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CT-Guided Needle Placement in the Central Nervous System: Results in 146 Consecutive Patients

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The authors present their experiences with 185 computed tomography (CT)-guided needle placement procedures in 146 consecutive patients. There was 100% accuracy in first-pass entry into the lesion using a needle guide; 100% success in drainage of intracranial abscesses; 100% success in palliative decompression of intracranial cystic lesions including tumor cysts; and 97% accuracy in histologic diagnosis of unknown lesions. CT-guided aspiration biopsy corrected clinically incorrect diagnoses and altered patient management in 23% of all cases biopsied. Tabulation of complications revealed 0% incidence of scalp infection, bone infection, dissemination of tumor, or dissemination of infection; 13.5% incidence of clinically *in*significant postprocedural bleeding; and 0.5% incidence of serious postprocedural hemorrhage leading to death (one patient only). Transient hemipareses were observed in three of 22 procedures for implantation of ^{192}Ir but in none of 163 procedures for aspiration biopsy alone.

Computed tomography (CT)-guided needle aspiration biopsy and brachytherapy can be extremely valuable procedures when performed by a radiologist and a neurosurgeon working in close cooperation. The device (Parol, St. Louis, MO) used for guiding needle placement, the techniques for performing aspiration biopsy and ^{192}Ir implantation, and preliminary results with these techniques have been reported [1–5]. Accumulated experience now permits assessment of the efficacy of CT-guided needle placement procedures in a large series of patients.

Subjects and Methods

Definitions

For the purposes of this communication, *CT-guided needle placement* and *CT-guided aspiration biopsy* are meant to indicate any procedure in which a needle was advanced into a lesion under direct CT control [6, 7]. The terms specifically exclude procedures in which the CT data were first converted into stereotactic coordinates for needle placement with a stereotactic frame. *Clinically significant complication* refers to any new neurologic deficit (even when transient), any worsening of a preexisting deficit (even if transiently), or patient death [6].

An initial CT/clinical diagnosis was considered to be erroneous when the final postaspiration, postsurgical, or postmortem diagnosis documented a significantly different *class* of pathology (e.g., glioma versus infarction). In patients with known extracranial primary tumors and/or known extracranial metastases, an initial CT/clinical diagnosis of intracranial metastasis was considered erroneous when the final pathologic diagnosis was *primary* intracranial tumor (of any type). Similarly, an initial CT/clinical diagnosis of *multiple* intracranial metastases was considered erroneous when the final pathologic diagnosis was multicentric glioma. Because of the limitations of CT scanning, however, in patients with *no known* extracranial primary tumor, the initial CT/clinical diagnoses were *not* considered to be erroneous when: (1) a single intracranial lesion diagnosed as "metastasis" proved to be a glioma; (2) a single intracranial lesion diagnosed as "glioma" proved to be a metastasis; or (3) a lesion diagnosed as "intracranial mass," "intracranial neoplasm," or "ring-enhancing tumor" proved to be either a

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glioma or a metastasis. Similarly, the initial CT/clinical diagnoses were *not* considered erroneous when a diagnosis of "glioma of grade X" proved to be a glioma of a different grade, or a diagnosis of "cystic tumor" proved to be a solid tumor [8, 9].

Patient Base and Biopsy Technique

The basis for the present report is a total of 185 CT-guided needle placement procedures performed in 146 consecutive patients by 14 different neurosurgical/radiologic teams at seven institutions. Indications for performing CT-guided needle placement procedures included possible abscess, probable primary tumor at a surgically inaccessible site, probable unresectable primary tumor, possible cerebral metastases, lesions of unknown nature, palliative decompression of cystic lesions, and intratumoral implantation of ^{192}Ir for brachytherapy. Of the 146 patients, 128 underwent CT-guided aspiration biopsy without brachytherapy, 15 underwent both CT-guided aspiration biopsy and ^{192}Ir implantation for brachytherapy, and three underwent only ^{192}Ir brachytherapy for tumors of known histology. Overall, 143 patients underwent 163 aspiration procedures and 18 patients underwent 22 ^{192}Ir implantation.

The 146 patients ranged in age from 8 months to 87 years (mean age, 58 years). Eleven (8%) patients younger than 17 years were designated pediatric patients. Eighty-two (56%) patients were male; 64 (44%) patients were female.

Biopsy Technique

The initial 10 procedures were performed "freehand" from November 29, 1976, to October 25, 1978, and reported previously [2]. The other 175 procedures were performed through a needle stabilization frame [3] from January 26, 1979, through November 26, 1983. The CT scanners used were the EMI-5005, Technicare 2020, and General Electric 8800 and 9800 scanners.

