JDMS 8:310–315, November/December 1992

Intraoperative Spinal Sonography

Frederick Sample Student Excellence Award
Second Place: Literature Review Category

GEORGE A. PLEITEZ, RT, GLENN A. ROUSE, MD,
MARIE DE LANGE, RDMS, RDCS

The uses of intraoperative spinal sonography are reviewed, including localization of lesions and monitoring of surgical correction. The sonographic appearance of intramedullary and extramedullary masses and cysts are reviewed and illustrated. The use of sonography in the surgical treatment of spinal fractures, herniated disks, and spinal stenosis is also discussed.

Key words: neurosonology, intraoperative spinal sonography, syringomyelia, hydromyelia, astrocytoma, meningioma, neurinoma, ependymoma, spinal fracture, disk disease, spinal stenosis.

Improved imaging of the vertebral column and spinal cord, including computed tomography (CT) and magnetic resonance imaging (MRI), has revolutionized the diagnosis of spinal disorders. Intraoperative spinal sonography adds the unique capability of imaging the spinal cord and the contents of the spinal canal during surgery, and aids in intraoperative localization of spinal lesions and in monitoring of the surgical process.

From the Department of Diagnostic Ultrasound, Loma Linda University, Loma Linda, California.

Correspondence: Marie DeLange, Department of Diagnostic Ultrasound, Loma Linda University Medical Center, Loma Linda, CA 92354.

TECHNIQUE

The patient is usually placed in a prone position on the operating table and the bony posterior neural arch is resected (laminectomy) for access to the spinal canal. Another surgical method is to approach the spine laterally. This approach is sometimes used in the chest; it requires a thoracotomy and deflation of one lung.

When the dura of the spinal canal is exposed, sonographic examination can be performed through a water offset by filling the surgical site with saline. Use of a 5-MHz to 10-MHz sector scanhead is optimal, because it can be used for both longitudinal and transverse imaging, but a linear transducer can be used in addition if desired. The transducer and cord must be covered with sterile drapes after ultrasound gel is placed on the transducer face. The surgical site is often quite small, and using a sector transducer makes it possible to look slightly above and below the margins of the surgical site along the spinal axis in case the surgical opening is not perfectly aligned with the lesion.

After the lesion is located and the dura opened, additional scanning may be necessary to monitor the surgical process of tumor removal or decompression of cystic structures.

