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ORIGINAL COMMUNICATION

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Discrepancies between brain CT imaging and severely raised intracranial pressure proven by ventriculostomy in adults with pneumococcal meningitis

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Abstract *Objectives* Computed tomography (CT) of the brain is recommended for assessment of intracranial pressure (ICP) of patients with acute bacterial meningitis who are comatose or show focal neurological deficits. The aim of this report is to draw attention to the possibility of a discrepancy between CT findings and ICP values in some patients with pneumococcal meningitis. *Methods* We describe three adult patients with pneumococcal meningitis who had both successive CT examinations and ICP measurements at the time of clinically evident cerebral herniation (n = 2) and/or prolonged coma (n = 2). *Results* Although measurements with a ventriculostomy catheter indicated that all three patients had severely raised ICP values of 90, 44, and 45 mmHg, repeated cranial CT greatly underestimated true ICP values. Despite clinical evidence of acute cerebral herniation, it was not detected in the contemporary CT findings of two patients. Continuous ICP monitoring in the ICU helped to guide treatment for increased ICP; nevertheless, two patients died. *Conclusions* The clinician must be aware that cranial CT may fail to rule out the possibility of severely raised ICP or cerebral herniation in a patient with pneumococcal meningitis. Therefore, ICP monitoring of patients with bacterial (especially pneumococcal) meningitis who are in prolonged coma should be considered early and regardless of the cranial CT appearances.

Key words bacterial meningitis · pneumococcal meningitis · intracranial pressure · CT

Introduction

Elevated intracranial pressure (ICP) is a well-known complication of acute bacterial meningitis [4, 11, 14, 23]. Disregard of increased ICP delays adequate adjunctive therapy and fatal cerebral herniation may occur [4, 12, 13]. Computed tomography (CT) of the brain is recommended in patients with bacterial meningitis whenever focal neurological deficits or a depressed level of consciousness suggest a raised ICP, in order to detect a mass, brain swelling, or hydrocephalus [18]. In this context it must be stressed that performing initial lumbar puncture (LP) without prior CT is very safe in patients with suspected bacterial meningitis who do not show a depressed level of consciousness or certain focal neurological signs such as hemiparesis [7, 19]. However, in comatose patients with acute bacterial meningitis, failure of CT to detect severe increases of ICP may occur.

We report on three adult patients with pneumococcal meningitis in whom we observed a discrepancy between normal or only moderately altered CT findings and a dramatic rise in ICP of more than 40 mmHg measured by a ventriculostomy catheter, accompanied by clinical signs of cerebral herniation or prolonged coma.

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Case Reports

Case 1

A 52-year-old man with a history of day-long earaches was agitated and confused and suffered a generalized tonic-clonic seizure. Clinical examination revealed a stuporose patient with fever (40.2 °C), neck stiffness, and gaze deviation to the left; his limbs were retracted symmetrically to painful stimuli. Emergency CT of the head was normal (Fig. 1a). Cerebrospinal fluid (CSF) analysis revealed a white blood cell count of 2290/mm^3 with 73 % polymorphonuclear cells, protein of 1400 mg/dl, and glucose of 1 mg/dl. The patient was transferred to the ICU, sedated, and mechanically ventilated. He was given ceftriaxone, initially ampicillin, dexamethasone, and heparin therapy. *Streptococcus pneumoniae* sensitive to penicillin was isolated from blood and CSF cultures. On day 2, repeated cranial CT and transcranial Doppler sonography still showed normal findings. A mastoidectomy on the left side was performed because of mastoiditis. On day 3 after admission, the patient was still deeply comatose without sedation and showed no reactions to painful stimuli. Repeated CT revealed minimal increase of brain volume and a slight decrease of gray-white matter differentiation (Figs. 1b, c). Eighty minutes after the scan, the patient's pupils became dilated and unreactive; this was combined with a phase of spontaneous arterial hypertension. Corneal and choke reflexes were absent. Seventy minutes after this event which sug-

