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Abstract
Permanent central venous access has become one of the cornerstones of modern hospital medicine. It is of particular importance in pediatrics as many treatments cannot start without reliable central access. For this reason using the optimal technique for central venous access is crucial. The decision about approach is based on the expertise but also balancing the early risks associated with insertion (such as pneumothorax and cardiac tamponade) against the long-term risks of venous occlusion. For patients requiring long-term venous access, occlusion of the great veins can become a life-limiting problem. This article discusses the evidence of the three established techniques of open cut down, landmark percutaneous and the ultrasound guided percutaneous technique. It also discusses the benefits of organization of central venous access service to improve the patient journey and increase the efficiency of the service provided. With local expertise and a well-organized service the literature confirms that the ultrasound guided percutaneous technique offers the best combination of low complications associated with insertion with a venous occlusion rate of less than 3%. This should now consider the gold standard for insertion of permanent venous access in children.

INTRODUCTION
Permanent central venous access has become one of the cornerstones of modern hospital medicine. It is of particular importance in pediatrics as many treatments cannot start without reliable central access. For this reason, using the optimal technique for central venous access is crucial to prevent complications and, in particular, to avoid venous occlusion which can limit long-term access to the central veins. This article discusses the evidence of open cutdown vs percutaneous approach for insertion of central lines and also the benefits of organization of central venous access service to improve the patient journey and increase the efficiency of the service provided.

History
Tunneled silastic central venous lines were first described by Broviac et al. [1], in 1973 for parenteral nutrition and by Hickman et al. [2], in 1979 for chemotherapy and proved to be a landmark moment in the development of increasingly intensive treatments.

Techniques
Presently, there are 3 standard techniques used for the insertion of permanent vascular access in childhood: open surgical cutdown (OSC), percutaneous landmark technique (LT) and the ultrasound guided percutaneous technique (USG).

Open surgical cutdown
Open surgical cutdown (OSC) can be either onto a peripheral tributary such as the cephalic, facial, or external jugular vein [3], or directly into the internal jugular vein [4]. It involves incision of the skin, with dissection and control of the vein. If a peripheral tributary is used, it is inevitably ligated; if the internal jugular vein is used, the line is inserted under direct vision via a venotomy that is then usually repaired with a fine nonabsorbable suture [3]. Potential problems of OSC include a relatively large scar in a visible part of the neck, and venous occlusion, which has been reported in up to 33% after internal jugular vein cutdown [5]. In open cutdown, the presumption is that the dissection and repair of the venotomy traumatize the vein, increase the difficulty of reoperation, and increase the risk of thrombosis [6,7]. It is also a relatively slow procedure, however, none of these complications are immediately life threatening and so it was the preferred technique for paediatric surgeons for many years.

Percutaneous landmark technique
The percutaneous landmark technique (LT) involves passing the needle along the anticipated line of the vein using anatomical landmarks on the skin surface as a guide and thus is essentially a blind procedure [8]. Once the vein has been punctured, the track...
is then dilated using the Seldinger wire technique; and the line is inserted via a peel-a-part introducer [9,10]. However, numerous complications [11] including failure to cannulate the vein [12], arterial puncture [13,14], haemo and/or pneumothorax [15], pericardial tamponade [15], and even death have been described in both adults and children [16-18]. The problem with the LT is that variations in anatomy and the depth of the cannulating needle are difficult to assess [19]. Alderson et al. [20], showed that 18% will have atypical venous anatomy and that age and weight correlate poorly with the size of the vein. This explains why, even in the most experienced hands (for instance cardiac anaesthetists), the LT will fail to cannulate the vein successfully at the first pass in over 10% of cases [21].

Ultrasound guided percutaneous technique

The use of ultrasound for percutaneous central venous cannulation was first described in the 1990s [12,22,23]. It allowed the operator to guide the needle into the vein much more accurately [24-26], under direct vision and randomized controlled trial evidence in adults has shown that fewer needle passes were required to cannulate the vein and that fewer complications occurred compared with the LT [8]. The reduced number of complications also makes this a cost-effective technique based on the premise that at least 90 complications are avoided per 1000 procedures [27,28].

The UK’s National Institute of Clinical Excellence has also now stated that the preferred method for insertion of temporary percutaneous central lines should be with ultrasound guidance [28]. It has also been endorsed by other medical societies including the European Society for Medical Oncology, and the American Society for Parenteral and Enteral Nutrition.

Which is best in paediatrics?

Historically, the debate on the optimal technique was between peri-operative safeties (i.e. complications associated with insertion using the percutaneous technique) versus the long-term benefits to the patient of avoiding venous occlusion (associated with open cutdown). In children there is the additional difficulty of variations in size and anatomy so that a baby less than 1 kg can be done as safely as a 15 year old. Concerns about the percutaneous approach are principally aimed at the technical difficulties of the smallest babies. A 2009 prospective study [29] of 500 Hickman lines insertions (in 403 patients and including 94 redo Central Venous Lines(CVLs), median age of 44 months (14 days-19 years)), showed an overall successful cannulation rate of 99.8% and a 2.4% peri-operative 30 day complication rate. This compares with a reported 10-20% unsuccessful cannulation rate when using LT [21,28].

The approach Arul et al., describe is a modification of the standard Seldinger technique, developed to improve ease of insertion and safety in small children [29].

