AJNR

# High Resolution CT with Image Reformation in Maxillofacial Pathology

Michael N. Brant-Zawadzki, Hideyo Minagi, Michael P. Federle and Lee D. Rowe

*AJNR Am J Neuroradiol* 1982, 3 (1) 31-37
http://www.ajnr.org/content/3/1/31

# High Resolution CT with Image Reformation in Maxillofacial Pathology

Michael N. Brant-Zawadzki[1]
Hideyo Minagi[1]
Michael P. Federle[1]
Lee D. Rowe[2]

**Twenty-four patients with maxillofacial pathology were examined with computed tomography (CT) using thin (1.5–5.0 mm) sections allowing computer reformation of images in multiple planes. Eight patients also had pluridirectional tomography. The patients included 14 with facial trauma, four with acute paranasal sinus infections, and six with suspected neoplasms. High resolution CT with reformations allowed thorough evaluation of facial trauma. Fracture sites were correctly identified, as were the relation of fragments to vital structures. The form of structural facial alteration was easily assessed, optimizing the presurgical plan for reconstruction. In addition, CT allowed simultaneous evaluation of associated brain injury. In acute infectious processes and neoplasms, CT defined the extent of involvement and directed the type of therapy. In both situations, accurate assessment of bony destruction permitted definitive planning for bony debridement in infection and helped in the differentiation of benign from malignant processes in neoplasia. Density determination also allowed differentiation of neoplastic soft tissue from inspissated mucus within obstructed sinuses. Experience suggests that CT can be the definitive imaging method in the diagnosis of complex maxillofacial pathology when sufficient evaluation is unavailable from plain films. It was superior to thin-section pluridirectional tomography in several instances.**

Both conventional and computed tomography (CT) can provide important radiologic information for evaluation of maxillofacial pathology. The inherently superior contrast resolution of CT has established it as the method of choice in the staging of maxillofacial neoplasm and in the evaluation of chronic inflammatory processes in the paranasal sinuses [1–5]. However, the spatial resolution of CT has lagged behind that of pluridirectional tomography until recently [6]; thus CT has had limited use in the evaluation of maxillofacial trauma in which visualization of bony detail is important.

A recent report from this institution suggested that third generation CT has the potential for supplanting conventional tomography in the evaluation of facial trauma [7]. Since that report, further advancements in CT technology have allowed very thin section scanning, thus improving spatial resolution. In addition, newer software packages allow great flexibility of data manipulation permitting image reformation in multiple planes and region-of-interest density analysis. These refinements have expanded the potential utility of CT in maxillofacial trauma and other pathology. We report our early experience with this enhanced capability of CT scanning.

## Subjects and Methods

We examined 24 patients with maxillofacial abnormalities. All CT scans were performed on a General Electric 8800 scanner, using either 1.5 mm contiguous sections, or 5.0 mm sections spaced 3.0 mm apart producing a 2.0 mm overlap of adjacent scans. Image reformation in multiple planes was performed via prototype software package supplied by the G.E. Corporation.

**This article appears in the January/February 1982 issue of *AJNR* and the March 1982 issue of *AJR*.**

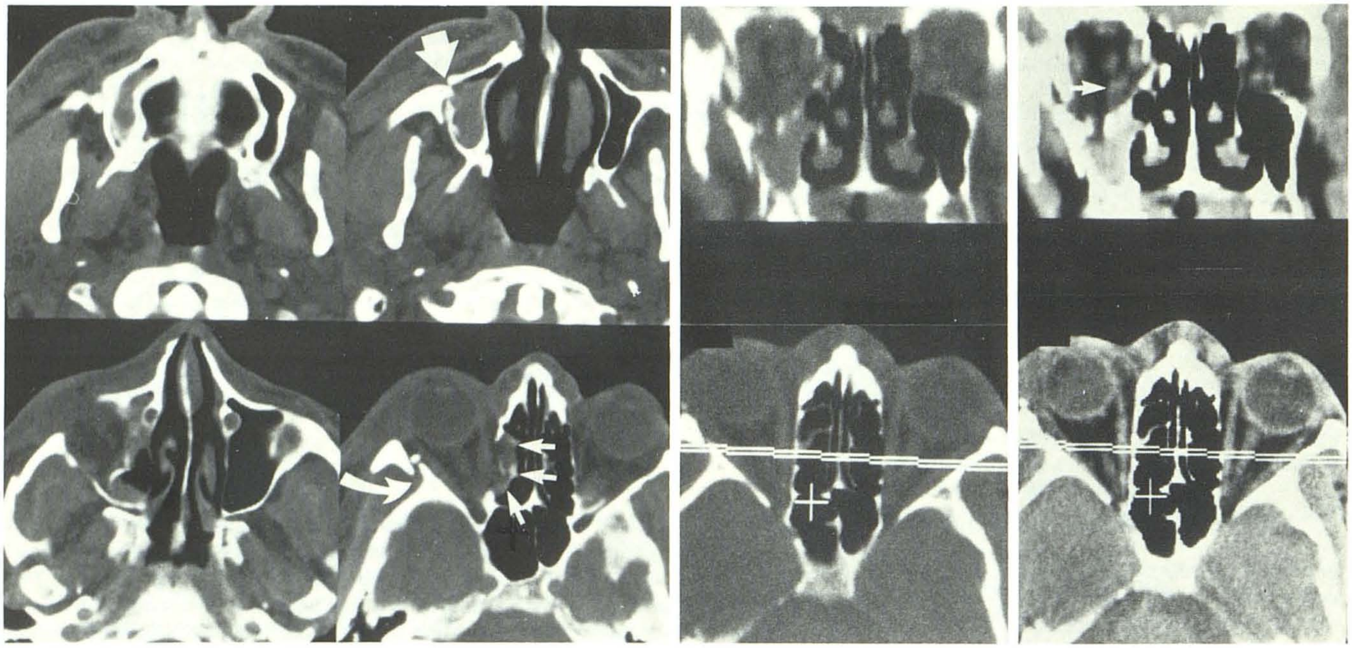
Received April 9, 1981; accepted after revision August 7, 1981.

