IMPLANTED VENTRICULAR SHUNTS IN THE UNITED STATES: THE BILLION-DOLLAR-A-YEAR COST OF HYDROCEPHALUS TREATMENT

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OBJECTIVE: To characterize admissions related to ventricular shunts in the year 2000 in terms of diagnoses, procedures, socioeconomic status, and other related data.

METHODS: The Nationwide Inpatient Sample database (year 2000) was analyzed retrospectively. We reviewed 7.45 million patient admissions for primary *International Classification of Diseases, 9th Revision,* procedure codes 023 to 0243 (ventricular shunts to peritoneal, atrial, pleural, and urinary systems for initial placement, revision, and removal); admissions listing ventriculostomy placement (code 022) were excluded from analysis.

RESULTS: Five thousand five hundred seventy-four admissions were identified. Admission sources primarily were routine (58.8%) and the emergency department (32.4%). Admission types primarily were elective (43.3%), emergent (33.2%), and urgent (21.9%). The top three primary diagnoses treated were shunt malfunction (40.7%), noncommunicating hydrocephalus (16.6%), and communicating hydrocephalus (13.2%). Shunt infection was the primary diagnosis in 7.2% of admissions. Age frequency of admissions was nonparametric, being highest for infants; the average stay was 8.4 ± 0.2 days (standard error range, 0–243 d). The most common procedures were ventriculoperitoneal shunt placement (43.4%) and ventricular shunt replacement (42.8%); ventricular shunt removal occurred in 7.3% of admissions, whereas ventricle-to-thorax (0.6%), ventricle-to-circulatory system (0.5%), and ventricle-to-urinary system (0.05%) shunts were rare. Average cost was $35,816 ± $810 (standard error range, $137–$814,748). Primary payers primarily were private insurers (43.8%), Medicare (26.0%), and Medicaid (24.5%). Disposition mainly was routine (78.4%, with home health care in 6.5%), and inpatient mortality was 2.7%. There was no socioeconomic disproportion in treatment with respect to average household income.

CONCLUSION: Ventricular shunts as primary procedures constitute a significant medical and economic problem.

KEY WORDS: Economic, Inpatient, Ventricular shunts

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Ventricular shunts remain one of the most common neurosurgical procedures performed. The high number of patients with hydrocephalus (receiving both virgin and revised shunts), multiplied by ever-changing technology, results in significant monetary cost from a national perspective. The goals of the present study were to examine a number of questions for which answers are not readily available in the literature: 1) approximately how many patients nationally are involved in a given year, where are they referred from, and for what diagnoses?; 2) what proportion are ventriculoperitoneal, ventriculopleural, ventriculoatrial, and ventriculourinary system shunts?; 3) did lower-income patients undergo ventricular shunt-related procedures in a different proportion?; 4) what is the average cost per related admission and the total cost per year in the United States, and who are the primary payers?; and 5) what is the disposition and mortality of these patients?

PATIENTS AND METHODS

A retrospective study reviewing the Nationwide Inpatient Sample (NIS) database for the year 2000 was conducted. A total of 7.45 million patient admissions were analyzed for the primary *International Classification of Diseases, 9th Revision,* procedure codes 023 to 0243, which included ventricular shunts to peritoneal, atrial, pleural, and urinary systems for initial placement, revision, and removal. The variables listed above were

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analyzed, along with age. Ventriculostomy placement as a primary diagnosis (code 022) was excluded from this analysis.

The quality of the cost data was limited to charges incurred (and not actual cost data with respect to collections, because this parameter is not available through the database). Also, cost data were standardized by the type of payer.

Attributes of the NIS as a Source of Data

Capabilities and limitations of the NIS were reviewed previously (20) and are considered in an overview herein. Overview of information regarding the NIS is currently available at http://www.ahcpr.gov/data/hcup/nisintro.htm, the source for the following information regarding this database.

