Comparison of three peripherally-inserted central catheters: pilot study

Michele Di Giacomo

Abstract

Peripherally-inserted central catheters (PICCS) are non-tunnelled, central catheters inserted through a peripheral vein of the arm. They are 50–60 cm long and are usually made of either silicone or second-third generation polyurethane. PICCs can be used for prolonged, continuous or intermittent infusion therapies (up to 3 months) both in hospitalized patients and in patients treated as outpatients, in a hospice, or at home. When establishing a vascular service it is key to select a PICC that meets the requirements of safety, cost-effectiveness, high resistance (ability to take increasing fluid volumes with high pressure devices) and durability, and low complications rate. The complications and dwell times of three different PICCs were studied: coated polyurethane, valved silicone and power-injectable. The study was conducted at the chemotherapy suite at the author's hospital with the aim of selecting the right PICC based on low incidence of complications, resistance and enhanced dwell time. Results show a low incidence of complications and long dwell time among patients with the power-injectable PICC. Furthermore, this study demonstrated a reduction on the rate of occlusion and rupture with power-injectable PICCs, which makes them safer to use for administration of chemotherapy and other vesicant agents, as well as for the management of patients in critical care.

Key words: Catheter ■ Dwell time ■ Intravenous therapy ■ PICC ■ Polyurethane ■ Silicone

Peripherally-inserted central catheters (PICC) are long catheters inserted into one of the major veins in the antecubital fossa, or upper arm, and advanced into the central veins. The tip is located in the lower superior vena cava (SVC) (National Association of Vascular Access Networks [NAVAN], 1998; Royal College of Nursing [RCN], 2003; Infusion Nurses Society, 2006).

Since the creation of the first nurse-led PICC insertion team in 1994 (Hamilton et al, 1995), the usage of PICCs in the UK has increased exponentially, with more nurses establishing and leading PICC teams. PICCs are largely used for administering chemotherapy, total parenteral nutrition, antibiotics, blood transfusions, intravenous (IV) fluids, and to perform frequent blood tests.

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Studies have shown that PICCs are as effective as tunnelled catheters for the management of critically ill patients with improved patient outcome and reduced costs; therefore, their usage is quickly expanding to critical care (Santolucito, 2007), long-term antibiotics and home care (Perrucca, 2001; Dougherty, 2006). The number of PICCs inserted annually in the UK is still unknown (Dougherty, 2006).

Advantages of PICCs and associated complications

The advantages of the use of PICCs versus other tunnelled central catheters have been clearly documented: reduced risk of pneumothorax, reduced catheter sepsis due to low skin colonization in the upper arm versus patient's chest and neck, reduced cost of insertion, reduced patient discomfort and easy maintenance (Dougherty, 2006).

The most common complications related to PICCs are:

- Possible vein irritation and thrombosis
- Catheter occlusion
- Catheter-associated infection
- Breakage of the catheter
- Difficulties making the necessary adjustment to the patient's lifestyle.

Vein irritation and thrombosis

PICCs are inserted into one of the veins of the patient's antecubital fossa or in the upper arm, and the line is advanced till its tip reaches the lower portion of the SVC (*Figure 1*). The puncture of the peripheral veins for the insertion and the advancement of the line through the venous system can cause irritation of the veins, which in severe situations can lead to thrombosis.

