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Cost Savings Associated with Antibiotic-Impregnated Shunt Catheters in the Treatment of Adult and Pediatric Hydrocephalus

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Key words
- Antibiotic-impregnated
- Hydrocephalus
- Infection
- Shunt

Abbreviations and Acronyms
AI: Antibiotic-impregnated
CSF: Cerebrospinal fluid

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■ BACKGROUND: **Cerebrospinal fluid (CSF) shunt infection is a major cause of morbidity and mortality in the treatment of hydrocephalus and is associated with significant medical cost. Several studies have demonstrated the efficacy of antibiotic-impregnated (AI) shunt catheters in reducing CSF shunt infection; however, providers remain reluctant to adopt AI catheters into practice because of the increased upfront cost. The objective of this study was to determine if the use of AI catheters provided cost savings in a large nationwide database.**

■ METHODS: **Hospital discharge and billing records from the Premier Perspective Database from 2003–2009 were retrospectively reviewed to identify all adult and pediatric patients undergoing de novo ventricular shunt placement. The incidence of shunt infection within 1 year of implantation was determined. Shunt infection–related cost was defined as all inpatient billing costs incurred during hospitalization for treatment of shunt infection.**

■ RESULTS: **In 287 U.S. hospitals, 10,819 adult (AI catheters, 963; standard catheters, 9856) and 1770 pediatric (AI catheters, 229; standard catheters, 1541) patients underwent ventricular shunt placement. AI catheters were associated with significant reduction in infection for both adult (2.2% vs. 3.6%, $P = 0.02$) and pediatric (2.6% vs. 7.1%, $P < 0.01$) patients. Total infection-related costs were $17,371,320 ($45,714 ± $49,745 per shunt infection) for adult patients and $6,508,064 ($56,104 ± $65,746 per shunt infection) for pediatric patients. Infection-related cost per 100 de novo shunts placed was $120,534 for AI catheters and $162,659 for standard catheters in adult patients and $165,087 for AI catheters and $395,477 for standard catheters in pediatric patients.**

■ CONCLUSIONS: **In analysis of this large, nationwide database, AI catheters were found to be associated with a significant reduction in infection incidence, resulting in tremendous cost savings. AI catheters were associated with a cost savings of $42,125 and $230,390 per 100 de novo shunts placed in adult and pediatric patients, respectively.**

INTRODUCTION

Despite improvements in perioperative antibiotic therapy and surgical technique, shunt infection remains the most morbid and financially significant complication associated with the treatment of hydrocephalus in both pediatric and adult patients (3, 11, 15, 26). Several independent risk factors have been identified, including patient age, etiology of hydrocephalus, duration of surgery, revision surgery, surgeon experience, previous shunt infection, postoperative cerebrospinal fluid (CSF) leakage, and external ventricular drain–to–shunt conversions (22). Ventricular shunt infection is a common complication, occurring in 3%–15% of patients (2, 4-6, 9, 20, 21, 23). This complication can be associated with significant morbidity, including reduced IQ, psychomotor retardation, seizures, and shunt failure (1, 5, 11, 13, 33, 35, 36). Shunt infection is also associated with a significant financial impact; the average hospital cost for the treatment of shunt infection has been reported to be approximately $50,000, representing the most costly implant-related infection in the United States (3, 11, 26). The direct medical cost of shunt infection has been shown to be $17,300–$48,454, with an estimated total annual cost of $100 million (3, 13, 31, 33).

Antibiotic-impregnated (AI) catheters have been introduced with the primary objective of reducing the incidence of shunt-related infections. AI catheters slowly release antibiotics over several weeks to prevent the colonization of shunt systems by gram-positive bacteria, which account for most shunt infections (7, 14, 22, 24, 27, 32). The bulk of the literature to date has demonstrated a reduction in shunt-associated infections associated with the use of AI catheters; however, there has been some reluctance to adopt these systems because of their increased cost compared with conventional catheters (10, 13, 16, 17, 25, 29). We assessed the overall costs associated with shunt infection in a nationwide database to determine whether the use of AI shunt catheters is cost saving.

METHODS

Data Source

This was a retrospective longitudinal analysis of hospital discharge and billing records obtained from the Premier Perspective™ Database, a hospital service database that includes detailed patient-level data from inpatient hospitalizations and hospital outpatient visits. This database includes information from >600 U.S. hospitals with information pertaining to patient demographics (age, sex, race), hospital characteristics, principal and secondary diagnoses, payer, cost of care, medication utilization, departmental cost and charge detail, length of stay, and physician specialty (8). Participating hospitals submit data to the Premier Perspective Database on a monthly or quarterly basis. The data undergo multiple, separate quality assurance and data validation checks before they are made available for research purposes. All data are deidentified in accordance with the Health Insurance Portability and Accountability Act.

