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Computed Tomography of Spinal Cord After Lumbar Intrathecal Introduction of Metrizamide (Computer-Assisted Myelography)[1]

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Computed tomography (CT) of the thoracic and cervical spine was carried out after lumbar intrathecal introduction of a water-soluble radiographic contrast medium (metrizamide). By choice, no head-down position of the patient was used to facilitate craniad movement of the contrast medium; rather, advantage was taken of the normal CSF flow. This technique, referred to as computer-assisted myelography (CAM), permits the demonstration of the metrizamide-containing subarachnoidal spaces surrounding the thoracic and cervical cord. Some examples of the diagnostic possibilities of the method are discussed.

INDEX TERMS: Computed tomography, spinal • Computed tomography, technique • Myelography, technique

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ASCENDING BULK FLOW of intrathecally introduced radiopharmaceuticals represents the basis of radionuclide cisternography (1). In 1974, Greitz and Hindmarsh proposed the use of computed tomography (CT) of the brain after intrathecal introduction of a water-soluble radiographic contrast medium (2). This technique, referred to as computer-assisted cisternography (CAC), takes advantage of the "third circulation" (3) rather than a gravitational-positional shift for the intracranial transport of contrast medium.

CAC is usually carried out with metrizamide (Amipaque), a compound extensively employed in Europe for myelography (4–7). In isolated cases, successful CAC has been obtained also with meglumine iocarmate (Dimer-X), but not with methiodal sodium (Abrodil). The molecular weight of methiodal sodium is 221, whereas the metrizamide and meglumine iocarmate weights are 789 and 1646, respectively. As discussed by Hindmarsh (8), low molecular weight products injected into the subarachnoid space are eliminated mainly through the meningeal membranes. Heavier compounds, on the other hand, follow the main CSF resorption route, *i.e.,* through the arachnoid villi. Only the latter media can be used for CAC. This is analogous to the situation encountered in radionuclide cisternography where ^{99m}Tc pertechnetate (molecular weight 163) cannot be used as a tracer due to its quick resorption at and around the site of injection (9).

The intrathecally introduced metrizamide reaches the intracranial CSF cavities in diluted form so that it cannot be recognized by conventional skull radiography. The one hundredfold increased capability of CT to resolve differences of x-ray attenuation coefficients (10) makes it possible to demonstrate the iodinated compound in the cisternal spaces (Fig. 1) or in the ventricular system (Fig. 2) if ventricular reflux is present. An iodine solution of 1 mg/ml has a higher absorption coefficient than brain (and

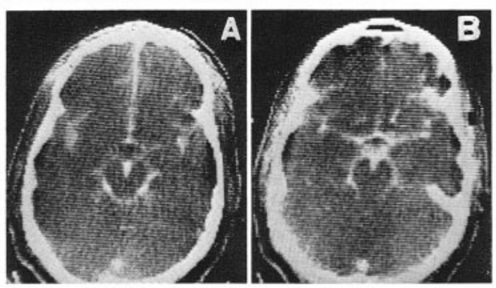

Fig. 1. Computer-assisted cisternography. Six hours after lumbar introduction of metrizamide, subarachnoid spaces around brain stem (A) and sella (B) as well as sylvian and interhemispheric fissures (A and B) are visualized.

spinal cord) tissue (2). In the CSF, 1 mg iodine per ml is sufficient to raise the x-ray attenuation, as measured with the EMI scanner, by 12.5 Hounsfield units (8). Considering that the total amount of CSF does not exceed 150 ml in normal conditions, it is obvious that even if only a small percentage of metrizamide usually injected for myelographic purposes (mean dose 2.50 g iodine; range 1.5 to 4 g iodine) reaches the cranial CSF cavities, CT visualization is possible. Metrizamide injected by the lumbar route is demonstrated in the basal cisterns and up to the sylvian fissures in 3 to 6 hours, and is seen around the convexity of the brain in the parasagittal area at 24 hours (2, 8, 11). CAC has been used in the diagnosis of communicating hydrocephalus (11) and of extracerebral tumors (12).

