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ORIGINAL ARTICLE

# An Alternative Central Venous Access Route for Pediatric Patients with Chronic Critical Illness: The Transhepatic Approach

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## Abstract

**Objective** To evaluate the safety and functionality of the transhepatic approach as an alternative route for central venous catheterization in pediatric patients with chronic critical illness.

**Methods** The study included data of 12 chronic critically ill pediatric patients who underwent central venous catheterization with transhepatic approach. The indications, procedure details, mean patency time, and catheter-related complications were retrospectively analyzed.

**Results** A total of 16 central venous catheters were placed through the transhepatic approach. A 5F port catheter was used in eight attempts, a 5F PICC in two attempts, and an 8–14F Hickman-Broviac catheter in six attempts. All procedures were performed with technical success. The mean patency time of the catheters was 132.1 d (range: 12–540 d). In the long-term follow-up, catheter-related sepsis was detected in a patient, and six catheters lost functionality due to malposition.

**Conclusion** The transhepatic approach is a safe and functional alternative route for central venous access in chronic critically ill pediatric patients requiring long-term vascular access. The procedure using ultrasonography and fluoroscopy can be performed with high technical success. In the long-term follow-up, Dacron felt cuff tunneled catheters placed in the subcostal space with a transhepatic approach remained functional for a long time.

**Keywords** Transhepatic approach · Chronic critical illness · Central venous access · Pediatric patients

## Introduction

Pediatric patients with a chronic critical illness are frequently admitted to the hospital and stay in intensive care unit long-term. During this process, many of these patients require central venous access for medications and parenteral nutrition [1, 2]. Traditionally, groin and neck veins are used for central venous access. The catheters placed through these veins are a safe and functional route for central venous access in chronic critically ill pediatric patients [3, 4]. However, repeated venous access and long-term catheterization make it difficult to protect these venous structures, leading to the exhaustion of all traditional venous access routes over time [5]. In addition, neck veins should be preserved for palliative surgical procedures that may be necessary for later periods in pediatric patients with congenital heart disease. For all these reasons, alternative routes, such as direct entry to the right atrium with thoracotomy, intercostal or azygos entry, and translumbar and transhepatic approaches have been defined to achieve central venous access [6–8].

The transhepatic approach to the central veins was first described in the early 1990s. Since then, pediatric cardiologists have predominantly used the approach for cardiac catheterization [9]. The hepatic veins are larger than peripheral veins, so venous access is easy, and these veins are resistant to thrombosis. In central venous access with a transhepatic approach, only a short vena cava segment is affected [9]. It preserves vena cava in terms of occlusion, which may need to be corrected later with surgical procedures [10]. However, the transhepatic approach is only employed when traditional venous access options are exhausted despite all its theoretical advantages. There is only limited experience in using the transhepatic approach for central venous catheterization in pediatric patients with chronic critical illness [10–13].

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This study aimed to evaluate the safety and functionality of the transhepatic approach as an alternative route for central venous catheterization in pediatric patients with chronic critical illness.

## Material and Methods

In this study, pediatric patients with chronic critical illness who underwent central venous catheterization with the transhepatic approach in the interventional radiology unit of the authors' hospital between December 2016 and April 2020 were retrospectively evaluated.

The Institutional Clinical Research Ethical Committee approved this single-center retrospective study. Informed consent was obtained from all patients' parents before all diagnostic and interventional procedures according to the 1964 Helsinki Declaration principles.

Patients under 18 y of age with chronic critical illness who required a central venous catheter for more than 3 wk for medications were included in this study. The main indication for the transhepatic approach was chronic occlusion secondary to multiple interventions in neck and groin veins. One of these peripheral ways was accessible in one patient, but these were preserved for future interventional. Contraindications were considered as massive ascites and hemorrhagic diathesis that increase the risk of hemorrhagic complications.

A pediatric intensive care doctor gave intravenous ketamine and midazolam to all patients during the procedure. In addition, fentanyl was administered to patients who had opened the port pocket. After the patient was placed on the angiography table, the right chest wall and subcostal area were sterilized using the appropriate technique for percutaneous access. Using a micropuncture access set (Cook Medical; Bloomington, USA), the right or middle hepatic vein was accessed from the subcostal section with a 21-gauge needle under ultrasound (US) guidance. After fluoroscopic confirmation, a 0.018-inch microwire and a 4 French (F) hydrophilic catheter (Terumo Cardiovascular Systems Co.; Tokyo, Japan) were placed in the right atrium over the hepatic vein. Subsequently, a 0.018-inch microwire was exchanged with a 0.035-inch rigid hydrophilic guidewire (Terumo Cardiovascular Systems Co.; Tokyo, Japan). After tract dilatation was achieved with an 8F dilatator, an 8F peel-away sheath was placed in the right atrium over a 0.035-inch wire. A small skin incision was made in the right subcostal section, and a subcutaneous tunnel was created for the patients to receive a Hickman-Broviac catheter, while a port pocket was created for those planning a port catheter. After the created tunnel was passed with a trocar, the catheter was placed over the stiff guidewire at the cavo-atrial junction. Catheter localization was checked under fluoroscopy guidance. The blood flow was confirmed by aspirating the catheter. The catheter lumen was washed with heparinized saline. Entry sites and tunnel and port pocket incisions were sutured with 5–0 Prolene and closed with a sterile dressing.