Patients selected for CT-guided needle placement procedures were first studied by routine CT to establish the presence, location, and probable nature of the pathology (fig. 1). Angiography was performed in those patients (46%) in whom: (1) the initial CT scan demonstrated intense enhancement of the lesion, (2) likely differential diagnoses included aneurysm or occult (ruptured) arteriovenous malformation (AVM), or (3) an attempt to characterize a lesion by its angioarchitecture was judged beneficial. Angiography was not performed routinely simply to assess lesion vascularity or to map the positions of surface and deep vessels. Corticosteroids and anticonvulsants were used only when indicated for controlling intracranial pressure and known seizure disorders. Antibiotics, anticonvulsants, and corticosteroids were not administered routinely for "prophylaxis."

In our series, half the adult patients were sedated and biopsied under local anesthesia alone. The rest required general anesthesia for inability to cooperate; need to maintain uncomfortable positions during long periods; or, rarely, medical indications. Six of 13 procedures in 11 pediatric patients were performed using sedation and local anesthesia; seven were performed under general anesthesia.

In practice, the aspiration procedure was performed as follows: The aluminum torus of the needle stabilization frame was mounted to the patient platter by a support base individualized for each different CT scanner [3] (fig. 2). The three lower support pads and two upper tension pads formed a five-point head clamp that immobilized the patient's head satisfactorily without need for calvarial impalement. The premedicated patient was brought into the scan suite, and general anesthesia was induced in those selected for this anesthesia. The head was shaved over the region of interest. In those patients whose lesions were best seen on the initial *contrast-enhanced* CT scan, contrast material was again administered intravenously at this time to help visualize the lesion during the subsequent needle placement procedure. The patient was placed in the needle stabilization frame with the head turned to bring the expected position of the lesion uppermost to facilitate passing the needle along the shortest safe trajectory from scalp to lesion (fig. 3). Such trajectory was carefully designed to avoid trauma to functional cortex and major vessels. The field was then prepared and draped, following which a sterile radiolucent Plexiglas needle holder and drill guide core [3] were inserted into the biopsy frame and positioned over the expected locus of the lesion (figs. 4 and 5A). CT scans were then obtained directly through the bore of the guide core to determine the precise position of the lesion under the guide core. Minor adjustments were made, as necessary, to bring the precise part of the lesion to be biopsied or the cyst to be drained directly under the guide core (fig. 4). The linear artifact resulting from the air-filled lumen of the guide core depicted the needle trajectory. Once the needle holder and guide

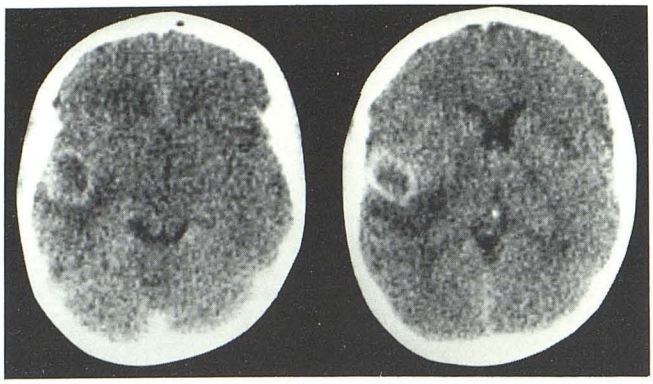


Fig. 1.—Brain abscess in 17-year-old man with known tricuspid atresia, atrial septal defect, and prior palliative Glenn and modified Pott procedures who was seen with left frontotemporal headache, episodic right facial and right arm numbness, and lethargy. Contrast-enhanced CT reveals superficial left superior temporal gyrus ring blush with thinner deep wall, subjacent edema, and mild mass effect, consistent with abscess.

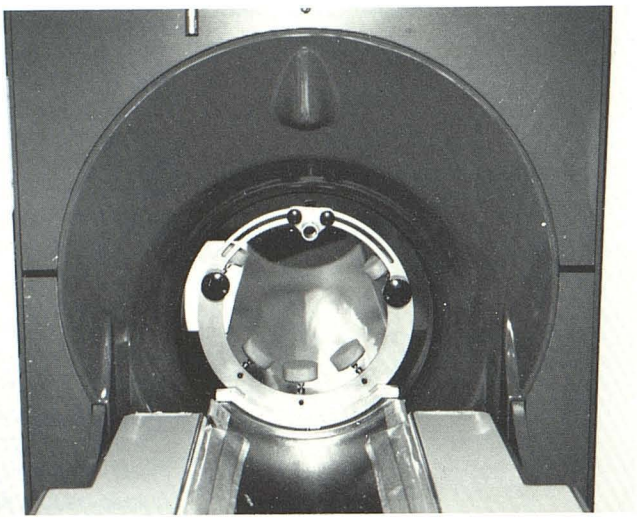


Fig. 2.—Biopsy device [3] mounted to patient platter by support base. Three lower support pads are adjusted to receive patient's head.

