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ORIGINAL ARTICLE

The effect of peripherally inserted central catheter (PICC) valve technology on catheter occlusion rates - The 'ELeCTRiC' study

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ABSTRACT:
Purpose: **Peripherally Inserted Central Catheters (PICCs) are increasingly being used to provide short to medium-term central venous access. The current study was designed to test the hypothesis that PICC valve technology does not influence PICC occlusion rates.**
Methods: **Intensive care unit (ICU) patients who required a PICC were randomized to one of three types of dual lumen PICC (open ended non-valved, Groshong valve, PASV valve). PICC occlusions were recorded and managed with a protocol that used urokinase.**
Results: **A total of 102 patients were recruited to the study. The overall risk of occlusion per catheter was 35% (95% CI 26% to 44%). The overall rate of occlusion was 76 occlusions per 1000 catheter days (95% CI 61 to 95). Presence or type of valve did not significantly influence this rate (open-ended non-valved PICC 38% of catheters, 79 occlusions per 1000 catheter days; Groshong 38% of catheters, 60 occlusions per 1000 catheter days; PASV 27% of catheters, 99 occlusions per 1000 catheter days). The dose of urokinase required to treat PICC occlusions did not significantly differ between PICC types.**
Conclusions: **Valved PICCs do not appear to influence PICC occlusion rates.**

Key words: Central venous catheters, Fibrinolysis, Occlusions, Peripherally inserted central catheters, Thrombosis, Valve

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INTRODUCTION

Peripherally inserted central catheters (PICCs) are increasingly being used in the intensive care unit (ICU) to provide short to medium-term venous access. While PICCs have been used extensively on general wards and in outpatients for several years, especially in oncology patients, their use in the ICU setting has only recently been explored and there remains a paucity of data regarding insertion techniques and complication rates (1).

We have been using PICCs in our ICU since 2006 in patients recovering from their acute illness but who still require venous access. In 2009 we published a retrospective service assessment of complications during one year of PICC insertions on the ICU (2). Whilst this service assessment revealed PICCs to have a low rate of severe complications, the rate of occlusion was felt to be high (approximately 40% of PICCs became occluded at some point with approximately 29.5 occlusions per 1000 catheter days). This occlusion rate is consistent with other reports suggesting that 25% to 30% of catheters become occluded at some point in their lifetime (3,4).

The vast majority of central venous catheter (CVC) occlusions are thought to be because of thrombosis or fibrin deposition at the catheter tip and this is consistent with the successful use of fibrinolytic agents to unblock them (4-8). A number of measures have been suggested to reduce the rate of catheter occlusion, including adequate flushing after phlebotomy, the use of heparin flushes (9), and the use of heparin bonded lines (10). One intervention that has been widely promoted by CVC manufacturers is the use of valved catheters, said to reduce thrombosis by preventing reflux of blood into the distal end of the catheter; however, there is a paucity of data supporting their use. As far as we aware, there are no randomized studies comparing valved with non-valved catheters.

The purpose of this study (The Effect of Line / Catheter Type on Risk of Complications – the 'ELeCTRiC' study) was to test the impact of valved PICCs on catheter occlusion rates in ICU patients.

MATERIALS AND METHODS

The study was approved by the local National Research Ethics Service and the hospital Research and

Development department. Informed consent was obtained from participants prior to being studied. Where this was not possible, informed consent was sought from the next of kin or from a professional legal representative and retrospective consent was obtained from the participant.

Inclusion criteria
ICU patients referred to the hospital Vascular Access Team (VAT) for insertion of a PICC.

Exclusion criteria
Failure to obtain consent, age under 18 years, contraindication to PICC insertion.

PICC insertion
Participants were randomized into one of three dual lumen 5 Fr PICCs:

Bard Groshong valved PICC (Bard Access Systems, UT, USA)

Navilyst Medical Vaxcel PICC with Pressure Activated Safety Valve (PASV) (Navilyst Medical, MA, USA)

Cook Medical non-valved Turbo-Flo PICC (Cook Medical, In, USA)

All PICCs were inserted by specialist vascular access nurses from the VAT at the bedside. The PICC was inserted into the upper arm basilic or brachial vein under sterile conditions using a Seldinger micropuncture technique. The catheter was advanced to a distance based on anthropometric measurements (distance from insertion point to mid-clavicle plus length of clavicle) and a portable chest x-ray was obtained to confirm the tip position. Bionector (Vygon, Swindon, UK) needleless injection devices were connected to both lumens and the PICC was cared for according to Trust protocols and policies. A daily Cambridge RAID assessment (required, appropriate, infected, dressed) was performed (2).

PICC occlusions

PICC occlusions were recorded and dealt with according to the following protocol. Both withdrawal occlusions and total occlusions were dealt with in the same way and we did not distinguish between the two or document which sort had occurred; 10000u urokinase was diluted into 1 ml 0.9% NaCl in a 10 mL syringe and instilled into each lumen using a push-pull technique. The urokinase was left for two hours before being aspirated and flushed with 20 mL 0.9% NaCl. If the PICC was still occluded, or if there was poor blood flow, then the protocol was repeated. PICCs that remained occluded after this were removed and replaced if clinically appropriate. An occlusion occurring after a successful unblockage was counted as a new event.

