Image-guided frameless stereotactic biopsy without intraoperative neuropathological examination

Clinical article

DAVID SHOOMAN, M.B.Ch.B.,1 ANTONIO BELLI, M.D.,2 AND PAUL L. GRUNDY, B.M. (Hons), M.D.1

1Department of Neurosurgery, Wessex Neurological Centre, Southampton General Hospital, Southampton, Hampshire; and 2Division of Clinical Neurosciences, University of Southampton, Southampton, United Kingdom

Object. Stereotactic biopsy is a safe and effective technique for the diagnosis of brain tumors. The use of intraoperative neuropathological examination has been routinely advocated to increase diagnostic yield, but the procedure lengthens surgical time, may produce false-negative and -positive results, and current biopsy techniques have a very low nondiagnostic rate. Therefore, the authors questioned the need for intraoperative histological evaluation.

Methods. The authors prospectively studied all patients undergoing image-guided biopsy under the care of a single surgeon (P.L.G.) between July 2005 and October 2007. A Stryker neuronavigation system with a trajectory guide was used to plan a single trajectory, and, using a side-cutting biopsy cannula, multiple biopsy samples were taken from between 1 and 4 sites within the tumor. Tissue was inspected macroscopically by the surgeon and was only submitted for neuropathological assessment postoperatively.

Results. One hundred thirty-four biopsies were performed during the study. A positive diagnosis was established in 133 cases (99.3%). One biopsy was negative (0.7%) and postoperative imaging (performed because the tissue was macroscopically normal) demonstrated inaccurate targeting of the lesion. Significant complications were seen in 3 patients (2.2%) who all had preoperative WHO performance scores of III or IV. Two patients suffered delayed deterioration and died due to probable surgical complications—one with thalamic glioblastoma multiforme (GBM) and one with gliomatosis cerebri. One patient with GBM suffered an intracerebral hematoma that was managed conservatively. Postoperative seizures were seen in 4 patients (3%), and 2 patients (1.5%) experienced a transient neurological deficit. Histological diagnosis showed a GBM in 64 cases, Grade III glioma in 19, Grade I or II in 23, metastasis in 10, lymphoma in 13, and other disease in 4. There were 32 patients discharged to home on the same day as surgery. Compared with the authors’ previous retrospective audit into 127 biopsies, this technique showed improved diagnostic yield (99.3 vs 94.5%, p = 0.032) with fewer complications (2.2 vs 4.7% [not statistically significant]).

Conclusions. This technique of image-guided biopsy has high diagnostic yield with acceptably low morbidity and may be performed as a day case. Intraoperative neuropathological examination would not have increased the diagnostic yield further in this study, and its routine use may not be necessary. In the authors’ department £70,350 (UK)/$114,522 (US) would have been saved by not using intraoperative neuropathology in this series. Therefore, intraoperative neuropathology should no longer be routinely recommended. (DOI: 10.3171/2009.12.JNS09573)

Key Words • stereotactic biopsy • intraoperative neuropathological examination • ambulatory day-case surgery • multiple specimens • brain tumor

Histological diagnosis is desirable for the management of a suspected brain tumor and can be achieved through either biopsy or resection. In our department, each case is considered individually and the surgeon carries out the procedure that is most appropriate for that particular patient after discussion at a neurooncology multidisciplinary team meeting. Complete resection is ideal when possible, but biopsy may be the only option for certain deep-seated tumors (thalamic, callosal, or brainstem), lesions involving some eloquent areas, diffuse lesions (multilobe or multifocal), and may be preferred for the elderly and those with a poor performance status (Karnofsky Performance Scale score < 70).26

Stereotactic brain biopsy is considered a low risk procedure. In a 1998 retrospective meta-analysis Hall25 found...
Image-guided frameless stereotactic biopsy

reported a morbidity rate of approximately 3.5% and a mortality rate of less than 1%; and the procedure can be carried out as a day case. Frameless computer-based neuronavigation is now widely used in brain tumor surgery, has many advantages over frame-based techniques, and provides similar accuracy to the rigid frame. Advantages of image-guided stereotaxy are related to its reduced invasiveness, better tolerance by the patient, and accurate diagnosis. Goldstein et al. have confirmed that stereotactic frames are uncomfortable for patients, may impede intraoperative neurological evaluation, and that the entire procedure is time consuming and costly. Contemporary studies also confirm our assessment of a high safety profile for frameless techniques. Therefore, this approach is becoming favored among many practitioners and is now the preferred technique at our institution.

