

Femoral Vein Cannulation Performed by Residents: A Comparison Between Ultrasound-Guided and Landmark Technique in Infants and Children Undergoing Cardiac Surgery

Marie T. Aouad, MD, Ghassan E. Kanazi, MD, Faraj W. Abdallah, MD, Farah H. Moukaddem, MD, Massud J. Turbay, MD, Mounir Y. Obeid, MD, and Sahar M. Siddik-Sayyid, MD

BACKGROUND: Percutaneous cannulation of the femoral vein, in the pediatric age group, can be technically challenging, especially when performed by residents in training. We examined whether the use of real-time ultrasound guidance is superior to a landmark technique for femoral vein catheterization in children undergoing heart surgery.

METHODS: Patients were prospectively randomized into 2 groups. In group LM, the femoral vein was cannulated using the traditional method of palpation of arterial pulse. In group US, cannulation was guided by real-time scanning with an ultrasound probe. The time to complete cannulation (primary outcome), success rate, number of needle passes, number of successful cannulations on first needle pass, and incidence of complications were compared between the 2 groups.

RESULTS: Forty-eight pediatric patients were studied. The time to complete cannulation was significantly shorter (155 [46–690] vs 370 [45–1620] seconds; $P = 0.02$) in group US versus group LM. The success rate was similar in both groups (95.8%). The number of needle passes was smaller (1 [1–8] vs 3 [1–21]; $P = 0.001$) and the number of successful cannulations on first needle pass higher (18 vs 6; $P = 0.001$) in group US compared with group LM. The incidence of femoral artery puncture was comparable between the 2 groups.

CONCLUSIONS: Ultrasound-guided cannulation of the femoral vein, in pediatric patients, when performed by senior anesthesia residents, is superior to the landmark technique in terms of speed and number of needle passes, with remarkable improvement in first attempt success. (Anesth Analg 2010;111:724–8)

The insertion of a percutaneous femoral catheter is the method of choice for central venous catheterization (CVC) in pediatric patients undergoing cardiac surgery in our institution because of its high safety standards.¹ Although the femoral line has been reported to have a higher incidence of thrombosis and infection, in the long term, it definitely has a lower complication rate in terms of hemothorax or pneumothorax and local hematoma. In addition, it provides easy access and lack of interference with airway management and resuscitation efforts in pediatric patients presenting for cardiac surgery.¹ It is usually performed with the blinded, external landmark-guided technique. As a teaching institution, we periodically train new residents to acquire the skills for an efficient and safe insertion of femoral lines in this high-risk population.

It has been recognized that the use of real-time ultrasound (US) guidance during central line insertion is one of the patient safety practices with the greatest strength of supporting evidence.^{2,3} It has been suggested as a standard of care^{4,5} and has been strongly advocated by the National Institute for

Clinical Excellence in the United Kingdom.⁶ However, one survey showed that the use of US during CVC remains limited despite evidence-based recommendations.⁷ Furthermore, the evidence favoring the use of US versus landmark technique mainly concerns the adult population.⁴ The evidence is less convincing in children,⁸ and most of the publications investigate the insertion of central lines using the internal jugular vein.^{4,9} No previous study examined the usefulness of US guidance versus the traditional landmark technique for the insertion of femoral CVC in the pediatric population, in particular for the teaching of residents.

Our hypothesis is that the use of US guidance by senior residents learning the technique of femoral vein catheterization is superior to the landmark technique. We designed a prospective randomized trial to compare the use of US guidance versus landmark technique in children undergoing cardiac surgery. The primary outcome was the time needed to achieve a successful cannulation of the femoral vein. Secondary outcomes included the success rate, the number of needle passes, the number of successful cannulations on first needle pass, and the incidence of arterial puncture and hematoma.

