Intraoperative ultrasonography: an important surgical adjunct for intramedullary tumors

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The echographic characteristics of 186 suspected intramedullary spinal cord tumors were reviewed. Ultrasonography was found to be specific in distinguishing the tumor type, the extent of the lesion, and the presence and type of associated cysts. Ultrasonography greatly facilitates the selection of respective sites for the placement of a myelotomy, and for initiation of the resection. Additionally, this indispensable adjunct provides ongoing images that allow the preoperative plan to be precisely followed in a surgical field where anatomical landmarks are limited and the margin for error is minimal.

Key Words • intraoperative monitoring • ultrasonography • intramedullary tumor • spinal cord

The traditional management of intramedullary spinal cord tumors consisted largely of biopsy and augmentation duraplasty, followed by adjunctive therapy.9,12,14 The major technical reason for this was the surgeon's inability, despite microsurgical techniques, to establish clear anatomical landmarks for guiding the resection. In recent years a more radical approach has been successfully adopted with both ependymomas and astrocytomas.4,5,7,8,11,14,17,18 We have found that intraoperative ultrasonography, first described in 1982,1,3,4 provides the anatomical guidelines previously lacking. In this report we describe important echographic characteristics that help the surgeon perform this surgery with minimal risk to the patient.

Clinical Material and Methods

Case Material

From 1982 to 1989, operative ultrasonography was utilized for the radical resection of 186 intramedullary spinal cord tumors at New York University Medical Center. Ninety lesions were recurrent, having been operated on elsewhere, and 96 were newly diagnosed. There were 132 astrocytomas, 47 ependymomas, and three schwannomas. Four cases were found to represent inflammatory processes rather than tumors and were included in the analysis.

Sonographic Technique

Intraoperative echographic images were obtained following removal of posterior bony elements. The wound was irrigated to remove blood debris, and a curved linear array 7.5-MHz probe* was gently apposed against the dura. A systematic echographic examination was performed in both sagittal and transverse planes, from the rostral to the caudal limits of the exposure. Findings were correlated with those of the preoperative images. Visualization of the spinal cord included a half vertebral segment above and a half segment below the laminectomy site by tilting the probe at the rostral and caudal limits. Exposure was increased appropriately when the echographic examination failed to show salient features as expected from the preoperative magnetic resonance (MR) images. The examination was repeated following opening of the dura and during tumor resection.

Operative Technique

Before resection, the echogenic characteristics of the lesion, its cross-sectional and longitudinal extent, and the size, location, and contour characteristics of asso-

* Ultrasonogram unit manufactured by Johnson and Johnson Co., New Brunswick, New Jersey.
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FIG. 1. A: Transverse ultrasonogram showing an isodense astrocytoma (T) and small intratumoral cysts (C). B: Transverse ultrasonogram showing a hyperechoic ependymoma (T). The tumor is located in the centrum of the spinal cord, expanding it symmetrically.

FIG. 2. Sagittal ultrasonogram disclosing a slightly hyperechoic astrocytoma (T) within an expanded spinal cord. The echogenic central canal (CC) and spinal cord rostral to the tumor are normal. The central canal is always obliterated over the length of an intramedullary tumor.

FIG. 3. Gadolinium-enhanced sagittal (left) and coronal (right) magnetic resonance images revealing a sharply defined neoplasm in the centrum of the symmetrically expanded spinal cord. This appearance is typical of ependymoma.

FIG. 4. Sagittal (left) and coronal (right) ultrasonograms disclosing a hyperechoic neoplasm in the centrum of the expanded spinal cord. These ultrasonograms are virtually "superimposable" on the magnetic resonance images in Fig. 3.

Associated cysts were noted. The posterior midline of the spinal cord was determined, using the dorsal root entry zones and the echographic localization of the dentate ligaments as landmarks. The longitudinal site for initiation of the myelotomy was determined by the location of rostral and caudal cysts, if present, as well as the area of greatest tumor bulk. The ongoing resection was monitored by comparing the size and ventral extent of residual tumor tissue with the appearance of the tumor at the beginning of surgery. Termination of the resection was believed to be warranted when the tumor limits were found to have been reached both by inspection of the interface and by comparing pre- and postresection echographic images. Indirect indices of incomplete resection were considered to be the presence of residual noncollapsed cyst as well as nonreappearance of cord pulsations on the echographic image.
Results

Solid Tumors

Astrocytomas expanded the spinal cord asymmetrically on transverse imaging. The echogenicity was variable, and frequently was only minimally more pronounced than that of the surrounding cord. Unlike astrocytomas, ependymomas tended to expand the cord symmetrically and were usually centrally placed. Their hyperechoic signal was remarkable for its intensity and uniformity when compared with that of astrocytomas. These lesions could be readily delineated from the surrounding cord (Figs. 1 and 2). The ultrasonographic echogenicity of ependymomas was almost superimposable on the gadolinium-enhanced MR image which disclosed a discrete lesion in the centrum of the cord (Figs. 3 and 4).

