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Intracranial *Serratia* Infection in Preterm Newborn Infants

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Four cases of cerebral *Serratia* infection in preterm infants were diagnosed with the aid of real-time sector sonography. Three cases had brain abscesses and one case had ventriculitis. In two cases brain abscesses had ruptured into the ventricles. *Serratia* brain abscess was common in our series of brain abscesses. Sonographic patterns of cerebritis, abscess formation, and ventriculitis correlated well with computed tomographic scans. Bedside cerebral sonography proved to be useful for the diagnosis, location, and follow-up of intracranial *Serratia* infection.

The use of a real-time scanner for cranial sonography of neonates, using the anterior fontanelle as an acoustic window, is accepted practice [1]. Diagnosis and follow-up of intraventricular and intracerebral hemorrhages by such means is well established. Apart from intracranial hemorrhage, less common entities such as neonatal meningitis and brain abscess should be considered when intracranial structures are studied by sonography. *Serratia* organisms can colonize and cause serious infection in a newborn nursery, and sporadic or epidemic system disease can result, including meningitis [3]. Sick newborn infants in intensive care who require procedures that compromise the skin, upper respiratory tract, or intestinal tract are most at risk for such infections. The use of systemic antibiotic therapy is often widespread, and the humid environment allows greater predisposition to attack by *Serratia* in immunocompromised preterm infants. We report four neonates with cerebral infections caused by *Serratia* who were studied by real-time sonography.

Materials and Methods

During a 3½ year period, 75 cases of cerebral infections were imaged by sonography using an ATL Mark II real-time sector scanner with a 5 MHz transducer at the Royal Alexandra Hospital for Children (RAHC) in Sydney, Australia; of these, we diagnosed four cases of cerebral infection caused by *Serratia marcescens*.

Case Reports

Case 1

A female infant was delivered at 28 weeks gestation by cesarean birth because of maternal hypertension and growth retardation. Her birth weight was 954 g. Apgar scores were 6 and 9 at 1 and 5 min, respectively. The infant developed hyaline membrane disease shortly after birth and was treated with assisted ventilation. Bilateral tension pneumothoraces developed and were treated with intercostal drains. *Serratia* was cultured from the endotracheal tube aspirate and the tip of the intercostal drain after removal. On day 14 there was an episode of fever and cyanotic attacks with a clinical suspicion of meningitis. No organism was recovered from the cerebrospinal fluid (CSF). The infant was well when discharged.

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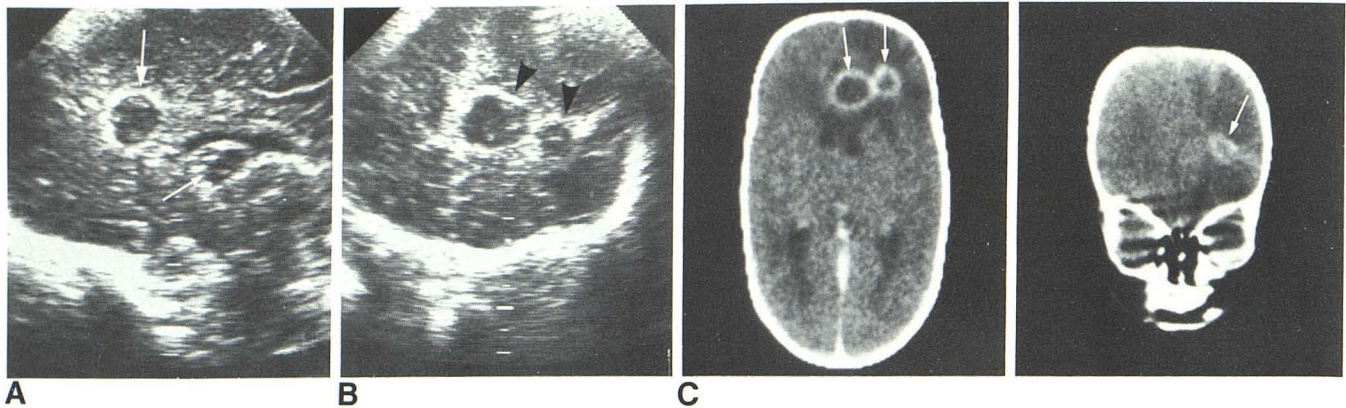