Presented at the annual meeting of the American Society of Neuroradiology, Chicago, April 1981.

[1] Department of Radiology, University of California, San Francisco School of Medicine, San Francisco General Hospital, San Francisco, CA 94110. Address reprint requests to M. Brant-Zawadzki.

[2] Department of Otolaryngology, University of California, San Francisco School of Medicine, San Francisco General Hospital, San Francisco, CA 94110.

***AJNR* 3:31–37, January/February 1982**
0195-6108/82/0301-0031 $00.00



A B C

Fig. 1.—Tripod fracture of right maxilla. **A**, Sequential axial CT sections. Posteroinferior separation of zygoma from right maxilla (*large arrow*); fractures of zygomatic arch, frontozygomatic suture (*curved arrow*), and medial orbital wall (*small arrows*). **B**, Coronal reformation verifies tripod fracture with posteroinferior displacement of malar eminence. **C**, Soft-tissue window setting. No herniation of the inferior rectus muscle (*arrow*).

Fourteen patients were evaluated for facial trauma, two of whom were specifically studied for cerebrospinal fluid (CSF) rhinorrhea several months after injury. Four patients were examined for acute infection; six others were evaluated for suspected tumors. Five of the trauma patients, one of the infection patients, and two of the tumor patients also had studies with pluridirectional tomography using 2.0–5.0 mm sections.

The conventional tomograms were retrospectively reviewed independently by one of us (H. M.), and findings were compared to the original interpretation of the CT study. We attempted to evaluate the contribution of the diagnostic information obtained by CT to the therapeutic approach and clinical outcome in each case.

## Results

### *Trauma*

Acute blunt trauma to the face in nine patients resulting in complex fractures was studied by CT. CT identified tripod fractures in seven patients. It showed the associated orbital floor fractures in all seven, and in three significant inferior rectus herniation was depicted (two of whom had diplopia). In one patient, these findings were superimposed on a complex Le Fort II fracture; both components of the injury were readily diagnosed. CT also showed multifocal maxillary sinus fractures, nasal fractures, and medial orbital blowout fractures in these patients.

Multiplanar image reformation in combination with thin axial cuts was especially valuable. It allowed three-dimensional display of bony distractions and the resulting displacement of the malar eminence in tripod fractures (fig. 1). When the zygomatic arch showed no fracture or only a single, nondisplaced one, the displacement of the malar eminence was minimal. In another patient, expected posterior displacement of the mid face in the Le Fort II injury was minimal, as the usual pterygoid fracture component was absent (fig. 2). Subtle orbital floor fractures were best seen on image reformations in a plane defined by the inferior rectus muscle. Herniation of that muscle, when present, was best seen in a plane perpendicular to its course (fig. 3).

CT fully evaluated complex fractures of the superior orbital rim region involving frontal and ethmoid sinuses in two additional patients and in the patient with a Le Fort II/tripod fracture mentioned above. Reformations of axial images again proved useful. Impingement on the superior rectus muscle was delineated in two, while in one case compression of the globe by fragments accounting for ophthalmoplegia was defined. These findings were difficult to ascertain on axial cuts alone. Two of these three patients with frontal sinus fractures also had distraction of the posterior wall, seen on both axial (Fig. 2A) and sagittally reformatted images.