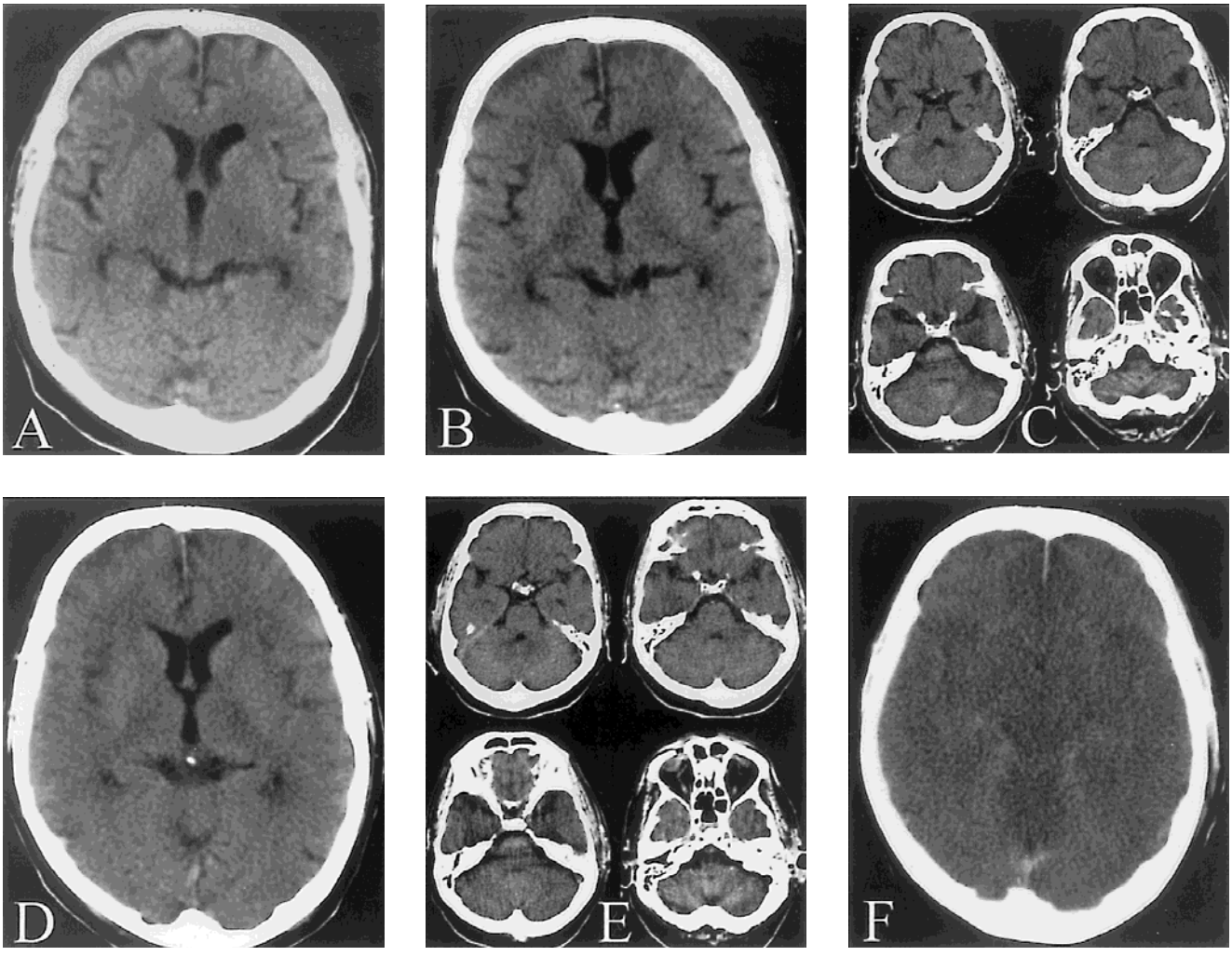

Fig. 1 Case 1. Computed tomographic scans of a 52-year-old man with pneumococcal meningitis. (**A**) On day of admission (day 1), a normal cranial CT scan was obtained. (**B**) On day 3, a CT scan of the comatous patient 80 minutes prior to clinical herniation still did not reveal signs of severely raised ICP: no evidence of hydrocephalus or sulcal effacement was detected. Note minor changes such as reduction of gray-white matter differentiation or frontal sulcal effacement. (**C**) In addition, there was no obliteration of the basilar cisterns or other signs of impending cerebral herniation. (**D**) A second CT scan 150 minutes after the first and 70 minutes after clinical herniation now shows sulcal effacement and loss of gray-white-matter differentiation. (**E**) Remarkably, no radiological signs of cerebral herniation are present. A ventriculostomy was performed 100 minutes later which showed an ICP of 90 mmHg. (**F**) A massive global cerebral edema is visible 11 hours later.

gested cerebral herniation (150 minutes after the first scan) another CT examination showed the beginning of loss of gray-white matter differentiation and moderate cerebral edema with sulcal effacement (Fig. 1d). Remarkably, there were still no radiological signs of cerebral herniation (Fig. 1e). A ventriculostomy was performed 100 minutes after the last CT examination; this revealed an opening pressure of 90 mmHg. Therapy to lower ICP was started immediately with mannitol, thiopental narcosis, mechanical hyperventilation, ventriculostomy drainage, and hypothermia (down to 35°C body temperature); nevertheless, ICP values stayed as high as 80 mmHg. Further CT 11 hours after the second scan showed a massive global cerebral edema with complete loss of gray-white matter differentiation and sulcal effacement (Fig. 1f). The patient died 5 days after admission.

Autopsy revealed swollen cerebral hemispheres with flattening of the gyri and narrowing of the sulci, distinct accumulation of pus over both cerebral convexities, and signs of intravital brain death with necrosis of the cerebellar tonsils and cerebellar herniation. Histologically there was a massive leukocyte infiltration in the subarachnoid space with extensive involvement of adjacent brain parenchyma. No further parenchymal lesions such as infarcts or bleedings were obvious. In addition, a fresh thrombosis of the superior sagittal sinus was present.

