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AJNR Am J Neuroradiol 1985, 6 (5) 815-822

<http://www.ajnr.org/content/6/5/815>

This information is current as of May 16, 2024.

Metrizamide Shuntography for Evaluation of Shunt Malfunction in Hydrocephalus

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Ventricular shunts were evaluated by a shuntographic technique using metrizamide for the contrast material and delayed spot films and computed tomography (CT) to evaluate shunt function. Thirty hydrocephalic patients were studied who had clinical presentations of shunt malfunction. Fifty-two shuntograms were obtained; most demonstrated the cause of shunt malfunction. No contrast-related complications resulted from the procedure. Diagnostic accuracy was greatly improved by this method, since both anatomic and functional evaluations could be performed. In patients with normal studies, unnecessary surgery was eliminated; in abnormal shuntograms, the duration of surgery and the likelihood of complications were reduced because the surgeons knew the exact anatomic derangements to be corrected.

Since July 1981, patients with clinical and computed tomographic (CT) findings suggesting ventricular shunt malfunction have been evaluated by shuntography using metrizamide as the contrast agent. Except for a few cases, CT showed hydrocephalus in all cases. The shuntogram was obtained to delineate the exact cause of shunt malfunction, thereby directing the surgical approach to the specific area of abnormality. This obviated total revision of the shunt and shortened the surgical procedure. A few symptomatic patients with normal or slightly enlarged ventricles were also evaluated, and it was shown that the patients' problems were not related to shunt malfunction. Shuntograms also delineated some rare causes of shunt malfunction that would have been missed by clinical or CT evaluation alone. We describe our technique and report our experience in 30 patients.

Materials and Methods

The patient population comprised 30 patients with clinical presentation of shunt malfunction and/or CT documentation of hydrocephalus. Most (26) were infants and young children. A total of 52 shuntograms were obtained, since some patients required more than one revision.

Shunt Anatomy

The shunt is a mechanical conduit designed to carry excess cerebrospinal fluid (CSF) from the ventricular system or subarachnoid or cystic spaces into an absorbing cavity such as the peritoneal or pleural space, ureter, or cardiovascular system. Ventriculoperitoneal or ventriculopleural shunts were used predominantly. Although other types of shunts are available, we prefer the Pudenz valve system. The Pudenz system, like the other shunt systems, has three major internal components: (1) the ventricular or proximal catheter, (2) the reservoir and valve, and (3) the peritoneal or distal catheter.

Ventricular catheter. This is a flexible silicone catheter with a small radiopaque tip and multiple side holes in its distal segment (fig. 1A). The position of the tip of the ventricular catheter outside of the ventricles does not necessarily imply shunt malfunction, since the ventricle is drained by the side holes rather than by the tip. The proximal segment of the ventricular catheter is attached to the shunt reservoir by a plastic joint.

Received October 11, 1984; accepted after revision March 1, 1985.

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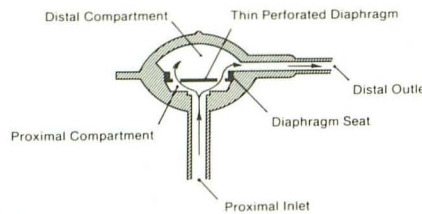
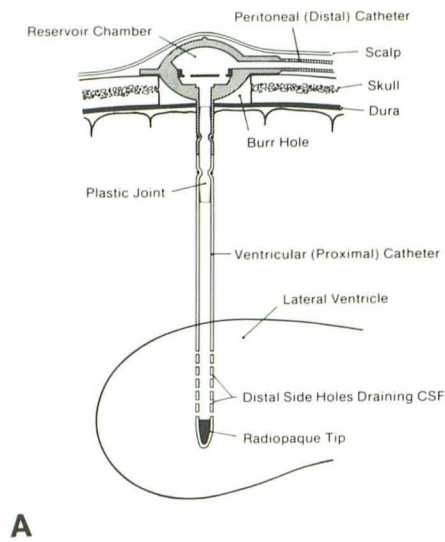
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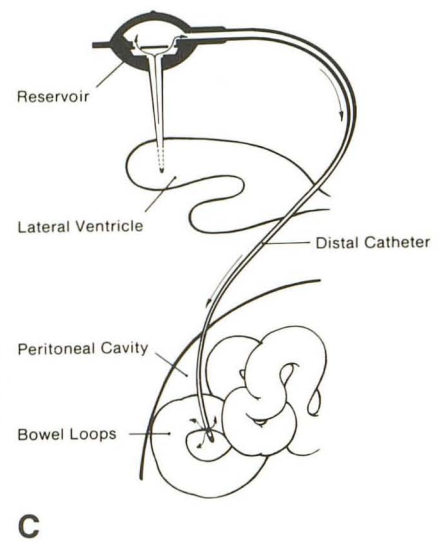
AJNR 6:815-822, September/October 1985
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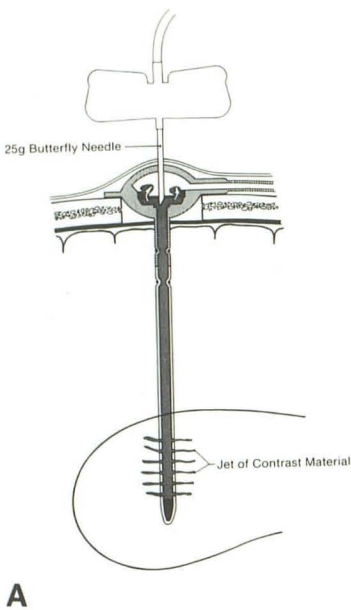


