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Özgün Araştırma

Çocuk Yoğun Bakımda Santral Venöz Kateterizasyon için Ultrasonografi Kullanımı; tek merkez deneyimi

Use of ultrasound for central venous catheterization in pediatric intensive care unit; a single center experience

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ÖZET

Amaç: Santral venöz kateterizasyon çocuk yoğun bakımlarda sağladığı faydalar nedeniyle sık kullanılmaktadır. Son yıllarda yoğun bakımlarda oldukça sık kullanılmakta olan ultrasonografi santral venöz kateterizasyon uygulamalarında da yararlı olmaktadır. Bu çalışmada çocuk yoğun bakım ünitemizde ultrasonografi eşliğinde yapılmış olan santral venöz kateter uygulamalarımızın değerlendirilmesi amaçlanmıştır.
Yöntemler: Üçüncü düzey, 12 yataklı çocuk yoğun bakımımızda ultrasonografi eşliğinde santral venöz kateter takılmış kritik hasta çocukların bulguları derlendi.
Bulgular: Nisan 2014 ve Nisan 2015 tarihleri arasında 55 hastaya 70 santral venöz kateter uygulaması yapılmıştı. Hastaların %50,9'una periferik damar bulunmadığı için, %47,3'üne çoklu ilaç ve sıvı tedavisi için santral venöz kateter takılmıştı. Kateter uygulamaları için %45,7 internal juguler ven, %54,3 femoral ven tercih edilmişti. Başarı oranı tek anatomik bölge için %98,6 (69/70) iken genelde %100 (70/70) olarak saptanmış olup, mekanik komplikasyon gelişmemişti. Bir hastada kateter ilişkili kan akımı enfeksiyonu saptanmış, enfeksiyon oranımız 1000 kateter günü için 1,12 iken, bir hastada kateter ilişkili tromboz saptanmıştı (%1,42, 1/70).
Sonuç: Santral venöz kateterizasyon çocuk yoğun bakımlarda özellikle kritik hastalarda tedavi başarısını ve konforunu arttıran bir uygulamadır. Çalışmamızda ultrasonografi eşliğinde santral venöz kateterizasyon uygulamasının güvenli ve komplikasyon oranlarının düşük olduğu görülmüştür. Uygun tüm girişimsel işlemlerde ultrasonografi kullanımının daha yaygın olması gerektiğini düşünmekteyiz. CAYD 2015;2(3):127-32.
Anahtar Kelimeler: santral venöz kateterizasyon, femoral ven, internat juguler ven, çocuk yoğun bakım, ultrasonografi

ABSTRACT

Introduction: Central venous catheterization (CVC) is commonly preferred due to its benefits in the setting of pediatric intensive care units (PICUs). Ultrasound, being frequently used in the PICU setting in recent years, is also beneficial in the practice of central venous catheterization. In this research we aimed to assess the practices of ultrasound-guided CVC at our PICU.
Methods: We reviewed the findings of ultrasound-guided CVC performed on critically ill children at a 12-bed, level 3 PICU.
Results: Between April 2014-2015, 55 patients underwent 70 procedures of CVC. Respectively 50.9% and 47.3% of the patients underwent CVC due to the absence of peripheral vessels and for the purpose of multiple drug and fluid treatment. The preference for the catheterization procedure was in favor of internal jugular vein and femoral vein at a rate of 45.7% and 54.3%, respectively. No mechanical complications occurred and the rate of success was 100% (70/70) in overall and 98.6% (69/70) for a single anatomic site. One patient showed central line-associated bloodstream infection; the rate of infection was 1.22 per 1000 catheter days and one patient had catheter-related thrombosis; of which the rate was 1.42% (1/70).
Conclusion: Central venous catheterization is a practice that enhances the treatment success and comfort in the setting of PICUs, particularly in critically ill patients. Our research revealed low rates of complications and manifested that ultrasound-guided CVC procedure has been safe. We think that the use of ultrasound for all appropriate invasive interventions should be more common in children. CAYD 2015;2(3):127-32
Keywords: central venous catheterization, femoral vein, internal juguler vein, pediatric intensive care, ultrasound

