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Original Article / Özgün Makale

The success rate and safety of internal jugular vein catheterization under ultrasound guidance in infants undergoing congenital heart surgery

Doğuştan kalp cerrahisi geçiren infantlarda ultrason rehberliğinde internal jugüler ven kateterizasyonunun başarı oranı ve güvenilirliği

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ABSTRACT

Background: In this study, we aimed to investigate the effect of central venous catheterization under ultrasound guidance on the success and complication rates in low-weight infants (under 5 kg) undergoing surgery due to congenital heart disease.

Methods: A total of 70 infants (38 boys, 32 girls; mean age of patients <1 month was 16.4±9.5 days [n=20; 28.6%]; 1-7.5 months was 126.3±47.8 [n=50; 71.4%]) who underwent ultrasound-guided internal jugular venous catheterization between October 2014 and October 2015 were retrospectively analyzed. All catheterizations were done under the guidance of ultrasound by two skilled anesthesiologists. Data including demographic characteristics of the patients, procedural success rate, catheter access time, number of attempts, and complications were recorded.

Results: The overall success rate of the procedure was 92.8% (n=65). In 82% of the patients (n=53), the insertion was successful at the first attempt. The mean catheter access time (time from the first puncture to the catheter insertion) was 214±0.48 sec. Complications were seen in five patients (7.14%), and the body weight of these patients was less than 2,500 g. There was no arterial puncture in any patients. One patient (1.42%) developed pneumothorax and four patients (5.7%) developed hematoma due to repeated attempts.

Conclusion: Our study results suggest that ultrasound-guided central venous cannulation is a safe and effective technique in pediatric population weighing less than 5 kg undergoing congenital heart surgery.

Keywords: Central venous catheterization; congenital cardiac surgery; internal jugular vein; pediatric; ultrasound.

ÖZ

Amaç: Bu çalışmada, doğuştan kalp hastalığı nedeniyle cerrahi uygulanacak olan düşük ağırlıklı infantlarda (5 kg'nin altında) ultrason rehberliğinde santral ven kateterizasyonunun başarı ve komplikasyon oranlarına etkisi araştırıldı.

Çalışma planı: Ekim 2014 - Ekim 2015 tarihleri arasında ultrason rehberliğinde internal jugüler venöz kateterizasyon uygulanan toplam 70 infant (38 erkek, 32 kız; hastaların ortalama yaşı <1 ay 16.4±9.5 gün [n=20; %28.6]; 1-7.5 ay 126.3±47.8 (n=50; %71.4]) retrospektif olarak incelendi. Tüm kateterizasyonlar, deneyimli iki anestezi uzmanı tarafından ultrason eşliğinde yapıldı. Hastaların demografik özellikleri, işlemin başarı oranı, kateterin takılma süresi, girişim sayısı ve komplikasyonlar dahil olmak üzere veriler kaydedildi.

Bulgular: İşlemin başarı oranı %92.8 (n=65) idi. Hastaların %82'sinde (n=53) ilk girişimde işlem başarılı oldu. Kateterin ortalama takılma süresi (ilk ponksiyondan kateter yerleştirilmesine kadar geçen süre) 214±0.48 sn. idi. Beş hastada (%7.14) komplikasyon gelişti ve bu hastaların vücut ağırlığı 2500 g'nin altındaydı. Hastaların hiçbirinde arteriyel ponksiyon görülmedi. Bir hastada (%1.42) pnömotoraks ve dört hastada (%5.7) tekrarlayan girişimlere bağlı olarak hematom gelişti.

Sonuç: Çalışma sonuçlarımız ultrason rehberliğinde yapılan santral venöz kateterizasyonunun doğuştan kalp cerrahisi yapılacak 5 kg'nin altındaki pediyatrik hasta grubunda güvenli ve etkili bir teknik olduğunu göstermektedir.

Anahtar sözcükler: Santral venöz kateterizasyon; doğuştan kalp cerrahisi; internal jugüler ven; pediyatrik; ultrason.

