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Clinical Study

Choice of valve type and poor ventricular catheter placement: Modifiable factors associated with ventriculoperitoneal shunt failure

Kealeboga Josephine Jeremiah [a,*], Catherine Louise Cherry [b,d], Kai Rui Wan [a], Jennifer Ah Toy [a], Rory Wolfe [a], Robert Andrew Danks [a,c]

[a] Neurosurgery Department, Monash Medical Centre, 246 Clayton Road, Clayton, VIC 3168, Australia
[b] Department of Infectious Diseases, Monash University and Alfred Hospital, Centre for Biomedical Research, Burnet Institute, Commercial Road, Melbourne, VIC, Australia
[c] Department of Surgery, Monash Medical Centre, Monash University, VIC, Australia
[d] School of Physiology, University of the Witwatersrand, Johannesburg, South Africa

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ABSTRACT

Ventriculoperitoneal (VP) shunt insertion is a common neurosurgical procedure, essentially unchanged in recent years, with high revision rates. We aimed to identify potentially modifiable associations with shunt failure. One hundred and forty patients who underwent insertion of a VP shunt from 2005–2009 were followed for 5–9 years. Age at shunt insertion ranged from 0 to 91 years (median 44, 26% <18 years). The main causes of hydrocephalus were congenital (26%), tumour-related (25%), post-haemorrhagic (24%) or normal pressure hydrocephalus (19%). Fifty-eight (42%) patients required $\geqslant 1$ shunt revision. Of these, 50 (88%) were for proximal catheter blockage. The median time to first revision was 108 days. Early post-operative CT scans were available in 105 patients. Using a formal grading system, catheter placement was considered excellent in 49 (47%) but poor (extraventricular) in 13 (12%). On univariate analysis, younger age, poor ventricular catheter placement and use of a non-programmable valve were associated with shunt failure. On logistic regression modelling, the independent associations with VP shunt failure were poor catheter placement (odds ratio [OR] 4.9, 95% confidence interval [CI] 1.3–18.9, p = 0.02) and use of a non-programmable valve (OR 0.4, 95% CI 0.2–1.0, p = 0.04). In conclusion, poor catheter placement (revision rate 77%) was found to be the strongest predictor of shunt failure, with no difference in revisions between excellent (43%) and moderate (43%) catheter placement. Avoiding poor placement in those with mild or moderate ventriculomegaly may best reduce VP shunt failures. There may also be an influence of valve choice on VP shunt survival.

1. Introduction

Ventriculoperitoneal (VP) shunt operations for the treatment of hydrocephalus are one of the most common procedures performed in neurosurgery [1–3]. However, shunt survival rates have not increased significantly since its inception in 1952 [1,4], despite improvements in both technical equipment [4,5] and operative skill [4]. In published series, 30–50% of shunts fail within the first 12 months [2,6–12], and only around one-third of shunts survive 10 years without revision [6,8]. The most common causes of shunt malfunction are obstruction, particularly of the ventricular catheter [2,3,11–21], followed by infection, disconnection and overdrainage [22,23]. One study estimated that approximately 41% of all shunting procedures performed were for malfunction and an additional 7% were related to shunt infection [24].

Despite significant developments in technology and design, shunt failure remains a significant problem in neurological surgery. It has been established that one of the important variables for shunt survival is good proximal catheter placement within a sufficient pool of cerebrospinal fluid (CSF) [3,15,16]. The follow-up duration in most of these studies is limited and insufficient to determine the long-term outcomes of VP shunt operations [24]. The current study aimed to identify any additional, potentially modifiable associations with shunt failure.

We undertook a retrospective review of all patients who underwent VP shunt placements at Monash Medical Centre, Australia, from 2005–2009. Our objective was to describe factors associated with long-term shunt survival/failure and in particular, to determine whether any modifiable factors exist.

* Corresponding author. Tel.: + 61 4 33 901 215.
E-mail address: josephinejeremiah2011@gmail.com (K.J. Jeremiah).

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2. Methods

2.1. Study population

Ethics approval was obtained from the Monash Human Research Ethics Committee to conduct an audit of all patients who underwent VP shunt insertion at Monash Medical Center during 2005–2009. Clinical, demographic radiological and operative data were collected from patients' medical records as at December 2013.

