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Radiologic placement of Hickman catheters using intravenous sedation in pediatric patients under 20 kg

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Abstract

Surgeons generally perform Hickman catheter insertion in children under general anesthesia. At times, it is difficult to perform procedures with an anesthesiologist for an interventional radiologist. Several diagnostic and therapeutic procedures are efficiently and safely conducted using intravenous (IV) sedation in children with a pediatrician. This study aims to evaluate the efficacy and safety of radiologically placed Hickman catheters using IV sedation in children under 20 kg.

Fifty-nine catheters were inserted in 45 children under IV sedation. With continuous monitoring of vital signs, IV midazolam and ketamine were slowly infused by a pediatrician. Mean age and body weights were 3.2 years and 15.2 kg, respectively. Acute leukemia was the most common disease for the procedure (72.9%). The location of the catheter tip was evaluated by measuring the height of the thoracic vertebra.

Technical success rate was 100%, and IV sedation-related complications did not occur. The right internal jugular vein was accessed for 51 catheters (86.4%), and the mean procedure time was 21.5 minutes. The 2 vertebral body units below the carina were the cavoatrial junction on a fluoroscopy image. Mean catheter life was 285 days, and catheters were removed post-treatment (35.6%). During follow-up, complications occurred in 29 cases (1.72 per 1000 catheter-days). Catheter-related infections were suspected in 4 patients (6.8%), with 1 positive result.

Radiological Hickman catheter placement in children under 20 kg using IV sedation by pediatricians is effective and safe, with minimal complications. The carina is a landmark to estimate the cavoatrial junction in pediatric patients.

Abbreviations: CAJ = cavoatrial junction, Fr = French, IJV = internal jugular vein, IV = intravenous, PACS = picture archiving and communication system, SVC = superior vena cava.

Keywords: central venous catheters, ketamine, midazolam, pediatric patient, sedation

1. Introduction

Hickman catheter insertion was first described in 1979 for chemotherapy.[1] It is now widely performed in adult and pediatric patients. It is a safe and effective method for providing venous access in various clinical situations, such as chemotherapy, total parenteral nutrition, bone marrow transplantation, and hemodialysis.[1–4] Several studies on safety, complications, and modified techniques of the Hickman catheter placement have been published. However, in most of these studies, the surgeons performed catheter insertions under general anesthesia in the operating room.[5–8] Depending on the circumstances at each hospital, procedures under general anesthesia might be limited. For more than a decade now at our tertiary hospital, which includes a children's hospital, instead of anesthesiologists administering general anesthesia, interventional radiologists have inserted the Hickman catheter for pediatric patients under intravenous (IV) sedation performed by a pediatrician. We aimed to evaluate the efficacy and safety of radiologically placed Hickman catheters with IV sedation in children under 20 kg. A proper position of the catheter tip was also evaluated.

2. Methods

2.1. Patients

Our institutional review board approved this retrospective study (05-2019-118), and the requirement for informed consent was waived. From November 2010 to December 2016, interventional radiologists inserted 73 Hickman catheters in 59 children, whose body weight was less than 20 kg. This was executed under IV sedation by pediatricians in angiography suites, instead of in the