Case 2

A 65-year-old woman had suffered recurrent episodes of bacterial meningitis (due to *H. influenzae* 6 years and pneumococci 4 years prior to admission). Surgery for obliteration of CSF leakage after a left petrous bone fracture 9 years previously was repeatedly performed. On the day of admission, the patient was comatose (Glasgow coma scale of 7), she had neck stiffness and fever. CT showed extensive brain edema with narrowed lateral ventricles and white matter hypointensities suggestive of extensive cerebritis; gray-white matter differentiation was still present (Fig. 2a). Therefore, lumbar puncture was not performed. Surgical revision of the left mastoid sinus revealed a purulent mastoiditis, and microscopy showed gram-positive diplococci indicating pneumococci. The patient was treated for bacterial meningitis with ceftriaxone, ampicillin, and clindamycin, and for raised ICP. MRI 2 days after admission did not reveal evidence of sinus thrombosis. Clinically, the patient did not react to painful stimuli under continued midazolam sedation, but showed intact pupilar responses and corneal reflexes. Cranial CT 3 days after admission showed a markedly reduced cerebral swelling with increased hypodense areas of white matter. On day 7, after another CT examination showed only slightly increased cerebral swelling (Fig. 2b), a ventriculostomy was performed that revealed an opening pressure of more than 25 mmHg. In the next few hours ICP increased up to 45 mmHg. Pupillary responses and corneal reflexes diminished on day 8. The patient died on day 10. Autopsy revealed extensive purulent meningitis with marked brain swelling and inflammatory infiltration of adjacent brain parenchyma. A beginning inflammation of the white matter was evident in the frontal lobe. Both mesencephalic necrosis and necrosis of the cerebellar tonsils indicated cerebral herniation. There was no evidence of a thrombosis of a venous sinus.