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Central venous catheterization (CVC) in pediatric patients with congenital heart disease weighing less than 5 kg is often difficult and may be associated with a high risk of complications, even with ultrasound (US) guidance. Low body weight may reduce the success rate, while increasing the complication rate and number of insertion attempts of central venous cannulation. In particular, US is recommended in low-body-weight pediatric patients and has been shown to be superior to conventional landmark technique.[1-5]

In recent years, the use of US as a guide has been increasing to reduce the risks associated with central venous catheter insertion. Several publications have demonstrated its role as a complementary tool in pediatric patients by reducing the incidence of complications during the catheter insertion.[5,6] With the guidance of US, it is also possible to identify the size and location of the vessel and to evaluate the presence of congenital anomalies and anatomic variations.[1,4]

Various factors contribute to the success rate of CVC, including patient characteristics, comorbidities, and access site. The most common complications include bleeding, hematoma, arterial puncture, and pneumothorax.[5]

In the present study, we aimed to evaluate the efficacy and safety of US-guided internal jugular vein (IJV) cannulation in terms of the complication and success rates in pediatric patients with congenital heart disease.

PATIENTS AND METHODS

In this study, medical records of a total of 70 low-weight infants weighing less than 5 kg (38 boys, 32 girls; mean age of patients <1 month was 16.4±9.5 days [n=20; 28.6%]; 1-7.5 months was 126.3±47.8 days [n=50; 71.4%]) who underwent US-guided IJV catheterization due to congenital heart disease between October 2014 and October 2015 were retrospectively analyzed. A written informed consent was obtained from each parent. The study protocol was approved by the Baskent University Faculty of Medicine Ethics Committee (No: KA157305). The study was conducted in accordance with the principles of the Declaration of Helsinki.

After retrospective evaluation of the medical charts and nursing documentations, data including demographic characteristics of the infants such as age, gender, and body weight and existing comorbidities were recorded.

A single anesthetic regimen was used in all patients (for induction 5 mg/kg sodium thiopental, 0.6 mg/kg rocuronium, and 2 μg/kg fentanyl). After orotracheal intubation, the patient was placed in the appropriate position for the cannulation to visualize the vein properly, and the area was washed and draped. The operator was positioned at the head of the bed.

For right IJV cannulation, the patient was positioned with a rolled towel under the shoulders with the head turned to the left. First, the right IJV was chosen for the primary insertion attempt. The right neck was wrapped using the standard sterile technique. The jugular venous anatomy was examined through a 7.5 MHz sonographic probe (Sonosite Titan, linear probe -7.5 MHz) (Figure 1). The compression of the vein with gentle pressure of a probe on the skin and the presence of the pulse in the carotid artery (CA) were confirmed.

The linear probe was connected to a real-time two-dimensional US device (SonoSite, Bothwell, WA, USA) and focused at 3.5 cm depth. The probe was covered with ultrasonic gel and wrapped in a sterile cover.

The real-time US is a technique of needle advancement and vessel puncture under the permanent US guidance (i.e., the needle is permanently seen on the US screen). The sonographic probe was placed perpendicular to the long axis of the vessel, visualizing

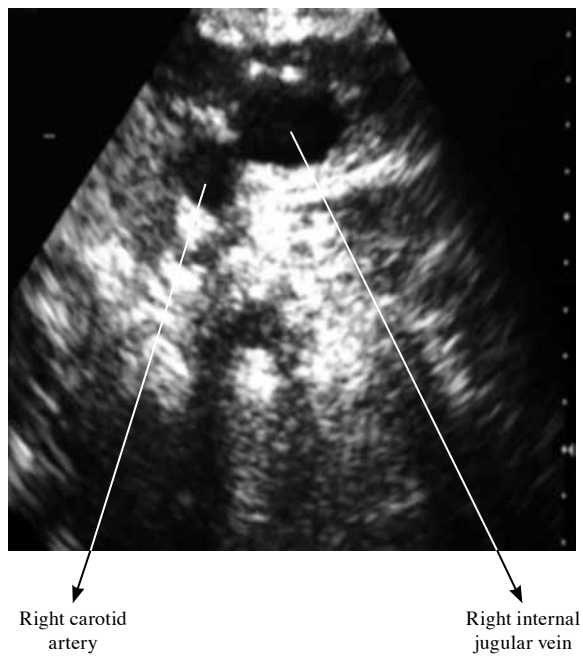

Figure 1. Two-dimensional ultrasound image of right femoral vein. Right neck central vein cannulation. Out-of-plane (short axis) ultrasound image.

