



Original Article

Use and outcomes of vascular access in complicated paediatric appendicitis – A multicentre prospective observational study

Paediatric Surgical Trainees Research Network (PSTRN)



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ABSTRACT

Background: Intravenous access is essential for post-operative management of complicated appendicitis. An alternative to peripheral cannulation is insertion of an advanced vascular access device (AVAD) which includes midlines, peripherally inserted central venous catheters (PICCs) and central venous catheters (CVCs). This study aimed to evaluate use and outcomes related to vascular access in complicated paediatric appendicitis with audit against national guidelines.

Method: Prospective multicentre observational study of children (<16 years) with complicated appendicitis at specialist and non-specialist paediatric surgical centres in the UK and Ireland with data collection over 3 months to January 2024. Outcomes included unplanned vascular access device insertion, complications of vascular access and peripheral cannulation attempts. Data are median(IQR), n(%) or odds ratios(95 % CI).

Results: Overall, 189 children were included from 27 centres with median age of 9.9 (5.3–12.8) years. Seventy-six children (40.2 %) underwent AVAD insertion at appendicectomy. The remainder were managed with peripheral cannulas.

AVAD insertion was associated with younger age (OR 1.19[1.09–1.30]), female sex (OR 3.14[1.47–6.71]), widespread intra-abdominal pus (OR 3.89[1.26–12.01]) and perforated appendicitis/appendix mass (OR 3.18[1.38–7.36]) on multivariable analysis. Unplanned AVAD insertion was undertaken in 12(6.3 %) children and was associated with younger age, higher admission C-reactive protein, appendicectomy at night and peripheral cannula or non-tunneled CVC at appendicectomy. AVADs were used for 5(4–8) days and 11/89(12.3 %) devices experienced complications.

Conclusion: AVAD insertion should be considered at appendicectomy in younger children with intra-operative findings of perforated appendicitis, appendix mass or widespread pus. Age, with a cut-off of 8 years, should be added to existing guidelines of AVAD use in appendicitis.

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1. Introduction

Intravenous access (IV) is essential for post-operative management of complicated appendicitis in children to deliver fluid, analgesia, antibiotics and in some, parenteral nutrition (PN). In children, insertion of peripheral cannulas can be challenging and distressing depending on the age of the child and the availability of peripheral veins [1]. Alternatives to peripheral cannulation include midlines, peripherally inserted central venous catheters (PICC) and central venous catheters (CVC). Central venous access carries the additional advantage of allowing blood sampling for monitoring of electrolytes and treatment response [2]. Although these alternatives are more invasive and expensive than peripheral cannulation and also typically require placement under general anaesthesia,

they usually last longer avoiding the need for subsequent and sometimes repeated, peripheral cannulation. All venous access techniques have associated risks including infection, blockage, extravasation, fracture or rarely thrombus/embolus formation, although little is known about the incidence of these when used relatively short term for children with complicated appendicitis [3]. Furthermore, the type of venous access has a significant impact on the experience of the child and family, particularly when one considers the need for repeated cannulation and/or venepuncture for blood sampling [1]. Since insertion of a PICC or CVC typically require general anaesthesia in children, insertion of one of these devices at time of appendicectomy might prevent need for a further general anaesthetic which comes with risk, resource use and further patient distress.

The Getting It Right First Time (GIRFT) programme is an initiative within the UK led by NHS England to consolidate data relevant to each specialty and provide recommendations for care. The recent GIRFT report for paediatric general surgery and urology specifically identified variation between hospitals in post operative venous

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Table 1

Summary of GIRFT abdominal pain pathway recommendations specific to vascular access device selection in complicated appendicitis [5].

