



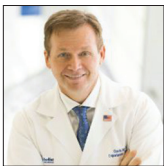
Original Article

## Ventriculoperitoneal shunt complications in an adult population: A comparison of various shunt designs to prevent overdrainage

Virendra Rajendrakumar Desai, Saeed Sam Sadrameli, Amanda V. Jenson, Samuel K. Asante, Bradley Daniels, Todd W. Trask, Gavin Britz

Department of Neurosurgery, Houston Methodist Neurological Institute, Houston Methodist Hospital, Houston, Texas, United States.

E-mail: Virendra Rajendrakumar Desai - virendra.desai@gmail.com; Saeed Sam Sadrameli - ssadrameli@houstonmethodist.org; Amanda V. Jenson - avjenson@houstonmethodist.org; Samuel K. Asante - skasante@houstonmethodist.org; Bradley Daniels - bsdaniels@houstonmethodist.org; Todd W. Trask - ttrask@houstonmethodist.org; \*Gavin Britz - gbritz@houstonmethodist.org



**\*Corresponding author:**

Gavin Britz,  
Department of Neurosurgery,  
Houston Methodist  
Neurological Institute, Houston  
Methodist Hospital, Houston,  
Texas, United States.

[gbritz@houstonmethodist.org](mailto:gbritz@houstonmethodist.org)

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### ABSTRACT

**Background:** Overdrainage after cerebrospinal fluid diversion remains a significant morbidity. The hydrostatic, gravitational force in the upright position can aggravate this. Siphon control (SC) mechanisms, as well as programmable and flow regulating devices, were developed to counteract this. However, limited studies have evaluated their safety and efficacy. In this study, direct comparisons of the complication rates between siphon control (SC) and non-SC (NSC), fixed versus programmable, and flow- versus pressure regulating valves are undertaken.

**Methods:** A retrospective chart review was performed over all shunt implantations from January 2011 to December 2016 within the Houston Methodist Hospital system. Complication rates within 6 months of the operative date, including infection, subdural hematoma, malfunction, and any other shunt-related complication, were analyzed via Fisher's exact test, with  $P < 0.05$  regarded as significant. Subgroup analyses based on diagnoses – normal pressure hydrocephalus (HCP), pseudotumor cerebri, or other HCP – were also performed.

**Results:** The overall shunt-related complication rate in this study was 19%. Overall rates of infection, shunt failure, and readmission within 180 days were 3%, 11%, and 34%, respectively. No difference was seen between SC and NSC groups in any complication rate overall or on subgroup analyses. When comparing fixed versus programmable and flow- versus pressure-regulating valves, the latter in each analysis had significantly lower malfunction and total complication rates.

**Conclusions:** Programmable and pressure regulating devices may lead to lower shunt malfunction and total complication rates. Proper patient selection should guide valve choice. Future prospective studies may further elucidate the difference in complication rates between these various shunt designs.

**Keywords:** Fixed, Flow regulating, Programmable, Siphon control, Ventriculoperitoneal shunt

### INTRODUCTION

Cerebrospinal fluid (CSF) diversion through ventriculoperitoneal shunt placement is one of the oldest and most common neurosurgical operations.<sup>[13,20,22]</sup> While shunt surgery has tangible benefits, numerous complications can occur – including infection, mechanical issues such as

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disconnection or kinking, obstruction, or over-drainage – with rates in adults ranging from 17 to 52%.<sup>[6,12,15,19-21,25,29]</sup>

Excessive CSF drainage may occur in the upright position, increasing the hydrostatic, gravitational pressure of the shunt system, and thereby leading to headaches, nausea, vomiting, impaired cognition, multiple hospitalizations, and repeated surgeries.<sup>[4,5,7]</sup>

In more severe cases, as CSF drains through the shunt, bridging veins can be stretched and subsequently tear, causing subdural effusions or hematomas, with incidences ranging from 3 to 33%.<sup>[1,7,12,23-27,30,31]</sup>

Variables influencing CSF flow through a shunt include intracranial pressure, intra-abdominal pressure, hydrostatic pressure (“siphon effect”), as well as shunt system factors such as valve setting and tubing patency.<sup>[7]</sup> Several innovations have addressed this so-called “siphon effect.” including programmable valves and siphon control (SC) mechanisms.<sup>[16,18]</sup> However, little data on complication rates with and without these mechanisms have been reported. In this study, we provide a direct comparison of siphon versus non-SC (NSC) valves, fixed versus programmable valves, and flow- versus pressure-regulating valves in an adult shunt population.

## MATERIALS AND METHODS

After obtaining Institutional Review Board approval, a retrospective study through chart review was performed for all adult ventriculoperitoneal shunts placed at any hospital within the Houston Methodist System from January 2011 to December 2016. Cases were included only if a new valve was placed during surgery either coupled with an initial, entirely new shunt system or with a revision of a prior shunt involving a valve replacement. Ventriculoatrial and ventriculopleural shunts were excluded, due to their rarity within our hospital system.

