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ORIGINAL ARTICLE

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Utilization and cost effectiveness review of shunt series to rule out ventriculoperitoneal shunt malfunction

Abstract *Purpose:* To evaluate the usefulness of the conventional radiographic shunt series in the initial work-up of patients suspected of having ventriculoperitoneal shunt malfunction, and to describe an imaging work-up algorithm. *Methods:* Charts of 33 patients with shunt series were retrieved from medical records and reviewed. Twelve patients were excluded either because there was no head CT scan done at the time of the shunt series or because the studies were done immediately postoperatively. The remaining 21 patients had a total of 67 shunt series and head CT scans performed to rule out shunt malfunction. Patients' age range was 8 months to 81 years. There were 9 female and 12 male patients. Only three patients were more than 17 years old. *Results:* In 12/67 cases (18%) the CT demonstrated normal-size ventricles. In none of these cases did the patients undergo shunt revision. Of the cases where there was an abnormal CT result, 22/67 (33%) showed increasing hydrocephalus, 5 (7%) showed enlarged ventricles with no comparison study, and 28 (42%) showed stable enlarged ventricles. The shunt was revised in 22/67 (33%) cases. No shunt series was interpreted as demonstrating abnormality of the shunt. *Conclusion:* Routine shunt series should not be the initial imaging study in the work-up of patients who present to rule out shunt malfunction. They may be helpful following CT and neurosurgical evaluation of those patients who are scheduled to undergo operative shunt revision.

Key words Shunts – Ventriculoperitoneal – Hydrocephalus – Disconnection – Malfunction – Radiography

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Introduction

Ventriculoperitoneal shunt malfunction can present with a variety of clinical manifestations. In their review of 119 patients with 201 shunt revisions, Sekhar et al. found the major indications for shunt revision in infants were: "an enlarging head, full tense fontanels, lethargy and/or irritability, persistent fluid collection along the shunt track, and abnormal neurological signs such as restriction of upward gaze and spasticity" [1]. In older children symptoms included "persistent headaches, abnormally enlarging head, deteriorating mental function, papilledema and an increased frequency of seizures." Lee reported one case where the patient's only symptom of shunt malfunction was loss of visual acuity [2]. In their review of 68 children treated for shunt malfunction, Ashkenazi et al. found that 22% presented with fever [3].

It is clear that a patient presenting to the emergency department with a history of ventriculoperitoneal shunt can be a diagnostic challenge. In their recent review "Diagnostic imaging of shunt malfunctions and complications," Goeser et al. point out that a variety of complications may occur with the shunt and that the radiologic work-up is important. They propose that the entire course of the shunt first be examined with conventional radiography for disconnections, kinks, breaks, or migration of the shunt tubing that may be confirmed afterward with other imaging modalities [4]. Indeed, one of the initial diagnostic studies performed on patients suspected of having shunt malfunction at our institution has been the conventional shunt series. This series usually includes a lateral skull, an anteroposterior chest and anteroposterior abdomen/pelvis radiograph. This

Fig. 1 CT scan depicts enlarged lateral ventricles with the shunt tip terminating in the corpus callosum

often is the first study performed in the emergency department, while the patient is waiting for a CT scan of the brain or a neurosurgical consultation.

We are not aware of a study addressing the need, cost effectiveness, and utility of the conventional shunt series. We performed a retrospective review of 33 patients receiving a shunt series at our institution to help us direct the imaging work-up of shunt malfunction, and to evaluate the usefulness of the shunt series.

Materials and methods

The records of 33 patients with shunt series were obtained from a computer database (IDXRAD) and their charts retrieved and reviewed. Twelve patients were excluded either because there was no head CT done at the time of the shunt series or because the studies were done immediately postoperatively. The remaining 21 patients had a total of 67 shunt series and head CT scans done to evaluate shunt function. The patients were initially evaluated in the emergency department. If clinical exam (including vital signs, fundoscopic evaluation, abdominal exam, and palpation of the shunt) or history indicated possible shunt malformation, a CT shunt series was ordered. All head CT scans were compared with prior studies when available. Results of the shunt series were recorded as negative or positive for demonstrating an abnormality of the shunt. The shunts were evaluated for kinks, knots, disconnections, breaks in the tubing, and migration. The CT scans were evaluated for ventricular size, subependymal absorption of cerebral spinal fluid, location of the shunt tip, and fluid tracking along the shunt. Results were summarized as: ventricles normal, ventricles enlarged but no comparison scan, ventricles enlarged but stable, or ventricles enlarged and increasing. The date and time of the shunt series and CT were recorded as well as any shunt tap or shunt revision. Cost effectiveness analysis was done by comparing the total cost of all shunt series to the number of positive shunt series.

