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# Short midline catheters: High success rates for antibiotic therapy in children with cystic fibrosis

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**Judith Glazner[1], Kate Steinfort[2], Yanhong Jessica Hu[3], William Browne[2], Ian Smith[2] and Christopher Brasher[2,3,4]**

## Abstract

**Objective:** Short midline catheter use in paediatric populations appears to be increasing, however data on success rates and efficacy are sparse. This study aims to describe the success rate when midline venous catheters are employed as a single device for intravenous antibiotic therapy in paediatric patients with cystic fibrosis.

**Methods:** A retrospective cohort study was performed in a single institution, retrieving electronic medical record data from July 2017 through March 2020. The primary outcome was device success, defined as a catheter that remained functional until the end of antibiotic therapy. Reasons for device failure were categorized in a standard fashion.

**Results:** Primary outcome data were available for 116 catheter insertions, involving 49 patients and 55 proceduralists. The success rate was 84% ($n = 98$). Median age at insertion was 15 years (range 4–19) and median weight 52 kg (13–81). Soft, polyether block amide, Arrow® Seldinger Arterial Catheters were employed. Only 16 patients (14%) required general anaesthesia. Median time to failure was 6 days, and median time to successful completion of treatment was 13 days. Six of 18 failures occurred within 48 h and were likely insertion complications. The most common reasons for device failure were occlusion, extravasation, phlebitis and dislodgement. More than half of patients (56%) received antibiotic therapy at home.

**Conclusion:** There is a high single device success rate when inserting short midlines for 13-day intravenous pulmonary antibiotic therapy in children with cystic fibrosis. These results should be confirmed with a prospective study.

## Keywords

Techniques and procedures, nursing, new devices, biomaterials, intensive care

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## Introduction

Over the last decade, midline catheters (Figure 1) are increasingly being used in clinical practice.[1–3] Softer, longer, extended dwell intravenous catheters may be inserted anywhere in the body, and midlines are defined as extended dwell venous catheters inserted into the mid upper arm, with a tip position in the peripheral venous system near the axillary crease. Originally described in the 1950s, they are used to provide non-central infusates for up to 2 weeks, with the intention of avoiding or reducing the dwell complications of Central Venous Access Devices (CVADs), notably central line-associated bloodstream infection (CLABSI) and deep venous thrombosis (DVT).[4,5] They initially fell out of favour following severe reactions to the Landmark brand of catheters specifically designed for midline use in the 1990s.[6] There is some debate and confusion regarding the terminology around extended dwell catheters and midlines. One recent paper

[1]Respiratory and Sleep Medicine, The Royal Children's Hospital, Parkville, VIC, Australia
[2]Anaesthesia and Pain Management, The Royal Children's Hospital, Parkville, VIC, Australia
[3]Murdoch Children's Research Institute, Parkville, VIC, Australia
[4]Critical Care, University of Melbourne, Parkville, VIC, Australia

**Corresponding author:**
Christopher Brasher, Department of Anaesthesia and Pain Management, The Royal Children's Hospital, 50 Flemington Road, Parkville, VIC 3052 Australia.
Email: christopher.brasher@rch.org.au