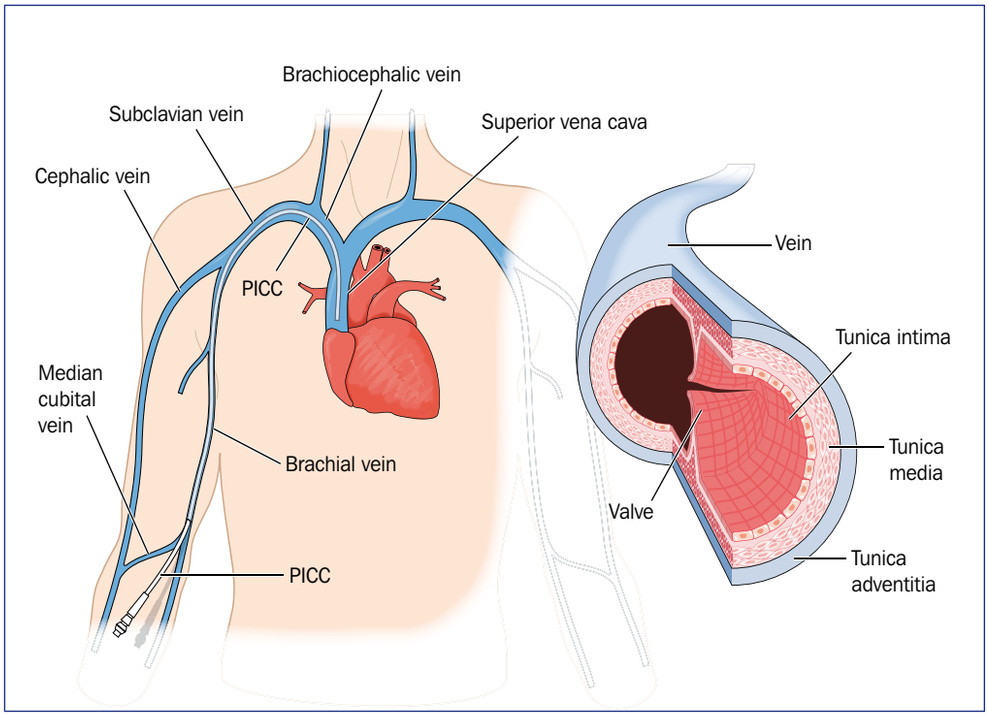
Veins are made of three layers or tunicas: tunica intima, media and adventitia (*Figure 1*). The tunica intima, which is made of squamous epithelial cells, facilitates blood flow along the vessel preventing the adhesion of blood cells to the wall of the veins. The insertion of a PICC can damage this lining of squamous cells, which can lead to platelets adhering to the vein wall, which in turn can lead to vein inflammation, known as phlebitis, or thrombus formation (Hadaway, 2003).

Incidence of vein irritation is increased by using a catheter too large for the lumen of the vein, poor securement of the lines, poor skin preparation prior to insertion, poor insertion technique, and usage of a catheter which remains relatively rigid after insertion (Dougherty, 2006). Hankins et al (2001) identified the high incidence of thrombotic events among patients with cancers and with sepsis. The main preventive measures are (Mayo, 2000):

- Correct placement of the tip of the line in the lower third of the superior vena cava
- Constant assessment of function while the central line is in situ
- Flushing the line using a meticulous pulsatile positive pressure flush.

The signs and symptoms of vein irritation and thrombosis can be vague or acute

Figure 1. Diagram showing (a) veins of the antecubital fossa or the upper arm, with peripherally-inserted central catheters inserted with tip in the superior vena cava; (b) transverse section of a vein: tunica intima, media and adventitia.



(Dougherty, 2006). The patient may report pain in the area, such as arm, neck or chest. Redness and oedema of the extremity, neck or face might be present. The patient might present with tachycardia, shortness of breath or an acute cough (Hankins et al, 2001).

Patients with a PICC experiencing any of these signs and symptoms require an accurate assessment and a venogram of the catheter to diagnose the thrombosis (Dougherty, 2006), and may require administration of oral or parenteral antibiotics. Confirmed thrombotic episodes require catheter removal and administration of anticoagulants (Hankins et al, 2001).

Catheter occlusion

The occlusion of a PICC can happen due to:

- Formation of a blood clot inside the lumen of the PICC
- Formation of a fibrin sheath/tail around the PICC
- Precipitation of drugs.