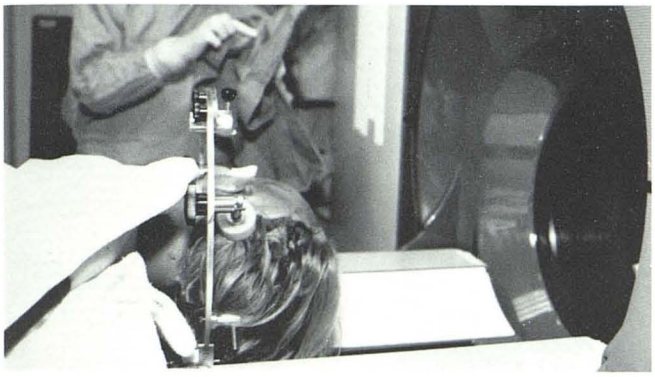


Fig. 3.—Patient's shaved head is immobilized by upper tension pads in proper position to facilitate true-vertical trajectory for aspiration of temporal lesion. Prepared field is about to be draped.

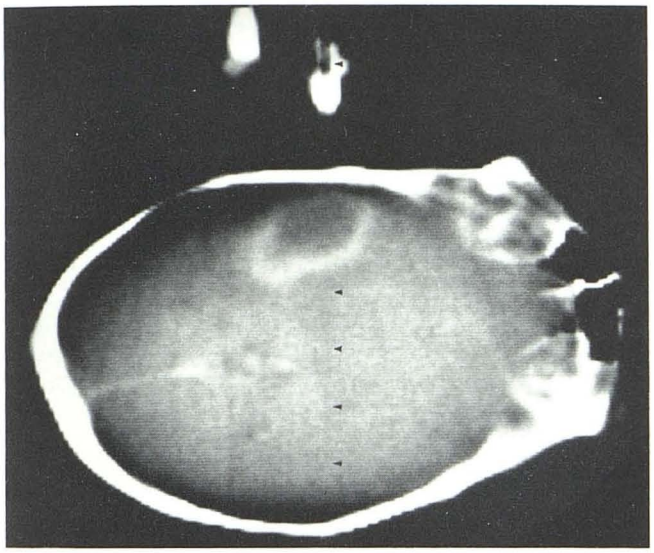


Fig. 4.—Intraprocedural control CT scan obtained directly through bore of needle guide (*top arrowhead*) documents that guide is positioned directly over lesion. Intraprocedural scans are regarded as working "blueprints" rather than as diagnostic images. Their quality is necessarily degraded because they are obtained through sterile field, which prevents proper bolusing, and patient is positioned eccentrically at bottom of scan field to permit insertion of long biopsy needle. Needle trajectory, barely visible (*lower arrowheads*) at wide window illustrated here, is readily visible at narrower windows obtained by simple manipulation of viewer controls.

core were properly positioned, the trajectory of the needle was fixed and the biopsy needle was constrained to pass directly into the lesion. The scalp beneath the guide core was then incised and the outer periosteum displaced with periosteal elevators.

Craniotomy was performed in one of two ways. In some patients, the calvarium was breeched with a hand-held twist drill positioned through the drill guide core to ensure precise placement of the narrow bone defect (fig. 5A). In most patients, however, a gas-powered craniotome was used instead of the hand-held twist drill, because early experience indicated that the craniotome did not rock the head and was less likely to disturb the alignment between lesion and needle guide. The drill was then removed and a repeat CT scan was obtained directly through the bore of the guide core to ensure that the core remained properly positioned.

Large bore (12- and 14-gauge) biopsy needles were selected to permit aspiration of thick pus and of true tissue cores suitable for histologic diagnosis rather than cytology. The biopsy needles used consisted of an inner aspiration cannula and an outer sheath that provided a conduit through which the aspiration needle could be advanced into the lesion repeatedly, as desired, without additional trauma to the intervening brain. This sheath is believed to reduce the likelihood of complications. The needle selected was placed into the guide core and advanced downward through the brain into the lesion (figs. 5B and 6). Intraprocedural control CT scans were obtained as the needle was advanced to document the exact position of the needle tip and the number of millimeters the needle had to be advanced to enter the cavity or to reach the precise point previously selected for biopsy. As experience increased, fewer and fewer control scans were required during the needle advance.

We found it highly advisable to obtain a CT scan through the needle *immediately before* actual aspiration to document the precise point from which the biopsy was obtained before partial lesion collapse distorted the image. Documentation of precise locus of biopsy offered some security in interpreting the significance of histologic diagnoses of "nonspecific inflammation," "necrosis," "edematous cerebellum," etc.