Until this series, our unit had been using a combination of frame-based CT-guided and ultrasound-guided biopsy procedures, both which were usually performed with general anesthesia. Typically, large supratentorial lesions were sampled using the ultrasound technique, whereas smaller deep-seated lesions and those in the posterior fossa were sampled using the CT-guided procedure. Frozen-section examination was performed in the majority of these cases in line with previous studies attesting to a statistically significant increase in diagnostic yield.

Indeed, intraoperative sampling is an established technique for the management of intracranial lesions. The precedent is based on the belief that a fast and reliable intraoperative tissue diagnosis will supply the neurosurgeon with important information that may affect intraoperative decisions. There is further argument for its role in verifying adequately sampled tissue in stereotactic biopsies of brain tumors. Most studies point to the high diagnostic yield as a confirmation of its utility. Martinez et al. showed that using intraoperative neurocytology and frozen sections increased their diagnostic accuracy from 88 to 95%.

However, despite its establishment as standard practice for many surgeons, our experiences have led us to question the utility of intraoperative neuropathological assessment. We have observed that intraoperative neuropathology rarely, if ever, influenced the procedures that were being performed, and diagnostic yields were invariably high. Furthermore, false-positive results left open the possibility that the biopsy might be ceased prematurely despite an ultimately negative sample. Hence, an operation may have been concluded with insufficient sampling for an accurate diagnosis and the consequence could be a negative or underdiagnosed tumor.

In addition, unless the pathologist scrutinizes all parts of every sample taken, false-negative results become another concern. A false-negative result may necessitate continuation of an ultimately fruitless procedure despite the acquisition of already ample material. Moreover, in cases in which the negative diagnosis is due to a targeting error, the intraoperative negative pathology may prolong sampling of normal tissue with all its morbid complications.

It is our view that if an intraoperative sample came back as nondiagnostic yet the navigation system suggested the tumor had been accurately targeted, it is most likely that an error has occurred. The safest step would then be to abandon the procedure and repeat the process as required rather than continue with further, futile sampling. An intraoperative diagnosis would have little effect on these decisions and be detrimental to the time taken and cost of the procedure.

Finally, making the most productive use of limited resources such as operating room time is paramount. The appropriate use of “awake” procedures, without the need for intraprocedural neuropathological assessment, shortens total operative time, improves efficiency, and yields significant cost savings. Therefore, these established practices required reevaluation.

Methods

Data were prospectively collected for all consecutive patients referred for diagnostic biopsy in cases involving an intraaxial brain lesion between July 2005 and October 2007. All cases were first discussed in a neurooncology multidisciplinary team meeting to determine further management in accordance with National Institute for Clinical Excellence guidelines. Cases referred for discussion were usually those considered to be suspiciously oncological in nature. A biopsy was advised when a lesion was considered unresectable or if craniotomy presented too great a risk. A biopsy was never undertaken if there was the possibility of craniotomy and resection.

Preoperative navigation imaging consisted of T1-weighted Gd-enhanced MR imaging for lesions that exhibited enhancement, with the inclusion of T2-weighted sequences for those lesions that were difficult to define on the former. Computed tomography scanning was conducted in cases of large, clearly identifiable lesions for which MR imaging would have provided no additional topographical information. The target site, entry point, and trajectory were planned on the workstation in prior surgery.

Initially, operations were performed after induction of general anesthesia. However, we subsequently changed to using a local anesthetic with intravenous sedation because this was found to be well tolerated and time efficient. Patients were placed in a Mayfield 3-pin head fixator and registered to the navigation system with fiducial or anatomical landmarks and surface matching. The incision site was located and infiltrated with local anesthetic, a short linear incision made, and a small bur hole was placed with a high-speed drill. A modified trajectory guide attached to a Yaşargil Leyla retractor arm (Codman GmbH) (Fig. 1) was then used, and once the trajectory was established, it was locked. The depth of the biopsy was shown on the navigation equipment and the side-cutting cannula was placed to this measure through the trajectory guide. This system did not allow “real-time” navigation of needle to biopsy site. Four quadrant biopsy samples were routinely taken from the first, and deepest, site. The needle was then serially withdrawn during a single trajectory and samples were procured at between 1 and 3 further sites. Cystic lesions were biopsied by place-
ment of the cannula centrally with full aspiration of the sac to allow samples to be taken from the collapsed cyst wall. In the case of peripherally enhancing and centrally necrotic lesions, samples were taken first from the center and then the superficial, enhancing peripheral portion on withdrawal.