Mayo (2001) identifies two main types of occlusions: persistent withdrawal occlusion and total line occlusion. With the former the practitioner is able to push fluids through the PICC but can not withdraw blood for sampling or to assess the patency of the line. With the latter, both the infusion of fluids and the withdrawal of blood is not possible. Occlusion can be prevented with meticulous positive flushing, as recommended by the RCN (2003).

In the event of an occluded PICC, the first step is to ascertain the cause. The main treatments are represented by the simple administration of boluses of NaCl 0.9% and the administration of antithrombolytic agents such as urokinase or streptokinase (Dougherty, 2006) or, where the occlusion is irresolvable, by removal of the catheter.

Infection

One of the most serious complications associated with the use of vascular access devices is bloodstream infection, and has been reported as leading to death in the US (Hadaway, 2003). In the UK the number of central lines inserted annually has been estimated around 200 000 (Elliott, 1993), and McGee and Gould (2003) reported an incidence of infection with central lines in the UK at 2–26%.

PICC insertion compromises the skin's integrity. The catheter then represents a pathway for microorganisms to migrate from the insertion site to the tip of the catheter, or travel along the lumen into the bloodstream (Dougherty, 2006). The most common organisms responsible for PICC infections are *Staphylococcus aureus* and *Candida albicans* (Gallieni et al, 2008). Most PICC infections occur by two mechanisms: infection of the exit site, followed by migration of microorganisms along the external catheter surface, contamination of the catheter hub, leading to entrance of microorganisms into the bloodstream.

Owing to the cost implications related to catheter infections, such hospital admissions and catheter replacement, as well as patient costs of increased morbidity and mortality, the Department of Health (DH) commissioned the epic guidelines – a set of national evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals (Pratt et al, 2001). Key recommendations from the epic guidelines are:

- Strict hand washing technique
- Use of 2% chlorhexidine gluconate for skin preparation
- Adoption of sterile measures for catheter insertions
- Usage of ultrasound devices for catheter placement.

Most PICC infections are not diagnosed, or only became recognized when the patient exhibits severe septicaemia. Patients with infected PICCs can manifest with either local or systemic signs of infection, or a combination of both (Elliott and Tebbs, 1998). Local signs are redness at the insertion site, pain and exudate. The systemic signs of PICC infection are pyrexia, positive distal catheter tip cultures and positive blood cultures taken both peripherally and centrally.

Elliott and Tebbs (1998) and the updated epic guidelines, epic2 (Pratt et al, 2007), report a lower risk of infection with PICCs as opposed to other central catheters. When PICC infection is confirmed, the patient needs to be started on parenteral antibiotic therapy and the catheter should be removed, depending on the patient's immunity status, severity of the illness and response to antibiotic therapy. Immunity status is important because if the patient is neutropenic or with poor immune defence then the line should be removed immediately without waiting for a response to antibiotics – otherwise severe septicaemia can occur.

Catheter breakage

PICCs run from the insertion site to the SVC, therefore their integrity is essential for patient safety. Catheter fracture or breakage can happen at several different sites: at the hub, catheter, just above or below bifurcation or in the internal catheter (the section of the PICC inserted into the vein).

The site of the damage or breakage can strongly influence whether the catheter can be repaired or needs to be removed (Dougherty, 2006). Internal fracture of the catheter as a result of 'pinch-off' syndrome,

due to compression between clavicle and first rib, can lead to severe complications if the catheter is not removed – the line can fracture leading to severe emboli formation and extravasation of drugs might occur (Dougherty and Lamb, 1999).

Lifestyle adjustment

When considering patients for PICCs, it is important to consider what adjustments to their daily activities will be necessary. PICCs require weekly maintenance and the avoidance of certain activities such as swimming or heavy lifting.

Oakley et al (2000) conducted a study to analyse the perception of having a PICC on the quality of life of cancer patients. The study showed that patients found PICCs useful for chemotherapy treatments and were adjusting well and quickly to the presence of the line.

