceedings and studies in which ctCVC data could not be distinguished from non-ctCVCs (Table 2). Immediate complications were defined as complications occurring during ctCVC insertion (i.e. inadvertent arterial puncture or damage to other surrounding structures). Long term complications were further separated into infectious complications (Central Line Associated Bloodstream Infections (CLABSI)) and mechanical complications (i.e. thrombosis, tip fragmentation, catheter dislocation, obstruction, or leak). Descriptive data analysis was performed independently by two separate investigators across key themes based on the research question described above. Disagreements were resolved by consultation within the team. Study quality was evaluated independently by two separate investigators using the Mixed Methods Appraisal Tool (Table 3) [10].

Database	Search strategy
Pubmed	(Tunneled central venous catheter OR Broviac catheter OR Groshong catheter OR ("Central Venous Catheters/adverse effects"[Mesh] OR "Central Venous Catheters/standards"[Mesh] OR "Central Venous Catheters/trends"[Mesh]) OR Hickman catheter)) AND (Complication OR Infection OR clot OR dislodgement OR leak OR mortality OR ("Patient Outcome Assessment"[Mesh]) AND (Pediatrics OR Child OR adolescent OR teen OR infant OR newborn OR neonate OR ("Intensive Care Units, Pediatric/statistics and numerical data"[Mesh] OR "Intensive Care Units, Pediatric/trends"[Mesh])) Filters: Child: birth-18 years, from 2000 - 2024
Cochrane Library	(Pediatric OR Child OR adolescent OR teen OR infant OR newborn OR neonate) AND (Tunneled central venous catheter OR Broviac catheter OR Groshong catheter OR Hickman catheter) AND (Complication Infection OR clot OR dislodgement OR leak OR mortality)
Web of Science	ALL=((Pediatric OR Child OR adolescent OR teen OR infant OR newborn OR neonate) AND (Tunneled central venous catheter OR Broviac catheter OR Groshong catheter OR Hickman catheter) AND (Complication Infection OR clot OR dislodgement OR leak OR mortality) AND (subclavian OR internal jugular OR femoral))

Embase	('pediatric'/exp OR pediatric OR 'child'/exp OR child OR 'adolescent'/exp OR adolescent OR teen OR 'infant'/exp OR infant OR 'newborn'/exp OR newborn OR 'neonate'/exp OR neonate) AND ('tunneled central venous catheter'/exp OR 'tunneled central venous catheter' OR (tunneled AND ('central'/exp OR central) AND venous AND ('catheter'/exp OR catheter)) OR 'broviac catheter'/exp OR 'broviac catheter' OR (('broviac'/exp OR broviac) AND ('catheter'/exp OR catheter)) OR 'groshong catheter' OR (('groshong'/exp OR groshong) AND ('catheter'/exp OR catheter)) OR 'hickman catheter'/exp OR 'hickman catheter' OR (('hickman'/exp OR hickman) AND ('catheter'/exp OR catheter))) AND ('complication'/exp OR complication OR 'infection'/exp OR infection OR clot OR 'dislodgement'/exp OR dislodgement OR 'leak'/exp OR leak OR 'mortality'/exp OR mortality) AND (subclavian OR 'internal jugular' OR (internal AND jugular) OR femoral)
CINAHL	(Pediatric OR Child OR adolescent OR teen OR infant OR newborn OR neonate) AND (Tunneled central venous catheter OR Broviac catheter OR Groshong catheter OR Hickman catheter) AND (Complication Infection OR clot OR dislodgement OR leak OR mortality) AND (subclavian OR internal jugular OR femoral)

Table 1: Search Strategies.

Inclusion criteria	Exclusion criteria
randomized control trials or cohort studies	systematic reviews or case reports
published in English	unpublished studies including conference proceedings
since 2000	studies in which ctCVC data could not be distinguished from non-ctCVCs
pediatric population (< 18)	
involving only ctCVCs	

Table 2: Inclusion and exclusion criteria.

Criterion	Murai et al.[11]	Arul et al.[12]	Alshafei et al.[13]	Lopez et al.[14]	Martynov et al.[15]	Soundappan et al.[16]
Are there clear research questions?	Yes	Yes	Yes	Yes	Yes	Yes
Do the collected data allow to address the research questions?	Yes	Yes	Yes	Yes	Yes	Yes
Are the participants representative of the target population?	Yes	Yes	Yes	Yes	Yes	Yes
Are measurements appropriate regarding both the outcome and exposure?	Yes	Yes	Yes	Yes	Yes	NA
Are there complete outcome data?	Yes	Yes	Yes	Yes	Yes	Yes

Are the confounders accounted for in the design and analysis?	Yes	Yes	Yes	Yes	Yes	Yes
During the study period, is the intervention administered (or exposure occurred) as intended?	Yes	Yes	Yes	Yes	Yes	Yes
Is randomization appropriately performed?	No	No	NA	NA	NA	Yes
Are the groups comparable at baseline?	Yes	Yes	Yes	Yes	Yes	Yes
Are outcome assessors blinded to the intervention provided?	Yes	Yes	Yes	Yes	Yes	Yes

Table 3: Quality appraisal as per MMAT.