Results

Patients presented to the emergency department with a variety of symptoms including headache, nausea and vomiting, swelling along the shunt, hemiparesis, lethargy, irritability, fever, increasing head circumference, mental status change, abdominal distention, and seizures.

The shunt series was performed prior to the CT in 39/67 (58%) of the cases and after the CT in 28/67 (42%) of cases. In 12/67 cases (18%) the CT demonstrated normal size ventricles. None of these patients had shunt revision. Of the remaining 55 cases, the patient had increasing hydrocephalus in 22, enlarged ventricles with no comparison in 5, and stable enlarged ventricles in 28. The shunt was revised in 22 cases. In 16 of the cases with shunt revision, the CT demonstrated increasing hydrocephalus. In 2 other cases revision was carried out for clinically evident shunt failure (redness and swelling along the course of the shunt). In 2 more cases shunts were revised after the CT revealed hydrocephalus with no comparison scan. In 1 other case the patient underwent shunt revision after the CT showed hydrocephalus stable for 3 months but with the shunt tip outside the ventricular system (Fig. 1). The shunt series depicted intact radio-opaque tubing, although the length of the radiolucent proximal connection was not known and therefore a disconnection could not entirely be excluded (Fig. 2). This patient had a shunt tap which revealed proximal flow obstruction. In 1 other case the patient underwent shunt revision after CT revealed hydrocephalus stable since 1 day prior. This patient had enlarged ventricles and continued clinical symptoms of shunt malfunction (persistent hemiparesis and pseudomeningocele). He was further evaluated with a shunt tap which revealed increased opening pressure but excellent flow into ventricles. There was peripheral runoff down to 6 cmH_2O. Proximal runoff was confirmed with shuntogram under fluoroscopy and CT following shuntogram. On conventional shunt survey, contrast was observed in the distal tubing to the base of the skull. No contrast was identified in the abdomen. The patient was taken to the operating room for distal shunt revision and experienced significant clinical improvement.

In three cases patients had increasing hydrocephalus with no shunt revisions. One of the patients had the shunt pumped, which improved runoff and the patient improved clinically. One patient had increase in size of the right ventricle only. This patient was evaluated with a shunt tap and observed by neurosurgical colleagues with clinical improvement. The third patient had an increase in the size of the lateral and third ventricles. A shunt trap was performed, demonstrating no increased pressure and good runoff. His CT was repeated the following day depicting no change. A shunt revision was performed 4 days later. No shunt series was interpreted as positive for demonstrating an abnormality of the shunt. The combined cost of all of the shunt series was $12,827.82.

