Comparison of ultrasound-guided versus anatomical landmark-guided cannulation of the femoral vein at the optimum position in infants

Ahmed Ali Eldabaa, Ahmed Said Elgebaly, Ahmed Ali Abd Elhafz and Ahmed Sobhi Bassun

Background Femoral vein cannulation may be required during major surgery in infants and children and may prove to be life saving under certain conditions. This study compared ultrasound (US)-guided cannulation of the femoral vein in infants with the traditional anatomical landmark-guided technique.

Methods Eighty infants who had been prepared for a major elective surgery under general anesthesia were randomly assigned to either group I, in which the femoral vein cannulation was guided by anatomical landmarks in optimally positioned patients, or group II, in which an US-guided technique was used for cannulation.

Results The procedure was successful in 35 cases in group I and in all cases in group II. The number of needle passes was higher in group I compared with that in group II [four (1–22) vs. one (1–8); $P=0.001$]. First-pass success was achieved in 20 cases in group I and in 35 cases in group II. The time to complete cannulation was

significantly shorter in group II compared with that in group I [145 (40–650) s vs. 350 (40–1600) s; $P=0.02$]. Three cases of arterial puncture occurred in group I, whereas there were no complications in group II.

Conclusion US-guided techniques for femoral vein cannulation are useful as they result in greater success, shorter cannulation times, less number of attempts, and lower complication rates. *Ann Pediatr Surg* 8:65–68 © 2012 Annals of Pediatric Surgery.

Introduction

The femoral vein is an important site of cannulation in infants particularly during anesthesia, cardiac catheterization, fluid therapy, or during cardiac resuscitation [1,2]. A higher incidence of thrombosis and infections were reported to be the long-term complications of the femoral line, but a few other complications such as local hematoma may also occur [3]. Femoral lines provide the advantage of easy access without interference with airway management and resuscitation efforts in pediatric patients during cardiac resuscitation [3].

During an emergency, where there is a necessity to insert a central line quickly, the ultrasound (US)-guided technique may be time consuming as every ward may not have a handheld US. Experienced anesthesiologists with expertise in femoral vein cannulation using the landmark-based approach may not prefer the US-guided technique, as they believe that this may take a longer time. However, studies have clearly shown that US-guided femoral vein cannulation can result in shorter cannulation times than anatomical landmark-based techniques [4]. The most common complication during femoral vein cannulation is femoral artery puncture, which may lead to an arteriovenous fistula, pseudoaneurysm, hematoma, arterial thrombosis, or peripheral embolism [3]. Moreover, pricking of the head of the femur may lead to avascular necrosis. Subtle variations in anatomy that may not be obvious externally (but may be observed with US) may be responsible for such complications [1,3].

The optimum site and position for femoral vein cannulation in infants is at the inguinal crease, with external rotation of the hip and 60° abduction of the leg. In this position, the cross-sectional area of the femoral vein is larger and femoral artery overlapping is minimal [4].

The study was carried out to determine whether US-guided femoral vein cannulation resulted in higher success and shorter time to cannulation as compared with the traditional anatomical landmark-guided technique with patients in the optimal position.

Materials and methods

After approval from the institutional ethical committee, written informed consent was obtained from the parents of the infants. Eighty infants aged 6–12 months, who had been prepared for major elective surgery, were randomized into two groups (40 patients in each group). To indicate the group to which each infant was assigned, randomization numbers were placed in sealed envelopes, which were opened by a chief nurse who was not participating in the study or involved in the patients' care.

The exclusion criteria were as follows: individuals with congenital anomalies in the hip region, those who had undergone previous catheterization of the femoral vein, those who had a coagulopathy, those who had an infection at the inguinal region, and refusal to participate by the parents.

After premedication with 0.1 mg/kg atropine (intramuscularly), general anesthesia was induced with sevoflurane

in 100% O_2, and atracrium (0.5 mg/kg, intravenously) was administered to facilitate endotracheal intubation and controlled ventilation with a tidal volume of (10 ml/kg). All patients were placed in the 10° reverse Trendelenburg position, with external rotation of the hip and 60° abduction of the leg.

In group I, femoral vein cannulation at the inguinal crease was guided by an external anatomical landmark. After placing the patient in the optimum position, with the inguinal area adequately exposed to allow for the identification of anatomic landmarks, the right femoral region was painted with povidone-iodine and sterile drapes were positioned to isolate the femoral area. After wearing a gown, mask, cap, and sterile gloves, the surface landmarks were identified by palpation by the operator; all operators in this study were pediatric fellows. Specifically, the position of the inguinal ligament, as well as pulsations of the femoral artery, was first identified. A point ~1 cm below the inguinal ligament and 0.5–1 cm medial to the femoral arterial pulsation was pinpointed, at which a 20-G needle was inserted through the skin at a 45° angle, in the direction of the umbilicus, and parallel to the arterial pulsation. This process was repeated until venous flow was adequate.