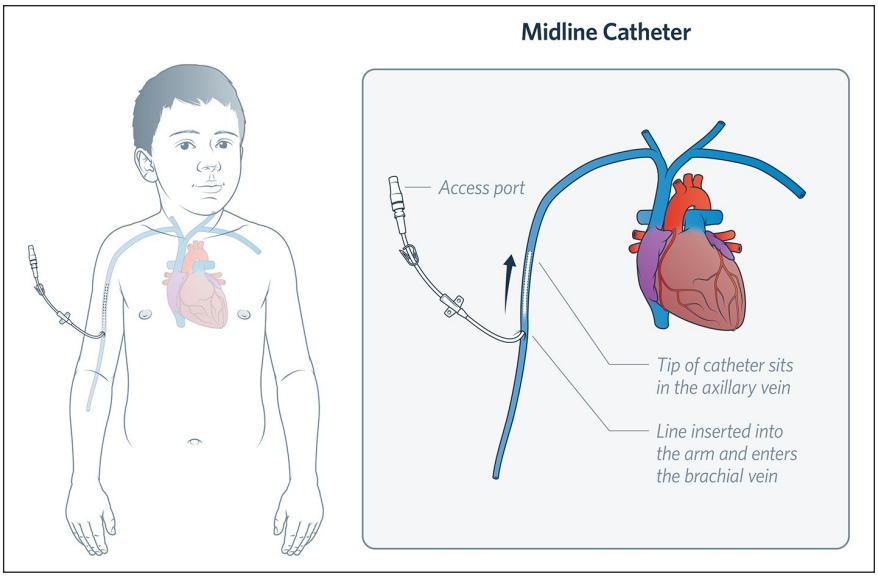


**Figure 1.** Midline catheter.

aims to address this confusion, and defines midlines as inserted into upper arm veins and being a minimum of 15 cm long.[7] As such, we decided to label the catheters inserted in this study 'short midlines', as they are inserted into the mid upper arm, but given the study population is paediatric, the catheters are shorter than those employed in adults. Our institution began to employ them in 2011, targeting paediatric cystic fibrosis (CF) patients requiring longer 10–21-day courses of intravenous antibiotic therapy. Intermittent extended duration intravenous antibiotic therapy in CF patients to reduce or eliminate pulmonary colonisation has been credited with the increases in life expectancy observed in these patients over the past few decades.[8] Patients were considered suitable for short midline insertion according to age and the presence of appropriate diameter upper arm veins for 22 g catheters as per published guidelines (i.e. >2 mm).[9] Topical anaesthesia with or without sedation was habitually employed, and soft, 22-gauge Arrow™ Seldinger poly ether block amide (PEBA) Arterial Catheters were inserted with ultrasound guidance by an anaesthesiologist, employing a Seldinger or modified Seldinger technique at the operator's discretion. All catheters were inserted into the upper arm. Soft arterial catheters were selected for repurposed use as venous catheters as there was a dearth of locally available alternative devices at the time. Apart from the obligation to use a transparent dressing, dressing and securement were not standardised, and local options include GRIP-LOK® adhesive securement devices, cyanoacrylate glue and both simple and advanced transparent adherent dressings (Tegaderm™ IV Advanced). Antibiotic prescription was performed by respiratory physicians and tailored to individual patients' sputum microscopy and culture results. If the patient was unable to provide a sample, a general anaesthetic and broncho-alveolar lavage was performed. All prescribed antibiotics were compatible with peripheral venous administration according to local protocols and the British National Formulary for Children (the latter accessed 7th May 2021). Once on the ward or at home the insertion site was inspected at least once daily. Dressings were changed weekly. All home antibiotics were administered via an elastomeric pump, and ward antibiotics through a syringe pump. Given that scientific data exploring the efficacy of such devices are lacking, we decided to retrospectively assess device success.

## Methods

This study is a retrospective cohort study. The primary outcome is device success – defined as completion of IV antibiotic therapy employing a single short midline device inserted at the beginning of therapy. Secondary outcomes included duration of successfully completed treatments, standardized types of failure and time to failure. Given the retrospective, observational, quality assurance nature of the study, there was no requirement to plan for a specific number of device insertions or enrolled patients.

Local Human Research Ethics Committee approval was obtained before commencing the study (Reference: QA/62456/RCHM-2020). Data was collected through a review of electronic medical records (EPIC© Systems Corporation Verona, WI). Inclusion criteria were patients who were booked for hospitalization under the respiratory team with a diagnosis of cystic fibrosis, and/or those brought to the operating theatre with a diagnosis of cystic fibrosis for a booked procedure of midline venous catheter insertion. Data was collected for short midline insertions at the initiation of intravenous antibiotic therapy from July 2017 until

March 2020. Exclusion criteria included short midline insertions for reasons other than intravenous antibiotics, devices that were inserted that were not Arrow™ Seldinger poly ether block amide (PEBA) Arterial Catheters, secondary devices inserted as replacements to already failed devices during the same course of therapy, and insertions for in patients with diagnoses other than cystic fibrosis.

Patient characteristics data collected included the following: age in years, weight in kilograms, gender and previous recorded midline and peripherally inserted central venous catheter (PICC) insertions, the latter as they employ the same veins. Device insertion data included the following: type of device, diameter (Birmingham or French gauge), length of device, target vein (basilic, brachial or other), senior or trainee proceduralist, laterality, number of attempts, sedation or general anaesthesia requirement. Device dwell data included: catheter infusate(s), duration of prescribed antibiotic therapy (days), dwell time, whether treatment was completed with the initial device (success), date of failure and dwell time to failure (days), types of failure (dislodgement, leakage, occlusion, local infection, blood stream infection, deep vein thrombosis, phlebitis, pain on injection without diagnosis and infiltration or extravasation).