Gunshot injury was thoroughly evaluated with CT in three patients. Location of bullet and bone fragments, associated bony disruptions, and intracranial penetration were easy to appreciate. The integrity of any structure lying in the plane originally scanned (axial) was best evaluated on reformations perpendicular to it.

Two patients were specifically studied for CSF rhinorrhea several months after blunt facial trauma. The first had meningitis. Axial 1.5 mm cuts showed no definite abnormality. However, sagittal and coronal reformations revealed a 5.0 mm defect in the fovea ethmoidalis with an associated

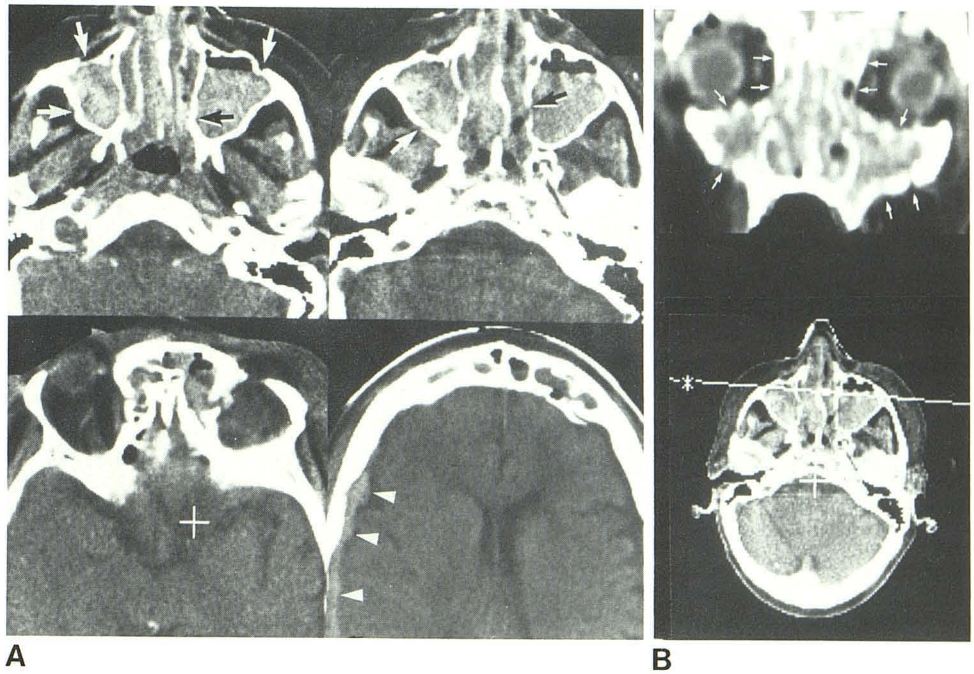



Fig. 2.—Le Fort II fracture after blunt facial trauma. **A**, Selected axial CT sections. Fractures of inferior orbital rims at infraorbital foramen level bilaterally, minimally displaced maxillary wall fractures elsewhere (*arrows*), and medial orbital wall disruptions characteristic of Le Fort II injury. Associated right subdural hematoma (*arrowheads*) and posterior wall frontal sinus fracture. **B**, Coronal reformation. Fractures (*arrows*). More posterior reformations (not shown) found no pterygoid fractures, possibly accounting for relative lack of posterior displacement of mid face.

encephalocele (fig. 4). Surgery corrected the defect. The second patient had an inconclusive radionuclide search for a CSF fistula and negative pluridirectional tomography. CT metrizamide study suggested posterior ethmoid CSF leak. This study and persistent rhinorrhea prompted surgical exploration; no obvious defect was seen in the dura of the cribriform plate. Although the region was packed with muscle at surgery, CSF rhinorrhea recurred 2 months later and necessitated shunting of CSF from the subarachnoid space into the peritoneum.

Early in our experience, five of the trauma group patients had pluridirectional tomography in addition to CT. In this small group, CT provided as much as or more information than did the conventional tomographic study. In addition to defining more facial (especially maxillary) fractures than conventional tomograhy, CT showed a temporal bone fracture not seen with pluridirectional tomograhy in one case and ruled out a lesser sphenoid wing fracture suspected on pluridirectional tomography in another. CT did miss one nondisplaced horizontal fracture of the lateral pterygoid plate which was seen with polytomograhy in a patient with tripod fracture.

CT defined brain parenchyma hematomas in two patients and a subdural hematoma (fig. 2A) in a third, information unsuspected clinically and unavailable from conventional radiography.