Fig. 1.—Case 1. Two frontal lobe abscesses. **A**, Sagittal sonogram. Larger abscess (large arrow) is anterosuperior to genu of corpus callosum. Small subependymal cyst (small arrow) is consistent with resolving subependymal hematoma. **B**, Coronal sonogram. Masses (arrowheads) have well defined

echogenic rims, and centers consist of low-amplitude echoes. Axial (**C**) and coronal (**D**) CT scans after intravenous contrast enhancement show left frontal masses have enhancing rims (arrows) consistent with brain abscesses.

She was referred to RAHC 3 months later with a history of poor feeding and fever. Lumbar puncture showed decreased glucose (1.4 g/L) and 5750 white blood cells/mm³, predominantly polymorphonuclear cells. Gram stain showed Gram-negative rods that were subsequently identified as *Serratia marcescens*. Brain sonography was performed through the anterior fontanelle using a 5 MHz transducer. There were two well defined round masses in the left frontal lobe (fig. 1B). The masses had relatively hypoechoic centers surrounded by an echogenic rim. The larger one measured about 3 cm in diameter and was anterosuperior to the genu of corpus callosum (fig. 1A). The smaller one measured 1.5 cm in diameter and was situated more laterally in the frontal lobe. The abscesses enhanced on computed tomographic (CT) scans after administration of contrast material (figs. 1C and 1D). The abscesses were identified at craniotomy to be thick-walled with a larger area of surrounding granulation tissue. The abscesses were removed as they were quite close to the ventricular system. Pathology confirmed the lesions to be old abscesses from which *Serratia marcescens* was cultured. The child was well when discharged.

Case 2

A male infant was born in an outlying hospital by breech delivery at 29 weeks gestation 2 weeks after rupture of membranes. His birth weight was 1100 g. Apgar scores were 5 and 8 at 1 and 5 min, respectively. He developed hyaline membrane disease shortly after birth and was transferred to RAHC. The hyaline membrane disease was treated with continuous positive pressure for 3 days with complete resolution.

The child continued to have apneic attacks. Initial brain sonography on admission was normal (figs. 2A and 2B). Apnea became worse suddenly on day 10 with bradycardia. Sonography revealed two echogenic foci in the left parietooccipital region (figs. 2C and 2D). Spinal tap showed CSF with a predominance of neutrophils. No organism was seen and subsequent culture was sterile. The endotracheal tube had grown *Serratia*. Cerebral sonography the next day showed that an anechoic center had developed in the previously echogenic focus (figs. 2E and 2F), consistent with abscess formation. CT at this stage showed a vague lesion in the left parietal region with a slight degree of enhancement after injection of intravenous contrast material (figs. 2I and 2J). A provisional diagnosis of *Serratia* meningitis

was made, and intravenous penicillin and chloramphenicol were commenced.

The infant developed frequent, short, tonic, clonic, and bulbar fits that were refractory to phenobarbital and diphenylhydantoin. Follow-up brain sonography showed extension of central hypoechoic areas with indentation of the roof of the occipital horn of the left lateral ventricle. He suddenly collapsed with hypotonia and circulatory shock on day 17. Sonography showed rupture of the abscesses through the roof into the mildly dilated lateral ventricles (figs. 2G and 2H). The child died on the same day. Postmortem examination confirmed the abscesses with brain destruction in the occipital white matter. The abscesses communicated with the left lateral ventricle. Both lateral ventricles showed ventriculitis. Pus from the base of the cerebrum grew *Serratia marcescens*.