Where the reason for device removal was not specified by the nursing entry in the electronic medical record ('end of treatment', or 'complication' being the typical entries at removal), two clinicians (KS and CB) independently assessed the patient's medication, nursing and medical entries to decide whether treatment was successfully completed. In the event of disagreement, a third clinician was invited to arbitrate.

Quantitative data were entered and analysed using Excel for Windows. Data were analysed using descriptive statistics – numbers and percentages, medians and inter-quartile ranges or medians and ranges where data were insufficient to estimate inter-quartile ranges. Comparative analyses and inferential statistics were not calculated as this study was exploratory and further analyses were not pre-planned.

## Results

Primary outcome data were available for 116 catheter insertions and 98 were associated with successful completions of treatment on a single device, at a rate of 84% (Table 1). Median patient age at insertion was 15 years (range 4–19 years) and median weight 52 kg (range 13–81 kg). A majority of patients were male ($n=77$, 66%) and displayed three or more recorded previous short midline or PICC insertions ($n=69$, 60%). One patient was in the Intensive Care Unit at the time of short midline insertion, all other patients came to the operating theatre as ambulatory planned admissions and were sent to a standard ward before the decision of suitability for home antibiotic therapy was addressed.

**Table 1.** Patient demographic data.

| | Overall | Success | Failure |
|---|---|---|---|
| Sex | | | |
| Female | 39 (34%) | 32 (33%) | 7 (39%) |
| Male | 77 (66%) | 66 (67%) | 11 (61%) |
| Total | 116 | 98 (84%) | 18 (16%) |
| Age, years | 15 [3] | 15 [3] | 16 [2] |
| Weight, kg | 52 [14] | 53.7 [19] | 52.5 [9] |
| Known previous ML and PICC* | | | |
| 0 | 20 (17%) | 16 (16%) | 4 (22%) |
| 1 | 14 (12%) | 11 (11%) | 3 (17%) |
| 2 | 13 (11%) | 12 (12%) | 1 (6%) |
| ⩾3 | 69 (60%) | 59 (60%) | 10 (56%) |

*n* (%) and median [IQR].
*ML: midline; PICC: peripherally Inserted central venous catheter.

**Table 2.** Catheter insertion data.

| | Overall | Success | Failure |
|---|---|---|---|
| Catheter device type | | | |
| Arrow 22 g 8 cm | 102 (88%) | 87 (88%) | 15 (83%) |
| Arrow 22 g 5 cm | 13 (11%) | 10 (10%) | 3 (17%) |
| Arrow 20 g 5 cm | 1 (1%) | 1 (1%) | 0 |
| Vein | | | |
| Basilic | 89 (76%) | 77 (79%) | 12 (67%) |
| Brachial | 21 (18%) | 17 (17%) | 4 (22%) |
| Other | 6 (6%) | 4 (4%) | 2 (11%) |
| Vein diameter* | | | |
| Diameter, mm | 5 [3–15] | 5 [3–15] | 5 [4–10] |
| Not reported | 41 (35%) | 34 (35%) | 7 (39%) |
| Laterality | | | |
| Left | 71 (61%) | 59 (60%) | 12 (67%) |
| Right | 45 (39%) | 39 (40%) | 6 (33%) |
| Operator | | | |
| Senior | 69 (59%) | 59 (60%) | 10 (56%) |
| Trainee | 47 (41%) | 39 (40%) | 8 (44%) |
| Sedation/GA/awake | | | |
| Sedation | 46 (40%) | 37 (38%) | 9 (50%) |
| General anaesthesia | 16 (14%) | 15 (15%) | 1 (6%) |
| Awake | 54 (46%) | 46 (47%) | 8 (44%) |

*Insufficient reporting for IQR. *n* (%) and median [range].