### *Infection*

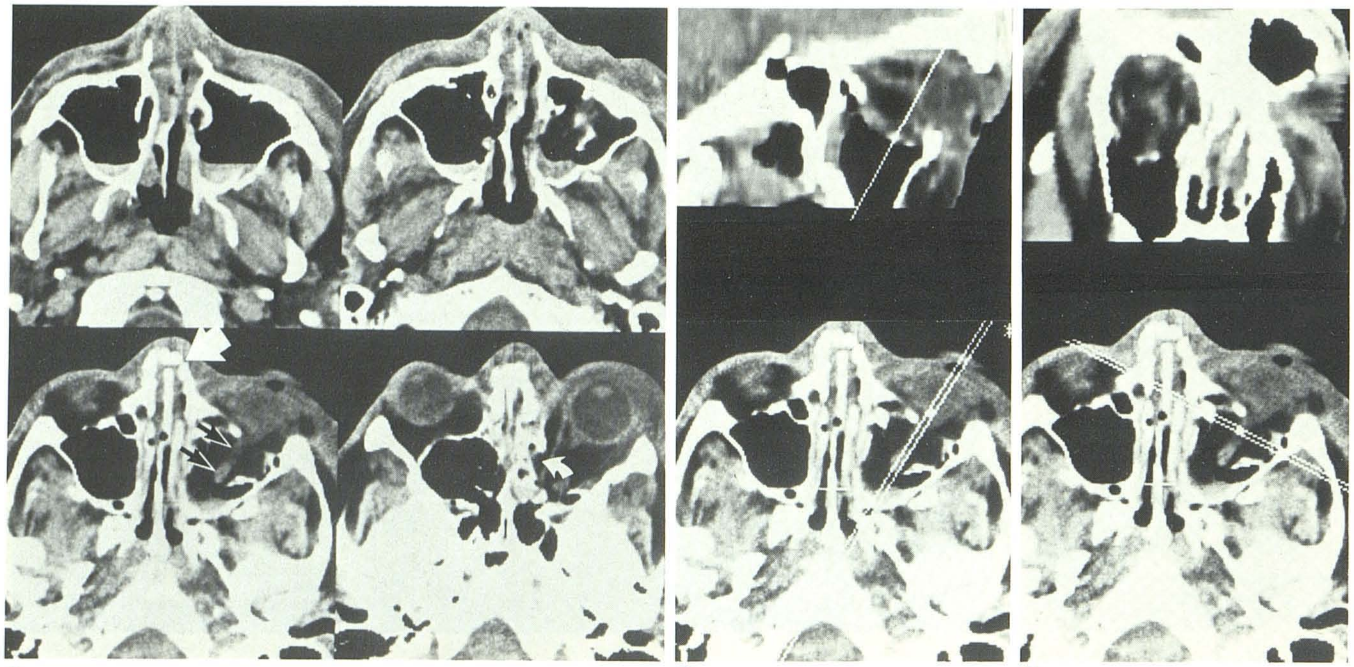
Four patients had acute sinusitis. Two developed fulminant maxillary sinusitis after tooth extraction. The first had a CT study that defined maxillary antral wall dehiscence at several sites indicating osteomyelitis. Image reformations revealed dehiscence of the orbital floor and extension of the process into the lower retroorbital space (fig. 5), information not definitely supplied by axial cuts alone. These findings preceded ophthalmoplegia which developed the next day and led the surgeon to a specific exploration and drainage of this region and the adjacent ethmoid cells, allowing rapid clinical improvement. The second patient had a draining sinus from his lateral orbital border. CT defined extension of a maxillary infection into the right superior ethmoid sinus and dehiscence of the lateral floor of this sinus with communication into the orbital roof. Coronal image reformation best showed the lateral spread across the roof of the orbit, explaining the drainage at the lateral canthus.

A third patient developed pansinusitis during a 2 week intensive-care-unit hospitalization after abdominal trauma; CT defined the involvement and helped rule out intracranial extension as a cause of his waning mental status. The fourth patient showed signs of a mild maxillary sinusitis. Plain films revealed a molar tooth in the maxillary antrum. CT defined an infected bony cyst containing the tooth with erosion of the maxillary walls and orbital floor by this process (fig. 6). An infected dentigerous cyst was found at surgery. Removal was greatly facilitated by knowledge of extension into the infratemporal fossa and orbital floor.