The NIS is a database of hospital inpatient stays, containing data from approximately 7 million hospital stays. According to compilers of this database, it "is the only national hospital database with charge information on all patients, regardless of payer, including persons covered by Medicare, Medicaid, private insurance, and the uninsured. Inpatient stay records in the NIS include clinical and resource use information typically available from discharge abstracts. Hospital and discharge weights are provided for producing national estimates. The NIS can be linked to hospital-level data from the American Hospital Association's Annual Survey of Hospitals and county-level data from the Bureau of Health Professions' Area Resource File, except in those States that do not allow the release of hospital identifiers." The sampling and weighing strategy has been revised to improve the representativeness of the data. One hundred percent of discharges from approximately 1000 sampled hospitals are included in the NIS database. As such, total volume of specified procedures (regardless of age or payer) is represented by the NIS. Overall, compilers of the NIS have designed it to reflect "approximately a 20-percent sample of U.S. community hospitals, defined by the American Hospital Association as 'all nonfederal, short-term, general, and other specialty hospitals, excluding hospital units of institutions.' Included among community hospitals are specialty hospitals such as obstetrics-gynecology, ear-nose-throat, short-term rehabilitation, orthopedic, and pediatric institutions. Also included are public hospitals and academic medical centers. Excluded are short-term rehabilitation hospitals (beginning with 1998 data), long-term hospitals, psychiatric hospitals, and alcoholism/chemical dependency treatment facilities. The NIS is a stratified probability sample of hospitals in the frame with sampling probabilities proportional to the number of U.S. community hospitals in each stratum; in turn, the frame is limited by the availability of inpatient data from the data sources. To facilitate the production of national estimates, both hospital and discharge weights are provided by the database, along with information necessary to calculate the variance of estimates."

RESULTS

A total of 5574 admissions were identified. Admission sources (*Fig. 1*) were the emergency department in 32.4%,

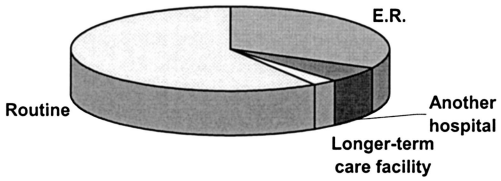

FIGURE 1. *Pie graph illustrating the referral pattern for ventricular shunt admissions.* E.R., *emergency room.*

another hospital in 6.2%, a longer-term care facility in 2.6%, and routine/other in 58.8% of admissions. The type of admission (*Fig. 2*) was considered emergent in 33.2%, urgent in 21.9%, and elective in 43.3% of admissions; 1.6% of the admissions were newborns. The top three most commonly treated diagnoses (*Fig. 3*) were shunt malfunction (40.7%), noncommunicating hydrocephalus (16.6%), and communicating hydrocephalus (13.2%); shunt infection was the primary diagnosis in 7.2% of admissions. Spontaneous intracerebral hemorrhage or subarachnoid hemorrhage was the primary diagnosis for 1.9 and 1.8% of admissions, respectively, with shunt placement listed as a primary procedure. Median age was 31 years (range, 0–93 yr). Average length of stay was 8.4 $\pm$ 0.2 days (standard error range, 0–243 d). The most common two procedures were ventriculoperitoneal shunt placement (43.4%) and ventricular shunt replacement (42.8%); ventricular shunt removal was listed in 7.3% of admissions, whereas ventricle-to-thorax, ventricle-to-circulatory system, and ventricle-to-urinary system shunts were placed in 0.6, 0.5, and 0.05% of admissions, respectively (*Fig. 4*). Data regarding ventricle-to-gallbladder shunts did not have a specific code and hence could not be uniquely analyzed; those shunt procedures, if performed, could be included in the 249 (4.5%) of 5574 of admissions undergoing "other" procedures. There was no apparent disparity with respect to socioeconomic status in admissions studied (one-sample test of proportion, $P > 0.10$) comparing different socioeconomic statuses in the context of their respective representation in the database. The average cost was \$35,816 $\pm$ \$810 (standard error range, \$137–\$814,748). Primary payer proportion (*Fig. 5*) was as follows: private insurance, 43.8%; Medicare, 26.0%; Medicaid, 24.5%; self-pay, 2.7%; no charge, 0.18%; and other, 2.8%. Disposition (*Fig. 6*) was routine for 78.4% of admissions (with 6.5% receiving home health care), transfer to a short-term care facility for 1.9% of admissions, and transfer to a longer-term care facility