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Introduction

Central venous catheterization is an invasive method used for invasive hemodynamic monitorization, parenteral nutrition, drug and fluid treatment, blood sampling, and administration of blood and blood products.[1-6] Related to technological developments; it is also used for continuous renal replacement therapies and plasmapheresis. At the PICUs, it can also be used due to absence of peripheral venous access besides the mentioned reasons. While the use of central venous catheters is increased due to its advantages in the setting of PICUs, the prevalence of use varies depending on the experience of the intensive care team. Since infectious, thrombotic and mechanical complications may occur during and following the CVC procedure, the procedure should be performed by an experienced physician, ensuring sterile conditions. Pediatric intensive care experts and pediatricians employed at the intensive care units mostly practice the "Seldinger" method, depends on anatomic landmarks, which was first described by Swen Seldinger in 1953.[2]

In recent years, ultrasound has become a powerful device to assist clinicians in the evaluation of traumatic injuries and to decrease the morbidity associated with procedures in both emergency and critical care.[7,8] In departments like emergency and critical care where time is of utmost importance, the possibility for the clinician to use a cheap imaging method with no radiation is a great advantage to the patient with respect to diagnosis and treatment[7]. In intensive care units ultrasound can be used for interventional procedures (vascular access, lumbar puncture, paracentesis, drainage of pleural effusions), the assessment of hemodynamic status and pneumothorax as well as the monitoring of intracranial pressure[7,8]. In this study, we aimed to assess the practices of CVC with the guidance of ultrasound performed at our PICU.

Material and Methods

The records of 616 patients hospitalized between the dates of April 1, 2014 and April 1, 2015 at a 12-bed, level 3 pediatric intensive care unit were retrospectively investigated. A total number of 55 patients, who underwent CVC procedure for the purpose of multiple drug and fluid treatment and due to absence of peripheral venous access, were evaluated with respect to age, gender and diagnosis of admission to intensive care. In addition, indications for catheter insertion, site of administration, the number of anatomic sites of attempt, the duration of catheter use, emerging complications and the rate of infection and the growing microorganisms were retrospectively reviewed.

Femoral and internal jugular veins were used for catheterization. The preference for femoral and internal jugular veins for catheterization was left at the discretion of the practitioner. Prior to the operation, jugular and femoral veins were evaluated with ultrasound. Catheterization was not performed in case of situations like thrombus and anatomic variation. In patients with high risk-low body weight and circulatory disorder where the vein could not be evaluated clearly, the CVC procedure was performed by an interventional radiology expert. Subclavian vein was not preferred since it complicated the insertion of the catheter into the clavicle under ultrasound guidance. Adequate anesthesia was achieved prior to the procedure (1 μgr/kg fentanyl); sedation was ensured using midazolam (0,1 mg/kg) or ketamine (1-2 mg/kg). During the procedure, the patients were followed under continuous monitoring of the cardiac rate and rhythm, the respiratory rate and oxygen saturation. Except emergency situations, patients with pre-existing thrombocytopenia and abnormal coagulation test results were given supportive treatment and the catheter was inserted in these patients after the test results returned to normal. Central venous catheters were inserted by the pediatricians employed at the intensive care unit or interventional radiology expert at the pediatric intensive care unit. Double-lumen 4-Fr, triple-lumen 5-Fr, triple-lumen 7-Fr polyurethane transient catheters were used for patients with a body weight below 5 kg, between 5 and 20 kg and above 20 kg, respectively (Guangdong Baihe Medical Technology, China).

For the purpose to recognize artery and vein; 1- the anatomic positions of internal jugular and femoral veins relative to arteries (internal jugular vein lies on the lateral side of the common carotid artery, femoral vein lies on the medial side of the femoral artery) (figure 1,2), 2- the compressibility of the internal jugular and femoral veins relative to arteries (figure 1,2), 3- in case of difficulty of discriminating the veins and arteries, the shape of the flow was investigated using Doppler mode of ultrasound (Figure 3). While transverse access was mostly used due to the size of the ultrasound probe, CVC was conducted using longitudinal access with real-time images in older patients (figure 4).

