

Original Article

Cuffed-tunneled hemodialysis catheter survival and complications in pediatric patients: a single-center data analysis in China

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Received December 4, 2014; Accepted May 15, 2015; Epub June 15, 2015; Published June 30, 2015

Abstract: This study aims to evaluate the outcome and complications of cuffed-tunneled catheters in pediatric patients. Between January 2010 and December 2013, 16 pediatric patients with end-stage renal disease (ESRD) were included. 21 cuffed-tunneled hemodialysis catheters were inserted in patients for long-term hemodialysis access. No serious complications were observed in all patients receiving catheter insertion operation, except one with hemopneumothorax. Median survival time was 413.5 days, with rate being 67.5% in the first year, 51.5% in the second year and 43.6% in the third year. Among attempted catheter insertions, 21 (100%) achieved successful vascular access with 13 (61.9%) being remained for the required period and 8 (38.1%) being removed due to death, intractable blood or tunnel infections, catheter thrombosis or malposition. The overall rate of catheter-related infections, thrombosis and malposition was 7.3, 23.4 and 3.4 episodes/1000 catheter days, respectively. Cuffed-tunneled hemodialysis catheters could be effectively used for maintenance of hemodialysis vascular access for pediatric patients with ESRD. Various surveillance measures should be taken to ensure cuffed-tunneled catheters' long-term patency.

Keywords: Complications, cuffed-tunneled hemodialysis catheter, hemodialysis, survival

Introduction

Renal transplantation was currently considered to be the best approach to treat pediatric patients with end-stage renal disease (ESRD) [1]. However, renal transplantation is just an extravagant hope for the majority of families on sick children due to the expensive cost and shortage of transplanted kidney resources [2]. In the middle region of China, peritoneal dialysis in pediatric patients continues to lag behind hemodialysis therapy because of poor sanitary conditions, complicated operation procedures, intensive parental education and the high incidence of peritonitis. As a result, doctors and parents are more willing to choose hemodialysis as a renal replacement therapy. A reliable vascular access was considered as the lifeline of hemodialysis patients and the lifeline's establishment and preservation has become a critical issue. Although surgically placed autogenous arteriovenous fistulae (AVF) and synthetic arteriovenous graft (AVG) are preferred for

long-term hemodialysis by NKF DOQI (National Kidney Foundation Disease Outcomes Quality Initiative) [3], cuffed-tunneled hemodialysis catheters are used more frequently in pediatric patients [4]. Actually, cuffed-tunneled catheters sometimes are the only approach for chronic hemodialysis access in pediatric patients with relatively small vessel size and innate fears of repetitive vascular puncture. Compared with AVF and AVG, cuffed-tunneled hemodialysis catheter has been reported to be associated with more complications that occurred during catheter insertion or throughout the catheter dwell period [4, 5]. Currently the most studies on cuffed-tunneled hemodialysis are focused on adult patients [6, 7] and there are few reports on pediatric patients, especially in China. Therefore analysis of cuffed-tunneled hemodialysis catheter survival and associated complications is significantly important in pediatric patients with ESRD. The purpose of this study was to evaluate the outcome of cuffed-tunneled catheters performed on pediatric

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Table 1. Characteristics of pediatric patients with ESRD