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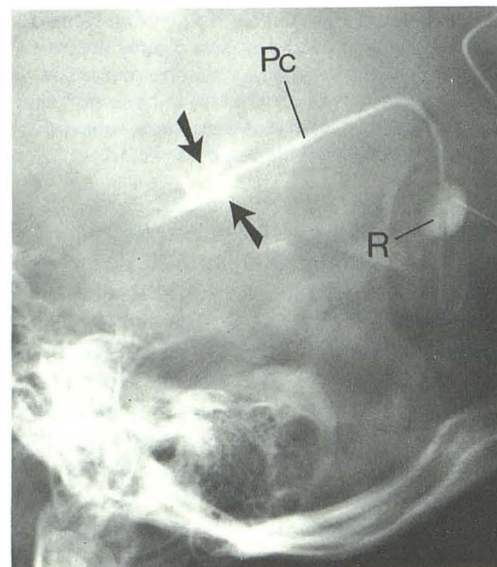
Fig. 1.—Anatomy of Pudenz flushing valve system. **A**, Proximal catheter. Tip of ventricular catheter is placed in ventricular system. Its proximal end is tied to proximal inlet of shunt reservoir. **B**, Cross section of shunt reservoir. Perforated diaphragm divides reservoir chamber into two compartments and acts as a one-way valve, preventing retrograde CSF flow. **C**, Distal peritoneal catheter. Distal tip is placed within absorptive cavity.



C



A



B

Fig. 2.—Technique for studying proximal catheter patency. **A**, Tip of 25-gauge butterfly needle is placed within proximal compartment, and contrast material is injected. Jet phenomenon at tip of catheter. Some contrast material will also pass through perforated diaphragm into distal chamber (arrows). **B**, Lateral film of skull. Jet phenomenon at tip of ventricular catheter (arrows). Contrast material was injected into proximal chamber of ACCU-FLO system. PC = proximal catheter; R = shunt reservoir.

Reservoir chamber. The reservoir is divided into proximal and distal compartments by a thin perforated diaphragm. The proximal chamber is in continuity with the CSF, while the distal compartment is connected to the absorbing space (fig. 1B).

Distal catheter. This is a relatively long, usually radiopaque catheter with either a single distal opening or multiple slits (fig. 1C).

Shuntographic Technique

The patient is placed in a supine position with the head in a lateral position. The skin over the shunt reservoir is shaved, prepared, and draped in sterile fashion. In infants, moderate sedation is required to prevent patient motion. The patient must be kept in the supine position for some time before the study so that the intraventricular pressure exceeds the opening pressure of the shunt system at the time of the shuntogram. If this precaution is not observed, the results

of the dynamic study will be inaccurate [1]. A small skin incision is made to prevent introduction of epithelium into the shunt system, and the center of the reservoir is punctured by a 25-gauge butterfly needle held perpendicular to the reservoir dome to avoid damage to the diaphragm seat; such damage could result in loss of pressure control function [2].

The tip of the needle is then gently advanced further through the diaphragm into the proximal compartment, and CSF return is noted in the butterfly tubing. For beginners, it may be desirable to position the patient's head in such a way that the reservoir is in a tangential position to the x-ray beam so that intracranial entrance is avoided.

Once CSF return is established, pressure measurements can be made that reflect intracranial pressure. If there is no CSF return, contrast material may be injected to pinpoint the obstruction. Under fluoroscopic control, 1 or 2 ml of metrizamide (170 mg/ml) is injected.

Fig. 3.—Technique for studying distal catheter patency. **A**, Tip of butterfly needle is withdrawn and positioned within distal chamber. Contrast material is then injected, closing valve and filling distal catheter (arrow). **B**, Radiograph of abdomen. Spillage of contrast material outlines bowel loops. Tip of peritoneal catheter (arrow).

