ORIGINAL ARTICLE

Comparison of ultrasound guidance and palpation technique for femoral artery catheterization in children undergoing cardiac surgery

Comparación de la técnica de palpación y guía por ultrasonido para el cateterismo de la arteria femoral en niños sometidos a cirugía cardíaca

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Abstract

Objective: *The aim of this study was compare the palpation technique and ultrasound-guidance for femoral artery catheterization in pediatric patients undergoing surgery for congenital heart disease.* **Materials and methods:** *This prospective and randomized controlled study included American Society of Anesthesiologists III-IV 40 children who underwent congenital heart surgery. The patients were divided into two groups; ultrasound-guided catheterization group and palpation-guided catheterization group. Demographic and clinical characteristics of the patients, access time, success rate, number of attempts, first-attempt success, number of trials, and failed cannulations were recorded.* **Results:** *The diameter of the femoral artery was significantly shorter, access time and numbers of trials were significantly lower, and first-attempt success rate was significantly higher in the US group. The complication rate was significantly higher in the P group. The number of failed catheterization was higher in the P group. Total cost required for the procedure was significantly lower in the US group.* **Conclusion:** *We found that ultrasound-guided arterial catheterization increases the success rate and the number of successful catheterizations, while reducing the overall procedure time, incidence of complications, and cost. Therefore, we believe that the use of ultrasound guidance in arterial catheterization in pediatric cardiac surgery would be a better choice.*

Keywords: *Anesthesia. Femoral arterial catheterization. Landmark. Pediatric cardiac surgery. Ultrasound.*

Resumen

Objetivo: *El objetivo de este estudio fue comparar la técnica de palpación y ecoguiado para el cateterismo de la arteria femoral en pacientes pediátricos operados de cardiopatías congénitas.* **Materiales y métodos:** *Este estudio prospectivo, aleatorizado y controlado incluyó a 40 niños ASA III-IV que se sometieron a cirugía cardíaca congénita. Los pacientes se dividieron en 2 grupos; Grupo de cateterismo guiado por ecografía y grupo de cateterismo guiado por palpación.* **Resultados:** *El diámetro de la arteria femoral fue significativamente más corto, el tiempo de acceso y el número de intentos fueron significativamente menores y la tasa de éxito del primer intento fue significativamente mayor en grupo estadounidense. La tasa de complicaciones fue significativamente mayor en el grupo P. El número de cateterismos fallidos fue mayor en el grupo P. El costo total requerido para el procedimiento fue significativamente menor en el grupo de EE.*

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Conclusiones: *Encontramos que el cateterismo arterial guiado por ultrasonido aumenta la tasa de éxito y el número de cateterismos exitosos, al tiempo que reduce el tiempo total del procedimiento, la incidencia de complicaciones y el costo. Por tanto, creemos que el uso de guía ecográfica en cateterismo arterial en cirugía cardiaca pediátrica sería una mejor opción.*

Palabras clave: *Anestesia. Cateterismo arterial femoral. Landmark. Cirugía cardiaca pediátrica. Ultrasonido.*

Introduction

Congenital heart disease is a leading cause of death in children and it has a prevalence of 0.6%. In the 2020 American Heart Association report, the prevalence of this condition is reported to be 0.24-13.7%[1]. Surgery is the first-line treatment for congenital heart disease. Arterial monitoring is essential in these patients, who require close hemodynamic monitoring and frequent arterial blood gas testing in the perioperative period. Arterial catheterization is more difficult in pediatric patients in whom cardiovascular surgery is planned than in adults due to narrow vessel diameter, non-pulsatile blood flow, low cardiac output, and anatomic variations. For arterial catheterization, the radial artery is most commonly used by anesthesiologists due to its superficial location, straight course, and low risk for intraoperative complications. However, in a study of children with congenital heart defects, blood pressure in the femoral and radial arteries was compared with respect to aortic pressure (systemic pressure) and found that blood pressure in the femoral artery was a relatively better reflection of systemic pressure[2]. In addition, Cho et al. reported that blood pressure monitoring by catheterization of the femoral artery provides more accurate results in depicting systemic arterial pressure than the radial artery, and recommended that the femoral artery be used for access[3]. The femoral artery also provides an easier procedure because it has a larger diameter compared with the radial artery. Inaccurate measurement of low blood pressure in patients undergoing cardiovascular surgery may lead to unnecessary use of inotropic drugs in the perioperative period and many associated complications. Therefore, femoral artery catheterization seems to be the better choice for intraoperative invasive monitoring of arterial blood pressure in pediatric patients with congenital heart disease.

