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Endoscopic fenestration and Endoscope-Guided Placement of Ventriculoperitoneal Shunt with additional side holes for Multiloculated Hydrocephalus: A Technical Note

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Running title: Endoscopic Placement of Ventriculoperitoneal Shunt with additional holes in multiloculated hydrocephalus

Abstract:

Multiloculated hydrocephalus (MLH) is characterized by multiple non-communicating cerebrospinal fluid (CSF) compartments and is associated with disproportionately high rates of shunt malfunction and revision surgery. We describe, in a stepwise technical format, an approach combining endoscopic cystoventriculostomy (inter-loculation fenestration) with endoscope-guided ventriculoperitoneal (VP) shunt catheter placement in an infant with multiloculated hydrocephalus. A 10-month-old male infant presented with progressive macrocephaly and developmental delay. Preoperative TORCH serology was notable for positive Rubella IgM and IgG, supporting a congenital rubella infection. Magnetic resonance imaging demonstrated multiple variable-sized loculated cysts (largest 30 × 39 mm) in the interhemispheric, bilateral parietal, and left temporal regions with mass effect on dilated lateral ventricles, in keeping with multiloculated hydrocephalus of probable post-infectious/congenital origin. A rigid neuroendoscope was used to sequentially fenestrate the intraventricular septa, and a single ventricular catheter, modified with additional side ports, was then advanced under direct endoscopic vision into the fenestrated common cavity. Wide endoscopic communication was established between the previously isolated loculations. A formal endoscopic third ventriculostomy was deliberately not attempted in this case because the distorted, loculated anatomy rendered safe access to the third ventricular floor unfavourable, compounded by the patient's young age and the extent of supratentorial multiloculation, which already necessitated shunt placement. The ventricular catheter tip and side holes were confirmed endoscopically to lie freely within the fenestrated cavity, away from choroid plexus and septal remnants, with free CSF drainage confirmed prior to closure. Postoperative CT confirmed marked decompression of the previously multiloculated cysts into a single residual cavity traversed by the catheter, without hemorrhage or new isolated loculation. Endoscopic fenestration combined with endoscope-guided, side-hole-modified catheter placement is a feasible and reproducible technique that allows direct, real-time confirmation of catheter position within a fenestrated common cavity. This may reduce the risk of isolated-compartment recurrence that complicates freehand or purely image-guided catheter placement in multiloculated hydrocephalus, although larger comparative series and longer follow-up are required.

Keywords: multiloculated hydrocephalus; neuroendoscopy; ventriculoperitoneal shunt; pediatric neurosurgery

Introduction:

Multiloculated hydrocephalus (MLH) refers to a complex form of hydrocephalus in which the ventricular system and/or extra-axial CSF spaces are subdivided by intraventricular septa into multiple, non-communicating compartments. [2, 9]. It most commonly follows neonatal meningitis or ventriculitis, intraventricular hemorrhage or postsurgical gliosis. It is increasingly being recognized as a sequela of congenital and perinatal infections grouped under the TORCH complex (toxoplasmosis, other agents, rubella, cytomegalovirus, herpes simplex) [2, 19]. Contemporary series similarly identify neonatal infection and intraventricular hemorrhage as important causes of compartmentalization [10, 12].

MLH remains a difficult problem in pediatric neurosurgery because standard single-catheter shunts are prone to draining only the compartment in which the tip happens to lie. This leaves the remaining loculations untreated or at risk of subsequent isolation and re-expansion. Early series of shunted MLH reported average shunt revision rates of three procedures per patient per year before any endoscopic intervention [2, 9]. This reflects the fundamental difficulty of ensuring durable drainage of multiple, anatomically distorted compartments with a single system.

Neuroendoscopy has emerged as the preferred first-line strategy for MLH because it allows septae to be fenestrated under direct vision, converting multiple isolated cavities into a single cavity that can then be drained by one ventricular catheter [2, 9, 14, 15]. However adequate fenestration alone is not sufficient. The position of the shunt catheter tip in relation to the compartments determines whether the benefit of endoscopic fenestration is sustained. If the tip lies unfavourably, a compartment may silently re-isolate and necessitate reoperation [3, 15]. Most published descriptions of catheter placement in this setting rely on either a freehand pass after endoscopic fenestration or with neuronavigation-assistance[10, 11, 12, 13, 17, 14].

