Comparison of ultrasound-guided vs. anatomical landmark-guided cannulation of the femoral vein at the optimum position in infant

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Abstract

Background: Femoral vein cannulation can be a routine process during major surgery in infants and children, and may prove to be lifesaving under certain conditions. This study compared ultrasound (US)-guided cannulation of the femoral vein in infants with the traditional anatomical landmark-guided technique.

Method: Eighty infants who had been prepared for major elective surgery under general anaesthesia were randomly assigned either to Group I, in which the femoral vein cannulation was guided by anatomical landmarks in optimally positioned patients, or to Group II in which the 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 to Group II [4 (1-22) vs. 1 (1-8); p-value = 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 to Group I [145 (40-650) vs. 350 (40-1 600) seconds; p-value = 0.02]. Three cases of arterial puncture occurred in Group I, while there were no complications in Group II.

Conclusion: The US-guided technique for femoral vein cannulation is useful as it results in greater success, shorter cannulation times, fewer attempts, and fewer complications.

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Introduction

The femoral vein is an important site of cannulation in infants, particularly during anaesthesia, cardiac catheterisation, fluid therapy or cardiac resuscitation.[1,2] A higher incidence of thrombosis and infections was reported to be a long-term complication of the femoral line, but fewer incidences of hemothorax, pneumothorax and local ahematoma can occur.[3] Femoral lines provide the advantage of easy access without interference with airway management and resuscitation efforts in paediatric patients during cardiac resuscitation.[3]

During an emergency, when there is a necessity to insert a central line quickly, the ultrasound (US)-guided technique is time-consuming as it is improbable that each ward will have a hand-held US device. Experienced anaesthesiologists who are adept at femoral vein cannulation using the anatomical landmark-based approach may be wary of US-guided cannulation, as they believe that this may take longer. However, studies have clearly shown that US-guided femoral vein cannulation can result in shorter cannulation times, than anatomical landmark-based cannulation.[4] The most common complication during femoral vein cannulation is femoral artery puncture, which may lead to 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 which may be detected with a 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-degree 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 undertaken to evaluate whether US-guided femoral vein cannulation resulted in higher success rates and shorter cannulation times, when compared to the traditional anatomical landmark-guided technique with patients in the optimal position.

Method

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

Exclusion criteria were individuals with congenital anomalies in the hip region, those who had undergone previous catheterisation of the femoral vein, who suffered from a coagulopathy or infection at the inguinal region, or whose parents refused to allow participation.

After premedication with 0.1 mg/kg atropine (intramuscular route), general anaesthesia was induced with sevoflurane in 100% O_2, and atracrium (0.5 mg/kg, intravenous route) was administered to facilitate endotracheal intubation and controlled ventilation (10 ml/kg). All patients were placed in the 10-degree reverse Trendelenburg position, with external rotation of the hip, and 60-degree abduction of the leg.

In Group I, femoral vein cannulation at the inguinal crease was guided by external anatomical landmark. After the patient had been placed in the optimum position, with the inguinal area adequately exposed to allow for identification of anatomic landmarks, the relevant right femoral region was painted with povidone-iodine, and sterile drapes were positioned so as to isolate the femoral area. After gown, mask, cap and sterile gloves had been donned, the surface landmarks were identified for palpation by the operator. All operators in this study were paediatric fellows. Specifically, the position of the inguinal ligament, as well as pulsations of the femoral artery, were identified first. A point approximately 1 cm below the inguinal ligament, and 0.5-1 cm medial to the femoral arterial pulsation, was pinpointed, at which a 20-gauge needle was inserted through the skin at a 45 degree 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 leg in the same position as that in Group I. The ultrasonography equipment used was a SonoSite® 180 PLUS with an L25/10-5 MHz linear array ultrasonic transducer (SonoSite, Bothell, Washington). The latter was prepared and sterilised by covering the sheath with an Opsite® dressing over the length of the transducer. The time taken to prepare it was not included in the calculation of 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 was centred 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-gauge needle was inserted with the right hand angled at 45 degrees, and its position in relation to the vein was adjusted, based on tissue movement visualised on the screen. After successful vein puncture, the US probe was kept aside, and the left hand was used to stabilise 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-gauge cannula allowed easy insertion of the guidewire, which was followed by insertion of a 5.5F paediatric multilumen CVC® kit (Arrow International, Reading, Pensylvannia), 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 to be a failure of insertion. The cannula was redirected, or the manoeuvre was repeated, until adequate venous flow was obtained. Every time the manoeuvre was repeated, it was considered to be 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 was successfully inserted, as described previously. The time from 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 at the first pass, the time taken for the procedure, and the incidence of complications were noted. In addition, the number of arterial punctures was recorded, and whether any significant hematoma occurred.