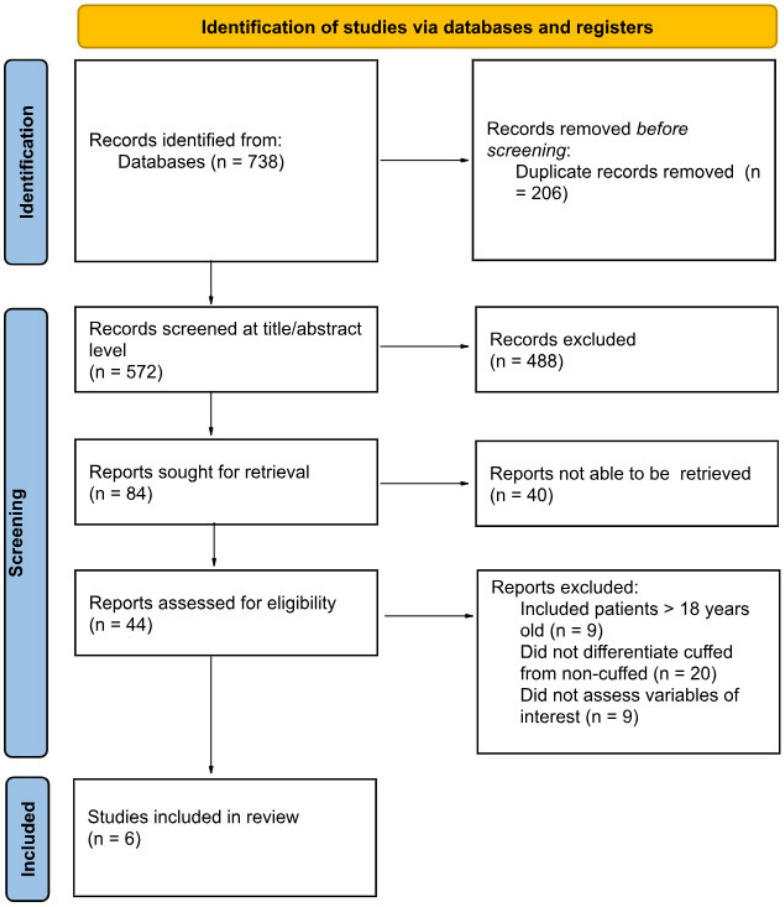

Figure 1: PRISMA 2020 flow diagram for new systematic reviews.

Results

Of the 738 studies identified through database searches, six studies met final criteria for inclusion (Figure 1). Study quality across all papers was determined to be sufficient using the MMAT (Table 1). This included one single-blinded randomized control trial, two prospective cohort studies, and three retrospective case control studies (Table 4). Common indications for ctCVC insertion included chemotherapy, total parenteral nutrition, hemodialysis, and antibiotic administration. Studies included a total of 1,581 patients with a total of 1,713 ctCVCs placed. Average age was 2.2 years and 52.3% were male. Of the 1,713 ctCVCs placed, 1,660 were placed in the internal jugular vein (96.9%), 48 were placed in the femoral vein (2.8%), two were placed in the subclavian vein (.12%), and three were placed in another vein (.18%). Average duration of IJ insertions was 179.1 days while average duration of femoral insertions was 24 days. There were a total of 52 immediate complications with IJ insertion (3.1%) and zero immediate complications with femoral insertion (0%). There were a total of 320 long term complications associated with IJ insertion (19%). There were a total of eight long term complications associated with femoral insertion (17%) (Table 5).

Author	Year	Study Design	Average age (years)	Total patients, N	Total ctCVC, N
Soundappan et al.[16]	2021	Single-blinded randomized controlled trial	6.4	108	108
Martynov et al.[15]	2018	Retrospective cohort	1.9	238	273
Lopez et al.[14]	2014	Retrospective cohort	1.1	11	31
Alshafei et al.[13]	2018	Retrospective cohort	1.2	761	690
Arul et al.[12]	2009	Prospective cohort	1.8	403	500
Murai et al.[11]	2002	Prospective cohort	0.58	60	111

Table 4: Study Characteristics.