In the event of significant hemorrhage from the biopsy needle, the cannula was left in situ and irrigated gently and intermittently until the bleeding arrested. If we believed that sufficient abnormal tissue had been sampled, the procedure was stopped. Otherwise, specimens were derived from a separate site along the same trajectory path. The needle was never withdrawn and then reinserted tangentially. The senior author (P.L.G.) performed or supervised each procedure and inspected every sample. After the wound was closed, tissue was submitted to neuropathology for postoperative histological evaluation and the patient was transferred to the recovery area. For patients undergoing a day-case procedure, CT scanning was routinely performed 4 hours postoperatively and the patient discharged to home after 6 hours of observation. This is now our routine and standard practice. For patients discharged before 48 hours, imaging is performed within the initial 24 hours of the biopsy, and for all other patients, they only undergo imaging if clinically indicated. This allows for safe postbiopsy discharge and aims to account for any clinically occult hemorrhage. Postoperative hospital LOS and all complications that occurred within 30 days of surgery were recorded for each patient. Additionally, we obtained the results from a previous retrospective study at our institution using the aforementioned methods for biopsy and pathology. These were then compared with the diagnostic yield and complication rates in our current study.

**Statistical Analysis**

The data were stored electronically and analyzed with SPSS software (SPSS 14.0, SPSS Inc.). Normalization was applied where appropriate; however, for clarity, data are reported in their original nonnormalized format. Spearman rank correlation, linear regression, and independent-sample t-tests were used to analyze the relationship between LOS and clinical parameters, such as age and tumor grade. To this end, pathological entities were dichotomized into high- and low-grade lesions (GBM and CNS lymphoma in one category and lower grade gliomas in the other). Using the Fisher exact test, we compared data obtained in the current series with that previously acquired at the same institution. Results were considered statistically significant at $p \leq 0.05$.

**Results**

A total of 134 biopsies were performed during the study of 133 patients between July 2005 and October 2007. The patients ranged in age from 14.7 to 82.4 (mean 58.8 years). There were 74 males and 59 females, the median LOS was 2 days (range 0–26 days), and 32 patients were discharged to home on the same day as surgery (Fig. 2). Length of stay correlated positively with age ($r = 0.269$, $p = 0.018$). The senior author (P.L.G.) performed 47 of the biopsies, supervising the Specialist Registrar during 80 procedures and the neurosurgical technician in 7.
A positive diagnosis was obtained in 133 (99.3%) of 134 biopsies. The histological diagnosis was GBM in 64, Grade III glioma in 19, low-grade lesion in 23, metastasis in 10, lymphoma in 13, and other pathological entities in 4. Isolated diagnoses consisted of a primitive neuroectodermal tumor and a single case of amyloid angiopathy. In the two other cases histological evaluation confirmed the presence of inflammatory CNS pathology and was consistent with the subsequent clinical course of the patients. Supratentorial lesions were noted in 129 patients, cerebellar lesion in 2, and midbrain lesions in 2. Patients with high-grade lesions had a significantly longer LOS than did those with low-grade entities (4.91 ± 5.6 days and 2.2 ± 3.3 days, respectively [mean ± SD]; p = 0.002) and were significantly older (65.6 ± 10.1 years and 48.2 ± 14.1 years, respectively [mean ± SD]; p = 0.0001). Table 1 shows the breakdown of the pathological diagnoses.

One biopsy (0.7%) was nondiagnostic, and postoperative imaging (performed because the tissue sample appeared macroscopically normal) demonstrated inaccurate targeting of the lesion (Fig. 3). The navigation system suggested that the cannula was placed in the center of the lesion, but on gross inspection the tissue obtained looked like normal white matter. A targeting error was suspected and the procedure was abandoned. This was confirmed on repeat imaging and the biopsy was repeated with eventual confirmation of a GBM.

