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Cerebrospinal Fluid Circulation: Evaluation by Single-Photon and Positron Emission Tomography

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Gamma camera cisternography after intrathecal administration of ^{111}In-DTPA is a widely used and well established technique for studies of cerebrospinal fluid (CSF) circulation. The radiation dose from ^{111}In, however, is a limiting factor that sometimes seriously affects the image quality and, hence, correct interpretation. This investigation was designed to assess the value of tomographic techniques for studies of CSF flow. Single-photon emission computed tomography (SPECT) was performed on 15 patients by means of the Karolinska Hospital rotating gamma camera system after injection of ^{111}In-DTPA or ^{99m}Tc-DTPA. The combination of SPECT and ^{99m}Tc-DTPA proved to be a valuable technique. It permits a clear evaluation of the location of the isotope intracranially and its precise relation to the ventricles. Positron emission tomography (PET) applied after intrathecal administration of ^{68}Ga-EDTA demonstrates that small amounts of radioactivity can be registered and that PET is a promising technique for the evaluation of CSF dynamics.

Indium-111-DTPA was introduced in 1972 as a suitable radiopharmaceutical for studies of the cerebrospinal fluid (CSF) circulation [1]. Since then ^{111}In has been the most commonly used radionuclide for such studies. Its physical half-life of 2.81 days is well suited for studies of CSF flow over a period of up to 72 hr.

The disadvantages are that only low amounts of radioactivity can be administered due to high radiation doses to the spinal cord and that the photon energies (171 keV and 245 keV) are not optimal for gamma camera scintigraphy. Therefore, the spatial resolution is poor, and accurate interpretation may be impossible, whether or not persistent intraventricular uptake is present. This is essential for correct evaluation of CSF flow, for example in patients with communicating hydrocephalus.

In order to improve spatial resolution and to reduce noise, ^{111}In-DTPA was replaced by ^{99m}Tc-DTPA, which has been used in conventional gamma cisternography [2].

Single-photon emission tomography (SPECT) has been used in the Karolinska Hospital since 1978 [3]. This technique seemed suitable for studies of the CSF circulation and, therefore, was applied in this investigation.

Positron emission tomography (PET) offers certain important advantages over SPECT, such as higher spatial resolution and more accurate quantitation. The device is routinely used in Karolinska Hospital for localization of CSF fistulas [4] and its value for CSF studies has now been evaluated.

Materials and Methods

Conventional gamma cisternography and SPECT were performed in seven cases with 18.5 MBq (0.5 mCi) ^{111}In-DTPA and in eight cases with 100 MBq (2.7 mCi) ^{99m}Tc-DTPA, using the rotating gamma camera system [3]. The radiopharmaceuticals were injected intrathecally by the lumbar route.

In order to facilitate adequate interpretation of regional CSF flow from SPECT studies, computed tomographic (CT) studies were included in the examination procedure. Both the CT and the SPECT studies were performed with the patient's head fixed to the examination table using an external fixation by a plastic helmet system of the same type as the one used during stereotaxic CT procedures [5]. A specially designed localizing plastic box was connected to the same base plate as the helmet (fig. 1). In the lateral wall the box carries an aluminum rod that is tilted 45° relative to the base plate. This rod can be localized in the CT image, and by means of the cursor system of the display unit the actual level of each slice can be determined. The walls of the box are further supplied with a tube system with one tube tilted in the same way as the aluminum rod. For visualization in the SPECT study the tube system is filled with ^{99m}Tc. The level of the individual SPECT slice as well as the coordinates within the slice can subsequently be calculated from the location of the tubes. This device allows a correlation between distribution of the radionuclide in the head using SPECT and the morphologic details of the CSF space from CT.

The PET scanner of the Karolinska Hospital [6] was used for localization of CSF fistulas in 14 patients. The intrathecally administered radioactivity was 30 MBq (0.8 mCi) ^{68}Ga-EDTA.

CT and PET slices of the same level can be superimposed using a specially designed software, which includes the transformation of the CT image to the matrix of the PET scanner system. The accuracy is very high due to the external helmet fixation. The possibilities of further analyzing the radionuclide distribution during CSF flow studies and of performing quantitative measurements were evaluated in this investigation.

