Emergency Department Evaluation of Ventricular Shunt Malfunction

Is the Shunt Series Really Necessary?

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Objective: The malfunction of a ventricular shunt is one of the most common clinical problems encountered in pediatric neurosurgery. Standard emergency department (ED) evaluation of suspected shunt malfunction consists of plain radiographs of the skull, neck, chest, and abdomen (shunt series) to look for mechanical breaks, kinks, and disconnections in the shunt, and a cranial computed tomography (CT) scan to evaluate for signs of increased ventricular size. We hypothesized, however, that in the context of a cranial CT scan that did not demonstrate a shunt malfunction, obtaining the shunt series would not prove to be clinically useful.

Methods: A retrospective chart review was conducted of all patients younger than 18 years with a history of a ventricular shunt who presented to an urban, tertiary pediatric ED between January 1, 2000, and September 30, 2004, for suspected shunt malfunction. Demographic and clinical characteristics of patients were recorded, as well as the results of shunt series and cranial CT scans. Shunt malfunction was defined as the performance of a shunt revision within 1 week of radiographic evaluation.

Results: During the study period, 291 children with a ventricular shunt were evaluated in the ED 461 times for suspected shunt malfunction. The mean age of patients was 90.6 months (SD, 71.5 months); 163 (58.5%) were men, and 209 (71.8%) were white. Three hundred sixty patients (78.1%) had a shunt series performed during their ED evaluation, and 410 (88.9%) had a CT scan of the head. Seventy-one patients (15.4%) were diagnosed with shunt malfunction. Twenty-two had a normal cranial CT scan. Of these patients, 6 had an abnormal shunt series, and 14 had a normal shunt series.

Conclusions: The routine use of the shunt series seems warranted in the evaluation of the child with suspected shunt malfunction as children with shunt malfunction may present with a normal cranial CT scan but an abnormal shunt series.

Key Words: ventriculoperitoneal shunt, malfunction

Ventricular shunt placement, the primary treatment of hydrocephalus, is one of the most commonly performed neurosurgical operations.[1] A recent epidemiological study in the United Sates estimated that 33,000 shunt procedures occur every year, 48% of which involve a revision of an original shunt.[2] A malfunction of a shunt results in increased hydrocephalus, clinical symptoms, or both, and is one of the most common clinical problems encountered in pediatric neurosurgery.[3] Most of these patients present to an emergency department (ED) with headache, nausea, vomiting, drowsiness, somnolence, irritability, and other signs of increased intracranial pressure.[4] However, many of these symptoms occur in the context of other common pediatric illnesses, making it difficult to distinguish patients with a shunt malfunction from those without. Given the associated high morbidity and mortality of shunt malfunction, detection of shunt malfunction is of high importance.

Standard ED evaluation of suspected ventricular shunt malfunction consists of plain radiographs of the skull, neck, chest, and abdomen (shunt series [SS]) to determine the presence of mechanical breaks, kinks, and disconnections in the shunt tubing. Computed tomography (CT) of the head is then obtained to detect a change in ventricular size. No studies to date have evaluated the usefulness of CT scan alone for the evaluation of shunt malfunction. We sought to describe the test characteristics of the SS and cranial CT scans in children with a ventricular shunt presenting to our ED with signs and symptoms consistent with shunt malfunction. We hypothesized that the cranial CT scan alone was predictive of malfunction and that the SS was an unnecessary addition to the evaluation.

METHODS

We retrospectively reviewed the charts of all patients younger than 18 years with a history of a ventricular shunt, who presented to the ED between January 1, 2000, and September 30, 2004. Patients were enrolled in the study if they presented with signs and symptoms suggestive of possible shunt malfunction (ie, fever, headache, nausea or vomiting, altered mental status, altered behavior such as irritability or fussiness, recent head trauma, and seizures [as a presenting symptom/sign]). Potential patients were identified through a search of a computerized database containing all ED patient visits during the study period. A standardized questionnaire was used to record data abstracted from each patient's medical record which included their ED record, inpatient progress notes, discharge summary, operative

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TABLE 1. Demographic and Clinical Characteristics Among Patients Who Underwent Radiographic Imaging and Those Who Did Not