As most adult shunt-related complications reported in the literature occur in the first 6 months, chart reviews were performed to identify complications occurring within 6 months of the operative date, including infection, shunt malfunction (proximal catheter, valve, or distal catheter), subdural hematoma formation, and any other shunt-related issue.<sup>[15,20,21]</sup> These complications were included if they resulted in hospitalization or a return to the operating room. In addition, re-admission to the hospital within 180 days for any reason was analyzed.

The cases were organized and analyzed in the following groups: SC versus NSC; flow versus pressure-control; and fixed versus programmable. Mean age between the SC and NSC groups was compared through student’s *t*-test. Demographics and complications rates were analyzed

through Fisher’s exact test to compare SC versus NSC, flow versus pressure regulating valves, and fixed versus programmable valves. Statistical analyses were performed through Microsoft Excel (Microsoft Office 365 MSO, Microsoft Corporation, Redmond, Washington) with  $P < 0.05$  regarded as significant.

In addition, subgroup analyses were performed to compare complication rates between SC and NSC valves in each diagnosis category – normal pressure hydrocephalus (NPH), pseudotumor cerebri (PTC), and hydrocephalus (HCP) – with statistical analysis performed through Fisher’s exact test. The HCP group comprised all patients with diagnoses other than NPH or PTC; this included those with communicating or obstructive HCP related to subarachnoid hemorrhage, tumor-related, aqueductal stenosis, congenital HCP, and more.

## RESULTS

A total of 476 patients met the inclusion criteria. Demographic information is shown in [Table 1]. The overall complication rate was 19%. The overall rates of infection, malfunction, subdural hematoma, and readmission within 180 days are listed in [Table 2].

The various complication rates for the different groups are shown in [Table 3]. No difference between SC and NSC valves was seen in rates of infection, malfunction, subdural hematoma, readmission within 180 days, or total complications. When comparing flow- versus pressure-regulating valves, the latter had significantly lower malfunction and total complication rates with no difference in infections, subdural hematomas, or readmissions within 180 days. For fixed versus programmable valves, the latter had significantly lower malfunction and total complications rates with no difference in infections, subdural hematomas, or readmissions within 180 days.

On subgroup analysis for each diagnosis category as shown in [Table 4], no difference was seen in any of the complication rates between SC and NSC valves.

## DISCUSSION

The total complication rate in this study of ventriculoperitoneal shunt surgeries in adults was 19%. The rates of infection, shunt failure, and readmission within 180 days for any reason were 3%, 11%, and 34%, respectively, with no significant difference in any of these variables between SC and NSC. The overall rate of SDH was 4%, and although this rate trended slightly higher in the NSC group relative to SC, this difference was not statistically significant.

Literature overdrainage complication rates range from 3 to 50%.<sup>[2,4,10,14,23,25-27]</sup> Several studies have evaluated overdrainage

Table 1: Demographics.

	Total	NSC	SC	P-value	Flow	Pressure	P-value	Fixed	Programmable	P-value
Age (mean±SD)	65.2±18.5	65.4±18.4	65.4±18.8	0.98	65.4±18.7	62.5±14.7	0.42	61.1±16.1	65.5±18.7	0.22
Gender (M:F)	244:232	47:43	181:177	0.81	16:12	228:220	0.56	16:13	226:218	0.70
NPH (n, %)	161 (34%)	30 (33%)	127 (35%)	-	-	-	-	-	-	-
PTC (n, %)	39 (8%)	8 (9%)	28 (8%)	-	-	-	-	-	-	-
HCP (n, %)	276 (58%)	52 (58%)	203 (57%)	-	-	-	-	-	-	-
Diabetes mellitus	107 (22%)	27 (30%)	74 (21%)	0.07	6 (21%)	101 (23%)	1	6 (21%)	101 (23%)	1.0
Hypertension	308 (65%)	59 (66%)	230 (64%)	0.9	19 (68%)	289 (65%)	0.84	19 (66%)	288 (65%)	1.0
Chronic kidney disease	63 (13%)	13 (14%)	47 (13%)	0.73	3 (11%)	60(13%)	1	3 (10%)	59 (13%)	1.0

Table 2: Overall complication rates.

Complication	Number	Percentage
Infection	15	3
Shunt failure	51	11
Subdural hematoma	19	4
Readmission within 180 days	163	34
Shunt-related complication	91	19

rates with SC versus NSC in NPH patients with mixed results: some demonstrating increased overdrainage symptoms with no difference in SDH rates and others showing the opposite [2,4,9,10,16,17,25]. The overall trend however appears to be a decrease in overdrainage with SC. Notably, improved clinical responses have been reported with SC devices as lower settings may be applied relative to NSC, improving CSF flow in the horizontal position; others have noted sub-par responses with SC even at the lowest setting, which improved with exchange to NSC.[2,28]. This suggests that proper patient selection is important, as some patients with lower intracranial pressures may benefit from NSC with no increased overdrainage rates, while others with higher intracranial pressures may benefit from SC to mitigate the risk of overdrainage while simultaneously reaping a satisfactory response to CSF diversion. In fact, NSC valves may be ideal for bedridden patients as SC valves may result in underdrainage with no difference in risk of overdrainage.[3]. In our study, given the retrospective nature, only the rate of SDH, and neither the symptomatology suggestive of overdrainage nor the clinical benefit, could be calculated, with no difference seen between SC and NSC. This remained true even in subgroup analyses of NPH, PTC, and HCP cohorts.