We present a technical note, describing a stepwise technique of endoscopic fenestration. This is combined with endoscope-guided placement of a side-hole-modified ventricular catheter. In our case, both the fenestration and the entire course of catheter insertion were performed under continuous direct endoscopic visualization. A similar approach in an infant of similar age with post-meningitic multiloculated hydrocephalus, treated with endoscopic cyst fenestration and endoscope-guided VP shunt placement, has been reported previously [16]. Our note aims to detail the individual technical steps of this strategy in a reproducible, stepwise format.

Case presentation:

A 10-month-old male infant presented with progressive macrocephaly and delayed attainment of motor milestones. Antenatal and perinatal history raised suspicion of an intrauterine or perinatal infective insult. TORCH serology performed as part of the diagnostic work-up was notable for positive Rubella IgM and IgG. As maternal IgM does not cross the placenta, a positive Rubella-specific IgM indicates infection in the infant rather than passively acquired maternal antibody.

Magnetic resonance imaging of the brain demonstrated multiple variable-sized, thin-walled cysts, the largest measuring 30 × 39 mm. These intraventricular cysts were hypointense on T1-weighted and hyperintense on T2-weighted sequences with signal suppression on FLAIR. There was mass effect on the lateral ventricles, with dilatation of the frontal horns and third ventricle and was associated with diffuse periventricular white matter T2 hyperintensity consistent with transependymal CSF seepage (Fig. 1). These findings were consistent with multiloculated hydrocephalus.

After multidisciplinary evaluation, written informed consent for surgery was obtained from the patient's parents. The infant subsequently underwent endoscopic fenestration with endoscope-guided ventriculoperitoneal shunt placement, as described below.

Surgical technique:

1. Patient positioning:

The infant was positioned supine on the operating table with the head in a neutral position, supported on a gel head-ring. A standard frontal (precoronal) entry point was chosen, with the trajectory and the burr hole site tailored to the preoperative MRI to allow access to the largest and most superficial of the loculated cysts.

2. Endoscopic exploration:

A rigid neuroendoscope (Karl Storz, Germany) was introduced through a frontal burr hole and passed into the dominant, most accessible loculated cavity. On entry, the endoscope revealed multiple thin, translucent, variably vascularized septa subdividing the supratentorial CSF space into discrete compartments (Fig. 2A). Systematic endoscopic exploration was used to map the relationship of the septae to the choroid plexus and to the walls of the lateral ventricle

3. Endoscopic fenestration strategy:

Each septum was opened at a relatively avascular point using a Fogarty balloon catheter (Fogarty arterial embolectomy catheter, 3 Fr, Edwards Lifesciences, Irvine, CA, USA) and the resulting opening (stoma) was then enlarged by inflating the balloon (Fig. 2B). Each stoma was enlarged as widely as the local anatomy safely permitted, in an attempt to reduce the likelihood of later reclosure by arachnoid scarring. This stepwise fenestration was continued until the maximum number of compartments safely communicated as a single, common CSF cavity.

4. Decision not to perform endoscopic third ventriculostomy (ETV):

Preoperative imaging also showed loculated cysts extending into the perimesencephalic cisterns. Nevertheless, a formal third ventriculostomy was deliberately not performed in this case for two reasons. First, we expected the intra-ventricular anatomy to be unfavorable for ETV. The loculated anatomy obscured the usual intraventricular landmarks, and reliable orientation to the floor of the third ventricle was not possible without neuronavigation.

Second, the patient's young age (<1 year) is independently associated with a lower probability of ETV success [6, 7, 18].

5. Side-hole modification:

Beyond the standard factory-made perforations near the catheter tip, additional side holes were fashioned along the distal few centimeters (up to 5 cm) of the ventricular catheter before insertion. This modification was intended to allow more than one fenestrated compartment to drain through the single catheter even if a small degree of re-septation were to occur adjacent to any one perforation.

6. Guided catheter insertion:

With the endoscope kept within the newly fenestrated common cavity, a ventricular catheter (Chhabra SH-202, G. Surgiwear Ltd., India) was advanced alongside the endoscope under continuous direct vision (Fig. 3A). The catheter tip and side-hole segment were confirmed, under direct endoscopic vision, to lie freely within the dominant communicating cavity created by fenestration, spanning the region of the former septa (Fig. 3B). No further adjustment was required after this visual confirmation.