Patient Population

All adult and pediatric (≤17 years old, excluding neonates) patients undergoing de novo ventricular shunt placement between April 2003 and July 2009 were included in this study. Neonates were excluded from analysis secondary to a lack of statistical comparison power for this age group. Patients were identified by the International Classification of Diseases, 9th Edition, procedure code 02.34 (placement of a ventricular shunt to abdominal cavity and organs). Patients in the AI cohort received both ventricular and distal AI catheters. Patients in the standard cohort received no AI catheters of any type. Additionally, it was confirmed that the patients had undergone no shunting procedures in the prior 2 years. The hospitalization for the initial placement of the shunt was defined as the index hospitalization.

Definition of Shunt Infection and Cost Calculation

Shunt infection was defined as a hospital claim with an infection diagnosis code of 996.63 (infection and inflammatory reaction due to nervous system device, implant, and graft electrodes implanted in brain) within 1 year after the initial shunt insertion procedure *and* 1 or both of the following: 1) shunt revision International Classification of Diseases, 9th Edition, procedure code (02.2, 02.3, 02.32, 02.35, 02.39, 02.4, 02.41, 02.42, 02.43, 54.95) within 1 year of the 996.63 code and 2) ≥5 consecutive days of any of the following antibiotics within 7 days before or after the 996.63 infection code: ceftriaxone, ceftazidime, cefotaxime, ceftizoxime, vancomycin, gentamicin, linezolid, cefepime, meropenem, or ciprofloxacin. Time to shunt infection was measured from the date of index shunt implantation to the first occurrence of the infection-related element within the first year. For the purposes of this study, shunt infection—related cost was defined as all inpatient billing cost incurred during the hospitalization for treatment of shunt infection. This cost calculation also included the cost difference of AI versus standard catheters.

Statistical Analysis

All analyses were performed using SAS version 9.3 (SAS Institute, Inc, Cary, North Carolina, USA). Summary data were presented as mean ± SD for parametric data. Nonparametric data were presented as median [interquartile range]. Percentages were compared via chi-square or Fisher exact test for intergroup comparison. Student *t*-test was used for parametric data, and Wilcoxon rank sum test was used for nonparametric data.

RESULTS

Overall Population

During the reviewed period, 12,589 consecutive adult and pediatric patients from 287 hospitals undergoing de novo ventricular shunt placement were identified. There were 496 (3.9%) patients identified who experienced and received treatment for a shunt infection within 1 year of the index shunt placement. The median [interquartile range] time to shunt infection was 4.6 [4.1—13.3] weeks. The total cost associated with treatment of shunt infections was $23,879,424 ($48,144 ± $54,021 per shunt infection).

Adult Population

Adult patient and hospital characteristics for the AI and standard catheter groups are listed in Table 1. During the reviewed time period, 10,819 adult patients were identified who underwent a de novo shunt placement. Of these, 380 (3.5%) patients experienced a shunt infection within 1 year of placement. The total cost associated with treatment of shunt infection within the adult population was $17,371,320 ($45,714 ± $49,745 per shunt infection) (Table 2).

AI shunt catheters were placed in 963 (8.9%) adult patients, and standard shunt catheters were placed in 9,856 (91.1%) patients. A shunt infection was experienced by 21 (2.2%) patients with AI catheters versus 359 (3.6%) patients with standard catheters ($P = 0.02$). There was no difference in time to shunt infection between the AI and standard catheter cohorts (8.6 [0.1—17.7] weeks vs. 4.6 [4.3—13.3] weeks; $P = 0.29$). The

Table 1. Patient and Hospital Characteristics for Adult Patients Receiving Antibiotic-Impregnated and Standard Shunt Catheters

	Antibiotic-Impregnated Catheter	Standard Catheter	*P* Value
Patient characteristics			
Age (years)	64.4 ± 18.0	62.5 ± 17.7	< 0.01*
Male (%)	50.2	50.6	0.80
White (%)	77.1	68.8	< 0.01
Number of diagnoses	12.6 ± 8.2	11.6 ± 7.8	< 0.01†
Hospital characteristics			
Private (%)	25.3	29.9	0.01
>500 beds (%)	68.5	52.8	< 0.01
Academic (%)	39.5	58.0	< 0.01
Southern region (%)	66.7	45.9	< 0.01

Mean ± SD. *P* values are from χ^2 test except where noted.
*Student *t* test.
†Satterthwaite *t* test.

