Cost and Safety of Pediatric Intensive Care Physician-Placed Broviac Catheters

Robert K. Fitzgerald, MD[1]; Jennifer C. Yu, MD[2]; Surender Rajasekaran, MD, MPH[1]; Scott E. Curtis, MD[1]; Daniel J. Robertson, MD[3]; Jenifer M. Wincek, RN, MSN[1]; Rachel Blanton, BS[1]; Dominic J. Sanfilippo, MD[1]

Objective: To compare the cost and safety of placement of Broviac catheters in children by pediatric intensivists in a sedation suite versus placement by pediatric surgeons in the operating room.

Design: Single-center retrospective analysis.

Setting: Pediatric sedation suite and operating rooms in a tertiary care children's hospital.

Patients: All pediatric patients with Broviac catheters placed ($n = 253$) at this institution over a 3-year period from 2007 to 2009.

Interventions: None.

Measurements and Main Results: We reviewed the charts of all pediatric patients with Broviac catheters placed, either by intensivists or surgeons, and compared cost and outcomes. Procedure safety was assessed and categorized into immediate, short-term (within 2 wk of procedure), and long-term outcomes. Anesthetic safety and billing data for the procedure were also collected. Among similar patient populations, immediate complications, such as pneumothorax, procedure failure ($p > 0.999$), and anesthetic complications ($p = 0.60$), were not significantly different. Short-term outcomes, including infection ($p = 0.27$) and catheter malfunction ($p > 0.999$), were not different. Long-term outcomes, including mean indwelling catheter days ($p = 0.60$) and removal due to catheter infection ($p = 0.09$), were not different between the groups. Overall cost of the procedure was significantly different: \$7,031 (± \$784) when performed by surgeons and \$3,565 (± \$311) when performed by intensivists ($p < 0.001$).

Conclusions: Pediatric critical care physicians can place Broviac catheters as safely as pediatric surgeons and at a lower cost in a defined patient population. (*Pediatr Crit Care Med* 2014; 15:71–76)

[1]Pediatric Intensive Care Unit, Helen DeVos Children's Hospital, Grand Rapids, MI.

[2]Pediatric Emergency Medicine, Children's Hospital of Michigan, Detroit, MI.

[3]Department of Pediatric Surgery, Helen DeVos Children's Hospital, Grand Rapids, MI.

The authors have disclosed that they do not have any potential conflicts of interest.

For information regarding this article, E-mail: robertf3@mac.com.

DOI: 10.1097/PCC.0000000000000022

Key Words: Broviac catheters in children; central venous access devices; complications of central catheter placement; cost; outcomes

Broviac catheters are widely used in the care of children with malignancies and other chronic illness who require long-term central venous access. These tunneled catheters allow for frequent blood sampling and administration of medication and nutrition in pediatric patients without the discomfort and anxiety of frequent needle sticks. The use and benefits of long-term central venous access devices (CVADs) in children are well established (1–5).

Traditionally, Broviac catheters have been placed in patients under general anesthesia by pediatric surgeons in the operating room (OR) (6, 7). This study examines an alternative approach—the placement of Broviac catheters by pediatric critical care physicians in a sedation suite. Earlier studies, mainly of adult patients, have compared cost, complications, and outcomes of central catheters placed by surgeons, anesthesiologists, and interventional radiologists, supporting the economic advantages and scheduling convenience of this method (7–10). Slavc and Urban (11) and Skladal et al (12) previously proposed that tunneled CVADs could safely be inserted in children by pediatric intensivists and oncologists. Other data provide evidence that performing this procedure outside of the OR does not compromise safety or sterility (7, 13).

Our children's hospital operates a high-volume pediatric sedation service, performing over 6,000 sedations annually. Pediatric intensivists insert approximately half of all Broviac catheters placed at our institution. Our Broviac catheter insertion protocol employs two intensivists: one to administer anesthesia and another to place the catheter under sterile conditions. Anesthesia for Broviac insertion is primarily done using propofol, often paired with an opioid analgesic. For patients who do not require any additional surgical procedures, this approach avoids the time and costs associated with the OR and postanesthesia care unit (PACU).

To evaluate the safety and cost-effectiveness of Broviac catheter placement in sedation suites, we reviewed procedural data from our institution and examined the associated billed charges. We present outcomes from several years of experience of Broviac catheter placement in children by trained pediatric intensivists. To our knowledge, no previous study has specifically examined this practice or its financial and patient-safety implications.