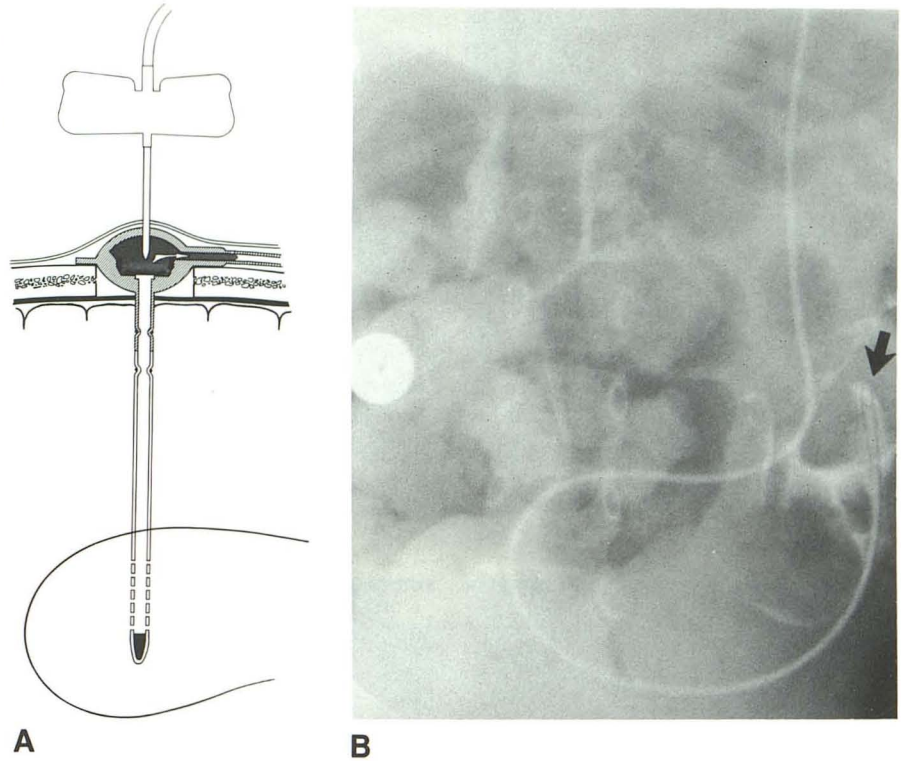


Fig. 4.—Blockage of distal holes in proximal catheter (PC) (open arrow). Radiopaque tip of ventricular catheter (solid arrow). R = reservoir chamber; N = butterfly needle; DC = distal catheter.

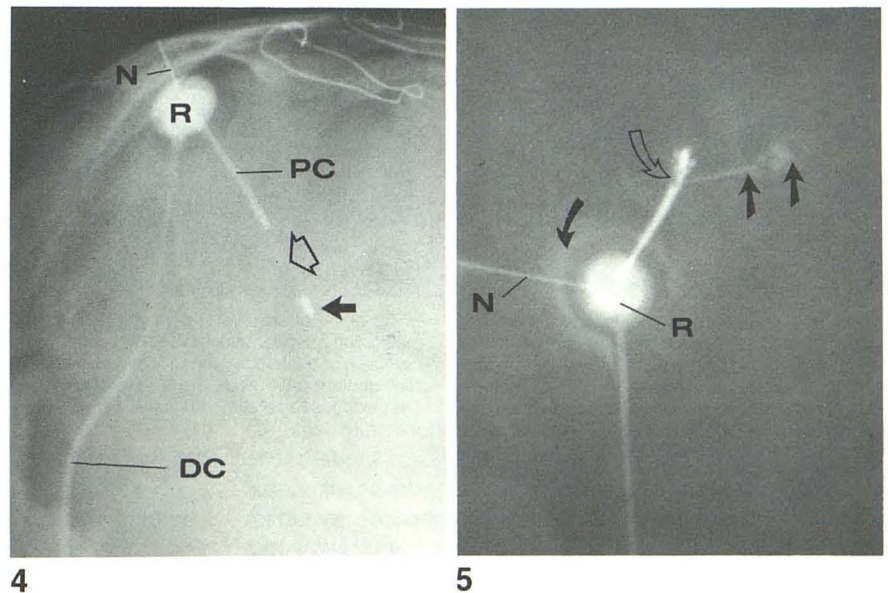


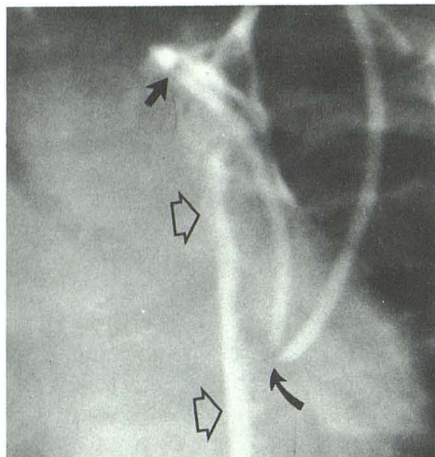
Fig. 5.—Partial blockage of ventricular catheter. Only one hole is patent, and single jet of contrast material is clearly demonstrated (straight arrows), while remaining holes are occluded and appear as multiple filling defects in distal catheter (open arrow). Minimal extravasation of contrast material (solid curved arrow) around shunt reservoir (R). Small circular area of increased density within reservoir chamber is proximal compartment. Distal compartment, as well as distal catheter, is also seen because of passage of contrast material through one-way valve. N = butterfly needle.