Hand hygiene and aseptic conditions were ensured to manage infections. The site of administration was sterilized using 10% povidone iodine. A sterile ultrasound gel (Aquatouch Jelly, Turkey) and sterile transducer cover (Medbar Cardboard Camera Cover, Turkey) was used. While inserting the catheter, a "laptop style" ultrasound device and a straight linear probe (7.5 MHz) was used (Mindray-M5 Ultrasound System, China). The catheters were inserted using the Seldinger technique. The location of the catheter was assessed by posterior-anterior chest radiograph for the internal jugular catheters and the localization was deemed appropriate if the tip of the catheter was in the space between the distal part of vena cava superior and the entrance of the right atrium. Dressings were applied once every two days. Patients exhibiting the same microorganism growth in the catheter culture and the peripheral blood culture with accompanying the sepsis clinical findings and signs were diagnosed as central line-associated bloodstream infection while those with erythema, indurations and tenderness within 2 cm distance around the catheter exit were diagnosed with catheter exit-site infection[9].

Statistical analysis

The statistical analysis was conducted using the "Statistical Package for Social Sciences" version 15 (SPSS Inc., Chicago, IL, USA). The descriptive statistics of the

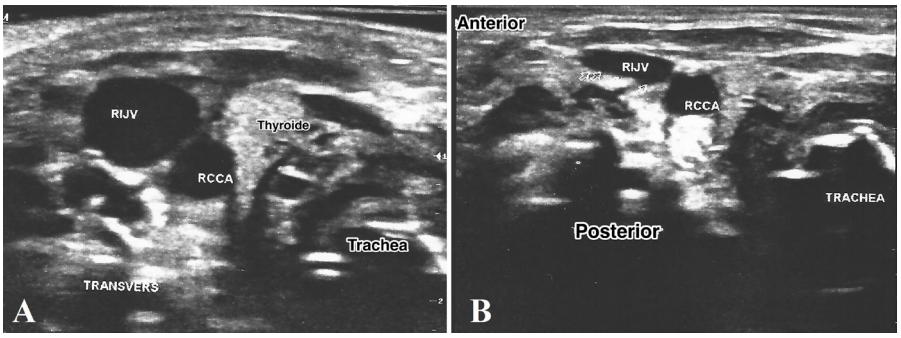

Figure 1. Ultrasonographic image of the jugular vein and common carotid artery on the transverse plane with and without compression. **A:** without compression. Internal jugular vein lies on the lateral side of the common carotid artery. **B:** with compression. Notice how the vein response to the compression.
RIJV: right internal juguler vein, RCCA: right common carotid artery

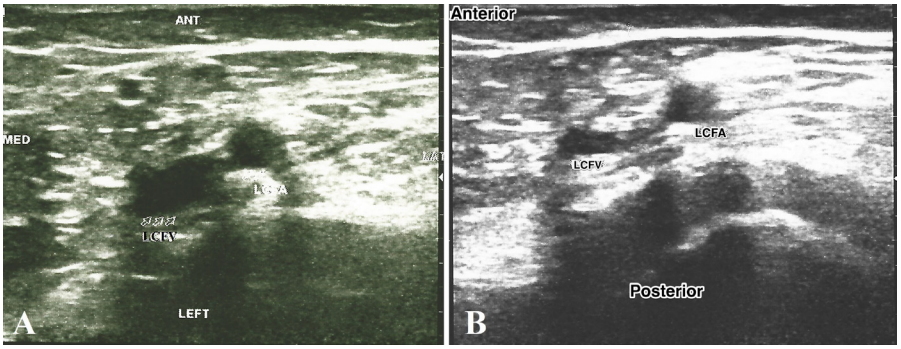

Figure 2. Ultrasonographic image of the femoral vein and artery on the transverse plane with and without compression. **A:** without compression. Femoral vein lies on the medial side of the common femoral artery. **B:** with compression. Notice how the vein response to the compression.
LCFV: left common femoral vein, LCFA: left common femoral artery

