Transcranial echo-guided transsphenoidal surgical approach for the removal of large macroadenomas

RYUTA SUZUKI, M.D., JUN-ICHIRO ASAII, M.D., GORO NAGASHIMA, M.D., HIROSHI ITOKAWA, M.D., CHIH-WEI CHANG, M.D., MASAYUKI NODA, M.D., MICHO FUJIMOTO, M.D., AND TSUKASA FUJIMOTO, M.D.

Department of Neurosurgery, Showa University Fujigaoka Hospital, Yokohama, Japan

Object. Transsphenoidal surgery for the removal of macroadenomas has some disadvantages, including the risk of performing procedures without adequate visualization, difficulties in estimating the amount of residual tumor, and the risk of injuring major vessels. To overcome these disadvantages, the authors have developed transcranial echo-guided transsphenoidal surgery.

Methods. Three patients with large macroadenomas and two patients with irregularly shaped macroadenomas were selected for this operation. In addition to standard preparations for transsphenoidal surgery, in each case the right frontal bone was trephined and an echo probe was inserted transdurally through the trephination hole. During tumor removal, brightness-mode echo images and Doppler color flow images were obtained. The echo images allowed for real-time visualization of the tumor and surrounding brain structures including major arteries and the cisterns; histological heterogeneities of the tumor could also be appreciated. The tumors were removed safely and maximal tumor removal was achieved.

Conclusions. Transcranial echo-guided transsphenoidal surgery provides real-time visualization of tumor removal. The method enhances the safety of this surgery, maximizes the removal of the tumor, and is inexpensive.

KEY WORDS • echo-guided surgery • transsphenoidal approach • pituitary macroadenoma

RECENTLY, transsphenoidal surgery has been chosen as the first procedure for removal of pituitary adenomas, including large macroadenomas. In cases of large or irregularly shaped macroadenomas, however, this approach has some disadvantages. It carries the risk of performing procedures without adequate visualization in the suprasellar mass. It is also difficult to estimate the amount of residual tumor during the operation, and thus tumor removal is less extensive than expected preoperatively. Using intraoperative MR images, Bohinski, et al.,4 found that 66% of patients still had unacceptable amounts of residual tumor after the initial resection. To achieve maximal removal of the tumor in a safe manner, we have developed a transcranial echo-guided transsphenoidal surgical approach. Several image-guided systems, including intraoperative MR imaging, fluoroscopic frameless stereotaxy, endoscopy, image-guided endoscopy, and computer-assisted navigation systems, have already been added to the transsphenoidal procedure.4,7,10–12,14 Nevertheless, this technique of transcranial echo-guided transsphenoidal surgery is superb in providing real-time images and is more cost and time effective than these other modalities. Using the echo-guided method, we can perform the operation safely and achieve maximal removal of the tumor.

Clinical Material and Methods

Three patients with large macroadenomas (maximum tumor diameter > 5 cm) and two patients with irregularly shaped macroadenomas were selected for this procedure. The cases are listed in Table 1.

A hole was placed in the right frontal bone by trephination and the standard operative exposure needed for the transsphenoidal approach was also performed. Lumbar spinal drainage was not used. An echo probe (HDI3000 [5.3 MHz]; ATL Ultrasound, Inc., Bothwell, WA) was placed in the epidural space created by trephination (Fig. 1). The probe was secured by a flexible holder. Brightness-mode ultrasonography was performed through the trephination hole. We initially obtained echo images of the coronal and sagittal planes and later observed the peritumoral arteries by using Doppler color flow imaging. The tumor was removed transsphenoidally by means of the suction–curettage method with the aid of real-time echo-image visualization.

Results

Initial Echo Images

Figure 2 shows coronal and sagittal MR images and intraoperative echo images obtained in the patient in Case 2. The margins of the macroadenoma, ventricular system, and intratumoral cyst can be observed clearly in the echo images. Using color Doppler ultrasonography, the internal carotid, middle cerebral, anterior cerebral, distal anterior cerebral, and basilar arteries can be located within the peritumoral space (Fig. 3). This feature enhances the safety of the operation.
Intraoperative Images

During suction–curettage, the location of the surgical instruments and changes in the tumor size can be easily observed using real-time echo imaging. Debulking of the tumor and opening of the cisterns, which preoperatively were dislocated and compressed by the tumor, can be visualized (Fig. 4). Furthermore, the histological heterogeneity of the tumor can be identified using B-mode imaging. Figure 5A shows a sagittal MR image of the tumor in Case 3. The tumor appeared primarily homogeneous in Gd-enhanced MR images; however, B-mode imaging revealed a hyperechoic area in the anterosuperior portion of the tumor and other areas that are relatively hypoechoic. In this case, the first echo-guided transsphenoidal surgery achieved only partial removal of the tumor because the lesion was huge and hard. A transcranial interhemispheric approach had to be performed secondarily. Histological studies (Fig. 5C and D) revealed fibrous tissue without tumor cells in the anterosuperior portion of the lesion, which was previously observed to be hyperechoic during the first operation, and adenoma cells in another portion of the tumor, which was previously visualized as a relatively hypoechoic area.

During echo-guided transsphenoidal surgery, backscattering effects, an artifact of B-mode imaging, were observed. The backscattering created the illusion that the surgical instruments were being inserted from the inferior edge of the echo image. This illusion did not interfere with the operative procedures because we recognized it as an artifact.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Max Size (cm), &amp; Shape of Tumor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63, F</td>
<td>6.0, solid</td>
</tr>
<tr>
<td>2</td>
<td>55, M</td>
<td>5.5, partially cystic</td>
</tr>
<tr>
<td>3</td>
<td>51, F</td>
<td>8.0, irregular</td>
</tr>
<tr>
<td>4</td>
<td>50, M</td>
<td>3.0, irregular</td>
</tr>
<tr>
<td>5</td>
<td>54, F</td>
<td>4.0, dumbbell shape</td>
</tr>
</tbody>
</table>

Fig. 1. Schematic drawing showing insertion of the echo probe into the right frontal trephination.