Case 3

A growth-retarded male infant was born at 36 weeks. His birth weight was 3.4 kg, and Apgar scores were 8 and 6 at 1 and 5 min. Shortly after birth he was noticed to be tachypneic; heart failure was diagnosed. He was transferred to RAHC for uncontrolled heart failure on day 7. Cardiac sonography followed by cardiac catheterization confirmed the clinical diagnosis of double outlet right ventricle and large ventricular and atrial septal defects. He developed fits after cardiac catheterization. Sonography on day 15 (fig. 3A) showed a left frontoparietal echogenic focus suggestive of a hemorrhagic infarct.

His condition deteriorated with frequent apneic attacks, and the blood film suggested sepsis. *Serratia* sensitive to gentamicin and chloramphenicol was cultured from the endotracheal tube. The left frontoparietal echogenic focus increased in size with midline displacement (fig. 3B). Cavitation of the infarct with an irregular edge followed (figs. 3C and 3D). The changes raised the possibility of superimposed *Serratia* infection within the infarct. Left lateral ventricular tap was done on day 20, and the CSF grew *Serratia*. The right lateral ventricle dilated subsequently. The abscess ruptured into the left lateral ventricle on day 23 (figs. 3E and 3F). The ependymal lining was thickened with septation of the ventricles consistent with ventriculitis [4]. This was confirmed by CT (figs. 3I and 3J). *Serratia* was repeatedly shown in CSF from ventricular taps until day 34. At this stage the ependymal thickening had resolved. The ventricular septations also decreased in number and thickness, suggesting fibrotic changes (figs. 3G and