Operative findings	Expectations post operation	Recommended device
Complicated appendicitis without significant peritoneal contamination	No further antibiotics Minimal ileus <12 h 'nil by mouth' post-op	Peripheral cannula
Complicated appendicitis with peritoneal contamination No significant bowel dilatation	<10 days of antibiotics Minimal ileus <48 h 'nil by mouth' post-op	Midline/non-central long line
Gross peritoneal contamination Significant bowel dilatation	Prolonged ileus ≥72 h 'nil by mouth' post-op	Peripherally inserted central catheter (PICC)
Physiologically unstable child who requires secure IV access when a PICC cannot be placed		Non-tunnelled internal jugular or subclavian lines

access management for children with complicated appendicitis [4]. The subsequently developed GIRFT abdominal pain pathway made recommendations for IV access for children with appendicitis. Given the paucity of evidence in this area, these could only be based on expert opinion [5]. The report recommends choice of IV access based on intraoperative findings of pus, bowel dilatation and anticipated post operative course (Table 1).

Given the absence of evidence in this area and a concern that current practice may not be consistent with the GIRFT recommendations, the aim of this study was to report use and outcomes related to vascular access in children with complicated appendicitis across the UK and compare these to audit criteria from GIRFT recommendations. A secondary aim was to understand decision making around the choice of IV access in these children.

2. Methods

2.1. Study design and participants

This was a multicentre observational cohort study of children aged between 1 month and 16 years at the time of appendicectomy with intraoperative findings of complicated appendicitis. Complicated appendicitis was defined as gangrenous or perforated appendicitis along with appendix mass undergoing an abdominal surgical procedure. All hospitals in the UK and Ireland were eligible to participate, this included specialist and non-specialist paediatric surgical centres. Data were collected at each site during a 3-month period between September 2023 to January 2024. Follow-up was censored at 28 days post initial hospital admission.

Children who were managed with peripheral cannulation only at appendicectomy were compared to those that underwent advanced vascular access device (AVAD) insertion at appendicectomy. The term AVAD was used to describe anything other than a peripheral cannula and therefore includes PICC, midline, non-central long line and non-tunnelled central venous catheter (NTCVC).

2.2. Data collection

Anonymous data were collected by local study teams and submitted using REDCap [6]. Data were collected regarding demographics, presentation and treatment provided including PN, and type of IV access used.

2.3. Outcomes

Outcomes relating to peripheral cannula or AVAD use were unplanned AVAD insertion and AVAD related complications (including sepsis, displacement, blockage, fracture, thrombus and embolus). Unplanned AVAD insertion was defined as AVAD

insertion after initial general anaesthetic for appendicectomy. Outcomes relevant to patient experience were length of hospital stay and number of peripheral cannulation attempts. Children were deemed to have required PN if they received PN for 5 days or longer. The significance of requiring PN is it may guide which children require central venous access rather than peripheral access, such as a midline or peripheral cannula, since PN is typically administered via a central venous route.

2.4. Statistical analysis

Statistical analysis was performed using StataSE v18 (StataCorp LLC, Texas, USA). The study was conducted according to the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines for observational studies [7]. Data are presented as median (IQR or range if specified) and/or number/total (%) as appropriate. Fisher's exact test or chi-squared test, as appropriate, were used for comparison of categorical data and the Mann Whitney-U test was used for non-parametric continuous data. Multivariable logistic regression was used to explore association between type of IV access used and patient/disease factors. The selected variables for the multivariable models were those which reached statistical significance in the univariate analysis of factors associated with AVAD use or those which appear in the GIRFT abdominal pain pathway recommendations. It was also determined whether the type of IV access provided for each case met the GIRFT abdominal pathway recommendations (Table 1).

2.5. Ethical considerations

This study was conducted as a multicentre audit using GIRFT guidance as audit standards. It was registered locally in each centre as such, based on UK health research authority (HRA) guidance and research ethical approval was not obtained.

3. Results

3.1. Participants

A total of 190 children from 27 centres, of which 22 were specialist and 5 were non-specialist paediatric surgical centres, were eligible for inclusion. One child was excluded as they presented with appendicitis already with a pre-existing tunnelled CVC. Therefore 189 children were included, of which 122 (64.5 %) were male with a median age of 9.9 (5.3–12.8) years. The majority of children were treated by specialist paediatric surgeons (n = 160, 84.6 %) whilst the remainder (n = 29, 15.4 %) were treated by general surgeons. Appendicectomy was completed laparoscopically in 165 children (87.3 %), started laparoscopically and converted in 8 children (4.2 %)

and 16 children (8.5 %) had an open appendicectomy. Appendicitis was gangrenous in 66 children (34.9 %), perforated in 110 children (58.2 %) and an appendix mass was found in 13 (6.9 %).