Injection of air must be avoided, since it may cause air embolism in cases of ventriculovenous shunt and because it may delay emptying, which would interfere with dynamic studies [3]. If the ventricular catheter is patent, contrast material will exit through the distal holes, and a jet phenomenon will be clearly seen (fig. 2).

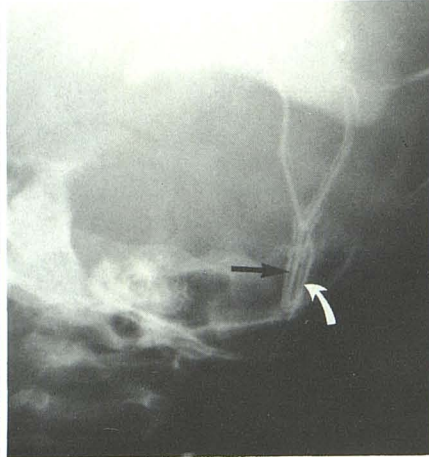
In the absence of loculation, contrast material mixes rapidly with CSF and may be seen in the dependent part of the ventricle. In cases of loculation, contrast material fills a cavity and does not diffuse into the rest of the ventricular system.

The tip of the needle is now slowly withdrawn until it lies within the distal chamber. Contrast material is again injected, opacifying the entire length of the distal catheter into the absorptive cavity, while the valve prevents intraventricular reflux (fig. 3A). In the case of ventriculoperitoneal shunts, normal peritoneal spillage is seen fluoroscopically, outlining loops of bowel (fig. 3B).

In normal shuntograms, delayed films of reservoir clearance are made at 3 and 9 min. A cranial CT scan can be obtained at 6, 12, and 24 hr after the shuntogram. Both of these methods display



6



7

Fig. 6.—Incomplete obstruction of ventriculo-pleural shunt is seen due to bending of distal catheter. Radiograph of left hemithorax demonstrates contrast material within pleural space (*open arrows*). Sharp kink (*curved arrow*) of distal catheter necessitated shunt revision. Tip of catheter (*straight solid arrow*).

Fig. 7.—Broken and dislocated distal catheter. Oblique view of skull. Broken distal catheter beyond Y junction. Overlapping broken fragments (*arrows*). Extravasation of contrast material in fibrotic tract along tubes.

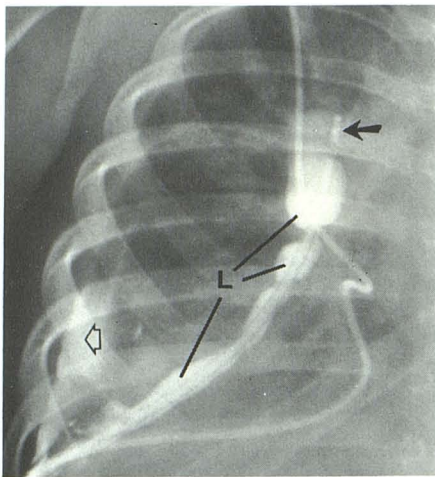
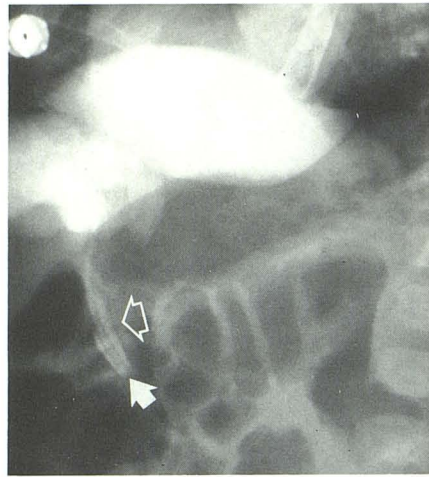
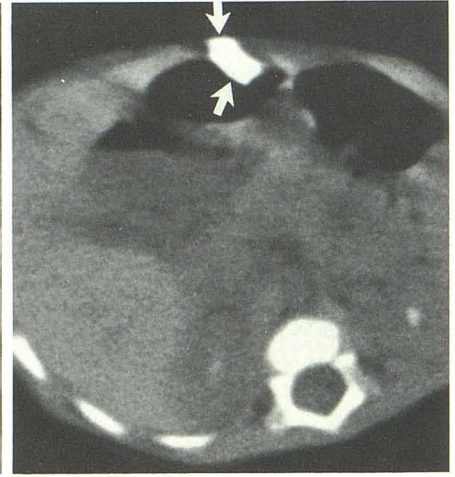


Fig. 8.—Pleural loculation causing shunt malfunction. Anteroposterior radiograph of right hemithorax. Tip of distal catheter in pleural space (*solid arrow*). Multiple loculations (L). Filling of pleural cavity (*open arrow*), since loculations are not complete. Increased distance between contrast-filled pleural space and lateral chest wall suggests pleural thickening. Distal shunt revision was needed because pleura had partially lost absorption capacity due to loculations and adhesions.