Firm aspiration through the inner needle with a 3-ml syringe and simultaneous withdrawal of the inner needle then yielded pus from an abscess or a core of tissue from brain and lesion. When pus was aspirated, the material was smeared on previously prepared, sterile glass slides for Gram stain and placed in aerobic, anaerobic, and specialized culture media to attempt salvage of especially fastidious organisms. When the material aspirated was a solid core, bisecting the core longitudinally and sending one-half for frozen section analysis ensured adequacy of the lesion sample and obviated repeat procedures. When the biopsy needle used had an open bore, the initial aspiration often yielded only the brain that entered the needle during the initial passage toward the lesion. Reinsertion of the needle through the sheath and second aspiration then yielded a true core of lesion tissue suitable for histologic diagnosis. At times, it was necessary to perform repeated aspiration of different parts of the lesion (through one or several drill holes) until frozen section documented that sufficient tissue had been obtained for pathologic diagnosis.

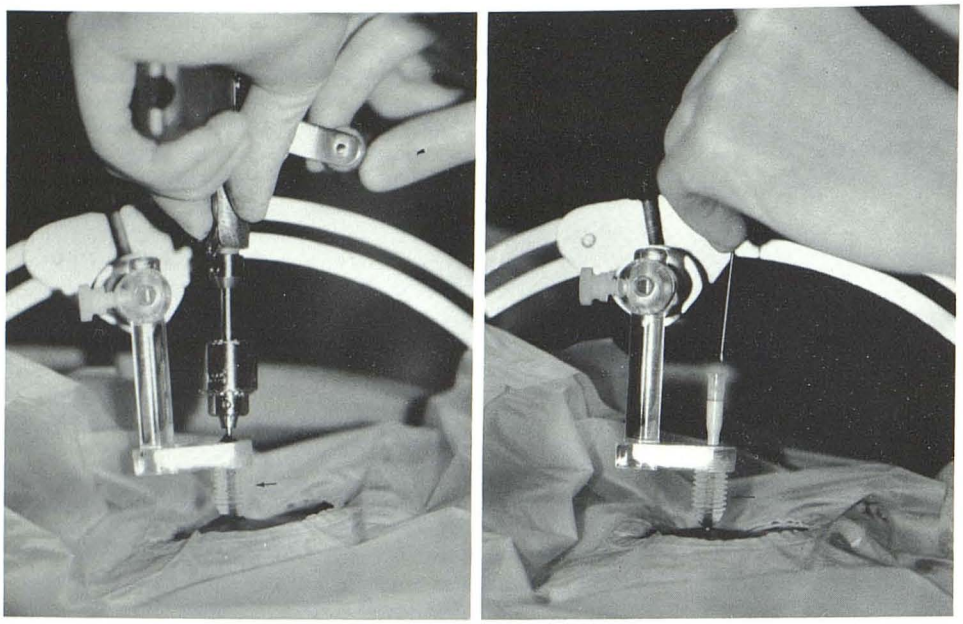
On termination of the procedure, the inner needle and outer sheath were withdrawn together, and a small bandage was applied to the scalp incision. In all cases, an immediate, postprocedure, complete CT scan was obtained to document immediate hemorrhage or other complication of the procedure.

Procedure time for CT-guided biopsy and cyst drainage averaged 60 min for both supratentorial and infratentorial lesions, including time for administration of anesthesia, patient positioning, preparation of the scalp, biopsy procedure, and return of frozen-section diagnosis. Iridium-192 implantation procedures required 2–3 hr depending on their complexity.

Results

In the 143 patients undergoing CT-guided aspiration biopsy, lesion location was superficial supratentorial in 106 patients; deep supratentorial (basal ganglial, corpus callosal) in 28; intraventricular in one; pineal region in one; cerebellar in five; cerebellopontine angle in one; and spinal cord in one. No opportunity to biopsy a brainstem lesion has yet arisen.

The lesions aspirated were 1–10 cm in diameter. As most lesions detected by CT are several centimeters in diameter,



A B

Fig. 5.—**A**, Placing bit of twist drill or craniotome through drill guide core (*arrow*) ensures precise placement of narrow hole. **B**, Biopsy needle is then placed into craniotomy through needle guide core (*arrow*) and is advanced downward through brain into lesion in serial stages monitored by intraprocedural control CT scans.

most in this series were of that size. The technique used permits accurate needle placement to within 5 ml, but has not been used for functional or vascular stereotactic surgery.

The final pathologic diagnoses were astrocytoma, grades I and II (13); astrocytoma, grades III and IV (including one mixed glioma) (65); primary lymphoma (three); neurilemoma (one); metastatic tumor including one frontal medulloblastoma (36); abscess (11); herpes encephalitis (one); hemorrhage (including two subdural collections) (seven); infarction (two); choroid plexus AVM (one); cyst (two); and normal (one).