Although the use of US in anesthesia is becoming more popular, the routine use of US in arterial procedures is not yet recommended by the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. However, they emphasize that US proves to be a salvage technique when the procedure fails, increases the success of catheterization, and shortens the procedure time[4]. Because children with congenital heart defects may require surgical procedures, long-term arterial catheterizations, and cardiac catheterizations for possible later diagnostic procedures, any procedure should preferably be performed using the least traumatic method and should aim for success on the first attempt[5].

This study aimed to compare the palpation technique and ultrasound (US)-guidance for femoral artery catheterization in pediatric patients undergoing surgery for congenital heart disease.

Materials and methods

This prospective and randomized study was approved by the Hospital Ethics Committee (12/20/2019-402). The study included children in the American Society of Anesthesiologists Physical Status Classification III-IV who underwent surgery for a congenital heart surgery between January 2020 and January 2021. Parental consent was obtained for each patient. These conditions were accepted as exclusion criteria: Infection, hematoma, femoral thrombosis, history of allergy to US gel, hemodynamic instability, refusal of the patient's relatives to participate in the study, absence of femoral artery pulsation, and emergency surgery.

The study included forty-six patients who underwent femoral artery catheterization. Two patients who underwent emergency surgery, two patients who were hemodynamically unstable, and two patients with hematomas in the femoral region were excluded from the study. Thus, the research involved 40 patients in total (Fig. 1).

After pre-operative anesthetic assessment, sealed envelopes were placed in the patients' charts. Patients were randomized based on these envelopes placed in the files at the time of the pre-operative assessment, immediately before the procedure. Patients were divided into two groups: The US-guided catheterization group (Group US, n = 20) and the palpation-guided

