Diagnosis of subdural haematoma by computed axial tomography: use of xenon inhalation for contrast enhancement

E. ZILKHA, B. E. KENDALL, L. LOH, R. HAYWARD, E. W. RADUE, AND G. S. INGRAM

From The National Hospital for Nervous Diseases, Queen Square, London

SUMMARY A subdural haematoma is described in which a definite computed tomographic (CT) scan diagnosis was made only after contrast enhancement had been achieved by the inhalation of xenon. The different types of enhancement obtained with iodide containing contrast media and with xenon are discussed. The use of xenon to obtain further information in conditions which are inadequately elucidated by conventional CT must be balanced against its anaesthetic effects and relatively high cost.

Adult patients with subdural haematoma may present with obvious clinical symptoms and signs but often the diagnosis is only one among many that have to be considered when planning the investigation of a neurological disorder. The patients are often elderly, with their health impaired by malnutrition or excessive alcohol intake, so that a noninvasive method of providing accurate topographical and pathological information about the intracranial contents is essential, and computed tomographic scan (CT) is now accepted as the primary and usually the only necessary neuroradiological investigation.

Unfortunately, in some cases of subdural haematoma the attenuation of x-rays is similar to that of the adjacent brain, and then the only evidence of a unilateral haematoma may be displacement of the ventricular system. Intravenous injection of contrast media containing iodides may cause no appreciable change, and the distinction between subdural haematoma and an intracerebral swelling may not be made with certainty. Bilateral isodense subdural haematomata can cause even more difficulty, since the lesions may balance each other, and there may be no obvious displacement of the ventricular system so that the scan can be considered to be normal.

Xenon is a nonradioactive chemically inert gas with a high atomic number (54), and hence a high x-ray absorption cross section. It is moderately soluble in water and two to three times more soluble in brain tissue; it crosses the blood brain barrier and is freely diffusible in brain, so that it can be detected by computed tomography when administered by inhalation. These features make xenon an enhancement agent in cerebral CT with radically different properties from those of the organic iodides. The latter are normally confined within the cerebrovascular system by the blood brain barrier. Extravasation only takes place into structures in which the barrier is absent or is damaged in certain pathological states, so that these conventional contrast media measure only vascularity and integrity of the blood brain barrier. Xenon enhances the brain substance itself.

We are using xenon inhalation in selected patients for contrast enhancement in cerebral CT. The method can make a significant contribution to the diagnosis of subdural haematoma, and we consider this to be of sufficient importance to merit the following report.

Case report

A 54 year old Guyanian Indian male was admitted to another hospital with a story of having collapsed on two occasions during the previous five days. The cause of each collapse was unknown, but on
one occasion he was thought to have struck his head.

When first examined, he was noted to be drowsy and confused. His pupils were small and unequal; he had marked left hemiparesis and both plantar responses were extensor. He was transferred to the Department of Neurosurgery at the National Hospital for Nervous Diseases where the clinical abnormalities were confirmed. Routine haematological investigations and radiographs of the skull and chest were normal.

The patient was unable to cooperate and moved continuously so that a general anaesthetic was necessary for CT. Plain CT (Fig. 1a) showed displacement of the ventricular system to the left with compression of the right lateral ventricle most marked in the frontal region.

The appropriate levels were then rescanned, (a) with the patient breathing 50% xenon, (b) with the patient breathing 70% xenon, and (c) 15 minutes after the end of the xenon inhalation and immediately after a bolus intravenous injection of 60 ml of 70% sodium iohalamate.

Both the xenon enhanced scans, especially that during 70% xenon inhalation, clearly showed the subdural effusion with its maximum thickness in the right frontal region (Fig. 1c). The lesion was not visible after intravenous iohalamate (Fig. 1b). After this investigation, the patient's clinical condition was unchanged.

The next day, a right frontal burrhole was made, and approximately 60 ml of thick, dark red haematoma fluid were allowed to drain without any attempt at a complete removal. Five days later a further 35 ml were removed. Subsequent aspirations produced no significant amounts of fluid.

The patient made an uncomplicated recovery and his neurological abnormality swiftly resolved.

**Anaesthetic technique**

Anaesthesia was induced intravenously with an ultrashort-acting barbiturate, methohexitone, and orotracheal intubation was performed using suxamethonium bromide after spraying the larynx and trachea with a local anaesthetic. Anaesthesia was maintained with intermittent doses of methohexitone and the patient allowed to breathe spontaneously 100% oxygen, in order to wash out as much nitrogen as possible from the lungs and other tissues. During this period the plain CT scans were performed.

Since xenon is an expensive gas, a totally closed-circuit anaesthetic technique was used in order to limit the volume required (Barton and Nunn, 1975).

A wet spirometer (Godart Expirograph) with a blower and carbon dioxide absorber in the circuit was primed with a mixture of 50% xenon in oxygen. The xenon concentration was assessed by the continuous monitoring of the oxygen percentage in the spirometer using a fuel cell oxygen analyser (Tekmar). At the appropriate moment the patient was switched from breathing pure oxygen to breathing 50% xenon in oxygen from the spirometer system. Initially the xenon concentration fell due to dilution of the xenon mixture with oxygen from the patient's lungs.

