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Magnetic Resonance Imaging of Traumatic Pneumocephalus

—Case Report—

Masaki KOMIYAMA, Toshihiro YASUI, Hisatsugu YAGURA, Yoshihiko FU, Hajime SUGATA and Mitsuru BABA

Department of Neurosurgery, Baba Memorial Hospital, Sakai, Osaka

Abstract

Computed tomographic scans and magnetic resonance (MR) images in a case of traumatic pneumocephalus are presented and discussed. MR images clearly demonstrated not only the accumulation of air but also the herniation of brain tissue through the fracture into a paranasal sinus. A fistulous tract for cerebrospinal fluid leakage was strongly suggested on the images of brain herniation. The clinical usefulness of MR images is compared with that of conventional diagnostic modalities.

Key words: pneumocephalus, head injury, cerebrospinal fluid leakage, magnetic resonance imaging, computed tomography, neuroradiology

Introduction

Recognition of intracranial air is of vital importance to the appropriate treatment of certain neurological disorders. Pneumocephalus can be easily diagnosed with plain skull films[8] and computed tomographic (CT) scans, the latter being more accurate in terms of locating the air.[3,15,16,21] However, identifying the entry route of air and the pathway of the concomitant cerebrospinal fluid (CSF) leakage is usually difficult, and sometimes impossible, with plain skull films and CT scans. Appropriate treatment of pneumocephalus depends not only determination of the location, volume, and mass effect of the air, but also on correct assessment of the fistula site.

To our knowledge, there have been no reports on the use of magnetic resonance (MR) imaging in pneumocephalus, or of visualization of brain parenchyma herniating through fractures. We present and discuss MR images in a case of traumatic pneumocephalus and compare the clinical usefulness of MR imaging in the diagnosis of pneumocephalus to that of other conventional diagnostic modalities.

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Case Report

A 19-year-old male was hospitalized immediately after a motorcycle accident. He was lethargic on admission, and his right forehead was markedly swollen. The right pupil was mildly dilated and unreactive to light. The left eye was intact. The neurological examination was otherwise unremarkable. A plain skull film demonstrated multiple comminuted fractures of the frontal bone, extending to the frontal base. CT scans showed thin, acute subdural hematomas in the bilateral frontal regions. Since there was no evidence of rhinorrhea or pneumocephalus at that time, he was treated conservatively and gradually recovered consciousness.

Three weeks after the accident he suddenly developed rhinorrhea from the right nostril. However, he did not experience headache or nausea. A plain skull film disclosed collections of air in the frontal base and the suprasellar area (Fig. 1). CT scans also showed multiple air pockets. However, although it was difficult to determine whether the air in the right frontal base was intracerebral, subdural, or subarachnoid, the CT scans strongly suggested that it had entered from the fracture at the right frontal skull base (Fig. 2).

He underwent MR examination with a 0.5-T superconductive MR scanning system (Picker Inter-

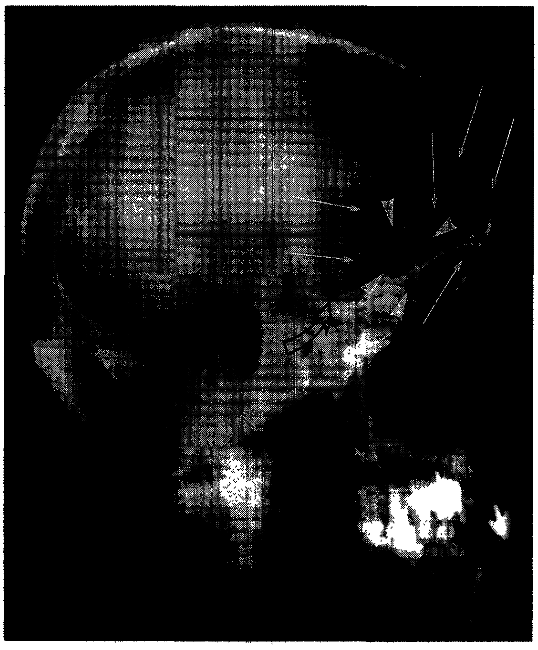

Fig. 1 Plain skull film showing multiple fractures (*arrows*) extending to the base of the frontal bone. Air accumulation is demonstrated at the frontal base (*arrowheads*) and in the suprasellar area (*thick arrow*).