In group II, femoral vein cannulation was guided by ultrasonography at the inguinal crease, with the hip and the leg in the same position as in group I. The ultrasonography equipment used was a SonoSite 180 PLUS with an L25/10–5 MHz linear array ultrasonic transducer (SonoSite Inc., Bothell, Washington, USA); the latter was prepared and sterilized by covering the sheath with an Opsite (Smith and Nephew, London, UK) over the length of the transducer and the time taken for preparation was not included in the total time of the procedure. The femoral artery and vein were identified by scanning the inguinal area immediately distal to the inguinal ligament, and the vein centered on the screen using an out-of-plane technique; the probe was held perpendicular to the patient's skin in the operator's left hand. A 20 G needle was inserted with the right hand angled at 45° and its position in relation to the vein was adjusted on the basis of tissue movement visualized on the screen. After successful vein puncture, the US probe was kept aside and the left hand was used to stabilize the cannula in position. The guidewire was then passed through the cannula into the vein and the cannula was removed.

In all patients, the 20-G cannula allowed easy insertion of the guidewire, which was followed by the insertion of a 5.5F pediatric multilumen central venous catheter (CVC) kit (Arrow; Arrow International Inc., Reading, Pennsylvania, USA) using the Seldinger technique.

A decision to shift from the right to the left side was made whenever the femoral pulse was lost, in group I, or whenever the ultrasonography image was lost, in group II; however, shifting to the opposite side was considered a failure of insertion. The cannula was redirected or the maneuver was repeated until adequate venous flow was obtained. Every time the maneuver was repeated, it was considered a new needle pass, and the total number of needle passes required for successful cannulation was recorded for both groups. Success was defined as femoral cannulation within three passes.

No time limit was set for the procedure. The time required for successful wire insertion was calculated from the time that the skin was penetrated until the guidewire had been successfully inserted, as described previously. The time from the insertion of the wire to complete cannulation using the triple-lumen catheter was also recorded. The total time for cannulation was then calculated as the sum of both recorded times.

The number of needle passes, the success rate, the number of cases with success achieved within the first pass, the time taken for the procedure, and the incidence of complications were noted. In addition, we recorded the number of arterial punctures and whether any significant hematoma occurred.

Statistics
The sample size required for the study was determined on the basis of the primary outcome measure. The primary outcome measures of this study were time and the number of attempts required for successful cannulation; the secondary outcomes include first attempt success and hematoma formation. Power analysis showed that 40 patients per group were required to detect a 35% difference between groups, with a power of 80%.

Student's t-test was used to compare demographic data and Fisher's exact test was used to compare categorical variables. A P value of less than 0.05 was considered statistically significant. Statistical calculations were performed using SPSS v.13 (SPSS Inc., Chicago, Illinois, USA).

Results
Patients' characteristics are presented in Table 1. There was no significant difference between the two groups.

The procedure was successful in 35 cases in group I, but in group II, all cases were successfully cannulated. The number of needle passes was higher in group I compared with that in group II [four (1–22) vs. one (1–8); $P = 0.001$]. First-pass success was achieved in 20 cases in group I and in 35 cases in group I ($P = 0.001$). Time to successful wire insertion [290 (16–1500) s and 55 (20–600) s; $P = 0.02$] and the time taken to complete cannulation were significantly shorter in group II compared with group I, being 350 (40–1600) s and 145 (40–650) s ($P = 0.02$) in groups I and II, respectively (Table 2).

In group I, three cases showed arterial puncture and hematoma formation, but no cases of arterial puncture were found in group II.

Discussion
In this study, we compared US-guided and anatomical landmark-guided femoral vein cannulation at the inguinal crease in infants in the 10° reverse Trendelenburg position.

Table 1 Baseline characteristics of the patients

	Group I ($n=40$)	Group II ($n=40$)	P value
Male/female	21/19	20/20	0.9
Age (months)	9.3 ± 1.9	9.2 ± 1.7	1.0
Weight (kg)	7.9 ± 0.8	8.1 ± 0.7	0.7

$P < 0.05$, statistically significant.

Table 2 Success rate, procedure time (s), and incidence of complications

	Group I (*n*=40)	Group II (*n*=40)	*P* value
Success rate	35	40	0.02
Needle passes for successful cannulation (*n*)	4 (1–22)*	1 (1–8)	0.001
First-pass success (*n*)	20	35*	0.001
Time to successful wire insertion (s)	290 (16–1500)*	55 (20–600)	0.02
Time from wire insertion to complete cannulation (s)	50 (10–270)	76.5 (10–200)	0.5
Total time to complete cannulation (s)=procedure time (s)	350 (40–1600)*	145 (40–650)	0.02
Incidence of arterial puncture	3	0	0.5

Data in median range or number %.
*$P<0.05$, statistically significant.