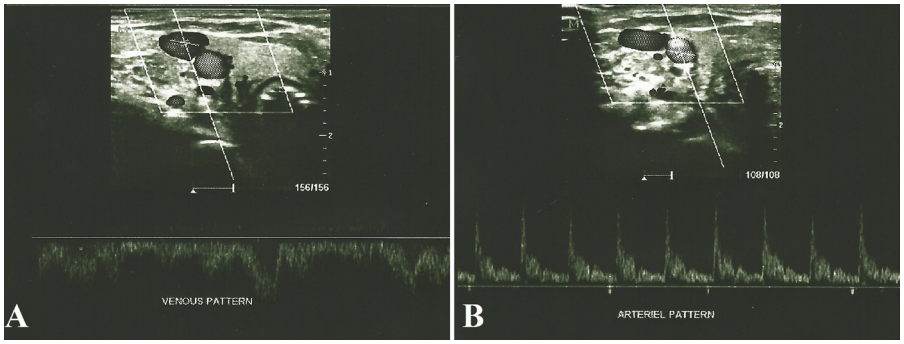

Figure 3. A: Venous flow pattern (right internal juguler vein) on a Doppler assessment. **B:** Arterial flow pattern (right common carotid artery) on a Doppler assessment

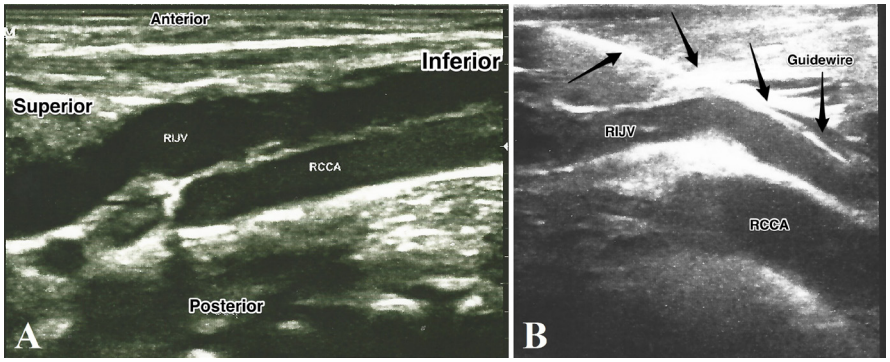

Figure 4. A: ultrasonographic image of the right internal jugular vein and common carotid artery on the longitudinal plane. **B:** ultrasonographic image of the guidewire in the right internal jugular vein on the longitudinal plane
RIJV: right internal jugular vein, **RCCA:** right common carotid artery

variables in the study group (number, percentage, mean and standard deviation, minimum and maximum values) were calculated.

Ethics Statement

Ethics committee approval was obtained from the "Adana Numune Training and Research Hospital Ethical Committee" on April 27, 2015. Due to the retrospective nature of this study, informed consent was waived by the Ethical Committee.

Results

We detected that 616 patients presented to PICU between April 2014 and April 2015 and 55 of them had been inserted 70 central venous catheters. At a rate of 54.5% of the patients with catheter requirement were mechanically ventilated and 17 (30.9%) of those patients who were inserted a catheter had died due to other reasons than the CVC procedure during the follow-up. Among the patients 25 were females (45.4%), 30 were males (54.6%) and the mean age was 41.73±51.42 months (the smallest: 1.5 months, the oldest: 192 months). The mean body weight was 14.25±12.74 kg (the lowest: 1.2 kg, the highest: 55 kg). The catheterized patients had a mean hemoglobin value of 10.99±2.02 gm/dl and a platelet count of 257,200±148,650/mm^3 (the lowest: 41/mm^3) (Table 1).

Examining the diagnoses for admission to the pediatric intensive care unit, we observed that the causes were infectious diseases, neurologic diseases, hematologic diseases, respiratory diseases and other reasons at a rate of 45%, 25%, 7.5%, 7.5% and 15% respectively (Table 1). Reviewing the indications for catheterization, we observed that while failure of peripheral vascular catheterization was involved at a rate of 50.9%, multi drug and fluid treatment accounted for 47.3% of the cases and one patient was for hemodialysis (1.8%) (Table 2). All the catheterization procedures were performed under ultrasound guidance.