Table 2. Incidence and Cost of Shunt Infections for Antibiotic-Impregnated and Standard Shunt Catheters in the Adult Population

	Number of Patients	Number of Shunt Infections	Incidence Shunt Infection	Median Time to Shunt Infection	Total Shunt-Related Cost	Mean Cost per Shunt Infection	Infection Cost per 100 De Novo Shunts
AI catheters	963	21	2.2%	8.6 weeks	$1,150,548	$54,788 ± $59,728	$120,534
Standard catheters	9856	359	3.6%	4.6 weeks	$16,220,697	$45,183 ± $49,146	$162,659

AI, antibiotic-impregnated.

infection-related cost totaled $1,150,548 for the AI cohort and $16,220,697 for the standard catheter cohort. The mean cost per shunt infection was similar for patients in the AI ($54,788 ± $59,728) and standard ($45,183 ± $49,146) catheter cohorts ($P = 0.39$). The infection-related cost per 100 de novo shunts placed (infection incidence multiplied by mean infection-related cost) was $120,534 for AI catheters and $162,659 for standard shunt catheters. The use of AI catheters was associated with an infection-related cost savings of $42,125 per 100 de novo shunts placed (Table 2).

Pediatric Population

Pediatric patient and hospital characteristics for the AI and standard catheter groups are listed in Table 3. During the reviewed time period, 1770 pediatric patients were identified who underwent a de novo shunt placement. Of these, 116 (6.6%) patients experienced a shunt infection within 1 year of placement. The total cost associated with treatment of shunt infection within the pediatric population was $6,508,064 ($56,104 ± $65,746 per shunt infection) (Table 4).

AI shunt catheters were placed in 229 (12.9%) pediatric patients compared with 1541 (87.1%) patients who had standard shunt catheters placed. A shunt infection occurred in 6 (2.6%) patients in the AI catheter cohort versus 110 (7.1%) patients in the standard catheter cohort ($P < 0.01$). There was no difference in time to shunt infection between the AI and standard catheter cohorts (13.3 [0.1–30.7] weeks vs. 4.6 [0.7–17.6] weeks; $P = 0.29$). The infection-related cost totaled $380,970 for the AI cohort and $6,127,110 for the standard catheter cohort. The mean cost per shunt infection was similar for patients in the AI ($63,495 ± $69,968) and standard ($55,701 ± $65,824) catheter cohorts ($P = 0.78$) (Table 4). The infection-related cost per 100 de novo shunts placed was $165,087 for AI catheters and $395,477 for standard shunt catheters. The use of AI catheters was associated with an infection-related cost savings of $230,390 per 100 de novo shunts placed.

DISCUSSION

In the analysis of this large, nationwide database containing data from 287 hospitals and 12,589 consecutive patients undergoing placement of a de novo ventricular shunt, AI catheters were associated with a 1.4% ($P = 0.02$) and 4.5% ($P < 0.01$) absolute reduction in infection for adult and pediatric populations, respectively. The reduction in infection associated with the use of AI catheters also resulted in cost savings for both adult and pediatric cohorts. For adults, use of AI catheters was associated with an infection-related cost savings of $42,125 per 100 de novo shunts placed. The cost savings was more dramatic in the pediatric cohort, with use of AI catheters being associated with an infection-related cost savings of $230,390 per 100 de novo shunts placed. The results of this analysis suggest that AI catheters provide significant cost savings when used for the treatment of hydrocephalus in both adult and pediatric cohorts.

Shunt infection is one of the most common etiologies of shunt-related complications, with a rate of 3%–15% as described by systematic reviews of the literature (24, 34). Previous studies have identified a multitude of independent risk factors associated with shunt infection, including length of surgery, number of prior revisions, experience of the surgeon, etiology of hydrocephalus, patient age, immune status, and postoperative CSF leakage (1, 10, 12, 18, 19, 27, 28, 30). Despite continued improvements in surgical and sterilization technique, perioperative antibiotic therapy, and appreciation of the

Table 3. Comparison of Patient and Hospital Characteristics for Pediatric Patients Receiving Antibiotic-Impregnated and Standard Shunt Catheters

