Author/s:
Kluckow, E;Perera, S;Clifford, I;Wilks, D;Cooper, MS

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SHORT REPORT

Increased risk of complications in lower versus upper limb peripheral intravenous cannulation in children with severe neurological impairment

Eliza Kluckow[1] | Sajini Perera[1] | Isaac Clifford[1] | Daniel Wilks[2,3,4] | Monica S. Cooper[1,2,5]

[1]Department of Neurodevelopment and Disability, The Royal Children's Hospital, Parkville, Victoria, Australia

[2]Department of Paediatrics, The University of Melbourne, Melbourne, Victoria, Australia

[3]Department of Plastic and Maxillofacial Surgery, The Royal Children's Hospital, Parkville, Victoria, Australia

[4]Facial Sciences, Murdoch Children's Research Institute, Melbourne, Victoria, Australia

[5]Neurodisability and Rehabilitation, Murdoch Children's Research Institute, Melbourne, Victoria, Australia

Correspondence
Monica S. Cooper, Neurodevelopment and Disability, The Royal Children's Hospital, 50 Flemington Road, Parkville, Victoria 3052, Australia.
Email: monica.cooper@rch.org.au

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Abstract

Background: Obtaining peripheral intravenous catheter (PIVC) access in children with severe neurological impairment (SNI) is often challenging and commonly associated with complications, including dislodgement, phlebitis and extravasation. In severe cases, extravasation injury may lead to tissue necrosis, ulceration and long-term morbidity. The aim of this study was to determine the relative incidence of PIVC complications secondary to lower limb cannulation, compared to upper limb, in children with SNI.

Methods: A single centre, retrospective, observational review was conducted. Patients with SNI, admitted at a tertiary paediatric centre over 6 months between July and December 2022, were included.

Results: One-hundred fifty-five PIVC procedures were conducted in 110 children over the study period. Complications were more common in lower limb PIVCs (12/16, 75%) compared to upper limb (58/139, 42%), $p = 0.01$.

Conclusion: Upper limb cannulation is preferred in children with SNI.

KEYWORDS
extravasation injury, extremity, insertion site, PIVC complications, severe neurological impairment

1 | INTRODUCTION

Severe neurological impairment (SNI) describes a group of disorders, arising in childhood, which cause significant limitations in neurological functioning across multiple domains (Allen et al., 2020). This cohort of children is particularly difficult to cannulate due to their medical complexity with frequent hospitalisations and repeated venepuncture attempts, as well as disease-specific aspects such as reduced mobility, communication difficulties, spasticity and contractures.

Cannulation in the upper limb is widely regarded as the preferred option for initial attempt at short-term venous access (Queensland Health, 2018; RCH Clinical Practice Guideline on Intravenous Access, 2019). When considering additional options, healthcare providers may choose to cannulate lower limbs, rather than resort to higher level access such as central lines, which require specialist input. Several complications may arise from peripheral intravenous catheter (PIVC) access including occlusion, dislodgement, phlebitis (vein inflammation) and extravasation (leakage of fluid into surrounding tissues).

Extravasation is defined as the unintentional leakage of vesicant fluids or medications from the vein into the surrounding tissue (Department of Health Queensland, 2018; RCH Clinical Practice Guideline on Extravasation Injury Management, 2020). The volume of unintended infused solution is also an important variable, which may cause neuromuscular compromise, ischaemia or compartment

syndrome. Injury to the skin and subcutaneous tissues may result from any inadvertent solution into the interstitial space causing harm. Tissue injury can especially be caused from fluids that are hyperosmolar, extremely acidic or basic, or vasoconstrictive (RCH Clinical Practice Guideline on Extravasation Injury Management, 2020). The clinical features are erythema, oedema, pain and difficulty flushing the cannula. In some cases, persistent induration, ulceration or skin necrosis ensue, which prolong recovery, may extend follow-up and may require surgical reconstruction (Gault, 1993; Horan et al., 2008). There are limited data on the incidence of PIVC complications in the paediatric population, due to varying definitions, inconsistent documentation in medical notes and the absence of state or nation-wide registries in Australia. Thirty to fifty per cent of PIVCs have complications (ben Abdelaziz et al., 2017; Tripi et al., 2016; Unbeck et al., 2015; van Rens et al., 2021, 2022), with extravasation injury requiring intervention reported to be <2% (Gault, 1993; Paquette, 2011). Neonatal and intensive care patients have a much higher incidence (Murphy et al., 2019; van Rens et al., 2022; Wilkins & Emmerson, 2004).