A number of 38 (54.3%) of the procedures were conducted in the femoral vein while 32 (45.7%) were conducted in the jugular vein (Table 2). For the catheterization site, the right and left side of the body was preferred at a rate of 65.7% and 34.3%, respectively. At a rate of 32.9% of the procedures were performed by a general interventional radiologist while 67.1% were performed by a general pediatrician (Table 2). While the interventional radiology expert inserted 60.9% of the catheters (14/23) into the jugular vein, and 39.1% of the catheters (9/23) into the femoral vein, the pediatrician inserted 38.3% of the catheters (18/47) into the jugular vein and 61.7% of the catheters (29/47) into the femoral vein. The mean age, the mean body weight of the patients treated by the interventional radiology expert was 39.65±53.92 months (the smallest: 2 months, the oldest: 160 months) and 13.47±12.87 kg (the lowest: 2.4 kg, the highest: 46 kg) respectively; and the mean age, the mean body weight of the patients treated by the pediatrician was 39.27±50.41 months (the smallest: 1.5 months, the oldest: 192 months) and 13.17±11.56 kg (the lowest: 1.2 kg, the highest: 55 kg) respectively. We obser-

Table 1: Demographic characteristics of the patients (n=55)

Characteristics	Value
Age (months)	46.7±51.4
Gender	
Male	30 (54.6%)
Female	25 (45.4%)
Weight (kg)	14.25±12.74
Diagnosis	
Infectious diseases	25 (45%)
Neurologic diseases	14 (25%)
Hematologic diseases	4 (7.5%)
Respiratory diseases	4 (7.5%)
Others	8 (15%)
Mechanical ventilation	30 (54.5%)
Hemoglobin	10.99±2.02 mg/dl
Platelet	257,200±148,650/mm^3

Table 2: Catheterization outcomes

Characteristics	Value
Indications for catheter insertion	
*Absence of peripheral venous access	28/55 (50.9%)
*Multiple drug and fluid treatment	26/55 (47.3%)
*Hemodialysis	1/55 (1.8%)
Catheterization performed by	
*Radiologist	23/70 (32.9%)
*Pediatrician	47/70 (67.1%)
Site of administration	
* Internal jugular vein	32/70 (45.7%)
* Femoral vein	38/70 (54.3%)
Mean catheter dwell time	11.73±6.54 days
Central line-associated bloodstream infection	1 (1.22 per 1000 catheter days)
Catheter-related thrombosis	1/70 (1.42%)
Catheter exit-site infection	None
Pneumothorax	None
Arterial puncture	None

ved that an attempt was made for the second anatomic site only in one patient while all the other patients achieved success with a single anatomic site. So the catheterization procedures were successful by 100% (70/70) in overall and 98.6% (69/70) for a single anatomic site respectively.

The mean catheter dwell time was detected to be 11.73±6.54 days (the shortest: 2 days, the longest: 30 days) (Table 2). This time was 12.40±6.53 days for femoral catheters and 10.96±6.58 days for jugular catheters. Following insertion of the catheter, a patient had developed thrombosis; this patient was detected to have a femoral catheter inserted and the catheter indwelling time was 26 days. Catheter-related thrombosis rate was 1.42% (1/70). None of the patients with jugular catheter insertion developed pneumothorax. Arterial puncture did not occur during insertion. No catheter exit-site infection developed after the procedure. A patient developed central line-associated bloodstream infection and the rate of infection was 1.22 per for 1000 catheter days. *Pseudomonas Aeroginosa* was detected as the cause of central line-associated bloodstream infection (Table 2). The catheter indwell time was 18 days in the patient with central line-associated bloodstream infection.