PICC materials

PICCs can be made of different materials, the most common are polyurethane and silicone. These two materials have characteristics in their structure that can affect the PICC performance.

Nurses establishing PICC teams are faced with the difficult decision of deciding the right product to use. Mayer and Wong (2002) suggested that the two most important features to consider in choosing the right PICC are resistance and flow rate. The material with which the catheter is made of influences both these factors. Silicone is a soft material, which means that the silicone PICC is flexible and easy to insert into the patient's vein with reduced vein trauma. However, because of the material flexibility, in order to achieve resistance the wall of the catheter has to be thick, which results in a reduced flow rate. Polyurethane is a stiff material, which results in increased catheter resistance and an increased flow rate due to the thinner wall of the catheter.

The optimal PICC carries fewer complications for the patient and an increased flow rate (Mayer and Wong, 2002). Silicone is associated with an increased risk of infection because it is more likely to get contaminated with *S. aureus* (Dougherty, 2006). Every healthcare professional must be aware of the characteristics of different PICCs so that they can make an educated choice regarding their usage.

Dwell time

The number of days a PICC is in place is called the dwell time. The placement of a PICC aims to make the clinical management of patients easier and more cost-effective. To achieve cost-effectiveness and good patient satisfaction the PICC has to be durable so it can be left in situ for the length of the therapy.

In choosing a PICC, dwell time is an important factor because short dwell times mean extra costs, interruption of therapy and increased patient anxiety (Mayer and Wong, 2002). Dwell time seems to be strongly correlated to the material of the PICC. Mayer and Wong (2002) conducted a study to compare the dwell time of silicone versus polyurethane catheters, and found that the polyurethane catheters had longer dwell times leading to financial savings and better patient satisfaction.

The present study

A PICC service was established at the author's hospital in 2007 as part of the cancer services department. To ensure an accurate and cost-effective choice was made on which PICC product to use it was decided by the chemotherapy/PICC nurse specialist, in accordance with the oncology/haematology team leader, to conduct a pilot study using three different products available on the vascular access market:

- Polyurethane PICCs with an antimicrobial coating
- Valved silicone PICCs
- Power-injectable PICCs.

For the purpose of this study, the chemotherapy/PICC nurse specialist decided to include only the 5 Fr double-lumens lines. This was to standardize the study samples to eliminate additional variables such as different internal lumen size and flow rate. Line insertion followed epic (2001) guidelines using ultrasound devices and Seldinger technique, which have been associated with lower complication rates. With the Seldinger technique, venipuncture is made with a small-gauge needle and a guide wire is threaded through the needle into the vein. The needle is removed and a peel-away sheath is threaded down to the skin over the guide wire introducer. The guide wire is removed and the catheter is advanced, stabilized, and the sheath removed and torn away.

The polyurethane PICCs used had an antimicrobial coating, which makes the line a brownish colour. The length of the line is 60 cm, which requires the operator to trim it before insertion. The coated polyurethane PICCS used are open-ended and require flushing with heparin 50 IU. The valved silicone PICCs are made with soft silicone with a three-way valve system – Groshong® valve – on the tip, and require weekly maintenance with NaCl 0.9% 10 ml.

The power-injectable PICCs (Pro–PICC™ CT) were supplied by MedCOMP and are made of a new third-generation polyurethane. The 5 Fr power–injectable PICCs are open-ended with a length of 55 cm and therefore require trimming prior insertion. Maintenance of the line involves weekly flushing with heparin 50 IU.

The sample

Each type of PICC was trialled on 100 patients, giving a total sample of 300, comprising 128 men and 172 women with ages ranging from 1–89 (*Table 1*). Patients were recruited from oncology, haematology and general medicine:

- Group 1 – 100 patients using coated polyurethane PICCs were trialled from 1 January 2007 to 1 March 2007; 55% oncology patients, 25% haematology and 20% general medical patients.
- Group 2 – 100 patients using valved silicone PICCs) were trialled from 2 April 2007 to 2 October 2007; 60% oncology patients, 20% haematology and 20% general medical patients.
- Group 3 – 100 patients using power-injectable PICCs were trialled from 3 October 2007 to 21 December 2007; 50% oncology patients, 35% haematology and 15% general medical patients.