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The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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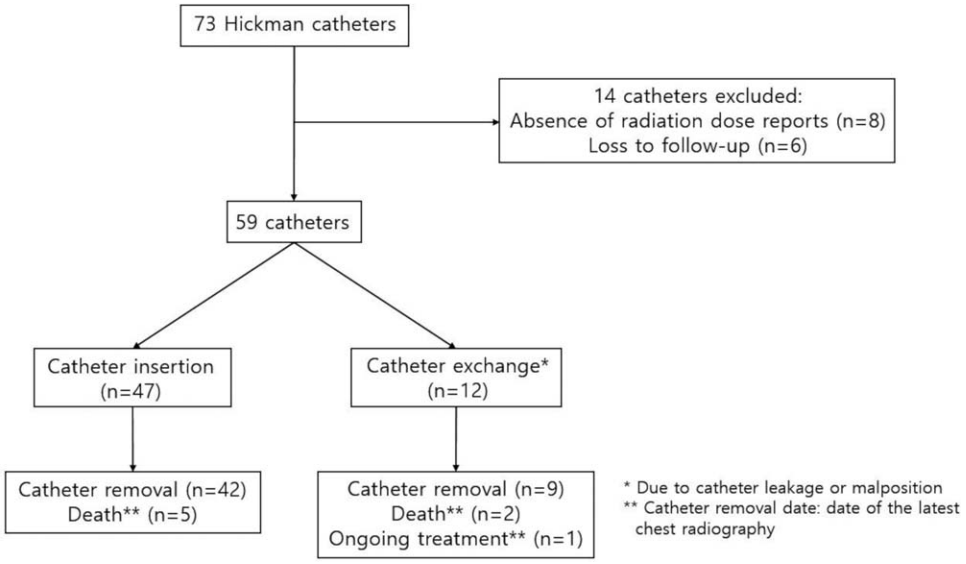

Figure 1. Flowchart of patient identification and inclusion for study.

operation room under general anesthesia. Fourteen patients were excluded owing to lack of follow-up (n=6) and absence of radiation dose reports for the procedure (n=8). Finally, 45 pediatric patients with 59 catheters were enrolled in this study (Fig. 1). All patients were followed until June 2019. The patients' mean age and body weights were 3.2 years (range, 3 months–8 years) and 15.2 kg (range, 5.6–19.2 kg), respectively. Chemotherapy was the primary indication for the Hickman line insertion (55/59, 93.2%). Among these, acute leukemia was the most common disease for the procedure (43/59, 72.9%). Indications for line insertion are shown in Table 1. If the patient died during the follow-up period or if the catheter was not removed owing to ongoing treatment, the catheter removal date was defined as the date of the latest chest radiography. Electronic medical records and picture archiving and communication system (PACS) data of all these patients were reviewed.

2.2. Patient preparation

For all patients, the platelet count and international normalized ratio were determined before the procedure, and transfusion was recommended if laboratory test results were abnormal (platelet $< 50{,}000/\mu L$ or international normalized ratio > 1.5). Prophylactic antibiotics were not administered. The patients were kept NPO for more than 4 hours prior to the procedure.

2.3. IV sedation

IV sedatives were administered by a pediatrician, with continuous monitoring of vital signs. Considering the weight and general condition of the children, 0.1 mg/kg of midazolam and 1 mg/kg of ketamine were slowly infused. If the dosage was inadequate, up to 2 additional injections were administered. Nasal oxygen was applied if required.

Table 1

Indications for Hickman catheter insertion.

Indication	n (%)
Hematological malignancies	50 (84.7%)
Solid tumors	5 (8.5%)
Non-malignant diseases*	4 (6.8%)

* Nonmalignant diseases include Fanconi anemia (n=2), total colonic aganglionosis (n=1), and short bowel syndrome (n=1).

2.4. Hickman catheter insertion

Seven-French (Fr), double-lumen Hickman catheters (Bard Access Systems, Inc, Salt Lake City, UT) were placed by interventional radiologists under ultrasonographic and fluoroscopic guidance using a standard technique (n=47). Local anesthesia was administrated with 2% lidocaine hydrochloride and the internal jugular vein (IJV) was punctured with a 4-Fr micropuncture set (MAK mini access kit; Merit Medical Systems, South Jordan, UT). A guidewire was placed through the IJV into the inferior vena cava or right atrium. A tunneler made a subcutaneous tunnel from a small exit site incision at the upper thorax to the puncture site. Subsequently, the catheter was inserted through the tunnel and a Dacron cuff was subcutaneously placed adjacent to the exit site. The catheter was cut to an appropriate length using fluoroscopic images. The planned tip position of the catheter was the cavoatrial junction (CAJ), which was defined as 2 vertebral body levels, including an intervertebral space, below the level of the carina.[9] Considering an anatomical difference and the patient's position, the area between half vertebral body levels above and below the CAJ was considered as a proper position (Zone 2 in Fig. 2). Finally, a catheter was inserted through the peel-away sheath introducer, and a purse-string suture was used at the tunnel exit site. In case of catheter replacement (n=12), the over-the-wire technique was used.