Accuracy of needle placement was assessed in the 175 consecutive procedures performed using the needle guide (excluding the 10 procedures performed freehand) [2]. Using the needle guide [3] and technique described [1], 14 different neurosurgeons were able to advance the biopsy needle precisely into the preselected target site *on the first pass* in *100%* of 175 consecutive aspiration procedures. With the needle guide used, accuracy of needle placement proved to be independent of lesion size and lesion location.

Success rates for lesion diagnosis, success rates for lesion drainage, and complication rates for the needle placement procedures were assessed in the full series of 185 procedures, including the 10 procedures performed freehand [2]. CT-guided aspiration biopsy achieved accurate histologic diagnoses in 97% of the 143 patients biopsied (table 1). There were four errors. In one patient, aspiration of the central cavity of the lesion provided a correct but unhelpful diagnosis of necrotic debris. In the second patient, attempted aspiration of the rim of a posterior fossa ring blush resulted in a "diagnosis" of edematous cerebellum. In the third patient, initial CT-guided aspiration biopsy diagnosis of "primary tumor" was proven erroneous when later craniotomy revealed poorly differentiated metastatic adenocarcinoma. In the fourth patient, repeated CT-guided aspirations failed to obtain either tissue or fluid from within a lesion later proved to be a choroid plexus AVM. In this case, prior arteriography had shown no hypervascularity. No hemorrhage followed the biopsy procedure. In all other patients, CT-guided aspiration biopsy provided tissue suitable for correct histologic diagnosis. In none of those patients has the CT-guided biopsy been proved inaccurate by later surgery or necropsy.

CT-guided aspiration biopsy achieved reduction of intracranial mass in 52 (95%) of 55 procedures performed for decompression of "cystic" intracranial masses (excluding abscess). All truly cystic lesions were aspirated successfully (100%), whether they were subdural collections, parenchymal hemorrhages, or tumor cysts. However, three lesions believed to be cystic prior to biopsy proved to be solid lesions instead, and could not be aspirated. Two were microcystic gliomas, while the third lesion, presumed to be an ependymal cyst obstructing the frontal horn, later proved to be the AVM of the choroid plexus. In three (5%) patients in this group, dense hemipareses cleared completely within minutes of the aspiration procedure. In 20 (36%) additional patients in this group, CT-guided decompression achieved clinically significant reduction of prior neurologic defects. In the other patients, reduction of intracranial mass effect by drainage did not achieve significant reduction in symptomatology.

In 11 patients with 13 abscesses to be drained, CT-guided needle aspiration achieved successful decompression of all 13 (100%) abscesses, whether the abscesses were unilocular or multilocular. Multiloculation was readily identifiable as failure of one or several parts of the abscess to collapse during drainage and was treated simply at the same session by serial puncture of each locule until the entire space was emptied. Only one abscess required subsequent craniotomy (for removal of associated foreign body, not for abscess drainage). The other abscesses were cured by initial drainage and subsequent antibiotic therapy guided by the Gram stain, bacterial culture, and antibiotic sensitivity studies of the ma-