In the present study, we have evaluated by CT the ascent of metrizamide injected by the lumbar route, through the entire spinal subarachnoid space up to the basal cisterns of the brain. We refer to this technique as computer-assisted myelography (CAM).

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In Re: Di Chiro G, Schellinger D. Computed Tomography of Spinal Cord after Lumbar lntrathecal Introduction of Metrizamide (Computer Assisted Myelography).

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Whereas by the end of the 19th century the pathways and function of the spinal cord were largely known, only at the beginning of the 20th century were invasive tests developed to localize spinal cord diseases. A significant original observation was made in 1903 when Froin demonstrated that after a lumbar puncture, xanthochromatic changes within the CSF, and its massive coagulation, pointed to spinal compression (1). Ten years later, Pierre Marie, Foix, and Robert pointed out the value of serial punctures at different levels of the spinal canal. The Queckenstedt test was described in 1916, followed by the first truly objective method of diagnosing compression of the canal, developed by Dandy, with the injection of air by use of lumbar puncture (2).

In 1922, Sicard and Forestier, two French investigators, proposed the intraspinal injection of lipiodol, a method called ‘‘myelography’’ by the Germans (3). The discovery of lipiodol for use in myelography was accidental. Sicard’s main interest was in the treatment of pain, for which he had developed a great reputation and was the leading physician in France (4). One of the substances he used for the treatment of sciatica and other neuralgias was lipiodol, which he injected into the lumbar muscles. There are two versions of the story relating how Sicard came to inject lipiodol intrathecally. In the first version, one of Sicard’s pupils injected lipiodol into the lumbar muscles and, when he drew back the plunger of the syringe, noticed to his horror that he was withdrawing spinal fluid. After hearing that there was no problem with the patient, Sicard and his pupil decided to look at the patient’s spine on a fluorescent screen. To Sicard’s surprise, the lipiodol had dropped to the bottom of the spinal canal; he then had the brilliant idea of tilting the patient’s head down and observing the movement of the lipiodol (4). This must have been a tour de force because tilting fluoroscopic tables were not available in those days. In the second version, in an attempt to inject lipiodol into the epidural space, Forestier pushed the needle too far and, to his surprise, observed that the lipiodol had sunk to the dependent part of the thecal sac (5). Whichever version is correct, a new diagnostic test was born.

Ayer introduced the concept of a cisterna magna injection to obtain samples of cerebrospinal fluid in 1920 (6), and cisterna magna injections of lipiodol were used by the two French physicians Sicard and Forestier in 1923 (6). After the publication of Sicard and Forestier’s article, lipiodol use was accepted in France; however, it was some time before lipiodol was used in other countries. Because leaving the dye in the subarachnoid space resulted in inflammatory changes, lipiodol myelography was not enthusiastically endorsed (5). Mixter, in 1925, was one of the first surgeons to describe the use of lipiodol in the United States (8). By 1932, a tilting table had been invented; in their book published in 1932, Sicard and Forestier described using such a device to observe the transit of lipiodol through the subarachnoid space (9).

The first article in the English-language literature describing the use of lipiodol myelography for diagnosing ruptured intervertebral disks appeared in 1934 (10). This touched off a much wider range of myelographic investigations, but with renewed controversy. In 1941, Kubik and Hampton (11) proposed the removal of the iodized oil after the performance of the myelogram, a technique that, when used in subsequent years after the injection of Pantopaque, often resulted in lancinating pain down the distribution of an aspirated nerve.

Other investigators were using more innocuous contrast agents. As early as 1918, Dandy raised the possibility of outlining the spinal cord by using the intraspinal injection of air (12). In July 1919, 3 months before Dandy’s article on encephalography was published, the Swede Jacobaeus performed the first air myelogram (4); he reported his results in 1921 (13). The Swedish school popularized gas myelography by combining the injection of air with tomography (14). Subsequently, polytomography was used in conjunction with air myelography, and exquisite images of the spinal cord were obtained. Pantopaque, a new contrast medium, was introduced in 1944 by Ramsey and Strain (15).

