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Use of programmable versus nonprogrammable shunts in the management of normal pressure hydrocephalus

A multicenter retrospective study with cost–benefit analysis in Turkey

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Abstract

Ventriculoperitoneal shunt systems that are used in the treatment of normal pressure hydrocephalus are often associated with drainage problems. Adjustable shunt systems can prevent or treat these problems, but they may be expensive. The aim of our study is to compare the complications and total cost of several shunt systems.

Patients with normal pressure hydrocephalus who underwent ventriculoperitoneal shunting between 2011 and 2016 were included in the study. The study involves patient consent and the informed consent was given. Complications and the average cost per person were compared between patients with adjustable and nonadjustable shunts. Shunt prices, surgical complications, and revision costs were taken into account to calculate the average cost.

Of the 110 patients who were evaluated, 80 had a nonadjustable shunt and 30 had an adjustable shunt. In the group with adjustable shunts, the rates of subdural effusion and hematoma were 19.73% and 3.29%, respectively. In the group with nonadjustable shunts, these rates were 22.75% and 13.75%, respectively. One patient in the adjustable group underwent surgery for subdural hematoma, while 8 patients in the nonadjustable group underwent the same surgery. Ten patients required surgical intervention for subdural effusion and existing shunt systems in these patients were replaced by an adjustable shunt system. When these additional costs were factored into the analysis, the difference in cost between the shunt systems was reduced from 600 United States dollars (USD) to 111 USD.

When the complications and additional costs that arise during surgical treatment of normal pressure hydrocephalus were considered, the price difference between adjustable and nonadjustable shunt systems was estimated to be much lower.

Abbreviations: AdSSs = adjustable shunt systems, CT = computed tomography, NAdSSs = nonadjustable shunt systems, NPH = normal pressure hydrocephalus, OP = opening pressure, SSI = Social Security Institution, USD = United States dollars, VP = ventriculoperitoneal.

Keywords: adjustable shunt, cost effective, hydrocephalus, normal pressure hydrocephalus, shunt, Turkey

1. Introduction

Normal pressure hydrocephalus (NPH) is a chronic disorder in which patients present with impaired gait, urinary disturbances, and complaints of mild cognitive impairment.[1–4] NPH is typically found in the elderly population, with several population-based studies reporting a prevalence of 21.9 per 100,000 people and an incidence of about 5.5 patients per 100,000 people per year.[5,6] Unfortunately, however, the diagnosis of NPH is confounded by other diagnoses, most notably cerebrovascular disease or neurodegenerative disorders.[7] Despite advances in medical knowledge, there is no clear clinical picture or diagnostic test currently available to distinguish NPH from other dementias.[8]

Ventriculoperitoneal (VP) shunt systems are used in the treatment of this illness. The first VP shunt system was introduced by Holter and Spitz in 1956.[9] Approximately 130 different types of shunts currently exist.[10] Although VP shunt surgery is still the gold standard treatment strategy for this disorder, the indications for surgery remain controversial.[11] Given that shunt surgery in elderly patients is often associated with complications, many investigators have sought to develop new surgical indication guidelines, but a consensus has not yet been reached.[11–15]

At the end of the 1980s, adjustable shunt systems (AdSSs) were described by Black et al.[16] In these shunt systems, the opening pressure (OP) can be transcutaneously adjusted, whereby complications related to under- or over-drainage can be prevented or fixed in a noninvasive manner. Thus, AdSSs can

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reduce the rate of complications. The cost of AdSSs in our country, however, is 2 to 6 times more than that of other types of shunt systems, and thus, AdSSs are not often preferred.

When compared with the total cost of treatment and care for complications in elderly patients from hydrocephalus surgeries,[17–19] however, AdSSs are relatively inexpensive. Adjustment of the OP can prevent various complications that arise from the shunt surgery, such as subdural effusions and hematomas,[20] and can also prevent shunt changes due to these complications. Taking this into consideration, the price difference between these 2 shunt types is likely not as high as predicted.