Complications

Significant complications were seen in 3 patients (2.2%). All of these patients had preoperative WHO performance scores of III or IV. In 2 of these patients delayed deterioration occurred and the patients died as a result of probable complications of surgery. One patient had a thalamic GBM and presented with hemiplegia and an inability to ambulate. After 2 days there was a sudden deterioration and no further intervention or imaging was performed because palliative care had already been considered the most appropriate management. We speculate that the presumed cause was ICH or hydrocephalus, but this cannot be confirmed.

The other patient had gliomatosis cerebri, severe cognitive impairment, and confusion on admission and suffered a gradual decline over several days. This was thought most probably due to a combination of progressive disease and edema, and although we provided steroid agents, the treatment was also aimed at palliation because the patient’s prognosis was thought to be very poor.

The third patient, preoperatively, had a left-sided hemiplegia and harbored a histologically confirmed GBM. This patient had multiple comorbidities including chronic renal failure (urea 24.6 and creatinine 310 on admission), Type 2 diabetes mellitus, and hypertension. The patient had also been on warfarin for atrial fibrillation, which was stopped 2 weeks prior to admission, and he had a preoperative platelet count of 104,000/mm³. He became slightly more confused on the 2nd postoperative day and would not open his eyes when commanded. The platelets at this time were 99,000/mm³, and the hematologist thought that this was not low enough to treat. Computed tomography scanning (Fig. 4) confirmed an ICH at the site of the biopsy, and because the patient’s prognosis was thought to be poor, conservative treatment was continued. The patient recovered to his preoperative condition and was then transferred for palliative care.

In terms of other complications, new seizures were seen postoperatively in 4 patients (3%), and 2 patients (1.5%) suffered from a transient neurological deficit.

In a previous series of 127 biopsies at our institution (WNC) between January 2002 and December 2003, performed using a combination of frame-based CT-guided and ultrasound-guided biopsy techniques, 120 procedures were definitive (diagnostic yield 94.5%) with regular use of intraoperative neuropathological assessment (J Duffill et al., unpublished data, 2003). This difference in diagnostic yield was statistically significant compared with the results of our current study (p = 0.032). The previous series had higher mortality rate (1.5%) and morbidity rate (3.1%), but this difference was not statistically significant (p = 0.32). The mean procedural time for patients undergoing CT-guided biopsy (from time of stereotactic ring placement to discharge in the recovery room) was 113 minutes, whereas it was 102 minutes for ultrasound-guided biopsy. Table 2 compares our diagnostic rate with this and other studies considering histological yield and complications of brain biopsies.

### Table 1: Summary of pathological diagnoses

<table>
<thead>
<tr>
<th>Tumor Diagnosis</th>
<th>No. of Lesions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBM</td>
<td>64 (48)</td>
</tr>
<tr>
<td>anaplastic astrocytoma</td>
<td>8 (6)</td>
</tr>
<tr>
<td>anaplastic oligodendroglioma</td>
<td>4 (3)</td>
</tr>
<tr>
<td>anaplastic oligoastroglioma</td>
<td>7 (5)</td>
</tr>
<tr>
<td>astrocytoma</td>
<td>9 (7)</td>
</tr>
<tr>
<td>oligodendroglioma</td>
<td>7 (5)</td>
</tr>
<tr>
<td>oligoastrocytoma</td>
<td>6 (4)</td>
</tr>
<tr>
<td>pilocytic astrocytoma</td>
<td>1 (1)</td>
</tr>
<tr>
<td>lymphoma</td>
<td>13 (10)</td>
</tr>
<tr>
<td>metastasis</td>
<td>10 (7)</td>
</tr>
<tr>
<td>primitive neuroectodermal tumor</td>
<td>1 (1)</td>
</tr>
<tr>
<td>other</td>
<td>3 (2)</td>
</tr>
<tr>
<td>nondiagnostic</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>

Discussion

Based on the literature and our center’s experience, we propose that image-guided brain biopsy is safe and resource efficient when the strategy is to obtain multiple tissue samples taken along a single trajectory within the lesion using a side-cutting biopsy cannula and without intraoperative neuropathological assessment. We confirmed a high diagnostic yield of 99.3% despite the omission of what, for many, is the routine use of confirmatory intraoperative neuropathological assessment.