	SS			Cranial CT Scan		
Characteristic	**Yes**	**No**	***P***	**Yes**	**No**	***P***
n	360	101		410	51	
Age (mo)	90.6	90.5	NS	89.9	95.9	NS
Sex (% male)	55.6	60	NS	55.9	62.7	NS
Race			NS			NS
% White	77.2	72.7		74.6	78.4	
% African American	15.2	20.2		16.6	11.7	
History of (%)						
Fever	20	26.7	NS	22.2	15.7	NS
Headache	36.1	23.8	NS	35.4	17.6	**0.01**
Vomiting	40	42.6	NS	41.2	35.3	NS
Altered level of consciousness	17.2	24.8	NS	19.8	11.8	NS
Altered behavior	40.3	41.6	NS	40	45.1	NS
Seizure	16.9	31.7	**<0.001**	18.8	31.4	**0.04**
Head injury	1.9	1	NS	1.2	5.9	**0.02**

Text in bold shows significant *P* values.
NS indicates not significant.

report, and consultant notes. Records were reviewed by medical students who were trained to review medical records and complete the questionnaire but were not involved in the study design. Reviewers were not blinded to the presence or absence of shunt malfunction.

Demographic and presenting clinical characteristics were recorded for each patient as well as the attending radiologist's interpretations of all radiographic studies (SS, CT, magnetic resonance imaging, etc). Only the results of radiographic studies obtained in the ED were included. Final disposition (hospitalization, operative repair of the shunt) and diagnosis (presence or absence of shunt malfunction) were also recorded.

Results of SS were described as either normal or abnormal. An abnormal result of the plain radiography SS was defined as a shunt disconnection, proximal discontinuity at the shunt bulb, a kink in the shunt tubing, a retracted shunt tip, or other abnormality suggesting malfunction. Results of cranial CT scans were described as either normal or abnormal. A normal cranial CT implied that there had been no interval change since the patient's last CT, any new pathology or suggestion of shunt failure. An abnormal result of a CT scan was defined as either an increase in ventricular size or change in shape of the ventricles when compared with prior CT scan, determined by the attending radiologist. A shunt malfunction was defined by a requirement for shunt revision within 1 week of the radiographic evaluation. The diagnosis of malfunction was not made based solely on the finding of an abnormal cranial CT scan.

For the purposes of analysis, each ED evaluation of a shunt for concerns of a possible malfunction was considered a separate event and entered into the database accordingly. Demographic and clinical characteristics of the study patients are presented as means, medians, ranges, and proportions with appropriate 95% CIs. Comparisons of demographic and clinical characteristics and of the results of radiographic studies were made between patients who did and did not have a shunt malfunction using Student *t*, Mann-Whitney *U*, χ^2, and Fisher exact tests. A *P* value less than 0.05 was considered significant, and odds ratios (ORs), with 95% confidence intervals (CIs) were calculated. To ensure a 95% CI of ± 5% around the calculated sensitivity and specificity for the results of both the cranial CT scan and SS, 400 patients were to be enrolled.

This study was reviewed and approved by the institutional review board of the Children's Hospital of Pittsburgh.

RESULTS

Demographic and Patient Characteristics

During the study period, 291 children with a ventricular shunt were evaluated in the ED 461 times for suspected shunt malfunction. The mean age of patients was 90.6 months (SD, 71.5 months; median, 65.6 months; range, 0.75 months to 24.6 years). One hundred sixty-three patients (56.0%) were men; 209 (71.8%), white; and 49 (16.8%), African American. Four hundred sixty of 461 ventricular shunts were noted to be of the ventricular peritoneal type, and 1 shunt was described as ventricular pleural. Four patients had 2 shunts in place, and 1 patient had 3.

Table 1 presents the characteristics of those patients who did and did not undergo radiographic imaging during their ED visit. Patients with a presenting history of seizure activity were less likely to have a SS ($P < 0.001$) or CT ($P = 0.04$) performed than those without a history of seizure activity. Patients with a history of a closed head injury were less likely to have a CT scan than those who did not ($P = 0.02$), and patients with a history of a headache were more likely to have a CT performed than those without ($P = 0.01$).

Plain Radiograph SS and Cranial CT Imaging Studies

Twenty (5.6%) of 360 SS and 80 (19.4%) of 410 CT scans were abnormal. No difference was found among patients with abnormal imaging, and those with normal studies with respect to their demographic characteristics or presenting signs except that patients with an abnormal SS were older (163.2 months vs. 83.8 months, $P < 0.001$).

Diagnosis of Shunt Malfunction

Seventy-one patients (15.4%) were ultimately diagnosed with a shunt malfunction; all underwent surgical repair. Overall, 75 patients (16.3%) underwent surgical repair of their shunt. Of the 4 additional patients who underwent surgery related to their shunt, 3 had a shunt infection but no evidence of malfunction, and 1 had a subdural hematoma requiring drainage.