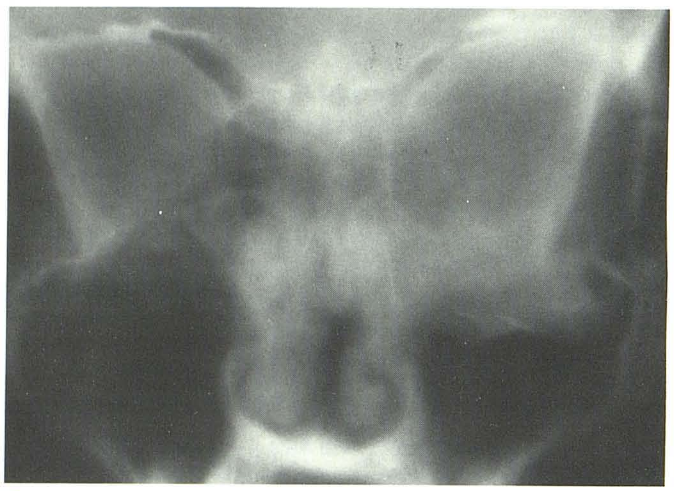
### *Tumors*

Six patients were studied for maxillofacial neoplasms. Two had aggressive carcinomas of the paranasal sinuses. Extension of these neoplasms into orbital and intracranial spaces was thoroughly demonstrated with multiplanar image reformation. Bony destruction was easily assessed.

One patient was studied for an intranasal mass. A tomographic study in this patient showed diffuse opacification within the nose and paranasal sinuses. CT density measure-



A B C



D

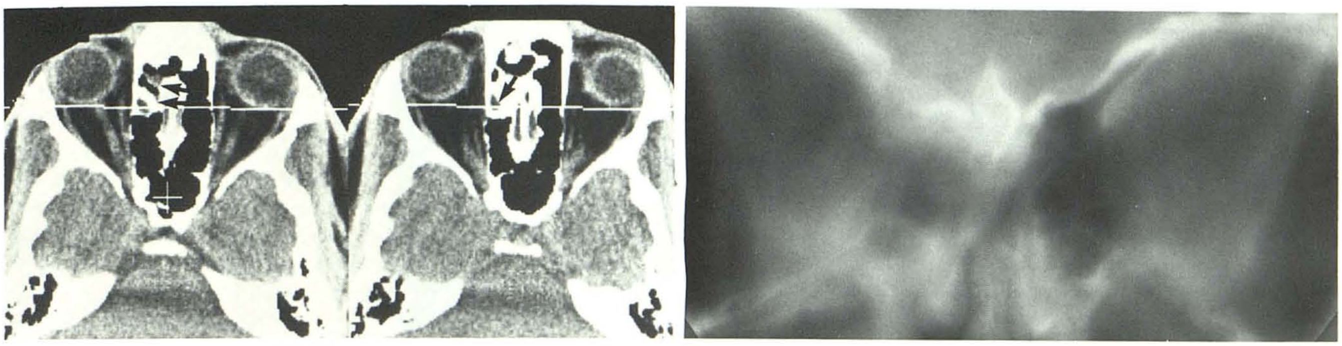
Fig. 3.—Orbital fracture with inferior rectus herniation. **A**, Sequential axial CT sections. Fractures of nose (*large arrow*), lateral maxillary antral wall, and lamina papyracea (*curved arrow*). Inferior rectus muscle in left maxillary antrum (*small arrows*) suggests herniation. **B**, Reformation along plane of inferior rectus muscle verifies its depression. **C**, Plane truly orthogonal to this muscle discloses extent of orbital floor displacement. **D**, Conventional tomograms. Orbital floor fracture with inferior displacement of soft tissues.

ment revealed that the maxillary "soft tissue" measured 20 Hounsfield units (H) below the nasal soft tissue (fig. 7). This suggested blockage of sinus drainage rather than antral tumor extension; the lack of obvious bony destruction also supported a benign inflammatory disorder. Surgery verified allergic polyposis.

One patient had a parotid tumor assessed with CT. Bone destruction and extension medial to the mandible was ruled out. Another patient had a glabellar tumor. CT showed no evidence of bony destruction, but delineated extension of this tumor into the medial orbit, where image reformations proved that the growth displaced (but did not involve) the globe and penetrated the nasal-lacrimal duct causing its expansion. Biopsy showed a benign mesenchymal tumor. The final patient was a woman with a hard mass felt in the superior medial orbit. CT demonstrated soft-tissue density arising from the ethmoid sinus bulging into the orbit. Bony thinning and apparent erosion was noted. Differentiation between malignant and benign process could not be made. A mucocele was found at surgery.