A collection data tool (available from author) was created to collect the following information: medical condition of the patient, date of insertion, reasons for insertion, date of removal, reasons for removal. The collecting tool was kept in the medical notes and filled in by the person removing the PICC and sent back to the chemotherapy clinical nurse specialist.

The high incidence of vascular complications, such as increased risk of thrombosis, in

Table 1. Age demographics of study participants

Age range	Number of patients
1–14	20
15–20	29
21–40	40
41–60	130
>61	81

patients with oncology and haematology conditions has been widely reported in the medical and nursing literature (Camp-Sorrell, 2004); Dougherty, 2006; Gallieni et al, 2008). In view of this documented increased risk of vascular complications, and for the accuracy of the study, the composition of each group was similar with regard to the number of patients from each medical speciality. In fact, the composition of the three groups appears to be very similar with 50–60% oncology, 20–35% haematology and 15–20% general medical patients.

To avoid discrepancies in the care of the PICC, such as usage of different dressing products or different cleaning, flushing or dressing techniques, which could have affected the outcome of the line and the result of the study, all 300 patients were required to attend weekly sessions in the chemotherapy suite for maintenance and care of the lines without outside interferences.

Results

Insertion of the PICCs occurred from January 2007 to December 2007, and each line was observed for a total of 180 days from the time of the insertion, which lead to a closure of the study in February 2008 when all the results were analysed. The areas analysed were:

- Reasons for insertion
- Complications encountered
- Dwell time.

Reason for PICC insertion

The requirement of chemotherapy administration seems to be the major factor for requirement of a PICC insertion in all three samples, followed by long-term antibiotic administration (*Table 2*). Therefore, the variable related to the immunosuppression and high vulnerability of the patients receiving chemotherapy agents is equally redistributed among the three groups.

Complications

The second area of interest in the study was the rate of complications related to insertion and usage of PICCs. Complications associated with central lines can increase patient morbidity and mortality and generate extra costs for the healthcare provider. The complications encountered by the patients included in this study are shown in *Table 3* and *Figure 2*.

Dwell time

The dwell time of the line is an important factor when choosing a PICC. A short dwell time means extra cost for replacement, increased patient discomfort and the interruption of treatments. *Table 4* shows the dwell time for each PICC.

The polyurethane PICCs had a dwell time of 1–60 days, 60% of the valved silicone PICCs had dwell times of 31–60 days and two lines stayed in situ for 60–90 days. The power-injectable PICCs had a dwell time of 31–180 days, with 19 lines still being used after 180 days. The dwell time was calculated from the date of insertion with the line being monitored for up to 180 days from the time of insertion.

Group 1: The coated polyurethane PICC group experienced a high rate of mechanical phlebitis (70), followed by occlusion (20) and infective phlebitis (10) and sepsis (10) (*Table 3*; *Figure 2*). Dougherty (2006) suggests that the stiffness of the polyurethane material could cause irritation of the tunica intima of the vein which can lead to vascular complications such as phlebitis.

Episodes of mechanical phlebitis were easily resolved with application of warm pads over the affected area for 20 minutes, at least four times at day, to promote circulation and reduce inflammation (Camp-Sorrell, 2004).

Occlusions experienced by patients in group 1 were in 95% partial occlusions and only required flushing with NaCl 0.9% and heparin 50 IU. The administration of urokinase was required in only 5% of the occlusions in the coated polyurethane group.