Discussion

A safe intravenous route that enables blood sampling and multi drug treatment is of critical significance at PICUs. Compared to the adults, it is technically more difficult in pediatric patients to insert central venous catheter with a higher risk of complications.[3,10] With the development of technology, the application of CVC under ultrasound guidance increasingly becomes a standard procedure in all pediatric age groups.[7,8,11] In contrary to other techniques, with the ultrasound guidance clinician can select the most appropriate and the safest vessel, thereby ensuring vascular puncture as safe as possible.[11]

In many studies performed in adults and children, ultrasound guided central venous catheter insertion has increased the rates of success relative to the "blind" Seldinger method and decreased the rates of complications.[2]

Similar to many other studies conducted in the PICUs, CVC was performed mostly due to the unavailability of the peripheral vascular catheterization in our study.[4,6] The success rates for catheterization are quite high at the PICUs. These high rates are attributed to the fact that the catheterization procedures were conducted by experienced intensive care experts or pediatricians trained in the field of intensive care.[4-6] The catheterization success rate (100%) in our study could be explained by the following aspects: before the operation, the patient was evaluated with ultrasound, the procedure was not done if the venous system was not convenient; in patients with high risk-low body weight and circulatory disorder the procedure was performed by an interventional radiology expert. In a trial by Yoshida et al performed in 2010, the use of ultrasound in CVC was reported to increase the success rates.[12]

In selecting the site of catheterization, the experience of the practitioner is also effective as well as the patient-associated factors[6]. While femoral vein is safer with respect to mechanical complications, the risk of infection and thrombosis is lower for subclavian and internal jugular region.[13] Catheter-related thrombosis vary from 2% to 26% in the literature.[14,15] In our study catheter-related thrombosis rate is 1.42% (1/70) and lower than the literature. Although it is known that thrombosis is not usually associated with needle insertion but occur after catheter placement, we think that the reduced number of attemps reduces the vein trauma and the thrombosis as well.[3,16,17] Similar with our results Alten et al. showed that there were fewer complications of venous thrombosis in patients where ultrasound was used compared with the standard landmark technique, but the results were not statistically significant.[18]

No potential mechanical complications (arterial puncture, malposition, arrhythmia and pneumothorax) associated with catheter insertion occurred in our study. Findings from the PICUs in our country, catheterization without the guidance of ultrasound has a mechanical complication rate of 3.3-9.7% while the rates are within the range of 0.3% and 25.5% in the literature.[4-6,19,20] We believe that the absence of mechanical complications in our study result from the fact that the distinction between the arteries and veins can be easily made in both femoral and jugular regions, and the fact that the depth of the needle to be inserted can be detected. In similarity to our results, Froeclich et al reported that the use of ultrasonography reduced complications and particularly the arterial puncture.[17]

One patient in our study developed central line-associated bloodstream infection following insertion. The rate of infection was 1.22 per 1000 catheter days. Findings from the PICUs in our country, catheterization without ultrasound guidance has a central line-associated bloodstream infection rate of 2.8-5.5% while the rates are within the range of 1.6% and 44.6% in the literature for children and adults.[4-6,21,22] At our PICU, we remove the central venous catheters when the need disappears.[1,9] While we may attribute our low rates of central line-associated bloodstream infection to the fact that nearly all catheters were inserted with a single anatomic site attempt as well as compliance to overall precautions of infection prevention, the correlation between the reduced infection rates and the use of ultrasound during CVC could not be clearly described[9]. The most effective methods of preventing central line-associated bloodstream infection are still revealed to be staff training and catheter maintenance.[21]

No matter how much the technology advances, the human factor will always be involved. Based on results by Van Rens RM et al, the hand and eye synchronization of the practitioner is the most important.[23]

The only result, which could be deemed unfavorable in pediatric trials on CVC and the use of ultrasound, is the extension of the application time. However, even in this trial, ultrasound guided catheterization was found to be more successful.[12] According to the Cochrane systematic review, the evidence suggest that the use of real time ultrasound guidance for CVC is safer than the conventional methods.[24]

Conclusions

Central venous catheterization is a practice that enhances the treatment success and comfort in the setting of PICUs, particularly in critically ill patients. In line with the literature, in our study, we observed low rates of complications, and that the procedure of CVC with the guidance of ultrasound was safe. However, even the minor complications may have severe outcomes in critically ill patients. Nowadays, the objective is to ensure complete absence of complications rather than reduction of complications. While almost all hospitals now have mobile ultrasound devices, the use of ultrasound for all appropriate invasive procedures should be more common in children.

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