7. Confirmation of free CSF flow:

Before withdrawal of the endoscope and connection of the distal shunt system, free, unobstructed egress of CSF through the ventricular catheter was confirmed at the free end of the catheter. The catheter was then connected to the valve and peritoneal catheter and tunneled in standard fashion, and the incisions were closed in layers.

Post-operative course: Non-contrast CT of the brain obtained on the first postoperative day (Fig. 4) showed a single, markedly decompressed residual cavity in place of the multiple large preoperative cysts, with the ventricular catheter tract traversing the fenestrated compartment and its tip lying close to the third ventricle. No evidence of postoperative hemorrhage, hygroma or new isolated loculation was identified on this early scan. At the most recent follow-up, 2 months after surgery, the child was alert and playful and was tolerating feeds well, with no increase in head circumference.

Discussion:

Why catheter position matters:

In multiloculated hydrocephalus, the durability of treatment depends less on the number of septae fenestrated and more on whether the shunt catheter subsequently remains in free communication with the fenestrated compartments. A catheter tip that comes to rest against a septal remnant, within the choroid plexus or inside a single small residual loculation effectively recreates a single-compartment shunt in a multi-compartment ventricle. In such a case, some loculations remain untreated or silently re-isolate over time, a well-recognized mechanism of shunt failure and repeat need for surgery [2, 11].

Freehand versus image-guided catheter placement:

Existing descriptions of catheter placement after endoscopic fenestration typically rely on either a freehand pass, guided only by the surgeon's spatial recollection of the fenestration once the endoscope has been withdrawn, or on frameless neuronavigation [14]. Navigated endoscopy has been shown to be safe and effective and further refines preoperative planning and intraoperative orientation in distorted ventricular anatomy [8, 14], but it requires dedicated navigation hardware, registration accuracy and is not universally available, particularly in resource-limited settings. Endoscopic visualization devices have also been reported as feasible for difficult pediatric catheter implantation, particularly when anatomy is distorted [13].

Advantages of endoscope-guided catheter placement:

Maintaining endoscopic visualization during catheter insertion allows the surgeon to confirm that the catheter tip and the side ports lie freely within CSF and not against a membrane, ependyma or choroid plexus. This is

particularly valuable in multiloculated hydrocephalus, where anatomical landmarks are grossly distorted and the relationship between septa can change as fenestration proceeds [5]. Combining this with a side-hole-modified catheter, as described here, is intended to provide redundancy: if one side hole becomes opposed to tissue or re-septation occurs adjacent to it, other side holes may continue to drain adjacent compartments, an approach that has been associated with a lower rate of redo surgery in a comparative series of complex multiloculated hydrocephalus (20% vs. 44%) [3].

Potential reduction in isolated-compartment recurrence:

Across published endoscopic series, the introduction of wide fenestration with attention to final catheter position has been associated with substantial reductions in shunt revision rate compared with historical, pre-endoscopic management, from almost 3 procedures per patient-year to 0.2 procedures per patient-year [2, 9]. These comparisons are drawn from heterogeneous retrospective cohorts rather than from the technique described in this note. Even so, they support a general principle. Meticulous attention to the fenestration-to-catheter relationship, rather than fenestration alone, is central to durable outcomes in multiloculated hydrocephalus [11]. In a series with 90 patients, neuroendoscopy reduced shunt complexity, with most patients ultimately having no shunt or only one shunt [10].

Limitations:

This report describes a single case and is therefore a technical illustration rather than an outcomes study; the reproducibility and durability of this specific combination of endoscopic fenestration, endoscope-guided insertion, and side-hole modification cannot be established from one patient. Constructive interference in steady state (CISS) MRI sequences were not available preoperatively in this case. Their use may further refine preoperative planning in future cases by helping to delineate intraventricular septa more clearly [1]. Postoperative imaging in this report is limited to a single early CT (Fig. 4). This confirmed early decompression without hemorrhage or new isolated loculation. It cannot, however, establish durable long-term compartment communication or catheter patency. Radiological and clinical follow-up over months to years is required before conclusions about durability can be drawn.

Conclusion:

Endoscopic fenestration combined with endoscope-guided, side-hole-modified ventriculoperitoneal shunt catheter placement is a feasible, technically reproducible strategy for multiloculated hydrocephalus that allows continuous, direct visual confirmation of catheter position within a fenestrated common cavity.