Statistics

The sample size required for the study was determined based on the primary outcome measures. The primary outcome measures of this study were time, and the number of attempts required for successful cannulation. Secondary outcomes included first-attempt success and haematoma formation. Power analysis identified 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 < 0.05 was considered to be statistically significant.

Results

Patients' characteristics are recorded in Table I. There was no significant difference between the two groups.

Table I: Baseline characteristics of patients

	Group 1 (n = 40)	Group II (n = 40)	p-value
Male and 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-value < 0.05, statistically significant

The procedure was successful in 35 cases in Group I, and in Group II, all cases were successfully cannulated. The number of needle passes was higher in Group I, compared to Group II [4 (1-22) vs. 1 (1-8); p-value = 0.001]. First-pass success was achieved in 20 cases in Group I, and in 35 cases in Group II (p-value = 0.001). The time to successful wire insertion [290 (16-1 500) vs. 55 (20-600) seconds; p-value = 0.02], and time taken to complete cannulation [350 (40-1 600) vs. 145 (40-650) seconds; p-value = 0.02] was significantly shorter in Group II, compared to Group I (see Table II).

In Group I, three cases showed arterial puncture and a haematoma 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-degree reverse Trendelenburg position. We showed that US-guided cannulation of the femoral vein offers 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 and shorter time to cannulation, and was associated with fewer complications.

There is ample evidence supporting the use of real-time US-guidance cannulation during central line insertion to improve patient safety practices,[5] and it has been strongly advocated as a standard of care by the National Institute for Clinical Excellence in the United Kingdom.[6-7] Nonetheless, despite evidence-based support for the use of US- guided cannulation when inserting central venous catheters (CVCs), a survey showed that the approach still has limitations,[8] and most of the evidence supporting the use of US-guided cannulation over the landmark-guided technique arises from studies carried out on adults.[6]

The evidence supporting the use of US-guided cannulation has been considered less compelling in children.[9] Publications involving the use of US-guided CVC in children mostly involve cannulation via 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, signifies the increasing importance and safety of this technique in children.[13,14]

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

The position of the hip and leg used in our study resulted 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]

Table II: Success rate, procedure time in seconds, 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)[a]	1 (1-8)	0.001
First-pass success (n)	20	35[a]	0.001
Time to successful wire insertion	290 (16-1 500)[a]	55 (20-600)	0.02
Time from wire insertion to complete cannulation	50 (10-270)	76.5 (10-200)	0.5
Total time to complete cannulation = procedure time	350 (40-1 600)[a]	145 (40-650)	0.02
Incidence of arterial puncture	3	0	0.5

a = p-value < 0.05, statistically significant
Data in median range or number %

The overlap between artery and vein may be partial or complete. Differences in the definition of the overlap may account for the different percentages of the overlap among the studies.[2] According to Warkentine et al, eight per cent of paediatric patients manifested complete overlap of the femoral vein by the femoral artery.[2] Partial overlap in the region immediately distal to the inguinal ligament was demonstrated in 45% of cases.[15]

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

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

Although the primary outcome of such studies is typically the time needed 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 at first-needle pass, and the incidence of arterial puncture and haematoma.[13] In this study, these secondary outcomes were remarkably improved in the US-guided cannulation 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 previously demonstrated femoral artery puncture occurring in seven per cent of a US-guided cannulation group, compared to 31.8% of a landmark-guided cannulation group (p-value < 0.01).[12] Moreover, visualisation via US also helps to avoid pricking the head of the femur, which introduces the possibility of inducing avascular necrosis, especially in neonates.[3]

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

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

Conclusion

US-guided femoral vein cannulation has a greater success rate, fewer attempts and fewer complications, and is superior to the landmark-based approach.

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