Three-Dimensional Display of Intracranial Soft-Tissue Structures

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Efficient three-dimensional surface reconstructions of intracranial bony, soft-tissue, and cerebrospinal fluid–filled structures have been created from serial narrowly collimated transaxial computed tomographic (CT) scans. These three-dimensional surface images are useful in visualizing the relations among intracranial details. Views may be produced in frontal, rear, 45° oblique (anterior and posterior), top and bottom, and both lateral projections. This method has been applied to image the surface of intracranial structures by reformatting the images with elimination of the overlying bone. This method was realized as a computer program that operates on a conventional unmodified CT scanner without operator intervention.

Three-dimensional display of surfaces derived from serial high-resolution computed tomographic (CT) scans has been investigated by several researchers [1–3]. Unfortunately, none of the proposed methods has found wide clinical acceptance. The limitations in applicability may be attributed to the complexity of the proposed methods, which require skilled operator intervention, large amounts of computation time, and expensive specialized computer and display hardware not commonly found in diagnostic radiology departments.

We have developed a technique for the production of three-dimensional surface reconstruction from serial CT scans [4] that has several important advantages over the three-dimensional surfacing methods proposed previously. This technique requires no operator intervention, produces multiple high-quality surface views for several standard projections in a reasonable length of time, and operates on an unmodified CT scanner without the need for additional equipment. This method has been applied to more than 100 patients with craniofacial anomalies, facial trauma, neoplastic disease of the head and neck, and intracranial soft-tissue abnormalities.

Materials and Methods

Sequential high-resolution narrowly collimated (2 mm) CT scans of the head were obtained using an unmodified commercially available CT scanner (Siemens Somatom 2). These scans were obtained without any special patient preparation or modificiation of the normal CT scan protocols used in our department. Gantry tilt or intravascular contrast media or both were used in the acquisition of the CT scans, depending on the clinical circumstances.

The scans were automatically stored on floppy disks for off-line storage. Disks containing the original scan data were copied into the CT scanner itself or a CT scan evaluation console (Siemens Evaluscope) for three-dimensional surface reconstruction. Typically, these reconstructions were done overnight, without the presence of an operator, using programs executed on the CT scanner or evaluation console. After beginning the reconstruction process, the system operates unattended and forms more than 50 surface views from each set of original scans (usually 20 to 64 scans in a set). When the operator comes to the scanner room the next morning, the surface views are available in the scanner or evaluation console disk memory in the same format as ordinary CT scans. These three-dimensional images were copied to blank floppy disks, manipulated using window level and width controls, and photographed in the same manner as ordinary CT scans.

The three-dimensional views for each case were produced in the frontal, rear, 45° oblique (anterior and posterior), top, bottom, and both lateral projections. Simultaneous production of bony and soft-tissue surfaces in these projections was done in all cases.

Our surface reconstruction method is based on a level slicing contour extractor and planar projection without the use of perspective depth. Irregularities at slice-to-slice interfaces parallel to an axis orthogonal to the transverse plane of section were removed using a very efficient nonlinear noninterpolating anisotropic digital filter designed specifically for this application.

The level slicing contour extractor we used requires threshold settings specified by the operator. These thresholds allow separation of water density (cerebrospinal fluid [CSF]), tissue density (skin, muscle, and brain parenchyma), intravascular and tumor mass contrast enhancement, dilute intrathecal contrast (e.g., metrizamide), and bone. In our experience these components can be reliably separated for surface reconstructions.

Results

To illustrate the application of this method in clinical problems, two examples are presented. Metrizamide ventriculography was performed in a 54-year-old woman with pinealoma to demonstrate the relevant anatomy (fig. 1). Parts of the frontal and occipital bones were removed, as were the bony floors of the middle and posterior fossae to improve intracranial CSF space visualization. The effect of a selectable threshold for surface reconstruction is exemplified in figure 1, where slightly higher levels (figs. 1A and 1D) of 70–75 Hounsfield units (H) render the interhemispheric and sylvian cisterns

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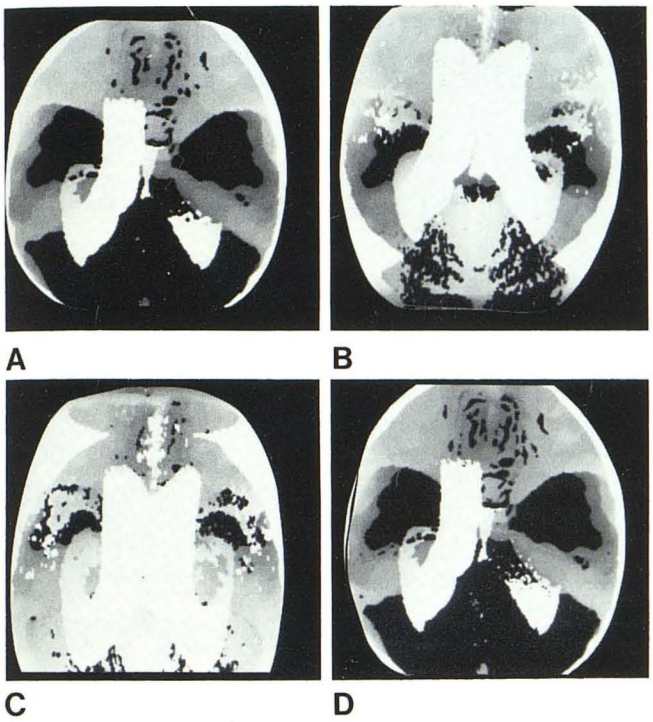