3.2. Vascular access at appendicectomy

At appendicectomy 76 (40.2 %) children had an AVAD inserted whilst 113 (59.7 %) were managed with peripheral cannulation alone (Fig. 1). Those who had AVAD insertion at appendicectomy were younger, had longer duration of symptoms, a greater admission C-reactive protein (CRP) and were more likely to be female, treated by a specialist paediatric surgeon, have localised or widespread pus intra-operatively, have perforated appendicitis or appendix mass and were anticipated to have a longer nil-by-mouth duration than those who had a peripheral cannula alone (Table 2a). After adjustment for confounding using multivariable logistic regression, AVAD insertion at appendicectomy was associated with younger age, female sex, widespread intra-abdominal pus and perforated appendicitis or appendix mass (Table 3). AVAD type used was midline, PICC and NTCVC in 35 (18.5 %), 35 (18.5 %) and 5 (2.7 %) children respectively whilst one child had both a PICC and NTCVC inserted at the time of appendicectomy. Of those who had a central venous access device (PICC, NTCVC or both) inserted at appendicectomy ($n = 41$), 37 children received prolonged antibiotics, 13 received PN and none required administration of blood products.

In the whole cohort and across the whole admission, the median number of peripheral cannula attempts was 2 (IQR 2–4, range 1–14).

3.3. Unplanned vascular access

Overall, in the post-appendicectomy period, 12 children (6.3 %) had an additional procedure for AVAD insertion. This included 8 (7.1 %, 95 % CI 2.4–11.8 %) of the 113 children managed initially with a peripheral cannula alone, who underwent unplanned AVAD

insertion at median 4 (2–4.5) days post appendicectomy. AVAD type inserted was midline ($n = 4$), PICC ($n = 2$) and NTCVC ($n = 2$). Number of peripheral cannulation attempts was greater for those who underwent unplanned AVAD insertion than those who didn't (5 [4–7] vs 2 [1–3] attempts, $p < 0.001$).

The other 4 children initially had an AVAD placed at the time of appendicectomy but subsequently required general anaesthetic for AVAD replacement between 6 and 17 days post appendicectomy. These were one midline replacement, one NTCVC replacement due to concerns of risk of infection, one NTCVC replacement due to blockage and one NTCVC replacement with a PICC, during the same anaesthetic where an intra-abdominal collection was drained.

These 12 children who underwent unplanned AVAD insertion were younger, had lower admission WCC, higher admission CRP and greater anticipated nil-by-mouth duration than those who didn't require an unplanned AVAD (Table 2b). Actual nil-by-mouth duration in these children was greater than those who didn't undergo unplanned AVAD insertion (5.5 [1.5–10] vs 1 [1–2] days $p < 0.0001$). Unplanned AVAD was also associated with appendicectomy at night and use of a cannula alone or NTCVC insertion. Nine out of the twelve children (75 %) that required unplanned AVAD insertion had an age between 1 and 7 years old.

3.4. PN administration

In the whole cohort nil-by-mouth duration was 1 (1–2) days and 18 (9.5 %) children received PN for 7 (5–16) days which was started 1.5 (1–4) days post appendicectomy. Three received PN for less than 5 days total and were therefore deemed post-hoc to not have required this. The 15 (7.9 %) children who were deemed to have required PN had a higher admission CRP and greater anticipated NBM duration than those who didn't receive PN or received it for less than 5 days. Additionally, they were more likely to have widespread intra-abdominal pus, perforated appendicitis and bowel dilatation (supplementary table 1).