There are several studies about the cost effectiveness of AdSSs in hydrocephalus, but only a limited number of studies with a specific focus on NPH. The aim of our retrospective study was to evaluate and compare the total cost of AdSSs and nonadjustable shunt systems (NAdSSs) exclusively in NPH patients.

2. Materials and methods

In this multicenter retrospective study, data from patients with NPH who underwent VP shunt surgery between June 2011 and March 2016 at Mustafa Kemal University in Antakya, Turkey, Ataturk University Medical Park Hospital in Erzurum, Turkey, and Bahcesehir University in Istanbul, Turkey were collected and analyzed.

A spinal tap test was performed in all patients over 3 consecutive days with drainage of at least 20 mL of cerebrospinal fluid. OP was also measured in all patients. After 3 days, a clinical evaluation was conducted to determine which patients would benefit from shunt implantation.

Shunt surgeries were performed with standard shunt surgery techniques and the decision about the type of shunt that was used (AdSS or NAdSS) and the selection of the OP value for each patient was based on the surgeon's preference.

There were 3 different OP types of the NAdSSs: 30 to 80 mm H_2O for the low-pressure shunt type, 80 to 120 mm H_2O for the medium-pressure shunt type, and 120 to 170 mm H_2O for the high-pressure shunt type. Two types of AdSSs were used. The OP of the first AdSS ranged from 30 to 200 mm H_2O in steps of 10 mm H_2O. The OP of the second AdSS ranged from 20 to 145 mm H_2O. Within the first 24 h after surgery, all patients underwent computed tomography (CT) scans to verify the placement of the ventricular catheter. CT scans were then also performed at 1, 3, 6, and 12 months postoperation. Neurologic examinations (mini mental examination and walking test) were performed at 1, 3, 6, 12, and 24 months postoperation.

2.1. OP adjustment

The selection of the value for the first OP adjustment was dependent on the surgeon's decision and was set while the valve was in its sterile package. The median OP setting was 130 mm H_2O at the time of implantation (range: 40–145 mm H_2O). After the operation, the OP settings were verified with a plain skull radiograph. Postoperative OP adjustment was gradually lowered and was done according to clinical and imaging follow up. A total of 62 adjustments were made in 21 patients. The average number of adjustments was 2.9 times per person.

2.2. Cost calculation

The cumulative treatment costs were calculated by including the costs of the primary shunt surgery, the shunt system, and, if applicable, the complication surgery. The Republic of Turkey Social Security Institution (SSI) payment rules of 2016 formed the basis for the cost calculation. The costs of the surgeries, medical equipment, and radiological evaluations were calculated by converting the price per patient that was billed to the SSI to United States dollars (USD) using the exchange rate.

The cost of the shunt surgery was 520 USD (including hospital admission, unlimited days at the ward, and postoperative care). The cost of an AdSS was 975 USD and the cost of an NAdSS was 375 USD. The cost of the complication surgery (subdural collection or hematoma evacuation) was 480 USD. According to the SSI payment rules, the cost of the radiological evaluations, care, and OP adjustments were disregarded.

2.3. Patient groups

Patients were retrospectively analyzed for age and sex. The implanted shunt type, complications, and any additional surgeries were also noted. All patients were classified into 2 groups according to the implanted shunt type (AdSS or NAdSS).

3. Results

A total of 110 patients were included in this study. The total observation time was 72 months (minimum observation period, 12 months). Thirty patients received an AdSS and 80 patients received an NAdSS. The age of the patients at the time of the first surgery ranged from 36 to 82 years. The mean ages were 62 years for patients who received an AdSS and 61 years for patients who received an NAdSS. Among all patients, the most common complication was effusion (21.74%), followed by chronic subdural hematoma (10.8%) and shunt dysfunction and infection (6.34%) (Table 1).

