Image-guided frameless stereotactic biopsy sampling of parasellar lesions

Technical note

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Interactive image-guided neuronavigation was used to obtain biopsy specimens of cavernous sinus (CS) tumors via the foramen ovale. In this study the authors demonstrated a minimally invasive approach in the management of these lesions. In four patients, whose ages ranged from 29 to 89 years (mean 61.2 years) and who harbored undefined lesions invading the CS, neuronavigation was used to perform frameless stereotactic fine-needle biopsy sampling through the foramen ovale. The biopsy site was confirmed on postoperative computerized tomography scanning.

The frameless technique was accurate in displaying a real-time trajectory of the biopsy needle throughout the procedure. The lesions within the CS were approached precisely and safely. Diagnostic tissue was obtained in all cases and treatment was administered with the aid of stereotactic radiosurgery or fractionated stereotactic radiotherapy. The patients were discharged after an overnight stay with no complications.

Neuronavigation is a precise and useful tool for image-guided biopsy sampling of CS tumors via the foramen ovale.

Materials and Methods

Four patients, two men and two women whose ages ranged from 29 to 89 years (mean 61.2 years), underwent an image-guided frameless biopsy procedure via the foramen ovale. All patients presented with undefined parasellar lesions related to the CS. Neuroimaging alone was insufficient to confirm the diagnosis. In patients with rapid progression of symptoms, which is often associated with infection or malignancy, tissue confirmation may be required before radiosurgery can be offered. In this report we describe an approach through the foramen ovale to perform biopsy sampling of a CS lesion by using a frameless image-guided technique. This method allows for the confirmation of histological diagnosis prior to offering focal radiotherapy.

Abbreviations used in this paper: CS = cavernous sinus; CT = computerized tomography; FNA = fine-needle aspiration; MR = magnetic resonance; 3D = three-dimensional.
Instrumentation Information

Localization was accomplished based on CT scanning and/or MR imaging. Results of CT scanning provided excellent visualization of the bone structures, including exquisite definition of the foramen ovale. The MR imaging results demonstrated the relationship of the tumor to important structures such as the carotid artery and optic apparatus, decreasing the risk of potential biopsy complications. The characteristics of the neuronavigational system used (Vector Vision; BrainLab, Heimstetten, Germany) have been already described elsewhere. Special pointer tools, equipped with two highly reflective markers as well as the Z-touch infrared device, were used for registration. A star-shaped tool was attached to the patient by using a headband for image registration and intraoperative navigation. The universal reflective instrument adapter was easily attached to the guide needle, allowing for its navigation through the foramen ovale. The mean target-localizing error obtained for the system during craniotomy was 4 mm (standard deviation 1.4 mm). The mean reference accuracy was 1.4 mm. For this application, which was based on bone landmarks demonstrated on CT scanning and without brain shift occurring during the procedure, we believed that this precision could be improved.

Surgical Procedure

General anesthesia was induced in the patient, and the head was positioned in the midline with slight extension aided by a foam doughnut-shaped cushion. No headrest fixation was used. A headband housing the reflective markers for neuronavigation was used to maintain registration. Because registration and intraoperative navigation were performed using a tool directly attached to the patient’s head, movements of the head during the procedure did not affect the accuracy of the technique. After sterile preparation, a local anesthetic agent (lidocaine; Astra, Westboro, MA) was injected from a point situated 2.5 cm lateral to the corner of the mouth up to the entrance of the foramen ovale. This entry point, which had been planned with the aid of neuronavigation, was in accordance with the classic approach to the foramen ovale described by Hakanson as well as others. An 18-gauge, 10-cm-long spinal needle attached to the instrument adapter of the neuronavigation system was advanced with the aid of frameless stereotactic guidance in the direction of the foramen ovale. This provided for the introduction of the needle with real-time imaging guidance throughout the procedure. The foramen ovale was penetrated and the needle was left in place. The coaxial needle technique for a CS biopsy through the foramen ovale was used and has been previously described by our group. A 22-gauge Chiba needle (Cook, Inc., Bloomington, IN) was used to obtain the tissue through an 18-gauge needle. Specimens were obtained and cytologically analyzed until a differentiation among benign, malignant, and infectious processes could be made. Slides from FNA were air dried and stained with Diff-Quick; some slides were also fixed in alcohol and stained using the Papanicolaou method. Cytospin pellets and tissue fragments were fixed in 10% buffered formalin, imbedded in paraffin, and stained with hematoxylin and eosin. Paraffin sections cut to a 6-μm thickness were also used for immunohistochemical studies performed on an autostainer (Dako, Carpinteria, CA) by using standard techn...
niques with mouse monoclonal primary antibody for epithelial membrane antigen (Dako), rabbit anti–mouse secondary antibody, and rabbit peroxidase (Envision; Dako).

Results

With the use of neuronavigation, it was possible to approach the CS and Meckel cave via the foramen ovale pathway without complication. Cytological studies were positive in all cases. Histological and immunohistochemical analyses were possible in only one case. This technique has a reliability comparable to fluoroscopic methods, with the distinct advantage that it can be performed as an image-guided procedure with visualization of the soft tissue being transected and subjected to evaluation. The instrument-adapter provides for convenience, allowing for the use of the biopsy needle as the navigation tool. This tool provides real-time assessment of the needle tip in its trajectory during the procedure to optimize placement of the biopsy needle and the optimized tumor site was possible. Computerized tomography scans obtained after the procedure demonstrated the site at which the tissue had been obtained with a slight bubble of air. Also, anteroposterior and lateral fluoroscopy was applied in all cases to confirm the position of the needle tip, to add safety in this pioneering phase of technique development. The quantity of diagnostic material obtained during the FNA passes varied from paucicellular to highly cellular. In all four cases, cells consistent with low-grade spindle cell neoplasms were displayed; in three of the four patients, the diagnosis was consistent with meningioma. In one case the interpretation was complemented by the availability of histological testing. The tumor in this patient was immunohistochemically stained to reveal immunopositivity for epithelial membrane antigen, thus confirming the cytological data (Table 1).