The primary aims of the study were to compare cost differences in Broviac catheter placement by surgeons and intensivists and to compare safety outcomes between the two groups of patients. Cost was calculated as the charge for the entire procedure of Broviac catheter placement and was obtained from hospital billing records.

MATERIALS AND METHODS

Study Design

This study was performed as a retrospective analysis with medical chart review at Helen DeVos Children's Hospital in Grand Rapids, MI. Approval for the study was obtained from the Institutional Review Board of Spectrum Health.

Subject Identification and Data Collection

All patients with Broviac catheters placed by pediatric intensivists and pediatric surgeons during a 3-year period from 2007 to 2009 were identified, and their charts and billing records were reviewed. All patients with Broviac catheters inserted in the OR or sedation suite were included. Patients with catheter insertion performed in either the PICU or neonatal ICU (NICU) were excluded.

We identified 176 patients who had 253 Broviac catheters placed during the study period. On preliminary review of the study population, we found that a large number of the pediatric surgery patients (83 of 141) were patients from the NICU. This considerably altered the similarity of the two groups, resulting in a significant difference in average patient age, weight, American Society of Anesthesiologists (ASA) class, and other morbidities such that we felt we were unable to accurately compare the two patient groups. At our institution, Broviac catheter insertion in NICU patients is performed by the pediatric surgery service exclusively. Therefore, we elected not to include this group in our final analysis of the outcomes, complications, and costs in this study.

The final study population included all non-NICU pediatric patients with Broviac catheters placed at our children's hospital from 2007 to 2009. Data were analyzed from 170 patients: 112 intensivist patients and 58 surgery patients. We collected information from each patient as recorded in the chart at the time of Broviac catheter placement, including age, weight, diagnosis, referring service, ASA class, and other procedures performed concurrently with Broviac placement.

In order to describe safety, we assessed findings in three categories: immediate complications (occurring at the time of catheter placement), short-term complications (within 14 d of the procedure), and long-term outcomes (over the lifespan of the catheter.)

From each procedure note, we recorded total procedure time, success of the procedure, and intraprocedure complications that required intervention, including dysrhythmia, airway compromise, or difficulty on induction of anesthesia. We used these data to determine any differences in immediate complications of the procedure across the two groups of patients.

We reviewed each of the patient charts to follow the outcome of the Broviac catheter after placement—average time the catheter remained in place, reason for removal, occurrences of catheter or site infection, and other complications such as catheter malfunction or inadvertent removal.

In order to compare cost, we obtained hospital billing records and calculated the charges for Broviac catheter placement for both the intensivist and surgical patients. As the pediatric surgeons are a private practice group, we also extracted the billed charges for each surgery patient from records provided by the pediatric surgery billing office. Charges for Broviac placement by intensivists included sedation suite fee, catheter placement fee, medications, supplies, and fluoroscopy and/or radiograph charges. Charges for Broviac placement by surgeons included OR fee, catheter placement fee, anesthesia fee, medications, supplies, fluoroscopy and/or radiograph charges, and PACU charges.

It was not possible to isolate the anesthesia charges and OR charges for the catheter placements alone from billing data for patients undergoing multiple procedures concurrently. Thus, for the purpose of charge comparison, we analyzed billing data for patients who underwent Broviac catheter placement only (26 surgery patients and 37 intensivist patients). In 14 of the intensivist patient records, charge data were either missing or incomplete. Overall charge data were compared in 26 surgical and 23 intensivist procedures.

Statistical Analysis

Characteristics of the study subjects are presented using frequency counts, percentages, mean, or median as specified. Continuous variables were analyzed using two-sample *t* tests. Chi-square test or Fisher exact test was used for categorical variables. Statistical significance was defined as a p value of less than 0.05.

RESULTS

Characteristics of the Main Study Group

A total of 170 Broviac placements (112 intensivist patients and 58 surgical patients) were included in the analysis. These two groups of patients were similar (**Table 1**). The majority of the surgical patients were referred from the hematology-oncology and gastroenterology services. Of the surgical patients, 32 of 58 underwent concurrent procedure at the time of Broviac placement, the most common of which was tissue biopsy ($n = 7$). Nearly all of the intensivist patients were referred from the hematology-oncology service. Of the intensivist patients, 75 of 112 underwent a concurrent procedure at the time of Broviac placement. The most common were lumbar puncture ($n = 37$) and bone marrow aspiration ($n = 22$).