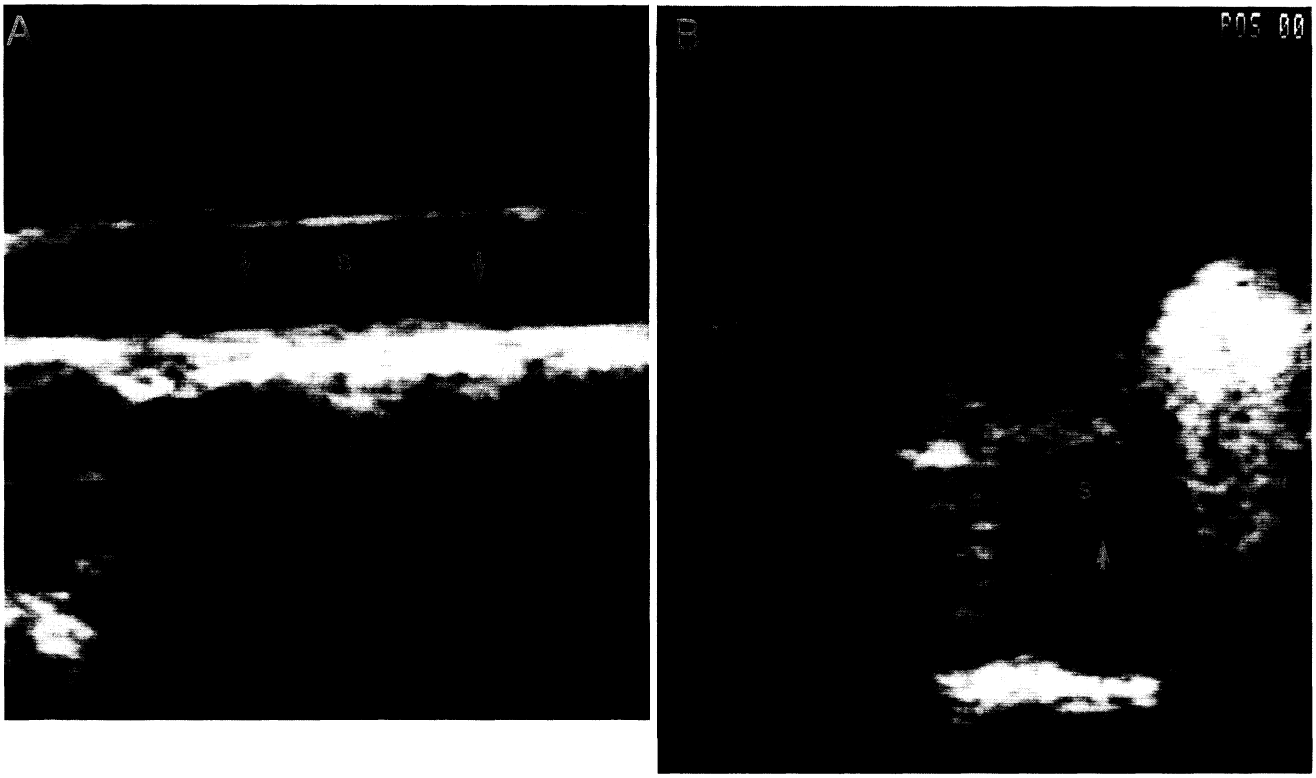

FIG. 1. Longitudinal (A) and transverse (B) intraoperative sonograms of the normal spinal cord (S). The anterior and posterior margins of the cord and the central echo (arrows) are visible.

NORMAL ANATOMY

The bony structures of the vertebral bodies appear brightly echogenic, and form the anterior boundary of the spinal canal (Fig. 1). In the longitudinal plane (Fig. 1A), the spinal cord appears hypoechoic and is bounded by echogenic parallel anterior and posterior borders. A mildly echogenic line representing the central echo of the cord runs parallel to the borders, closer to the anterior cord surface. In the transverse plane (Fig. 1B), the central echo is less distinct, and appears as a smudgy transverse area of increased echoes. The nerve roots and dentate ligaments can sometimes be visualized with the anechoic subarachnoid fluid surrounding the spinal cord. In the lumbar region, the tapered tip of the spinal cord (conus medullaris) and bundle of nerve roots arising from the cord (cauda equina) can be identified.[1]

CYSTIC INTRAMEDULLARY LESIONS

Lesions within the spinal cord (intramedullary lesions) may be cystic, solid, or complex. Intraoperative spinal sonography is particularly valuable in the visualization of intramedullary lesions, for the microsurgical procedures used in the cord are time-consuming, and precise location of the lesion can minimize the length of the procedure and trauma to the cord.[2]

The causes of cystic lesions of the spinal cord include congenital malformation, trauma, infection, and neoplasia.[3] Initially, the term hydromyelia was used to indicate symmetrical dilation of the central canal (Fig. 2), and the term syringomyelia was used to indicate asymmetric diverticulation of cystic spaces from the central canal into the surrounding cord tissue. Currently, the terms are used interchangeably to indicate cystic cord lesions; the terms syringohydromyelia and syrinx are also used to describe cystic cord lesions.[4]

Congenital intramedullary cysts of the spinal cord have been documented in Dandy-Walker malformation, Klippel-Feil syndrome, diastematomyelia, and the Chiari malformations.[3] In Chiari II malformation (hydrocephalus, spina bifida, and meningomyelocele), 45% to 95% of patients have intramedullary cysts of the cervical or thoracic spinal cord. The syrinx cavities are often dorsal to the