In terms of catheter insertion data (Table 2), 116 devices were inserted into 49 patients by 55 recorded proceduralists. The employed device was always a soft, polyether block amide, Arrow® Seldinger Arterial Catheter. All devices were inserted into the upper arm, three quarters of devices were inserted into the basilic vein ($n=89$, 76%), and an 8 cm device length was recorded in 102 procedures (88%). The remaining devices were 5 cm in length. Median vein diameter was 5 mm (IQR [3–15]), however just 65% of insertions recorded vein diameter ($n=75$). The recorded operator was a senior anaesthesia doctor in 71 (61%) insertions, and a

**Table 3.** Catheter dwell data.

| | Overall | Success | Failure |
|---|---|---|---|
| *N* | 116 | 98 (85%) | 18 (15%) |
| Dwell time (days) (95% CI) | 6 [4.5–6.8] | 12 [11.4–12.8] | 6 [3.8–7.6] |
| Antibiotics (*n*)[a] | | | |
| 1 | 11 | 9 (9%) | 2 (11%) |
| 2 | 81 | 71 (72%) | 10 (56%) |
| 3 | 15 | 13 (14%) | 2 (11%) |
| 4 | 5 | 4 (4%) | 1 (5.6%) |
| 5 | 1 | 1 (1%) | 0 (0%) |
| Hospital in the home | | | |
| No | 51 (44%) | 38 (39%) | 13 (72%) |
| Yes | 65 (56%) | 60 (61%) | 5 (28%) |
| Reason for removal | | | |
| End of treatment | | 98 | |
| Occlusion | | | 5 |
| Extravasation | | | 4 |
| Dislodgement | | | 3 |
| Phlebitis | | | 3 |
| Kinking | | | 1 |
| Local infection | | | 1 |
| Unknown | | | 1 |

*n* (%) and median [IQR].
[a]Three patients did not receive any antibiotics in the failure group.

trainee doctor in 45 (39%) of insertion procedures. Just 16 patients (14%) required general anaesthesia.

In terms of catheter dwell data (Table 3), median time to failure was 6 days, and median time to successful completion of treatment was 13 days. Six of 18 failures occurred within 48 h of insertion and difficulties were reported in use in all six on the first day of use, and three patients did not receive any antibiotics through their catheters due to dysfunction. Most patients received a combination of two antibiotics ($n=81$, 70%), and a majority (56%) received antibiotic therapy at home. Of the 19 different antibiotics prescribed, the most commonly prescribed in order of frequency were tobramycin ($n=74$), ceftazidime ($n=58$), ceftriaxone ($n=37$), piperacillin/tazobactam ($n=26$) and flucloxacillin ($n=23$). Differences in success rates between antibiotics or with increasing numbers of administered antibiotics could not be determined. Only two patients received vancomycin and both successfully completed therapy on a single device. The most common reasons for device failure were occlusion ($n=5$), extravasation ($n=4$), phlebitis ($n=3$) and dislodgement ($n=3$). No cases of catheter associated systemic infection were recorded, and only one patient was treated in the intensive care unit, for respiratory support only.

## Discussion

A high success rate of completion of intravenous pulmonary antibiotic therapy was observed when short midline catheters were inserted at the beginning of treatment.

The original decision to employ short midline devices was based upon the difficulties encountered with the alternatives. That is, for peripheral intravenous catheters, insufficient longevity, missed doses whilst waiting for new device insertions and the morbidity of repeated pain and discomfort upon re-insertion.[10] For other CVADs, inconveniences include the requirement for general anaesthesia at insertion, the potential for serious but rare complications during insertion, and a higher likelihood of blood stream infection once contaminated.[11,12]

It is of note that the median number of previous recorded devices was three or more, that is, previous insertions did not impede the successful use of short midline devices in our small cohort. That said, the use of ultrasound in all cases to identify a healthy section of vein may have assisted in this process and led patients inappropriate for midline catheterization to be referred for a CVAD. The selection of a proximal upper arm vein was to optimize for vein diameter and device longevity. Vein diameter was not well reported, however, according to local protocols, patients were only selected for short midline insertion if minimum vein diameter of 2 mm was identified in either the basilic or brachial vein, and both the selection criteria diameter and the lowest recorded vein diameter value recorded (3 mm) fall well within current guidelines for device to vein diameter relationships for 22 gauge catheter insertions.[9] The elevated child age and weight are indicative of the selection criteria, and the tradition within our institution that short midlines generally be reserved for older patients with CF. Eliminating the one patient treated in this cohort whilst no longer strictly paediatric at 19 years of age would not have significantly impacted our findings.