METHODS

Forty-eight children aged 0 to 12 years, ASA physical status III or IV, with congenital heart disease undergoing cardiac surgery were enrolled in a prospective randomized clinical trial. After obtaining approval from the IRB of the American University of Beirut, written informed consent was obtained from parents and from children older than 7 years of age. Exclusion criteria were hemodynamic instability or allergy to

From the Department of Anesthesiology, American University of Beirut, Beirut, Lebanon.

Accepted for publication May 6, 2010.

Supported by the Department of Anesthesiology, American University of Beirut.

Disclosure: The authors report no conflicts of interest.

Address correspondence and reprint requests to Sahar M. Siddik-Sayyid, MD, Department of Anesthesiology, American University of Beirut, P.O. Box 11-0236, Beirut, Lebanon. Address e-mail to ss01@aub.edu.lb.

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DOI: 10.1213/ANE.0b013e3181e9c475

the US gel. Patients were randomly assigned using a computer-generated table of random numbers to either group LM or US. Results of randomization were concealed in sealed opaque envelopes and opened after patients' consent. All patients were connected to monitors and received general anesthesia using a peripheral IV line. After induction of anesthesia, all patients were positioned supine, with their legs revolved externally and bent at the knees (frog position). While the resident was scrubbing, the attending cardiac anesthesiologist localized and marked the femoral artery in the LM group and scanned the inguinal area in the US group. After prepping, a CA-3-level anesthesia resident with no experience in US guidance and minimal experience with femoral line insertion using the landmark technique attempted cannulation of the right femoral vein by the Seldinger technique using a 5.5F pediatric multilumen CVC kit (Arrow; Arrow International, Inc., Reading, PA) under the supervision of a cardiac anesthesiologist. The residents were instructed about the use of US guidance for femoral line insertion by watching 3 cases before the beginning of the study. Patients in group LM had their femoral line inserted using the blinded, external landmark-guided technique. After localization of the femoral artery by identifying the pulse in the femoral triangle immediately distal to the inguinal ligament, a 20-gauge catheter was inserted medial to the artery. The attempt was repeated until adequate venous flow was obtained, which allowed the insertion of the guidewire. Patients in group US had their femoral lines inserted under the guidance of US. The US equipment used was a SonoSite 180 PLUS with an L25/10- to 5-MHz linear array transducer (SonoSite, Inc., Bothell, WA). The transducer was covered by a sterile sheath. The inguinal area was scanned immediately distal to the inguinal ligament and the femoral artery and vein were identified. Using an out-of-plane technique, the vein was centered in the middle of the screen with the probe held with the left hand perpendicular to the skin. A 20-gauge cannula was introduced with the right hand below the US probe at its center while watching for tissue movement on the US screen. The cannula was redirected or the maneuver repeated until adequate venous flow was obtained that allowed easy insertion of the guidewire. In both groups, 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. The femoral vein was localized first, either by identification of the femoral pulse in group LM or by US in group US, and the timing was then started using a stopwatch. Similar to previous studies,^{8,10-13} the time to successful wire insertion was calculated from the time of skin penetration until successful wire insertion. Also, the time from wire insertion to complete cannulation with the triple-lumen catheter was calculated. The time to complete cannulation was the sum of both times. In addition, the incidence and number of arterial punctures and the occurrence of significant hematoma were recorded. No time limit was set. Shifting from the right to the left side was decided whenever the femoral pulse was lost in the LM group or the US image was lost in the US group. Shifting to the opposite side was considered a failure of insertion.

A pilot study was conducted and resulted in a mean time for femoral line cannulation with the landmark technique of 350 ± 200 seconds. Assuming a 50% reduction

Table 1. Patient Characteristics

	Group LM (n = 24)	Group US (n = 24)
Age (mo)	29.8 ± 28.3	39.7 ± 30.8
<6 mo (n)	5	1
6–23 mo (n)	7	7
24–96 mo (n)	12	15
>96 mo (n)	0	1
Weight (kg)	11 ± 5.5	14.3 ± 7.2
Height (cm)	82 ± 20.5	92.2 ± 19.8
Sex (male/female)	12/12	11/13

LM = landmark; US = ultrasound.