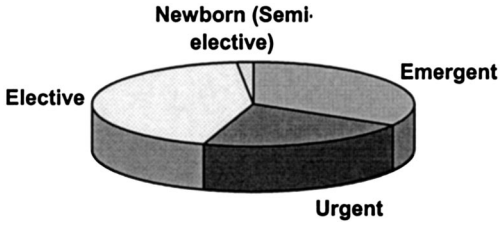

FIGURE 2. *Pie graph illustrating the type of admissions with respect to urgency.*

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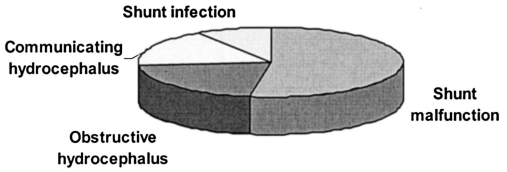

FIGURE 3. *Pie graph illustrating the distribution of most common diagnoses treated.*

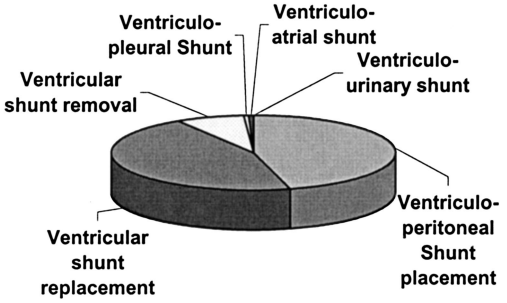

FIGURE 4. *Pie graph illustrating the procedure types (including distal catheter sites).*

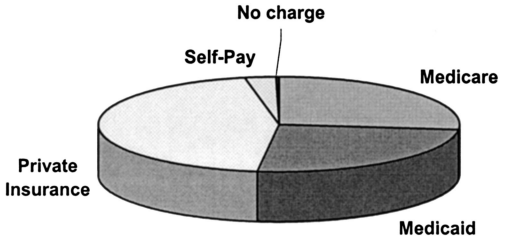

FIGURE 5. *Pie graph illustrating the primary cost provider distribution.*

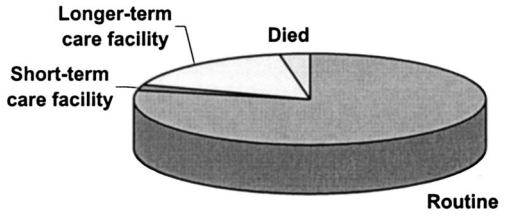

FIGURE 6. *Pie graph illustrating the discharge disposition of patients by location.*

for 17.1% of admissions. For all admissions primarily involving a shunt-related procedure, inpatient mortality was 2.7%.

The age, length of stay, and total charges per admission are shown in *Figure 7*. A secondary procedure dealing with a ventricular shunt was performed in 1176 patient admissions; among these, 368 admissions had a shunt-related procedure listed as both primary and secondary procedures. These would have been included in the 5574 admissions, whereas the remaining 808 admissions had a non-shunt-related procedure listed as a primary procedure. Among these 808, a total of 336 primary procedures involved a cranial procedure ("incision of meninges, unspecified brain excision, or related procedures," including 94 for aneurysm clipping); 142 admissions listed "ventriculostomy" as the primary procedure. Other primary procedures for which ventricular shunt-related procedures were listed as secondary included myelomeningocele repair (28 procedures) and tracheostomy (30 procedures, likely because of a primary diagnosis and here illustrating the difference in coding). *Figure 8* shows total admissions with primary versus primary/secondary versus primary/secondary/tertiary procedures (during one admission) coded as relating to ventricular shunts.