The ten cases of infective phlebitis were resolved with the administration of broad-spectrum oral antibiotics while the ten episodes of septicemia required parenteral administration of antibiotics and in five out of ten cases the PICC had to be removed because infections were not resolving with the administration of antibiotics.

Group 2: In the valved silicone PICC group a complete decrease in the mechanical phlebitis was noted. However, there was a high rate of occlusion and rupture of lines. The 28 cases of occlusion out of the 30 were complete line occlusions and required removal.

To avoid causing increased anxiety and risk of vascular complications, PICC inserters are trained to repair or replace lines using a technique called 'exchange over the wire'. This technique involves the insertion of the guide wire through the damaged or occluded line, the subsequent removal of the damaged line and the insertion of a new line (*Figure 3*). An inability to perform an exchange-over-the-wire insertion was caused by the presence of valves on the tip of the PICC. Hence, occlusion or rupture of lines meant a complete reinsertion of the PICC.

Three patients experienced migration of the lines, which required the removal and reinsertion of the lines in two out of three cases. NAVAN (2006) state that the tip of the PICC has to be located in the lower part of the SVC. Especially in chemotherapy settings,

Table 2. Reasons for peripherally-inserted central catheter insertion

	Coated polyurethane	Valved silicone	Power-injectable
Chemotherapy	80	80	85
TPN	1	0	2
Antibiotic	19	20	13

TPN = Total parenteral nutrition

Table 3. Complication occurances for each type of peripherally-inserted central catheter insertion

Complication	Coated polyurethane	Valved silicone	Power-injectable
Occlusion	20	30	2
Rupture/split	0	20	0
Mechanical phlebitis	70	0	10
Infective phlebitis	10	3	0
Malposition/migration	1	3	1
Sepsis	10	10	1

the position of the tip in the lower two third of the SVC reduced all complications related to administration of vesicant agent, which can cause tissue necrosis if extravasation occurs (Polovich et al, 2005). Therefore, episodes of migration of PICCs represent a serious complication for patients and nurses because they can lead to extravasation of drugs with subsequent tissue necrosis and even patient death.

Group 3:The power-injectable group showed a dramatic reduction in the rate of occlusions, with only two episodes recorded. Mechanical phlebitis was recorded in ten cases and only required heat application for a few days. Sepsis was only recorded in one patient, as was migration.

Discussion

When establishing a PICC team, one of the most important steps is to choose the right PICC to use. It is important to choose a product which fulfils all the requirements of:

- Safety
- Durability
- Resistance to pressure
- Reliability.

Medical and nursing communities are still debating the characteristics and attributes of silicone versus polyurethane PICCs. There have been a few studies to ascertain which material best meets all the criteria for the perfect PICC (Rivitz and Drucker, 1997; Tingey, 2000; Mayer and Wong, 2002), but so far these studies have been inconclusive.

As discussed previously, silicone is a soft and flexible material which requires the line to have a thick walls with reduced internal diameters. Silicone lines are more comfortable for patients but they present low flow rates and increased risk of rupture. Polyurethane, on the other hand, is a resistant and stiff material. This allows the lines to achieve high resistance with thin walls and large internal diameters, which translates to in increased dwell time and high flow rates.