A



B

Fig. 9.—Retraction of distal catheter with formation of small pseudocyst in epigastric area. **A**, Lateral radiograph of upper abdomen. High position of shunt tip (*solid arrow*) caused by patient's growth. Small collection of contrast material (*open arrow*) around distal segment of catheter suggests cyst formation. **B**, High abdominal CT scan. Small pseudocyst (*arrows*) within peritoneal cavity around distal shunt catheter. Cyst extends to anterior abdominal wall. Absence of contrast material within rest of peritoneal cavity.

the shunt's dynamic functions. In cases of anticipated complex intracranial pathology, a CT study is done immediately, since the amount of contrast material used is insufficient to evaluate the entire ventricular system with routine radiographic techniques. To avoid pooling of contrast material in the dependent part of the ventricular system before the CT scan, the patient's head must be repositioned to insure adequate CSF-metrizamide mixing.

Results

The shuntograms in all 30 patients were obtained without complications. In most, the cause of shunt malfunction was

mechanical, including obstruction of proximal or distal catheters (figs. 4 and 5) or bending, breakage, or dislocation of the distal catheter (figs. 6 and 7). Cyst formation around the distal end of the peritoneal or pleural catheters contributed to shunt malfunction in some patients (figs. 8–10). The most important contributions of the shuntogram, however, were in those patients who had loculated hydrocephalus or intracranial cyst formation, which necessitated exact anatomic evaluation before shunt revision (figs. 11–13). The CT shuntogram demonstrated the location of the lesions and confirmed the presence or absence of communication between the cystic struc-

Fig. 10.—Pseudocyst formation around distal catheter tip within abdominal wall. **A**, Anteroposterior view of right abdomen after introduction of metrizamide in reservoir (R) of lumboperitoneal shunt. Cyst (C) around distal segment of peritoneal catheter (arrow). Suggestion of medial displacement of ascending colon by cyst. Cyst was believed to be either in extraperitoneal space or within peritoneal cavity. **B**, CT scan at level of cyst shows exact cyst location between external and internal oblique muscles. Minimal mass effect on ascending colon.

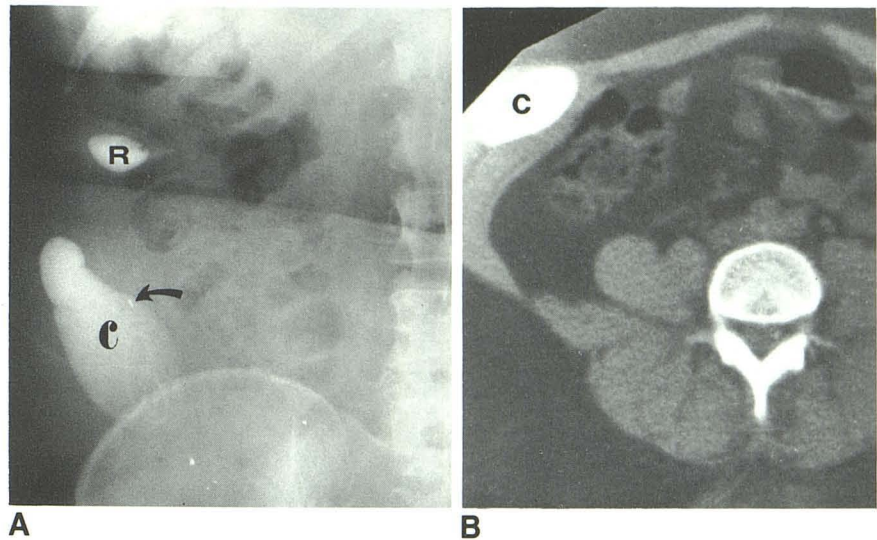
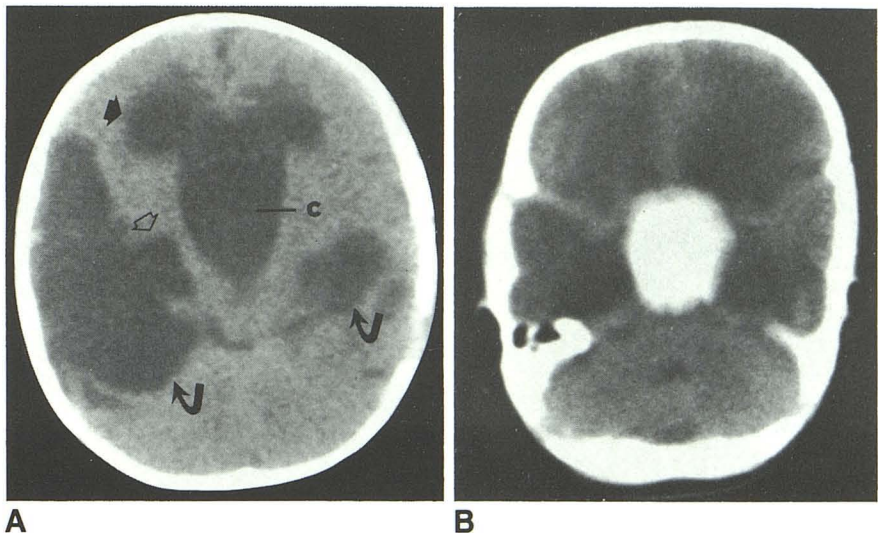