Case 3

A 41-year-old woman complained of severe headache, neck stiffness, and vomiting on the day of admission. She had had pneumococcal meningitis 14 months prior to admission. After an unremarkable cranial CT scan (Figs. 3a, b), a lumbar puncture of the confused patient was performed. It revealed 6485 cells/mm^3 with 96% polymorphonuclear cells, protein of 243 mg/dl, and glucose of 54 mg/dl. Therapy with ceftriaxone and amoxycillin was started; S. pneumococcus was isolated from blood and CSF. In the first hour after admission to the ICU, the patient's level of consciousness decreased to coma, and she developed a downbeat nystagmus and a dilated and unreactive right pupil. These signs suggesting cerebral herniation immediately resolved after intubation, mechanical hyperventilation, and intravenous administration of 125 ml mannitol. CT 1 hour after the initial clinical signs of herniation revealed minimal ventricular enlargement, but no sulcal effacement, cerebral edema, or midline shift (Fig. 3c); in addition, no signs of cerebral herniation could be seen (Fig. 3d). A ventriculostomy was performed immediately for clinically suspected raised ICP; the opening pressure was 44 mmHg.

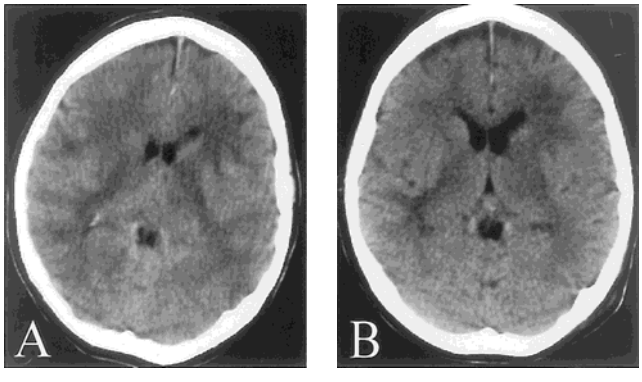

Fig. 2 Case 2. Computed tomographic scans of a 65-year-old woman with pneumococcal meningitis. (**A**) A CT scan on day of admission showed extensive brain edema with sulcal effacement. The diffuse white matter hypointensity suggests white matter edema or beginning cerebritis. (**B**) On day 7, cerebral edema was markedly improved, and no signs of severely raised ICP could be detected. A subsequent ventriculostomy revealed ICP values up to 45 mmHg.

