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Predictors of distal malfunction after ventriculoperitoneal shunting for idiopathic normal pressure hydrocephalus and effect of general surgery involvement

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ABSTRACT

Objectives: Distal obstruction is a common cause of shunt failure and need for revision in patients undergoing ventriculoperitoneal shunting (VPS) for idiopathic normal pressure hydrocephalus (iNPH).

Patients and Methods: Records of patients with iNPH treated with VPS between 2001 and 2017 were reviewed. Patients undergoing initial shunt placement at our institution were included for analysis and the incidence of revision surgery due to distal obstruction was noted. Risk factors for distal obstruction were identified using a stepwise Cox proportional hazards model.

Results: There were 341 patients included for analysis. Assistance from a general surgeon in placement of the peritoneal catheter was provided in 54 patients (15.8%). Shunt revision was necessary in 69 patients (20.2%), with 17 patients (5.0%) found to have a distal malfunction. On univariate analysis, increasing age was associated with reduced risk of distal malfunction (Unit RR 0.92, 95% CI 0.89–0.96; $p < 0.001$). BMI ≥ 38.9 (RR 6.60, 95% CI 1.84–19.00), prior abdominal surgery (RR 2.95, 95% CI 1.11–7.70; $p = 0.032$), and fixed-setting valve (RR 6.24, 95% CI 1.27–112.72; $p = 0.020$) were associated with increased likelihood of distal malfunction. General surgery involvement had no effect on distal malfunction rates (OR 1.30, 95% CI 0.25–3.21; $p = 0.693$). On multivariate analysis, increasing age (Unit RR 0.92, 95% CI 0.89–0.95; $p < 0.001$) and prior abdominal surgery (RR 3.30, 95% CI 1.23–8.71; $p = 0.019$) were independently associated with decreased and increased risk of distal obstruction, respectively.

Conclusions: We identify multiple factors associated with distal shunt obstruction, and found that general surgery assistance was not protective against distal malfunction. These data may aid in the risk-stratification of patients undergoing VPS for iNPH.

1. Introduction

In carefully selected patients, ventriculoperitoneal shunting (VPS) is an effective therapy for idiopathic normal pressure hydrocephalus (iNPH), [5,12] though the frequent need for revision surgery may lower the cost-effectiveness of this procedure [11,16]. The most common cause of shunt failure in this population is malfunction, [12] which often occurs due to blockage of the peritoneal catheter [3,8]. While a number of studies have aimed to determine risk factors for shunt failure in general [1,7,9], there is comparatively little data on risk factors for distal malfunction, especially for patients with iNPH. General surgery assistance with laparoscopic placement of the distal catheter has also been increasingly used, and there is a paucity of data on the benefits of this approach. Additionally, identifying risk factors for distal malfunction may aid in the risk-stratification of patients, and given the option to place the distal catheter in the atrium or pleural space, inform treatment selection strategies in order to lower the likelihood of shunt failure. Herein, we reviewed the clinical course of patients with iNPH undergoing initial VPS placement in order to determine the incidence and predictors of distal shunt obstruction.

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2. Patients and methods

2.1. Patient selection

After approval from the institutional review board (IRB #18-000051), the clinical course of patients diagnosed with iNPH undergoing initial VPS placement between the years 2000 and 2017 were retrospectively reviewed. Patients were diagnosed with iNPH on the basis of typical clinical symptomatology [2], imaging findings of ventriculomegaly without a clear obstruction, and high volume lumbar puncture with opening pressure < 25 cm H_2O [13]. Patients with a history of previous shunt placement prior to evaluation at our institution were excluded from analysis, as were patients undergoing placement of ventriculopleural or ventriculoatrial shunts.

2.2. Determination of distal malfunction

The medical records of patients undergoing initial VPS placement and the incidence of revision surgery due to suspected shunt malfunction was noted. The operative report of each revision surgery was carefully reviewed and the etiology of shunt failure was determined. In general, in patients without an obvious cause of shunt failure after initial clinical and radiographic evaluation, each shunt component (proximal catheter, shunt valve, and distal catheter) was intra-operatively interrogated in a sequential fashion. Minimal or absent flow through the distal catheter in addition to increased manometric values was considered to represent a distal malfunction. Patients with peritoneal catheters that had been extruded into the pre-peritoneal space were also considered to have a distal malfunction, as were patients with a peritoneal catheter confined to an intra-peritoneal fluid collection or those with obvious kinking of the distal catheter. While the formation of a peritoneal fluid collection is considered evidence of infection in the pediatric population, the etiology of such collections may differ in adult populations, [4] and thus these patients (n = 2) were considered to have distal malfunction.