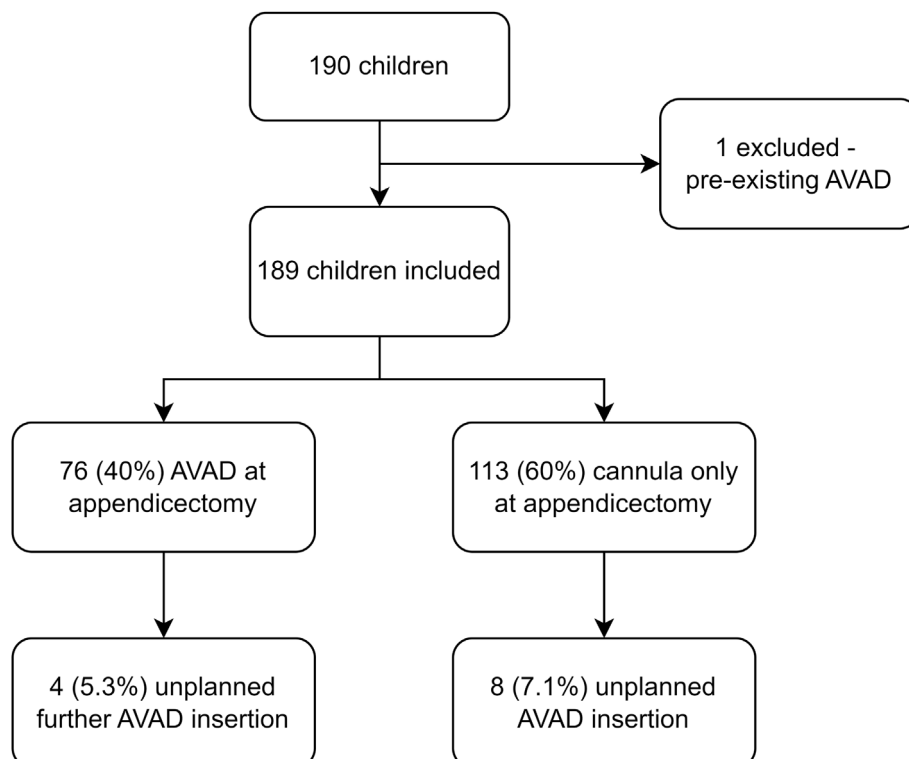


Fig. 1. Study flow diagram. AVAD = advanced vascular access device.

Table 2
Characteristics of children treated with (a) peripheral cannula alone versus advanced vascular access device insertion at appendectomy and (b) children who required unplanned advanced vascular access device insertion versus those who didn't.

