

# A Cluster of Failures of Midline Catheters in a Hospital in the Home Program: A Retrospective Analysis

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## ABSTRACT

A cluster of 11 midline catheter failures occurred during a 2-week period in a Hospital in the Home program in an urban tertiary hospital in Australia. These failures prompted a 4-month retrospective audit of patients receiving outpatient antimicrobial therapy between December 1, 2016 and March 1, 2017. Primary outcomes were dwell time and catheter failure. Peripherally inserted central catheters had significantly fewer failures and significantly longer dwell times compared with midline catheters. Women experienced higher rates of midline catheter failure than men. The proportion of patients with midline catheters receiving continuous infusions who experienced a failure was markedly higher than those receiving bolus doses. Suggestions for further related research are discussed.

**Key words:** catheter failure, cluster, complication, dislodgement, failure, intravenous, midline catheter, OPAT, outpatient, PICC, thrombosis

**T**he Hospital in the Home (HITH) program at Liverpool Hospital in Sydney, Australia manages patients in an outpatient setting with intravenous (IV) antibiotics or other antimicrobial agents

administered via a vascular access device (VAD), usually a midline catheter or a peripherally inserted central catheter (PICC). For patients requiring IV therapy lasting 7 or more days, IV antimicrobial therapy is initiated via a short

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peripheral catheter (SPC) and replaced with the elective insertion of a PICC or, less frequently, a midline catheter. This procedure is usually performed by a member of the hospital's central venous access service (CVAS). Ideally, the PICC or midline catheter should remain in place for the full course of IV antimicrobial treatment without complications.

Midline catheters are 8 to 20 cm in length with varying designs.<sup>1-5</sup> They are inserted proximal to the antecubital fossa and terminate below the axillary line within the peripheral circulation.<sup>1-5</sup> Midline catheters are a popular alternative to PICCs for delivering nonirritant infusates when vascular access is required for more than 5 days. They have improved dwell time and exhibit lower phlebitis and extravasation rates compared with traditional SPCs.<sup>2,4,6</sup> Midline catheters do not require confirmation of tip placement by radiographic or imaging technologies, and they have lower rates of catheter-related infections compared with PICCs.<sup>2,6,7</sup> Like other VADs, midline catheter failure (defined as a dwell time shorter than the prescribed treatment course) may be caused by occlusion (0.6%-20% of midline catheters become occluded), phlebitis (infective, chemical, and mechanical), dislodgement, or catheter-related infections.<sup>2,4,6,8-11</sup>

Midline catheters have an expected dwell time of 2 to 4 weeks.<sup>1-4,9,11</sup> The HITH program experienced a cluster of midline catheter failures in patients undergoing IV antibiotic therapy in January 2017. There are limited outcome data about midline catheters in the outpatient setting for antimicrobial treatment.

## OBJECTIVE

A retrospective analysis of midline catheter and PICC survival time in the hospital's outpatient population during a 4-month period was undertaken, which included the cluster of midline catheter failures.

## METHODS

This retrospective cohort study was performed to establish the dwell time and explore factors associated with dwell time of both PICCs and midline catheters in the patients treated in the HITH program at Liverpool Hospital, a comprehensive, 850-bed tertiary referral hospital in South Western Sydney, Australia, with 50 000 emergency department admissions annually.

The records of all outpatients admitted to the HITH who received antimicrobial therapy between December 1, 2016 and March 1, 2017 were included in the analysis. Data were obtained from 3 sources: the clinical registry maintained by the HITH program, the Liverpool Hospital clinical records, and the database maintained by the CVAS at Liverpool Hospital, which records the details of all VADs inserted by that service.

The primary outcomes measured were dwell time in situ and failure rate of intravascular catheters, with failure defined as a catheter dwell time less than the planned duration of therapy. Demographic details and device characteristics were collected, which included body mass index (BMI), presence of diabetes, brand of device, and length of device. All dwell times were calculated from the time of placement of the VAD until the time of removal. Patients with tunneled PICCs and other types of VADs were excluded from the analysis.

Student *t* tests and chi-square tests were employed depending on the distributional characteristics of the data. Survival graphing was performed using Statistica (Tibco Software Inc, Palo Alto, CA). Ethics approval for the study was obtained from the Human Research Ethics Committee for the South Western Sydney Local Health District (HREC number LNR/17/LPOOL/378).