TABLE 1. Characteristics of Pediatric Patients Undergoing Broviac Catheter Placement

Variable	Intensivist	Surgeon
Number of cases	112	58
Mean age (mo)[a]	51.4	60.9
Mean weight (kg)[b]	20.6	19.2
Mean American Society of Anesthesiologists class[c]	2.8	2.9
Referring service (%)		
Hematology/oncology	103 (92)	27 (46.6)
Gastroenterology	4 (3.6)	22 (37.9)
Infectious disease	2 (1.8)	8 (13.8)
Cardiothoracic surgery	3 (2.7)	0 (0)
Concurrent procedure	75 (67.0)	32 (55.2)
Broviac placement only	37 (33.0)	26 (44.8)

[a]$p = 0.20$.
[b]$p = 0.51$.
[c]$p = 0.21$.

Broviac placement was performed using one of two techniques differing by the approach to cannulating the vein. The first technique uses a percutaneous approach and Seldinger technique, whereas the second is an open cut-down procedure. The intensivists only perform the percutaneous approach, whereas the surgeons use either technique, depending on surgeon preference. Of the 57 of 58 available surgical procedure reports, 39 (68%) were done using the percutaneous approach, whereas 18 (32%) used the cut-down approach. Most of the venous cut-down procedures were performed on younger children, with 10 of 15 catheters (67%) being placed in children younger than 1 year old using this technique compared with only 8 of 42 (19%) in children older than 1 year.

All intensivist Broviac catheters were placed in the subclavian vein. Most of the surgical Broviac catheters inserted via the percutaneous approach were also placed in the subclavian vein 37 of 39 (95%), with the remaining 2 of 39 (5%) positioned in the internal jugular vein. Catheters inserted using the cut-down approach were either placed in the external jugular vein 15 of 18 (83%) or the facial vein 3 of 18 (17%). In the sedation suite, position of the catheter was confirmed by the intensivist using real-time bedside fluoroscopy. In the OR, surgeons confirmed location of the catheter using fluoroscopy or chest radiograph. Ultrasound was not used in the placement of any of the catheters.

Safety

Immediate Complications. Immediate complications encountered at the time of the procedure, including procedure failure, dysrhythmia requiring intervention, and complications of anesthesia, were not significantly different between the two groups (**Table 2**). There were no occurrences of pneumothorax or hemothorax in either group. Mean procedure time for Broviac catheter placement was 39 minutes for intensivist patients and 30 minutes for surgical patients ($p = 0.84$). Each group experienced one unsuccessful procedure attempt in which Broviac placement was not achieved. One intensivist patient experienced dysrhythmia that required intervention: an episode of supraventricular tachycardia successfully treated with adenosine. Each group had two patients experiencing complication with initiation of anesthesia. Of the surgeon patients, one experienced an aspiration event that resulted in a postoperative PICU admission, ventilatory support, and tracheostomy. Another patient, with Hunter syndrome and a known difficult airway, experienced problems with intubation and airway compromise in the OR, leading to cardiopulmonary arrest. Of the intensivist patients, one experienced bradycardia and another experienced airway obstruction. Both cases resulted in intubation in the sedation suite and transfer to the PICU, and both subsequently recovered without permanent sequelae. None of the immediate complications occurring during placement of Broviac catheters was significantly different

TABLE 2. Immediate Complications of Broviac Catheter Placement

Variable	Intensivist ($n = 112$) (%)	Surgeon ($n = 58$) (%)	p
Unsuccessful procedure	1 (0.9)	1 (1.7)	> 0.999
Dysrhythmia	1 (0.9)	0 (0)	> 0.999
Complication with anesthesia	2 (1.8)	2 (3.4)	0.61

TABLE 3. Short-Term Outcomes of Broviac Catheter Placement (Reasons for Removal Within 14 Days of Placement)

Variable	Intensivist ($n = 112$) (%)	Surgeon ($n = 58$) (%)	p
Infection	1 (0.9)	2 (3.4)	0.27
Malfunction	1 (0.9)	0 (0)	> 0.999
Not needed	1 (0.9)	0 (0)	> 0.999
Inadvertent removal	8 (7.1)	1 (1.7)	0.17
Patient death	0 (0)	1 (1.7)	0.34

between the two groups. The overall success rate of the both groups was greater than 98%.

Short-Term Outcomes. Short-term outcomes were defined as events resulting in removal of the Broviac within 14 days of placement (**Table 3**). Occurrences of catheter infection, catheter malfunction, and the patient no longer requiring a central catheter were similar in both groups. Loss of the catheter due to inadvertent removal was more frequent among the intensivist patients, although was not statistically significant. Neither of the groups had occurrence of infection within 5 days of Broviac catheter placement. The earliest incidents of infection were at day 7 in a surgical patient and day 12 in an intensivist patient.