	Soundappan et al.[16]	Martynov et al.[15]	Lopez et al.[14]	Alshafei et al.[13]	Arul et al.[12]	Murai et al.[11]
Sample size (catheter placements)	108 (108)	238 (273)	11 (31)	761 (690)	403 (500)	60 (111)
IJ placements	108	270	28	690	500	64
IJ duration in days	301.2	188	210	210	47	17
IJ immediate complications	11	35			6	
IJ infection complications	12	19	3	70	47	6
IJ mechanical complications	1	58	11	45	47	2
Femoral placements			1			47
Femoral duration in days						24
Femoral immediate complications			0			

Femoral infection complications			0			6
Femoral mechanical complications			1		1	2

Table 5: ctCVC characteristics and complications.

Discussion

This is the first systematic review to compare complications between ctCVC sites in the pediatric population. Our review analyzed 1,713 ctCVC placements across 1,581 children with a clear preference for the IJ vein, with 96.9% of ctCVCs placed in this site. This preference may be attributed to the IJ vein's ease of access and lower risk of pneumothorax compared to the subclavian vein. However, this high utilization is not without its drawbacks. The average duration of IJ catheterization was 179.1 days, during which 19% of cases experienced long-term complications. These complications most commonly included Central Line-Associated Bloodstream Infections (CLABSI), thrombosis, and dislocation. Rates of infectious complications and mechanical complications were similar at 9.5% and 9.9% respectively. In the studies that reported immediate complication rates there was an average immediate complication rate of 5.9%. The most common immediate complications associated with the IJ vein included pneumothorax and puncture of internal carotid artery. While femoral vein ctCVC placements were significantly less common (2.8% of cases), the complication rate for femoral placements was 17%, with a 0% immediate complication rate in the one study that reported this outcome. However, it is important to note the average duration of catheter use was significantly shorter at 24 days. Unfortunately, the authors did not provide an explanation for this shorter duration. Rates of infectious complications and mechanical complications in femoral placement were similar at 12.5% and 8.3% respectively. However, the lower complication rate observed in femoral placements is likely influenced by the shorter duration of catheter use, highlighting a need for further research into the long-term safety of this approach.

Several studies have demonstrated that femoral lines placed with a traditional approach near the inguinal crease carry a higher risk of infection due to the close proximity to the groin and diaper region [17-19]. However, ctCVCs theoretically circumvent this risk as the site at which the catheter exits the skin is tunneled away from the groin and diaper region. Additionally, advantages of femoral access include the reduced need for paralysis and mechanical ventilation during insertion, as well as a lower risk of mechanical damage to adjacent structures [19,20]. These benefits are particularly pertinent in pediatric patients, who may face greater risks from sedation and immobilization. Additionally,in neonates and infants weighing 5 kg or less, the internal jugular vein is often very small (typically under 5 mm) and compressible, making IJ access technically more difficult when compared to femoral access [21]. However, it is important to note the popularization of ultrasound guidance has improved the safety of central line placement at all anatomical sites [16].

Despite the insights provided by this review, several limitations must be acknowledged. The included studies varied in design, with only one single-blinded randomized controlled trial among them, and the remainder comprising prospective and retrospective cohort studies. While less time-consuming and more cost-effective, due to the nature of retrospective studies there is a risk of missing data due to selective reporting. This heterogeneity in study design and quality, as well as potential biases in retrospective analyses, may affect the generalizability of our findings. Another major limitation of this study involves the low number of femoral access sites as well as the shorter average duration with femoral sites making it difficult to accurately compare to IJ access sites. However, given the promising findings regarding femoral vein access, further high-quality research is essential to validate its safety and efficacy relative to IJ placements. Randomized controlled trials specifically comparing immediate and long-term outcomes of IJ and femoral ctCVC placements in pediatric patients would provide robust evidence to inform clinical practice.

Conclusion

IJ vein remains the predominant site for ctCVC placement in pediatric patients. However, our review highlights the potential benefits of femoral access, particularly in terms of safety profile during placement. These findings emphasize the need for continued research to optimize ctCVC site selection and improve patient outcomes. By addressing the limitations of current studies and exploring innovative solutions, we can enhance the care provided to pediatric patients requiring long term central venous access.

Declarations

Ethics Approval and Consent to Participate: Not applicable.

Consent for Publication: Not applicable.

Competing Interests: All contributing authors declare no conflicts of interest.

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Authors' Contributions: Conception and design of study: AH, AM, BS; Acquisition of data: AH, AM, AC; Analysis of data:

AH, TP, AM; Drafting of manuscript: AH, TP, AC; Revising the manuscript for critically important intellectual content: AM, BS; Approval of final version: AH, AM, AC, TP, BS.

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