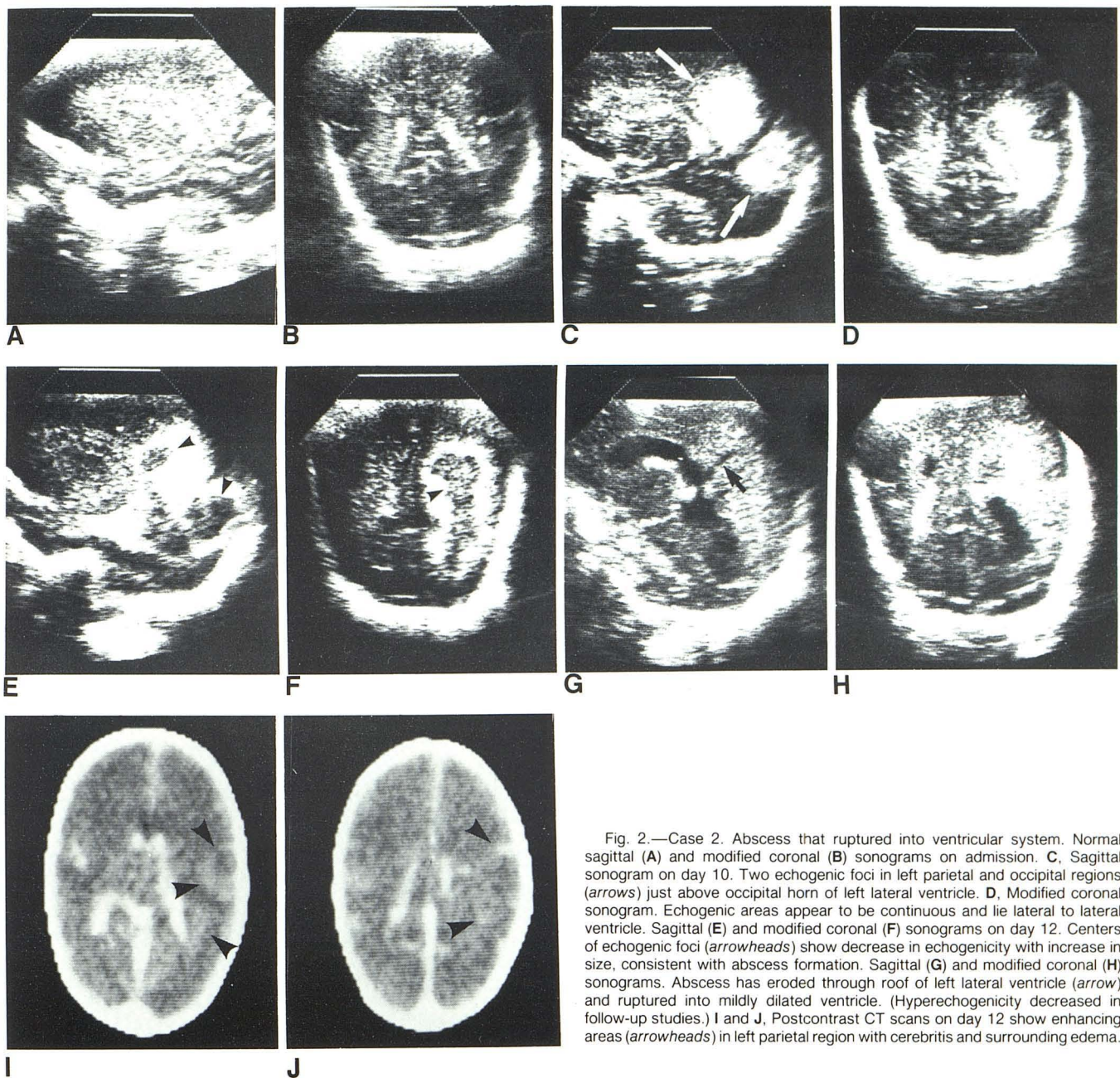


Fig. 2.—Case 2. Abscess that ruptured into ventricular system. Normal sagittal (A) and modified coronal (B) sonograms on admission. C, Sagittal sonogram on day 10. Two echogenic foci in left parietal and occipital regions (arrows) just above occipital horn of left lateral ventricle. D, Modified coronal sonogram. Echogenic areas appear to be continuous and lie lateral to lateral ventricle. Sagittal (E) and modified coronal (F) sonograms on day 12. Centers of echogenic foci (arrowheads) show decrease in echogenicity with increase in size, consistent with abscess formation. Sagittal (G) and modified coronal (H) sonograms. Abscess has eroded through roof of left lateral ventricle (arrow) and ruptured into mildly dilated ventricle. (Hyperechogenicity decreased in follow-up studies.) I and J, Postcontrast CT scans on day 12 show enhancing areas (arrowheads) in left parietal region with cerebritis and surrounding edema.

3H). When the infection was controlled, the infant was discharged to the referral hospital on day 48.

Case 4

A female infant was delivered at 36 weeks gestation by elective cesarean birth. Open lumbosacral meningocele with frontal encephalocele was noted after delivery. The child was referred to RAHC for further management. Sonography on admission showed a frontal midline encephalocele and Chiari type 2 malformation. The lumbosacral meningocele was repaired on day 2. The baby developed fever, salaam-type spasms with cyanosis, and apnea on day 7. Repeated cerebral sonography showed mild ventricular dilatation.

Linear septations were noted in both frontal horns of the lateral ventricles consistent with ventriculitis. Ventricular tap showed elevation of intracranial pressure, and the CSF grew *Serratia*. Despite maximal antibiotic therapy her condition progressively worsened, and the infant died after cardiorespiratory arrest on day 10. Postmortem examination was refused by the parents.