2.5. Tip position

The heights of 2 vertebral body levels (including an intervertebral space; T7-8) and a vertebral body (T8) were measured on fluoroscopy images using the PACS (INFINITT PACS M6; INFINITT Healthcare, Seoul, Korea) to determine the proper tip position of the catheter. We evaluated whether the carina was an

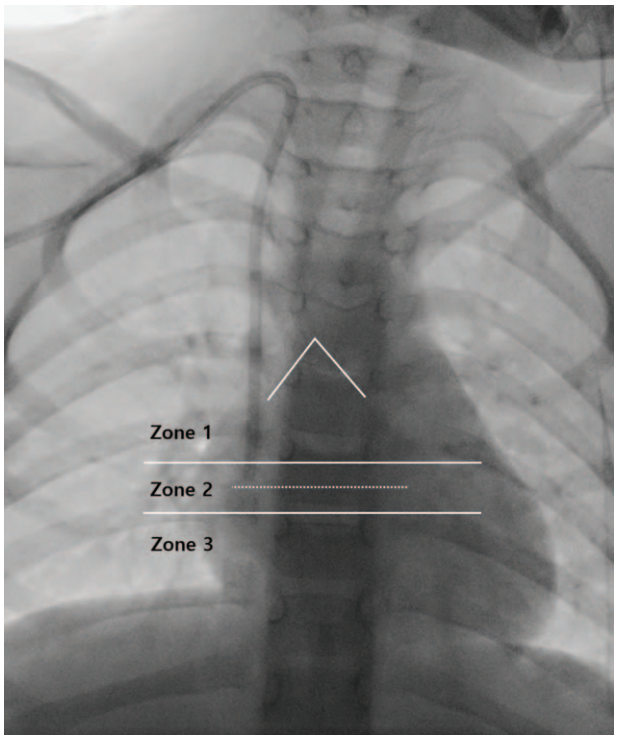

Figure 2. A fluoroscopic image of the chest in the supine position illustrates zones used to classify catheter tip location. Cavoatrial junction (CAJ) is defined as the height of 2 vertebral body levels below the level of the carina (dotted line). The area between half vertebral body levels above and below the CAJ is considered a proper position of the tip (Zone 2). Above and below Zone 2 is located in superior vena cava (Zone 1) and right atrium (Zone 3).

appropriate landmark to estimate the CAJ in pediatric patients. According to the tip position, mean catheter-days were compared using a Kruskal–Wallis test (SPSS 26.0; IBM Corp, Armonk, NY).

3. Results

The technical success rate of Hickman catheter placement under IV sedation was 100%, and there were no IV sedation-related complications. Most catheters were inserted in the right IJV (n = 51), with catheter tip position in the CAJ (zone 2, n = 46; Table 2). Mean heights of 2 vertebral body levels (T7-8) and 1 vertebral body (T8) were 24.5 ± 3.4 mm and 10.7 ± 1.7 mm, respectively.

Twelve catheters (20.3%) were exchanged through the previous access route, using guide wires among all procedures due to catheter leakage (n = 6) and malposition (n = 6). The mean procedure time, which was defined as the time between IV sedation and the end of the procedure, radiation dose for the procedure, and mean fluoroscopy time were 21.5 minutes (range, 10–50 minutes), 5.1 mGy (range, 0.1–38.4 mGy), and 1.91 minutes (range, 0.1–11.6 minutes), respectively.

Table 2

Laterality and tip position of the catheters.

Tip position	Right	Left	Total
SVC (Zone 1)	4 (6.8%)	1 (1.7%)	5 (8.5%)
CAJ (Zone 2)	42 (71.1%)	4 (6.8%)	46 (77.9%)
RA (Zone 3)	5 (8.5%)	3 (5.1%)	8 (13.6%)
Total	51 (86.4%)	8 (13.6%)	59 (100%)

CAJ = cavoatrial junction, RA = right atrium, SVC = superior vena cava.