We found that US-guided cannulation of the femoral vein showed superior results to those of cannulation guided by an anatomical landmark. In this study, we showed that US-guided cannulation resulted in higher success rates, shorter time to cannulation, and was associated with fewer complications.

There is ample evidence supporting the use of real-time US guidance during central line insertion for improving patient safety practices [5], and it has been strongly advocated as a standard of care by the National Institute for Clinical Excellence in the UK [6,7]. Nonetheless, despite evidence-based support for US during CVC, one survey showed that the approach still has limitations [8], and most of the evidence supporting the use of US guidance over the landmark-guided technique involves studies carried out in adults [6].

The evidence supporting the use of US has been considered less compelling in children [9].

Publications involving the use of US-guided CVC in children mostly involved cannulation through the internal jugular vein [6,10,11].

There is limited literature on the two guidance approaches for cannulation of the femoral vein in children [12]. However, a recent study and an accompanying editorial have indicated the increasing importance and safety of this technique in children [13,14].

We positioned the patient in a reverse Trendelenburg position with external rotation and a 60° abduction of the leg for femoral vein cannulation. This position has been shown to increase the diameter of the femoral vein as well as minimize overlap between the femoral artery and vein [4].

The position of the hip and leg used in our study results in the least overlap of the femoral vein by the femoral artery and maximum diameter of the vessels. Previous studies have shown that overlapping of the femoral vein by the femoral artery occurs in about 12% of cases, but other studies have shown that this overlapping may occur in more than 50% of cases [2].

The overlap between artery and vein may be partial or complete; differences in the definition of overlap may account for the different percentages of overlap among the studies [2]. According to Warkentine *et al.* [2] complete overlap of the femoral vein by the femoral artery was found in 8% of pediatric patients. Partial overlap in the region immediately distal to the inguinal ligament was found in 45% of cases [15].

A study by Hopkins *et al.* [15] showed that a variable relationship exists between the femoral artery and vein in both the straight leg and the frog leg position. However, the diameter of the veins increases with the frog leg position.

It has also been reported that the level of experience of the operator (resident, fellow, or attending) can impact the outcomes of studies comparing US-guided and landmark-guided central line insertion. Verghese *et al.* [16] compared the use of real-time two-dimensional US or landmark guidance in children undergoing internal jugular vein cannulation performed by inexperienced operators (pediatric fellows, as in our study), and found that US guidance improved the overall success, speed, and incidence of carotid puncture. A more recent study, in which experienced cardiac anesthesiologists performed cannulation of the internal jugular vein in children, reported that the landmark-guided technique was more often successful, and involved fewer arterial punctures, than the US-guided technique [9]. An interesting observation in a pediatric intensive care showed that the time needed for successful CVC was less when using US rather than landmark guidance, but only when the operators were residents, and not with experienced operators [17]. It is plausible that the discrepancy may be because of the fact that experienced operators are more familiar with the use of landmark-guided techniques, but may have various levels of training with the use of US [9].

Although the primary outcome of such studies is typically the time required to achieve successful cannulation of the femoral vein, secondary outcomes include the success rate, the number of needle passes required for successful cannulation, the number of successful cannulations on first needle pass, and the incidence of arterial puncture and hematoma [13]. In this study, these secondary outcomes were markedly improved in the US group. Improvement in these secondary outcomes is important, as repeated attempts at cannulation may result in thrombosis or compression of the vein by the surrounding hematoma, reducing the chances of subsequent successful cannulation [12].

Our study was not sufficiently powered to detect any difference in the incidence of femoral artery puncture between the two guidance techniques. However, Iwashima *et al.* [12] have previously reported that femoral artery puncture occurred in 7% of patients in an US-guided group, compared with 31.8% in a landmark-guided group ($P < 0.01$). Moreover, visualization through US also

helps avoid pricking the head of the femur, which may induce avascular necrosis, especially in neonates [3].

Other studies have used a different definition of time to successful cannulation. Åsheim *et al.* [18] reported the time to aspiration of blood as the time to successful cannulation. However, the time to successful guidewire insertion as used in our study was considered more clinically useful, because the identification of venous blood flow through the cannula is not always an indication that the guidewire will be inserted successfully, especially in young children. For instance, Grebenik and colleagues [9,11] described the inability to insert the guidewire, despite successfully aspirating venous blood, as the most common problem during internal jugular cannulation in children.

Although there was no statistically significant difference between the age distribution of the two groups, a better design in our study would have been to stratify patients by age. For instance, Finck *et al.* [19] reported a success rate of 78.8% in patients younger than 6 months, compared with 96% in children older than 6 months, for subclavian vein cannulation.