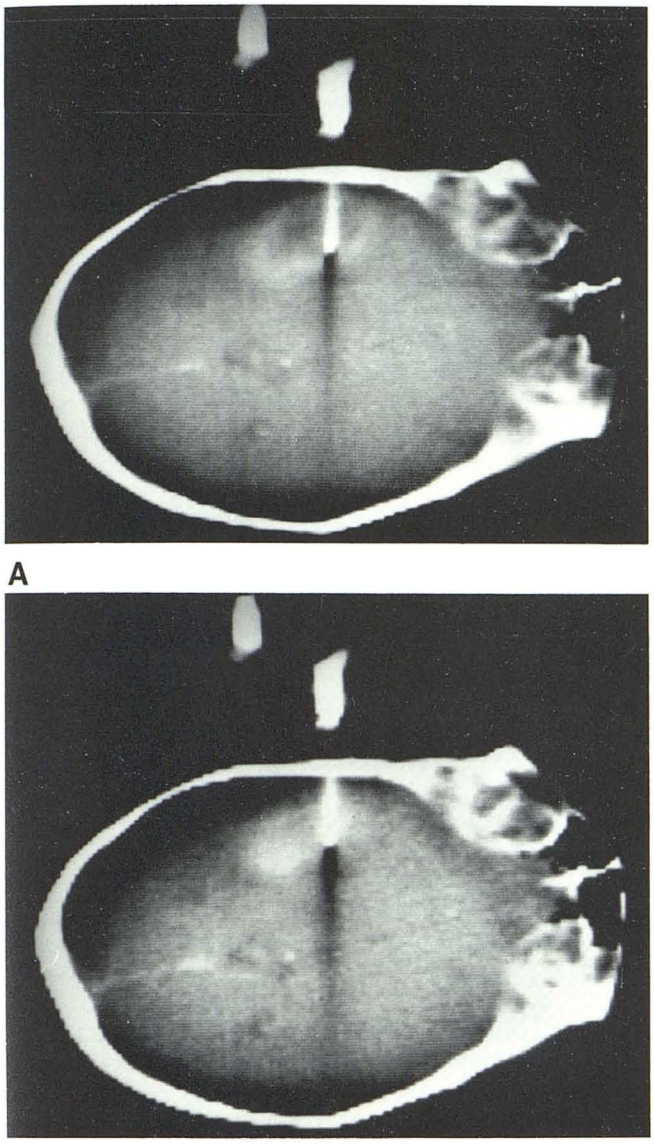


Fig. 6.—**A**, Intraprocedural control CT scan discloses aspiration needle at bottom of abscess cavity in proper position for beginning aspiration. Linear artifact of needle depicts trajectory of needle more strongly than does air column of empty guide core. One may deliberately place needle in guide core and scan through it *before* advancing into brain to "triple-check" needle trajectory before puncture. **B**, Toward end of aspiration, abscess walls collapse around needle, and needle may have to be withdrawn slightly to ensure complete drainage.

terial obtained at the CT-guided aspiration procedure (figs. 1–7). Three of the 11 patients with abscesses were neurologically intact. In six patients, CT-guided abscess drainage cured the neurologic deficits or returned the patients to their prior neurologic status. CT-guided abscess drainage effected no clinical improvement in two patients, one with severe concurrent neuropathology and the second with dense hemiparesis and aphasia from a large unilocular abscess in the centrum semiovale.

Comparison between the initial prebiopsy diagnoses and the subsequent, histologically proved diagnoses is given in table 2. These data document that even strongly held clinical

TABLE 1: **Results of CT-Guided Aspiration Biopsy**

Biopsy Finding	No. of Patients Biopsied	No. of Accurate Diagnoses
Astrocytoma, grades I and II	13	13
Astrocytoma, grades III and IV (including one mixed glioma)	65	64*
Primary lymphoma	3	3
Neurilemoma	1	1
Metastases	36	34†
Abscess	11	11
Herpes encephalitis	1	1
Hemorrhage (parenchymal and subdural)	7	7
Infarction	2	2
Cyst	3	2‡
Normal	1	1
Total	143	139

Note.—Three of the 146 patients in this series underwent CT-guided ^{192}Ir implantation without CT-guided biopsy.

* In one patient, only necrotic material was aspirated from the central cavity of the lesion.

† In one patient, attempt to biopsy the rim of a posterior fossa ring blush led to a diagnosis of "edematous cerebellum." In a second, CT-guided biopsy was interpreted as "primary tumor," but later surgery documented a poorly differentiated metastatic adenocarcinoma.

‡ In one patient, a presumed "ependymal cyst" obstructing the frontal horn could not be collapsed by aspiration. Later surgery revealed an AVM of the choroid plexus of the lateral ventricle.

diagnoses, supported by sophisticated neuroradiology, proved *in*correct in 23% of cases. The exact error rate depends largely on the precise definitions of erroneous diagnosis given in Subjects and Methods. Even by the conservative definitions used, however, in 33 of the 143 patients studied, CT-guided aspiration biopsy altered the incorrect clinical diagnosis and thereby improved the management of the patient. Ten patients believed to have nonneoplastic pathology proved to have primary tumors (five) or metastases (five). Six patients believed to have malignancies proved to have benign disease [9]: infarction (two), hemorrhage (two), abscess (one), benign tumor (one). Twelve patients believed to have metastases proved instead to have primary tumors, seven of them multicentric gliomas, one multifocal intracerebral lymphoma, and four single intracranial gliomas. Surprisingly, the incidence of incorrect clinical diagnoses has held steady at 20%–25% of all cases throughout the entire study period and has *not* decreased with time.

Four clinically significant and 26 clinically *in*significant complications were encountered in the entire series of 185 procedures. Contrary to some expectations, there has been no instance of scalp, calvarial, or intracranial infection (0%) and no instance of dissemination of infection or tumor as a result of the procedure (0%). Postprocedure cerebrospinal fluid (CSF) leakage did not occur in any patient undergoing aspiration biopsy or lesion drainage alone, but did occur in several patients in whom multiple punctures at different sites were required for brachytherapy. The incidences of swelling, hemorrhage, and neurologic deficit are best analyzed for biopsy and brachytherapy separately.