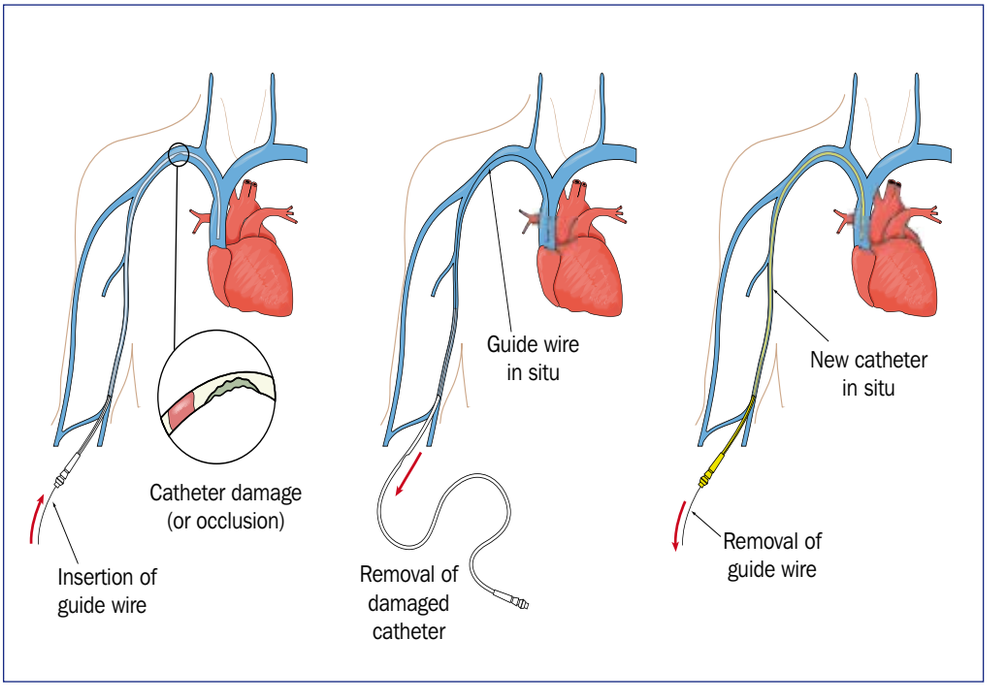
There are no official recommendations on which type of PICC to use from organizations such as the RCN, the National Institute for Health and Clinical Excellence (2003) or the Association for Vascular Access. Therefore, practitioners need to decide wisely on which PICC meets the requirements and needs of their services and patients.

This pilot study aimed to review the characteristics of three PICCs available on the market and, using this information, make an evidence-based decision on which product was most suitable for patients requiring PICC insertion at the author's hospital.

As previously noted, the 100 patients were recruited for each group and each PICC was observed for up to 180 days, depending on dwell times, from the date of insertion. Group 1 (coated polyurethane) were recruited January–March 2007, but data collection occurred until June 2007. Group 2 (valved silicone) were recruited April–October 2007, but data collection occurred until January 2008. Group 3 were recruited October–December 2007 and data collection was completed in February 2008. Discrepancies in recruitment times were due to the unpredictability of the time required to recruit 100 patients for each group.These discrepancies in recruitment times have not affected the results of the pilot study because each PICC was observed for up to 180 days from the moment of the insertion.

After reviewing the data, the PICC team at the author's hospital decided to select the power-injectable as the line of choice. The reasons behind this choice were the low complication rates and the long dwell times of this type of PICC, which translates to higher

Figure 3. Exchange over the wire technique – insertion of a guide wire through the damaged or occluded line, the subsequent removal of the damaged line and the insertion of a new line.