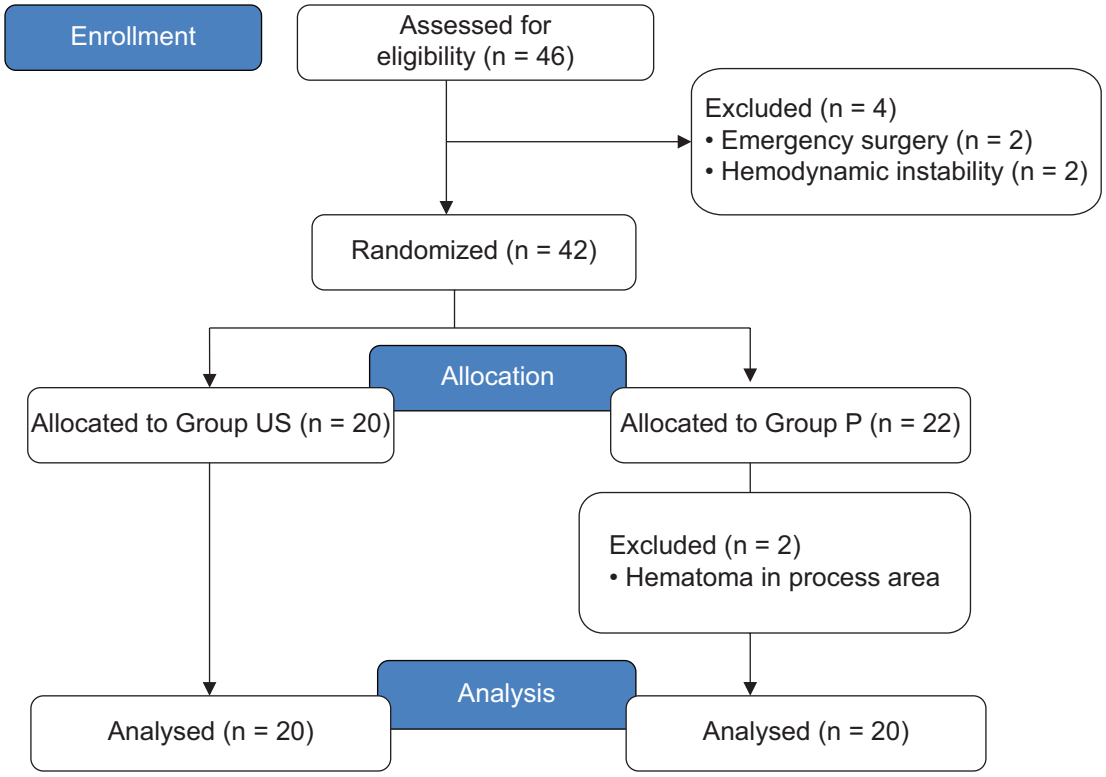

Figure 1. *Flow diagram.*

catheterization group (group P, n = 20). In both groups, arterial catheterization was preferentially performed in the right femoral region. However, in patients with evidence of hematoma, infection, or thrombosis at the access site, the contralateral side was used. All catheterizations were performed by the same anesthesiologist, who had at least 5 years of experience in pediatric cardiac anesthesia and was experienced in US-guided catheterization in children and adults.

Anesthesia was administered with 0.1 mg/kg midazolam, 2-3 mcg/kg fentanyl, 2-3 mg/kg propofol, and 0.6 mg/kg rocuronium. After orotracheal intubation, patients were connected to a ventilator (Draeger Primus; Draeger AG, Luebeck, Germany).

Following previous studies, puncture was routinely performed 1 cm distal to the inguinal ligament in all patients for superposition and easier access; the short-axis/out-of-plane approach was used in the US group[6,7]. A patient pad was placed under the pelvis for support, and the legs were abducted to 30° to achieve a neutral position. The anterior-posterior diameters of the femoral artery were recorded. The femoral region was disinfected with 10% povidone-iodine and covered with sterile perforated surgical drape. All catheterizations were performed with a standard 24/22-gauge catheter if the patient's weight was < 10 kg or with a 22-gauge catheter if the patient's weight was > 10 kg (22/24-Ga, 3 cm, arterial Leadercath, VYGON, France).

In the US group, a linear probe (5-12 MHz, Esaote, MyLab Six, Netherlands) was used. After covering the probe with a sterile sheath, the femoral artery vein was localized. The femoral artery was located from the distal part of the inguinal ligament using the short axis of the linear probe. The location of the artery was confirmed with color Doppler and pressure wave functions of the US. The linear probe was held and fixed in an appropriate position in the left hand when the femoral artery was placed in the center of the image, and a short-axis view was obtained using the out-of-plane technique, and the procedure was started with a 20-gauge needle. Arterial puncture was performed through the skin and subcutaneous tissue with the right hand without a syringe. After blood flow was observed, a guidewire was inserted and its advancement in the lumen was observed in the long and short axis under US guidance. The catheter was inserted over the guidewire using the Seldinger technique, and the guidewire was withdrawn. The catheter was fixed to