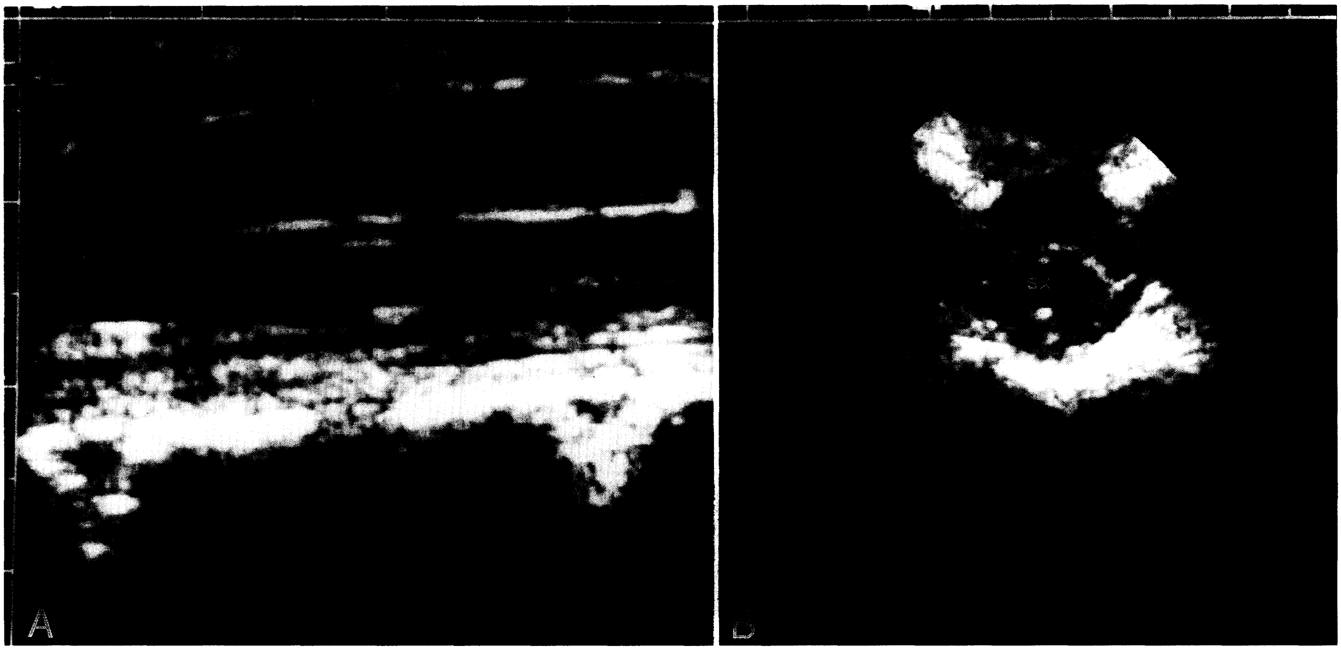

FIG. 2. Longitudinal (A) and transverse (B) intraoperative sonograms of the syrinx. Note the cystic dilitation of the central canal (sx). Subsequently, drainage tube was placed and decompression of the syrinx was documented sonographically.

central canal and communicate with the subarachnoid space. The central canal is nearly always abnormal, and multiple central canals are observed in 9% of patients with Chiari II malformation.[4]

If a patient has had trauma to the spinal cord, cystic changes in the spinal cord may develop months or years later, causing a deterioration of neurologic function.[4] Sonographically, posttraumatic cysts are round or oval with fairly well defined edges, or they may be lobulated, cylindrical, and multiseptated. The cysts obliterate the central echo of the cord, and may be surrounded by damaged cord tissue with increased echogenicity (myelomalacia). Intraoperative spinal sonography can confirm that cystic areas are present in a patient with myelomalacia and direct decompression of the cysts.[3]

Other causes of cystic cord lesions include infection and neoplasia. Usually infectious cord cysts are due to cystic infarction following infection, but cysticercosis may form cystic lesions in the central spinal canal as part of a primary infection.[3] In spinal cord tumors, the intramedullary cysts are accompanied by solid mass effect.[3] Intramedullary cysts usually require decompression. Intraoperative spinal sonography can assist the neurosurgeon in locating the cysts and can confirm that the cyst is adequately decompressed after shunting.

SOLID INTRAMEDULLARY LESIONS

Solid masses in the spinal cord are usually isoechoic or subtly hypoechoic. The mass obscures the central echo of the spinal canal, and the margins of the lesion are often indistinct. Sometimes a subtle change in echogenicity delineates the margin of the lesion (Fig. 3); this appearance has been observed in glioma, metastasis, arteriovenous malformation, myelitis, and necrosis.[3] Other lesions appear homogeneously echogenic with sharply defined edges, including some ependymomas, dermoid tumors with calcification, and metastatic lung carcinoma.[3] Many astrocytomas and ependymomas undergo cystic degeneration or are associated with adjacent cystic dilation of the central canal. Tumors with cystic degeneration are usually heterogenous in echogenicity, with solid and cystic components. Intramedullary tumors may obstruct the central canal, causing it to dilate above or below the mass.[3] In general, the sonographic appearance of intramedullary tumors does not specifically indicate a specific tumor type.[5]

EXTRAMEDULLARY CYSTS

Cystic lesions that do not involve the spinal cord itself may be within the dural covering of the spi-

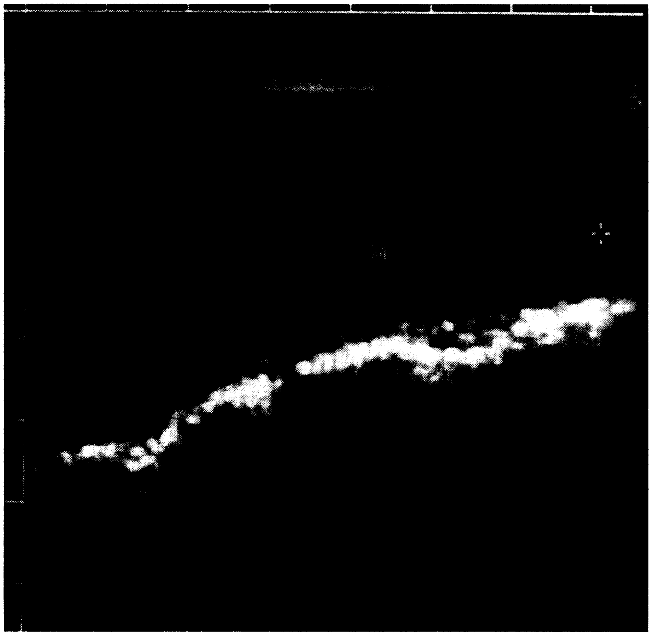

FIG. 3. Longitudinal sonograms of an intramedullary mass (M), outlined by cursors. The preoperative magnetic resonance imaging scan suggested ependymoma, but microscopic tissue examination showed cord infarction.