Long-Term Outcomes. Between the two groups, there were no statistically significant differences in the long-term endpoints of the Broviac catheters (**Table 4**). Mean indwelling catheter days were similar, with an average 149 days (± 111 d) for surgical patients and 161 days (±133 d) for intensivist patients ($p = 0.60$). Infection requiring removal of the catheter occurred at similar rates in both groups with a mean number of days to infection of 136 days (± 166 d) in the intensivist patients and 89 days (± 86 d) in the surgeon patients. Nearly all the patients could be accounted for, with a small number in each group with records that were incomplete or could not be located.

Cost of Broviac Catheter Placement

Overall charge for the procedure was significantly different: $7,031 (± $784) when performed by surgeons and $3,565 (± $311) when performed by intensivists ($p < 0.001$) (**Table 5**).

DISCUSSION

Our findings demonstrate that the insertion of Broviac catheters by pediatric intensivists can be a successful, safe, and cost-effective alternative to insertion by surgeons in the OR. This study adds to a larger body of current literature, which consistently shows that CVADs can be inserted economically outside of the OR with excellent outcomes. Our experience emphasizes that this procedure can be reliably performed by nonsurgeons through a pediatric sedation service.

Safety

We found that the safety of the immediate procedure and time required for Broviac placement were not significantly different between the two groups. Procedure failure was rare in either group, with success rates more than 98%, above the range of 64–89% reported in other studies (9, 12). Our results support earlier adult and pediatric studies validating that the percutaneous approach used by intensivists and the venous cut-down technique favored by surgeons have similar success and safety profiles (9, 12–19). Additional procedure-related complications of CVAD insertion, such

TABLE 4. Long-Term Outcomes of Broviac Catheter Placement (Reasons for Removal of Catheter)

Variable	Intensivist ($n = 112$[a]) (%)	Surgeon ($n = 58$[a]) (%)	p
Infection[b]	15 (13.4)	14 (24.1)	0.09
Malfunction	29 (25.9)	14 (24.1)	0.85
Not needed	42 (37.5)	14 (24.1)	0.09
Inadvertent removal	14 (12.5)	8 (13.8)	0.81
Patient death	3 (2.7)	2 (3.4)	> 0.999
Catheter change	1 (0.9)	1 (1.7)	> 0.999
Still in place	3 (2.7)	0 (0)	0.55
Lost to follow-up	5 (4.5)	5 (8.6)	0.31

[a]The two unsuccessful procedures (one in each group) were counted as malfunction.

[b]Number of catheters removed for infection across the life of the catheters

TABLE 5. Cost of Broviac Catheter Placement

Variable	Intensivist	Surgeon	*p*
Mean (± SD) total billed charges	$3,565 (± $311)	$7,031 (± $784)	< 0.001

as pneumothorax, hemothorax, dysrhythmia, and airway compromise (6, 20–22), were infrequent and not different between the groups.

Concerns regarding sterility of the environment outside of the OR are not substantiated in recent literature. Multiple studies document no difference in rates of infection, complications, or related morbidity in patients with catheters inserted in the OR compared with other settings, including sedation rooms, interventional radiology, and ICUs, where sterile technique is observed (7, 13). Muhm et al (13) showed that intensivists and anesthesiologists performed CVADs insertion in adult patients in a radiology suite as safely as surgeons in the OR. Our experience supports these findings.

The function and duration of the catheters, when examined at 2 weeks after placement and at the time of removal, were comparable between the two groups. The reasons for removal were similar between the groups. Common complications associated with long-term venous access devices, including catheter infection, dislodgement, and mechanical difficulty with the catheter (4, 15, 18, 23, 24), were not significantly different. Rate of infection necessitating removal of intensivist-placed catheters was 13%—less than those of other published studies, which report infection rates of 17–42% (1, 9, 12, 13, 20). No infections occurred in either group within 5 days of placement, suggesting that neither group had an infection related to insertion technique. Likewise, our rates of inadvertent removal or dislodgement (12.5%) were comparable to those of other studies with rates of 11–17% (9, 12, 13, 20). These data, along with a similar mean indwelling catheter time of over 6 months, are evidence that the longevity and security of intensivist-placed catheters compares favorably with the surgeon-placed catheters. Although not statistically significant, there was a trend toward more inadvertent removals in the intensivist group. We theorize that this may be due to the relatively high proportion of new cancer patients in this group with potentially compromised wound healing around the cuff during active chemotherapy treatment. However, we are investigating the trend and examining the possibility of inadequate securing of newly placed Broviacs.