Discussion

Our data indicate that the approach to the middle cranial
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fossa through the foramen ovale can be accomplished using a frameless stereotactic technique. Considering the precision necessary to approach the reduced dimensions of the foramen ovale, the procedure was reliable in allowing 3D visualization of the needle trajectory during the procedure. The tumors located within the limits of the CS could be subjected to biopsy sampling without complication. The accumulated experience in using fluoroscopy to approach the Meckel cave for the treatment of trigeminal neuralgia has exhibited neuronavigation as a commonly used tool in neurosurgery. In sampling of the CS in and around the CS, neuronavigation techniques have begun to replace traditional image-guided tools, such as fluoroscopy and plain x-ray filming. Initially used for microsurgical guidance during craniotomies and brain biopsy procedures, frameless techniques are increasingly applied to different areas of neurosurgery. Moreover, modern neuronavigation techniques have begun to replace traditional image-guided tools, such as fluoroscopy and plain x-ray filming.

The advent of image-guided neurosurgery and frameless stereotactic localization has advanced a new concept of stereotaxy. The development of multiple systems that utilize unique imaging and guidance technologies has established neuronavigation as a commonly used tool in neurosurgery. Initially used for microsurgical guidance during craniotomies and brain biopsy procedures, frameless techniques are increasingly applied to different areas of neurosurgery. Moreover, modern neuronavigation techniques have begun to replace traditional image-guided tools, such as fluoroscopy and plain x-ray filming.

The use of frameless stereotaxy has advantages over traditional fluoroscopic procedures. It provides a virtual trajectory of the needle pathway after registration and visualization of soft tissue and anatomical structures. This decreases the risk of damage to eloquent anatomical structures as well as other structures like the carotid artery. Additionally, the lesion slated for biopsy can be segmented and displayed on the computer screen as a 3D object (Fig. 1). This feature allows for the correlation of the biopsy needle with the anatomical position of the lesion and any at-risk structures. Furthermore, the ability to plan the needle pathway enables the surgeon to choose the most appropriate entry point for each individual patient. This customized approach may provide advantages over the use of standardized anatomical landmarks.

Although the size limitations of the foramen ovale do not allow for significant changes in the standard method, small variations in the entry site and trajectory can provide a safer and successful procedure. The difficulties in penetrating the foramen ovale and the risk of pursuing a wrong trajectory are real. The use of image guidance can minimize these difficulties by not only guiding the entry point, but also providing the best angle of needle entrance. This is probably the most important factor in cases of an inappropriate trajectory. This is especially important when the approach to the foramen ovale is not directed to the trigeminal nerve but to parasellar and CS lesions located more medially and superiorly.

An advantage of neuronavigation is the fact that it is not overly cumbersome to the operator. In addition, this procedure is no more time consuming than traditional methods. Registration can be achieved by the simple movement of the registration tool or, even more expeditiously, by using the reflection of an infrared beam over the patient’s facial surface (Z Touch; Brainlab). This latter approach works by infrared reading of the anatomical surface contour of the patient’s face and forehead. Furthermore, the tool that can be attached to the biopsy needle allows for the use of any instrument as a localizing tool. This enables real-time visualization of the needle trajectory throughout the procedure and does not preclude the use of fluoroscopy in conjunction with this approach.

The strategy in treating any intracranial lesion is better planned with an existing histological diagnosis. This minimally invasive approach to lesions of the CS and Meckel cave is important not only because it provides tissue for diagnosis, but also because its use avoids a major surgical procedure. Attempts to perform a complete microsurgical resection of intracavernous lesions are often related to cranial nerve complications. Subtotal resection is common, which includes stereotactic radiotherapy a necessity during the course of treatment. Radiosurgery or stereotactic fractionated radiotherapy are excellent treatment alternatives; in fact, data from many reports have confirmed the efficacy of radiotherapy in treating CS tumors. In this study the choice of radiosurgery or stereotactic radiotherapy was based on our previously described grading system for sellar and parasellar lesions.

Although we had no complications in this small series, serious complications related to the foramen ovale approach can occur, as previously reported. These include oculomotor palsies, trigeminal sensory deficits, masseter weakness, facial hematoma, and aseptic meningitis. The most important possible complication, as in other stereotactic procedures, is hemorrhage caused by a highly vascularized tumor. A carotid artery lesion accompanied by the development of a carotid artery–cavernous sinus fistula represents another possible serious complication. The biopsy procedure is performed using a very small diameter (22-gauge) needle together with visualization of the vasculature in the CS; thus, the risk of a hemorrhage or fistula generation is unlikely. Moreover, the use of the 18-gauge needle for the coaxial technique allows for evacuation of bleeding until hemostasis is accomplished.

The availability of interventional MR imaging, which serves as a means of checking the location of the biopsy in near-real time and of ruling out complications, may further enhance the precision and safety of frameless procedures. The association of frameless stereotaxy and interventional MR imaging guidance might be the ideal approach for these lesions.

Conclusions

In this report we described a practical, reliable, and low-risk means of obtaining tissue for diagnosis in and around the CS. Given that there is growing evidence that tumors in this region are effectively treated using stereotactic radiation techniques, a minimally invasive approach to tissue diagnosis becomes warranted, especially to avoid irradiation of lesions that could develop into lymphoid tumors or infectious processes that would be more appropriately treated using other treatment strategies.

References

48. Samii M, Carvalho GA, Tatagiba M, et al: Surgical management of
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