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Original Article

Central Venous Catheter-related Complications in a Paediatric Neurosurgical Population: A Retrospective Study

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ABSTRACT

Aim: Central venous catheters (CVCs) are frequently used in paediatric neurosurgical procedures but are also associated with potentially serious complications. Sometimes, these complications are life-threatening or require the premature removal of the CVC, which may impair medical care. The aim of this study was to evaluate the incidence and characteristics of CVC-related complications in a paediatric neurosurgical population and to identify factors associated with their occurrence.

Materials and Methods: We conducted a retrospective observational study including children who underwent neurosurgical procedures under general anaesthesia with intraoperative CVC placement at a single tertiary hospital between January 2017 and January 2022. Demographic data, clinical characteristics, catheter-related variables, and complications were collected from the electronic medical records. Complications were classified as either immediate or delayed. Associations between patient- and procedure-related factors and the occurrence of complications were analysed using appropriate statistical tests.

Results: A total of 193 paediatric patients were included in the final analysis. The median age of the patients was 81.8 months. Overall, CVC-related complications occurred in 24 patients (12.4%). Delayed complications accounted for the majority of events (91.7%), with device dysfunction being the most frequent complication. Immediate complications were rare (8.3%). An American Society of Anesthesiologists Physical Status (ASA-PS) classification of 3 was significantly associated with a higher incidence of complications (p=0.038). No significant associations were found between complications and patient age, sex, catheter location, ultrasound guidance, or intraoperative blood product transfusion.

Conclusion: In this paediatric neurosurgical cohort, CVC-related complications occurred in 12.4% of patients and were predominantly delayed, with device dysfunction being the most common event. Higher ASA-PS was the only factor associated with increased complication risks. These findings highlight the importance of careful postoperative catheter management and the necessity of ongoing CVC assessment in this vulnerable population.

Keywords: ASA Physical Status, central venous catheter, neuroanaesthesiology, paediatric neuro-surgery, ultrasound

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Introduction

The insertion of a central venous catheter (CVC) is frequently necessary in surgical settings, particularly in paediatric neurosurgical procedures. Approximately 25% of hospitalized children receive a central venous access device (CVAD) for medical reasons (1), as it provides durable and atraumatic venous access for blood sampling and for the safe administration of cytotoxic drugs, intravenous drugs, blood components, and parenteral nutrition (2). Approximately five million CVCs are placed annually in the United States, in the paediatric population (3). Nevertheless, the placement of a CVC is not without risk and CVAD failure prior to treatment completion remains high (20-25%) due to mechanical, infectious, and vascular complications (4,5).

Children with CVADs are already vulnerable to complications and disability due to their underlying health conditions. This vulnerability is worsened by the risk of adverse events associated with the insertion and management of CVADs (6,7). The complications associated with indwelling CVCs may be immediate or delayed (8). Immediate complications are related to the technique at the time of the insertion procedure and include vascular injuries (injury, bleeding, and/or hematoma), pulmonary complications (pneumothorax, pneumomediastinum, chylothorax, tracheal injury, recurrent laryngeal nerve injury and/or air embolism) and cardiac complications (arrhythmia and/or cardiac arrest) (8). Ultrasound has significantly reduced the incidence of immediate complications from rates previously as high as 11.8% to between 4 and 7% (9,10). Delayed complications include device dysfunction and infection (8). Device dysfunction may be caused by fibrin sheath formation, fracture, thrombosis, central venous stenosis, or infection (8). Subclavian CVCs have been reported to have the lowest rate of thrombosis (11,12), whereas femoral lines have the highest rate of thrombosis (11). Infection is a serious delayed complication associated with central venous access which can lead to sepsis, shock, and even death (8). Catheter infection sources include contamination from skin flora, contamination from infused substance, or from hematogenous spread from an unrelated site (13). In some circumstances, these complications are life-threatening or require the premature removal of the CVC, which may result in the inability to receive prescribed medications, fluids, or nutrition (14-17).

In our centre, the placement of CVCs in the paediatric neurosurgical population is relatively common and only performed by anaesthesiologists. The aim of this study was to evaluate CVC-related complications in a paediatric neurosurgical population of a single tertiary hospital centre, between 2017 and 2022, and to identify any possible risk factors related to these complications.