Complications of CT-Guided Aspiration Biopsy

In the 128 patients undergoing CT-guided aspiration biopsy without brachytherapy, biopsy-induced cerebral swelling was

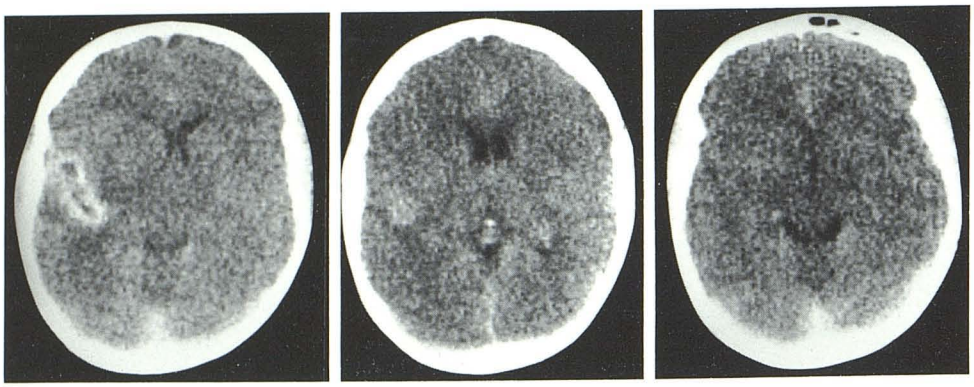


Fig. 7.—Serial contrast-enhanced CT scans document complete regression of aspirated abscess. **A**, 1 day after procedure. Abscess walls are nearly collapsed. **B**, 7 weeks after procedure. CT documents reduction of abscess, perifocal edema, and mass effect. **C**, 14 weeks after procedure. Abscess has disappeared completely. Patient suffered no complications or even unpleasantness associated with procedure and was discharged 21 days after procedure on antibiotic therapy determined from Gram stain and cultures of aspirated material.

TABLE 2: **Correction of Erroneous CT/Clinical Diagnoses**

Initial CT/Clinical Diagnosis: Final (Postaspiration) Diagnosis	No. Cases
Metastases:	
Primary tumor	12*
Metastases of different histology	1
Hemmorhage	1
Exophytic brainstem glioma:	
Cerebellopontine angle neurilemoma	1
Neoplasm:	
Hemorrhage	1
Infarction	2
Abscess	1
Abscess:	
Primary tumor	2
Metastasis	2
Cyst	1
Encephalitis:	
Primary tumor	1
Normal	1
Sarcoid:	
Metastasis	1
Ischemia:	
Primary tumor	2
Hematoma:	
Metastasis	2
Hematoma and abscess	1
Ependymal cyst:	
Choroid plexus AVM	1
Total	33

Note.—Diagnoses were altered in 33 (23%) of the 143 patients. AVM = arteriovenous malformation.

* Of the 12, seven had multicentric glioma; one, primary intracerebral lymphoma; three, primary glioma with known extracranial primary tumor; and one, primary glioma with extracranial primary tumor and disseminated extracranial metastases.

TABLE 3: **Nature of Postaspiration Hemorrhage in 185 CT-Guided Needle Placement Procedures**

Procedure: Extent and Location of Hemorrhage	No. Occurrences	(% by Procedure)
Aspiration biopsy (n = 163):		
Minimal intraventricular	2	1.2
Modest intraventricular	1	0.6
Minimal subarachnoid	1	0.6
Modest parenchymal	1	0.6
Minimal–modest intracavitary:		
Within an abscess	2	1.2
Within a cystic tumor	5	3.1
Within solid tumor	9	5.5
Subtotal	21	12.9
^{192}Ir brachytherapy (n = 22):		
Modest intraventricular	1*	4.5
Within solid tumor	4*	18.2
Subtotal	5	22.7
Total	26	14.1

* One patient with hemorrhage in two locations is counted twice.

a transient, clinically *in*significant CT observation in one patient only (0.6% of procedures). Biopsy-induced hemorrhage at varying sites and of varying severity was observed in 12.9% of procedures (table 3). The hemorrhage was clinically significant in only one case.

In this one patient with a hypervascular glioblastoma multiforme, delayed postprocedural hemorrhage increased intracranial mass effect. CT immediately after biopsy disclosed no hemorrhage. After 20 min, the patient became decerebrate. Despite immediate surgical decompression of an intratumoral hemorrhage, the patient failed to recover and ultimately succumbed 2 weeks after biopsy. This is the sole mortality in the entire series of patients (0.5% of 185 procedures).

CT-Guided ^{192}Ir Implantation

In the 18 patients undergoing brachytherapy (with or without aspiration biopsy), as many as 38 iridium-containing catheters were inserted into the tumor in a single session. Postprocedural hemorrhage was observed in five (23%) of 22 procedures. Two of the hemorrhages caused increased mass effect on CT, but none of the five was clinically significant.

