

# Ten Years of Clinical Experience in the Use of Fixed-Pressure Versus Programmable Valves: A Retrospective Study of 159 Patients

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**Abstract Aim:** The aim of this study was to present our 10-year experience with the use of fixed-pressure and programmable valves in the treatment of adult patients requiring cerebrospinal fluid (CSF) diversion.

**Material and methods:** Patients ( $n=159$ ; 89 male and 70 female) suffering from hydrocephalus of various causes underwent CSF shunt implantation. Forty fixed-pressure and 119 programmable valves were initially implanted.

**Results:** The observed revision rate was 40% in patients with fixed-pressure valves. In 20% of these patients, a revision due to valve mechanism malfunction was undertaken, and the initial valve was replaced with a programmable one. The revision rate in the adjustable-pressure valve subgroup was 20%. The infection rate for the fixed-pressure and programmable valve subgroups were 3%, and 1.7%, respectively. Similarly, subdural fluid collections were noticed in 17% and 4% of patients with fixed-pressure valves and programmable valves, respectively.

**Conclusions:** The revision and over-drainage rates were significantly lower when using programmable valves, and thus, this type of valve is preferred whenever CSF has to be diverted.

**Keywords** Hydrocephalus • Outcome • Fixed-pressure valves • Programmable-pressure valves

## Introduction

Hydrocephalus has traditionally been defined as the excessive accumulation of cerebrospinal fluid (CSF) within the brain cavities, as a consequence of abnormal CSF production, flow, or absorption [12]. The estimated prevalence of hydrocephalus has been reported to be as high as 1–1.5% in the general population [6].

CSF diversion procedures and endoscopic third ventriculostomy are the two major surgical treatment options. Nowadays, a great variety of shunt mechanisms and diversion pathways are available [2, 6, 10]. Shunt implantation is considered a routine procedure in everyday neurosurgical practice, but the valve-related complications still remain a major problem for the neurosurgeon [2, 4–6]. The latter include, among others, undershunting or overshunting problems (subdural fluid collections, slit-ventricle syndrome), mechanical malfunctions, and infections [2, 3, 5, 6, 8, 12–13].

The goal of the present study is to review the use of adjustable valves in the treatment of hydrocephalus, as it permits a noninvasive management of many shunt- and valve-related complications [1–8, 15]. Toward this end, we collected data from adult patients who underwent CSF diversion in a teaching hospital serving central Greece during the last 10 years.

## Materials and Methods

In a retrospective study, we reviewed 159 consecutive patients treated in our institute from 2001 to 2010. The patients were all adults, with a mean age of 58.2 years (range 23–78 years), among whom 89 were men (56%) and 70 women (44%). The indications for CSF-shunt implantation are shown in Table 1. All fixed-pressure valves were Codman Hakim valves (DePui, Warsaw, IN, USA). Regarding the programmable valves, 110 were Codman Hakim, 5 Miethke proGAV (Christoph Methike GMBH & CO KG, Potsdam, Germany), and 4 Sophysa (Sophysa, Orsay, France) (with an antisiphon device). A ventriculoatrial shunt was implanted in three cases,

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**Table 1** The description of the study groups

	Fixed-pressure valve group	Programmable-pressure valve group	Whole study sample
Number of patients	40	119	159
<i>Age</i>			
Mean years (range)	55.3 (23–73)	60.1 (35–78)	58.2 (23–78)
<i>Sex</i>			
Male	21 (52.5%)	57 (48%)	89 (56%)
Female	19 (47.5%)	62 (52%)	70 (44%)
<i>Etiology</i>			
Post-hemorrhagic hydrocephalus	8 (20%)	34 (28.5%)	42 (27%)
Posttraumatic hydrocephalus	8 (20%)	11 (9.24%)	19 (22%)
Space-occupying lesions	14 (35%)	32 (26.5%)	46 (28%)
INPH	10 (25%)	39 (32.7%)	49 (31%)
Pseudotumor cerebri	–	3 (2.5%)	3 (2%)

*INPH* idiopathic normal pressure hydrocephalus

lumboperitoneal in five cases, while in all other cases a ventriculoperitoneal shunt was initially inserted.

The decision for the selection of the opening pressure for each patient was based on the underlying diagnosis and the radiological findings, as these were demonstrated on computed tomography (CT) or magnetic resonance imaging (MRI). In the group of patients with idiopathic normal pressure hydrocephalus (INPH), a tap test was performed with drainage of 30 mL of CSF, and in some cases, the opening pressure was recorded during a lumbar infusion test, to determine which patients were likely to benefit from a shunt insertion [14]. Referring to the group of patients with adjustable-pressure valves, the determination of the initial pressure setting of the implanted valve was based on the intraoperative opening intracranial pressure. In uncertain cases, we preferred to arbitrarily adopt a median initial pressure of 120 mmH<sub>2</sub>O, and then consequently modify it according to the clinical and imaging follow-up.

Patients were categorized into two groups according to the type of the implanted valve (fixed-pressure valves vs. programmable valves). All patients with CSF shunts implanted prior to 2004 received fixed-pressure valves, while those after that year carried programmable-pressure valves. The two groups were comparable in terms of age, sex, and etiology (Table 1).

The outcome of the CSF diversion was evaluated by assessing the patients' neurological examination, their

Mini-Mental State Examination, and their imaging findings [6]. All patients received a postoperative CT within 48–72 h, to assure the proper placement of the ventricular catheter, and a shunt X-rays series. Clinical evaluation was obtained at 1, 3, 6, 12, and 24 months, postoperatively. Radiological examination was required at 6 and 12 months or when there was a clinical deterioration. The minimum follow-up period was 12 months, while the mean follow-up time was 24 months.