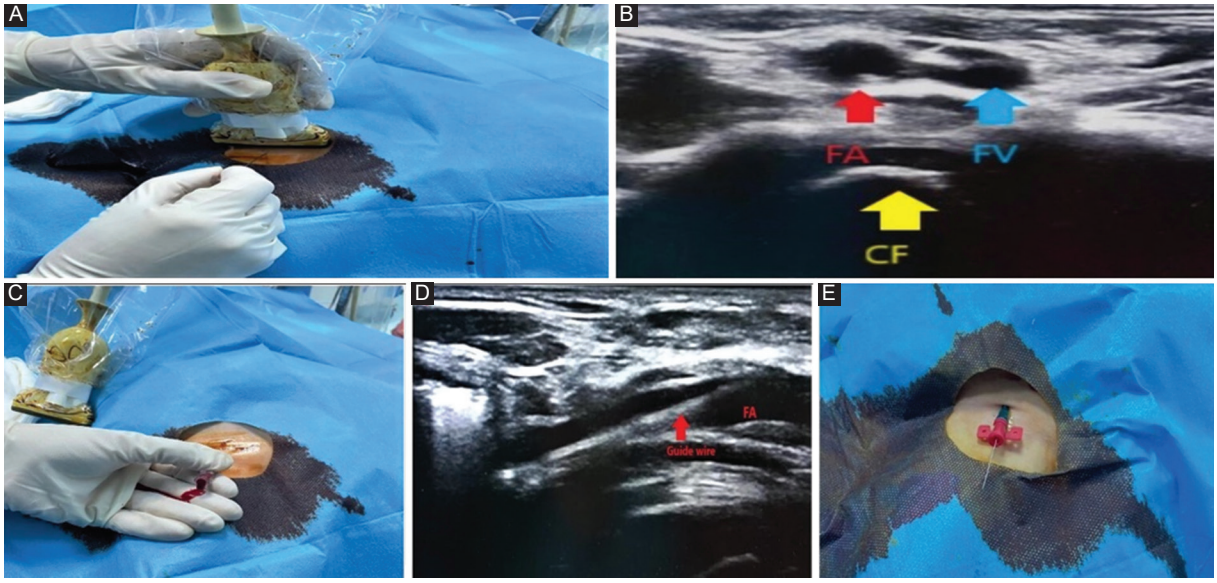

Figure 2. *Procedure of arterial catheterization.* **A:** *probe positioning for short-axis (transverse) view,* **B:** *short-axis ultrasound view of femoral artery (FA), femoral vein and caput femoris,* **C:** *arterial puncture,* **D:** *long-axis real-time ultrasound image for guide wire view within FA,* **E:** *Seldinger technique.*

the skin with appropriate sutures, and the procedure was successfully completed (Fig. 2).

In the P group, arterial puncture was performed with a 20-gauge needle after manually palpating the pulse of the femoral artery distal to the inguinal ligament. After active blood flow was detected, a guidewire was inserted. The catheter was, then, inserted over the guide wire using the Seldinger technique. The guide wire was then withdrawn, and the catheter was fixed to the skin.

Demographic and clinical characteristics of the patients were recorded. All previous procedures at the intervention site were identified and recorded. Achievement of arterial catheterization to the target vessel was considered a "success" and recorded accordingly. The timer was started at the time of initial needle insertion into the skin and stopped after catheter insertion and blood sampling, which was defined as "access time." In both groups, any procedure that failed despite three attempts or could not be completed in 15 min was considered a failure, recorded, and replaced with alternative methods. Selection of the alternative method was based on a joint decision by the anesthesiologist and surgeon-including use of the contralateral side, radial artery catheterization, and cut down. Each insertion of the needle into the skin during the procedure was considered an "attempt," and the number of attempts was recorded. The number of attempts, the success of the first attempt, the number of successful attempts, the time to successful access, and the number of cannulas used were recorded. Complications such as hematoma, pseudoaneurysm, and venipuncture during and after the procedure were recorded. After completion of the procedure, blood flow to the lower extremity was assessed and any discoloration was recorded. In all groups, all materials used during the procedure were noted to allow cost analysis. Five days after the procedure, the procedure site and legs were examined for possible ischemia, and patients with signs of ischemia were recorded. After withdrawal of the arterial cannula, a pressure dressing was applied, and after hemostasis, the patient was reexamined by ultrasound for possible complications such as hematoma and thrombosis.

Statistical analysis

To determine the sample size, the G-Power program, version 3.1.9.4 (Kiel College, Germany), was employed. The allocation ratio was assumed to be N2/N1:1 based on data from an earlier study, and the alpha error was set at 0.05, the power was 0.95, and the effect size was 1.187939. It was determined that 40 patients would be the bare minimum for the study[8].

Table 1. Patient characteristics

Demographic data and clinical features	Group US (n = 20)	Group P (n = 20)	p-value
Age (month)	16.6 ± 10.0	14.6 ± 12.6	0.583
Weight (kg)	4.8 ± 2.2	5.7 ± 2.0	0.192
Height (cm)	57.7 ± 10.3	63.4 ± 10.8	0.096
Sex (male/female), n	15/5	14/6	0.723
Diagnosis, n			0.189
Ventricular septal defect	3	7	
Tetralogy of Fallot	1	5	
Hypoplastic left hearth	3	1	
Pulmonary atresia	2	0	
Transposition of great artery	6	4	
Atrioventricular canal defect	1	1	
Others	4	2	
Baseline heart rate (rate/min)	129 ± 11	120 ± 17	0.080
Baseline systolic blood pressure (mmHg)	69 ± 21	81 ± 19	0.057
Baseline diastolic blood pressure (mmHg)	40 ± 16	44 ± 12	0.399
Baseline central venous pressure (mmHg)	4.7 ± 2.8	3.9 ± 3.2	0.410
Femoral artery diameter (mm)	2.0 ± 0.3	2.2 ± 0.4	0.048
Previous cannulation, n (%)	13 (65%)	16 (80%)	0.288

Data are means ± SD or numbers. $p < 0.05$ is considered clinically significant.