Materials and Methods

Ethical Considerations

Ethical approval for this study was obtained from the Ethics Committee of Centro Hospitalar Universitário de São João (CHUSJ), Porto, Portugal (approval no.: 181/2022, date: 07.09.2022). This study was conducted in accordance with the Declaration of Helsinki and all collected data were saved anonymously.

Study Design

Our initial population consisted of all children who had undergone neurosurgical procedures under general anaesthesia in our hospital's Neurosurgical Department, between January 2017 and January 2022. A total of 202 children with a record of a CVC placed in the operating room were identified.

The only exclusion criteria were incomplete records concerning the CVC (date, duration, site of placement or complications). Nine children were excluded due to missing data concerning their catheter location.

Obtaining Data and Definitions

Data were obtained by assessing and consulting the electronic medical records of all of the children in our sample. The collected data included sex, age, weight, American Society of Anesthesiologists Physical Status (ASA-PS), neurosurgical diagnosis, neurosurgical procedure, thrombotic risk (Caprini score), the presence of a previous CVC, CVC length and calibre, CVC location, the total number of insertion attempts, ultrasonographic technique usage, administration of tranexamic acid, hypertonic solutions or blood products and CVC-related complications.

Data regarding coagulation status, including platelet count and the presence of coagulopathy, were collected retrospectively when available. However, documentation was incomplete for a substantial proportion of the patients, precluding robust statistical analysis of these variables. Similarly, information regarding catheter length, calibre, and dwell time was inconsistently recorded, particularly in the earlier years of the study period.

Statistical Analysis

A descriptive analysis of the variables was performed in order to summarize the data. Dichotomous categorical variables are presented as relative or absolute frequencies.

Complications were evaluated as a dichotomous variable (the presence or absence of complications). In order to compare categorical variables, the chi-square or Fisher's exact test were performed. Differences were considered statistically significant when $p<0.05$. Statistical analysis was performed using the Statistical Package for Social Sciences version 27.0.

Results

Demographics Characteristics and CVC Locations

From a total of 202 paediatric patients enrolled, 115 were male (56.9%) and 87 were female (43.1%). Nine patients (4.4%) had missing data concerning their CVC location (and so were excluded from posterior statistical analysis), resulting in a sample of 193 children.

Table I shows the study's final population characteristics. The patients' ages ranged between 27 days and 17 years old, with a median age of 81.8 months (standard deviation ± 68.4). Of the 193 children, 62 were younger than one year, 21 were between one and three years old (11%), 49 were between three and 10 years old (25%) and 61 were older than 10 years old (32%). Most children were classified as ASA-PS 2 (n=66; 34.2%) and had oncologic neurosurgical diagnoses (n=112; 58%). Most catheters were inserted into the internal jugular vein (n=82; 42.5%).

Table I. Final population patient characteristics (n=193)

Variable	Total
Sex	
Male (%)	111 (57.5)
Female (%)	82 (42.5)
Mean age (months)	81.8±68.4
ASA physical status	
I (%)	51 (26.4)
II (%)	66 (34.2)
III (%)	57 (29.5)
IV (%)	14 (7.3)
V (%)	5 (2.6)
Neurosurgical diagnosis	
Oncological (%)	112 (58)
Non-oncological (%)	81 (42)
CVC location	
Internal jugular vein (%)	82 (42.5)
Femoral vein (%)	70 (36.3)
Subclavian vein (%)	41 (21.2)
CVC complication	
Yes (%)	24 (12.4)
No (%)	169 (87.6)
Delayed (%)	22 (91.7)
Immediate (%)	2 (8.3)
Device disfunction (%)	13 (54.1)
Infection/Inflammatory (%)	8 (33.3)
Thrombosis (%)	1 (4.2)
Haemorrhagic (%)	1 (4.2)
Mixed (T + I) (%)	1 (4.2)

Data presented as n (%) or mean ± standard deviation
ASA: American Society of Anaesthesiology, CVC: Central venous catheter, I: Infection, T: Thrombosis

Complications

As shown in Table I, in total, 24 complications were observed, accounting for 12.4% of all patients. Delayed complications (n=22; 91.7%) were far more frequent than immediate complications (n=2; 8.3%) and multi-cause device disfunction accounted for more than half of the complications (n=13; 54.1%). No more than a single complication episode was observed in any patient.