Patient No.	Gender	Renal disease	Age (months)	Duration of hemodialysis (months)	History & site of catheter insertion	Outcome
1	F	Dysplastic kidneys	62	18.5	Cuffed: RIJV	Successful transplantation
2	F	Focal segmental glomerulosclerosis	48	13	Temporary: FV Cuffed: RIJV	Successful transplantation
3	M	Systemic lupus erythematosus	126	39.5	Temporary: RIJV Cuffed-1: RIJV Cuffed-2: FV	Died
4	M	Diabetic nephropathy	180	14	Cuffed: RIJV	Remains on hemodialysis
5	M	IgA nephropathy	96	38	Cuffed: RIJV	Successful transplantation
6	F	Congenital nephritic syndrome	64	35	Cuffed: RIJV	Successful transplantation
7	F	Focal segmental glomerulosclerosis	56	8	Temporary: FV Cuffed: RIJV	Remains on hemodialysis
8	M	Unknown	192	28.5	Temporary: RIJV Cuffed-1: RIJV Cuffed-2: REJV	Remains on hemodialysis
9	F	Obstructive uropathy	120	39	Cuffed: RIJV	Successful transplantation
10	M	IgA nephropathy	86	6	Cuffed: RIJV	Died
11	M	Dysplastic kidneys	82	15	Temporary: FV Cuffed: LIJV	Successful transplantation
12	F	Oxalosis	63	27.4	Temporary: FV Cuffed-1: RIJV Cuffed-2: LIJV	Transplantation failure, return to hemodialysis after 1 years
13	M	Unknown	108	30	Cuffed-1: RIJV Cuffed-2: LIJV	Successful transplantation
14	M	Hemolytic uremic Syndrome	156	85	Temporary: FV Cuffed: RIJV	Died
15	F	Diabetic nephropathy	192	19	TC: FV Cuffed-1: RIJV Cuffed-2: RIJV	Remains on hemodialysis
16	M	Rapidly progressing glomerulosclerosis	124	34.5	Cuffed: RIJV	Successful transplantation

TC: Temporary catheter; Cuffed: Cuffed-tunneled catheter; RIJV: Right internal jugular vein; LIJV: Left internal jugular vein; FV: Femoral vein; REJV: Right external jugular vein; Cuffed-1 and Cuffed-2: Multiple catheterizations.

patients with ESRD for long-term hemodialysis access, such as survival rates, causes of catheter loss, and the risk factors contributing to catheter-related complications.

Patients and methods

Patients

This study was approved by the Institutional Review Board of Zhengzhou University. We performed a retrospective review of all pediatric patients aged less than 18 years old, who received hemodialysis maintenance for at least 3 consecutive months in the hemodialysis center, the first affiliated hospital of Zhengzhou University from January 2010 to December 2013. Newly inserted cuffed-tunneled catheters in pediatric patients who already had been on hemodialysis were included, while those

inserted for other reasons (such as plasmapheresis), lost to follow-up and less than 3 months of hemodialysis treatment were excluded. At last, 16 pediatric patients were included into this study. There were 9 males and 7 females with a median age of 10 ± 4.2 years old (range 4-18) and mean body weight of 26.3 ± 9.8 kg (range 9-65). The following parameters were evaluated: renal disease, age at start of hemodialysis, duration of hemodialysis (months), history of catheter insertion (including temporary and cuffed-tunneled hemodialysis catheter), sites of catheter insertion, complications and catheter outcome (reason for removal and duration of dwell). Hemodialysis was performed with Fresenius 4008S (Fresenius, Germany) and hollow-fiber double acetate membrane dialyzer dialyzers FB-130G (Nipro, Japan), by using standard dialysate solu-

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Table 2. Catheter outcomes

	Single catheterization	Multiple catheterizations
Total	7	14
Still functional	1	4
Elective removal	5	3
Catheter failure	1	7

tion. The routine dialysis was performed as follows: two or three times per week, 4-h sessions, blood flow (5 ml/kg/min) and dialysate flow (300-500 ml/min) with target KT/V > 1.3. Heparinization was performed with 50-70 U/kg low molecule weight heparin and monitored by the activated coagulation time (ACT) test with target ACT of 180-220 s. Erythropoietin, intravenous iron, vitamin D analogs and blood-pressure medications was given towards the end of dialysis as needed.

Cuffed-tunneled catheter management and care

Tunneled, cuffed double-lumen hemodialysis catheters (Quinton®) were inserted through central veins by the interventional radiologists. The size and the length of the catheters were based on the pediatric patients' weight as follows: 9-Fr 12-cm for 10-15 kg, 10-Fr 12-cm for 16-20 kg, and 11-Fr 15 to 17-cm for > 20 kg. All the parents of pediatric patients gave their informed consents for the operation. Procedures were performed by percutaneous technique in the interventional suite by using standard digital fluoroscopic equipment. Insertion operation was performed in 2 pediatric patients under local anesthesia and the remaining 19 under general anesthesia. No prophylactic antibiotics were given.