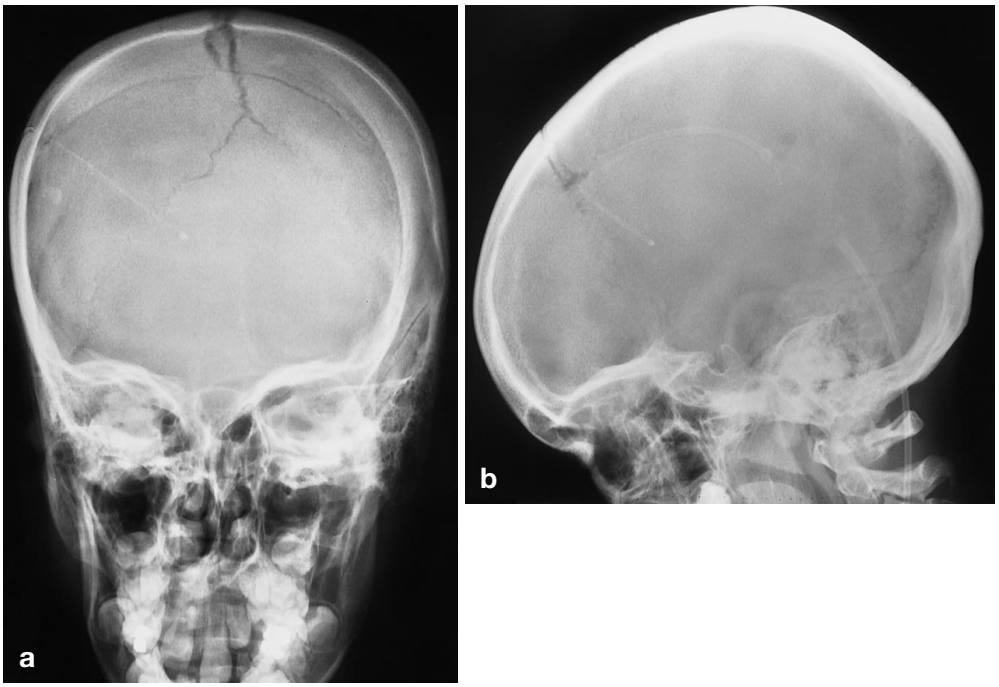


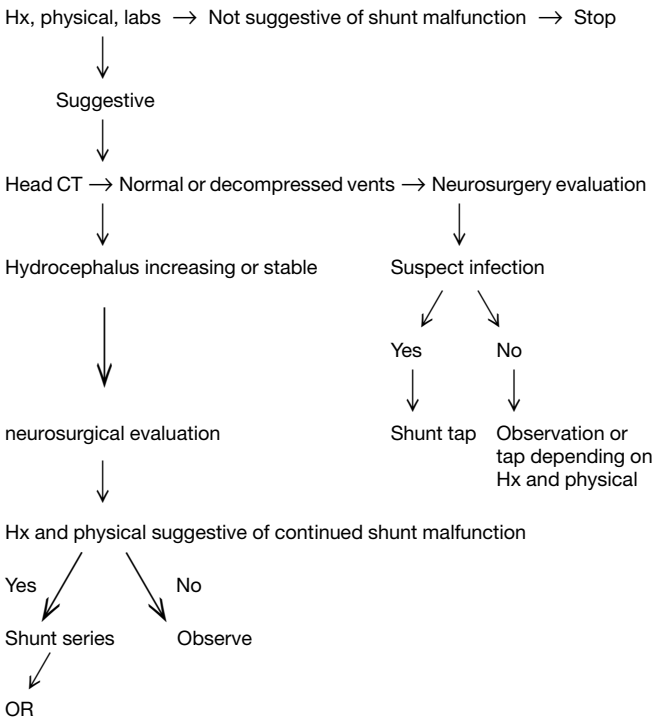
Fig. 2 a, b Anteroposterior and lateral skull radiographs demonstrate no breaks or kinks in the opaque shunt tubing; however the lucent connecting tubing varies in length depending on the type of tubing and the manufacturer

Discussion

Our radiology department and neurosurgery department agree that the shunt series is not always needed in the work-up of suspected shunt malfunction, and should be reserved for those cases where the CT clearly shows hydrocephalus without obvious explanation. If the CT depicts hydrocephalus, the neurosurgeon often "pumps" the shunt by manual compression of the shunt reservoir. If the reservoir does not refill, a proximal occlusion is suspected. Distal obstruction is likely if there is resistance to compression. A shunt percutaneous puncture or "tap" of the reservoir may be performed for CSF pressure readings and laboratory analysis. At our institution, a shunt tap is not routinely performed unless there is a clinical suspicion of infection. Often the results of the shunt tap and shunt pump can be misleading depending on the type of the shunt, the experience of the physician performing the test, and patient cooperation. If the CT findings, clinical symptoms, and the shunt pump test are inconclusive, the patient may be evaluated with other imaging modalities such as nuclear medicine CSF shunt study. This can be performed using ^{99m}Tc-albumin colloid, ^{99m}Tc-diethylenetriaminepentaacetic acid (DTPA), or ^{111}In-DTPA [6]. If DTPA is used, delayed images demonstrating renal activity indicate distal shunt patency. If macroaggregated albumin is used, lung activity indicates distal shunt patency. The radionuclide study may demonstrate shunt patency in a shunt with inadequate flow. Ventriculomegaly can be seen with functional obstruction of the antisiphon device despite a normal radionuclide study. Attempts at quantifying the rate of disappearance of radioactivity to determine shunt patency have had various success [6].

Injection of iodinated contrast into the shunt reservoir under fluoroscopic guidance and left anterior oblique view can be used to evaluate patency. Fluoroscopic assessment of the ventricles is necessary to avoid increasing intracranial pressure [4] Sonography is sometimes used to evaluate pseudocysts which may form around the distal tip in the abdomen. CSF production and flow has been studied by magnetic resonance imaging (MRI) in patients with normal-pressure hydrocephalus, pediatric patients with hydrocephalus, and in evaluation of shunt malfunction [7, 8, 9]. At our institution, MRI has not routinely been used to evaluate shunt malfunction, but may in the future replace CT as the initial imaging technique.

The cost of a radiographic shunt series at our hospital is determined by the Health Services Cost Review Commission (HSCRC) which establishes Relative Value Units (RVUs) for all procedures and approves the rate charged by the hospital. The cost of a radiographic shunt series at our institution is \$70.46 for the hospital charge and \$121.00 for the professional fee, total \$191.46. Of the 67 cases in which patients had shunt series performed, 22 shunts were revised intraoperatively. If the shunt series had not been performed on the remaining 45 patients, there would have been a \$8,615.70 (45 × \$191.46) savings. An estimated radiation exposure for the anteroposterior and lateral skull, anteroposterior chest, and anteroposterior abdomen radiographs included in the shunt series is 660 mR. Each of the 45 patients not requiring revision could have been spared this exposure. We propose the following imaging algorithm to save the patient the radiation exposure and the cost of unnecessary shunt series:



Conclusion

Shunt series do not contribute to the work-up or management of most cases of suspected shunt malfunction. In all of our cases shunt revision was based on CT findings and clinical evaluation. We propose a shunt series be done only when CT reveals hydrocephalus, the clinical evaluation supports probable shunt malfunction and the neurosurgeon is planning to evaluate the shunt in the operating room. A conventional shunt series could provide valuable information about the integrity and placement of the shunt tubing prior to operation. It is important to emphasize that a normal head CT does not exclude shunt malfunction and that clinical evaluation and observation is imperative.