## Discussion

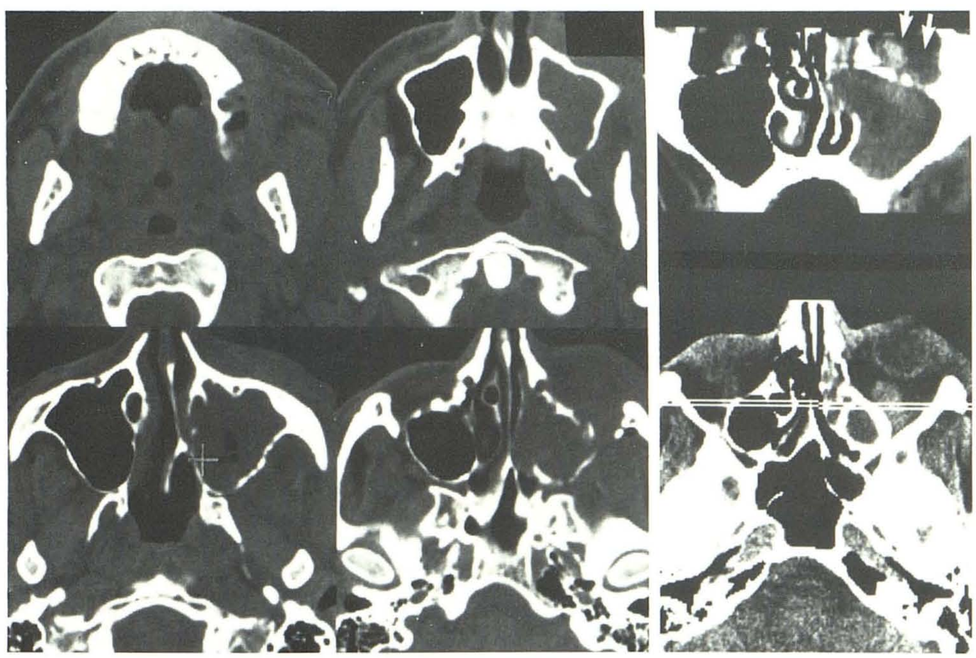
The diagnostic usefulness of maxillofacial CT depends on the type of disease. In major facial trauma, not only is the delineation of fractures important, but a three-dimensional understanding of gross structural alterations is desirable for proper cosmetic reconstruction. CT image reformation into coronal and sagittal planes was useful in this respect; reformation along planes containing structures such as the



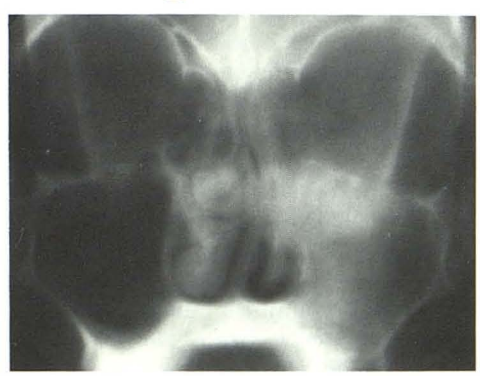
A C

B

Fig. 4.—Traumatic CSF fistula with meningitis. **A**, Contiguous 1.5-mm-thick axial CT sections through ethmoid region. Only minimal right anterior ethmoid opacification (*arrows*). Coronal (**B**) and sagittal (not shown) reformations through ethmoid roof in this region depicted bony defect and associated small encephalocele. **C**, Conventional tomographic study obtained initially. Soft tissue in right ethmoids and erosion of ethmoid roof.