Port catheters, peripherally inserted central catheters (PICC), and Hickman-Broviac catheters were used as catheters during the procedures. The type and size of the catheter used were selected according to the patient's anatomical features. PICC and port catheters were used to administer nutrition and infusion of medications. Hickman-Broviac catheters were preferred for interventional procedures, blood transfusion, and hemodialysis. All catheters were flushed with heparinized saline after each use, or monthly, if not used. Pediatric intensive care doctors checked the location of the catheter tip, hepatic vein, and inferior vena cava patency at regular intervals with ultrasonography. And All patients were administered prophylactic anticoagulation (LMWH) to prevent thrombosis.

The demographic and clinical data of the patients were collected using the hospital's database. Date of insertion and removal of catheters, and the number of instances of tissue plasminogen activator (tPA) administration were recorded. In addition, complications related to the transhepatic approach and reasons for nonelective removal of the catheters were noted.

All analyses were performed using IBM SPSS Statistics v.20.0 statistical software package (IBM, USA). Categorical variables were expressed as numbers and percentages, whereas continuous variables were summarized as mean and standard deviation and median and range, where appropriate.

## Results

Twelve pediatric patients (8 males, 66.6%; median age 143 mo (range 15 d to 141 mo) were included in the study. All the patients were treated in the intensive care unit due to chronic critical illness (Table 1).

A total of 16 central venous catheters, more than one for three patients, were placed through the transhepatic approach. A 5F port catheter was used in eight attempts (Fig. 1), a 5F PICC in two attempts, and an 8–14F Hickman-Broviac catheter in six attempts (Fig. 2). All procedures were completed in 60 min or less. After the procedure, all patients were followed up for at least 24 h in the intensive care unit.

Complications developed within and after the first 24 h were defined as early and late complications, respectively. During follow-up, none of the patients developed intra-abdominal bleeding, cardiac arrhythmia, and liver dysfunction as early complications of the transhepatic approach. In the long term, 4 patients died due to chronic illness when their catheter was still functional, and there was no catheter-related complication. Two catheters were

**Table 1** The clinical characteristics of the patients, types and sizes of the catheters used, and the developed complications

| Patient number | Disease | Indication | Age/Gender | Number of catheters | Catheter used | Duration of catheterization (days) | Complication |
|---|---|---|---|---|---|---|---|
| 1 | Laryngeal web, tracheostomy | Total or partial parenteral nutrition | 1 y 7 mo/Male | 1 | Port catheter/5F | 193 | None |
| 2 | Hypoxic–ischemic encephalopathy | Total or partial parenteral nutrition | 10 mo 7 d/Male | 1 | Port catheter/5F | 34 | Malposition |
| 3 | West syndrome | Hemodialysis | 11 y 9 mo/Male | 1 | Hickman-Broviac/14F | 208 | None |
| 4 | Propionic acidemia | Hemodiafiltration | 4 y 6 mo/Male | 1 | Hickman-Broviac/11.5F | 60 | None |
| 5 | Propionic acidemia | Hemodiafiltration | 6 y 6 mo/Female | 2 | Hickman-Broviac/8F<br>Hickman-Broviac/11.5F | 21<br>49 | Malposition<br>None |
| 6 | Ohtahara syndrome | Administration of antibiotics | 2 y 8 mo/Female | 1 | Hickman-Broviac/10F | 540 | None |
| 7 | Protein C deficiency | Replacement therapy | 2 y 1 mo/Male | 2 | Port catheter/5F<br>Port catheter/5F | 30<br>460 | Infection<br>None |
| 8 | Prematurity | Total or partial parenteral nutrition | 14 d/Male | 1 | PICC/5F | 13 | None |
| 9 | Intrauterine TORCH infection | Total or partial parenteral nutrition | 3 y 5 mo/Female | 3 | PICC/5F<br>Port catheter/5F<br>Port catheter/5F | 213<br>30<br>12 | Malposition<br>Malposition<br>Malposition |
| 10 | Methylmalonic acidemia | Hemodiafiltration | 3 y 8 mo/Female | 1 | Port catheter/5F | 27 | None |
| 11 | Hypoxic–ischemic encephalopathy | Administration of antibiotics | 2 y 21 d/Female | 1 | Hickman-Broviac/10F | 198 | None |
| 12 | Sandhoff disease | Administration of antibiotics | 6 y 5 mo/Male | 1 | Port catheter/5F | 25 | Malposition |