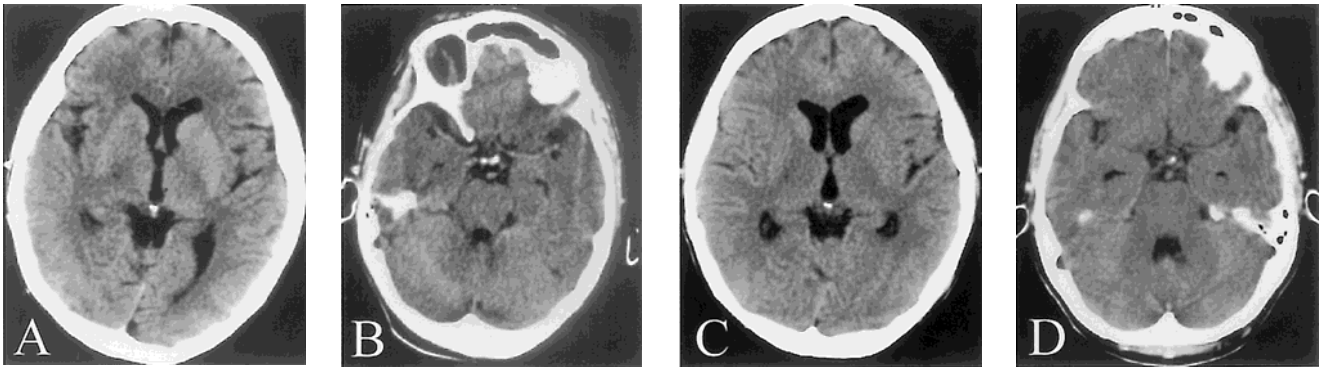

Fig. 3 Case 3. Computed tomographic scans of a 41-year-old woman with pneumococcal meningitis. (**A**) On day of admission (day 1), a first CT scan 3 hours prior to clinical herniation revealed no signs of raised ICP, and no obliteration of the basilar cisterns or other radiological signs of impending cerebral herniation (**B**). (**C**) One hour after clinical herniation (4 hours after the first CT scan) mild enlargement of the lateral and third ventricle was evident, but there was no sulcal effacement or other signs of raised ICP. (**D**) In addition, basilar cisterns were unchanged and not obliterated. A ventriculostomy 5 minutes after the scan revealed an opening pressure of 44 mmHg.

ICP was lowered by ventriculostomy drainage. On day 5, cranial CT showed no hydrocephalus, cerebral edema, or other signs of raised ICP. The ventriculostomy catheter was removed on day 7. After withdrawal of sedation, the patient regained consciousness and was discharged with a residual mild tetraparesis due to critical illness polyneuropathy. In the following months the patient had a full recovery.

Discussion

Cranial CT is usually recommended in adults suspected of having bacterial meningitis who present with focal neurological signs or a decreased level of consciousness [18]. This is done to look for specific complications of bacterial meningitis that can increase ICP, such as cerebral edema, infarction, cerebritis, or hydrocephalus [1, 2, 12, 21, 22].

However, it is a known phenomenon among clinicians that a discrepancy between brain imaging and the patient's clinical state may occur in meningitis and other conditions such as head injury. Surprisingly, only a few studies in the literature have addressed the question of the sensitivity of CT for raised ICP in bacterial meningitis. One report on children with bacterial meningitis shows that cranial CT may be insufficient to rule out raised ICP: Rennick et al. reported on a series of 445 children with bacterial meningitis, 4.3 % of whom showed clinical signs of cerebral herniation, most probably as a fatal complication of raised ICP [13]. CT was performed at about the time of herniation on 14 occasions, and 5 (36 %) of these scans yielded normal results [13]. There has been only one report on an adult with bacterial meningitis and a similar discrepancy so far: a woman with pneumococcal meningitis had cranial CT that showed no signs of cerebral abnormalities despite a raised ICP of 58 mmHg [20]. However, the CT was performed only once and was not published. All in all, little is known about the precise usefulness of CT for excluding raised ICP in bacterial meningitis, especially in adult patients.

Here we described three adult patients with pneumococcal meningitis who had severely raised ICP without appropriate corresponding signs on serial CT. Clinical deterioration with signs of cerebral herniation (cases 1 and 3) or the lack of clinical improvement (case 2) called for urgent ICP monitoring. Subtle radiological abnormalities in these patients suggest the importance of identifying any such changes in patients with bacterial meningitis. The three patients reported here were among a total of 14 patients (21 %) with pneumococcal meningitis who were admitted over 3 consecutive years to the neurological intensive care unit of our university hospital. In seven of these 14 patients, ICP was measured invasively. A discrepancy between CT and ICP findings was observed in the three patients reported on in this paper. In the four remaining patients, in whom ICP was measured, the values agreed with the CT findings: both CT findings and ICP values were normal in one patient despite coma, whereas CT showed relevant cerebral edema in the presence of raised ICP in the remaining three patients.