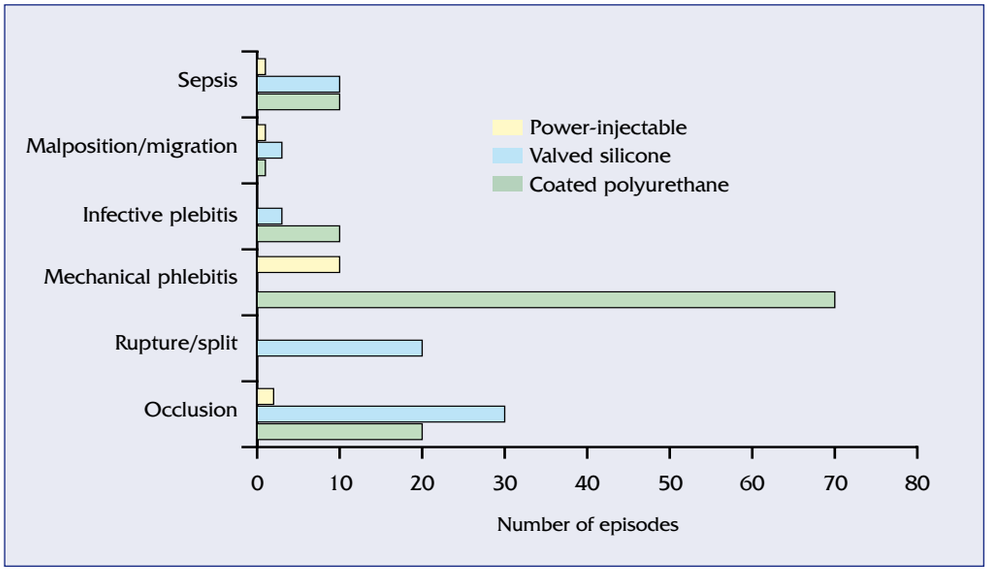


Figure 2. Number of complications occurances for coated polyurethane, valved silicone and power-injectable peripherally-inserted central catheters used in study.

Table 4. Dwell times for each type of peripherally-inserted central catheter insertion

Days	Coated polyurethane	Valved silicone	Power-injectable
1–30	70	19	1
31–60	30	60	40
60–90		2	20
90–180			20

patient satisfaction and overall cost saving. Furthermore, due to the nature of the majority of the PICC recipients, it was noticed that the power-injectable PICC was fulfilling all the needs of the cancer sample group.

There are different power-injectable PICCs available on the market, such as Pro-PICC™ (MedCOMP) and Power-PICC™ (Bard). In choosing the ideal power-injectable PICC for the author's hospital, the Pro-PICC from MedCOMP was chosen because of the cost-effectiveness of the product compared with other available products.

With the valved silicone PICCs it was noted that because of the presence of valves, there were issues with completing home infusions of chemotherapy. It was also noted that because of the softness of the silicone, nurses found it difficult to draw blood. The inability to administer blood products without using infusing devices was also reported.

Cancer patients have an increased risk of requiring critical care admissions. It was noticed that the power-injectable PICCs were safely used in critical care areas for the management of critically ill patients, such as monitoring central venous pressure. This was not possible with valved silicone PICCs. The power-injectable PICCs met all the requirements for cost-effectiveness and their characteristics and attributes meant they can be used for a range of medical situations, from providing long-term antibiotics to critical care situations.

Conclusions

The aim of this pilot study was to help the author select a PICC product which can fulfil all the requirement and needs of a perfect PICC, i.e. durability, resistance to increased pressures, ease of insertion and low associated complications. Data were collected on complication rates and dwell times for three different PICC products with the objective of identifying a PICC with low complication rates and high dwell times. This would result in better patient management, cost savings, decreased patient mortality from to complications and better usage of nursing and medical times.

The power-injectable PICC proved to be an effective tool for the achievement of all the above. This type of PICC proved to be effective in all clinical situations, from safe administration of chemotherapy agents to the management of critical patients, as was found by Santolucito (2007). Hence, the power-injectable PICC reduced the need of having different lines for different medical patients which results in lowered costs and less risk of confusion among staff. BJN

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KEY POINTS

- Peripherally-inserted central catheters (PICCs) are associated with a variety of complications, including vein irritation and thrombosis, occlusion, catheter-associated infection, breakage of the catheter, and difficulties making the necessary adjustment to the patient's lifestyle.
- When establishing a vascular service it is key to select a PICC that meets the requirements of safety, cost-effectiveness, high resistance (ability to take incresing fluid volumes with high pressure devices) and durability, and low complications rate.
- The new generation of power-injectable PICC in one of the safest and effective PICCs for the management of patients with chronic conditions and those in critical care.
- Power-injectable PICCs meet all the criteria of durability, resistance, low complications rates and cost-effectiveness.
- More research is required to ascertain patient satisfaction and comfort regarding other central line devices.