Data are means ± SD or numbers.

There was no statistical significance between the 2 groups.

Table 2. Outcome Data

	Group LM (n = 24)	Group US (n = 24)	P value
Time to successful wire insertion (s)	300 (18–1560)	55 (20–600)	0.02
Time from wire insertion to complete cannulation (s)	60 (10–275)	77.5 (10–205)	0.5
Total time to complete cannulation (s)	370 (45–1620)	155 (46–690)	0.02
Number of needle passes for successful cannulation (n)	3 (1–21)	1 (1–8)	0.001
Successful cannulations on first needle pass (n)	6	18	0.001
Patients with time to wire insertion <5 min (n)	11	20	0.007
Arterial puncture (n)	1	3	0.6

LM = landmark; US = ultrasound.

Data are medians and ranges or numbers.

$P < 0.05$ is considered clinically significant.

of this mean with US guidance, 23 patients would be required in each group ($\alpha = 0.05$, $\beta = 0.2$). Continuous data were reported as mean ± SD and were analyzed using the Student *t* test. Categorical data were reported as numbers and percentages and were analyzed using χ^2 or Fisher exact test as appropriate. Nonparametric data (times and number of attempts) were reported as median and range and were analyzed using Mann-Whitney *U* test. $P < 0.05$ was considered significant. All analyses were performed using SPSS software (version 16; SPSS, Inc., Chicago, IL).

RESULTS

Forty-eight patients were analyzed, 24 in each group. Most of the patients had prior femoral cannulation for diagnostic cardiac catheterization and/or previous cardiac surgery with no evidence of occluded femoral vessels. The operations included the following procedures: atrial septal defect or ventricular septal defect closure or both, atrioventricular canal repair, Glenn or Fontan procedure, tetralogy of Fallot repair, pulmonary artery banding, conduit replacement, pulmonary artery conduit, unifocalization, resection of subaortic membrane, mitral valve repair, and repair of pulmonary stenosis. All patients were hemodynamically stable with an adequate hydration status. Patients' characteristics were comparable between the 2 groups (Table 1). All patients received successful right femoral vein cannulation, except for 2 patients, 1 in each group, in whom the cannulation was successful after a shift to the left side. Thus, the success rate was 95.8% in both

Table 3. Outcome Data in Each of the Infants Younger than 6 Months of Age

Infant no.	Time to successful wire insertion (s)	Time from wire insertion to complete cannulation (s)	Total time to complete cannulation (s)	Needle passes for successful cannulation (n)
1 (group US)	95	60	155	1
2 (group LM)	320	21	341	11
3 (group LM)	30	30	60	1
4 (group LM)	490	10	500	6
5 (group LM)	915	60	975	10
6 (group LM)	300	60	360	3

LM = landmark; US = ultrasound.
Data are numbers.

Table 4. Outcome Data in Children Older than 6 Months of Age

	Group LM (n = 19)	Group US (n = 23)	P value
Time to successful wire insertion (s)	275 (18–1560)	50 (20–600)	0.03
Time from wire insertion to complete cannulation (s)	60 (15–275)	85 (10–205)	1
Total time to complete cannulation (s)	380 (45–1620)	155 (46–690)	0.04
No. of needle passes for successful cannulation (n)	3 (1–21)	1 (1–8)	0.005
Successful cannulations on first needle pass (n)	5	17	0.002
Patients with time to wire insertion <5 min (n)	10	19	0.036
Arterial puncture (n)	1	3	0.6

LM = landmark; US = ultrasound.
Data are medians and ranges or numbers.
P < 0.05 is considered clinically significant.