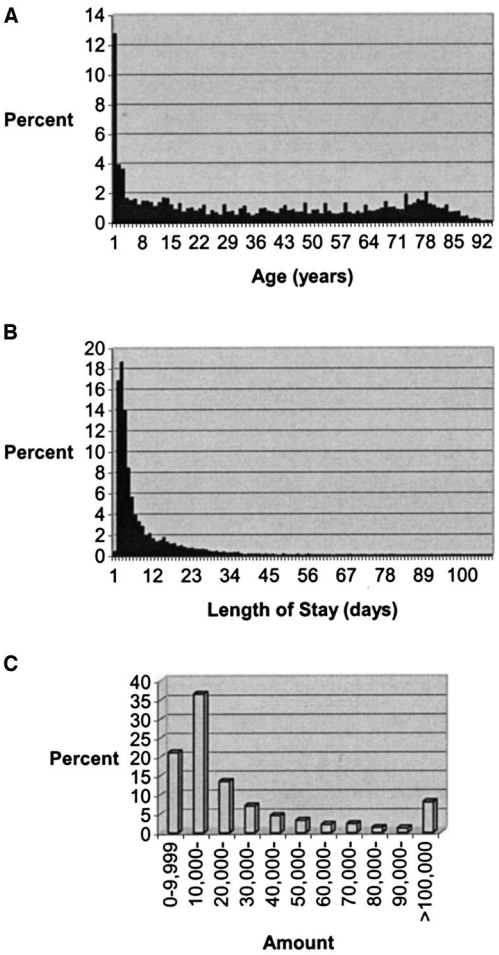

FIGURE 7. *Histograms of age* (A)*, length of stay* (B)*, and total charges for ventricular shunt-related admissions* (C)*.*

DISCUSSION

Number of Patients, Referral Sources, and Urgency

A total of 5574 admissions were noted for the year 2000. Because the NIS database represents 20% of the United States, this indicates that a total of approximately 27,870 patients had shunt-related primary procedures in the year 2000. According to a PubMed search retrieving articles before August 19, 2003

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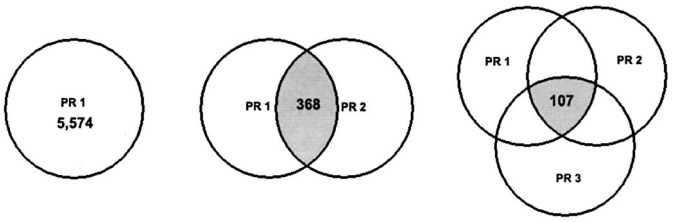

FIGURE 8. *Venn diagrams showing all admissions undergoing a ventricular shunt-related procedure as a primary procedure (*PR1*) (*A*), those admissions undergoing ventricular shunt-related procedures as both primary and secondary procedures (*PR1 *and* PR2*) (*B*), and those undergoing ventricular shunt-related procedures as the three primarily coded procedures (*PR1, PR2, *and* PR3*) during the same admission (*C*). As seen in* C*, 107 (1.9%) of all ventricular shunt-related admissions underwent three procedures during the same admission.*

(using the keywords *shunt, ventricular, United States,* or *shunt procedures, cerebrospinal fluid*), only one study estimating the epidemiological/economic impact of cerebrospinal shunts in the United States was retrieved (1). According to this study, approximately 69,000 discharges each year with the diagnosis of hydrocephalus were noted, with nearly 36,000 shunt-related procedures (33,000 of which involved the placement of a shunt). Another study noted approximately 16,000 shunt-related operations in the United States in the year 1988 (7).

Figure 2 depicts the level of urgency. Interestingly, although emergent and urgent admissions constituted 55.1% of admissions, more than 43% were elective admissions.

Virgin Shunts, Revisions, and Sites

The incidence of hydrocephalus is difficult to quantify overall; it may be extrapolated from the number of new ventricular shunts placed each year. The results of the present study indicate that, of 5574 patient admissions, 16.6% were for noncommunicating hydrocephalus and 13.2% were for communicating hydrocephalus (*Fig. 3*). Because 29.8% of the sample seems to be new operations, we estimate that 8305 new cases of hydrocephalus were treated in the United States in 2000.

Shunt malfunction occurred in 40.7% of admissions, whereas infection was noted as the primary diagnosis in 7.2% of all shunt-related procedures. This is comparable with previously published data for infection (14) and malfunction (2, 15) that found correlations with younger age, the surgeon's experience, and prior revision of the same shunt. In an analysis of 1183 shunt failures in 839 patients, failure time from the first shunt procedure was an important predictor for the second and third episodes of failure, thus establishing an association between the times to failure within individual patients. That study also found an age younger than 40 weeks of gestation at the time of the first shunt implantation carried a hazard ratio of 2.49 for malfunction; the cause of hydrocephalus was significantly associated with the risk of initial failure and, to a lesser extent, of later failures. Concurrent other surgical procedures also were associated with an increased risk of failure (22). Although we compare our results in the context of the prior literature, this comparison is not strictly accurate because the previously published data relate to malfunction and infection rates after a shunt has been inserted, whereas data from the current study relate simply to the diagnosis related to a shunt operation.