SPSS 22.0 for Windows program (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Numerical data were calculated as mean and standard deviation. Results were expressed as percentages (n%) using the Chi-square test for comparison of categorical data between groups. Whether the numerical data fit the normality distribution was tested using the Kolmogorov-Smirnov test. As the numerical data were not normally distributed, the Kruskal–Wallis test was used to compare the groups. Student t-test and Mann–Whitney U-test were used to compare normally distributed pairwise groups. $p = 0.05$ was used to determine whether a comparison was significant.

Results

The demographic characteristics of the patients are shown in table 1. The groups did not differ with respect to age, weight, height, diagnosis, and sex. No significant difference was found between the groups with regard to heart rate, basal systolic-diastolic arterial pressure, and basal central venous pressure. The femoral artery diameter was significantly shorter in the US group than in the P group ($p = 0.048$). Comparison between groups in terms of previous femoral interventions showed that the majority of patients had undergone a femoral intervention for diagnostic angiography, with no significant difference between groups.

The results of the interventions are shown in table 2. Access time and number of attempts were significantly lower in the US group than in the P group ($p = 0.002$ and $p < 0.001$, respectively). The first-attempt success rate was significantly higher in the US group than in the P group ($p < 0.001$). In addition, successful catheterization was significantly more frequent in the US group than in the P group ($p = 0.037$).

When complications were analyzed, two complications were observed in the US group: arterial occlusion in one patient and hematoma in one patient. In contrast, in the P group, complications occurred in eight patients, including artery occlusion in 3 and hematoma in 5. The

Table 2. Outcome data

Parameters	Group US (n = 20)	Group P (n = 20)	p-value
Time of attempted cannulation (min)	5.5 ± 2.7	9.3 ± 4.3	0.002
Successful cannulation on first attempt, n (%)	17 (75%)	5 (25%)	< 0.001
Patients with successful cannulation, n (%)	19 (95%)	14 (70%)	0.037
Number of attempts	1.2 ± 0.6	2.2 ± 0.8	< 0.001
Complications (n)	2	8	0.028
Causes of failure (n)			0.102
Failure to puncture vessel	0	2	
Failure to place guide wire	1	4	
Number of cannulae used	1.2 ± 0.4	1.6 ± 0.6	0.015
Vein puncture (n)	0	2	0.147
Surgical cutdown (n)	0	1	0.311
Total cost for procedure ($)	44.5 ± 8	53.5 ± 8	0.014

Data are means ± SD, medians, and ranges or numbers. $p < 0.05$ is considered clinically significant.

complication rate was significantly higher in the P group than in the US group. No serious long-term complications such as lower limb ischemia or nerve damage occurred in any group.

Failed catheterization occurred in one patient in the US group and in six patients in the P group. All five failed catheterizations in the P group were successfully completed when performed under US guidance. The failed catheterization in the US group was because the guidewire could not be advanced, whereas in the P group, failed arterial puncture occurred in two patients and the guidewire could not be advanced in four patients. The number of cannulas used was statistically significantly lower in the US group than in the P group ($p = 0.015$). The number of patients who underwent surgical cut-down after failed catheterization was similar in both groups.

Cost analysis showed that the total cost of the procedure was significantly lower in the US group than in the P group ($p = 0.019$).

Discussion

Our study compared US guidance and palpation technique for femoral artery catheterization in pediatric patients undergoing cardiac surgery and found that US guidance was superior to palpation technique in terms of success rate, total procedure time, complication rate, and cost.

Numerous studies have reported that the use of US guidance instead of palpation during arterial catheterization reduces procedure time and increases first-attempt success rate and overall success rate. Based on these results, many authors have recommended the use of US in arterial catheterization[7,9,10]. In addition, most studies have emphasized that high success rates and short procedure times are the most important indicators of the superiority of this technique[11,12]. Ganesh et al. showed that the use of US in arterial catheterization in pediatric patients did not reduce the number of attempts or procedure time compared with the palpation technique[13]. However, a review of the methodology of this study revealed that none of the operators who performed procedures in the US group had performed > 10 US-guided catheterization procedures.