Fig. 2. Case 2. Coronal (A) and sagittal (B) MR images demonstrating the tumor, and intraoperative B-mode echo images (C and D).
Operative Results

In four patients gross-total removal of the tumor was achieved (Fig. 6). In the patient in Case 3, only partial removal was achieved because the tumor was huge and hard, requiring us to perform the transcranial interhemispheric approach after the transsphenoidal one. Visual symptoms were improved in all cases. Permanent diabetes insipidus developed in two patients (Cases 3 and 4); however, replacement of vasopressin was not needed in the patient in Case 4 because the diabetes was very mild. Replacement of some anterior pituitary hormones was needed in three patients (Cases 1, 3, and 4).

Discussion

Transsphenoidal surgery for removal of large or irregularly shaped macroadenomas has some disadvantages. It carries the risk of performing procedures without adequate visualization in the suprasellar mass. In addition, it is difficult to estimate the amount of residual tumor that is left during the operation, resulting in a less extensive removal of the tumor than expected preoperatively. Using intraoperative MR imaging, Bohinski and colleagues found that 66% of patients with macroadenomas still harbor unacceptable amounts of residual tumor after the initial resection.

Recently several imaging modalities have been introduced, including image-guided navigation, endoscopy, and intraoperative MR imaging monitoring. Some of the methods are useful for avoiding misdirected surgical approaches; however, image-guided navigational systems are not suitable for the removal of macroadenomas via the transsphenoidal approach because tumor bulk and shape change dramatically during the operation, and these systems are not useful for estimating the amount of residual suprasellar tumor. Intraoperative MR imaging can provide useful information, but the additional cost and time required may not justify its routine use. In addition, Fahlbusch, et al. have reported that the value of intraoperative MR images is limited because of drill artifacts from metal debris or blood in the resection cavity, which was present in 30% patients. Endoscopic-assisted surgery is minimally invasive, but only offers an increase in the direct visual field. Thus, some authors use image-guided navigation combined with endoscopic methods to prevent misdirected approaches. Using echo-guided transsphenoidal surgery, we can monitor dynamic changes in tumor bulk and shape, as well as in surrounding brain structures by real-time imaging. Thus, echo-guided imaging is superior to other imaging methods, particularly in its ability to generate real-time images, its cost effectiveness, its contribution to the safety and simplicity of the surgical procedure, and its maximization of tumor removal.

Intraoperative use of real-time echo images in neurosurgery was introduced in the 1980s. Since then, echo-
Echo-guided transsphenoidal surgical approach

Fig. 5. Case 3. A preoperative sagittal Gd-enhanced T₁-weighted MR image (A) and a corresponding intraoperative B-mode echo image (B). The MR image demonstrates that the tumor has a homogeneous pattern except for a slight enhancement in its upper region. The intraoperative B-mode echo image shows a hyperechoic region in the anterosuperior portion of the tumor (C in B), whereas other parts of the tumor reveal a relatively hypoechoic area (D in B). Photomicrographs (panels C and D) of tissues obtained via the interhemispheric surgical approach. (These tissues were obtained from the regions marked C and D in panel B.) Only fibrous tissue (no adenoma cells) is seen in the tissue shown in panel C, whereas typical adenoma cells are clearly seen in the tissue in panel D. H & E, original magnification × 100.

Fig. 6. Case 1. A: Preoperative coronal Gd-enhanced T₁-weighted MR image revealing the tumor. B: Intraoperative B-mode echo image. C: Coronal MR image obtained 6 months postoperatively. D: Intraoperative B-mode echo image obtained when the suprasellar mass was removed.
guided transphenoidal surgery has been performed on a few occasions. Several authors have relied on transellar Doppler ultrasonography. They obtained echo images before and after tumor removal by filling the sphenoid sinus with saline. These images were useful, but real-time echo images could not be obtained during the tumor removal procedure. Using the same intraoperative transellar ultrasonography, Watson and associates localized 69% of microadenomas in patients with Cushing disease in whom MR imaging findings had been nondiagnostic. Atkinson, et al., reported the only case involving transcranial–transdural real-time ultrasonography in the literature. The methods described in that report were almost the same as ours except for our use of Doppler color flow imaging to detect major cerebral arteries. It would be an advantage to detect major cerebral arteries during surgery and thus avoid damaging vessels. Therefore, several authors have tried intraoperative monitoring of large cerebral arteries by using pulse Doppler ultrasonography during transphenoidal surgery. This method does not provide images, however, and does not give information on the dislocation of vessels during the procedure. In this report, we confirm the value of transcranial echo-guided transphenoidal surgery for the treatment of patients with large or irregularly shaped macroadenomas. In particular, the real-time monitoring of tumor debulking and visualization of surrounding brain structures, including vessels, are superb compared with other imaging modalities.

Conclusions

We have developed an echo-guided transphenoidal surgical approach. Using this method, the location of surgical instruments, changes in tumor size, and surrounding brain structures can be easily observed during the operation on a real-time basis. Thus, we can safely perform the operation and achieve maximal removal of the tumor. This method is suitable for resecting large macroadenomas and some irregularly shaped adenomas in the suprasellar region.

References


Manuscript received May 12, 2003. Accepted in final form September 18, 2003.
Address reprint requests to: Ryuta Suzuki, M.D., Department of Neurosurgery, Showa University Fujigaoka Hospital, 1-30 Fujigaoka, Aoba-ku Yokohama, Kanagawa 227-8501, Japan. email: ryuta@med.showa-u.ac.jp.