		(a) Vascular access at appendectomy			(b) Unplanned AVAD insertion		
		Cannula only n = 113	AVAD n = 76	p	No n = 177	Yes n = 12	p
Age, years		11.00 (7.00–13.00)	7.71 (4.08–11.04)	<0.001	10.08 (5.67–12.83)	4.71 (3.54–8.67)	0.01
Age range	1–7 years	34 (46.6 %)	39 (53.4 %)	0.01	64 (87.7 %)	9 (12.3 %)	0.02
	8–12 years	48 (66.7 %)	24 (33.3 %)		71 (98.6 %)	1 (1.4 %)	
	13–16 years	31 (70.5 %)	13 (29.5 %)		42 (95.5 %)	2 (4.5 %)	
Male		81 (66.4 %)	41 (33.6 %)	0.01	115 (94.3 %)	7 (5.7 %)	0.64
Surgical specialty	General	26 (89.7 %)	3 (10.3 %)	<0.001	29 (100 %)	0 (0 %)	0.13
	Specialist paediatric	87 (54.4 %)	73 (45.6 %)		148 (92.5 %)	12 (7.5 %)	
Symptom duration, days		2.00 (1.00–3.00)	3.00 (2.00–4.00)	0.005	2.00 (1.00–3.00)	2.00 (2.00–5.00)	0.26
Admission WCC, x 10 ⁹ /L		16.2 (13.6–19.7)	16.1 (11.8–21.9)	0.89	16.3 (13.4–20.0)	12.1 (8.8–18.5)	0.03
Admission CRP, mg/L		72.5 (35.0–149.1)	127.0 (55.5–228.0)	0.004	82.2 (38.00–166.0)	185.0 (77.0–334.0)	0.01
Time of surgery	Day	68 (56.2 %)	53 (43.8 %)	0.34	117 (96.7 %)	4 (3.3 %)	0.002
	Evening	27 (69.2 %)	12 (30.8 %)		37 (94.9 %)	2 (5.1 %)	
	Night	18 (62.1 %)	11 (37.9 %)		23 (79.3 %)	6 (20.7 %)	
Intra-op findings - pus	None	38 (70.4 %)	16 (29.6 %)	0.006	52 (96.3 %)	2 (3.7 %)	0.13
	Localised	61 (62.2 %)	37 (37.8 %)		93 (94.9 %)	5 (5.1 %)	
	Widespread	14 (37.8 %)	23 (62.2 %)		32 (86.5 %)	5 (13.5 %)	
Severity	Gangrenous	49 (74.2 %)	17 (25.8 %)	0.007	65 (98.5 %)	1 (1.5 %)	0.08
	Perforated	59 (53.6 %)	51 (46.4 %)		101 (91.8 %)	9 (8.2 %)	
	Mass	5 (38.5 %)	8 (61.5 %)		11 (84.6 %)	2 (15.4 %)	
Bowel dilatation		15 (45.5 %)	18 (54.5 %)	0.07	31 (93.9 %)	2 (6.1 %)	0.94
Anticipated post operative ileus/NBM duration	None	73 (70.2 %)	31 (29.8 %)	<0.001	101 (97.1 %)	3 (2.9 %)	0.01
	<12 h	22 (55.0 %)	18 (45.0 %)		37 (92.5 %)	3 (7.5 %)	
	12–48 h	17 (50.0 %)	17 (50.0 %)		31 (91.2 %)	3 (8.8 %)	
	>72 h	1 (9.1 %)	10 (90.9 %)		8 (72.7 %)	3 (27.3 %)	
Vascular access at appendectomy	Cannula only	113 (100 %)	0 (0 %)	–	105 (92.9 %)	8 (7.1 %)	<0.001
	Midline	0	35 (100 %)		34 (97.1 %)	1 (2.9 %)	
	PICC ^a	0	36 (100 %)		36 (100 %)	0 (0 %)	
	NTCVC	0	5 (100 %)		2 (40.0 %)	3 (60.0 %)	

Data are median (IQR) or n (%). AVAD = advanced vascular access device, WCC = white cell count, CRP = C-reactive protein, NBM = nil by mouth. PICC = peripherally inserted central venous catheter, NTCVC = non-tunnelled central venous catheter.

^a One child received a PICC and NTCVC at appendectomy and are in this category here.

3.5. Adherence to GIRFT recommendations

The GIRFT abdominal pain pathway recommendations were followed in just 34 % (n = 65) of children. The recommendations for PICC/NTCVC insertion were followed in 33.3 % (n = 22/66) of children who met criteria for this, for midline insertion 14.6 % (n = 12/82) children met the criteria, whilst for peripheral cannula alone 75.6 % (n = 31/41) met criteria for this (Fig. 2). There were also 9.5 % (n = 18) of children who received a PICC when GIRFT recommended a midline or peripheral cannula and 3.2 % (n = 6) of children who received a midline when a peripheral cannula was recommended.

3.6. Vascular access outcomes

Overall, 89 AVADs were used in 84 children for a median of 5 (4–8) days and complications were experienced in 11/89 (12.3 %) AVADs of which 7 were midlines, 3 PICCs and 1 NTCVC. These were

Table 3
Multivariable logistic regression of factors associated with advanced vascular access device insertion at appendectomy.