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**Fig. 1** (a) Plain scan—the right lateral ventricle is compressed and the ventricles are displaced to the left side. The subdural haematoma isodense with cerebral substance. (b) Scan at same level after intravenous sodium iohalamate after xenon washout. The subdural haematoma still appears isodense with cerebral substance. (c) Scan at same level during inhalation of 70% xenon. The cerebral substance has increased in attenuation and the right sided subdural haematoma is now clearly shown as a superficial band of lesser density.
However, the uptake of oxygen from the spirometer, which was greater than the tissue uptake of xenon, allowed the xenon concentration to rise to 50% again after a few minutes. Thereafter, the concentration of xenon could be maintained constant by introducing into the spirometer a continuous flow of oxygen equivalent to the oxygen consumption.

Soon after CT scanning on 50% xenon, the concentration was increased to 70% by adding more xenon to the spirometer. After a further period of equilibration, a scan at the same level was performed. Provided adequate denitrogenation has taken place before inhaling xenon, the amount of nitrogen introduced into the closed circuit system is small and will not affect the value of the xenon concentration derived by subtraction of the oxygen concentration. Anaesthesia for the subsequent sodium iothalamate enhanced CT scan was maintained using oxygen, nitrous oxide, and halothane.

Detailed analysis of the CT scans

Using a computer as previously described (Zilkha et al., 1976), on the plain CT scan the mean EMI number of (a) the whole of the haematoma, (b) the right frontal lobe between the haematoma and the lateral ventricles, and (c) the left frontal lobe were measured (Table). These figures confirmed that the regions were virtually isodense. The attenuation of the fluid removed on the first drainage of the haematoma was measured by CT. It was 21.3 EMI units, corresponding well to the in vivo measurement of 20.6 EMI units.

Computer subtraction (Zilkha et al., 1976) of the 70% xenon enhanced scans from the plain scans were made (Fig. 2). The mean increase in EMI units of the regions examined on the plain scan were measured in the subtracted 70% xenon scan, and the same procedure was performed on the similarly subtracted postiodide scan (Table). The marked enhancement during 70% xenon inhalation of the brain substance (7 EMI units), while the haematoma was virtually unenhanced (0.7 EMI units), accounts for the easy visibility of the haematoma. The difference of 3 EMI units between the haematoma and the brain after iodide enhancement, which was not clearly detectable on viewing the scans, is in fact largely accounted for by retention of some xenon in the brain.

Discussion

Our report demonstrates the value of xenon for the diagnosis of this isodense lesion, a subdural haematoma, which did not enhance with intravenous iodide contrast media. This patient, in whom the clinical history, neurological examination, and conventional CT scan provided equivocal information, would otherwise have been subjected to angiography.

Phantom experiments (Winkler et al., 1977) have shown that there is a linear relationship between the fat content of various solutions and the change in attenuation factor shown on the EMI scanner when the solutions are brought into equilibrium with xenon. The same investigators also showed that it was possible to obtain easily discernible changes in attenuation in vivo in the brains of Rhesus monkeys.

Xenon has been used previously in human subjects for contrast enhancement during EMI scanning, and a few results were presented at the 1976 Bethesda Computed Tomographic Symposium (Houghton et al., 1976) but up to the present a clear indication of its value has not been established.

![Computed subtractions of difference between scan taken during inhalation of 70% xenon and plain scan. (a) and (b) Adjacent cuts passing through the subdural haematoma. The cerebral substance has increased in density but the ventricular system and the subdural haematoma have absorbed very little xenon. They have, therefore, remained virtually unchanged in density between the scans and are consequently well shown.](image-url)
Xenon is detectable by the EMI scanner at 20% gas concentration but there is a linear increase in the attenuation factor with partial pressure. To obtain optimum results it is desirable to use a high concentration of xenon, approximately 70%, but this dosage acts as a general anaesthetic in man after only two or three minutes inhalation (Cullen and Gross, 1951). For this reason it is necessary to proceed to intubation of the patient before the scan is started. It is our usual policy to use general anaesthesia for CT scans only when the patient’s respiratory state or lack of cooperation make sedation either undesirable or inadequate. It is from such patients that those for xenon enhancement as part of CT examination are at present selected.

Since the fat content of tissue influences the uptake of xenon, some conditions which cause changes in the brain lipids and which are frequently not revealed by conventional CT—such as demyelination in, for example, multiple sclerosis and encephalomyelitis, and possibly low grade infiltrating tumours—may be more readily identified. Xenon scans may also clarify the extent of brain damage caused by tumours, inflammations, and strokes. The physiological and pathophysiological aspects of xenon enhancement are of considerable interest but it remains to be determined in which conditions the procedure will aquire a sufficiently important place among diagnostic techniques to warrant both an otherwise unnecessary general anaesthetic and the additional cost of the xenon, currently £40 to £50 per examination.

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References