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Table 2 presents the demographic and clinical characteristics of patients diagnosed with and without a shunt malfunction. Patients with a shunt malfunction were older than patients without a shunt malfunction (113.4 months vs. 86.4 months, $P = 0.003$). Patients with a history of vomiting ($P < 0.001$; OR, 2.3; 95% CI, 1.4–3.8) or headache ($P = 0.03$; OR, 3.3; 95% CI, 2.0–5.5) were more likely to have a shunt malfunction, whereas patients with a history of fever ($P = 0.01$; OR, 0.35; 95% CI, 0.2–0.8) or seizure activity (as a presenting symptom/sign) ($P < 0.001$; OR, 0.39; 95% CI, 0.2–0.9) were less likely.

Analysis of the SS

Of 71 patients ultimately found to have a shunt malfunction, 59 (83.1%) had a SS performed, and 16 (27.1%) were abnormal (Fig. 1). As expected, those patients with an abnormal SS were more likely to have a shunt malfunction than those with a normal series ($P = 0.001$). Importantly, 6 patients with shunt malfunction were among 8 patients for whom only the SS was abnormal.

Overall, there were 20 patients who had an abnormal SS. In all 20 cases, the patient was found to have a shunt disconnection or discontinuity. Four patients were thought to have outgrown their need for a shunt.

Analysis of the CT Scan

Of 71 patients ultimately diagnosed with a shunt malfunction, 61 (85.9%) had a CT scan of the head, and 45 (73.8%) were abnormal (Fig. 1). Of 80 patients with an abnormal CT scan, 45 (56.3%) were found to have a shunt malfunction, 26 had signs of altered ventricle size but were not found to have shunt malfunction, 4 were found to have a