## Results

### **Fixed-Pressure Valve Group**

In our cohort, 40 patients received fixed-pressure valves (Table 1). Catheter-related complications such as obstruction, kinking, migration, or disconnection were observed in three patients (7.5%). Surgical revision with replacement of the proximal or distal catheter was performed in these cases. The observed cumulative revision rate was 16/40 (40%), while the valve replacement rate was 13/40 (32.5%) (Tables 2 and 3). In addition, nine patients (22.5%) required replacement of their initially implanted valves due to undershunting or overshunting. Three patients underwent replacement of their initially implanted valve due to valve mechanism malfunction. One patient (2.5%) had his valve replaced because of an infection.

### **Programmable Valve Group**

In our current series, 119 patients received programmable valves. One hundred and two patients required at least one adjustment of the initially programmed opening pressure. Pressure adjustment problems were encountered in one patient with a lumboperitoneal shunt, which was replaced by a ventriculoperitoneal one. Shunt-related subdural fluid collections were observed in five patients, while a symptomatic slit-ventricle syndrome occurred in one patient. In these cases, pressure adjustment was possible with consequent absorption of subdural effusions and resolution of the slit-ventricle-related symptoms, without any surgical interventions. Proximal or distal catheter-related malfunction requiring surgical revision, occurred in 19/119 patients (16%). The cumulative valve replacement rate was 5.5% caused by valve malfunctioning, pressure adjustment difficulties, and infections (Tables 2 and 3). Seventeen patients (15%) were never reprogrammed after the initial valve implantation, and their clinical and imaging examinations showed improvement of their condition.

**Table 2** The complication type and rate of CSF shunting

Type of complication	Fixed-pressure valve group	Programmable-pressure valve group	Whole study sample
	No. of patients (%)	No. of patients (%)	No. of patients (%)
Valve-mechanism malfunction	3 (7.5%)	2 (1.7%)	5 (3%)
Catheter-related complications	3 (7.5%)	19 (16%)	22 (19%)
Adjustment difficulties	9 (22.5%)	1 (0.85%)	10 (6%)
Subdural collections	7 (17.5%)	5 (4%)	12 (7.5)
Infection	1 (2.5%)	2 (1.7%)	3 (2%)
Symptomatic slit-ventricle syndrome	0	1 (0.85%)	1 (0.6%)
Total	23 (57.5%)	30 (25.2%)	53 (33.3%)

CSF cerebrospinal fluid

**Table 3** The cause of revisions

Indication for revision	Fixed-pressure valve group	Programmable-pressure valve group	Whole study sample
	No. of patients (%)	No. of patients (%)	No. of patients (%)
Valve mechanism malfunction	3 (7.5%)	2 (2%)	5 (3.14%)
Catheter-related complications	3 (7.5%)	19 (16%)	22 (13.8%)
Readjustment difficulties	9 (22.5%)	1 (0.84%)	10 (6.3%)
Infections	1 (2.5%)	2 (1.68%)	3 (1.9%)
Total	16 (40%)	24 (20.1%)	40 (25.1%)

## Discussion

Treatment of hydrocephalus remains a controversial issue [1, 6, 9]. Despite the advances in CSF drainage techniques achieved in recent decades and the large number of different types of valves available nowadays, the optimal treatment of shunt-dependent patients still remains a problem.

Pollack et al. reported that the shunt system survival rate was 52% and 50% for the programmable and the fixed-pressure valves, respectively [11]. In contrast, we found that the shunt survival rate for the programmable valve group was 79.9%, while this percentage for the fixed-pressured valve group was only 60%. Interestingly, the single most common cause for surgical revision in the fixed-pressured group was

the need for setting a different opening pressure, accounting for 56% of the revisions in this group. The respective percentage in our programmable valve group was only 0.8%.

Similarly, the complication rate was significantly lower in the programmable valve group in our study. The cumulative complication rate was 25.2% in the programmable-valve group, while the respective percentage in the fixed-valve group was 57.5%. The most common complication we encountered in the adjustable-pressure group was catheter-related problems in 16% of our patients, while adjustment difficulties (22.5%) and subdural collection formation (17.5%) were the most common complications in the fixed-valve group. The infection rates observed in both groups seem to be comparable, with slightly increased rates among patients with fixed-pressure valves (2.5% vs. 1.7%).

Programmable-pressure shunts seem to be superior to fixed-pressure systems, as they offer the ability to readjust the opening pressure and to avoid overdrainage and/or underdrainage [3, 8, 15]. Moreover, the use of a programmable valve seems to be an independent factor that predisposes to a longer survival time of the shunt, as it spares the patient from further surgical interventions, caused by mismatching between the opening pressure and the patient's CSF-flow dynamics [9, 11, 15].

## Conclusion

Data presented in this study indicate a clear advantage in using programmable valves in the treatment of patients requiring CSF diversion. The use of programmable-pressure valves enables the clinician to modify noninvasively the valve's opening pressure, thus minimizing the overdrainage or underdrainage complications. More controlled modulation of CSF-distorted hydrodynamics leads to a significant improvement of the patient's clinical status by means of avoiding new surgical interventions and decreasing the days and the financial cost of hospitalization.

**Conflicts of interest statement** We declare that we have no conflict of interest.

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