groups. In group US, the artery was overlapping the vein in 4 cases (17%) and it was medial to the artery in the remaining 20 cases. The degree of overlap ranged between 60% and 80%. The time to femoral vein cannulation was shorter (155 [46–690] vs 370 [45–1620] seconds; *P* = 0.02) and the total number of needle passes was lower (1 [1–8] vs 3 [1–21]; *P* = 0.001) in group US compared with group LM. The number of successful cannulations on first needle pass, and the number of patients who had the guidewire successfully inserted in <5 minutes was higher in group US than in group LM (Table 2). The incidence of arterial puncture was comparable between the 2 groups (Table 2). The results of the studied outcomes for each of the infants younger than 6 months are reported in Table 3. If we exclude from analysis the infants younger than 6 months and repeat the analysis between the 2 groups (*n* = 19 in group LM and *n* = 23 in group US), the same statistical significance is obtained for all studied outcomes (Table 4). No significant hematoma occurred in any patient in either group.

DISCUSSION

Our results showed that real-time 2-dimensional ultrasonography by senior residents in training for the cannulation of the femoral vein in children undergoing cardiac surgery reduces the time of insertion as compared with the landmark technique. A more clinically significant result is the remarkable improvement in first attempt success (18 vs 6) and the lower median number of passes for success in the US group (1 vs 3). Repeated attempts may create distortion and jeopardize subsequent success of femoral

vein cannulation. The vein may become compressed by surrounding hematoma or become thrombosed.¹²

Most of the data of US use in children were reported for internal jugular vein cannulation,^{10,11,14–17} with only 1 article comparing US versus landmark for the cannulation of the femoral vein.¹² The majority of these studies have supported the use of real-time US guidance. The level of the operator (resident, fellow, or attending) has influenced outcomes. Verghese et al.¹⁰ compared real-time 2-dimensional US in children undergoing internal jugular vein cannulation versus the landmark technique and found that overall success, speed, and incidence of carotid puncture were improved with the use of US. Similar to our study, the Verghese et al. study was performed by inexperienced operators (pediatric fellows). A more recent study with opposite results using experienced cardiac anesthesiologists showed that the landmark technique had a higher success rate and fewer arterial punctures than the US technique for the cannulation of the internal jugular vein in children.⁸ Moreover, a recent study in pediatric intensive care unit patients showed that the time to successful placement of central lines was decreased with the US versus landmark technique only when the operators were residents and not experienced operators.¹³ One can argue that experienced operators have more experience with the use of landmark techniques whereas their level of training with the US probe may vary,⁸ which may explain the discrepancy in the results. Our results and the above studies confirm that US is a valuable teaching tool for beginners for the placement of central lines in children.^{10,13} It has been suggested that minimal training is required to use US scanning for the purpose of central line insertion,¹⁸ whereas more extensive training is required for the landmark technique, which may predict a faster learning curve with US. A survey of the use of US during CVC by the members of the Society of Cardiovascular Anesthesiologists showed that physicians in academic hospital settings were significantly more likely to use US. The need of US for teaching the residents may explain its increased use in the academic settings.⁷ However, the routine use of US-guided insertion of central lines as a teaching tool for residents in training may lead to poor landmark method skills that may be required in some emergency situations.⁴ Guidance from the National Institute for Clinical Excellence states that it is important that “operators maintain their ability to use the landmark method and that the method continues to be taught alongside the two-dimensional ultrasound guided technique.”

Previous studies have demonstrated significant differences between external landmarks and internal anatomy.^{19,20} A major advantage of US is that anatomic variations and the relation of the vein to the artery are easily identified. In our