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Editorial comment

This is a simple study that approaches a question that emergency physicians specialized institutions face often. Namely, "*When is a ventriculoperitoneal shunt series cost effective?*" In the study the authors reviewed 67 shunt series performed on 21 patients who presented to the emergency department with complaints *possibly* referable to shunt malfunction. It is interesting to note that of these 67 presentations, a total of 22 visits eventually culminated in a trip to the operating room for a shunt revision. That is slightly more than one shunt revision per patient. This number is higher than my clinical experience would suggest. Although I praise the authors for attempting to determine the utility of ventriculoperitoneal shunt series in the evaluation of this patient population, this study falls short for the following reasons.

First, this study demonstrates the classic problem with looking at an issue out of the context of the clinical scenario. Patients who present with complaints possibly referable to shunt malfunction are a specialized patient population in many respects. First, these patients have invariably gone through a vigorous screening process in which they have usually been seen and examined by a private practitioner prior to arrival in the emergency department. This increases the pretest probability that their condition is referable to their underlying neurologic condition. Second, after arrival in the emergency department they undergo a second evaluation by a practitioner, again to eliminate other causes for their complaints. If this second exam does not reveal a proximate cause then a complete neurosurgical evaluation is essential. Third, these patients and their families are usually aware of the symptoms that they have had in the past that were associated with their neurosurgical condition. Fourth, often these patients have difficulty communicating, making the reliability of the clinical evaluation more tenuous. As pointed out in the study, most of these patients are pediatric patients and all have an underly-

ing neurosurgical condition. To try and reassure parents that their child's shunt is *probably* or *most likely* not the cause of their symptoms without a complete evaluation is a fruitless endeavor. The clinician's time would be better served seeing other patients.

Second, the study lacks the statistical power to safely accept or reject the hypothesis. For the 21 patients (67 patient visits) reviewed the authors felt that the shunt series did not contribute any useful information, but the sample size of the study population is to small to make a meaningful statement about the results. If the next patient evaluated did have a shunt series that in the authors' estimation contributed meaningful information, then a shunt series may indeed be useful at least 5 % of the time. A larger study needs to be done to adequately answer the question.

Third, superficial cost analyses of clinical scenarios such as this one are often fraught with error. Often hidden costs do not readily come to mind. Because there is not a glut of neurosurgeons in the United States these patients often have to travel moderate to long distances to be evaluated. This alone rules out the possibility of outpatient observation in many cases. If a complete evaluation in the emergency department prevents a potential admission to the hospital, then the additional cost of saved hospital days needs to brought into the equation. In addition, when the cost of the time and effort spent defending a missed shunt malfunction case is considered, there are not too many practitioners who would not perform the shunt series. Finally, the overall patient flow in the emergency department is a real consideration. Where time in the radiology suite is at a premium and where patient flow is often delayed while specialists order additional radiology tests, one cannot afford to delay an inevitable test. This cost of patient flow delay and potential harm to patients distant from the study patient is most difficult to quantitate. Considering all of these factors, it seems to the practicing clinician more cost effective to order the shunt series while ordering the initial head CT.

Fourth, the suggestion that negative information is not useful information is incorrect. Of 67 patient visits reviewed, in 22 (33 %) the patients eventually made their way to the operating room. In every one of these cases a negative shunt series was useful to the neurosurgeon prior to entering the operating room suite.

Finally, when considering the risk/benefit analysis of this test we should put it into context with other similar tests. Where the risks are high if the disease is missed we are more apt to perform the complete work-up and overturn every stone. For example, the risk of missing a bacterial meningitis in a febrile child less than 6 weeks of age by not doing a lumbar puncture is around 1–2 %. How many practicing clinicians are willing forego the lumbar puncture simply because they have a 98 % chance that the child does not have meningitis? The old teaching passed down in medical school regarding lumbar punctures has served many a clinician well: "If you think about it you need to do it." Another example is a lumbar puncture to rule out subarachnoid bleeding in selected patients who have had a negative head CT. In this particular patient population, with third-generation scanners, again the odds are 98 % that the test result will be negative. However, for both of these invasive tests the potential benefit of the test greatly outweighs the risk. A shunt series in the work-up of a patient with a ventriculoperitoneal shunt carries very few inherent risks for the patient, and a negative shunt series represents useful information to the neurosurgeon.

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