Cuffed-tunneled catheters were handled only during dialysis sessions with no irrigation during hemodialysis treatments. According to standard nursing procedure, povidone iodine solution was used to clean-up catheters' exit site and two ports. In addition, a Biopatch® (chlorhexidine-impregnated dressing) was also given to patients at the end of each dialysis session. Each port of the catheter was filled with 5,000 U/ml of heparin solution according to manufacturer's recommendation. This process mentioned above was repeated strictly after each hemodialysis treatment. In case of

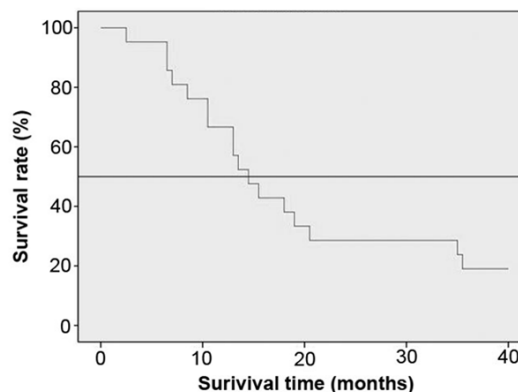


Figure 1. Overall survival in pediatric patients receiving cuffed-tunneled catheters.

catheter thrombotic occlusion, urokinase (5,000-1,0000 units) was kept in situ for half an hour or pumped into the catheter via port for 2-4 hours. Catheters were removed if poor flow could not overcome or irreformable-malposition occurred. In the event of suspected catheter-related bacterial infection (CRBI), cultures were obtained through catheter, peripheral venous blood or abnormal secretions. If the symptoms of CRBI were identified without any other demonstrable clinical reasons, the bacteremia was assumed to be catheter related. Both systemic and intra-catheter antibiotics were administered to treat both gram-positive and gram-negative organisms. The treatment regimen was later adjusted according to the result of drug sensitivity test. Pediatric patients with persistent symptoms of infection after more than 7 days of systemic antibiotic treatment had their cuffed-tunneled hemodialysis catheters removed.

Statistical analysis

Data was represented as Mean \pm SD. By using SPSS 19.0, student t test and Chi square test was used for the analysis of continuous and categorical variables respectively. The survival rate was determined by Kaplan-Meier curves. P value less than 0.05 ($P < 0.05$) were considered significantly different.

Results

Characteristics of patients

16 pediatric patients with ESRD were included into this study and received maintenance of

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Table 3. Catheter-associated complications

Complications	Number of patients	Total numbers of patients	Percentage (%)
Blood infection	9	16	56.3
Tunnel infection	3	16	18.8
Exit site infection	5	16	31.3
Thrombus	12	16	75
Malposition	4	16	25

hemodialysis (> 3 months) with 21 cuffed-tunneled catheters for long-term vascular access, including 9 males and 7 females. The characteristics of the study group are shown in **Table 1**.

Mean age at start of hemodialysis was 124 ± 10.5 months (range 48-192). 3 patients were younger than 5 years old. Mean duration of hemodialysis was 12.3 ± 4.3 months (range 6-36.5). The primary renal disease in the 16 patients was: focal segmental glomerulosclerosis (3), IgA nephropathy (2), dysplastic kidneys (2), diabetic nephropathy (2), obstructive uropathy (1), hemolytic uremic syndrome (1), congenital nephritic syndrome (1), oxalosis (1), systemic lupus erythematosus (1) and Unknown (2). 8 patients (50.0%) were successfully bridged to renal transplantation and 1 patient (6.3%) returned to hemodialysis treatment after 2 years due to chronic renal transplantation rejection. Comorbid-cardiac or pulmonary-related death occurred in 3 patients (18.8%). The remaining 4 patients (25%) were still on hemodialysis treatment at the end of study.