Discussion

Serratia marcescens is an aerobic, mobile, Gram-negative bacillus [4]. Until the 1950s, the organism was generally regarded as a harmless saprophyte. The organism has now

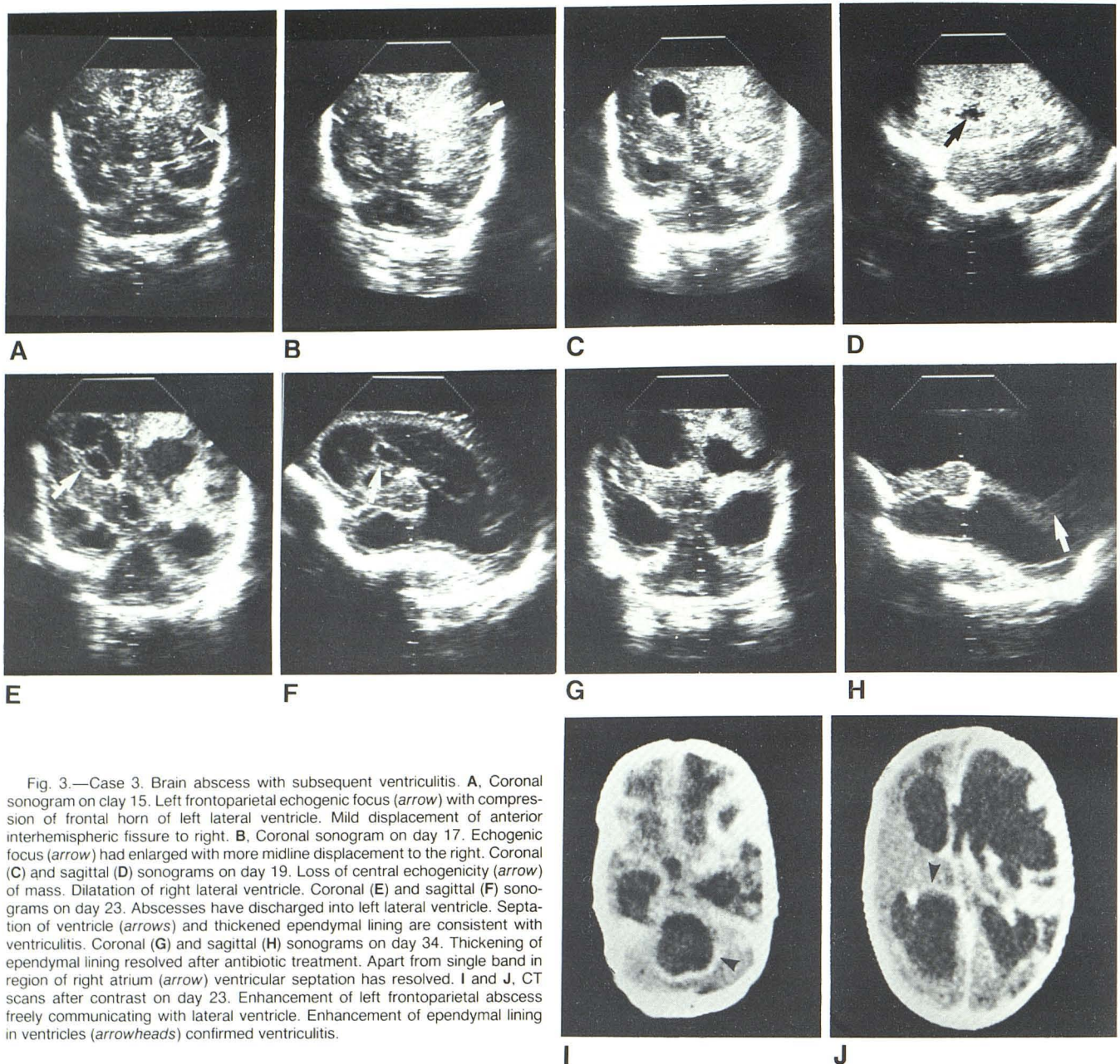


Fig. 3.—Case 3. Brain abscess with subsequent ventriculitis. **A**, Coronal sonogram on day 15. Left frontoparietal echogenic focus (*arrow*) with compression of frontal horn of left lateral ventricle. Mild displacement of anterior interhemispheric fissure to right. **B**, Coronal sonogram on day 17. Echogenic focus (*arrow*) had enlarged with more midline displacement to the right. Coronal (**C**) and sagittal (**D**) sonograms on day 19. Loss of central echogenicity (*arrow*) of mass. Dilatation of right lateral ventricle. Coronal (**E**) and sagittal (**F**) sonograms on day 23. Abscesses have discharged into left lateral ventricle. Septation of ventricle (*arrows*) and thickened ependymal lining are consistent with ventriculitis. Coronal (**G**) and sagittal (**H**) sonograms on day 34. Thickening of ependymal lining resolved after antibiotic treatment. Apart from single band in region of right atrium (*arrow*) ventricular septation has resolved. **I** and **J**, CT scans after contrast on day 23. Enhancement of left frontoparietal abscess freely communicating with lateral ventricle. Enhancement of ependymal lining in ventricles (*arrowheads*) confirmed ventriculitis.

been implicated as an etiologic agent in a wide range of infections, including those of the respiratory tract, urinary tract, meninges, musculoskeletal system, and eye. Nursery epidemics and pediatric ward infections have been well documented [5, 6]. Medical equipment associated in the dispersal of *Serratia marcescens* in hospital epidemics includes mechanical respirators, ultrasonic nebulizers, polyethylene intravenous catheters, scalp-vein needles, arterial pressure monitors, blood gas analyzers, and fiberoptic bronchoscopes.

Brain abscesses in neonates are uncommon [7] and, although often not identified [8], have been described in the first week of life [9]. Correct diagnosis is important because

they are potentially treatable if identified early. A brain abscess carries the hazards of possible rupture into the ventricular system, as in cases 2 and 3, leading to catastrophic fulminating ventriculitis and death. Most of the reported cases of brain abscess in neonates are caused by Gram-negative bacteria, with the common organism being *Escherichia coli*, *Proteus mirabilis*, and *Citrobacter freundii*. Among the 54 cases of bacterial meningitis imaged by sonography at RAHC, nine were complicated by brain abscesses: the three reported here caused by *Serratia*; four caused by *Proteus mirabilis*; one caused by *Citrobacter freundii*; and one caused by *Streptococcus B*.