## RESULTS

### Patient Characteristics

Fifty-nine patients were treated with PICCs and midline catheters during the study period (36 men and 23 women). The mean age was 60.4 ± 14 years. The mean ages of men and women were not significantly different. Overall, 71 admissions were analyzed, comprising 44 episodes with men and 27 with women. In the HITH program during the period, 2 patients had 3 admissions each, and 8 patients had 2 admissions each. There were 38 patients with diabetes (27 men and 11 women). One patient with a VAD with a successful dwell time of 81 days receiving bolus doses of daptomycin was excluded from the analysis because the type of catheter could not be confirmed, though it was likely a midline catheter. Descriptive statistics of patient characteristics appear in Table 1. The differences in the data for the characteristics listed in Table 1 were not statistically significant.

### Sentinel Cluster Characteristics

Four women and 7 men admitted to the HITH program experienced a midline catheter failure during a 2-week

TABLE 1

### Descriptive Statistics of Patient Characteristics

Characteristics	Men	Women
Number	36	23
Age (years)	61.5	58.7
Diabetes	27	11
BMI	31.1	29.6
PICC placement	18	15
Midline catheter placement	26	12

Abbreviations: BMI, body mass index; PICC, peripherally inserted central catheter.

**TABLE 2****Midline Catheter Statistics**

Characteristics	Success Group	Failure Group	Number of Patients in Group	Significance Level
Men/women	15/2	11/10	38	$P = .019$
BMI	$32.1 \pm 7.7$	$30.2 \pm 4.5$	37	NS
Dwell time	$25.1 \pm 17.9$ days	$13.4 \pm 11.5$ days	38	$P = .02$
Catheter length	$13.9 \pm 2.16$ cm	$13 \pm 1.8$ cm	38	NS
Diabetes present	13 (76%)	15 (71%)	38	NS
Bolus/pump	5/12	1/20	38	$P = .035$

Abbreviations: BMI, body mass index; NS, not significant.

period in mid-January 2017. The midline catheter mean dwell time in this group was  $15.09 \pm 13.36$  days. The sentinel cluster consisted of 6 occluded midline catheters, 5 of which were dislodged.

**Midline Catheter Data**

Midline catheters were present in 38 admissions (26 men and 12 women), with 17 (45%) successful completions without replacement and 21 failures (65%). Dwell time of midline catheters in patients completing the planned course was  $25.17 \pm 17.9$  days and  $13.47 \pm 11.5$  days for midline catheter failures. The difference between means of 11.7 days for successful and failed midline catheters was significant ( $P = .02$  [95%]; confidence interval [CI] 1.95-21.44 days). The mean insertion length was  $13.4 \pm 2$  cm ( $n = 37$ ). There was no significant difference between insertion length for successful and failed midline catheters. There was no significant difference between numbers of patients with diabetes in the successful and failure groups. There was no significant difference between BMI in the successful (mean 32.16,  $n = 16$ ) and failure (mean 30.21,  $n = 21$ ) admissions. The most common cause of midline catheter failure was obstruction secondary to venous thrombosis ( $n = 13$ , 62%), followed by dislodgement ( $n = 8$ , 38%). The proportion of women who experienced a midline catheter failure (83%) was significantly higher than that of men (42%); a difference of 41%;  $P = .019$  [95%]; CI 7.16%-61.6%.

**PICC Data**

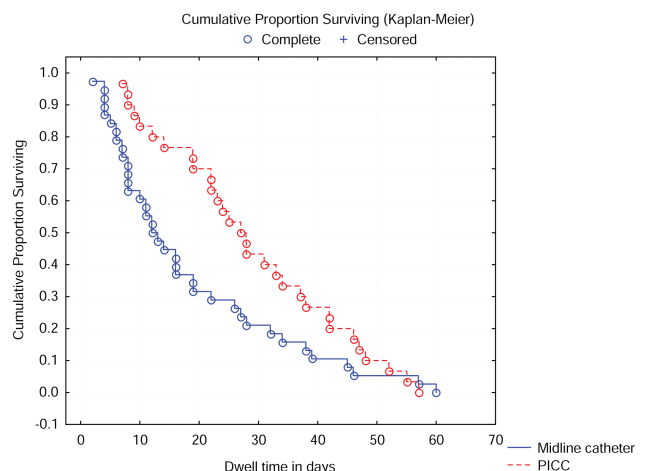
PICCs were used in 33 patients (18 men and 15 women). There was 1 failure due to dislodgement by the patient after 10 days. Outcome data were missing for 1 patient who transferred to a different service. The mean dwell time of successful PICCs was  $35.38 \pm 28.06$  days. There was no significant difference between the BMI of patients in the midline catheter admission group (mean 31.05,  $n = 37$ ) and the PICC admission group (mean 29.63,  $n = 26$ ).