Nondiagnosis

In the single case of nondiagnosis, intraoperative...
There were multifocal imaging with gadolinium showing a partly enhancing and necrotic lesion in close relation to the right motor strip. This patient initially presented with a left-sided hemiparesis. Right: Immediate, postoperative axial CT demonstrating the biopsy track immediately anterior to the targeted abnormality as evidenced by the bubble of air. On gross inspection, this biopsy was macroscopically nondiagnostic. It was subsequently repeated, confirming a GBM.

A dedicated neurooncology surgeon, indicated the specimen to be suspicious for normal white matter. Postoperative CT scan confirmed an inaccuracy with targeting of the lesion. In this situation intraoperative negative histology would not have altered our management strategy for the patient and may even have been deleterious. Continuation of the procedure might have led to potentially catastrophic consequences with futile biopsy of normal tissue. Hence, this operation was abandoned. After repeat imaging, the procedure was carefully reprimed with the subsequent successful targeting of what was postoperatively confirmed to be a GBM.

This inaccuracy could have happened for several reasons. There are reports in the literature that, although excellent for initial planning, the reliability of maps from preoperative MR images for intraoperative guidance can decrease during surgery owing to brain shift. In different circumstances this phenomenon can be attributable to ongoing CSF loss or brain edema. Other postulations are that the trajectory guide may have moved after it had been locked or that the initial registration may have been inaccurate. Following this study our method for biopsy has evolved. We now use a screw-on trajectory guide, which obviates the need for the Mayfield clamp and provides real-time guidance by tracking of the tip of the cannula (Stealth AxiEM, Medtronic USA). This new technology was introduced in October 2007 when this current series ended.

**High Diagnostic Yield**

Despite omission of intraoperative pathology, our series shows an improved histological yield compared with other studies and a large meta-analysis of 7471 patients. There are several possible explanations for this high diagnostic return.

First, improvements in imaging and neurooncological services may be reasons why our diagnostic yield is high. Previously, with frame-based stereotactic biopsy, in the majority of cases it was standard practice to use CT alone. Our practice of using MR imaging, particularly including T2-weighted data sets for nonenhancing tumors, may lead to more optimized biopsy site targeting.

Second, a dedicated neurooncological team, led by an experienced specialist in this area who considers and performs every case may be an additional factor governing our results. Each case is considered carefully by the dedicated team. Prior to this, biopsies were performed by all neurosurgeons and often by trainees without direct supervision. Therefore, this study may contribute to the growing evidence base advocating improved services and standards of care with the advent of subspecialization.

A third factor may be that the diagnostic yield is higher than that reported in many historical series owing to the discriminating nature of a neurooncology practice. A high proportion of the cases referred for consideration at the neurooncological multidisciplinary team meeting usually involve suspicious lesions that are more likely to have an oncological derivation. A neuroscience center without this service will more likely receive a more wide ranging caseload. Although this must be taken into account when comparing our series, it may also act to reinforce how subspecialization can improve the discretion with which cases can be discerned for biopsy.
Image-guided frameless stereotactic biopsy

Finally, we have appropriated a technique whereby multiple samples are taken along a single trajectory through the tumor. Studies suggest that when evaluating stereotactic needle biopsies, variability in the histology of brain tumor specimens should be taken into consideration. Tissue heterogeneity and rapid tumor progression can decrease the accuracy of stereotactic brain biopsy.\(^{32,54}\) Woodworth et al.\(^{54}\) have suggested that increasing the number of specimens taken through the long dimension of tumors improves diagnostic accuracy. In light of this, a single core may well not be fully representative of the tumor volume and unless this fragment contains all the histological hallmarks of a GBM, undergrading or inaccurate diagnosis are real risks.\(^{21}\) Glantz et al.\(^{21}\) have confirmed that the grading of glial tumors by stereotactic biopsy may produce a significant underestimate of the degree of malignancy and may be invalid in some cases. Thus, inaccurate diagnosis may lead to suboptimal therapy, incorrect prognosis, and misinterpretation of clinical trials. Subsequently, in our study, due to multiple sampling, there were no identifiable causes of clear undergrading of a tumor. For example, in patients diagnosed with low-grade tumors there were none with radiologically or clinically apparent higher-grade lesions.

