Compartmentalization of the cerebral ventricles as a sequela of neonatal meningitis

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Although occlusions of the interventricular foramina, aqueduct, and fourth ventricular outlets are well documented sequelae of bacterial meningitis in the newborn, complete bilateral septation of the lateral ventricles by postinflammatory membranes is an infrequently described complication, mentioned in only a few previous reports. Thirteen infants with compartmentalization of the lateral ventricles, diagnosed by air encephalography, computerized tomography (CT), or autopsy are reported. In each case, the body of one or both lateral ventricles was completely divided by a membrane posterior to the foramen of Monro. Recognition of this entity is important from both therapeutic and prognostic standpoints.

KEY WORDS • neonatal meningitis • compartmentalization of ventricles

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Summary of Cases

Clinical Material

This series includes 13 infants seen at the James Whitcomb Riley Hospital of the Indiana University Medical Center during a 12-year period. These patients had a history of meningitis during the first month of life and were found to have compartmentalization of the lateral ventricles. Nine children had had meningitis caused by Gram-negative enteric organisms, including E. coli in six cases, Klebsiella species in two, and a Proteus species in one. In three infants, all of whom had received antibiotic therapy before lumbar puncture, an organism was not isolated, although clinical and laboratory data were consistent with suppurative meningitis. An additional patient had meningitis due to Staphylococcus aureus. Six infants had been born prematurely. Four infants, all born at term, had myelomeningocele complicated by Gram-negative infection of the central nervous system. Before diagnosis of compartmentalization, 12 of the 13 infants had received parenteral antibiotic

Fig. 1. Gross specimen showing the membrane completely dividing the lateral ventricle just posterior to the foramen of Monro.
therapy, and six of these had received intraventricular antibiotics as well.

All patients were brought to the hospital 2 to 4 months after the episode of acute meningitis, with a complaint of progressive enlargement of the head. Compartmentalization of the ventricles was demonstrated premortem in 11 cases. Multiple cultures of cerebrospinal fluid from lumbar and ventricular sites were sterile in each case. Five infants had had ventriculoatrial and two had ventriculoperitoneal shunts placed prior to the documentation of the compartmentalization. The other six had septae present before introduction of any foreign body into the lateral ventricles.

Three children survived and are severely developmentally retarded. Three have been lost to follow-up review, but had shown developmental delay at the time of the last visit. Seven infants have died.

Radiographic Investigations

A block within the body of the lateral ventricle just posterior to the foramen of Monro was present in every case. The lateral ventricles were thus divided into two compartments, a frontal horn that communicated with the opposite ventricle (unless additional obstruction was present), and a blind posterior compartment consisting of the atrium, and occipital and temporal horns (Fig. 2). Ten of the 13 had symmetrical compartmentalization. In two patients, the block was demonstrated to be unilateral in an initial air study; however, subsequent ventriculograms showed that compartmentalization had taken place in the opposite lateral ventricle (Fig. 3).

Three patients had displacement of midline structures. In two, the shift was secondary to unilateral enlargement of a blind posterolateral ventricle, and in one, a large midline cyst displaced the third ventricle laterally (Fig. 4).

Moderate to severe hydrocephalus was present in all cases, and most had porencephalic cavities. In eight instances, one or both interventricular foramina were occluded. The aqueduct was completely obstructed in three cases.

Multiple ventricular punctures were necessary for complete pneumoencephalography. Direct puncture of the atria through the lambdoid suture was the only method by which air could be introduced into sequestered posterior compartments.

Computerized tomography (CT) was performed in the last four patients, two of whom also had ventriculograms. The CT scan showed multiloculated ventricles associated with moderate to marked hydrocephalus (Figs. 5 and 6) as well as porencephaly.

Discussion

In the infant who exhibits an enlarging head following neonatal meningitis, the possibility of postinflammatory occlusion of the interventricular foramina, aqueduct, fourth ventricular exits, or the subarach-
noid space is usually considered. Septation of the lateral ventricles was not seen in a review of the findings at autopsy of 29 infants with neonatal meningitis. Salmon reported isolated unilateral hydrocephalus following shunt placement in five infants, two of whom had compartmentalization of the ventricles. Rhoton and Gomez reported one case and mentioned another in which membranes dividing the ventricular compartments were incised under the surgical microscope. Intraventricular septation complicating neonatal meningitis has been reported by Schultz and Leeds. Brown, et al., have reported a single case in which a CT scan demonstrated septations. The fact that 13 cases of complete septation of the lateral ventricle have been seen at Indiana University since 1965 suggests that the entity is not rare.