The overall dwell time performance significantly favored PICCs with a mean of  $34.59 \pm 27.96$  days ( $n = 32$ ) versus the midline catheter mean of  $18.71 \pm 15.68$  ( $n = 38$ ) ( $P = .003$  [95%]; CI 5.28-26.47). The difference between

means of 10.11 days for successful PICCs and successful midline catheters was not significant, although the difference favored PICCs. The data for patients with midline catheters are shown in Table 2. A survival curve for dwell times of patients with PICCs and midline catheters is shown in Figure 1. For the purposes of the survival analysis, data for 1 patient with a PICC who completed their planned course but lacked an exact removal date, and data for 2 patients with a PICC with outlying dwell times of 87 days and 153 days, were excluded. The Gehan-Wilcoxon test shows the survival curves to be significantly different ( $P = .002$ ).

**Effect of Dosing Method and Specific Antibiotics**

Bolus doses, infusions, and combined bolus doses and infusion of antimicrobials were administered. Continuous infusions were administered via elastomeric pumps. All bolus doses were delivered according to the pump manufacturers' instructions for use. All bolus doses apart from the initial loading schedule for teicoplanin were single daily doses. Antibiotics prescribed are listed in Table 3. In the group of patients with midline catheters, 1 out of the 21 failures was prescribed bolus doses, versus 5 out of the 17



**Figure 1** Survival curve for PICCs and midline catheters. Abbreviation: PICC, peripherally inserted central catheter.

**TABLE 3****Antibiotic Usage**

Antibiotic	Daily Dose (In Order of Frequency of Use)	Method of Administration
Piperacillin/tazobactam	13.5 g; 9 g	Pump
Flucloxacillin	8 g; 12 g	Pump
Ceftriaxone	2 g; 1 g	Bolus
Cephalothin	12 g	Pump
Benzylpenicillin	10.8 g; 7.8 g; 7.2 g	Pump
Daptomycin	700 mg; 350 mg; 300 mg	Bolus
Meropenem	3 g	Pump
Piperacillin/tazobactam with vancomycin	13.5 g/3 g; 13.5 g/1.5 g; 13.5 g/1 g	Pump/bolus
Teicoplanin	400 mg; 400 mg second daily	Bolus
Ampicillin with ertapenem	8 g/1 g	Pump/bolus
Piperacillin/tazobactam with teicoplanin	13.5 g/400 mg	Pump/bolus
Flucloxacillin with ceftriaxone	8 g/2 g	Pump/bolus
Cefepime	1 g	Bolus
Cefazolin	6 g; 2 g twice daily	Pump/bolus

successes. There was a significant 25% difference in proportions between those prescribed bolus doses in the failure and success groups for midline catheters ( $P = .035$ ; 95% CI 1.21%-48.97%). There was no significant difference between midline catheter dwell times for those receiving bolus doses ( $26.3 \pm 22.2$  days) and those receiving continuous infusions ( $17.2 \pm 14.1$  days), and there was no association between success or failure with the use of specific antibiotics.

### Cut and Taper Effect

All the midline catheters were modified by cutting PICCs to size for proper placement. Reverse-taper catheters were placed in 2 patients (11%) in the midline catheter success group and 6 (28%) in the midline catheter failure group. There was no significant difference between the proportions of reverse-taper catheters in the 2 groups. In the midline failure group, there was no significant difference between the numbers of reverse-taper catheters associated with thrombosis (38%,  $n = 13$ ) and those that were dislodged (12.5%,  $n = 7$ ).