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Results

Due to the poor spatial resolution using ^{111}In-DTPA, it was impossible to obtain SPECT images of the CSF space of sufficient clinical value. SPECT using ^{99m}Tc-DTPA on the other hand demonstrated additional detail, especially in cases where it was difficult to decide whether intraventricular radioactivity was present or not (fig. 2).

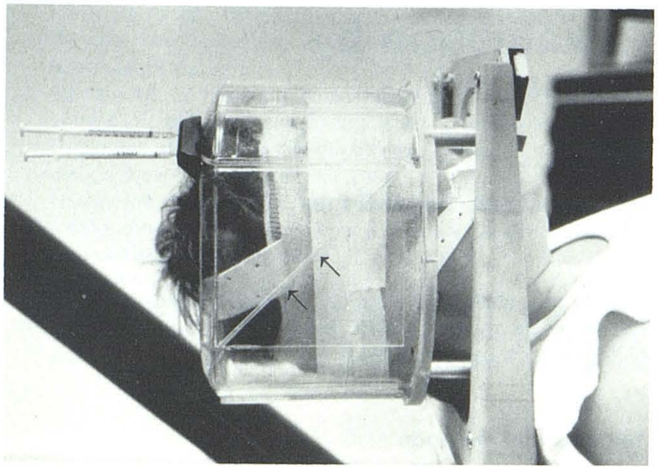

Fig. 1.—Plastic helmet and localizing box applied to head and examination table. Tube system for slice level determination (*arrows*).

When conventional views demonstrated clear-cut normal or pathologic (fig. 3) conditions, SPECT did not add further morphologic information. Tomography, however, is probably necessary for accurate quantification of CSF flow.

Studies done with PET and ^{68}Ga-EDTA clearly show that the anatomy of CSF spaces can be accurately studied with positron-emitting isotopes (fig. 4). However, the short half-life (68 min) of ^{68}Ga-EDTA makes it unsuitable as a tracer for periods longer than 2–3 hr.

Discussion

A radioactivity of 100 MBq (2.7 mCi) of ^{99m}Tc-DTPA will be sufficient for SPECT studies and for conventional gamma camera scintigraphy of the CSF space within about 24 hr after lumbar injection. This period of time is, according to our experience, sufficient for a correct interpretation of CSF flow. Static views have been taken at 2, 4, 6, 9, and 24 hr after administration, but registrations after 4, 6, and 24 hr are probably sufficient for evaluation of flow dynamics.

Although 100 MBq of ^{99m}Tc-DTPA is insufficient for tomographic registration after 24 hr, the presence of an intraventricular uptake