The main consideration regarding multiple sampling is its influence on the incidence of ICH. Fritsch et al.\(^{20}\) have shown that a higher number of biopsies did not lead to an increase in adverse developments. Their diagnostic yield was 98.5 ± 1.5% and the complication rate was 1.5%. A median number of 14 biopsy samples (range 1–48) were taken per lesion.

A study by McGirt et al.\(^{41}\) into 270 image-guided stereotactic biopsies confirmed that it is the needle track rather than the specimen harvest that contributes to post-biopsy deficits. Their series indicated that increasing the number of biopsy samples along an established track for deep-seated lesions rather than passing the needle numerous times will minimize the risk of morbidity. Therefore, they advocated harvesting at multiple depths along a single trajectory and confirm an effort to avoid the need for a second needle trajectory regardless of lesion location.

Our approach suggests a good safety profile for this technique with only 1 patient (0.7%) suffering an ICH. This patient had thrombocytopenia and uremia, which both increased hemorrhagic susceptibility. The results of an analysis by Field et al.\(^{18}\) into 500 patients undergoing stereotactic biopsy proved that the risk of hemorrhage increased steadily as the platelet count fell below 150,000/mm\(^3\) (p = 0.006). This is a valuable finding that, along with the multiple comorbidities suffered by the patient involved in our case, may have contributed to our single incident. Most studies also suggest the timing of hematoma occurrence shows predictability and for this reason does not present a barrier to short-stay image-guided biopsies.\(^{5,6,31,51}\) Hence, every patient undergoes postoperative imaging within 4 hours of the biopsy and is closely monitored for at least 6 hours.\(^{5,51}\) Therefore, it seems plausible that multiple sampling along a single trajectory captures appropriate histological specimens without aggravating the risk of ICH and we now routinely use day-case surgery for these procedures.\(^{24}\)

### The Future for Intraoperative Neuropathology

Notably, there is still continuing debate over the best technique for specimen analysis.\(^{19,45}\) The 2 distinct methods for tissue preparations both have advantages: smear preparations provide the opportunity to study single cells and details of the nucleus, whereas frozen sections generate better impression of the tissue composition and vascular proliferation.\(^{28,38,47}\) The authors of one study advised caution with the use of intraoperative neuropathological evaluation, reiterating that little inquiry has been conducted into its diagnostic accuracy and associated problems; they indicated that the technique warranted a review.\(^{52}\)

In reality, the cost factor, together with the space required for operation room pathology, makes it generally

### Table 2: Comparison of morbidity and mortality rates in the present series to historical studies\(^*\)

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Cases</th>
<th>Nondiagnosis (%)</th>
<th>Combined Morbidity &amp; Mortality Rate (%)</th>
<th>Morbidity Rate (%)</th>
<th>Mortality Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>present series, 2010</td>
<td>134</td>
<td>0.7</td>
<td>2.2</td>
<td>0.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Kreth et al., 2001</td>
<td>326</td>
<td>2</td>
<td>3.1</td>
<td>3.1</td>
<td>0</td>
</tr>
<tr>
<td>Paleologos et al., 2001</td>
<td>125</td>
<td>2.4</td>
<td>3.2</td>
<td>2.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Yu et al., 2000</td>
<td>550</td>
<td>3.4</td>
<td>7.8</td>
<td>7.8</td>
<td>0</td>
</tr>
<tr>
<td>Barnett et al., 1999</td>
<td>218</td>
<td>3.7</td>
<td>3.8</td>
<td>2.9</td>
<td>0.9</td>
</tr>
<tr>
<td>WNC 2002–2003</td>
<td>127</td>
<td>5.5</td>
<td>4.6</td>
<td>3.1</td>
<td>1.5</td>
</tr>
<tr>
<td>Aker et al., 2005</td>
<td>130</td>
<td>6</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Ferreira et al., 2006</td>
<td>170</td>
<td>8</td>
<td>4.1</td>
<td>2.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Kim et al., 2003</td>
<td>300</td>
<td>8.3</td>
<td>4.5</td>
<td>3.9</td>
<td>0.6</td>
</tr>
<tr>
<td>Shahzadi et al., 2005</td>
<td>288</td>
<td>8.3</td>
<td>5.4</td>
<td>5.4</td>
<td>0</td>
</tr>
<tr>
<td>Hall, 1998*</td>
<td>7471</td>
<td>9</td>
<td>4.2</td>
<td>3.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Dammers et al., 2008</td>
<td>391</td>
<td>10.6</td>
<td>12.1</td>
<td>10.6</td>
<td>1.5</td>
</tr>
</tbody>
</table>