Seventeen different senior anaesthesiologist doctors and 38 different trainees were recorded, a total of 55 individual proceduralists. This may be inaccurate, as the signed-in anaesthesia provider on the EPIC© electronic record is selected by default as the operator for any anaesthetic procedures, and as such, a junior, trainee doctor may erroneously be entered as the operator if they are documenting the procedure for a senior who is performing the insertion. Furthermore, there is no institutional or personal financial incentive in the Australian public hospital system to correctly name the operator where two doctors are present. The contrary is also possible, that senior staff may have documented insertions performed by junior staff, although in the authors' experience senior staff generally delegate administrative tasks rather than volunteer to perform them. However, even if it were the most extreme possible case, where only 17 senior proceduralists inserted all 124 devices, this still represents evidence that the insertion procedure is accessible to a large number of clinicians in our institution. Anecdotally, a vast majority of trainees and senior doctors do regularly perform midline insertions for various indications. The fact that only 14% of patients received general anaesthesia is also significant in that alternative devices – PICCs & tunnelled, uncuffed central

venous catheters (CVCs) – are usually inserted under general anaesthesia in our hands.

It is of note that six out of 18 failures occurred within 48 h and that all six had reported problems in the first 24 h of use, and that three patients received no antibiotics at all on their initial device. Three catheters were removed as a result of occlusion, one for kinking, one for extravasation and one for unknown reasons. On the balance of this information the authors believe all six to be likely insertion complications and/or failures.

The absence of any catheter associated sepsis is also of note. Catheter associated sepsis is defined in our institution as follows: temperature > 38°C, any one of hypotension, tachycardia, or shock, a venous catheter in situ, and no other explanation for the clinical signs. Our study therefore represents 1480 sepsis free catheter days. By comparison, one study describes catheter associated bloodstream infection in central venous catheters in adults, reporting 4.4% of devices associated with infection at a rate of 2.7/1000 catheter days.[13]

Cost reduction is another potential benefit of short midline catheters when compared with central venous catheters. The arterial catheter devices employed as midlines in our institution are less expensive than the central venous alternatives, and they are quicker to insert. Similar catheters have been employed in at least one other Australian centre for these reasons.[14] Arrow® Seldinger Arterial Catheters have a local unit cost of $28 AUD at time of writing, where the PICC kits used for both PICC and tunnelled uncuffed CVC insertions in our institution cost $174 AUD. Furthermore, the standard operating theatre booking time for a short midline is 20 min in our institution. Alternative devices, such as a PICC or a tunnelled uncuffed CVC, are booked for 60 min of theatre time. One recent estimate of mean the hourly cost of operating theatre time to the local government was $2004 AUD ($1462 USD or €1222 at time of writing).[15] As such, presuming equivalent outcomes, a minimum per-procedure saving in our institution may be estimated at $1510 AUD ($1102 USD, €920), before taking into account cost reductions associated with general anaesthesia and hospital admission.

The decision to study only short midlines used for intravenous antibiotic therapy in patients with a diagnosis of cystic fibrosis resulted in the exclusion from analysis of a significant population of patients with other respiratory disease – notably bronchiectasis. Any future, prospective research should aim to include all extended intravenous antibiotic therapies.

This study has limitations. It is a retrospective study, and the accuracy of default standardized electronic medical record entries, particularly with respect to the proceduralist, is questionable. Primary outcome data, however, are both well recorded and reliable, as all intravenous antibiotic administrations must be entered into the patient electronic record for legal purposes. As mentioned above, 57 operators were recorded but the real number may be lower, and vein diameter was poorly reported. It is also of note that this study only examines one specific group of patients – those suffering from cystic fibrosis and requiring intravenous antibiotics.

## Conclusion

There is a high single device success rate when short midline PEBA catheters are inserted into the upper arm under ultrasound by anaesthesiologists for median 13-day intravenous antibiotic therapy in children with Cystic Fibrosis. Further, prospective evaluations of device reliability for this indication should be performed, and further evaluation of their use in other paediatric patients is also required.

### Authors' contributions

Drs Glazner, Browne and Smith participated in study design, in the clinical pathways that led to the study, and reviewed and revised the manuscript. Dr Steinfort participated in data entry and data management, and reviewed and revised the manuscript. Dr Hu participated in statistical analyses and descriptions, and reviewed and revised manuscript. Dr Brasher conceived initial study design, participated in data entry and data management, drafted the initial manuscript and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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### ORCID iD

Christopher Brasher https://orcid.org/0000-0003-1037-3604

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