The total catheter life of 59 lines was 16,817 days, and the mean catheter life was 285 days (median, 121 days; range, 0–1190 days). Mean catheter-days, according to the tip position, were 248 (superior vena cava, SVC; zone 1), 256.6 (CAJ; zone 2), and 471.6 days (right atrium; zone 3), respectively. They were not significantly different ($P = .17$). Catheter removal was undertaken as follows: after the treatment (n = 21, 35.6%), catheter leakage (n = 15, 25.4%), malposition (n = 9, 15.3%), death (n = 7, 11.9%), suspicion of catheter-related infection (n = 4, 6.8%), conversion to a venous port (n = 1, 1.7%), and concern of arrhythmia (n = 1, 1.7%). One catheter was not removed because of ongoing treatment at the time of evaluation (Table 3).

During follow-up, complications were reported in 29 cases, indicating an overall incidence of 1.72 per 1000 catheter-days. Catheter leakage occurred in 15 cases (0.89/1000 catheter-days), and malposition of the catheter tip was observed in 9 cases (0.54/1000 catheter-days). Four patients had fever, with suspicion of catheter-related infection (0.24/1000 catheter-days) (Table 4). However, positive results were detected in 1 case (*Staphylococcus aureus*) when samples from the removed catheters were cultured (catheter life, 57 days).

4. Discussion

Central venous catheterization is more difficult to perform in children than in adults, owing to smaller vessel size.[10,11] Uncooperative pediatric patients are another concern. Therefore, the technical success rate is lower, and complications are more common in children.[10] In most previous articles that studied the efficacy, a modified technique, and complications of Hickman catheter placement in pediatric patients, surgeons inserted Hickman lines under general anesthesia administered by an anesthesiologist.[5–8] In the present study, interventional radiologists inserted Hickman catheters safely and efficiently under IV sedation administered by pediatricians in children weighing less than 20 kg. IV sedation is helpful in situations where general anesthesia cannot be maintained under the supervision of an anesthesiologist. It can reduce the risk of general anesthesia in pediatric patients, the cost, procedure, and recovery time.

Midazolam is a sedative and amnestic agent with a rapid onset, short recovery period, and low risk of respiratory depression. It is the most widely used agent in children who undergo procedures or examinations. Ketamine is a sedative and anxiolytic drug that causes dissociative anesthesia with minimal cardiovascular and respiratory side effects. Previous studies suggested that a combination of IV midazolam and ketamine was safe, effective, and tolerated by pediatric patients. Uludağ et al reported that midazolam–ketamine combination provides better hemodynamic stability than the combination of midazolam and propofol.[12] Miqdady et al[13] suggested that midazolam–ketamine sedation appears effective and safe for diagnostic gastrointestinal endoscopy for children aged > 1 year and weighing > 10 kg without comorbidities. In the present study, none of the patients developed severe complications during the procedure and recovery, such as cardiac arrest, bradycardia, or emergence reaction; these findings were consistent with those from previous studies.[12,13] A temporary decrease in oxygen saturation during the sedation was rare, and it was addressed immediately by

Table 3

Indications for Hickman catheter removal.

Initial tip position	End of treatment	Catheter leakage	Catheter malposition	Suspicious of infection	Others*
SVC (Zone 1)	1	2 (13.3%)	1 (11.1%)	1† (25%)	0
CAV (Zone 2)	15	12 (80%)	8 (88.9%)	2 (50%)	9
RA (Zone 3)	5	1 (6.7%)	0	1 (25%)	1
Total	21	15	9	4	10

CAJ = cavoatrial junction, RA = right atrium, SVC = superior vena cava.

* Others include death (n = 7), conversion to a venous port (n = 1), arrhythmia (n = 1), and non-removal due to ongoing treatment (n = 1).

† Positive result on catheter tip culture (*Staphylococcus aureus*).

Table 4

Complications during follow-up periods.