Fig. 11.—Suprasellar arachnoid cyst. **A**, Axial unenhanced cranial CT scan. Dilated frontal (straight solid arrow) and temporal (open arrow) horns. Cystic structure (C) in midline is larger than lateral ventricles, excluding possibility of its being third ventricle. Porencephalic changes in both temporal lobes (curved arrows). **B**, After introduction of metrizamide. Proximal catheter inadvertently entered cystic structure. No filling of lateral or third ventricle.



tures and the rest of the ventricular system or subarachnoid space. There was only one failure in our study. In that case, improper technique was used, and the shunt reservoir was punctured incorrectly. The tip of the butterfly needle entered the subarachnoid space through the burr hole (fig. 14). Fortunately, no complication occurred, and the patient was studied later and found to have proximal catheter blockage.

Discussion

The introduction of ventricular shunting has greatly improved the life span of patients with hydrocephalus. The new shunt systems with unidirectional valves are very flexible, increasing both their efficiency and dramatically decreasing postshunting complications. But shunt malfunction does occur. Aside from the patient's symptoms and clinical signs, the

simplest examination of shunt patency is digital compression of the shunt reservoir. In a normally functioning shunt, the reservoir chamber compresses easily and reexpands in a matter of seconds. Inability to compress the reservoir indicates obstruction of the distal catheter; failure to reexpand indicates obstruction of the proximal catheter. This test, however, is not entirely reliable. It has been shown that the reservoir may pump well despite shunt obstruction, and it may not pump well when it is working satisfactorily. A shunt may work well in the presence of increased intracranial pressure secondary to subdural hematoma or hygroma or multiloculated or isolated unilateral hydrocephalus [4-7].

A second mode of evaluation is CT, which is now widely used. Although CT demonstrates dilated ventricles or other causes of increased intracranial pressure, if CT alone is used, a small but significant number of patients with increased intracranial pressure will be missed. The size of the ventricles