In a randomized controlled trial of adult patients in an angiography department, Seto et al. demonstrated that the use of US in femoral artery catheterization reduced procedure time and increased the first-attempt success rate[14]. Siddik-Sayyid et al. reported, that the use of US in femoral artery catheterization by residents (with experience of < 2-3 years and < 5 times) in children, who underwent pediatric cardiac surgery shortened procedure time and increased first-attempt success rates without increasing overall success rates[15]. However, after an additional analysis in infants aged < 1 year, they

reported that the US method was superior only in terms of number of trials and did not lead to a difference in other outcomes. Our study confirms these findings but also indicate that the use of US in conjunction with sufficient experience decreases procedure time and number of attempts and increases first-attempt success rates and successful catheterization even in younger pediatric groups.

Arterial diameter is an important factor contributing to the likelihood of successful arterial catheterization. Bhatia et al. performed measurements 1 cm distal to the inguinal ligament using US and found that the mean femoral artery diameter was 2.8 ± 0.8 mm in the 1st month of life and 5.6 ± 1.1 mm in the 5-7-year-old group[6]. In our study, femoral artery diameters in both groups by age group were similar to those reported in this study. Although the mean femoral artery diameter was statistically significantly lower in the US group in our study compared with the palpation group, the US group had a higher likelihood of successful catheterization and a lower complication rate compared with the palpation group; this is another indicator of how successful US-assisted catheterization is.

The incidence of complications after arterial catheterization is quite high in critically ill patients, including pediatric patients undergoing cardiovascular surgery[16]. Furthermore, repeated arterial procedures in pediatric patients not only lead to an increased incidence of complications but also decrease the chances of success[9]. In a meta-analysis of numerous studies with a total of 444 cases of pediatric arterial catheterization, Aouad-Maroun et al. demonstrated that the use of US increased the chances of success on the first attempt and decreased the number of attempts required as well as the incidence of complications[11]. Our study also found a lower incidence of complications in the US group. We believe that this is due to the lower number of attempts and shorter procedure times with US-guided catheterization. King et al. studied 10,394 patients undergoing arterial catheterization and found that the most common complications were infections (61.8%), mechanical complications (14.1%), and thromboembolic events (7.5%)[16]. The most common complication in our study was arterial occlusion. No catheter-related infections occurred in our patients. This may be due to the fact that perioperative prophylactic broad-spectrum antibiotherapy was given to patients undergoing cardiovascular surgery in our study.

Oulego-Erroz et al. compared the Landmark technique and US guidance in intensive care patients and emphasized that the most common cause of failed arterial catheterization was failure to advance the guidewire and that this was independent of the use of US[17]. Our findings regarding failed cannulation support previous studies.

Tan et al. found that the use of US for arterial catheterization in children younger than 2 years of age reduced procedural costs compared with the palpation technique[18]. In contrast, Ganesh et al. compared US and the palpation technique for radial artery catheterization in patients < 18 years and found no significant difference between the groups in terms of cost[13]. However, to our knowledge, based on a literature search, no study to date has compared different methods of femoral artery catheterization in pediatric patients in terms of cost. The results of our study are valuable in that they show that the US method can also reduce costs in this patient group.

Our study has some limitations: The study was single-center, the number of patients was small, not all patients were preoperatively evaluated by US for possible malposition of the femoral artery, the procedure duration was limited to 15 min, and the procedure duration was calculated as the time from insertion of the needle into the skin to successful catheterization, not including the time for preparation of the US device.

Conclusion

It was found that US-guided arterial catheterization increased the success rate and number of successful catheterizations while decreasing overall procedure time, the incidence of complications, and cost. Furthermore, all five failed catheterization procedures in the palpation group were successfully completed when performed under US guidance. Therefore, we conclude that the use of US guidance is the better choice for arterial catheterization in pediatric cardiac surgery. We have found that all of these advantages of the US technique are more pronounced in younger children. We believe that this issue should be further investigated in multicenter prospective studies with larger cohorts of patients.

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Conflicts of interest

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Ethical disclosures

Protection of human and animal subjects. The authors declare that the procedures followed were in accordance with the regulations of the relevant Clinical Research Ethics Committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained approval from the Ethics Committee for analysis and publication of routinely acquired clinical data and informed consent was not required for this retrospective observational study.

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