As expected with respect to distal site, ventriculoperitoneal shunts were the most common; however, it is important to note that ventriculopleural (0.6%, or approximately 167 per year) and ventriculoatrial shunts (0.5%, or approximately 139 per year) continued to be performed, as did ventriculourinary system shunts (0.05%, or approximately 14 procedures for the year 2000). Ventriculoperitoneal shunts generally are associated with less severe complications than ventriculoatrial shunts (6, 13, 16). Traditionally, ventriculopleural and ventriculoatrial shunts have been used to varying degrees as alternative options to ventriculoperitoneal shunting (17); ventriculourinary shunts have been performed rarely (2, 18, 24). There is evidence that greater surgical experience correlates with fewer shunt-related problems (3).

Figure 8 depicts the number of patients who underwent multiple procedures during the same admission, in comparison to those who underwent a single procedure. A search limiting the database to those patients undergoing primary and secondary ventricular shunt-related procedures revealed 427 entries. Among these, the most common diagnoses were related to mechanical complication (listed as a primary diagnosis in 169 admissions [39.6%], and as a secondary diagnosis in 137 admissions [32.3%]) and infections (listed as the primary diagnosis in 112 admissions [26.2%] and a secondary diagnosis in 7.1% of admissions).

Age at Admission

Figure 7A shows the age distribution of patient admissions for ventricular shunt-related procedures. Analysis of these data shows a nonparametric distribution, with highest number of admissions for age 1 year or younger; this trend tends to plateau after age 3 years, and thereafter a small increase in incidence is observed for the late 70- to early 80-year-old patients. This is not dissimilar to existing data, which suggest that a significant number of shunt revisions occur in younger patients in comparison with the older population (21). Tuli et al. (22), in a study that attempted to predict factors associated with failure of shunts, cited age as an important consideration; age from 40 weeks of gestation to 1 year (at the time of the initial surgery) proved to be an important predictor of first shunt malfunctions (hazard ratio, 1.77; 95% confidence interval, 1.29–2.44). Davis et al. (4), in a study performed to determine the role of age in shunt infections, found no significant difference in comparing subgroups of patients age 1 year or younger versus those older than 1 year of age at admission.

Length of Stay

Length of stay analysis, represented by *Figure 7B*, yields a nonparametric distribution, with more than 50% of patients being discharged within 5 days after admission. Perhaps more

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remarkable is that nearly 50% of patients required a hospital stay of more than 5 days. Although the reasons for this likely are multifactorial, attributable to the initial level of morbidity sustained from hydrocephalus, comorbidity from an associated or unassociated process, or multiple shunt-related procedures performed during the same admission, this remarkable trend suggests that in all patients admitted in the year 2000 for a ventricular shunt-related primary procedure, nearly one of two will be hospitalized for more than 5 days.

Comparison with prior relevant data regarding length of stay after shunt-related procedures reveals a similar trend, although such data are scarce and are not always phrased in a comparable context. For example, a Spanish study found the average "ICU stay" was 8.2 days (8). A British study revealed an average yearly stay of 5.1 days (26 d over 5 yr) while auditing the Hakim valve (12).

Socioeconomic Status

Our study did not find any overwhelming disproportion in admissions of these groups, relative to their representation in the database (as noted under Results). There is little evidence from the literature that children with specific shunt infections may fare more poorly because of a poorer socioeconomic background (19). However, poor socioeconomic status was thought to play a role in the latency of presentation for patients who had hydrocephalus in countries with less well-developed medical systems (23). The literature is relatively sparse with respect to the topic of socioeconomic status and cerebrospinal fluid shunt allocation.