In our series, cerebral sonography proved to be an effective imaging method to diagnose and follow the progress of the brain abscess. Initially, the developing abscess or cerebritis appears as an echogenic focus. It is usually space-occupying, compressing the adjacent ventricle and displacing the midline structures. It is impossible to differentiate from a hemorrhagic infarct at this stage, and confirmation by CT is necessary. When the abscess develops, it appears sonographically as a mass with a well defined, irregular, and thick rim around the hypoechoic center. This corresponds well to the reported experimental findings [10]. Low-amplitude echoes were observed in the center representing collections of necrotic tissues and acute inflammatory cells. Both the echogenicity of the hypoechoic center and the wall thickness decreased as the abscess responded to the antibiotics. All the *Serratia* cerebral abscesses were located in the periventricular white matter in the frontal or occipital region.

Two types of clinical presentation of *Serratia* cerebral abscess were observed in our series. Case 1 represents a late-onset type with possible exacerbation of an old *Serratia* abscess. Cases 2 and 3 are more malignant, and unfortunately the more common type of presentation. The widespread hemorrhagic necrosis of cerebral cortex and white matter is quite similar to the single reported case [11], in which there is striking invasion of brain parenchyma by bacteria via the hematogenous route.

Our case 4 represented an unusual ascending *Serratia* infection from open lumbosacral meningocele, resulting in ventriculitis including ventricular wall thickening, ventricular bands, and ventriculomegaly [12].

Most neonates with meningitis are debilitated. Real-time sonography, being performed with a mobile unit, should be the first imaging technique when *Serratia* cerebral infection is suspected clinically. CT is useful to distinguish cerebritis from hemorrhagic infarcts before the abscess finally develops. The progress of the cerebral infection can then be followed closely by bedside sonography to chart its response to the therapy. Cerebral sonography is capable of demonstrating the abscess in different planes, and it can accurately locate the abscess before or during surgery [13].

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