Factors Associated with Complications

Table II summarizes the relationship between the population characteristics and the occurrence of complications. The observed complications were identical in male and female patients (12 each), with no association between sex and the presence of complications ($p=0.565$). Most complications occurred in those patients aged between more than three and 10 years old. No association was found between age and the presence of complications ($p=0.375$).

An ASA-PS classification of 3 was significantly associated with a higher incidence of complications ($p=0.038$).

Table II also demonstrates that 23.5% (n=4) of those children with a vascular disease diagnosis had a complication, followed by 12.5% (n=6) of children with a congenital malformation diagnosis, 12.5% (n=1) of children with a central nervous system (CNS) infection, and 11.6% (n=13) of those with a CNS tumour diagnosis. No association was found between the neurosurgical diagnosis and complications ($p=0.537$).

Internal jugular vein CVCs were associated with the most complications (13 of a total of 24), followed by femoral and then subclavian veins. There was no statistically significant difference between CVC location and complications ($p=0.381$).

Ultrasound was used to aid CVC placement in 25 patients (13%). There was no statistically significant association between ultrasonographic technique usage and the presence of complications ($p=0.799$).

A total of 46 patients (23.8%) needed intraoperative blood product transfusions. We did not find any association between intraoperative blood product transfusions and the presence of CVC-associated complications ($p=0.362$).

Table II. Relationship between population characteristics and occurrence of complications (n=193)

Variable	Complications		Chi-square test		
	Yes	No	χ^2 (df)	Effect size (Cramér's V)	p value
Sex Male (%) Female (%)	 12 (10.8) 12 (14.6)	 99 (89.2) 70 (85.4)	0.331 (1)	0.041	0.565
Age <1 year old (%) 1-3 years old (%) 3-10 years old (%) >10 years old (%)	 8 (12.9) 1 (4.8) 9 (18.4) 6 (9.8)	 54 (87.1) 20 (95.2) 40 (81.6) 55 (90.2)	3.11 (3)	0.127	0.375
ASA physical status I (%) II (%) III (%) IV (%) V (%)	 2 (3.9) 6 (9.1) 11 (19.3) 4 (28.6) 1 (20)	 49 (96.1) 60 (90.9) 46 (80.7) 10 (71.4) 4 (80)	10.15 (4)	0.23	0.038
Neurosurgical diagnosis Epilepsy (%) CNS infection (%) Congenital malformation (%) CNS tumour (%) Vascular (%)	 0 (0) 1 (12.5) 6 (12.5) 13 (11.6) 4 (23.5)	 8 (100) 7 (87.5) 42 (87.5) 99 (88.4) 13 (76.5)	3.13 (4)	0.127	0.537
CVC location Femoral vein (%) Internal jugular vein (%) Subclavian vein (%)	 8 (11.4) 13 (15.9) 3 (7.3)	 62 (88.6) 39 (84.1) 38 (92.7)	1.931 (2)	0.10	0.381
Ultrasonographic technique Yes (%) No (%)	 4 (16) 20 (11.9)	 21 (84) 148 (88.1)	0.065 (1)	0.018	0.799
Transfusion Yes (%) No (%)	 8 (17.4) 16 (10.9)	 38 (82.6) 131 (89.1)	0.830 (1)	0.066	0.362

Data presented as n (% of given variable)
ASA: American Society of Anaesthesiology, CNS: Central nervous system, CVC: Central venous catheter, df: Degrees of freedom, χ^2: Chi-square value

Age

Table III summarizes the relationship between our defined age intervals and neurosurgical diagnosis, CVC location and ultrasonographic technique usage.

Among those patients of less than one year old, most had a malformative disease diagnosis (n=43; 69.4%). Oncologic diagnosis was the most common neurosurgical diagnosis in the other age groups. We found a statistically significant association between age and neurosurgical diagnosis (p<0.001).

In those patients of less than one year old, most CVCs (n=36; 58.1%) were placed in the femoral vein, as was also the case in patients aged between one and three years old (n=10; 47.6%). The jugular vein was the most common location in children aged between more than three years old and 10 years old (n=28; 57.1%). In children older than 10 years old, the most common CVC location was the subclavian vein (n=26; 42.6%). We found a statistically significant association between age and CVC location (p<0.001).