Tumoral Cysts

Intratumoral Cysts. Cysts located within the tumor were frequently found in previously irradiated lesions of both astrocytic and ependymal nature. They were extremely rare in nonirradiated ependymomas, but were detected with some regularity in nonirradiated astrocytomas. As seen on ultrasound images, these cysts expanded the spinal cord asymmetrically, had irregular walls, and were of variable size. The walls tended to be hyperechogenic but could be calcified focally. The cysts were usually septated. Previously irradiated tumors typically had a Swiss-cheese appearance (Fig. 5), whereas nonirradiated tumors tended to contain larger, solitary septated cysts.

Rostrocaudal Cysts. Rostrocaudal cysts were not part of the tumor proper, but rather a reactive dilatation of the central canal (Fig. 6). Approximately 60% of intramedullary spinal tumors are associated with such cysts. Transverse ultrasonography showed that rostral or caudal cysts expanded the central canal symmetrically, occupied approximately two-thirds of the cross-sectional volume of the spinal cord, and had smooth walls. They were not septated, and their walls were devoid of echogenicity or calcification signals.

Demyelinating Disease

In four cases, when the clinical course and preoperative imaging were suggestive of a tumor, we discovered demyelinating lesions. The echographic characteristics in these cases consisted of a minimally expanded or nonexpanded spinal cord, a hyperechogenic signal without associated hyperechogenicity, and an echographic
visualization of the central canal (Fig. 7). On the other hand, the central canal was not visualized in any of the 182 cases of actual tumor.

Discussion

Tumor Localization

The exposure in spinal tumor surgery must be very carefully controlled. If it is too limited rostrocaudally, an incomplete resection is probable. Conversely, an excessively large exposure, particularly in the pediatric patient, can lead to severe kyphoscoliosis. Adequacy of exposure can be established by comparing the intraoperative echographic image with the preoperative MR image. Ultrasonography permits tailoring the exposure to the need before opening the dura, thereby preventing contamination of the subdural space with epidural debris.

Tumor and Cyst Characterization

Ultrasonography allows the planning of surgery prior to dural opening; echographic characteristics will provide important clues to the type of tumor present. This can be determined by analyzing the pattern of echogenicity and of spinal cord expansion, as well as by studying the cystic compartments identified. The technique of resection will vary greatly according to the type of neoplasm discovered.

Placement of Myelotomy

Myelotomy placement can also be determined by echographic characteristics. Spinal cord distortion and the position of the dorsal root entry zone can be determined from the cord contour and the location of the dentate ligaments. The transverse image therefore localizes the posterior midline, and the longitudinal image will dictate where in the cephalocaudal plane the myelotomy should be placed. If the lesion is associated with a rostral and/or caudal cyst, it is best started at the cyst-tumor junction in the posterior midline. If no extratumoral cysts are found, the myelotomy should be placed where the tumor is bulkiest and where the surrounding cord is most splayed, again in the posterior midline. In either case, the myelotomy is then extended along the posterior midline over the length of the tumor proper as determined by serial ultrasound images. Limiting the myelotomy to the extent of the neoplasm is particularly important at the level of the conus, where cord segments are closely approximated, and where an unnecessarily long myelotomy could lead to postoperative deficits.

Monitoring Tumor Resection

The echogram is most useful in cases of astrocytoma because the glial-tumor interface is often difficult to identify as the resection proceeds. A coronal ultrasound image may be compared with the initial one (Fig. 8), and the magnitude of the residual echogenic signal, the amount of lateral and ventral cord remaining, and the presence of residual intratumoral cyst or calcification can be established. The decision is then made as to whether further resection is required and, if so, in what direction along the cavity.

Clearly, residual echogenic tissue or residual intratumoral cysts dictate continued resection. Unchanged rostral or caudal extratumoral cysts also suggest residual tumor at the poles of the resection cavity. One further finding useful in assessing the completeness of resection is the return of pulsatile movements in neural structures. Such a movement is dampened in the presence of intramedullary tumor, but will reappear following a radical resection.

Conclusions

Ultrasonography has permitted more complete and better-guided radical resection of spinal cord neoplasms, with improved postoperative quality of neuro-
logical function. We believe, as do many others, that a working knowledge of the technique is imperative for any surgeon performing this procedure.

References


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