Conclusion
US-guided femoral vein cannulation, with higher success rates, lesser number of attempts, and less complications, is superior to the landmark-based approach.

Acknowledgements
Conflicts of interest
There are no conflicts of interest.

References
1   Akingbola OA, Nielsen J, Hopkins RL, Frieberg EM. Femoral vein size in newborns and infants: preliminary investigation. *Crit Care* 2000; **4**:120–123.
2   Warkentine FH, Pierce MC, Lorenz D, Kim IK. The anatomic relationship of femoral vein to femoral artery in euvolemic pediatric patients by ultrasonography: implications for pediatric femoral central venous access. *Acad Emerg Med* 2008; **15**:426–430.
3   Chiang VW, Baskin MN. Uses and complications of central venous catheters inserted in a pediatric emergency department. *Pediatr Emerg Care* 2000; **16**:230–232.
4   Suk EH, Lee KY, Kweon TD, Jang YH, Bai SJ. Ultrasonographic evaluation of the femoral vein in anaesthetised infants and young children. *Anaesthesia* 2010; **65**:895–898.
5   Shojania KG, Duncan BW, McDonald KM, Wachter RM, Markowitz AJ. Making health care safer: a critical analysis of patient safety practices. *Evidence Rep Technol Assess* 2001; **43**:i–x, 1–668.
6   Hind D, Calvert N, McWilliams R, Davidson A, Paisley S, Beverley C, *et al.* Ultrasonic locating devices for central venous cannulation: meta-analysis. *Br Med J* 2003; **327**:361–364.
7   Calvert N, Hind D, McWilliams RG, Thomas SM, Beverley C, Davidson A. The effectiveness and cost-effectiveness of ultrasound locating devices for central venous access: a systematic review and economic evaluation. *Health Technol Assess* 2003; **7**:1–84.
8   Bailey PL, Glance LG, Eaton MP, Parshall B, McIntosh S. A survey of the use of ultrasound during central venous catheterization. *Anesth Analg* 2007; **104**:491–497.
9   Grebenik CR, Boyce A, Sinclair ME, Evans RD, Mason DG, Martin B. NICE guidelines for central venous catheterization in children. Is the evidence base sufficient? *Br J Anaesth* 2004; **92**:827–830.
10   Randolph AG, Cook DJ, Gonzales CA, Pribble CG. Ultrasound guidance for placement of central venous catheters: a meta-analysis of the literature. *Crit Care Med* 1996; **24**:2053–2058.
11   Hosokawa K, Shime N, Kato Y, Hashimoto S. A randomized trial of ultrasound image-based skin surface marking versus real-time ultrasound-guided internal jugular vein catheterization in infants. *Anesthesiology* 2007; **107**:720–724.
12   Iwashima S, Ishikawa T, Ohzeki T. Ultrasound-guided versus landmark-guided femoral vein access in pediatric cardiac catheterization. *Pediatr Cardiol* 2008; **29**:339–342.
13   Aouad MT, Kanazi GE, Abdallah FW, Moukaddem FH, Turbay MJ, Obeid MY, *et al.* Femoral vein cannulation performed by residents: a comparison between ultrasound-guided and landmark technique in infants and children undergoing cardiac surgery. *Anesth Analg* 2010; **111**:724–728.
14   Pivalizza EG, Maposa D. 'Evidence' for ultrasound-guided femoral vein cannulation in infants and children? *Anesth Analg* 2011; **112**: 991–992.
15   Hopkins JW, Warkentine F, Gracely E, Kim IK. The anatomic relationship between the common femoral artery and common femoral vein in frog leg position versus straight leg position in pediatric patients. *Acad Emerg Med* 2009; **16**:579–584.
16   Verghese ST, McGill WA, Patel RI, Sell JE, Midgley FM, Ruttimann UE. Ultrasound-guided internal jugular venous cannulation in infants: a prospective comparison with the traditional palpation method. *Anesthesiology* 1999; **91**:71–77.
17   Froehlich CD, Rigby MR, Rosenberg ES, Li R, Roerig PLJ, Easley KA, *et al.* Ultrasound-guided central venous catheter placement decreases complications and decreases placement attempts compared with the landmark technique in patients in a pediatric intensive care unit. *Crit Care Med* 2009; **37**:1090–1096.
18   Åsheim P, Mostad U, Aadahl P. Ultrasound-guided central venous cannulation in infants and children. *Acta Anaesthesiol Scand* 2002; **46**:390–392.
19   Finck C, Smith S, Jackson R, Wagner C. Percutaneous subclavian central venous catheterization in children younger than one year of age. *Am Surg* 2002; **68**:401–404.