Statements and declarations:

Ethics approval:

This technical note describes routine clinical care; no experimental intervention was performed. Reporting followed institutional guidance for single-case technical reports.

Consent to participate / Consent for publication:

Written informed consent was obtained from the patient's parents for the surgical procedure, and separately for the use of intraoperative photographic and video material for academic and educational purposes. All identifying patient information (name, hospital identifiers, and address) has been removed from this manuscript and its supplementary material.

Funding:

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Conflict of interest / Competing interests:

The authors declare that they have no conflict of interest.

Data availability:

The imaging and video data supporting this report are not publicly available due to patient privacy but de-identified excerpts are provided as figures with this submission.

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Figure legends:

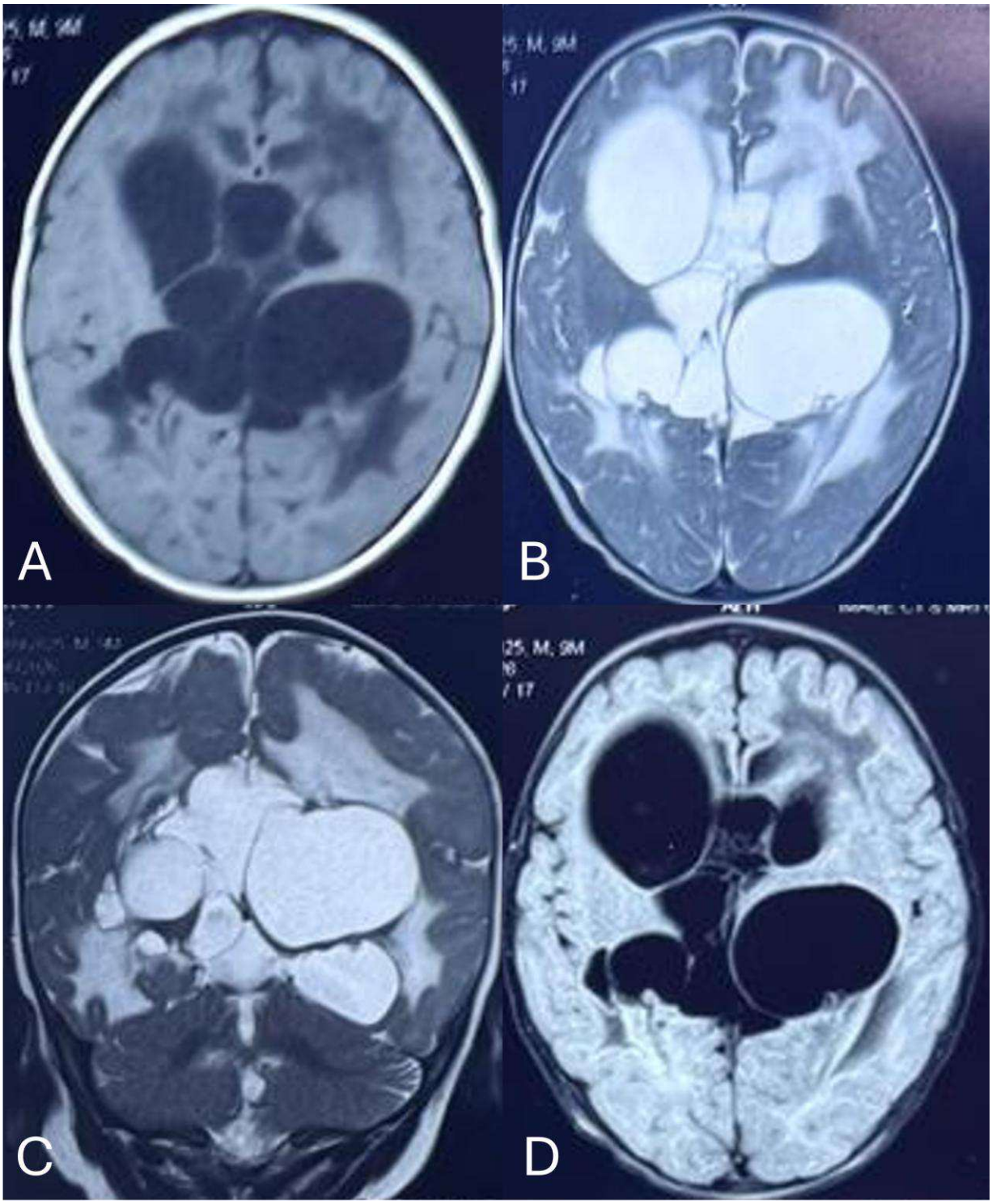


Fig. 1 Preoperative MRI brain demonstrating multiloculated hydrocephalus. (A) Axial T1-weighted image shows multiple thin-walled, hypointense intraventricular cysts of different sizes. (B) Axial T2-weighted image shows that the cysts are hyperintense, with thin intervening septa, mass effect on the lateral ventricles and dilated frontal horns. (C) Coronal T2-weighted image shows multiple stacked loculated compartments extending inferiorly towards the perimesencephalic region. (D) Axial FLAIR image shows suppression of cyst fluid signal, which is consistent with CSF-filled compartments. The largest cyst measures 30 × 39 mm.

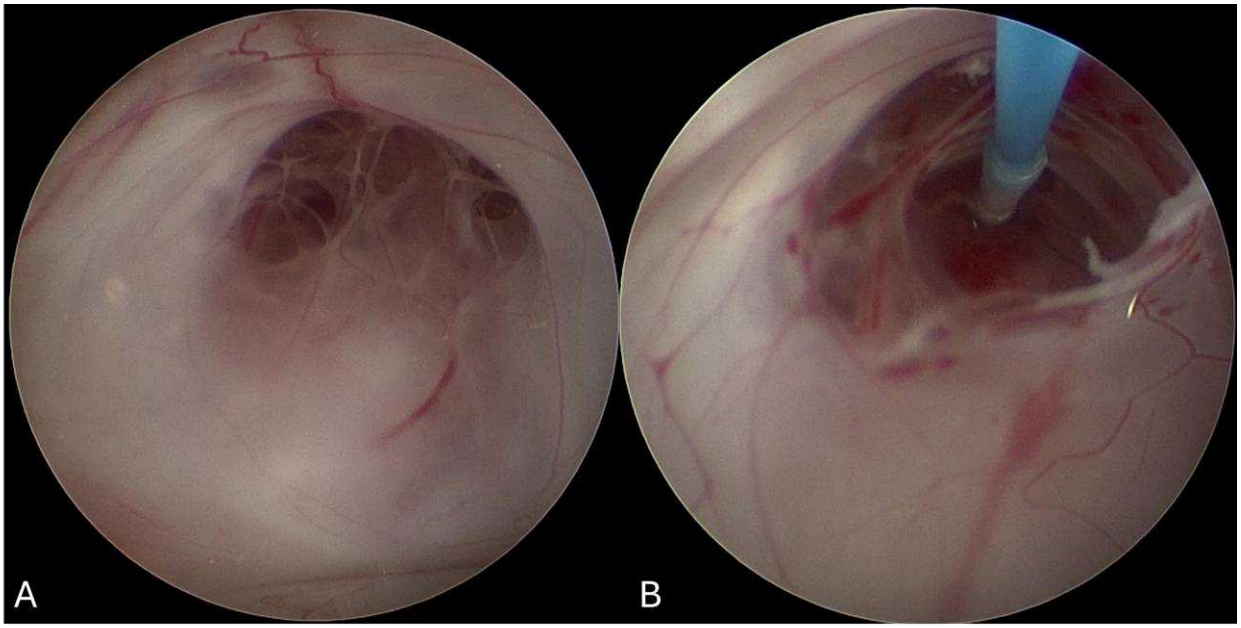


Fig. 2 Endoscopic treatment of septated compartments. (A) Initial exploration showing multiple thin, translucent, vascularized septa subdividing the ventricular system. (B) A Fogarty catheter creates and enlarges a fenestration through an intraventricular septum