*F* French, *PICC* Peripheral inserted central catheters

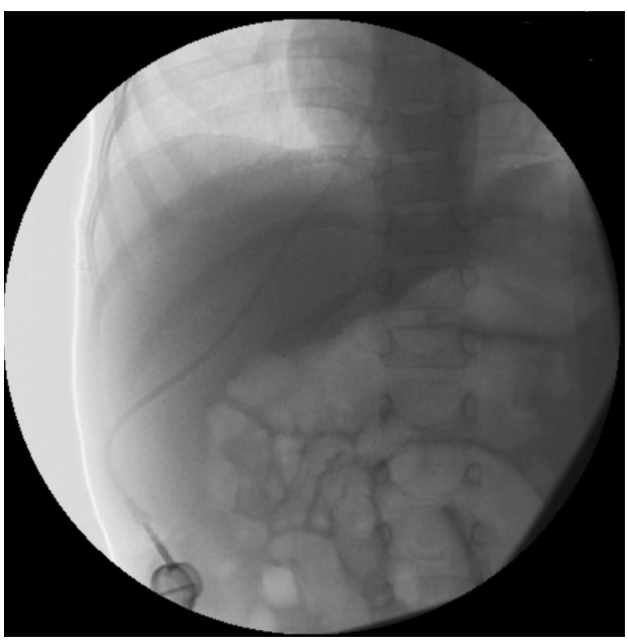

**Fig. 1** A port catheter in hepatic vein placed with transhepatic approach on fluoroscopic view

removed electively at the request of the clinician. Seven catheters were removed due to catheter-related complications. The mean patency durations of all catheters were 132.1 d (range: 12–540 d). The mean patency durations for the different types of catheters were 112.3 d (range: 12–460 d) for port catheters, 113 d (range: 13–213 d) for PICC, and 157.2 d (range: 21–540) for Hickman-Broviac catheter. The mean patency duration for the patients with complications was 52.1 d (range: 12–213 d).

Long-term complications were catheter-related sepsis and catheter malposition. One catheter (5F port catheter) was removed due to catheter-related sepsis. The blood culture was positive, Pseudomonas aeruginosa growth. Six catheters were removed due to loss of functionality caused by malposition. The catheter was detected outside the hepatic vein, and its tip extended into the intraperitoneal space. In addition, tPA was administered in one case with a 14F Hickman-Broviac catheter due to the development of intra-catheter thrombosis. The catheter has become functional again after the tPA procedure. Table 1 presents the clinical characteristics of the patients, types, and sizes of the catheters used, and complications that developed.

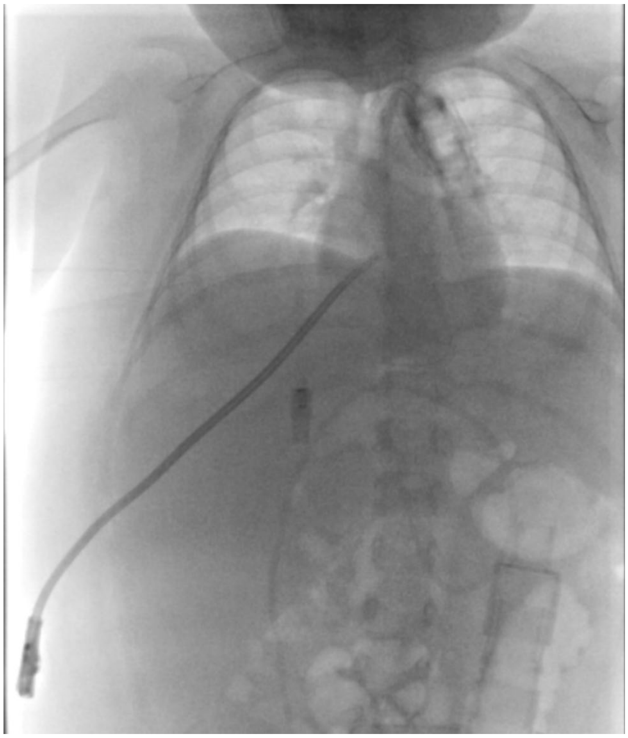

**Fig. 2** A Hickman-Broviac catheter in hepatic vein placed with transhepatic approach on fluoroscopic view

## Discussion

This study demonstrated the procedural stages of central venous catheterization using the transhepatic approach in pediatric patients with chronic critical illness, early and late complications related to the procedure, and catheter functionality. Although the transhepatic approach has been defined for many years, clinicians prefer it only when exhausted traditional venous access [14, 15]. The majority of the patients included in this study had occluded groin and neck veins, and the central venous access routes were exhausted. In 1 patient aged 14 d, the authors did use the transhepatic approach as the first choice to preserve traditional venous structures and prevent adjacent vascular injury.