Obtaining PIVC access in children with SNI presents unique challenges. Although some literature describes PIVC complications in the paediatric population, few compare upper to lower limb insertion and none to our knowledge focus on children with SNI. These are potentially life-changing injuries, significantly impacting quality of life and further compounding the medical complexity of patients who already have multi-system medical issues and pre-existing high care needs.

Key messages

- Children with severe neurological impairment have increased complications and are less likely to complete intravenous treatment when peripherally inserted venous catheters are placed in the lower limb, compared to the upper limb.
- Extravasation injury secondary to peripherally inserted venous catheters can cause significant harm and may require ongoing follow up.
- Upper limb cannulation should be preferenced in children with severe neurological impairment, especially those with cerebral palsy functioning within Gross Motor Function Classification System Level V.

2 | AIM

The aim of this study is to determine the relative incidence of PIVC complications in lower limb cannulation, compared to upper limb, in children with SNI.

3 | COHORT

Children with PIVCs inserted in lower or upper limb while admitted as inpatients under the Neurodevelopment and Disability team, with diagnoses compatible with SNI, at the Royal Children's Hospital, a tertiary paediatric centre in Victoria, Australia, between July and December 2022. A total of 110 patients with 155 PIVCs were included (see Figure S1).

4 | METHOD

A retrospective review of the hospital's electronic medical record (EMR) was conducted. Patient demographic data including primary diagnosis and Gross Motor Function Classification System (GMFCS), cannula insertion site, utilisation of ultrasound to assist with cannula insertion, PIVC dwell time, complications and reason for removal were compiled. Complications were categorised as dislodged/tissued (displacement of the cannula from its position in the vein, presenting clinically as difficult flushing or complete displacement with cannula no longer in the patient), phlebitis (inflammation of the vein, presenting clinically as tenderness, swelling or erythema) or extravasation (leakage of fluids from cannula into surrounding tissues). Extravasation injury was defined as unintentional administration of vesicant fluid causing tissue damage requiring plastic surgery input. Objective grading of extravasation injuries was used (RCH Clinical Practice Guideline on Extravasation Injury Management, 2020). The primary outcome was PIVC complication (dislodged/tissued, phlebitis or extravasation injury), and the secondary outcome was successful treatment completion. These outcomes were analysed between upper and lower extremities using independent-sample *t* tests for continuous variables and chi-square (or Fisher's exact test when less than five) for categorical variables. Number needed to harm (NNH) of PIVC in the lower limb was calculated. This study received ethics approval from the Royal Children's Hospital.

5 | RESULTS

One-hundred fifty-five PIVC procedures were conducted in 110 patients, with a mean of 1.4 cannulas per patient (see Table S1). Age at admission ranged from <1 to 19 years old (mean = 9.9). Most patients (92%) were functioning within GMFCS level IV or V. The upper and lower limb cannulation groups were of comparable age, sex, GMFCS level, use of ultrasound and IVC dwell time (Table 1). Of the 155 PIVCs inserted, 89% ($n = 139$) were placed in the upper limb and 10% ($n = 16$) in the lower limb. All patients with lower limb cannulations were functioning within GMFCS level IV or V, with the majority (88%) functioning within GMFCS level V. Forty seven (30%) of PIVCs were inserted under ultrasound-guidance. Eight per cent of the PIVCs were inserted in the intensive care unit (ICU), 68% were inserted in the emergency department and 24% were inserted on the ward. Of those PIVCs inserted on the ward, 1/3 required insertion by an anaesthetist due to escalation for difficult access.

TABLE 1 Demographic and clinical characteristics of upper versus lower limb peripheral intravenous catheters.