Ultrasound utilization for CVC placement was higher among those patients younger than one year old (n=14; 22.6%). There was a statistically significant association between age and ultrasonographic technique usage (p=0.030).

Table III. Relationship between neurosurgical diagnosis, CVC location and ultrasonographic technique usage, and age (n=193)

Variable	Age				Chi-square test		
	<1 yo	1-3 yo	>3-10 yo	>10 yo	χ^2 (df)	Effect size (Cramér's V)	p value
Neurosurgical diagnosis							
Epilepsy (%)	1 (1.6)	1 (4.8)	1 (2.0)	5 (8.2)			
CNS Infection (%)	3 (4.8)	0 (0.0)	2 (4.1)	3 (4.9)			
Congenital malformation (%)	43 (69.4)	2 (9.5)	3 (6.1)	0 (0.0)	108.28 (12)	0.432	<0.001
CNS tumour (%)	14 (22.6)	18 (85.7)	36 (73.5)	44 (72.1)			
Vascular (%)	1 (1.6)	0 (0.0)	7 (14.3)	9 (14.8)			
CVC location							
Femoral vein (%)	36 (58.1)	10 (47.6)	12 (24.5)	12 (19.7)			
Internal jugular vein (%)	24 (38.7)	7 (33.3)	28 (57.1)	23 (37.7)	41.64 (6)	0.328	<0.001
Subclavian vein (%)	2 (3.2)	4 (19.0)	9 (18.4)	26 (42.6)			
Ultrasonographic technique							
Yes (%)	14 (22.6)	3 (14.3)	5 (10.2)	3 (4.9)	8.95 (3)	0.215	0.030
No (%)	48 (77.4)	18 (85.7)	44 (89.8)	58 (95.1)			

Data presented as n (% of total in each age interval)
df: Degrees of freedom, yo: Years old, χ^2: Chi-square value, CVC: Central venous catheter, CNS: Central nervous system

Discussion

This retrospective observational study involving 193 paediatric patients provided a focused evaluation of CVC complications in a paediatric neurosurgical cohort, demonstrating a complication rate of 12.4%, which is lower than in many of the previously published paediatric populations where rates often exceeded 40% (18-20). These studies reported haematological diseases, Hickman-Broviac catheters, low neutrophil counts and haematological diseases as risk factors for CVC complications. In our study, none of the patients had these characteristics, which may explain our lower rate of complications. The predominance of delayed complications (91.7% of all complications), particularly catheter dysfunction, highlights the unique characteristics of neurosurgical patients and the perioperative pathways in which CVCs are used.

There was no statistically significant association between ultrasonographic technique usage and the presence of complications. However, this finding should be interpreted with caution. Ultrasound was used in only 13% of patients, substantially limiting the statistical power of this study to detect meaningful differences and increasing the likelihood of a type II error. In addition, immediate complications were rare across the entire cohort, regardless of whether ultrasound was used or not, which may further reduce the observable effect of ultrasound on complication rates. Given the strong and consistent evidence supporting ultrasound-guided CVC placement in paediatric patients (21-25), including higher success rates and fewer mechanical complications, our results should not be interpreted as contradicting the current recommendations. Rather, they likely reflect the limited sample size of ultrasound-guided insertions and the low baseline rate of immediate complications in this neurosurgical population.

We did not identify a significant association between the location of the CVC and complications. It has been reported that internal jugular lines have the lowest complication rates (26) and femoral lines have the highest rate of thrombosis (11). Conflicting evidence exists regarding infection risks in femoral lines (27,28). Nevertheless, one observational study in paediatric surgical patients showed an association between femoral lines and bloodstream infection (29). Although CVC location was not statistically associated with complications in our cohort, age-related anatomical and procedural considerations should continue to guide site selection

Interpretation in the Context of Our Cohort

Children undergoing neurosurgical procedures represent a specific clinical group with distinct vascular access needs. In our population: most CVCs were employed for intraoperative management, where rapid fluid administration, vasoactive infusions, and reliable venous access are required; immediate complications were rare, consistent with modern ultrasound-guided techniques and experienced anaesthesia teams (21-23); and delayed complications dominated, with device dysfunction accounting for more than half of all events. This pattern aligns with the shorter perioperative dwell times in neurosurgery, where CVCs often remain in place only briefly postoperatively. Femoral access is more common in younger children, reflecting anatomical constraints and the clinical realities of urgent neurosurgical care. ASA-PS 3 was

the only factor significantly associated with complications, suggesting that physiological vulnerability rather than procedural factors played a larger role in catheter failure. To date, there is a lack of published studies on this association, but it is logical to assume that more seriously ill patients are more susceptible to CVC-associated complications.