3.1. AdSS group

For patients who received an AdSS, the total complication rate was 26.33% (Table 2). The most common complication was subdural effusion, which was seen in 6 patients (19.7%). All of these patients were treated with OP adjustment alone and none required surgical drainage. Nontraumatic subdural hematoma was observed only in 1 patient (3.3%) and required surgical drainage. Infection was observed in 1 patient and was treated with intravenous antibiotic administration. Shunt revision was never performed in these patients.

The total cost of the surgery was 520 USD + 975 USD = 1495 USD × 30 patients = 44,850 USD. The additional cost of the

Table 1

All patients' complication rates.

Effusion	21.74%
Hematoma	10.87%
Dysfunction	6.34%
Infection	6.34%

Table 2

Adjustable shunt system group's complication rates.

Effusion	19.75%
Hematoma	3.29%
Infection	3.29%

Table 3

Nonadjustable shunt system group's complication rates.

Effusion	22.5%
Hematoma	13.75%
Dysfunction	8.75%
Infection	7.50%

complication surgery that was performed to relieve the subdural hematoma in 1 patient was 480 USD. The total cost was determined to be 45,330 USD and the average costs per capita were determined to be 1511 USD for patients who received an AdSS.

3.2. NAdSS group

Seventy-nine patients in this group received a medium-pressure NAdSS and 1 patient received a low-pressure NAdSS. The total complication rate was 52.5% (Table 3). The most common complication was subdural effusion, which was seen in 18 patients (22.5%). Of these patients, 8 were followed closely and the effusions were reabsorbed on their own. In 10 patients, the shunt systems were changed to an AdSS.

Nontraumatic subdural hematoma was observed in 11 patients (13.7%). Of these patients, 8 required surgical evacuation and all of their shunt systems were changed to an AdSS. Two of these patients were treated with a shunt tie and 1 had a hematoma that was resorbed. Two of the 8 patients who underwent this surgery developed an infection and both of them died. Shunt infection was observed in 6 patients (7.5%) and 2 of these patients died. Shunt dysfunction was observed in 7 patients (8.7%). The shunt systems were changed in these patients, but an AdSS was not selected.

The total cost of the NAdSS surgery was 520 USD + 375 USD = 895 USD × 80 patients = 71,600 USD. Shunt replacement with an AdSS was performed in 18 patients due to complications (effusion or hematoma). The additional cost of these surgeries and shunt systems were 18 × 1495 USD = 26,730 USD. Evacuation surgery was performed in 8 patients because of subdural collection. The additional cost of these surgeries was 8 × 480 USD = 3840 USD. Replacement of the original shunt with the same type of shunt was performed in 11 patients due to infection and shunt dysfunction. The additional cost of these surgeries was 11 × 895 USD = 9845 USD. The total cost was determined to be 112,015 USD and the average cost per capita was determined to be 1400 USD among patients who received a NAdSS.

The difference in cost between the AdSS and the NAdSS was initially determined to be 600 USD. When the costs of shunt revisions and the operations that were performed due to complications were considered, the difference between these shunt types was reduced to 111 USD.

4. Discussion

NPH is a disease that occurs primarily in the elderly population.[21] Tanaka et al determined the prevalence of possible NPH in elderly adults to be 1.4% (95% confidence interval = 0.6–2.9).[6] Evident changes in mortality and fertility rates will lead to the aging of the world population in the twenty-first century.[22] From the year 2000 to 2030, the proportion of those age >65 years is projected to increase from 15.5% to 24.3% of the total population in Europe.[23,24] Furthermore, the number of people in the population who are 85 years and over was 9.3 million in 2000 and is predicted to rise to 19.5 billion by 2030.[22] In the future, we are therefore likely to encounter many more people with NPH disease.