### Other Catheter Care

Normal saline boluses of 5 to 10 mL were routinely used as flushes before and after bolus dose delivery and at elastomeric pump changes for all PICCs and midline catheters. There was no difference between types of securement devices and dressings used for PICCs and midline catheters. Several patients with PICCs had additional securement with a subcutaneous engineered stabilization device, which was not used in patients with a midline catheter. Securing the catheters with sutures was not done. All antibiotic dose administrations, pump changes, device flushes, and dressing changes were performed by trained nursing staff. No patients self-administered antimicrobial agents in this cohort.

## DISCUSSION

The sentinel cluster prompted a review of processes and procedures within the CVAS. The CVAS had increased the frequency of use of midline catheters in December 2016 for patients requiring a VAD dwell time of greater than 14 days, but less than 4 weeks. Previously, midline catheters were inserted for patients with an expected dwell time of 14 days or less, or when a PICC could not be placed because of obstruction secondary to venous tortuosity. Placing a midline catheter incurs reduced risk for the patient as the central venous system is not accessed and radiographic or imaging catheter tip confirmation is not required. No change in insertion or dressing techniques could be detected before or after the identification of the cluster. After the cluster was discovered, there was a reversion to previous practice of selecting PICCS or midline catheters. The frequency of use of midline catheters decreased, and the midline catheter failure rate dropped sharply. Midline catheter use is now confined to patients requiring less than 14 days of IV therapy. The change in practice to increase the frequency of midline catheter use aligns with the findings of a review by Moureau et al,<sup>7</sup> who advocated for midline catheter use, especially in patients with difficult venous access who require long-dwell vascular catheters. They report an average dwell time for midline catheters that exceeds that of SPCs and even PICCs.

The survival curve for midline catheters to some extent reflects the fact that patients who had midline catheters placed were receiving shorter courses of antimicrobial therapy compared with patients who had PICCs. However, most of the difference in dwell time is explicable by the higher-than-expected midline catheter failure rate compared

with PICCs, with 55% of midline catheters not reaching their target removal date versus a 3% PICC failure rate. The survival curve shows an artifactual crossing of the curves secondary to exclusion of the patients that have PICCs with outlying extended dwell times.

Bolus dosing was associated with a higher success rate than continuous infusions using midline catheters. A continuous infusion requires a constant connection between the pump and the midline catheter, which increases the risk of dislodgement secondary to catching the administration set on objects. It might also result in more movement created at the tip of the midline catheter during a 24-hour period than with a bolus dose. With bolus dosing, in addition to the midline catheter securement device, the external portion of the midline catheter is secured on the skin of the upper limb when not in use. With continuous infusions, traction forces can be transmitted from the pump tubing to the securement device and then to the midline catheter, causing movement of the midline catheter tip, which might induce trauma of the vessel wall and, consequently, thrombosis. In addition, vigorous flushing of SPCs can result in significant stress on the blood vessel wall, leading to injury and thrombosis,<sup>12</sup> and this may apply to midline catheters.

### Possible Gender Effect on Limb Movement

In Australia, census data indicate that employed women perform more unpaid work (eg, housework, grocery shopping, gardening, household repairs) than employed men.<sup>13</sup> Adjei and Brand<sup>14</sup> examined time use data from Europe and the United States and found that elderly men spent remarkably fewer hours cleaning, cooking, and shopping than elderly women (88.7 vs 217.9 min/day). Regarding the time allocation to total housework, elderly women devoted more hours to these activities (4.7 h/day) compared with elderly men (3.1 h/day). An association between gender and midline catheter failure rate was detected in the present study, with the proportion of women experiencing midline catheter failure significantly higher than that of men. This might represent a gender difference involving the use of the upper limb in the home, with women continuing to perform more household duties than men despite the presence of an IV catheter connected to a pump; this places women at an increased risk of thrombosis or dislodgement. Some patients in the cohort study were on paid sick leave from their employer during their admission to the HITH, so there is a presumed equal exposure to a domestic environment within the cohort. The patterns of upper limb movement in the overall patient sample are unknown. The reason for the gender difference in midline catheter failure in this cohort is also unknown. However, motion sensors could be used to test the hypothesis that there is a difference in upper limb movement between men and women while using a midline catheter for a continuous infusion.