Variable	Upper limb, $n = 139$ (%)	Lower limb, $n = 16$ (%)	*P* value
Age (years), mean	10.1	9.6	0.75
Sex—female	62 (45)	3 (19)	0.06
Gross motor function classification system			
I	1 (<1)	0	
II	5 (4)	0	
III	4 (<1)	0	
IV	24 (17)	2 (12)	N/A
V	102 (73)	14 (88)	
Not cerebral palsy	3 (2)	0	
Ultrasound assisted	45 (32)	2 (13)	0.15
Dwell time (hours)			
0–24	23 (17)	3 (18)	
24–48	30 (22)	4 (25)	0.78
48–72	11 (8)	3 (18)	
>72	32 (23)	4 (25)	
Unknown[a]	43 (31)	2 (13)	
Treatment not completed due to complication	58 (42)	12 (75)	0.01
Complication			
Dislodged/tissued	52 (37)	7 (44)	
Phlebitis	6 (4)	3 (19)	N/A
Extravasation injury	0 (0)	2 (13)	

Abbreviation: N/A, not applicable because cell included 0.
[a]Unknown group excluded from calculation.

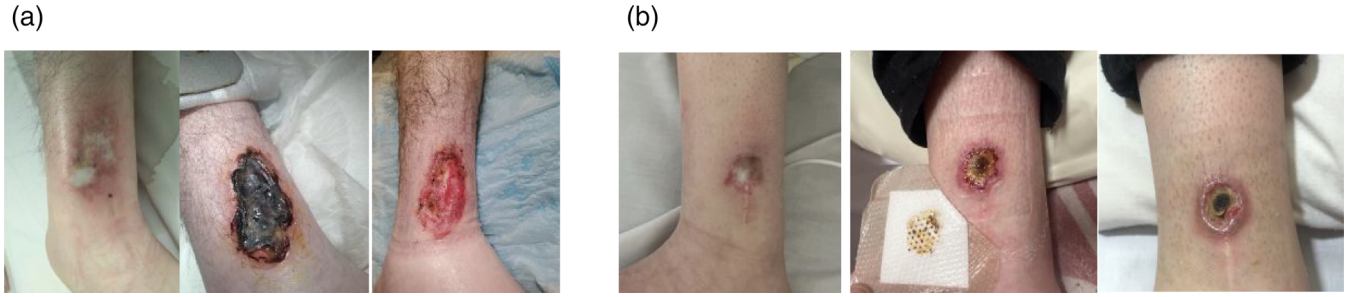

FIGURE 1 (a) Fifteen-year-old male with cerebral palsy secondary to neonatal hypoxic ischaemic encephalopathy, functioning within GMFCS level V. Extravasation of flucloxacillin at left anterior ankle PIVC. The area of necrosis was managed conservatively with plastic surgery input given multiple, complex co-morbidities. Plastic surgery follow-up was ongoing at 5 months post injury. Image (i) initial injury, (ii) 1 month post injury, and (iii) 3 months post injury. (b) Fourteen-year-old female with cerebral palsy secondary to Aicardi syndrome functioning within GMFCS level V. Extravasation of flucloxacillin at right medial ankle PIVC. Managed conservatively with absorbent foam dressings. Discharged from plastics surgery follow-up 1 week post injury, with ongoing follow-up from regular paediatrician. Image (i) initial injury, (ii) 1 month post injury, and (iii) 3 months post injury.

PIVC-related complications were responsible for 45% of cannula removals, which predominately dislodged or tissued (38%), followed by phlebitis (6%) and extravasation (1%). Complications (and therefore treatment failures) were more common in lower limb PIVCs (12/16, 75%) compared to upper limb PIVCs (58/139, 42%), $p = 0.01$. Meaning, 75% of PIVCs in the lower limb failed to remain in for the duration of treatment. All extravasation injuries occurred in the lower limb. Vignettes of the two cases of lower limb extravasation injuries are presented in Figure 1.

Of the 116 PIVCs inserted in patients functioning within GMFCS level V, 21% of lower limb PIVCs remained in for the duration of treatment, compared to 79% of upper limb PIVCs. The NNH when inserting PIVC into the lower limb in patients functioning within GMFCS level V is 2.7 (95% confidence interval 1.7–7.8). Meaning,

for every 2.7 lower limb PIVCs inserted, one complication was observed.