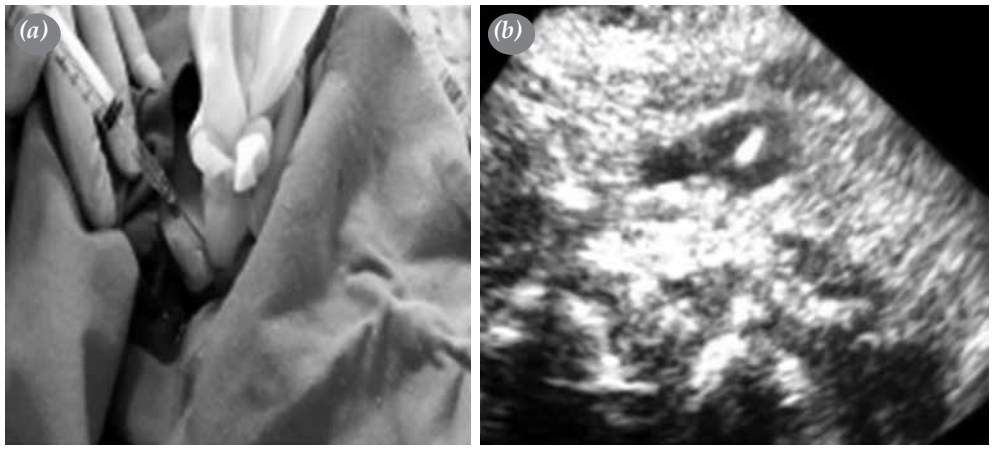

Figure 2. Needle insertion perpendicularly. **(a)** Out-of-plane (short axis). **(b)** Needle tip clearly seen in the internal jugular vein.

the vein in the short-axis view as a circle (Figure 2). Under the sonographic guidance, the right IJV was punctured (Figure 2).

The success rate, access time, number of attempts, the incidence of complications during each attempt (i.e., CA puncture, hematoma, hemodynamic alteration, pneumothorax, and catheter-related complications such as kinking or threading difficulties) were recorded. The access time was defined as the time from the needle penetration of the skin and to the insertion of the catheter into the vein over the guidewire with the removal of the needle entering the skin.

Statistical analysis

Statistical analysis was performed using the SPSS for Windows version 15.0 software (SPSS Inc., Chicago, IL, USA). Descriptive data were expressed in mean ± standard deviation (SD) and number and frequency (%). Student's t-test was used for comparison of quantitative variants. Qualitative variants were compared using chi-square tests or the Fisher's exact test as appropriate. Pearson correlation analysis was used to examine the relationships between the parameters that conform to the normal distribution. A p value of <0.05 was considered statistically significant.

RESULTS

Of a total of 70 patients, 20 were younger than 30 days of age and 50 patients were one month to 7.5 month-old. The body weight of the infants were as follows: four patients (5.7%) less than 2 kg, 10 patients (14.3%) between 2 to 3 kg, and 56 patients (80%) between 3 to 5 kg (Table 1).

The success rate of the IJV catheter insertion was 92.8%. Only in five patients (7.14%), the procedure failed. In these patients, the catheter was inserted into the femoral vein. In total, 53 CVC (81.5%) were successful at the first attempt and nine (13.8%) at the second attempt, while three patients (4.6%) required ≥3 punctures.

Complications were observed in five patients (7.14%) weighing less than 2,500 g. One of them had a giant teratoma which limited the neck movements of the patient with a body weight of 950 g. In these patients, femoral vein catheterization was done rather than the IJV puncture.

Pneumothorax occurred only in one patient (1.42%). Hematoma occurred in four patients (5.7%) due to the multiple IJV cannulation attempts. There was no CA puncture in any patients (Table 2).

Table 1. Demographic characteristics of patients (n=70)

Characteristic	n	%
Age (month)		
<1	20	28.6
1-7.5	50	71.4
Gender		
Male	38	54.3
Female	32	47.7
Weight (kg)		
≤2	4	5.7
2-3	10	14.3
3-5	56	80

Table 2. Outcome measures of ultrasound-guided catheterization (n=70)

Outcome measures	n	%	Mean±SD
Success rate		92.8	
Access time (seconds)			216±0.48
Carotid puncture	0	0	
Hematoma	4	5.7	
Pneumothorax	1	1.42	
Failed attempt	5	7.14	

SD: Standard deviation.

The mean access time was 214±0.48 sec (Table 2). The weight was correlated with the catheter insertion time using the Pearson's correlation coefficient. There was a statistically significant and negative correlation between total catheter insertion time and body weight of the patients (57.7%; $p<0.05$).