It is difficult to implicate either shunt placement or the intraventricular instillation of antibiotics as factors contributing to the development of compartmentalization, since half of the cases reviewed had neither procedure performed. Certainly, early removal of shunts in patients with Gram-negative infection is advisable. Except for one of our cases in which a bacterial etiology was unlikely, ventricular compartmentalization has been seen with documented neonatal meningitis and ventriculitis caused by Gram-negative enteric organisms. Salmon's cases of unilateral hydrocephalus also occurred following Gram-negative infections, and six of seven cases reported by Schultz and Leeds were due to Gram-negative organisms.

The configuration of the anterior horns of the

![Image](https://example.com/image.jpg)

**Fig. 3.** Repeat ventriculogram, 3 months after films shown in Fig. 2. *Upper Left:* Brow-down anteroposterior view. Again the left lateral ventricle is larger than the right. *Upper Right:* Brow-down lateral view. Occlusion of the body of the right lateral ventricle (arrows) is again demonstrated. Air now fails to pass posteriorly into the left atrium indicating development of membranous occlusion of the ventricle on that side. *Lower Right:* Brow-down lateral film after introduction of air through the left lambdoid suture. The enlarged atrium of the left lateral ventricle is now seen. This confirms the presence of a block in the body of that ventricle.
lateral ventricles is characteristic, but may be obscured by postinflammatory cysts of the third ventricle, occlusion of the foramen of Monro, postpuncture cysts, or multiple porencephalies. In eight of the present cases, hydrocephalus was severe and the membranes bridged ventricles with a large diameter. It is interesting that the position of the membranes was almost identical in each case, just posterior to the foramen of Monro. Septation was shown to progress long after the acute infection.

Awareness of the possible presence of midline cysts and ventricular displacement secondary to enlargement of compartments will prevent the misdiagnosis of neoplasm on air encephalogram. If air is introduced through the coronal suture, the ventricles may appear truncated at the posterior portion of the body of the ventricle. The trigone and temporal horn will not be visualized until air is introduced directly through the lambdoid suture. Protein concentrations in the various cavities vary greatly, and this finding should suggest the presence of compartmentalization. Fluid obtained through different needles at the time of en-
cehalography should be examined separately and not pooled. The CT scan may not show the septations early in the disease process, but follow-up scans will demonstrate the compartmentalization and the progression of hydrocephalus.

Although multiple shunts were often placed, one infant's head growth was controlled with a single tube in a sequestered portion of a lateral ventricle. Asymmetry did not result, suggesting that the membrane may have been at least partially permeable. Puncture of membranes during insertion of a multiperforated ventricular catheter may prove to be adequate treatment for control of compartmentalization. Often, bilateral catheters are needed, and did achieve control of the hydrocephalus in most of our patients. The high protein content of some compartments must be considered in selecting a valve.

Rhoton and Gomez treated two patients with craniotomy and surgical resection of localized cysts. The cortical mantle is frequently quite thin; therefore, bilateral cortical incisions may result in troublesome subdural fluid collections, especially after shunting.

The use of CT scanning for follow-up review of patients with neonatal meningitis will facilitate earlier diagnosis of compartmentalization of the lateral ventricles, document progression of the hydrocephalus, and probably help in the earlier diagnosis of shunt malfunction.

Presently, prognosis in this condition is poor. In the series of Schultz and Leeds, 70% died and all survivors were severely damaged. Seven of our 13 patients died, and the known survivors have psychomotor retardation. Risk factors that may predispose to compartmentalization could not be determined in our series. Compartmentalization appears to be a progressive disease that leads to death or severe psychomotor retardation. Although early diagnosis and intraventricular administration of antibiotics improved the outcome of neonatal meningitis and ventriculitis in one series of patients, intraventricular antibiotics increased the mortality in a controlled study of 52 patients performed by the Neonatal Meningitis Cooperative Study Group.

Summary

Following neonatal meningitis, especially in cases caused by enteric organisms, a membrane may form behind the foramen of Monro and thus isolate the posterior ventricular system. This event, when combined with midline cysts, often presents a very confusing encephalographic picture. Computerized tomography permits safe, accurate diagnosis; however, it may need to be repeated to monitor progression of the lesion. Sequestration may result in mechanical shunt failure and contribute to persistent or recurrent shunt infection. The magnitude of the protein concentration in cyst fluid should be considered in the choice of a valve, and the use of bilateral, multiperforated ventricular catheters may serve to decrease the necessity of multiple shunt revisions.

References

4. Dodge PR, Swartz MN: Bacterial meningitis — a review of selected aspects. II. Special neurologic problems,


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