These findings reinforce the notion that the neurosurgical perioperative environment is distinct from oncology or critical care settings, where prolonged device dwell times contribute more heavily to infectious and thrombotic complications.

Given that all vascular access devices in this cohort were temporary CVCs placed intraoperatively, our findings specifically reflect perioperative neurosurgical practice and should not be extrapolated to other device types such as peripherally inserted central catheters (PICCs) or midlines. The absence of these devices in our cohort underscores the distinct vascular access requirements of paediatric neurosurgical patients.

Clinical Implications

While CVCs are essential during neurosurgical procedures, the high proportion of delayed complications in our cohort underscores the importance of early postoperative evaluation and the consideration of alternative vascular access devices when clinically appropriate. Integrating structured, individualized vascular access planning aligned with updated paediatric guidance (30) may help to reduce complication rates and improve overall safety in this vulnerable population. Additionally, our findings underscore the need to optimise perioperative vascular access strategies in this population. As delayed complications, particularly device dysfunction, were the most frequent events, clinical teams should routinely reassess the ongoing need for a CVC after surgery and consider an early transition to alternative devices when appropriate. PICCs or midlines may provide safer medium-term options for selected patients, especially those with oncological diagnoses or anticipated prolonged postoperative therapy. Shorter CVC dwell times, stricter criteria for initial CVC placement, and routine consideration of catheter removal on postoperative day one, unless central access remains clearly required, may further reduce complication risks. These approaches are consistent with contemporary paediatric vascular access guidance and promote a more individualised, safety-focused strategy for device selection and maintenance.

Study Limitations

The retrospective design and relatively limited sample size of this single-centre study must be considered when interpreting the results. Given that all vascular access devices in this cohort were temporary CVCs placed intraoperatively, our findings specifically reflect perioperative neurosurgical practice and should not be extrapolated to other device types such as PICCs or midlines. The absence of these devices in our cohort underscores the distinct vascular access requirements of paediatric neurosurgical patients. Missing data, particularly regarding CVC dwell times, catheter lengths, calibres, the number of insertion attempts and coagulation status (e.g. platelet count and the presence of coagulopathy), reduced the statistical power and prevented the inclusion of potentially relevant variables in this study. Nine patients were excluded due to missing CVC location data, and incomplete documentation was likely affected by the transition to a new anaesthesia recording system during the study period. Second, this study's retrospective design limited control over confounding factors, and the six-year timeframe may reflect practices which have since evolved, particularly the increased adoption of ultrasound guidance and the decreasing use of femoral access in younger children. Third, this study was not powerful enough to detect small effect sizes, and the relatively low incidence of complications, especially immediate complications, may have limited our ability to identify subtler associations. Finally, we did not differentiate between complication types (immediate vs delayed) in the statistical analysis, which may partially explain the absence of an association between ultrasound guidance and complications.

Conclusion

In this paediatric neurosurgical population, CVC complications occurred in 12.4% of patients, with delayed device dysfunction being the most common. ASA-PS 3 was the only factor significantly associated with increased risk, despite strong existing literature associating CVC location and ultrasonographic technique usage to the risk of complications. These findings support the ongoing efforts to optimize catheter maintenance strategies and the adoption of updated paediatric vascular access guidance. We acknowledge that our study may have some limitations and prospective studies are needed in order to further refine risk prediction and prevention strategies.

Ethics

Ethics Committee Approval: Ethical approval for this study was obtained from the Ethics Committee of Centro Hospitalar Universitário de São João (CHUSJ), Porto, Portugal (approval no.: 181/2022, date: 07.09.2022).

Informed Consent: Retrospective observational study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: F.B., P.S., H.P., J.G.A., Concept: F.B., P.S., H.P., J.G.A., Design: P.S., H.P., J.G.A., Data Collection or Processing: F.B., C.C., P.S., J.G.A., Analysis or Interpretation: F.B., C.C., H.P., J.G.A., Literature Search: F.B., C.C., J.G.A., Writing: F.B., C.C., P.S.

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