DISCUSSION

In general, CVC is challenging in pediatric patients due to the small diameter of the vessels. Therefore, more insertion attempts are often unavoidable, before successful catheterization can be performed. Usually, the number of insertion attempts increase the risk of complications such as CA puncture, pneumothorax, hemothorax, and subcutaneous extravasation.[3-6] According to many studies, the success rate is lower and the complication rate is higher in infants and children, compared to older children and adults. Moreover, anomalies and syndromes, prematurity and short neck can also decrease the procedural success rate and increase the complication rate.[5-7]

In a retrospective study including 149 patients undergoing cardiac surgery, Leyvi et al.[8] reported a success rate of 91.5% in the US group and 72.5% in the landmark group. In another study including 60 pediatric patients younger than 12 years old who underwent cardiac surgery, Dalvi et al.[9] found that the first attempt success was higher in the US group (73.3%) than the landmark group (36.6%). In the aforementioned study, the CA puncture was also higher in the landmark group (43.3%) than the US group (10%), and the mean number of attempts were higher in the landmark group than the US group ($p=0.008$). Similar findings were also reported by Verghese et al.[10] In our study, we retrospectively evaluated the success rate of US-guided CVC in low-weight pediatric patients undergoing congenital heart surgery. The overall success rate was 92.8% (n=65), requiring only one attempt in 81.5% of the patients (n=53). Only 12 patients (18.4%) needed multiple attempts for successful catheterization, and all of these patients requiring multiple attempts had lower weight, compared to the others. The complication rate was also low (7.1%, n=5). There was no CA puncture in any patients.

Furthermore, anatomic variations and vascular anomalies about the IJV and CA in children with congenital cardiac disease may compromise the catheterization. According to Troianos et al.,[11] there was a high incidence (54%) of posteriorly inserted CA which predisposed the patients to CA puncture, if the cannulation needle traversed the IJV. According to Alderson et al.'s study[12] where they examined the jugular venous anatomy by US in 50 patients younger than six years of age, there was an anomalous venous anatomy with an incidence of 18%. In 10% of the patients, CA was positioned posteriorly. The diameter of the IJV was also unusually small (≤3 mm for neonates and infants, ≤5 mm for older children) in 4% of the patients. All of these anomalies increased the complication rate (20%) in the aforementioned study.

Visualization of the vessels and confirmation of anatomical variations regarding the IJV-CA relationship can be obtained by US-guided technique (Figure 1). The IJV is usually located laterally to the CA. With the US guidance, this anatomical relationship, arterial pulsation of the CA and the compression of the IJV can be seen easily.[13-16] Another important point of the visualization of the structures is that it is also possible to see the position of the guidewire and the catheter.[17]

In our clinic, we routinely perform IJV catheterization as the first choice, if there is no any contraindication. In this study, similar to previous studies, we were able to visualize the anatomical structures and IJV-CA relationship easily under the guidance of US. We believe that high procedural

success rate in our study may be due to the advantage of using US. Similarly, Verghese et al.[18] and Grebenik et al.[19] achieved higher success rates in the US group. In many studies, it was reported that CVC with the US guidance reduced the access time and number of puncture attempts for successful catheterization.[18-21]

On the other hand, according to the study of Froehlich et al.,[3] there was no significant difference between the US guidance and landmark technique in terms of the time spent for catheterization; however, the authors reported that the time was also dependent on the experience of the practitioner. In our study, the mean access time from the first puncture to the catheter insertion was 214±0.48 sec and catheterization was performed by two anesthesiologists specialized in this area.

The age and weight of patients are also critical factors which affect the success rate and the number of attempts in catheter insertion. According to our study, there was a negative correlation between the weight of the patient and catheter insertion time and success rate ($p<0.05$). Froehlich et al.[3] demonstrated that success rate was lower in children with low-weight (median weight <16.25 kg) and multiple attempts were required for both techniques (US and landmark), compared to high-weight children (median weight >16.25 kg).

In our study, we found that, with the guidance of US, CVC could be performed with fewer complications and a higher success rate in a short period. Since children with congenital heart disease are exposed to multiple procedures and frequently require vascular access for diagnostic, interventional or medical reasons, CVC with the aid of US seems to be beneficial. Moreover, we believe that, in addition to the use of US guidance, optimal positioning, profound sedation, and the correct choice of the site and cannulation materials are the other important factors which affect the success rate.

The limitations of this study include retrospective design with small sample size and lack of a control group to compare the usual technique of anatomic landmarks. Nevertheless, our data can be generalized, as there are no missing data for any of the patients.

In conclusion, our study results suggest that the success rate of central catheterization under the guidance of ultrasound is high and ultrasound-guided central venous cannulation is a safe and effective technique, particularly in the pediatric population weighing less than 5 kg undergoing congenital heart surgery.

Declaration of conflicting interests

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