Shunt surgery is the easiest and the most common treatment strategy for NPH, but unfortunately up to 51.9% of surgeries are associated with complications and require shunt revisions.[25,26] The most common shunt complication during the first year is over-drainage, which can occur in up to one-third of patients.[27–29]

Large series retrospective studies of complications in patients with VP shunting, which have included patients with pediatric hydrocephalus, reported that the most common complication was proximal and distal shunt occlusions, with complication rates ranging from 40% to 50%, while the next most common complication was infections, with a rate of 5% to 15%.[30–39] Due to NPH, the most common complications that are seen in shunt-attached patients have been shown to be over-drainage and under-drainage. The infection rate in these patients is between 5% and 10%, which is close to the complication rates detected in pediatric hydrocephalus cases.[13,15,40,41]

The results of Wu et al's retrospective studies of 11,550 adults and 13,889 pediatric cases between 1990 and 2000 support this data. This study showed that the most common complication that develops in pediatric cases is shunt dysfunction; in NPH patients, the most common complication was subdural effusion.[42] In our study, the most common complication was over-drainage and issues associated with over-drainage (such as subdural effusion and hematoma), which occurred at a rate of 32.61%.

These data align with the results of our study and support the hypothesis that the use of AdSSs will reduce the rate of complications after NPH surgery. These types of shunt systems will be encountered more often with over-drainage and under-drainage pathologies in NPH patients.

There are several reports that have shown that gradually lowering the OP settings from high values to lower values during postoperative periods can minimize the rate of complications.[13,40,43–46] Several studies, however, have indicated that ameliorating drainage complications with AdSSs and revision surgeries can only be avoided with noninvasive settings.[10,47–52] The results of the current work support these findings. Over-drainage and related complications were seen in 32.61% of patients in our cohort, but revision surgeries for over- or under-drainage were never needed in patients who received AdSSs. In these patients, OP adjustment was enough.

In our study, 10 patients in the NAdSS group developed subdural hematoma and 8 of these patients were surgically treated. In the AdSS group, however, only 1 patient developed subdural hematoma. It is also important to note that this patient did not come to routine controls. It is an undeniable reality that recurrent operations will increase the rate of infection. In the NAdSS group, 2 of the patients who underwent a second operation and whose shunt systems were changed due to subdural hematoma, developed infection and died. However, several studies have shown that shunt types do not change the rate of infection or occlusion and that AdSSs only reduce the complication of over- or under-drainage.[53–59] Therefore, it is not correct to conclude that AdSSs contribute to a reduced infection rate on their own, but rather that AdSSs reduce the need for patients with NPH to undergo repeated surgical procedures. This then contributes to the reduction in infection rate, which ultimately reduces mortality.

In our study, we showed that the additional cost of AdSS usage as compared with NAdSS usage was 600 USD but was then reduced to 111 USD when the complication surgeries were considered. The cost difference between the 2 shunt types was therefore not actually as high as predicted. The rate of surgeries performed due to complications was much lower in the adjustable shunt group. This would ultimately serve to reduce the morbidity and mortality rates that are associated with a second operation, especially in elderly people. With these advantages, however, it is important to keep in mind that electromagnetic devices may alter the OP settings of the AdSS; therefore, OP settings should be controlled after magnetic resonance imaging evaluations.[59]

Our study is limited, however, in that only SSI payment rules from 2016 formed the basis for the cost calculation in these analyses. The length of hospitalization and the complications that arise and additional examinations, however, will likely increase the cost beyond that which was calculated in our studies. The cost difference between the different shunt types will thus be further reduced when these additional costs are considered.

5. Conclusions

In NPH patients, over drainage and under drainage are frequent problems and these complications can be avoided with the help of an adjustable shunt. Although adjustable shunts may appear to be more expensive, this difference is greatly reduced when the cost of complication surgeries is considered. Given the morbidity and mortality rates that may arise from repeated operations, adjustable shunts should be the preferred shunt type for this patient population. We therefore recommend the use of programmable shunts in the management of NPH.

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