Potential causes for raised ICP in bacterial meningitis include generalized brain edema and hydrocephalus, also extensive meningitis-associated cerebritis, cerebral infarction and cerebral venous thrombosis with subsequent brain swelling, status epilepticus, and the syndrome of inappropriate antidiuretic hormone secretion [3, 11, 12, 23]. Brain edema is a major pathophysiological event in bacterial meningitis, leading to increased ICP [10]. It is generally expected that these conditions are visible on CT [4]. Two of our patients had an extensive brain edema with broad inflammation of brain parenchyma and subsequent coning that was confirmed on autopsy. Patient 1 had a fresh thrombosis of the su-

perior sagittal sinus which may have promoted cerebral swelling. A review of the CT scans with and without contrast enhancement did not reveal any typical signs of cerebral sinus thrombosis (such as bihemispheric bleeding, empty delta sign, or filling defect of a sinus), and prophylactic heparin therapy had been administered since admission. Therefore, we cannot clarify whether the thrombosis caused brain edema and raised ICP or evolved in the moribund state, when ICP was excessively elevated and probably led to reduced brain perfusion. An early alteration of CSF hydrodynamics is the most likely cause for the increase in ICP in patient 3, since the ventricles were slightly dilated on the second CT scan.

There are several possible explanations for the failure of our patients' CT to demonstrate severely raised ICP. One involves the specific pathomorphological features of meningeal diseases, such as alterations in intracranial compliance: a collection of subarachnoid or ventricular purulent material may prevent narrowing of the subarachnoid or ventricular space. Extensive accumulation of purulent material on the surface of the brain was seen on autopsy in cases 1 and 2. In addition, meningeal hardening, particularly due to chronic or recurrent meningitis, can be hypothesized to lead to changes in meningeal compliance (e. g. due to arachnoid fibrosis), which hinders the brain from extending toward the subarachnoidal or ventricular space despite high parenchymal pressure. Two of our patients (cases 2 and 3) suffered from recurrent meningitis. Similarly, patients with chronic meningeal diseases have been reported to show severe intracranial hypertension or coning without signs of relevant hydrocephalus [6, 16].

Furthermore, the simultaneous occurrence of a decreased CSF absorption and a significant cerebral edema could abolish significant radiological signs; the forces of ventricular dilatation may oppose the forces of cerebral swelling for a limited period of time. The condition of benign intracranial hypertension (BIH) is possibly analogous since brain edema as well as markedly increased CSF outflow resistance are both well known features of bacterial meningitis and BIH [4, 5, 15, 17]; this could explain normal ventricles despite significantly raised ICP in both diseases.

Finally, the absence of plateau waves in our patients could explain the discrepancy between their CT appearances and ICP values. Hayashi et al. [8] demonstrated in patients with significantly raised ICP that the patient group without plateau waves showed no ventricular dilatation on CT, but many patients of the group with evident plateau waves had hydrocephalus. In addition, the group without plateau waves revealed clinical signs of herniation at much lower ICP levels (70–98 mmHg) than the group with plateau waves (120–150 mmHg) [9].

In summary, our cases show that CT may severely underestimate raised ICP in adults with pneumococcal meningitis, even in those with clinical evidence of cerebral herniation. Therefore, to judge whether ICP is raised or not, one should not rely too much on the CT appearance: it must be assumed that ICP is probably raised in the presence of bacterial meningitis, and the more comatose the patient, the greater the elevation of ICP. If CT is performed, rather subtle features, as shown in some of our cases, should be taken as indicators of a very active brain inflammatory process likely to be associated with high ICP. Invasive ICP monitoring is of course not a routine method for all patients with bacterial meningitis: it should be restricted to those with prolonged coma during antibiotic therapy and those who have severe neurological deficits (e. g., clinical signs of cerebral herniation) and are clinically inaccessible because of sedation. The exact number of patients who benefit from the ICP monitoring device as a guide to therapy is currently unknown.

All in all, these case reports draw attention to the fact that neurological signs of increased ICP should be taken very seriously in patients with bacterial meningitis regardless of the CT findings. Above all, severely increased ICP has to be suspected in every comatose patient with this disease.

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