Cost per Admission, Total National Cost, and Primary Payers

Because hydrocephalus is one of the most frequently encountered problems in neurosurgery today, cost considerations for shunts are paramount. Valve technology continues to be evaluated (25), driving up the cost in many cases. We found an average cost of $35,816, which projects to more than $1.1 billion for the United States for the year 2000. A Canadian study focused on Manitoba found similar costs per population: for 1.1 million persons, the number of discharges with a primary diagnosis of hydrocephalus was more than 200 annually, 80 shunt procedures were performed annually, and the annual cost of inpatient care was estimated to be $3.5 million (in Canadian dollars) (5).

The trend of total charges per admission is depicted in *Figure 7C*, which shows, once again, a nonparametric distribution, with the most significant peak indicating charges of $10,000 to $19,999 per admission. A steadily decreasing trend is thereafter noted in *Figure 7C*, with a significant proportion charged more than $100,000. Because total charges can be influenced by a number of variables including comorbidity and multiple shunt procedures (and other non-shunt-related procedures) performed during the same admission, the analysis becomes difficult and data gleaned from this limited analysis merit cautious interpretation.

Primary payer proportion (*Fig. 5*) revealed private insurance to be the greatest cost provider (43.8%), followed by Medicare (26.0%) and Medicaid (24.5%). "Free" or no-charge care was provided to only approximately 50 patients over the entire year in the United States, as projected from data acquired from this study.

Disposition and Mortality

Disposition (*Fig. 6*) was routine in 78.4% of admissions (with 6.5% receiving home health care), was transfer to a short-term care facility in 1.9% of admissions, and was transfer to a longer-term care facility in 17.1% of admissions. For all admissions primarily involving a shunt-related procedure, inpatient mortality was 2.7%. Although the inpatient mortality rate found in our study is higher than reported previously (10, 11), this is probably because non-hydrocephalus-related causes of mortality cannot be excluded in our analysis. One important aspect of this analysis is also that the more specific cause of hydrocephalus (other than communicating or noncommunicating, for example, for postintraventricular hemorrhage in premature babies, normal-pressure hydrocephalus, or myelomeningocele) cannot be gleaned reliably from this database. Such analysis is important in that myelomeningocele patients have a significantly higher mortality rate of 11.8% (21) compared with other underlying problems (such as normal-pressure hydrocephalus, which has an associated combined risk of mortality or permanent deficit of approximately 6% [9]).

Limitations of the Database

Although the NIS data offer reasonable analyses of numerous aspects of data pertinent to ventricular shunts, several limitations exist. For example, it is not possible to note which patients were readmitted during the same year for a ventricular shunt-related procedure. In addition, a ventricular shunt revision is not always able to be classified further with respect to the site of revision.

The validity of coding also is important. For example, if a patient with subarachnoid hemorrhage underwent ventriculostomy placement, craniotomy for aneurysm clipping, and then a ventriculoperitoneal shunt placement, then the craniotomy or ventriculostomy may have been coded as the primary procedure. Because the goal of the present study was to determine those admissions in which the ventricular shunt-related procedures were primary, a more comprehensive analysis was conducted whereby all procedures with ventricular shunt-related as the secondary procedure shunt were analyzed for type of primary procedure coded. It was found that a secondary procedure dealing with a ventricular shunt was performed in 1176 patient admissions; among these, 368 admissions had a shunt-related procedure listed as both primary and secondary procedures. Hence, these would have been included in the 5574 admissions, whereas the remaining 808 admissions had a non-shunt-related procedure listed as a primary procedure. Among these 808, a total of 336 primary

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procedures involved a cranial procedure ("incision of meninges, unspecified brain excision, or related procedures," including 94 for aneurysm clipping); 142 admissions listed ventriculostomy as the primary procedure. Other primary procedures for which ventricular shunt-related procedures were listed as secondary included myelomeningoceles (28 procedures) and tracheostomy (30 procedures, likely because of a primary diagnosis and here illustrating the difference in coding). We have added an additional illustration (*Fig. 8*) that uses Venn diagrams to show total admissions whose primary, secondary, and tertiary procedures (during one admission) all related to shunts.

In a separate analysis, it was found that ventricular shunt-related procedures were coded as the primary procedure for 5574 admissions, as secondary procedures in 1182 admissions, as tertiary procedures in 816 admissions, as the fourth procedure in 431 admissions, and as the fifth procedure in 287 admissions.