	Odds ratio (95 % CI)	p
Age, decrease per year	1.19 (1.09–1.30)	<0.001
Female	3.14 (1.47–6.71)	0.003
Duration of symptoms of appendicitis, increase per day	0.99 (0.82–1.19)	0.88
Admission CRP, increase per unit	1 (1–1.01)	0.30
Intra-op findings - pus	Reference	
None		
Localised	1.31 (0.55–3.14)	0.54
Widespread	3.89 (1.26–12.01)	0.02
Perforated appendicitis or appendix mass	3.18 (1.38–7.36)	0.007
Bowel dilatation	1.68 (0.67–4.21)	0.27

CRP = C-reactive protein.

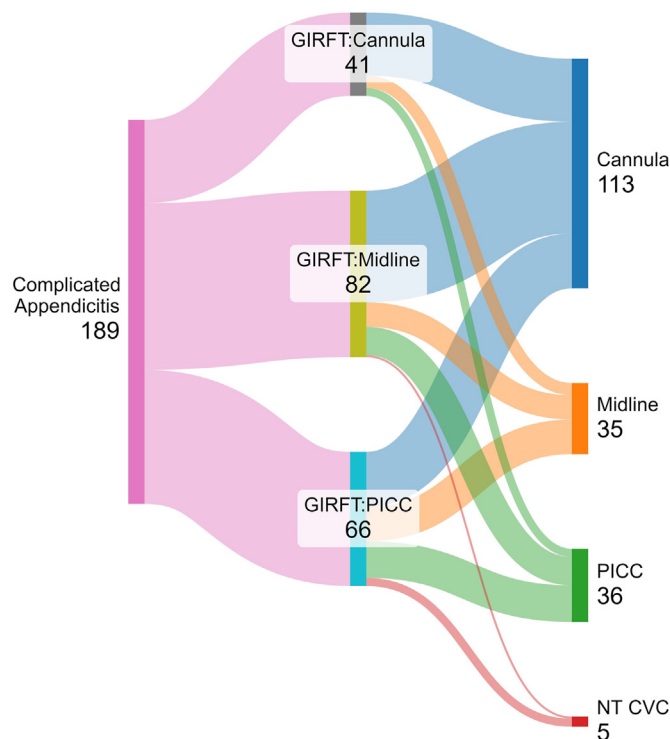


Fig. 2. Sankey diagram showing GIRFT abdominal pain pathway recommendation for vascular access device type and device type received at appendectomy. PICC = peripherally inserted central venous catheter, NTCVC = non-tunnelled central venous catheter.

displacement/accidental removal ($n = 6$, 6.4 %), blockage ($n = 4$, 4.5 %) and infection ($n = 1$, 1.1 %). PICC related complications were displacement/accidental removal ($n = 1$), blockage ($n = 1$) and infection ($n = 1$). The NTCVC complication was line blockage. Neither AVAD associated systemic thrombus or embolus were reported.

3.7. Appendicitis outcomes

Complications of appendicitis were experienced by 26 (13.7 %) and were intra-abdominal collection ($n = 22$), adhesional small bowel obstruction ($n = 6$) and pneumonia ($n = 2$). Some children experienced multiple complications. Unplanned AVAD insertion rate was similar between those with and without appendicitis related complications (3/26 [11.5 %] vs 9/163 [5.5 %], $p = 0.22$). There was no mortality.

4. Discussion

This study aimed to report practice surrounding vascular access in complicated paediatric appendicitis. We found several factors associated with AVAD use, minimal AVAD related complications and a modest requirement for unplanned AVAD insertion following appendicectomy. We also found that actual practice seldom meets GIRFT abdominal pain pathway recommendations regarding use and type of AVAD, suggesting other factors currently guide clinician choice of AVAD.