2.2. Outcome variables

Variables recorded included patient demographics, cause of hydrocephalus, medical comorbidities, surgical technique, valve type and results of pre- and post-operative imaging. Hydrocephalus was defined on radiological grounds. The pre-operative and post-operative size of the ventricles were measured objectively, with the frontal occipital horn width ratio; and subjectively categorised into normal size, mild, moderate or severe dilatation by the radiologist. The justification for these definitions is described in Wan et al. [25]. The location of the ventricular catheter was defined as excellent if at least 2.0 cm of the tip was within the CSF pool, good if 1.5–2.0 cm of the tip was within the pool of CSF and poor if the tip was not within the ventricular system. The position of the catheter tip was measured by two trained observers using objective criteria. The five point grading system, based on the measured length of the perforated tip region that lay within the ventricular CSF, has good inter-observer reliability, with two of the authors (K.W. and J.A.) having a 75% exact agreement (kappa = 0.63, 95% confidence interval 0.51–0.75) on measuring the position of the catheter tip [25].

2.3. Statistical analyses

Statistical analyses were performed using Stata11 (StataCorp, College Station, TX, USA). Descriptive statistics were expressed as mean ± standard deviation for normally distributed, continuous variables, median (range) for non-normally distributed variables and number (%) for categorical variables. Univariate associations between shunt failure (yes/no) and underlying clinical, demographic and surgical risks were performed using t-tests, chi [2] tests, or Wilcoxon rank-sum tests, as appropriate. Multivariate analyses to determine factors independently associated with shunt failure was performed using logistic regression modelling, including all factors associated with shunt failure on univariate analysis ($p < 0.1$), followed by a stepwise removal process. Survival analysis was performed using Kaplan–Meier curves and the log-rank test of survival.

3. Results

3.1. Cohort description

One hundred and forty patients underwent VP shunt insertion at Monash Medical Centre between January 2005 and February 2009. The cohort included 74 (53%) females and ages ranged from 0–91 years, with 36 (26%) being children (age <18 years). Demographic and clinical details of the cohort are shown in Table 1. We found no association between cultural or linguistic background and risk of adverse health outcomes. There were no shunt infections in this cohort.

3.2. Factors associated with VP shunt failure

Fifty-eight (41%) patients had undergone at least one shunt revision procedure by the time of this audit. Table 2 shows univariate associations between clinical, demographic and operative factors and requiring at least one shunt revision procedure. We found that revision surgery was more likely to be required if initial catheter placement was extraventricular (as expected) and also that there was a trend towards paediatric patients being more likely to require revision surgery. Patients with programmable valves were less likely to require revision procedures. We saw no other associations between shunt failure and patient demographics, cause of hydrocephalus or comorbid medical conditions ($p \geqslant 0.2$ for all).

On logistic regression modelling, factors that were independently associated with shunt revision were poor catheter placement (*versus* unknown or better placement), which was associated with substantially increased risk, as expected, and having a programmable valve (*versus* any other valve type or valve type not recorded), which was associated with reduced risk of shunt failure (Table 3).

Survival analysis confirmed that shunts with known poor catheter position were substantially more likely to require early revision than all others ($p < 0.0001$, log-rank test for equality of survivor function) (Fig. 1). Among the 105 patients where post-operative imaging was available, there was little difference in shunt survival between those with fair, moderate, good or excellent placement

Table 1
Cohort characteristics of patients with ventriculoperitoneal shunt insertion

Characteristic	Description
Demographics	
Age, years	Range 0–91
<18	36 (26%)
18–60	59 (42%)
60+	45 (32%)
Female	74 (53%)
English-speaking	131 (94%)
Australian born	107 (76%)
Cause of hydrocephalus	
Past intracranial haemorrhage	34 (25%)
Tumour	35 (25%)
Congenital	36 (26%)
Normal pressure hydrocephalus	26 (19%)
Benign intracranial hypertension	4 (3%)
Past infection	5 (4%)
Comorbidities	
Type 2 diabetes	12 (9%)
Non-CNS malignancy	5 (4%)
Valve type	
Programmable	47 (33%)
Non-programmable	84 (67%)
Number of revision procedures	
None	82 (59%)
1	29 (21%)
2	14 (10%)
>2	15 (11%)

CNS = central nervous system.

Table 2
Univariate associations between patient factors and patients requiring valve revision after ventriculoperitoneal shunt insertion

	No revision (n = 82)	Revision (n = 58)	p value
Female	46 (56%)	28 (48%)	0.36
Australian born	63 (77%)	44 (76%)	0.9
Age <18 years	17 (20%)	19 (33%)	0.1
Poor shunt placement	3 (4%)	10 (17%)	0.008*
Ventricular dilatation			
Unknown	9 (11%)	12 (21%)	0.2
Not present	13 (16%)	10 (17%)	
Present	60 (73%)	36 (62%)	
Programmable valve	34 (41%)	13 (22%)	0.019

p value calculated using chi^2 unless marked * indicating Fisher's exact test.