Programmable valves represent an alternate development initially geared toward reducing overdrainage complications.[13]. The advantage of programmable valves is the ability to adjust CSF pressure-related flow percutaneously in response to a patient's clinical response or development of subdural effusions.[23,27,30,31]. Fixed versus programmable shunts have been studied mainly in pediatric populations with fewer adult studies.[1,8,11,26]. In adult studies, complication rates range from 22 to 40% with fixed pressure valves, and 7–21% with programmable valves.[1,8,11,14]. Interestingly, while programmable valves can cost 2–6 times the price of fixed valves, the difference in total cost may be much smaller or even reversed when taking into account the increased reoperation and rehospitalization rates with fixed valves.[1,8,11,26].

While several studies suggest a decreased risk of overdrainage with programmable valve, this was not seen in our study possibly due to the low frequency of fixed valve usage.[14,23,26,27].

Notably, in this study, complications were designated as such not only if they required re-operation but also if they required hospitalization with shunt adjustment only,

**Table 3:** Complications by group.

Infection	P-value	NSC	SC	Flow control	Pressure control	Fixed	Programmable
		3 (3%)	10 (3%)	2 (7%)	13 (3%)	2 (7%)	13 (3%)
		<b>0.73</b>		<b>0.219</b>		<b>0.243</b>	
Shunt failure		11 (12%)	33 (9%)	7 (25%)	44 (10%)	7 (23%)	44 (10%)
	P-value	0.43		0.02		0.03	
Subdural hematoma		5 (6%)	13 (4%)	1 (4%)	18 (4%)	1 (3%)	18 (4%)
	P-value	0.38		1		1	
Readmission within 180 days		29 (32%)	121 (34%)	13 (46%)	150 (33%)	13 (43%)	150 (34%)
	P-value	0.8		0.22		0.32	
Shunt-related complication		20 (22%)	60 (17%)	11 (39%)	80 (18%)	11 (37%)	80 (18%)
	P-value	0.22		0.01		0.02	

**Table 4:** Subgroup analysis.

Complication		NPH		PTC		HCP	
		NSC	SC	NSC	SC	NSC	SC
Infection	(n, %)	1 (3%)	1 (1%)	1 (14%)	0 (0%)	1 (2%)	9 (5%)
	P-value	0.35		0.22		0.36	
Shunt failure	(n, %)	1 (3%)	3 (2%)	2 (33%)	4 (17%)	8 (18%)	26 (15%)
	P-value	0.58		0.40		0.39	
Readmission within 180 days	(n, %)	11 (58%)	39 (44%)	1 (14%)	11 (65%)	17 (49%)	71 (54%)
	P-value	0.34		0.16		0.45	
Subdural hematoma	(n, %)	4 (15%)	11 (9%)	0 (0%)	0 (0%)	1 (2%)	2 (1%)
	P-value	0.31		1		0.50	
Shunt-related complication	(n, %)	6 (25%)	17 (15%)	2 (33%)	5 (22%)	12 (30%)	38 (23%)
	P-value	0.26		1		0.30	

whether from subdural hygroma development or increased ventricular size. These cases were included as complications as many cases of subdural hematoma development were managed conservatively, but the mere fact that this SDH was symptomatic and required hospitalization merited inclusion as a complication in our view.

No difference was seen between SC and NSC valves in our adult population in terms of infections, malfunctions, subdural hematomas, readmissions within 180 days, or total complications. Higher malfunction and total complication rates were seen with flow- versus pressure-regulating valves and fixed versus programmable valves, with no difference in rates of infection, subdural hematoma, or readmission within 180 days.

The retrospective nature of this review limited a thorough assessment of patients' clinical responses to CSF diversion and may have missed a number of subdural hygromas managed conservatively in the outpatient setting through adjustment of programmable valve setting. In addition, the true causative factors for SDH development – whether over-shunting versus traumatic – are unknown. Finally, multiple surgeons within a single city-wide hospital system performed the shunt operations; given that each surgeon

may favor a certain valve type over others, this may present a confounding factor in the analysis.

## CONCLUSIONS

The overall complication rate in this study was 19%. No difference was seen in complication rates between SC and NSC valves. Increased malfunction and total shunt-related complication rates were seen when comparing flow- versus pressure-regulated valves and fixed versus programmable valves. Proper patient selection should guide valve choice to minimize rates of under- and over-drainage. Future prospective studies may further elucidate the difference in complication rates between SC and NSC valves.

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## Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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**Conflicts of interest**

There are no conflicts of interest.

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