Cost

This study also demonstrates that the charge for Broviac catheter insertion by intensivists in a sedation suite is significantly less ($p \leq 0.001$) than insertion by surgeons in the OR. At our hospital, relocating Broviac catheter insertion from the OR to a sedation suite cuts the cost in half, for a savings of nearly $3,500. The cost differences are multifactorial, but the bulk of the savings is derived from eliminating OR and PACU billed time associated with the procedure, which are not applicable in the sedation service model.

Few previous studies have specifically examined the cost of placing CVADs in children outside of the OR. Lally et al (7) showed that Broviac catheters inserted in the NICU by surgeons was a safe and cost-effective alternative to the OR. Several pediatric studies have illustrated that CVADs can be placed by interventional radiology at a lower cost and with similar safety to OR placement (9, 10, 25).

Study Limitations

The retrospective nature of this study may not account for differential recording of procedure details and complications. The number of actual insertion attempts for each case may be relevant to complications and was not specified. As a single institution analysis, our results may not be generalizable to charges and outcomes at other institutions.

With the exclusion of the NICU population, the two groups of children with Broviac catheters placed at our institution were quite similar, other than a larger percentage of intensivist patients originating from the hematology-oncology service. We cannot comment on applicability of our study findings to NICU patients, as our pediatric intensivists do not currently insert Broviac catheters in NICU patients.

An important consideration not within the scope of this study is the issue of billing and reimbursement. Our records provided us access to determine the billed charges for the procedures, but we do not have data as to the actual reimbursement collected from various payers. Some cost analysis studies have examined reimbursements (26) or attempted to create a value estimate based on services provided (8). However, the differential between billed costs and actual reimbursement is a central factor in healthcare cost analysis, and this number may be highly variable with each individual hospital, private practice group, and patient insurance plan (27). We cannot comment as to how billed charges at our institution compare to costs nationally.

The volume and success of Broviac catheter placement by intensivists at our institution is enhanced by a cooperative and complementary relationship with the pediatric surgery service. Patient selection is highly collaborative, with both intensivists and surgeons referring patients to the other team, as they feel appropriate. Additionally, we presume that there are a minimum number of procedures necessary for each practitioner to regularly perform to maintain proficiency and safety. It is not definitive that our safety findings would be comparable for practitioners at other institutions.

Implications

We address Broviac catheter insertion in a specific group of pediatric patients who do not require other concurrent surgical treatment. Our service does not eliminate the need for placement of some CVADs in the OR. However, these results

present potential practice implications for pediatric intensivists and surgeons, as well as children's hospitals with the capability of expanding pediatric sedation programs. This joint endeavor is recognized as advantageous to all those involved.

For the pediatric critical care physician, integration of surgical procedures with sedation services offers an opportunity to enhance scope of practice, develop additional skills, and expand academic interests beyond the ICU. For the pediatric surgeon, allocating appropriate procedures to the sedation service allows valuable OR time to be used for other cases and decreases scheduling wait time. For children's hospitals, potential benefits include cost savings, revenue from increased procedure volume, and patient satisfaction. Although not quantified in this study, anecdotally, utilization of the pediatric sedation service is positively accepted by children and their families, as well as the referring services.

CONCLUSIONS

Pediatric critical care physicians in a sedation suite can place Broviac catheters as safely as pediatric surgeons in the OR, at a lower cost, in a defined patient population. This practice offers both patients and children's hospitals the economic and scheduling benefits of an intensivist-led procedural pediatric sedation service.

ACKNOWLEDGMENTS

We thank Pediatric Surgeons of West Michigan, Grand Rapids Medical Education Partners Research Department, and Alan Davis for statistical support.