Data collection

Data was collected whilst the patient had the PICC in situ or until they were discharged from the ICU, whichever came first. Insertion details, patient demographics, the number of PICC days, occlusions, urokinase administration, PICC removals, and visual infusion phlebitis (VIP) score were recorded (11).

Statistics

Power calculations and data analysis was performed in conjunction with the Center for Applied Medical Statistics, University of Cambridge. The study was designed to have 80% power to show a 20% absolute reduction in occlusion rate (thought to be a clinically relevant figure) using a 5% significance level (two-sided). Depending on the occlusion rate the sample size was calculated to be between 62 (occlusion rate 30% in group 1, 10% in group 2) and 97 per group (occlusion rate of 60% in group 1 and 40% in group 2), and therefore the study was designed to recruit 100 patients per group (total of 300 patients).

The risk of occlusion for each line type was estimated and line types were compared using 95% confidence intervals of differences in independent proportions. Similarly, rates of occlusion were calculated per PICC days with approximate 95% confidence intervals for rate differences between the groups. The Kruskal-Wallis test was used to test for differences in the total urokinase dose between the catheter groups. For the subgroup of patients experiencing occlusions, differences in the average urokinase dose per occlusion were tested using a one-way ANOVA. Analysis was on an intention-to-treat basis (i.e. the data was analyzed according to the groups as randomized). A *P*-value of less than .05 was taken to be statistically significant.

RESULTS

The study was discontinued early after 102 patients were recruited because of four episodes of hemolysis in blood samples taken from the Navilyst PASV PICC. These episodes occurred inspite of a training programme that took place both before and during the study to ensure that blood samples were being taken correctly. Hemolysis did not occur in samples taken from the other two types of PICC.

Baseline characteristics

Comparisons of baseline characteristics between groups are shown in Table I. In one patient, the PICC (Navilyst PASV) could only be advanced a short distance and it was not possible to aspirate blood from it. This patient was excluded from further analysis.

TABLE I - COMPARISON OF BASELINE CHARACTERISTICS BETWEEN GROUPS. CATEGORIC DATA ARE EXPRESSED AS NUMBER (%); AND CONTINUOUS DATA ARE EXPRESSED AS MEAN (STANDARD DEVIATION)

	Cook (n=34)	Groshong (n=34)	PASV (n=33)
Male sex	12 (35%)	20 (59%)	22 (67%)
Age (y)	60.7 (14.9)	53.7 (18.7)	58.5 (16.1)
Depth (cm)	45.1 (2.62)	44.9 (2.76)	44.2 (4.13)
Number of removals for occlusion	1	1	0
Right side	10 (29%)	16 (47%)	10 (30%)*
Tip position			
Axillary vein	0	0	1
BCV	0	0	1
High SVC	10 (29%)	7 (21%)‡	6 (18%)‡
Low SVC	15 (44%)	19 (56%)	19 (58%)
RA	9 (26%)	8 (24%)	6 (18%)
PICC days	10.4 (10.4)	11.9 (10.0)	7.9 (7.4)
PICC days (total)	355	403	262

* One catheter was re-inserted on the opposite (i.e. left) arm. ‡ One high SVC catheter switched to low SVC after replacement.
BCV, brachiocephalic vein; SVC, superior vena cava; PICC, peripherally inserted central catheter; RA, right atrium

TABLE II - FREQUENCY TABLE SHOWING THE NUMBER OF OCCLUSIONS PER LINE TYPE

		Number of occlusions								Total
		0	1	2	3	4	5	6	9	
Line type	Cook	21	6	2	4	0	0	1	0	34
	Groshong	21	8	2	1	1	1	0	0	34
	PASV	24	5	0	1	1	1	0	1	33
Total		66	19	4	6	2	2	1	1	101

PASV, pressure activated safety valve

PICC Occlusion rate

The numbers of occlusions for each line type are shown in Table II.

In the Cook group, 13 out of 34 catheters became occluded at least once during the study period (38%). In the Groshong group, 13 out of 34 catheters became occluded at least once during the study period (38%). In the PASV group, nine out of 33 catheters became occluded (27%). The difference in percentage occluded between the Cook/Groshong group and PASV group was calculated to be 11% (95% CI, 11% to 32%). Therefore, there is no significant difference between the catheter types in terms of risk of occlusion. Overall, 35% of catheters had at least one occlusion (95% CI 26% to 44%). In total there were 78 occlusions in 1020 days (76 occlusions per 1000 catheter days [95% CI 61 to 95]).

There were 28 occlusions in 355 PICC days in the Cook group (79 occlusions per 1000 catheter days) compared to 24 occlusions in 403 PICC days in the Groshong group (60 occlusions per 1000 catheter days). The rate ratio of the Cook catheter relative to the Groshong catheter was calculated to be 1.32 (95% CI 0.77 to 2.28). Therefore, there is insufficient evidence of a difference in occlusion rates between the Cook and Groshong catheters.