Intra-abdominal bleeding, perforation, liver dysfunction, and arrhythmia have been described as early complications for the transhepatic approach [16]. All procedures were performed with technical success, and none of these complications developed in the postprocedure follow-up in the current study. Together, ultrasonography and fluoroscopy together guidance could prevent procedure-related complications during venous access. Multiple and improper entries into the hepatic vein can damage the portal vein, hepatic arteries, and bile ducts, leading to liver dysfunction and intra-abdominal bleeding [16]. The use of fluoroscopy is important to determine the end position of the catheter. Arrhythmias may develop, if the catheter touches the tricuspid valve or right atrial septum. Otherwise, endothelization and associated occlusion occur over the long term if the catheter tip comes into contact with the vein wall [16]. Therefore, the authors think that the use of first US followed by fluoroscopy rather than fluoroscopy alone for venous access significantly reduces the number of early complications and also decreases the procedure time, which is especially important to minimize radiation exposure in pediatric patients. Mortell et al. [14] used only a fluoroscopy guide for central venous catheter placement with the transhepatic approach; they reported the mean duration of the procedure as 89 min [14]. In the current study, US and fluoroscopy were used together, and all procedures were completed within 1 h.

Four studies have reported the duration of catheter patency and the time of complication development in chronically critically ill pediatric patients who had undergone central venous catheterization with the transhepatic approach [10, 12, 14, 16]. Three of these studies were conducted with pediatric patients including a child with a critical chronic illness other than heart disease. In the referred studies, PICC and Hickman-Broviac catheters were placed in the right intercostal space under fluoroscopy [10, 12, 14, 16]. The patency durations of catheters reported in these studies are shown in Table 2. When compared with these studies, the patency time of the catheters was found to be longer in the present study, which can be attributed to the use of the subhepatic approach rather than the intercostal approach. Theoretically, intercostal insertion may cause the catheter to be exposed to compression by the ribs. The patient's spontaneous movement or respiration may lead to deformation in the catheter wall. However, to clarify this issue, studies with a large sample size are needed in which subhepatic and intercostal insertions are compared.

Long-term complications for central catheters placed with the transhepatic approach have been reported as malposition, infection, occlusion due to thrombosis, and skin wound [12]. Boe et al. [12] found the long-term complication rate as 39.7%. They detected that the most common cause of complications was dysfunction due to thrombosis of catheters. In the present study, the rate of long-term complications was similar, at 41.1%, but malposition was the most common cause of complications. This difference may be related to the types of catheters used in the two studies and technical reasons. Boe et al. [12] mostly used tunnel catheters with Dacron felt cuffs to anchor the catheters. In the present study, port catheters without cuffs were used, in addition to, tunnel catheters. The use of tunnel catheters with Dacron felt cuffs in the transhepatic approach seems advantageous in preventing malposition in the long term. In support of this hypothesis, in the present study, port catheters were used in 3 of the 4 patients, who developed malposition.

**Table 2** Comparison of the literature data on central venous catheters placed with the transhepatic approach

| | Number of patients/ Catheters placed | Type of catheter | Patency time (days) (mean) |
|---|---|---|---|
| Marshall et al. [10] | 12/19 | Hickman-Broviac | 98 |
| Mortell et al. [14] | 5/5 | Hickman-Broviac | 98.8 |
| Boe et al. [12] | 54/92 | Hickman-Broviac and PICC | 21* |
| Qureshi et al. [16] | 32/40 | Hickman-Broviac and PICC | 36** |
| Current study | 12/17 | Hickman-Broviac, PICC, Port | 131.1 |

*Minimum

**Median

*PICC* Peripheral inserted central catheters

There were a number of limitations in this study. Firstly, the study was performed retrospectively, and all catheter complications could not be documented systematically. Secondly, the different types and numbers of catheters used may have affected the overall results. Thirdly, the causes of the chronic critical illness of the patients were different, which may also have affected the results. Despite the limitations, this study has strengths because it provides information on the use of port catheters in central catheterization with the transhepatic approach, which was not previously reported in the literature. In addition, the results obtained in this study may be important evidence for more frequent use of the transhepatic approach in the future.

## Conclusion

The transhepatic approach is a safe and functional alternative route for central venous access in chronic critically ill pediatric patients requiring long-term vascular access. The procedure using ultrasonography and fluoroscopy can be performed with high technical success. In the long-term follow-up, Dacron felt cuff tunneled catheters placed in the subcostal space with a transhepatic approach remained functional for a long time. Future clinical studies with larger numbers of patients are needed for further evidence of the safety and functionality of the transhepatic approach.

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### Declarations

**Consent to Participate** Informed consent was obtained.

**Consent for Publication** Informed consent was obtained.

**Conflict of Interest** None.

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