### Possible Factors Influencing Thrombogenicity

Continuous exposure to infusates might be more thrombogenic than intermittent bolus exposure. Bolus doses

of ceftriaxone were used in 4 patients in the successful midline catheter group and in none of the failures. Bolus ceftriaxone might be less thrombogenic than continuous infusions of piperacillin/tazobactam, though the study of Urbanetto et al<sup>15</sup> does not support this suggestion. Vancomycin has been reported as a risk factor for the development of central catheter thrombosis in patients receiving infusions for more than 2 weeks.<sup>16</sup> The numbers in this study, however, do not allow firm conclusions to be drawn about the relative thrombogenicity of the different antibiotics used in the midline catheter group including vancomycin. No association was identified between success or failure of a device and the use of a particular antibiotic in this study.

### Modified Tip Midline Catheters

Steele and Norris<sup>17</sup> have suggested that trimming the tip of reverse-taper PICCs increases the risk of postinsertion thrombosis. This increased risk is presumably due to the sharp surfaces resulting from the cut of the catheter abrading the endothelial lining of the vessel and precipitating a prothrombotic cascade. As all midline catheters in this series had modified (ie, cut) tips, this might be a possible explanation for the high frequency of failures in this series, though not all PICCs converted to midline catheters had a reverse taper. Modified PICCs rather than proprietary midline catheters were used at Liverpool Hospital. The proprietary midline catheters that were available in the hospital had a significant reverse taper, which was considered by the CVAS to be a risk for thrombosis, and the insertion wire was of less-than-optimal design. The price difference between PICCs and midline catheters at the time of the change of practice was considered negligible. Other proprietary midline catheters available on the market at the time were more expensive than the PICCs used in the hospital. Steele and Norris's photomicrographs<sup>17</sup> showed lancinate edges in previously smooth terminal sections of cut PICCs. This adds considerable weight to the hypothesis that there is an increased propensity of cut PICCs to abrade the endothelium and provoke thrombosis. Testing of this hypothesis by a randomized trial of proprietary midline catheters versus midline catheters generated from modified PICCs would be possible.

Patients experiencing catheter occlusion usually require subsequent visits to the hospital to resolve the problem, which is corrected either by establishing the patency of the catheter by flushing or by replacing the catheter. The economic cost of a VAD failure during a planned course of outpatient parenteral antimicrobial therapy (OPAT) in an HITH program in New South Wales is unknown. All of the patients in this series were publicly funded patients, and the exact costs of visits, equipment, procedures (including radiology), and drugs required to enter and maintain a patient in OPAT in an HITH program in New South Wales public hospitals would require a formal economic study.

## LIMITATIONS

The major disadvantages of the study are its small sample size and its retrospective nature. The limited data available do not permit strong conclusions to be drawn about possible factors that might have resulted in the high failure rate in midline catheters, such as the modified tips, the possible difference in patterns of upper limb activity associated with gender, possible movement of the midline catheter tip secondary to forces transmitted from the infusion tubing, and the possible relative increase in thrombogenicity of infused antibiotic solutions compared with bolus doses.

## CONCLUSIONS

A cluster of midline catheter failures in an HITH program resulted in a review of policies and procedures for the insertion and care of midline catheters. This study identified that a previous change in practice called for the placement of midline catheters in patients with an expected dwell time of more than 14 days. Reversing the change in practice—so that midline catheters were confined to patients requiring 14 days or less of IV therapy—resolved the problem rapidly. A PICC or other central VAD apart from a midline catheter is now inserted for any patient requiring antimicrobial therapy for more than 2 weeks. This practice is consistent with the preferences expressed by the panelists in the Michigan Appropriateness Guide for Intravenous Catheters<sup>1</sup> study, in which a panel of experts using the RAND/UCLA Appropriateness Method developed criteria for the use of IV catheters across patient populations.

Women had a higher rate of midline catheter failure than men. The reason for this is unknown. All the midline catheters in the series were modified PICCs, and it is not known whether a proprietary midline catheter would have a higher success rate than the midline catheters used in this cohort. Studies of upper limb movement in patients with midline catheters and PICCs, as well as formal trials of PICCs against proprietary midline catheters, may provide further insight.

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