study, the artery was partially overlapping the vein in 4 patients (17%) in which case the vein could be easily cannulated without femoral artery puncture; the US probe was slightly tilted and repositioned to allow a more oblique inclination of the needle from medial to lateral. The needle was then gently advanced while observing tissue movement. The reported incidence of overlap of the femoral vessels in children varies widely. Differences in the definition of overlap from partial to complete may account for the different percentages of overlap among the studies. Warkentine et al.²⁰ showed that the femoral artery completely overlapped the femoral vein in 8% of pediatric patients. Hopkins et al.²¹ demonstrated 45% partial overlap immediately distal to the inguinal ligament. In their study, frog position versus straight leg position did not influence the incidence of overlap, but it showed that the femoral vein diameter increased in frog leg position and when scanned close to the inguinal ligament versus straight legs and more distal scanning in children younger than 2 years of age. Overlap of the femoral artery and vein combined with smaller femoral vessel diameter may increase difficulties associated with central line placement in the pediatric population. Thus, US guidance may explain the lower number of needle passes needed to achieve successful cannulation with ensuing decreased likelihood of thrombosis in the vein.¹⁵ US also helps avoid pricking the head of the femur with the possibility of inducing avascular necrosis, especially in neonates.²² Of note, our study was not sufficiently powered to detect any difference in the incidence of femoral artery puncture. However, a previous study by Iwashima et al.¹² showed that femoral artery puncture occurred in 3 of 43 patients (7%) in the US group and in 14 of 44 patients (31.8%) in their LM group ($P < 0.01$).

Other studies used a different definition of time to successful cannulation. Instead of the time to successful guidewire insertion used in our study, Asheim et al.¹⁶ reported the time to aspiration of blood, which was 12 seconds for the internal jugular vein in children. We consider our definition more clinically useful because identification of venous blood flow through the localizing cannula is not always an indication of successful insertion of the guidewire, especially in young children. Grebenik et al.⁸ found that the most common problem during internal jugular cannulation in children was the inability to pass a guidewire despite successfully aspirating venous blood.

Despite the absence of statistical significance between the 2 groups with regard to age distribution, a better design would have been to stratify by age. The success rate and occurrence of complications are closely related to age in the pediatric population where it is generally accepted that success rates are increased with children older than 2 years.⁸ Finck et al.²³ showed that, for subclavian vein cannulation, the success rate was 78.8% in patients younger than 6 months versus 96% in children older than 6 months. It has been suggested that the difference between the vein and artery using US is not always pronounced in pediatric practice.²⁴ This difficulty may be further exaggerated in small infants with relatively smaller body surface areas who have smaller femoral vessels than older children and adults,²⁰ and there is a possibility that the tiny vessels could be compressed with the probe. In our study, the discrepancy in the number of infants younger than 6 months old (1

in group LM vs 5 in group US) did not account for the differences between the 2 groups. Comparison between the 2 groups excluding infants younger than 6 months yielded the same statistical significance in all studied outcomes. However, future studies involving younger patients may be needed. Another limitation of our study is that the operator was not blinded to the group allocation. However, we do not believe that the lack of blinding exposed the study to a potential bias because patients were randomly assigned to 1 of 2 groups to have their right femoral vein cannulated with no possibility for the operator to change the target vessel or the side of cannulation.

In conclusion, the use of real-time 2-dimensional US by senior residents in training for the cannulation of the femoral vein in children undergoing cardiac surgery reduces the time of insertion and decreases the number of needle passes with a remarkable improvement in first attempt success as compared with the landmark technique. However, despite the advantages offered by US, residents should not be deprived from also gaining skills in the landmark technique. Future studies may be needed to confirm the advantage of US in younger patients. ■■

AUTHOR CONTRIBUTIONS

MTA helped design and conduct the study, analyze the data, and write the manuscript. This author has seen the original study data, reviewed the analysis of the data, approved the final manuscript, and is the author responsible for archiving the study files. GEK helped design and conduct the study, analyze the data, and write the manuscript. This author has seen the original study data, reviewed the analysis of the data, and approved the final manuscript. FWA helped design and conduct the study. This author has seen the original study data, reviewed the analysis of the data, and approved the final manuscript. FHM helped design and conduct the study. This author has seen the original study data, reviewed the analysis of the data, and approved the final manuscript. MJT helped conduct the study, analyze the data, and write the manuscript. This author has seen the original study data, reviewed the analysis of the data, and approved the final manuscript. MYO helped design and conduct the study, and write the manuscript. This author has seen the original study data, reviewed the analysis of the data, and approved the final manuscript. SMS-S helped design and conduct the study, analyze the data, and write the manuscript. This author has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.

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