2.3. Patient variables of interest

Information collected on patient and treatment characteristics included patient age at the time of shunt placement, sex, body mass index (BMI), prior abdominal surgery, frontal versus parietal approach for ventricular catheter placement, use of fixed-setting versus programmable valve, assistance from general surgery for placement of the peritoneal catheter, incidence of enterotomy at the time of initial shunt placement, and time to distal malfunction and overall follow-up time in days. BMI was considered as both a continuous and categorical variable. When considered as a categorical variable, the cut-off for BMI was determined using classification and regression tree analysis (CART). For a continuous variable, in this case BMI, CART determines the value above and below which is observed the greatest difference in the incidence of a particular outcome, in this case distal obstruction. Patients were then dichotomized according to whether their BMI was less than or greater than or equal to the calculated cut-off (38.9). At our institution, assistance from a general surgeon with placement was not routinely provided, but was instead requested on an ad hoc basis when deemed necessary by the consultant neurosurgeon. For all cases in which VPS placement was performed without general surgery, the peritoneal catheter was placed via mini-laparotomy. When general surgery assistance was provided, the frequency of peritoneal catheter placement via mini-laparotomy versus laparoscopic surgery was noted. Follow-up time was considered to be the time in days from initial shunt placement and date of last follow-up appointment with either a neurologist or neurosurgeon for evaluation of the patient's hydrocephalus.

2.4. Statistical analysis

Descriptive statistics for continuous and categorical variables were provided as a mean, standard deviation, and range and frequency and percentage, respectively. Comparisons between continuous and categorical variables were performed using the Student's *t*-test and Pearson's Chi-squared or Fisher's exact test, where appropriate. Risk factors for distal obstruction were determined using a Cox proportional hazards model. Independent risk factors for distal malfunction were identified using a stepwise multivariate Cox proportional hazards model. Factors associated with distal malfunction on univariate analysis with a p-value of ≤ 0.10 were included in the stepwise model and removed using a backward elimination method on the basis of strength of association. Kaplan-Meier curves were compared using the log-rank test. Alpha levels for statistical significance were set at 0.05. Analyses were performed using commercially available software (JMP® 10.0.0, ©2012 SAS Institute Inc., Cary, North Carolina).

3. Results

3.1. Incidence and characteristics of distal malfunction

Of the 341 patients undergoing VPS placement, 69 patients (20.2%) required revision surgery. Among these patients, there were 17 (5.0%) who met criteria for distal malfunction. The most common subtype of distal malfunction was blockage of the peritoneal catheter manifested as poor distal flow on intra-operative interrogation (n = 8, 47.1%), followed by extrusion of the peritoneal catheter into the pre-peritoneal space (n = 6, 35.3%). Two patients (11.8%) were found to have an encapsulated intra-peritoneal fluid collection within which the peritoneal catheter was confined. Both patients were taken for abdominal exploration, drainage of the fluid collection, and temporary explantation of shunt components. Microbial testing of the fluid collection and shunt components was negative for organismal growth in both patients. In one patient, the shunt was reinserted into the peritoneal space, whereas in the other patient the shunt was converted to a ventriculoatrial shunt. Neither patient required further shunt revision surgery. Overall, two patients (11.8%) required additional revision surgery after the initial revision; one patient initially presented with blockage of the peritoneal catheter while the other presented with an extra-peritoneal catheter. The latter patient ultimately required a total of three abdominal revision surgeries, and also developed a ventral hernia requiring surgical repair. After initial revision, the VPS was converted to a ventriculoatrial or ventriculopleural in three patients (17.6%). Finally, there was one patient who presented with symptoms of meningitis due to suspected shunt infection. On abdominal exploration, the peritoneal catheter was found to be intra-colonic, entering through a colotomy occurring either surreptitiously at the time of initial shunt placement or subsequently from erosion due to positioning of the catheter. The shunt was removed and the patient completed a prolonged course of antibiotics. A shunt was not reinserted due to equivocal benefit prior to the patient's presentation for malfunction. The mean time to distal malfunction was 485.9 days; a Kaplan-Meier curve depicting survival from time of shunt placement without distal malfunction is visible in Fig. 1A.

In patients who developed distal malfunction, assistance from general surgery with placement of the peritoneal catheter was provided in three patients (17.6%), with two patients undergoing mini-laparotomy and the third undergoing laparoscopic-assisted catheter placement. The etiology of distal malfunction in the patient undergoing laparoscopy was blockage of the distal catheter, whereas in patients undergoing mini-laparotomy one patient developed an intra-peritoneal fluid collection and one patient was found to have an extra-peritoneal catheter.