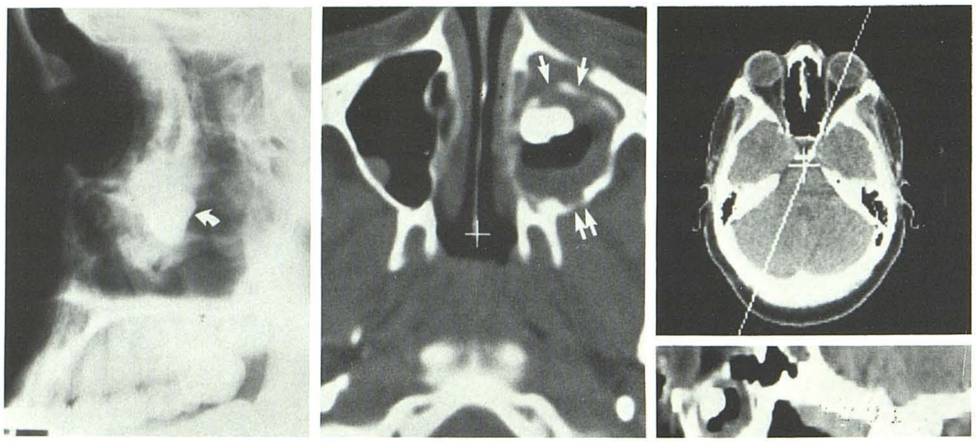


A B



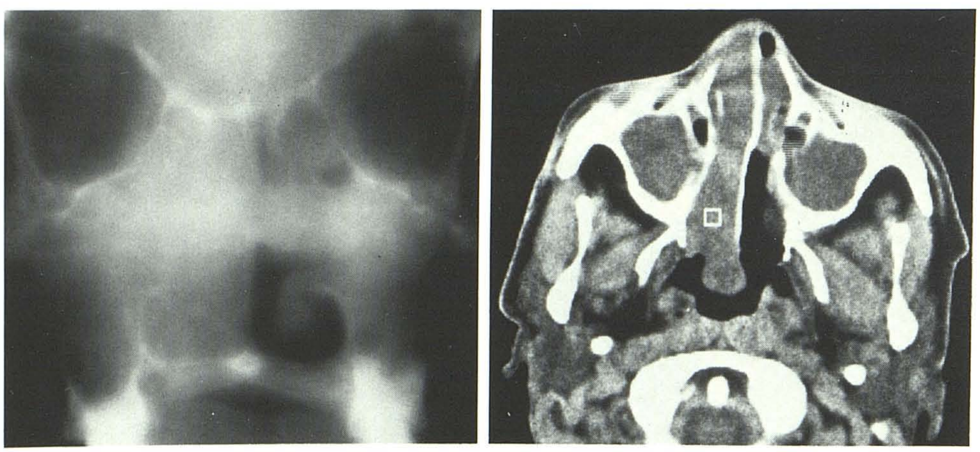
C

Fig. 5.—Sinus infection and osteomyelitis after tooth extraction. **A**, Sequential axial CT sections. Multifocal bone resorption of maxillary antrum floor and walls. **B**, Coronal reformation. Destruction of orbital floor and extension of inflammation into retroorbital fat (*arrows*). **C**, Conventional tomographic study 1 day before CT. Maxillary sinus and ethmoid opacification seen; bony involvement suggested. Orbital findings on CT actually preceded clinical development of ophthalmoplegia by 8 hr and altered surgical treatment (see text).



A B C

Fig. 6.—Dentigerous cyst in maxillary sinus. **A**, Tooth-shaped density near maxillary roof (*arrow*). **B**, Axial CT section. Cystlike structure (*arrows*) expands maxillary antrum, eroding its posterior wall. **C**, Reformation along midsagittal orbital plane shows extent of cyst to level of orbital floor. Surgery verified dentigerous cyst.



A B

Fig. 7.—Allergic polyps suggesting neoplasm; soft-tissue mass protruding out of nares. **A**, Conventional tomogram. Opacification of nasal and maxillary antral cavities; evidence of bony erosion was equivocal. **B**, Axial CT sections. Soft tissue within nose and maxillary antra extends into ethmoids. Thickening of maxillary antrum walls suggested chronic process; no bony erosion was noted. Density analysis revealed CT numbers within maxillary antrum to be 25 units less than those of nasal soft tissue, suggesting obstruction of sinuses, rather than tumor invasion. Biopsy disclosed allergic polyp.

optic nerve or inferior rectus muscle was specifically helpful. In addition, rapid evaluation of damage to vital structures, such as the globe and optic nerve, or associated brain injury is crucial and is directly obtained through the superior contrast resolution of CT. Accurate early diagnosis is vital, because delayed complications of unrecognized injury such as diplopia, mucocele, cosmetic disfigurement, and meningitis are serious and difficult to treat. Further, the complex facial skeleton requires a technique with high spatial resolution for evaluating subtle but important disruptions in its framework when plain films are equivocal.

CT offers certain advantages over pluridirectional tomography in regard to gross bone trauma and soft tissue injury. To reconstruct a three-dimensional image from conventional tomograhic cuts in two projections conceptually is difficult. Patient positioning affects interpretation of architectural derangements, since rotation may simulate structural displacement. Multiplicity of fragments in gross trauma can cause "ghost" artifacts due to superimposition of blurred images onto the plane of section leading to occasional misinterpretation of fractures with conventional tomography [7, 8].

Direct visualization of soft-tissue structures is the forte of computed tomography. In our earlier experience, one-third of patients with maxillofacial trauma had associated intracranial findings [7] that CT recognized. Of our current 14 patients with trauma, five had findings of some importance relating to the intracranial contents (hematoma, encephalocele, frontal sinus-brain communication).

Subtle facial trauma tests CT sensitivity. The ability of CT to detect orbital floor, maxillary, and ethmoid wall fractures (some missed with pluridirectional tomography) in our series shows that thin section CT shows even subtle fractures. Image reformation in planes perpendicular to that of the bone in question (e.g. orbital floor, fovea-ethmoidalis) are key to the diagnosis. Yet the technique has its limits. Thus, thin fractures in the plane being scanned may be missed when insufficient distraction exists to visualize them on axial or reformatted images. Also, patient motion detracts from image spatial resolution, especially on image reformations. Short tube-cooling intervals are needed for rapid sequence scanning and are allowed with low milliampere settings without loss of resolution in bony structures, although some loss of soft-tissue resolution occurs. Yet in none of our cases did these minor limitations affect either therapy or clinical outcome.