Fig. 1.—CT cisternogram and ventriculogram after intrathecal administration of metrizamide. Top views of skull with different CT thresholds shown. **A**, With patient supine, densest (>70 H) part of intraventricular metrizamide has collected in most dependent parts of lateral and third ventricles and in cerebral aqueduct. **B**, With slightly lower threshold level (34 H), remaining contrast is seen in lateral ventricles, interhemispheric and sylvian fissures, and outlining superior surface of cerebellum. **C**, Same threshold level with skull mathematically tilted slightly above horizontal axis. **D**, Same view as **A**, but higher threshold (75 H).

and supracerebellar CSF space invisible. The simultaneous production of all the images shown in figure 1 is a routine function of the computer software we have developed.

Intracranial three-dimensional soft-tissue views of contrast-enhancing lesions have also been developed (fig. 2). In our standard surface reconstruction series for a contrast medium–enhanced mass, the lesion and vascular structures (including both middle cerebral arteries) are readily demonstrated.

Discussion

The availability of a fast method for obtaining three-dimensional surface views of intracranial soft-tissue structures has significant implications for clinical management of complex neurologic and neurosurgical problems. The image data contained in a series of sequential CT scans are difficult to assimilate into three-dimensional anatomic relations. The full appreciation of the information contained in a set of CT images requires experience and time for a skilled neuroradiologist, and the precise communication of abnormal findings and complex anatomic relations to nonneuroradiologists is often difficult. Our method provides a powerful tool to enhance the usual communications by converting CT scans to a surface representation that is more compact and more meaningful to the referring physician.

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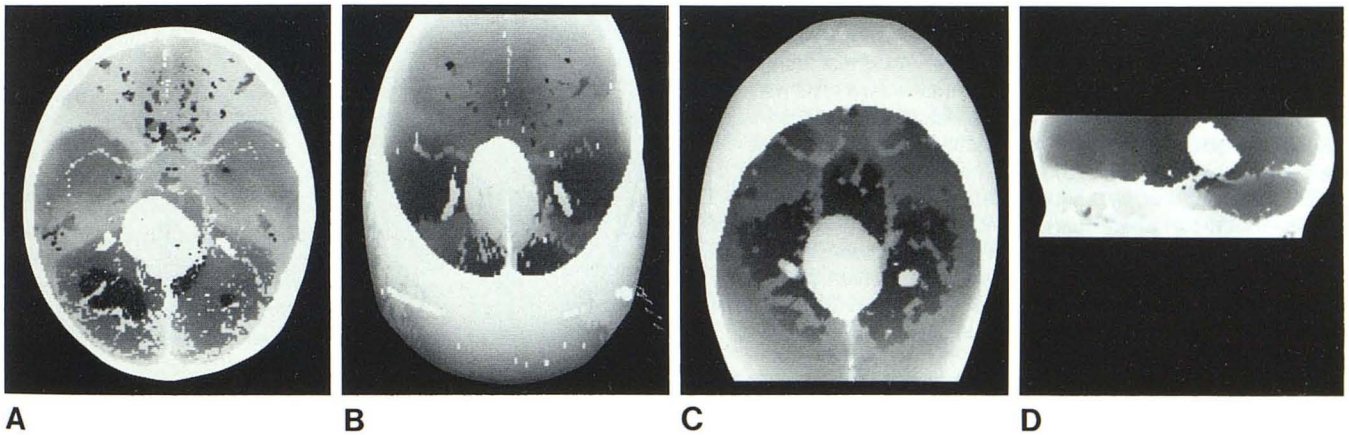

Fig. 2.—Postcontrast three-dimensional surface views from routine CT examination of 55-year-old woman with soft-tissue mass in tentorial notch. **A**, Plan or top view showing midline enhancing soft-tissue mass. Patient's nose at upper margin of head. Middle cerebral arteries are seen bilaterally. Scattered enhancement over tentorium and interhemispheric fissure. **B**, (Observer has moved slightly dorsad and caudad.) Calcified glomus in choroid plexus is seen bilaterally. **C**, (Observer has moved ventrad and caudad from **A**.) Nose, globes, and zygomatic arches at top margin of image. Midline mass is shown in another perspective. **D**, Midsagittal surface view. Entire left hemicranium and contents have been removed. Orbit is located at bottom left corner of image. Cerebellum occupies space below tentorium at bottom right. Mass and its relation to slightly enhanced tentorium are clearly demonstrated.