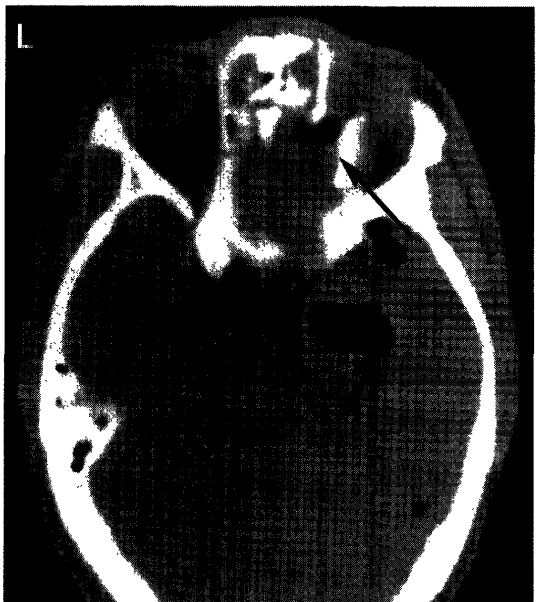

Fig. 2 CT scan demonstrating the fracture of the medial wall of the orbit. Air collection is noted in the vicinity of this fracture (*arrow*). It is difficult to ascertain whether the air is intracerebral, subdural, or subarachnoid. Subarachnoid (*arrowhead*) and intraventricular (*curved arrow*) air pockets are also demonstrated.

national, Cleveland, OH). Spin echo (SE) and inversion recovery (IR) sequences were used. The thickness of the images was about 1.0 cm. The data matrix was 256^2 and the data were averaged once. MR images clearly demonstrated the intracerebral accumulation of air in the frontal lobe and the brain herniation through the frontal skull base fracture into the right ethmoid sinus (Fig. 3). High intensity brain lesion surrounding the air was also evident (Fig. 3C). He was fairly alert, although he had bilateral anosmia and blindness in the right eye. There were no other neurological signs or symptoms.

Two days after the onset of rhinorrhea a right frontal craniotomy was performed. A dural defect measuring 1 × 1 cm was noted at the right frontal pole, where linear fractures of the posterior wall of the frontal sinus were found. The mucous membrane of the frontal sinus was intact. Brain contusion was observed at the site of dural defect. Intradural exploration of the frontal skull base disclosed herniation of the brain into the right ethmoid sinus through the frontal skull base fracture. A large dural defect (2 × 3 cm) was also present in this region. Adhesions were noted between frontal lobe and dura mater. The right olfactory bulb could not be identified. The herniated brain tissue was debrided; during this procedure CSF flowed out. The air collection in the frontal lobe was not explored further. The dural defect in the skull base was tightly closed with a fascia lata graft, and the dural defect in the frontal pole was directly approximated. It was concluded that the herniated brain contained a fistula and that it was through this fistula that air had entered and CSF had leaked. It was also suspected that the fistula extended to the ventricle. Postoperatively, both the rhinorrhea and the pneumocephalus disappeared. However, his neurological status did not change.

Discussion

Luckett,[10] in 1913, was the first to demonstrate traumatic pneumocephalus radiologically. In 1926, Dandy[4] provided the first comprehensive description of pneumocephalus. Since then, the condition has been extensively reported. Among the numerous causes of pneumocephalus[1] are trauma,[9,18] neoplasms,[2,12,17] congenital anomalies,[11] infection,[14,20] surgery (especially posterior fossa surgery in the sitting position),[13] and invasive neurological diagnostic procedures, such as pneumoencephalography and pneumoventriculography.

Pneumocephalus is classified according to location, *i.e.*, epidural, subdural, subarachnoid, intracerebral (parenchymal), and intraventricular. Often,