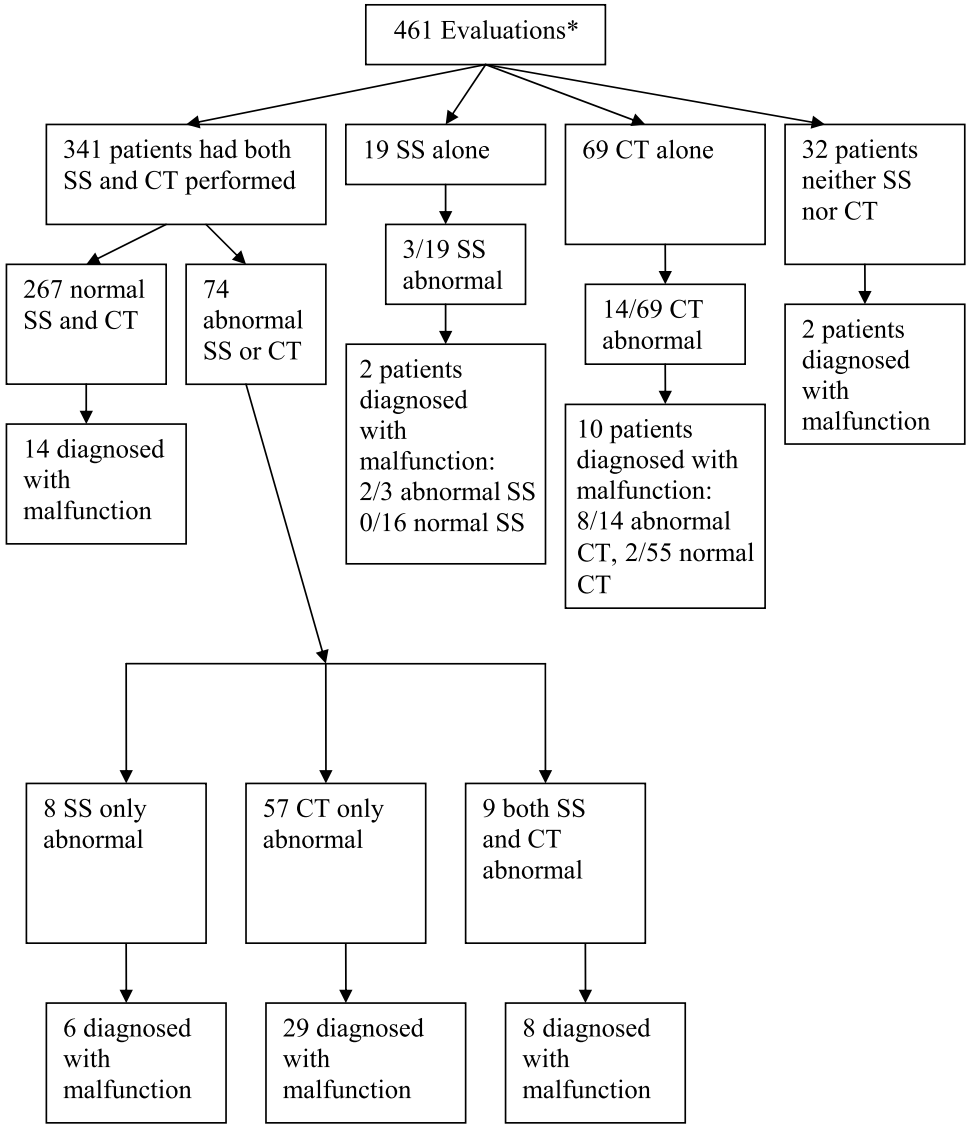

FIGURE 1. Results of radiographic imaging and diagnosis of shunt malfunction.

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TABLE 2. Demographic and Clinical Characteristics Among Patients With and Without Shunt Malfunction

Characteristic	Shunt Malfunction		
	Yes	No	*P*
n	71	390	
Age (mo)	113.4	86.4	**0.003**
Sex (% male)	63.3	55.4	NS
Race			NS
% White	75.4	76.4	
% African American	13	16.9	
History of (%)			
Fever	9.9	23.6	**0.01**
Headache	57.7	29	**0.03**
Vomiting	57.7	37.4	**<0.001**
Altered level of consciousness	18.3	19	NS
Altered behavior	50.7	38.7	NS
Seizure	9.9	22.1	**<0.001**
Head injury	0	2.1	NS

Text in bold shows significant *P* values.
NS indicates not significant.

subdural hemorrhage, and 5 were found to have an abnormality such as a cyst. Twenty-two patients had a normal CT scan of the head but were found to have a shunt malfunction. Of these 22 patients, 6 were suspected of having a shunt malfunction because of an abnormal SS. Fourteen patients with a shunt malfunction had both a normal CT scan and SS. Of patients with a shunt malfunction, there was no difference in age, sex, race, or presenting signs and symptoms among patients with a normal CT scan of the head and an abnormal scan.

Table 3 describes the predictive value of the cranial CT scan and/or SS with regards to identifying shunt malfunction.

DISCUSSION

Evaluating a child with a suspected malfunction of a ventricular shunt is an infrequent but important problem for both the pediatrician and the emergency medicine physician. Typically, the evaluation includes both cranial CT scan and a plain radiographic SS. We hypothesized, however, that although a CT scan should always be part of the evaluation, the physician may be able to omit inclusion of a SS when the cranial CT scan was normal. To that end, in children presenting with signs and symptoms suggestive of shunt malfunction, we sought to determine how often a SS was indicative of a malfunction when the cranial CT scan was normal.

In our study, we found that 6 patients with signs and symptoms suggestive of a shunt malfunction, but a normal cranial CT scan, were ultimately diagnosed with a shunt malfunction because of an abnormal SS (either a shunt disconnection or discontinuity). Thus, we believe that in all cases of suspected shunt malfunction, both the SS and a cranial CT scan should be necessary components of the evaluation.

Similar findings were reported by Zorc et al[5] in 2002. In a review of 233 patients with a ventricular shunt, 3 patients were diagnosed with a shunt malfunction that was not detected by CT scan.[5] Combined, CT and SS had a sensitivity of 88% and a negative predictive value of 95%. Two of the patients had a shunt disconnection, and one had a retraction of a ventriculoatrial shunt from the atria. Our rate of malfunction identified by SS but not CT was similar; 6 (2%) of 291.

Of great interest to us was the finding that 22 patients had a normal cranial CT scan but were found to have a shunt malfunction. Unfortunately, there were no clinical signs or symptoms that differentiated those patients with a shunt malfunction and a normal CT scan of the head from those with an abnormal CT scan. Clearly, radiographic testing alone cannot be relied upon to diagnose shunt malfunction. We believe that patients with signs and symptoms highly suggestive of shunt malfunction, even in the context of normal radiographic testing, should be referred for neurosurgical consultation. Similar findings have been reported. Iskandar et al[3] published a series of 68 patients with 100 episodes of known shunt malfunction. One third had a normal CT scan or magnetic resonance imaging of the brain.[3]

The literature indicates that pediatric neurosurgeons vary in their management of shunted children who present with suspected malfunction.[6] In a recent survey, 140 pediatric neurosurgeons were asked how they would manage the evaluation of a suspected shunt malfunction.[6] Nearly one third of physicians would not obtain a plain radiographic SS routinely during their evaluation. In fact, only 57% of physicians would obtain a SS more than 75% of the time. Conversely, 90% of physicians would obtain a head CT more than 75% of the time. In particular, most participants felt that the clinical signs and symptoms were the most important variable in the evaluation for a shunt malfunction.