REFERENCES

1. Zganjer M, Cizmić A, Butković D, et al: Central venous catheters for chemotherapy of solid tumors–Our results in the last 5 years. *Coll Antropol* 2008; 32:767–770
2. Hollyoak MA, Ong TH, Leditschke JF: Critical appraisal of surgical venous access in children. *Pediatr Surg Int* 1997; 12:177–182
3. Shapiro CL: Central venous access catheters. *Surg Oncol Clin N Am* 1995; 4:443–451
4. Wiener ES, McGuire P, Stolar CJ, et al: The CCSG prospective study of venous access devices: An analysis of insertions and causes for removal. *J Pediatr Surg* 1992; 27:155–163
5. Stockwell M, Adams M, Andrew M, et al: Central venous catheters for out-patient management of malignant disorders. *Arch Dis Child* 1983; 58:633–635
6. Bagwell CE, Salzberg AM, Sonnino RE, et al: Potentially lethal complications of central venous catheter placement. *J Pediatr Surg* 2000; 35:709–713
7. Lally KP, Hardin WD Jr, Boettcher M, et al: Broviac catheter insertion: Operating room or neonatal intensive care unit. *J Pediatr Surg* 1987; 22:823–824
8. Noh HM, Kaufman JA, Rhea JT, et al: Cost comparison of radiologic versus surgical placement of long-term hemodialysis catheters. *AJR Am J Roentgenol* 1999; 172:673–675
9. Nosher JL, Shami MM, Siegel RL, et al: Tunneled central venous access catheter placement in the pediatric population: Comparison of radiologic and surgical results. *Radiology* 1994; 192:265–268
10. Crowley JJ: Vascular access. *Tech Vasc Interv Radiol* 2003; 6:176–181
11. Slavc I, Urban C: Percutaneous insertion of Broviac catheters by pediatricians on the oncology ward. *Pediatr Hematol Oncol* 1992; 9:191–198
12. Skladal D, Horak E, Maurer K, et al: Complications of percutaneous insertion of Hickman catheters in children. *J Pediatr Surg* 1999; 34:1510–1513
13. Muhm M, Kalhs P, Sunder-Plassmann G, et al: Percutaneous nonangiographic insertion of Hickman catheters in marrow transplant recipients by anesthesiologists and intensivists. *Anesth Analg* 1997; 84:80–84
14. Masumoto K, Uesugi T, Nagata K, et al: Safe techniques for inserting the hickman catheter in pediatric patients. *Pediatr Hematol Oncol* 2006; 23:531–540
15. Swartz RD, Messana JM, Boyer CJ, et al: Successful use of cuffed central venous hemodialysis catheters inserted percutaneously. *J Am Soc Nephrol* 1994; 4:1719–1725
16. Stellato TA, Gauderer MW, Cohen AM: Direct central vein puncture for silicone rubber catheter insertion. An alternative technique for Broviac catheter placement. *Surgery* 1981; 90:896–899
17. Gauderer MW, Stellato TA, Izant RJ Jr: Broviac silastic catheter insertion in children: A simplified direct subclavian approach. *J Pediatr Surg* 1982; 17:580–584
18. Gauderer MW, Stellato TA: Subclavian Broviac catheters in children–Technical considerations in 146 consecutive placements. *J Pediatr Surg* 1985; 20:402–405
19. Castaldo P, Langnas AN, Stratta RJ, et al: Long-term central venous access in pediatric liver transplantation recipients: Role of percutaneous insertion of subclavian Broviac catheters. *Transplant Proc* 1991; 23:1991
20. Perdikaris P, Petsios K, Vasilatou-Kosmidis H, et al: Complications of Hickman-Broviac catheters in children with malignancies. *Pediatr Hematol Oncol* 2008; 25:375–384
21. Cesaro S, Corrò R, Pelosin A, et al: A prospective survey on incidence and outcome of Broviac/Hickman catheter-related complications in pediatric patients affected by hematological and oncological diseases. *Ann Hematol* 2004; 83:183–188
22. Chait PG, Temple M, Connolly B, et al: Pediatric interventional venous access. *Tech Vasc Interv Radiol* 2002; 5:95–102
23. Uderzo C, D'Angelo P, Rizzari C, et al: Central venous catheter-related complications after bone marrow transplantation in children with hematological malignancies. *Bone Marrow Transplant* 1992; 9:113–117
24. Stamou SC, Maltezou HC, Pourtsidis A, et al: Hickman-Broviac catheter-related infections in children with malignancies. *Mt Sinai J Med* 1999; 66:320–326
25. Tierney SN, Katke J, Langer JC: Cost comparison of electrocardiography versus fluoroscopy for central venous line positioning in children. *J Am Coll Surg* 2000; 191:209–211
26. Sticca RP, Dewing BD, Harris JD: Outcomes of surgical and radiologic placed implantable central venous access ports. *Am J Surg* 2009; 198:829–833
27. Huang Y: Cost analysis with censored data. *Med Care* 2009; 47:S115–S119