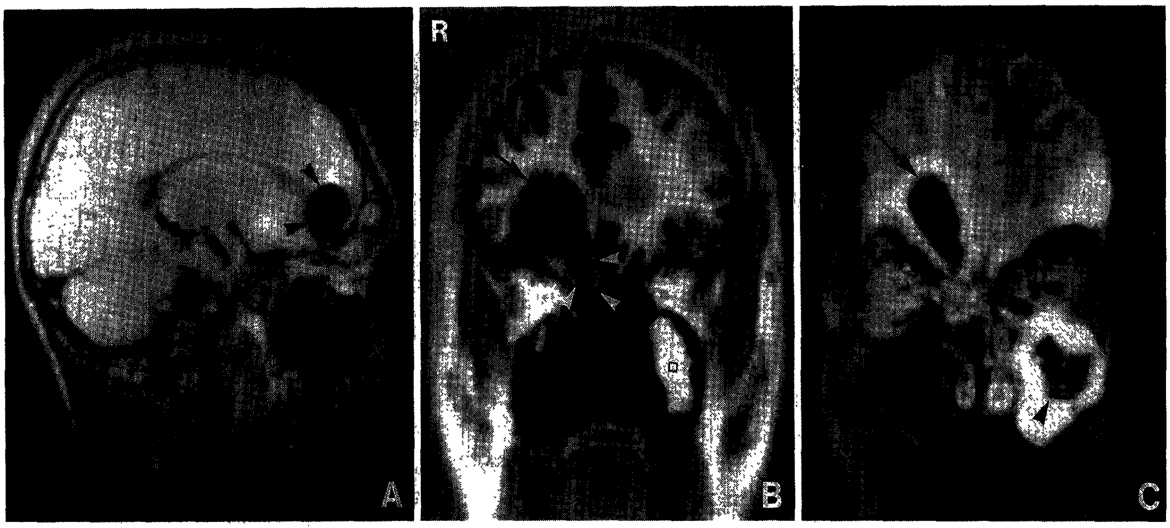

Fig. 3 A: Sagittal T_1-weighted SE image [repetition time (TR)/echo time (TE), 600/40 msec] shows intracerebral air (*arrowheads*) in the frontal lobe. B: Coronal IR image (TR/inversion time/TE, 2100/600/40 msec) showing the herniated brain (*arrowheads*) and a low intensity area of brain contusion (*arrow*). However, the basal skull fracture is barely discernible. Note the asymmetry of white matter in the frontal lobes. The left maxillary sinus (*open square*) is filled with hematoma, whereas the right one is empty. C: Coronal T_2-weighted SE image (TR/TE, 2100/120 msec) of an area 1 cm anterior to the image in B. Intracerebral air (*arrow*) surrounded by contused brain tissue is clearly demonstrated. The arrowhead indicates the hematoma in the left maxillary sinus.

more than one compartment is involved.[1)]

Traumatic pneumocephalus results from injury to the bony wall of a paranasal sinus or mastoid air cell contiguous to the cranial cavity. Fractures of the frontal sinus are the most common source of air entry, followed by fractures of the ethmoid and sphenoid sinuses and mastoid air cells.[21)] The dura mater, arachnoid, and/or brain tissue may herniate through the fracture. Intracerebral pneumocephalus most frequently extends upward from the floor of the anterior fossa or backward from the anterior wall in close apposition to the intracranial surface of the frontal or ethmoid sinus on one side.[8)]

Pneumocephalus is readily identifiable on plain skull films and CT scans. CT is valuable because it can demonstrate as little as 0.5 ml of air.[15)] Locating fistulous tracts, on the other hand, remains a diagnostic problem, and much effort has been expended in attempts to overcome it. Plain skull films with the patient both erect and supine and multidirectional laminography are usually the first means used to locate a fistula, but they are often unhelpful. Cisternography with the use of intrathecal iodinated contrast medium[6,7)] or a radioactive tracer[5)] may be deemed necessary. However, even these methods do not always succeed in locating the fistula, although ventricular reflux may be clearly depicted.

CT scanning is superior to MR imaging in demonstrating bony structures, due to a lack of resonating protons in the cortial bone. However, MR imaging may clearly demonstrate brain protruding through the fracture into the paranasal sinus. Even with MR imaging, it is difficult to identify the fistulous tract itself, since it is usually collapsed, but brain herniation usually corresponds to the fistulous tract. Surgical intervention should therefore be directed to the area of brain herniation.

IR images provide greater contrast between gray and white matter than do SE images (Fig. 3B).[19)] MR images may demonstrate edema or contused brain tissue, owing to the prolonged proton relaxation times (T_1 and T_2), especially on T_2-weighted SE images (Fig. 3C). Normal brain parenchyma and its subtle changes are far more clearly demonstrated with MR images than with CT scans.

Another advantage of MR imaging is its multiplanar capability, through which coronal and sagittal images can be obtained with the patient's neck in a neutral position. A drawback of MR imaging is that it cannot always be performed in the acute stage of head trauma; such patients are often in serious or critical condition, and the MR scanning time, which is far longer than that required for CT scanning, precludes this procedure.

On the basis of a single case, we cannot draw conclusions concerning the relative usefulness of MR imaging and CT scanning in traumatic pneumocephalus. However, we feel certain that the two techniques can be used in a complementary way. Although CT scanning is widely regarded as the most useful diagnostic method for CSF fistula, we found MR imaging to be valuable in demonstrating both pneumocephalus and CSF fistula. MR imaging may come to play an important role in these conditions as well, particularly in the selection of appropriate surgery.

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Address reprint requests to: M. Komiyama, M.D., Department of Neurosurgery, Baba Memorial Hospital, 244 Higashi-4, Hamadera-funao-cho, Sakai, Osaka 592, Japan.