Ionic, water-soluble contrast agents for myelography were first used in the United States in 1931, but because of their initial irritating effects on the meninges, never became popular. In the late 1960s, the first successful nonionic, water-soluble contrast medium was developed (16). Metrizamide was not entirely nontoxic, and second-generation nonionic agents such as iohexol (Omnipaque) and iopamidol (Isovue) essentially replaced metrizamide.

The head CT scanner was first shown in the United States in May 1972, and first mentioned in a publication in 1973 (17, 18). Many investigators were unhappy with the scanner’s inability to image parts of the body other than the cranium. Robert

Ledley, a dentist by training with an MA in physics, was a professor of physiology, biophysics, and radiology at the Georgetown University Medical Center. He was stimulated by the limitations posed by the head scanner. In 1974, he solved the problem by developing the automatic computerized transverse axial (ACTA) scanner, a device that was the first to use the convolution method for CT image reconstruction and could scan the whole body. Furthermore, the device eliminated the need for the interposition of an absorption-equilibrating medium (water) as was needed in the original scanner (19). Di Chiro was stationed at the National Institutes of Health at that time and was also a clinical professor at the Georgetown University Medical Center, where the research on the new body scanner was carried out. The first article on computerized body tomography appeared in October 1975 (20). In January 1975, Di Chiro and his coworkers (21) published an article on the diagnosis of syringomyelia based on ACTA scanner findings. In seven cases scanned before syringomyelic cavities were surgically verified, syrinxes were clearly shown in three and were questionable in two. In their article, De Chiro et al suggested in the concluding paragraph that for a complete diagnostic evaluation of patients with the syringomyelia syndrome, the ACTA scanner should be used in conjunction with myelography. The potential applications of total body CT applied to neuroradiology, an interest in the spine and spinal canal, and the early clinical trials of metrizamide, all stimulated the research that forms the basis of this review. The featured article was published in July 1976 by Di Chiro and Schellinger, and describes the value of combining metrizamide injected by the lumbar route with CT of the spine.

Di Chiro and Schellinger's article develops sequentially from what was then known about CSF flow. After discussing the normal ascending bulk flow of intrathecally introduced radiopharmaceuticals for radionuclide cisternography, the value of computer-assisted cisternography with metrizamide is discussed. The article primarily studies the ascent of metrizamide, injected by the lumbar route, through the spinal subarachnoid space up to the basal cisterns. Imaging the spinal canal was almost an after-thought, but it was Di Chiro and Schellinger who coined the term computer-assisted myelography. Ten patients were included in the study, six for the evaluation of disk disease, three for spinal tumors, and one for the assessment of normotensive hydrocephalus. Diagnostic images showed one case of an intramedullary conus glioma and another case of a foramen magnum meningioma. Other images in the article illustrate the normal appearances of the midthoracic and cervical cords. Essentially, the authors claimed to have added to the Swedish research in CT-assisted cisternography.

Thus, Di Chiro and Schellinger's concept has led to the current practice, albeit limited, of using CT in conjunction with nonionic, water-soluble contrast media for the evaluation of patients who cannot otherwise undergo MR imaging. This method is still in the armamentarium of practicing neuroradiologists, though it has been overshadowed by the excellence of current MR applications for the evaluation of spinal disease. It is interesting that although Di Chiro and Schellinger's article was recognized as being one of the most frequently cited in *Radiology* from 1985–1986 (it was ranked #51) (22), Di Chiro did not think that his article was of major importance (Schellinger, personal communication). An argument can also be made that in Di Chiro's oeuvre, other publications should be recognized as of equal if not more significant neuroradiologic importance (23). His work on the use of I-131 to study the flow of CSF, his atlases on pneumoencephalography, anatomy, and pathology, his contributions to spinal cord angiography, and his use of positron emission tomography to distinguish between brain tumor and radiation necrosis are highly commendable publications. Although these contributions are worthy of recognition, when MR is contraindicated in patients with cardiac pacemakers or spinal instrumentation, CT-assisted myelography is still needed. For this reason, and because this article meets the requirements of being original, innovative, and part of current practice, it has been included in this series.

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