CONCLUSIONS

Ventriculoperitoneal shunts constitute a significant medical problem, in terms of both urgency of treatment and economic costs (which approximate $1 billion for the United States for the year 2000) if only admissions that list a shunt-related procedure as a primary diagnosis are counted. The inpatient mortality rate for admissions listing a shunt-related procedure as primary is 2.7%. This underscores the need for better technology for treatment of shunt infections, malfunctions, and other reasons resulting in shunt revisions.

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COMMENTS

The authors of this article performed a retrospective review of the National Inpatient Sample database for the year 2000 and estimated that there were 5574 patients who had a shunt either inserted, revised, or removed. They calculate that the average cost per patient was $35,861 and the total cost to be $1.1 billion in the United States for the year 2000. Their conclusion is "ventricular shunts as primary procedures constitute a significant medical and economic problem."

There is no question that the best way to avoid shunt problems is not to insert shunts. One would hope that all the shunts that were inserted or revised were done so because there was no other option in treating the hydrocephalus. Before the development of shunt technology, those with hydro-

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cephalus sustained either central nervous system injury or death. To say that cerebrospinal fluid-diverting shunts constitute a significant medical and economic problem is to state that the development of chemotherapy to treat leukemia is a problem or that the cost of vaccinating against polio, pertussis, tetanus, etc., is an economic problem. Agreed, a significant reduction in the complications of the shunting would certainly diminish costs. The elimination of obstruction and infection would certainly reduce the number of operative procedures that are required. The demographics of the patients receiving shunts is a moving target. The percentage of premature infants who develop intraventricular hemorrhage and resultant hydrocephalus has dropped remarkably, as has that of newborns with myelomeningoceles. These are two groups that often require multiple shunting procedures. Conversely, the number of elderly patients who develop normal-pressure hydrocephalus is on the increase. In this patient group, the complications also include either underdrainage or overdrainage to a much higher degree.

J. Gordon McComb
Los Angeles, California

The authors have retrospectively reviewed the Nationwide Inpatient Sample database for the year 2000 with respect to admissions for ventricular shunt procedures. The goals of the review were to characterize the demographics, diagnoses, types of shunt procedures, costs related to admission, socioeconomic status, and the disposition and mortality of these patients. This information about ventricular shunts will be of interest to those involved in the management of patients with hydrocephalus. There are no surprises in this study, which provides an overview of the issues using a large database.

Paul Steinbok
Vancouver, British Columbia, Canada

This article describes the admissions related to ventricular shunt in 1 year (2000) from the Nationwide Inpatient Sample database of 7.45 million admissions. A considerable amount of information is gleaned, such as from where the patients were admitted, urgency of admission, proportion of newborns, primary diagnosis, average stay, and procedure type shunt placement (43.5%) and shunt revision (42.8%), as well as the average cost of $35,816. Inpatient mortality was 2.7%. Extrapolating from the data, the authors estimate approximately 28,000 shunt-related procedures per year, at a cost of more than 1 billion dollars.

This analysis is quite similar to one conducted 1995, and the estimates of shunt procedures are fairly simple. The authors of this report used what seems to be a much larger database and more up-to-date data. The epidemiology of cerebrospinal fluid hydrocephalus and shunting is important to understand the prevalence of the problem, some idea of the demographics of the patients, their outcomes, and the costs. The costs, both economically and in patient morbidity and mortality, are significant. Almost half of the procedures were shunt revisions, an indication of the persistent shortcomings of these devices as a treatment.

James M. Drake
Toronto, Ontario, Canada

World Federation of Neurosurgical Societies Web Site

On behalf of the World Federation of Neurosurgical Societies, I would like to invite you to log onto the web site of the WFNS at www.wfns.org. Our web site editor, Dr. Eduardo A. Karol of Argentina, has done a wonderful job in presenting on the web site not only information about the many activities of the WFNS, but also opportunities for young neurosurgeons all around the world to communicate with each other and to participate in web-based educational activities. These include interesting cases, clinicopathological conferences, and the web-based journal *Critical Reviews*, the official electronic journal of the WFNS. We hope you will participate. Those of you who would like to become more involved in the WFNS web site activities are very welcome to volunteer your efforts, which will be much appreciated.

Edward R. Laws, Jr.
President

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