Modifications include:

1. Continuous scanning with the ultrasound while the needle is being punctured allows the needle tip to be observed throughout the procedure until it can be dearly seen within the lumen without puncturing the back of the vein.
2. The initial vein puncture is with a 4-cm-long 21-gauge needle, the lumen of which will allow passage of a 0.018 " wire. This wire is then used to pass a 4F introducer that in turn can accept the larger 0.025 " or 0.038" wire that is part of the percutaneous insertion kit.
3. Assessing the correct length of the line by holding the line over the anterior chest wall just above the nipple and taking a fluoroscopic image to check the position of the line tip at the level of the upper right atrium.

Venous Occlusion and Redo Vascular Access

The single biggest advantage of the ultrasound guided percutaneous approach is not improved cosmesis or even the reduction of peri-operative complications but the ease of redo surgery and the reduction in long term venous occlusion. Children who require long term venous access (for instance short gut patients who require parenteral nutrition for life) need multiple new lines to be inserted over their lifetime. Performing an open cutdown on an internal jugular vein that has already been accessed is a technically difficult procedure with a significant chance the vein is already scarred or occluded [30]. Long term follow-up of patients who had USG approach had a less than 3% vein occlusion rate [31] compared with published rates of over 25% for OSC 0 or up to 20% in LT [32].

Venous access in tiny babies

Concerns about complications with the percutaneous approach in tiny babies including bleeding, pneumothorax, line malposition, venous occlusion, and even death [16-18] limited a wider degree of adoption. However, experience in the use of ultrasound can almost completely avoid these problems. A 2010 paper [33] looked specifically at Broviac line insertion with the USG in neonates(weight 0.63 to 4.1 kg and age 14 to 209 days). Of the 36 patients there were no cases of failure to cannulate the vein (25 lines inserted in the right internal jugular and 11 in the left internal jugular) or perioperative surgical complications; in particular there were no cases of arterial puncture, pneumothorax, haemothorax or pericardial tamponade [33].

Slight modifications improved the efficacy in these small infants and neonates:

- The vein was initially punctured with a 22G IV cannula under ultrasound guidance, a small 0.01 inch nitrinol guide wire inserted and the cannula exchanged for a tunnelled 2.7 Fr cuffed Broviac line.

Though the conclusions from this paper proved USI guided CVL insertion is safe even in small sized neonates and infants, the authors felt that an essential part of the success was having experience [33]. The benefits of using a small experienced team to both coordinate and perform vascular access were demonstrated by Wells et al. [34], who compared complications before and after the introduction of a dedicated consultant led Vascular access team (VAT). The team consisted of 3 consultants, one paediatric surgeon and 2 paediatric anaesthetists, working on twice weekly elective lists (Table 1).
Median time taken for insertion of tunnelled Hickman lines in 2005 to 2006 was 67 (56-82) minutes electively, which is significantly less than insertions on an emergency list, which took a median of 85 (65-110) minutes; note that this time included anaesthesia but excluded any other associated procedures such as laparotomies or tumor biopsies [34]. Since the introduction of the vascular access team there was a significant fall in the number of unsupervised trainee insertion from 38 (8%) to 19 (3%) and an increase in supervised trainee line insertions from 20 (4%) to 91 (16%) after the introduction of the VAT.

SUMMARY

There is now overwhelming evidence that the ultrasound guided percutaneous approach is a safe procedure in the paediatric age group for all sizes from tiny babies less than 1 kg to children over 15 years and of adult size. However, skill in the use of ultrasound to accurately cannulate a tiny vein requires training and experience. The operative complication rates published by the Birmingham group are very low [29,33] suggesting that a small team of experienced consultants working on regular elective lists improves the complication rates, patient journey, training of junior surgeons and efficiency of the service [34]. We therefore believe that the ultrasound guided percutaneous technique delivered by a dedicated consultant vascular access team should become the gold standard for permanent vascular access insertions done in children.

INTEREST DECLARED

Our Hickman lines are all (except 2.7 Fr) supplied by Bard Access Systems, Utah, USA, who financially support vascular access educational events in which the authors participate. Our 2.7 Fr lines are supplied by Vygon Ltd, Ecouen, France. Other manufacturers make similar products. Neither of our suppliers has in any way influenced the content of this paper, nor have the authors received any incentive to endorse a particular product or technique.

Table 1: Number of insertions separated by time of surgery before and after the introduction of the VAT.

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<thead>
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<th>Total insertions</th>
<th>Elective</th>
<th>Emergency</th>
<th>Out-of-hours</th>
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<tr>
<td>Pre-VAT</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(2002-2003)</td>
<td>465</td>
<td>324 (70%)</td>
<td>112 (24%)</td>
<td>29 (6%)</td>
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<tr>
<td>VAT</td>
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<tr>
<td>(2005-2006)</td>
<td>569</td>
<td>480 (84%)</td>
<td>72 (13%)</td>
<td>17 (3%)</td>
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</table>
| Emergency indicates procedure done on emergency list between 9 AM and 6 PM; out-of-hours, procedure done on emergency list between 6 PM and 9 AM (P b .05).

Table 2: Number of insertions separated by the grade of surgeon and level of supervision for insertions of PCVAD before and after the introduction of the VAT (Pb.05).

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<th>Total Consultant Supervised</th>
<th>Unsupervised insertions</th>
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<tr>
<td>Pre-VAT</td>
<td>(2002-2003)</td>
<td>465</td>
</tr>
<tr>
<td>VAT</td>
<td>(2005-2006)</td>
<td>569</td>
</tr>
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