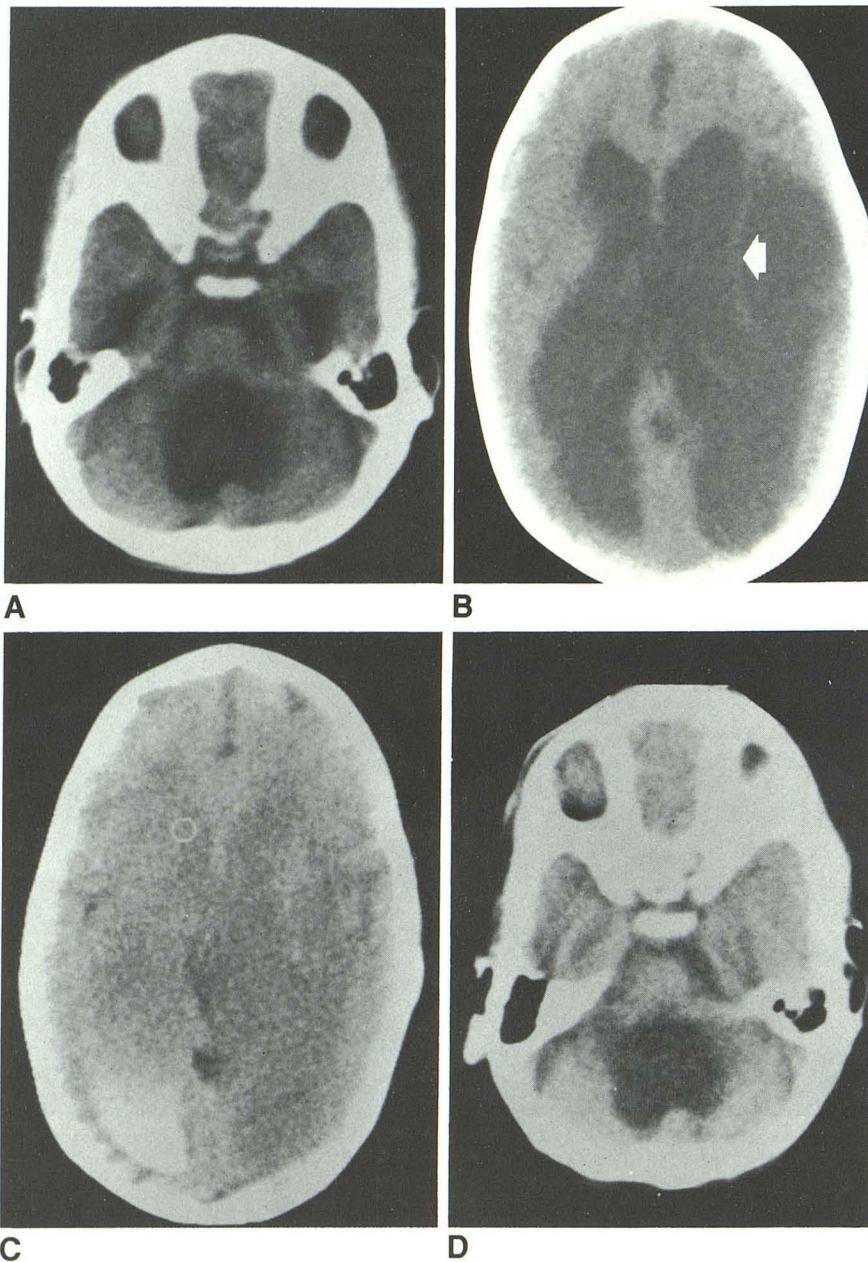


Fig. 12.—Incomplete loculated hydrocephalus and trapped fourth ventricle. **A**, Axial CT scan. Dilated fourth ventricle. Moderate dilatation of temporal horns. **B**, Higher section. Dilated lateral ventricles. Evidence of porencephalic cyst on left side, with suggestion of incomplete septum (*arrow*) separating it from ventricle. **C**, Delayed scan after introduction of metrizamide into ventricular system. Simultaneous filling of lateral ventricle and porencephalic cyst, confirming incomplete septation. **D**, Lower cut. Lack of fourth ventricle filling, confirming trapped fourth ventricle.

does not necessarily indicate the presence or absence of shunt malfunction.

Large ventricles may be seen in patients with working shunts who have a thin cortical mantle [8]. Likewise, malfunctioning shunts in the presence of small or normal ventricles have been observed [9–14]. It is extremely important that such patients be recognized so that proper management can be instituted. In such patients, the ventricles cannot expand despite the presence of increased intraventricular pressure. The mechanism of this phenomenon is not well understood; however, subependymal gliosis and granulation have been seen and may account for the decreased compliance of the ependyma [10, 14].

CT is also unreliable in diagnosing or accurately demonstrating some intraventricular loculations (multiloculated hydrocephalus) or intracranial cystic structures (i.e., suprasellar arachnoid cysts). Although CT may show some of the septations, because of the averaging effect it does not demonstrate thin membranes well [15–20]. A ventriculogram is needed to document the presence of loculations or cystic lesions.

Because of these limitations, other methods have been used to evaluate shunt function. These include radionuclide imaging, sonography, heat and cold transfer determination, subarachnoid infusion studies, and contrast shuntography [1, 3, 6, 21–28]. The radionuclide and contrast shuntograms can

Fig. 13.—Multiloculated hydrocephalus. **A**, Axial CT scan at level of lateral ventricles. Hydrocephalus with multiple septations (*arrows*). **B**, Metrizamide CT scan. Filling of ventricular system with no filling of loculations.