A previous study of vascular access in complicated paediatric appendicitis conducted in the USA found that, in a similar setting to this study, PICCs were used in just under 20 % of children with complicated appendicitis [8]. This previous work used administrative data so has limited information regarding indications for use. The GIRFT abdominal pain pathway recommendations were derived from expert opinion alone [5]. This current study has provided some evidence that may allow refinement of these guidelines to ensure that children with complicated appendicitis receive the most appropriate vascular access device for them. Unplanned AVAD requirement was relatively uncommon in this study but didn't just occur in children who had only a cannula placed at appendicectomy. It was observed frequently in those who had a NTCVC placed at appendicectomy, hence the use of a midline or PICC might reduce the need for an unplanned AVAD insertion and highlights the importance of initial correct device insertion. Even if a NTCVC is required due to physiological instability, concurrent midline or PICC insertion is likely beneficial. Additionally, unplanned AVAD insertion was associated with appendicectomy at night suggesting that current service provision may not support optimum device placement out of hours. This is likely related to availability of clinicians trained in this procedure or unavailability of additional resources such as in-theatre radiography. The former could be readily addressed through training [9].

Unplanned AVAD insertion was associated with younger age with 75 % of unplanned AVADs being placed in children aged less than 8 years. This study found that many surgeons already consider patient age when considering AVAD use – over 50 % of children under 8 years had an AVAD inserted at the time of appendicectomy. Together these data provide evidence to support the addition of age to GIRFT recommendations. Our data also suggest surgeons currently place less emphasis on other factors such as bowel dilatation. We also found that AVAD insertion at appendicectomy was associated with female sex, even after adjusting for measured confounders, and the reason for this is unclear. Clinicians possible consider sex, either consciously or unconsciously, during their decision-making process when deciding on AVAD insertion, or this finding might be due to chance alone. Unsurprisingly, the actual nil-

by-mouth duration in those that underwent unplanned AVAD insertion was greater than those who didn't and was generally greater than predicted at time of appendicectomy. Therefore, clinicians may be misguided by their prediction which currently features in the GIRFT guidance on AVAD use in appendicitis [5].

Choice of AVAD is important and use of PICC carries greater risk than midline of serious complications [10]. The advantages of a PICC are ability to administer central PN and greater reliability for venous blood sampling. Use of PN was low in this study and a number of children received a PICC in whom GIRFT recommended a midline. This may represent an opportunity to use fewer PICCs and instead use midlines in the majority of children with complicated appendicitis.

Indeed, use of any AVAD carries additional resource use and risk [11,12]. Some studies have reported PICC related complications to be as high as 30 % with longer term use [3]. In this study AVADs were only used for a median of 5 days with a significantly lower complication rate (12 %), of which most had minimal clinical impact.

Vascular access in paediatric appendicitis is an under researched area and more robust study is required to ensure that children with complicated appendicitis receive the optimal device at time of appendicectomy. Important outcomes not considered in this current study are healthcare costs and patient experience. Venepuncture, including peripheral cannula insertion, is known to be distressing for children and caregivers, and further work should robustly capture data regarding this to better understand the impact of AVAD use in appendicitis [1]. Many methods of measuring patient experience exist and are available for future work [13]. The closest this current study comes to measuring this is peripheral cannulation attempts in which the number of these was greater in those who required unplanned AVAD insertion and the maximum number of attempts recorded was 14 during the index admission. Repeated cannulation attempts could be avoided with appropriate AVAD insertion at appendicectomy.

4.1. Limitations

This study is the first of its kind to report use and outcomes of vascular access in paediatric appendicitis prospectively and benefits from a multicentre approach. It is however limited by its observational nature meaning decision-making around AVAD use was non-standardised and outcomes are association rather than causation. Additionally, we report limited measures of patient experience. Follow-up was limited to 28 days post index admission but it is unlikely that any events relevant to vascular access occurred after this time point. This study includes almost all specialist paediatric centres in the UK however only a handful of general surgical centres which may limit the generalisability of these results outside of specialist centres and outside of the UK.

To conclude, AVADs are used in 40 % of children with complicated appendicitis and consideration of age, along with surgical findings related to disease severity, may allow better patient selection to ensure that each child receives the correct device at appendicectomy. Specifically, these data support the addition of age to the GIRFT recommendations, and we suggest that those with an age of less than 8 years should have an AVAD inserted at appendicectomy. Reassuringly, AVAD insertion at time of appendicectomy appears safe with few reported complications, the majority of which had negligible clinical impact.

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Conflicts of interest

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jpedsurg.2025.162447>.

PSTRN

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