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● *Original Contribution*

INTRAOPERATIVE SONOGRAPHY OF INTRA- AND EXTRAMEDULLARY TUMORS

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Abstract—Intraoperative ultrasound (IOUS) was used in planning the operative resection of intradural spinal tumors, to define its diagnostic potential and limitations. Since 1997, 78 patients diagnosed with an ependymoma ($n = 24$), astrocytoma ($n = 7$), hemangioblastoma ($n = 7$), neurinoma ($n = 15$), meningioma ($n = 17$) and filum terminale ependymoma ($n = 8$) were examined using intraoperative transdural sonography. Intramedullary tumors turned out to show a heterogeneous image with occasional cystic alterations and an indistinct demarcation to the myelon of comparable echogenicity. Intramedullary tumors are easily distinguishable from their extramedullary counterparts, which display a homogeneous signal intensity and sharp demarcation on IOUS. In conclusion, IOUS allows a reliable diagnosis of intraspinal tumors, allowing the distinction between intra- and extramedullary tumors through their respective signal characteristics. Using IOUS, the extension of the neurosurgical approach can be adopted to the true extent of the tumor; thus, avoiding further bone work while the dura is already opened and the frequently edematous spinal cord protrudes through the opening. Our experiences have shown that IOUS may reduce the procedure-related morbidity and should, therefore, be used as a standard intraoperative tool in these high-risk surgical entities. (E-mail: j.regelsberger@uke.uni-hamburg.de)
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Key Words: **Intraoperative ultrasound, Sonography, Spinal tumor, Intramedullary tumor, Extramedullary tumor.**

INTRODUCTION

In 1887, W. R. Gowers (1845–1915) diagnosed a spinal tumor with compression of the myelon through neurologic-topic allocation of the symptoms and asked the surgeon, Victor Horsley (1857–1916), to remove the tumor (Toellner 2000). This is the first reported case of a successful removal of a spinal meningioma. Meanwhile, technical developments have substantially refined the possibilities in radiologic diagnosis and surgical therapy. Microsurgery, laser and intraoperative sensory and motor-evoked potential monitoring have reduced the surgical risks of worsening the preoperative neurologic condition remarkably. It is now well-established that 50% of patients may be stabilized and that 40% improve by tumor removal, if the correct diagnosis is made early (Brotchi and Lefranc 1999). But, still, 5 to 40% of patients undergoing surgical resection of an intradural tumor develop new neurologic deficits, depending on the preoperative neurologic condition and location and size of the tumor (Sandalcioglu et al. 2004).

During many years of experience, intraoperative ultrasound (US), or IOUS, has become an indispensable aid for localizing and controlling the resection of cerebral tumors and vascular anomalies in our institution (Regelsberger et al. 2000; Woydt et al. 1996). In spinal tumor surgery, IOUS has not been proved in a larger series for its diagnostic potential or even usefulness in influencing the surgical strategy or reducing the procedure-related morbidity, especially in intradural pathologies.

PATIENTS AND METHODS

Between January 1997 and October 2004, 78 patients with the diagnosis of an intradural tumor were intraoperatively examined with transdural sonography in our institution. The histopathological workup revealed intramedullary ependymoma in 24 patients, astrocytoma ($n = 7$) and hemangioblastoma ($n = 7$). IOUS of extramedullary tumors was performed in 17 patients with histologically verified meningioma, in 15 with neuri-

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Table 1. Histopathology of intradural tumors investigated by IOUS

Intramedullary tumors	*n*	Gender (f:m)	Medium age (y)	Upper cervical	Cervical-thoracic	Thoracic-lumbar
Ependymoma	24	10:14	47.1	6	14	4
Astrocytoma	7	2:5	41.3	2	3	2
Hemangioblastoma	7	5:2	62.2	1	4	2
Extramedullary tumors						
Meningioma	17	14:3	63.8	6	10	1
Neurinoma	15	9:6	47.1	3	2	10
Filum terminale ependymoma	8	5:3	51.1	–	–	8

noma and in 8 with filum terminale ependymoma. Further uncommon diagnoses with a frequency of less than 3% of all intradural tumors, such as oligodendroglioma, cavernoma, primary neuroectodermal tumor, lymphoma and neurofibroma, as well as the extrinsic intramedullary tumors (*e.g.*, hematogenous metastases) were excluded from this study. The histologic type of tumor and its location, as well as the demographic data of the patient, are presented in Table 1.

After laminotomy of the appropriate layers, transdural US (Siemens Elegra, Siemens Medical Systems, Issaquah, WA, USA) was carried out before opening of the dura. Provided that the paraspinal musculature and soft tissue are sufficiently mobilized, a single-layer hemilaminectomy was, in general, sufficient to facilitate the insertion of the smaller (15 × 10 mm) scanner (8 to 3 MHz) in the sterile NaCl-solution-filled entrance. In more expanded surgical approaches, a linear scanner (7.5L40) with a head surface of 40 × 10 mm was applicable. In 10 additional intraspinal tumor cases, the surgical approach was not large enough to employ any of the scanner for adequate image quality. These patients were excluded from the study. The sonographic findings were matched against the preoperative magnetic resonance imaging (MRI) recordings as well as the histological examination results.

RESULTS

A total of 20 (83%) of 24 ependymomas presented with a macrocystic (> 5 mm) appearance and 24% with an associated syrinx in the tumor pole areas, which rarely occurred with astrocytoma (29%). Microcysts (< 5 mm) were more frequent in ependymomas (79%) than in astrocytomas (43%). A satisfactory differentiation between astrocytoma and ependymoma by IOUS was not possible because echogenicity of the tumor was comparable to the myelon in 28 (82%) of 34 patients. The capsule wall or tumor/myelon border of hemangioblastoma showed an impressive hyperechogeneous seam on IOUS in 4 patients (67%). Of 7 patients, 4 presented on IOUS with a macrocystic or syrinx-like lesion. The solid tumor parts of hemangioblastomas with homogeneous echogenicity, nearly always visible on MRI, were only detectable in 2 (29%) of 7 patients. The vascularization in intradural spinal tumors is not necessarily apparent in color-duplex mode. Thus, no reliable diagnostic criteria for hemangioblastoma could be attained using US (Table 2).

Filum terminale ependymoma produced homogeneous hyperechogenic resonance in 7 (87%) of 8 patients of our study; thus, allowing a clear demarcation of the tumor from the surrounding nerve tracts. Surrounding edema was seen in none of these patients. The cerebrospinal fluid circulates around the tumor and sporadic

Table 2. Sonographic characteristics of intra- and extramedullary tumors

	Echogenicity of solid tumor part		Microcystic appearance with CSF-like echogenicity	Macrocystic appearance with CSF-like echogenicity	Syrinx
Intramedullary tumor		*n* = 38			
Ependymoma	Comparable with myelin	92% (22 of 24)	79% (19 of 24)	83% (20 of 24)	58% (14 of 24)
Astrocytoma	Comparable with myelin	86% (6 of 7)	43% (3 of 7)	29% (2 of 7)	29% (2 of 7)
Hemangioblastoma	Tumor nodule comparable with myelin	29% (2 of 7)	none	71% (5 of 7)	71% (5 of 7)
Extramedullary tumor		*n* = 43			
Meningioma	Higher than myelin	100% (17 of 17)	17% (3 of 17)	none	none
Neurinoma	Higher than myelin	87% (13 of 15)	33% (5 of 15)	20% (3 of 15)	none
Filum terminale ependymoma	Higher than myelin	87% (7 of 8)	50% (4 of 8)	37% (3 of 8)	none

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