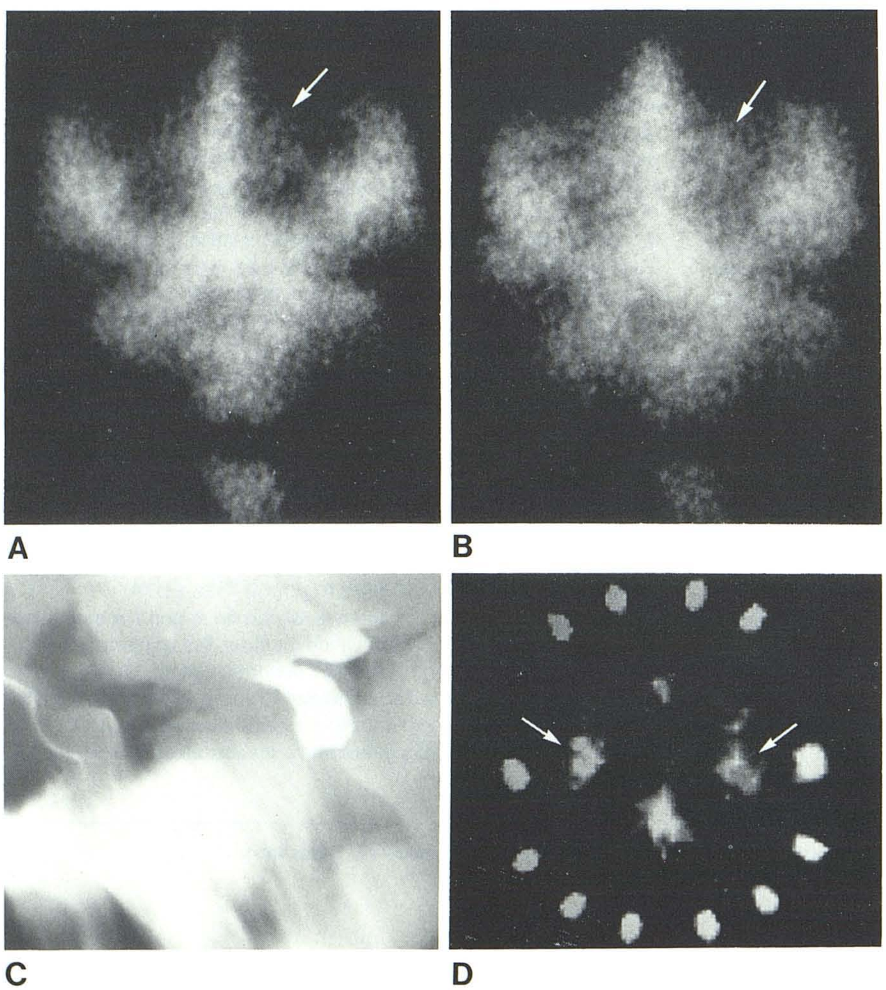

Fig. 2.—Frontal views 4 (**A**) and 12 (**B**) hr after intrathecal injection of 100 MBq of ^{99m}Tc-DTPA. **C**, Radioactivity in lateral ventricles (*arrows*) cannot be excluded in this patient with aqueduct stenosis. **D**, SPECT slice at level of lateral ventricles demonstrates radioactivity in sylvian fissures (*arrows*) and quadrigeminal cistern but no radioactivity within ventricle system. Peripheral radioactivity represents cross sections of tube system.

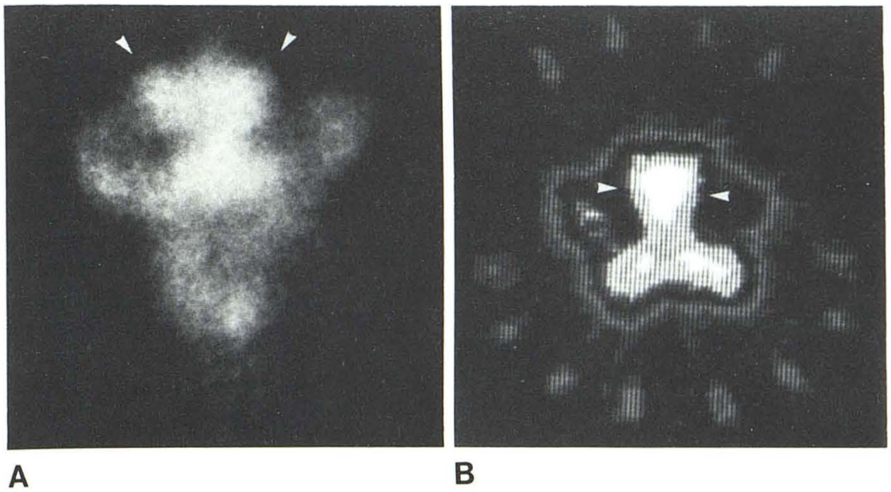

Fig. 3.—Patient with communicating hydrocephalus. Gamma cisternography, conventional frontal view (**A**) and transverse axial SPECT slice (**B**) at level of lateral ventricles. Radioactivity within ventricular system (*arrowheads*) is well demonstrated with both techniques.

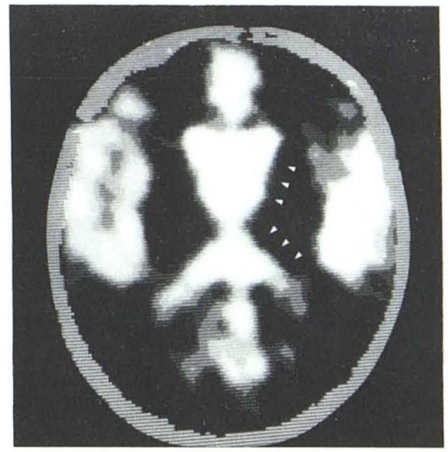

Fig. 4.—Superimposed CT and PET slices at same level demonstrate activity in ventricular system (*arrowheads*) and CSF cisterns and relation to skull bone.

can usually be inferred by comparing the static view with the tomographic images obtained at 6–9 hr.

For accurate quantification and clearance curves of the radioactivity from the CSF spaces repeat SPECT studies are needed. This is presently under investigation. PET offers these options but new positron-emitting radiopharmaceuticals have to be prepared and tested.

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