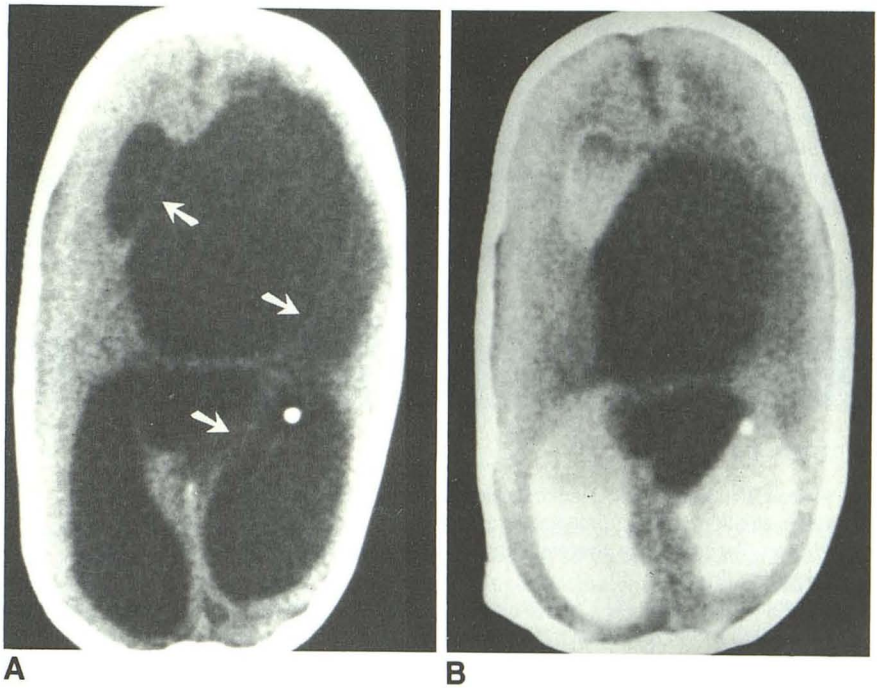
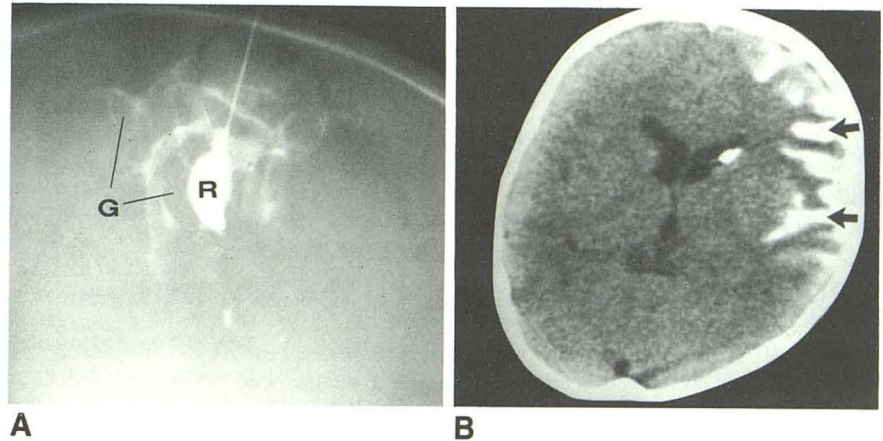


Fig. 14.—Inadvertent introduction of metrizamide into subarachnoid space. **A**, Radiograph after shuntography. Metrizamide in subarachnoid space, outlining gyri (G). R = reservoir. **B**, Axial CT scan. Metrizamide in subarachnoid space (*arrows*). Tip of proximal catheter in frontal horn. No complication occurred after subarachnoid introduction of metrizamide.



evaluate shunt patency and function, but metrizamide CT shuntograms provide the best anatomic detail.

The documentation of shunt patency does not rule out shunt malfunction. Even with gentle injection, contrast material is introduced into the system at a pressure higher than CSF pressure; therefore, contrast material could overcome incomplete obstruction. The measurement of opening pressure before introduction of metrizamide is useful to estimate intracranial pressure. However, according to Early and Fink [29], this measurement is not reliable since the ventricular system may enlarge despite normal pressure and continue to enlarge despite the presence of a patent shunt.

If metrizamide shuntograms show an abnormality, no further functional tests are needed. However, if the shuntogram is negative, functional evaluation of shunt performance must

be made to rule out shunt malfunction. So-called "deceptive patency," a patent shunt with inadequate capacity to keep the patient free of symptoms, was observed in 40% of the patients in the series of French and Swanson [1]. Functional evaluation can be performed by obtaining spot films of the shunt reservoir 3 and 9 min after completion of the shuntogram [3, 27]. Another method is to perform serial cranial CT examinations at 6, 12, and 24 hr after intraventricular introduction of metrizamide. In functioning shunts, the reservoir should be clear of any residual contrast material in 3 min. Persistence of residual contrast material at 9 min and beyond denotes shunt malfunction. Also, serial cranial CT studies should show complete clearing of intraventricular metrizamide at 24 hr [30, 31]. The presence of transependymal absorption of CSF is another finding indicative of shunt malfunction.

Our technique combines anatomic and functional studies of the shunt system by using metrizamide as the contrast agent, delayed filming, and CT. This combination greatly improved our diagnostic accuracy and eliminated unnecessary surgery. In cases of shunt malfunction, the duration of surgery was shortened significantly by informing the surgeons of the exact anatomic derangement to be corrected.

ACKNOWLEDGMENTS

We thank Chuck Campbell and Elaine Pullin for technical assistance and Rhoda Lancaster and Katy Dillard for assistance in manuscript preparation.

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