TABLE 3. Predictive Value of the Cranial CT Scan and/or SS

Radiographic Study	Sensitivity, % (SD)	Specificity, % (SD)	Negative Predictive Value, % (SD)	Positive Predictive Value, % (SD)
Abnormal SS	27.1 (20.2–31.1)	98.7 (97.3–99.5)	87.4 (86.2–88)	80 (59.7–91.8)
Abnormal CT scan	67.2 (57.3–75.7)	89.9 (87.9–91.5)	93.4 (91.4–95.1)	56.3 (48–63.4)
Either abnormal CT scan or SS	66.2 (56.8–74.4)	90.3 (88.4–92)	92.8 (90.8–94.5)	58.8 (50.4–66)

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In this regard, several studies have evaluated clinical predictors of shunt malfunction. Clinical signs including headache, drowsiness, decreased level of consciousness, irritability and vomiting have been associated with the presence of a ventricular shunt malfunction.[7–11] Interestingly, seizure activity, not infrequently a presenting complaint of shunted children, has been shown to be a negative predictor of shunt malfunction.[12] In our study, univariate testing of clinical predictors of shunt malfunction identified patients presenting with headache or vomiting as more likely to have a shunt malfunction, whereas patients with a history of fever or seizure activity as less likely. In fact, patients who presented with a seizure were *2.5 times less likely* to have a shunt malfunction than those patients without a history of seizures.

Findings from our study may be limited based on the retrospective nature of the study and the fact that not all patients had both a SS and a cranial CT scan performed. In addition, the retrospective design may make this study prone to indication bias. However, medical records of patients were initially selected for review based on the presence of a shunt, irrespective of their presenting complaint. Upon review, only those patients with a chief complaint that could potentially be related to a shunt malfunction were included in the study. Thus, all patients with a shunt who presented to the ED during the study period were reviewed and assessed for study inclusion, not just those who underwent radiological testing.

CONCLUSIONS

In our study, we report that ventricular shunt malfunction may be present in children whose cranial CT is normal, but that the SS was able to identify some of the patients with malfunction. As a result, we believe that the SS cannot be omitted from the routine evaluation of children with suspected shunt malfunction.

REFERENCES

1. Kaufman BA. Management of complications of shunting. In: Cheek WR, eds. *Pediatric Neurosurgery*. 3rd ed. Philadelphia, PA: WB Saunders; 2000:529–547.
2. Bondurant CP, Jimenez DF. Epidemiology of cerebrospinal fluid shunting. *Pediatr Neurosurg*. 1995;23:254–259.
3. Iskandar BJ, McLaughlin C, Mapstone TB, et al. Pitfalls in the diagnosis of ventricular shunt dysfunction: radiology reports and ventricular size. *Pediatrics*. 1998;101:1031–1036.
4. Lee TT, Uribe J, Ragheb J, et al. Unique clinical presentation of pediatric shunt malfunction. *Pediatr Neurosurg*. 1999;30:122–126.
5. Zorc JJ, Krugman SC, Ogborn J, et al. Radiographic evaluation for suspected cerebrospinal fluid shunt obstruction. *Pediatr Emerg Care*. 2002;18:337–340.
6. Li V, Dias MS. The results of a practice survey on the management of patients with shunted hydrocephalus. *Pediatr Neurosurg*. 1999;30:288–295.
7. Barnes NP, Jones SJ, Hayward RD, et al. Ventriculoperitoneal shunt block: what are the best predictive clinical indicators? *Arch Dis Child*. 2002;87:198–201.
8. McClinton D, Carraccio C, Englander R. Predictors of ventriculoperitoneal shunt pathology. *Pediatr Infect Dis J*. 2001;20:593–597.
9. Traynelis VC, Powell RG, Koss W, et al. Cerebrospinal fluid eosinophilia and sterile shunt malfunction. *Neurosurgery*. 1988;23:645–649.
10. Lan CC, Wong TT, Chen SJ, et al. Early diagnosis of ventriculoperitoneal shunt infections and malfunctions in children with hydrocephalus. *J Microbiol Immunol Infect*. 2003;36:47–50.
11. Garton HJ, Kestle JR, Drake JM. Predicting shunt failure on the basis of clinical symptoms and signs in children. *J Neurosurg*. 2001;94:202–210.
12. Johnson DL, Conry J, O'Donnell R. Epileptic seizure as a sign of cerebrospinal fluid shunt malfunction. *Pediatr Neurosurg*. 1996;24:223–228.

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