	Antibiotic-Impregnated Catheter	Standard Catheter	*P* Value
Patient characteristics			
Age (years)	—*	—*	
Male (%)	50.2	54.7	0.20
White (%)	59.8	54.3	0.11
Number of diagnoses	9.1 ± 8.5	8.1 ± 7.8	0.06†
Hospital characteristics			
Private (%)	41.5	40.0	0.16
>500 beds (%)	38.0	67.4	< 0.01
Academic (%)	75.6	73.2	0.45
Southern region (%)	76.0	66.3	< 0.01

Mean ± SD. *P* values are from χ^2 test except where noted.
*Patient age <15 years unavailable because of the Health Insurance Portability and Accountability Act.
†Student *t* test.

Table 4. Incidence and Cost of Shunt Infections for Antibiotic-Impregnated and Standard Shunt Catheters in the Pediatric Population

	Number of Patients	Number of Shunt Infections	Incidence Shunt Infection	Median Time to Shunt Infection	Total Shunt-Related Cost	Average Cost per Shunt Infection	Infection Cost per 100 De Novo Shunts
AI catheters	229	6	2.6%	13.3 weeks	$380,970	$63,495 ± $69,968	$165,087
Standard catheters	1541	110	7.1%	4.6 weeks	$6,127,110	$55,701 ± $65,824	$395,477

AI, antibiotic-impregnated.

aforementioned risk factors, significant reductions in infection rates remain elusive (10). Shunt-associated infections prolong in-hospital stays and lead to significant morbidity and mortality, with 33% of shunt-related deaths occurring secondary to shunt infection (13, 26, 31, 37).

The literature to date contains multiple studies demonstrating a reduction in shunt infection associated with the use of AI catheters. A systematic literature review showed AI catheters to be associated with a significant infection reduction overall (3.3% vs. 7.2%), for adult-specific cohorts (0.9% vs. 5.8%), and for pediatric-specific cohorts (5.0% vs. 11.2%) (24). The results of the current study further corroborate the findings from the literature as a whole. This infection reduction has previously been shown to result in significant cost savings. Attenello et al. (3) demonstrated that the introduction of AI catheters into their institutional practice resulted in significant hospital cost savings for pediatric patients. The authors reported that although mean hospital cost per shunt infection was similar for AI and standard catheters, the infection-related hospital cost per 100 patients receiving shunts was markedly lower in the AI cohort versus standard cohort ($151,582 vs. $593,715) because of the decreased incidence of shunt infection in the AI cohort. A similar cost savings has been demonstrated in the adult population. Farber et al. (15) reported that AI shunt catheters were associated with a direct cost savings of $47,193 per 100 shunt surgeries performed. The reluctance of providers and health care systems to adopt AI catheters into routine practice has largely been secondary to the direct initial cost of these systems. Each AI catheter costs approximately $400.00 more than a standard shunt catheter, which can represent a significant upfront cost in high-volume centers (13, 26). However, when considering the significant cost savings associated with the reduction in infection reported here, AI shunt catheters may be extremely cost-effective.

Analyses of large, administrative databases such as this one can provide valuable information but have inherent limitations with regard to determination of causality. As with all retrospective analyses, it was not possible to control completely for patient and surgeon characteristics that may affect the selection of treatment or the risk of infection. The neonate population could not be assessed with this data set because of an insufficient number of patients to compare. Because neonates are at particular risk for CSF infection, further studies are warranted to better understand this patient cohort. The costs reported here represent only inpatient hospitalization costs and are limited to charges occurring within 1 year after the index shunt procedure. Costs after discharge, such as home health, rehabilitation, missed work, and lost productivity, were not assessed in the current study, and these factors can contribute a significant component to the overall costs of treatment in this patient population. It is also possible that infection occurred beyond the 1-year follow-up period for this study. All of these factors would increase further the costs associated with CSF infections in this patient population. Although randomized controlled trials remain the "gold standard" for assessing safety and efficacy and would control for potential catheter selection bias inherent in an observational study, administrative databases provide the ability to assess multiple risk factors and the association of different treatments with clinical and economic outcomes among extremely large cohorts. Results from large population studies are more likely to be generalizable to the average patient undergoing these procedures.

CONCLUSIONS

In analysis of a large, nationwide database, AI catheters were found to be associated with a significant reduction in incidence of infection, resulting in cost savings. AI catheters were associated with a cost savings of $42,125 and $230,390 per 100 de novo shunts placed in adult and pediatric patients, respectively.

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