6 | DISCUSSION

This study demonstrates that children with SNI are more likely to have PIVC complications and less likely to complete their intravenous treatment if they have a PIVC inserted in the lower limb compared to the upper limb. The frequency of PIVC complications in this study of 45% is consistent with previous reports of 30–50% (ben Abdelaziz et al., 2017; Tripi et al., 2016; Unbeck et al., 2015; van Rens et al., 2022). Extravasation injury requiring plastic surgery input (reviews, dressings advice or surgery) of 1% is also consistent with the published literature of <2% for paediatric inpatients (Gault, 1993; Paquette, 2011). Interestingly, this cohort with SNI did not have a higher rate of PIVC-related complications compared to the general paediatric population despite sometimes posing challenges with cannulation due to frequent hospitalisation, repeated venepuncture attempts, vein fragility, reduced mobility and difficulties in communication. This finding may be explained by the high rate of ultrasound-guided cannulation; 30% of practitioners used ultrasound rather than landmark techniques in this cohort. This may relate to the study being completed in a high-resource, tertiary care setting where ultrasound training is commonplace. Ultrasound guided cannulation, when equipment is available and staff are adequately trained, can facilitate more secure, longer term access (Badger, 2019; Burek et al., 2022; Paladini et al., 2018; Ye & Li, 2022); hence, educating and training healthcare providers in its use, including those outside of the ICU setting, is likely beneficial for this patient cohort.

Cannulating upper extremities is generally preferred by healthcare providers (Queensland Health, 2018; RCH Clinical Practice Guideline on Intravenous Access, 2019), and this is reflected in the low rate of lower limb cannulations. The higher incidence of complications in lower limbs may be reflective of children with SNI having more difficult venous access and multiple previous cannulations, such that less-preferable sites are utilised. This is further supported by the finding that most children with lower limb cannulations were functioning within GMFCS level V.

All extravasation injuries in this study occurred in the lower limb. Figure 1a,b displays the severity of these injuries, which both required ongoing medium term follow up. Prevention of extravasation injury includes careful PIVC site selection, secure dressings, use of catheter glue and regular site inspection (Gault, 1993; RCH Clinical Practice Guideline on Extravasation Injury Management, 2020; van Rens et al., 2023). Visual inspection and hospital-specific grading systems are currently used to identify extravasation injury; however, there are novel technological solutions being developed to detect extravasation injuries earlier, for example, various sensors monitoring impedance, temperature, radio-frequency and fluid pressure (Hirata et al., 2023). Prompt recognition and management, preferably with practitioners trained to evaluate tissue viability such as plastic surgeons, may reduce unnecessary complications, shorten length of hospital stays and reduce hospital costs (Gault, 1993; RCH Clinical Practice Guideline on Extravasation Injury Management, 2020).

Our study had several limitations. First, the study was retrospective and so relies on the accuracy of the EMR. Second, the study was conducted at a single centre and so may not be representative of other health-care settings. Third, PIVC dwell time was unknown in 30% of cannulations due to incomplete EMR documentation. Lastly, although not a primary aim of our study, there was incomplete documentation of the number of attempts prior to a successful PIVC insertion. Work should be done to improve this documentation. However, at our centre, there are guidelines limiting the number of attempts a clinician can have to insert a PIVC to a maximum of two attempts (RCH Clinical Practice Guideline on Intravenous Access, 2019). Furthermore, and increasingly, an inter-disciplinary approach with Child Life Therapy involvement, can empower children and families to reduce negative hospital experiences from medical procedures.

Our study had several strengths. First, the study was conducted at a tertiary paediatric hospital, which has a specialty service for children with SNI providing us with a large cohort to review. Second, data collection was conducted by medical practitioners who worked clinically, such that coding was standardised and clinically relevant, and third, the EMR is a real-time and relatively accurate source of standardised and easily accessible data.

7 | CONCLUSION

In children with SNI, especially those with cerebral palsy functioning within GMFCS level V, cannulation in the lower limb, compared to the upper limb, significantly increases PIVC-associated complications and significantly decreases the chance of completing intravenous treatment. Extravasation injury can cause significant harm with patients experiencing physical discomfort, emotional distress and decreased quality of life as a result. Avoiding iatrogenic complications is essential for prioritising patient safety, reducing care-burden and reducing hospital costs from prolonged admissions and outpatient follow-up. Upper limb cannulation should be preferenced in children with SNI to prevent additional co-morbidities in an already medically complex patient cohort.

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CONFLICT OF INTEREST

The authors declare they have no competing interest.

DATA AVAILABILITY STATEMENT

Full access to data is possible upon reasonable request and with additional ethics application.

ETHICS STATEMENT

The authors confirm they have read the journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

ORCID

Eliza Kluckow https://orcid.org/0000-0003-1151-4632
Daniel Wilks https://orcid.org/0000-0003-0617-6712
Monica S. Cooper https://orcid.org/0000-0002-6589-8451

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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