Complication	n (%)	Mean* (median) catheter-days	Complication/1000 catheter-days
Catheter leakage	15 (51.7%)	158.6 ± 168.6 (100)	0.89
Catheter malposition	9 (31.1%)	48.6 ± 96.2 (15)	0.54
Suspicion of catheter-related infection	4 (13.8%)	93.3 ± 96.2 (49)	0.24
Arrhythmia	1 (3.4%)	9 (9)	0.06

* Data are represented as mean ± standard deviation.

applying nasal oxygen. Therefore, technical failure due to sedation-related complications did not occur. An unexpected adverse reaction can be managed safely by pediatricians by continuously monitoring vital signs and having an antidote ready.

When the tip of the central catheter is located in the right atrium, the risk of arrhythmia and cardiac perforation is high. On the other hand, thrombotic occlusion of the catheter or SVC can happen if the tip is placed in the upper portion of the SVC.[9,14,15] In this study, 46 catheters (77.9%) were placed at the CAJ, defined as 2 vertebral body levels below the carina. Catheter occlusion was not reported in 59 cases, regardless of tip location. One catheter was removed 9 days after insertion (Zone 3) owing to ventricular premature complexes; it improved after catheter removal. In 45 patients, the mean heights of 2 vertebral body levels (T7-8) were 24.5 ± 3.4 mm on fluoroscopy images. It was similar to the distance measured from the carina to the CAJ (22.0 ± 9.98 mm) in a previous study on pediatric patients.[16] Therefore, the point 2 vertebral body units below the carina under fluoroscopy guidance is a reliable landmark of the CAJ in children under 20 kg, the same as for adult patients.[9]

During follow-up, leakage from catheters was common in our patients (n = 15, 25.4%), compared with adult patients.[17] A small-caliber (7-Fr) silicone catheter that we inserted to fit the vessel size was thought to be more fragile than 9- or 12-Fr ones. Malposition of the catheter tip (n = 9, 15.3%) was relatively an early complication (mean, 48.6 days; range, 0–302 days). Although a purse-string suture was used at the exit site, malposition occurred before fibrous adhesion around the Dacron cuff owing to difficulty managing long catheters in the upper chest in pediatric patients. The recently released 9.5-Fr polyurethane Hickman catheter (Power Hickman Central Venous Catheter; Bard Access Systems) would be more durable, and it has suture holes that prevent dislocation of the catheter. Complications such as malposition and leakage are expected to decrease, and further studies are required.

In this retrospective study, catheter-related bloodstream infection was confirmed in only 1 case during the follow-up period (1.7%), and the rate was lower than that in previous studies.[7,17] In case of catheter leakage (n = 6) or malposition (n = 6), catheters were exchanged using the over-the-wire technique instead of catheter removal and reinsertion. Guttmann et al[18] reported that catheter exchange in tunneled catheters results in a higher infection rate than removal-replacement at a new access site. However, in the present study, there was no evidence of catheter-related infection in 12 catheter-exchange cases. Therefore, catheter insertion or exchange in children with IV sedation did not increase the infection rate associated with the procedure. Since there was no difference in management after catheter placement in patients who underwent general anesthesia or IV sedation, this result is presumed to be because the procedure was completed in a relatively short time in the present study (mean, 21.5 minutes).

There are several limitations to this study. First, this study was a retrospective design with a small sample size. A more extensive study in different age groups with a long-term follow-up period might reveal a significant advantage of central venous catheterization using IV sedation in pediatric patients. Second, the infection rate may have been low because only a patient with a positive catheter culture was included among patients with clinically suspected catheter-related infections, without considering the blood culture results of all patients. Removal of the Hickman catheter was considered if recurrent infection or persistent bacteremia occurred despite appropriate medical therapy. It is difficult to accurately assess the infection rate because other factors that may cause infection must be considered.

In conclusion, Hickman catheter insertion by interventional radiologists in pediatric patients under 20 kg using IV midazolam and ketamine administered by pediatricians is effective and safe with a low complication rate. The carina is a landmark to estimate the CAJ in pediatric patients.

Author contributions

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