Cuffed-tunneled catheters outcome

21 cuffed-tunneled catheters were inserted for long-term vascular access, including 2 in situ wire-guided exchanges and 3 replacement catheters. 5 cuffed-tunneled catheters were still functional at the end of the study (**Table 2**). 9 catheters were removed after successful kidney transplantation. Catheter failure occurred in 8 out of 21 cuffed-tunneled catheters (1 in single catheterization and 7 in multiple) due to patient death, catheter-related infections, thrombosis or malposition. Cuffed-tunneled catheters remained for a total cumulative duration of 3,526 (213.2 ± 65.4) days, ranging from 60 days to 45 months. The median survival time was 14.0 ± 2.21 months and the 95% confidence interval was 9.66~18.34 months. The catheter survival rate was 85.7% at 6 months, 66.7% at first year, 28.6% at second year and

19% at third year (**Figure 1**). Of the 21 cuffed-tunneled catheters, 16 (76.2%) were placed in the right internal jugular vein (RIJV), 3 (14.3%) in the left internal jugular vein (LIJV), 1 (4.8%) in the femoral vein (FV) and 1 (4.8%) in the right external jugular vein (REJV).

Complications of cuffed-tunneled catheters

Catheter placements operation was 100% success. Acute complications after catheter insertion were infrequent. Only one case of hemopneumothorax occurred during the procedure. The No. 2 pediatric patient (**Table 1**) made a full recover finally and did not result in catheter loss. No other immediate complications were observed. In the subsequent 3 years, clinical observations on cuffed-tunneled catheter complications were infections, thrombosis and malposition (**Table 3**). More precisely, 75% catheter thrombosis followed by 56.3% blood infection, 31.3% exit site infection, 25% malposition and 18.8% tunnel infection. Despite the high incidence of catheter thrombosis, no obviously serious consequences of catheter removal due to the reasonable application of urokinase. However, infections posed the major problem for the use of cuffed-tunneled catheters. A total of 26 episodes of infection were documented in the 21 cuffed-tunneled catheters. Of these, 18 (69.2%) were found in exit site and tunnel. The rate of exit site and tunnel infections was 6.9 episodes/1000 catheter days. *Staphylococcus aureus* (73.8%) was found by exit site and tunnel culture. The usual cause of exit site and tunnel infections were abnormal secretions, redness, swelling, local heating and tenderness. Of the 8 episodes of catheter related blood infections, the rate was 3.7 episodes/1000 catheter days. The most common isolate from the catheter and peripheral venous culture showed 51.4% *Staphylococcus epidermidis*. The most common symptoms of catheter-related blood infections were chill and fever, especially during the hemodialysis treatment. 3 episodes of bacteremia were responsible for catheter failure. The remaining 2 cuffed-tunneled catheters were lost due to thrombus and malposition.

Of the 16 cases included in the study, 8 had temporary catheter at initiation and underwent conversion of temporary catheter to cuffed-tunneled catheter later on. 8 pediatric patients had cuffed-tunneled catheter as their first hemodialysis access. We also observed 5 pedi-

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Table 4. Comparative analysis of biochemical parameters between single and multiple catheterizations

	Single catheterization (n = 7)	Multiple catheterizations (n = 9)	P value
Hemoglobin (g/dl)	11.8 ± 0.6	7.2 ± 0.3	< 0.05
Albumin (g/dl)	3.9 ± 0.2	3.5 ± 0.3	> 0.05
CRP	4.2 ± 1.3	13.5 ± 1.6	< 0.05
Ferritin (mg/dl)	386.2 ± 97.5	621.8 ± 101.3	< 0.05
WBC (10 ⁶ cells/ μ L)	7389.5 ± 1436.1	11242.8 ± 1743.9	< 0.05
Neutrophil (%)	67.6 ± 10.1	85.3 ± 13.5	< 0.05

atric patients with cuffed-tunneled catheter insertion history twice (**Table 1**). Compared with single catheterization (**Table 2**), patients with multiple catheterizations posed a greater risk of catheter failure ($P < 0.05$). Level of serum hemoglobin was significantly higher in patients with single catheterization than that with multiple catheterizations, while level of C-reaction protein (CRP), ferritin, white blood cell (WBC) count and percentage of neutrophil were significantly higher in patients with multiple catheterizations (**Table 4**).