\* Study was a meta-analysis.
impractical for most hospitals to have this as a resource in theater. According to DiNardo et al., this consideration, together with the cost of dead time in the operating room, accounts for the escalating costs of frozen sections in modern hospital practice. In an analysis of the economic cost of frozen section’s at St. George’s Hospital, London, Young et al. have estimated the marginal cost of theater time at University College London Hospitals Trust to be in the order of £500/hour ($814) and the cost for frozen section at around £50 ($81) (Great Britain pounds sterling conversion to US dollars is contemporaneous for September 2nd, 2009). A CAP-sponsored study of almost 33,000 frozen sections done in 700 hospitals from different countries showed that 90% of the procedures were completed within 20 minutes, measured from the time that the pathologist received the specimen to the time the frozen-section diagnosis was returned to the surgeon. At our institution, an audit has estimated the neuropathology process to take on average 30 minutes per biopsy and theater time has been calculated at £16/$26 a minute. This implies a saving of at least £480/$781 per procedure on top of the cost benefits from not performing intraoperative pathological evaluation. Moreover, the value of a consultant pathologist and a laboratory technician for 30 minutes has been evaluated by our human resources department to be worth £45/$73. Therefore, 67 hours of theater time for the 134 cases in our series, potentially accounts for at least £70,350/$114,518. This is a saving of at least £31,267/$50,908 a year, which can be redirected to other services.

Additionally, there are reports in the literature that intraoperative neuropathological assessment rarely influences immediate operative management and our experience underscores this. It is certainly true that appeals to minimize hospital-based morbidity along with increasing pressures to deliver resource-efficient health care have led to the need for safe solutions to shorten duration of admissions. What we have introduced proves this is possible.

Study Limitations

The study is limited as time taken for each operation has not been prospectively recorded, which could have further supported our findings. However, our experiences are that current techniques of image-guided biopsy are significantly more time efficient. At our center, patients were previously placed under general anesthesia in the operating room, with subsequent transfer to a CT unit and then back to theater for planning and undertaking of the procedure. Current application of local anesthetic without intraoperative imaging has dramatic time-saving benefits. Additionally, the estimated costs and timings for intraoperative neuropathological evaluation at our center are based on variables that may vary across institutions. Finally, comparing our study’s diagnostic yield and morbidity and mortality figures to historical series is fraught with inconsistencies. Definitions of mortality are not always documented and morbidity analysis is not standardized across centers.

D. Shooman, A. Belli, and P. L. Grundy

Conclusions

Contemporary stereotactic doctrine advocates the use of intraoperative histological evaluation to improve diagnostic yield for brain biopsy. However, our data suggest a reassessment of current approaches, possibly negating the need for procedure, especially if multiple specimens are taken.

Hence, image-guided brain biopsy with multiple specimens sampled along a single track represents a safe, efficacious, and fiscally viable treatment option. The procedure is well tolerated, resulting in a high diagnostic return with an excellent safety profile. Intraoperative neuropathological examination would not have increased our yield further. Elimination of intraoperative histological assessment results in significant time and cost savings, which is incredibly important given the limitations on health care resources. Additionally, this study provides further evidence for the value and benefits of neurosurgical subspecialization.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Acknowledgments

The authors wish to thank Mr. C. Oluigbo, Mr. A. Des Etages, Mr. G. Vajramani, Ms. R. Abeyguarane, and Mr. J. Duffill for their contributions to the series of 127 biopsies performed at our institution (WNC) between January 2002 and December 2003 and for their permission to use information and data from this for our study. We would also like to acknowledge Mr. P. Gladwell for his technical input with images and equipment.

References

Image-guided frameless stereotactic biopsy


Manuscript submitted April 13, 2009. Accepted December 16, 2009. Please include this information when citing this paper: published online February 5, 2010; DOI: 10.3171/2009.12.JNS09573. Address correspondence to: David Shooman, M.B.Ch.B., Wessex Neurological Centre, Southampton General Hospital, Southampton, SO16 6YD, Hampshire, United Kingdom. email: shooman@doctors.org.uk.