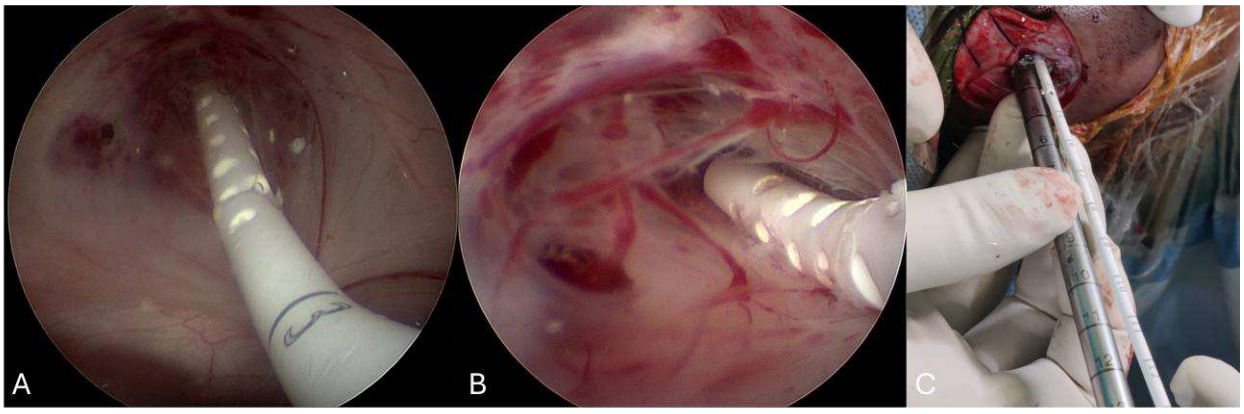


Fig. 3 Endoscope-guided ventricular catheter placement. (A) The ventricular catheter is advanced through the fenestrated septum under continuous direct visualization. (B) The side-hole-modified catheter lies freely within the fenestrated common cavity. (C) Intraoperative photograph through the frontal burr hole. The ventricular catheter is passed alongside the graduated rigid endoscope sheath, and the two are kept parallel so that the catheter can be inserted to the planned depth under endoscopic vision.

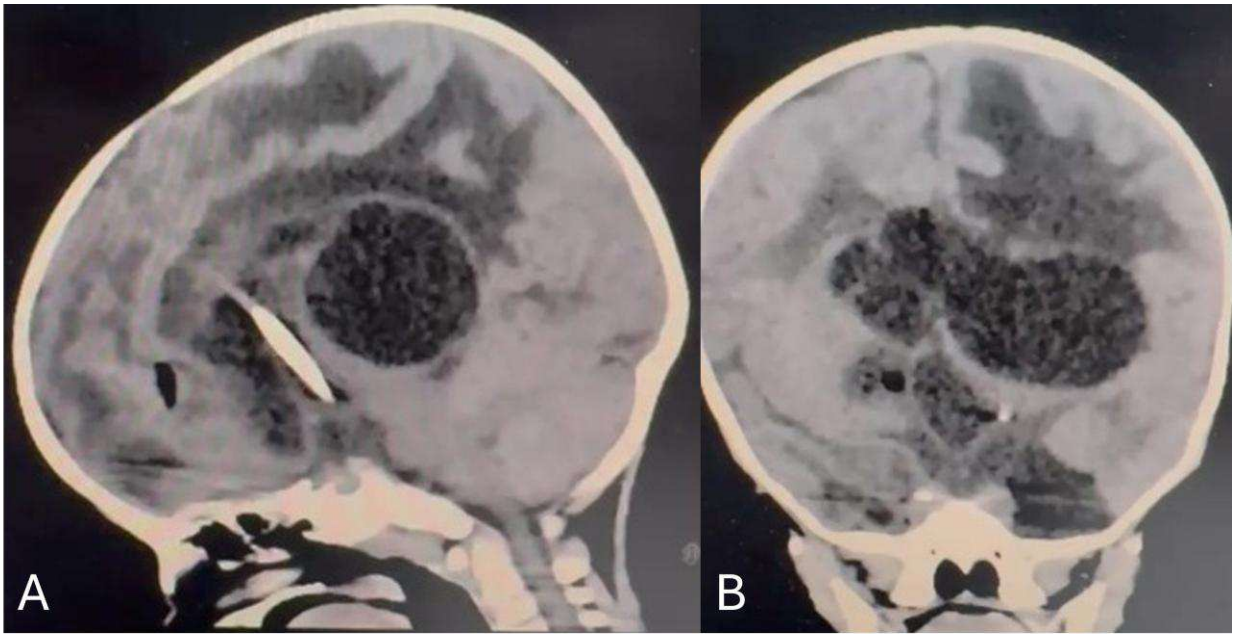


Fig. 4 Postoperative non-contrast CT brain. (A) Sagittal reformat and (B) coronal image show a single markedly decompressed residual cavity, with the ventricular catheter traversing the fenestrated compartment and the tip within the residual cavity. No hemorrhage, hygroma, or new isolated loculation is seen