Discussion

Chronic hemodialysis treatment requires permanent vascular access that can be used for several months or years. Previous studies showed autogenous AVF and synthetic AVG were associated with lower complications, shorter hospitalization times, better outcome and higher quality of life as well as increased survival, compared to hemodialysis catheters [8]. However, in most Chinese hemodialysis units, cuffed-tunneled catheters for hemodialysis maintenance in pediatric patients has become common practice due to size-related technical difficulties and anticipated repetitive vascular punctures [4]. Subcutaneous tunneling and the cuff itself make these long-term catheters not easy to slip from in vitro and may provide a barrier to bacterial infection. Meanwhile, the ability of cuffed-tunneled catheters to prevent thrombus formation and infection has been improved with the development of new material and tip design [9]. At present, cuffed-tunneled catheter has become the preferred approach for long term hemolysis vascular access for pediatric patients. However, severe complications associated with cuffed-tunneled catheters are observed leading to higher mobility and mortality [10]. The present

study describes outcomes and complications of cuffed-tunneled catheters inserted in 16 pediatric patients requiring hemodialysis for chronic renal failure over a period of 36 months.

21 cuffed-tunneled catheters were inserted with 100% success, except 1 pediatric patient experienc-

ing postoperative hemopneumothorax. From this study, we showed that serious or lethal complications during cuffed-tunneled catheter insertion are rare and the risk of catheterization surgery could be reduced by experienced and skilled experts, radiological or ultrasound guidance and anesthesia adjuvant [11-13]. In addition to death, infections were the most common causes of catheter failure. The infection rate leading to catheter failure was 1.3 episodes/1,000 catheter days, consistent with previous studies showing that the overall infection rate was 1.2-1.6 episodes/1,000 catheter days for cuffed-tunneled catheters in children [14-17]. Exit site infection (proven or suspected) can be treated by strengthening local disinfection dressing and most cases do not need antibiotics [18]. If necessary, local antibiotic agent is given, such as Mupirocin Ointment. Bacteremia episodes in tunnel and blood infection were treated with systemic antibiotics and intra-catheter antibiotics with heparin/urokinase lock. This antibiotic lock can significantly prolong the exposure of internal surface of the catheter to antibiotics, which could not be achieved by systemic antibiotics and is now a recommended approach for the alleviation of catheter-related infections in our hemodialysis center [19]. The rate of catheter failure caused by thrombosis and malposition was 0.8 episodes/1,000 catheter days; consistent with previous reports demonstrating catheter failure rate to be varied from 0.66 to 1.88 episodes/1,000 catheter days [14-17]. The two mechanical obstruction factors often result in poor blood flow, but both conditions can usually be corrected by the application of local urokinase, systemic oral anticoagulants and reposition of catheter tip.

Although cuffed tunneled catheters were ultimately created in 100% of pediatric patients with ESRD, only 50% of these patients had

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cuffed-tunneled catheters as their first hemodialysis vascular access. Patients were therefore likely to require temporary catheters until the therapeutic regimen for chronic hemodialysis was established. In this study, we demonstrated that multiple catheterizations were associated with an increased incidence of complications in pediatric patients, consistent with higher occurrence of venous stenosis, thrombosis and subsequent infections caused by repeated punctures [20].

Two well-known prospective randomized controlled cohort studies, National Cooperative Dialysis and Dialysis Outcomes and Practice Patterns Study (DOPPS) have provided sufficient evidence to guide the medical care for patients with hemodialysis catheters [21, 22]. However, it is difficult to perform a cohort study on pediatric patients with hemodialysis in China due to the limited numbers of patients and the fact that renal transplantation is the ultimate goal of the treatment for pediatric patients with ESRD in our hemodialysis center and hemodialysis is often provided as a relatively short-term therapy until transplantation can be performed. In the future, we expect to hold large multi-center clinical studies to improve cuffed-tunneled catheter's clinical prognosis and outcome.

In conclusion, our results suggest that cuffed-tunneled catheter is a safe and effective approach of hemodialysis vascular access for many pediatric patients. However, ongoing surveillance and reducing catheterizations are required in order to prevent catheter-related complications.

Acknowledgements

Thanks for the efforts of all co-authors.

Disclosure of conflict of interest

None.

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