There were 26 occlusions in 262 PICC days in the PASV group (99 occlusions per 1000 catheter days). The rate ratio of the PASV line relative to the Cook line type was calculated to be 1.26 (95% CI 0.74 to 2.15). Therefore, there is insufficient evidence of a difference in the occlusion rates between the PASV and Cook catheters.

The rate ratio of the PASV catheter relative to the Groshong catheter was calculated to be 1.67 (95% CI 0.96 to 2.90). Therefore, there is insufficient evidence of a difference in the occlusion rates between the PASV and Groshong catheters.

In our sample, the Groshong catheter had the lowest rate of occlusions per 1000 catheter days compared to the other catheter types, but this did not attain statistical significance.

Urokinase dose

The total doses of urokinase used to treat PICC occlusions are shown in Table III. There were no statistically significant differences in total urokinase dose between groups (H=0.76, *P*=.68). For those patients experiencing occlusions, there were no statistically significant differences in the mean average urokinase dose per PICC occlusion between the different catheter groups (F=0.64, *P*=.53).

DISCUSSION

We have shown, both in a retrospective service assessment (2), and in the current study, that in critically ill patients the rate of PICC occlusion is high with approximately 35% of catheters becoming occluded at some point during the patient's intensive care stay. There is a paucity of data in the literature to compare this figure with but we feel that it is representative of the likely PICC occlusion rate in this group of patients. In our opinion, this occlusion rate is high and carries with it a significant burden of morbidity, including time during which the catheter cannot be used for blood sampling or drug/fluid/blood product administration. Furthermore, the costs of unblocking occluded lines are significant in terms of nursing time and thrombolytic therapy.

There are two predominant mechanisms thought to lead to central venous catheter occlusions. The first of these is a buildup of fibrin around the catheter tip; the second is the reflux and subsequent thrombosis of blood from the venous circulation into the catheter tip. Theoretically, a valved system whose opening pressure is higher than the pressures found in the venous circulation would prevent the reflux of blood and reduce the incidence of thrombotic catheter occlusions. Furthermore, valved systems have the potential to reduce bleeding complications or air embolism should the catheter hub fail. Two main valve technologies exist, the Groshong valve and the PASV valve. The Groshong valve consists of a slit at the distal end of the catheter that remains closed at normal venous pressures and only opens during positive pressure (injection) or negative pressure (aspiration). The PASV valve works in a similar way but is positioned at the proximal end of the catheter. In spite of the theoretical advantages of these valves on the catheter occlusion rate, as far as we are aware no prospective study has been published to confirm the manufacturer's claims.

Our randomized pragmatic study in intensive care patients failed to show any significant difference in occlusion rate between valved PICCs (Groshong and PASV) and an open ended non-valved PICC (Cook). Our results are consistent with an earlier retrospective study that compared complication rates in Groshong Portacaths and open-ended (Deltec) Portacaths in oncology patients (12). This study concluded that the thrombosis rates were equivalent between the two groups (Deltec vs. Groshong, 0.07 vs. 0.06 events per 1000 catheter days, *P*>.05).

These results suggest that the predominant mechanism for catheter occlusion is fibrin deposition or thrombosis around the catheter tip rather than intra-luminal thrombosis and that future strategies should focus on this area. Expert catheter care probably remains the most important strategy for reducing occlusions; however, future advances in material technology may reduce the occlusion rate further by limiting the deposition of the fibrin sheath or thrombus on the catheter.

Whilst our study is a relatively large randomized study it does have certain limitations. The first of these is whether the intensive care unit patients in our study are representative of other patients who have PICCs in situ. Many critically ill patients have pro-thrombotic tendencies, and by the nature of their illness, require multiple drug/fluid/blood product administrations. For these reasons they are probably at a higher risk of catheter occlusion than many other patients and the occlusion rate may not reflect that found in the general population. However, it is in these high risk patients that interventions to reduce occlusions are most likely to be of benefit. We did not find that an intervention based on valve technology significantly reduced the occlusion rate.

The second limitation is that the study was discontinued early because of a number of episodes of blood he-

TABLE III - FREQUENCY TABLE OF CATHETER TYPE AGAINST TOTAL UROKINASE DOSE

		Total urokinase dose (u)									Total
		0	10000	20000	30000	40000	50000	60000	80000	90000	
Line type	Cook	21	4	5	1	2	0	0	0	1	34
	Groshong	22	6	3	0	2	0	1	0	0	34
	PASV	24	3	2	1	1	1	0	1	0	33
Total		67	13	10	2	5	1	1	1	1	101

PASV, pressure activated safety valve

molysis in blood samples taken from the PASV PICC. For safety reasons we did not think it was ethical to continue the study. Our conclusion that there are no differences in occlusion rate between the different valve technologies may represent a lack of statistical power to detect clinically relevant differences because we did not recruit the entire number of patients specified by the power calculation.

To conclude, PICC occlusion rates are high in critically ill patients and our study has not revealed current catheter valve technology to have a demonstrable impact on these rates. Other strategies may be required to reduce the occlusion rate and to reduce the health and economic burden of these blockages.

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