Clinically significant but transient hemipareses were observed in three patients undergoing brachytherapy. None had bled. In two patients, the hemipareses were exacerbations of prior deficits. In one patient, the hemiparesis was new. Each patient improved to preprocedural status within 2 weeks.

Discussion

Our study proves that rapid and accurate histologic diagnosis, cyst decompression, and abscess drainage may be

performed safely in a busy radiology CT suite with relatively simple, inexpensive equipment [1–3]. With routine precautions, the theoretic hazards of local infection, dissemination of tumor or infection, and CSF leakage are not practical problems in the performance of the procedure. No clinically significant complication was encountered in 162 (99.4%) of 163 procedures performed for aspiration biopsy alone. The transient hemipareses encountered during ^{192}Ir implantation all cleared spontaneously.

The high incidence of clinically *in*significant hemorrhage in this series reflects the use of cutting needles for biopsy (principally Angiocath [Desert Pharmaceutical, Sandy, UT]) and the diligence with which complete CT scans were obtained immediately after the procedure [6]. Since these patients have no new symptoms or signs that require CT scanning, and since we have seen many small hemorrhages "disappear" in one to several days after the biopsy procedure, it is probable that many such postprocedural hemorhages escape detection in other series.

In our opinion, there is no absolute contraindication to biopsying hypervascular lesions. We have now placed aspiration needles into several hypervascular lesions, including one choroid plexus AVM, without inducing lesion hemorrhage. One patient who died several days after biopsy of a hypervascular glioblastoma multiforme manifested no hemorrhage within the lesion or along the needle track at necropsy.

In very careful analysis, Greenblatt et al. [6] reviewed the rate of serious complications associated with CT-guided needle placement procedures. The combined data from our series, from Greenblatt et al., and from others [1–3, 7, 10–15], excluding Feild et al. [16], demonstrate that CT-guided needle placement is associated with clinically significant complications in 4.7% of cases (13 of 276 procedures). It is associated with patient mortality in 1.1% of cases (three of 276 procedures). This death rate is comparable to the 2.3% mortality for true stereotactic biopsy reported by Ostertag et al. [17] (seven of 302 procedures). The risk of serious, even fatal complication in a few patients must then be balanced against the benefit of reducing patient morbidity and achieving correct histologic diagnosis in the larger number of patients.

The extremely high yield of sufficient tissue for positive diagnosis (97%) is an advantage of this method. We believe this success is due to use of 12- and 14-gauge Angiocath needles for aspiration biopsy and frozen-section analysis of part of the biopsy specimen. The large-bore, sharp (cutting) needles deliver a core of tissue suitable for actual histologic preparation rather than scattered cells suitable only for cytologic evaluation. Since most pathologists are more familiar and comfortable with histologic material, they are able to render correct diagnosis in a far higher percentage of cases. The use of frozen-section analysis of tumor samples documents the adequacy of the tissue sample obtained, obviating repeat biopsy procedures (necessary very early in the series).

The strongly held, clinical diagnoses subsequently proved erroneous were based largely on prebiopsy CT scans interpreted by experienced neuroradiologists and on the patients' known clinical histories. We have attempted to minimize the "error rate" by using conservative definitions of error. Several criticisms may still be raised: The error rate is probably inflated by the inevitable bias in selecting cases for biopsy. Unusual clinical suspicion prompted biopsy of the two "infarctions" included in this series, and indeed, both "infarctions" proved to be primary gliomas. However, the cause for increased concern in one case was the known extracranial primary tumor and risk of metastasis, not glioma. The error rate could also be inflated by poor quality of initial CT/clinical diagnoses, inaccurate biopsies, and incorrect interpretation of the biopsy specimens. In any given case, it is possible that another team might have appreciated the correct diagnosis we failed to see. On average, however, we believe our expertise, patient care, and case material are likely representative of those throughout the medical community. The sites to be biopsied were carefully selected before the procedure. The precise points of biopsy were confirmed by intraoperative CT at the moment of biopsy. The adequacy of tissue was checked by frozen section before withdrawing the biopsy sheath, and the pathologic diagnoses obtained by aspiration biopsy have not been contravened by subsequent clinical events in any patients (except the two specifically cited as diagnostic errors in table 1). The error rate we report, then, is likely representative of the error rate experienced in comparable institutions elsewhere.

The high error rate (23%) documents the poor ability of CT to distinguish accurately among similar-appearing lesions of different histologies. The constancy of this high error rate throughout the study and the lack of improvement with increasing experience suggests that the error rate may reflect intrinsic limitations of the modality. In our opinion, it is inadvisable to depend solely on CT confirmation of clinical expectations for guiding patient management. Rather, proper management and, indeed, development of improved tumor treatment protocols must depend on precise proof of lesion histology. CT-guided aspiration biopsy is one good method for obtaining such histologic proof.

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