The savings in radiation dosage offered with CT are appreciable. A single 1.5 mm section at a 320 mA setting with a 3 sec pulse width delivers about 4 rad (0.04 Gy) at the entrance site in the patient's face (in our experience, the amperage and pulse width settings can be even lower without significant loss of bone resolution). Sections 5 mm thick with 3.0 mm spacing result in 2.0 mm of overlap. This technique doubles the speed of the study while allowing sufficient resolution on image reformation for accurate diagnosis. Even with this overlap technique, total radiation dosage to any section of the patient's face is less than 9 rad (0.09 Gy) [9]. Total examination time in our patients varied from 20 to 40 min depending on the number of sections needed to cover the region of interest, and the amperage/pulse-width selected.

In contrast, a conventional set of 4-mm-thick facial tomograms in two projections necessitates up to 15 cuts in each of the two planes. Since radiation passes through all anatomic layers of the head irrespective of which layer is in focus, a dose of about 30 rad (0.3 Gy) to the facial region can result [6]. In younger individuals, radiation considerations might be a factor in preferring computed tomography.

The usefulness of CT in facial infection and neoplasia rests mainly on its ability to delineate extent of the process into various anatomic compartments, to detect bony destruction, and to provide densitometric analysis. In all three areas, CT is uniquely valuable by virtue of its superior contrast resolution and its multiplanar viewing capability [10]. However, microscopic infiltration into surrounding tissues will still cause errors in assessment of tumor and infection extension. Also, extremely thinned bony structures may be falsely assumed to be eroded due to density averaging of adjacent soft tissues in the tomographic section, as in our mucocele patient. Further, some tumors may have areas of necrosis; thus, density measurement alone for differentiating neoplastic soft tissue from inspissated mucus within a sinus may not be dependable.

On the basis of this early experience, our current approach to the evaluation of maxillofacial disease involves CT as the first diagnostic method after plain films. Not all patients with trauma or other maxillofacial pathology need a tomographic study for thorough evaluation, but we find CT especially helpful in evaluating complex facial trauma where two or three different categories of fracture coexist. Direct visualization of inferior rectus herniation helps the thorough diagnosis and surgical approach to patients with orbital blow-out injuries as well.

Although image reformation is currently tedious, software packages that automatically reformat axial images into any chosen plane at a designated distance interval are now becoming available. This should greatly reduce the amount of computer interaction required.

We currently reserve pluridirectional tomography for such fine detail work as orbital foramen views and inner ear evaluation. It is possible that further innovations in CT technology will obviate conventional pluridirectional tomography in these applications as well.

REFERENCES

1. Parsons C, Hodson N. Computed tomography of paranasal sinus tumors. *Radiology* **1979**;132:641–645
2. Forbes WStC, Fawcitt RA, Isherwood I, et al. Computed tomography in the diagnosis of diseases of the paranasal sinuses. *Clin Radiol* **1978**;29:501–511
3. Takahashi M, Tamakawa Y, Shindo M, et al. Computed tomography of the paranasal sinuses and their adjacent structures. *Comput Tomogr* **1977**;1:295–310
4. Hesselink JR, Weber AL, New PFJ, Davis KR, Roberson GH, Taveras JM. Evaluation of mucoceles of the paranasal sinuses with computed tomography. *Radiology* **1979**;133:397–400
5. Som PM, Shugar JMA. Antral mucoceles: a new look. *J Comput Assist Tomogr* **1980**;4:484–488
6. Maue-Dickson W, Trefler M, Dickson DR. Comparison of dosimetry and image quality in computed and conventional tomography. *Radiology* **1979**;131:509–514
7. Rowe LD, Miller E, Brant-Zawadzki M. Computed tomography in maxillofacial trauma. *Laryngoscope* **1981**;91:745–757
8. Christensen EE, Curry III TS, Nunnally J. *An introduction to the physics of diagnostic radiology*. Philadelphia: Lea & Febiger, **1973**:204–205
9. Pentlow KS. Dosimetry in computed tomography. In: Newton GH, Potts DG, eds. *Radiology of the skull and brain: technical aspects of computed tomography*. St. Louis: Mosby, **1981**: 4228–4258
10. Hesselink JR, New PFJ, Davis KR, et al. Computed tomography of the paranasal sinuses and face: II. Pathological anatomy. *J Comput Assist Tomogr* **1978**;2:568–576