nal canal or may lie outside the dura. Cystic loculation of the subarachnoid space is usually due to previous trauma or inflammation; prior surgery, myelography, epidural anesthesia, and ankylosing spondylitis may cause such changes.[4] Congenital intradural arachnoid cysts occur most often in the posterior subarachnoid space.[4] If subarachnoid cysts compress the cord and cause new neurologic symptoms, intraoperative spinal sonography-directed lysis of adhesions or shunting of the cyst is indicated.[4,6] Extradural cysts are usually the result of degenerative joint disease. Ganglion cysts and synovial cysts are located near the posterior facets; synovial cysts may cause spinal cord or nerve root impingement.[4] Diverticulation of the dura along the nerve roots is another cause of extradural cysts.[4]

SOLID EXTRAMEDULLARY MASSES

Solid masses not arising within the spinal cord may lie within the dura (extramedullary intradural) or outside it (extramedullary extradural). Extramedullary intradural tumors are usually round or oval homogeneously hyperechoic masses with well defined borders that displace the spinal cord to one side within the spinal canal (Fig. 4). The enlarged subarachnoid space allows fluid to outline the superior and inferior margins of the mass. Meningioma, neurinoma, ependymoma, lipoma, and metastasis are tumors that may be located in the subarachnoid space.[3]

Extradural lesions include metastases, hematomas, bone tumors, spinal infections, and lymphomas.[4,7] If these lesions lie anterior to the spinal canal, they are difficult for the neurosurgeon to visualize, and intraoperative spinal sonography will aid location of the lesions and assessment of the completeness of removal.

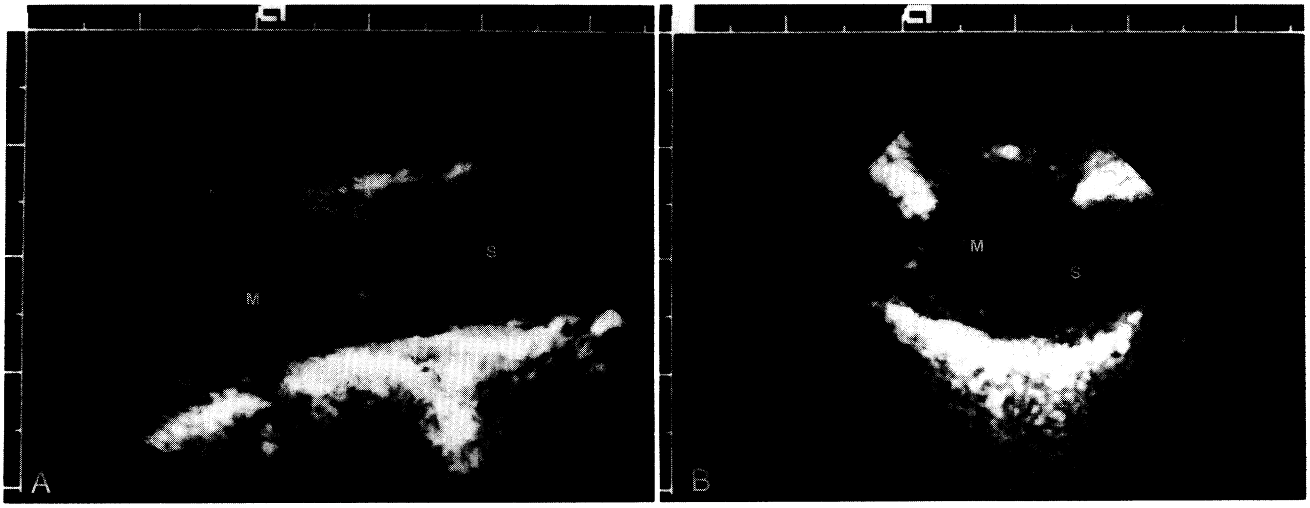

FIG. 4. Longitudinal (A) and transverse (B) sonograms of an extramedullary mass (M) displacing the spinal cord (S) to the left. The mass proved to be a neurofibroma.

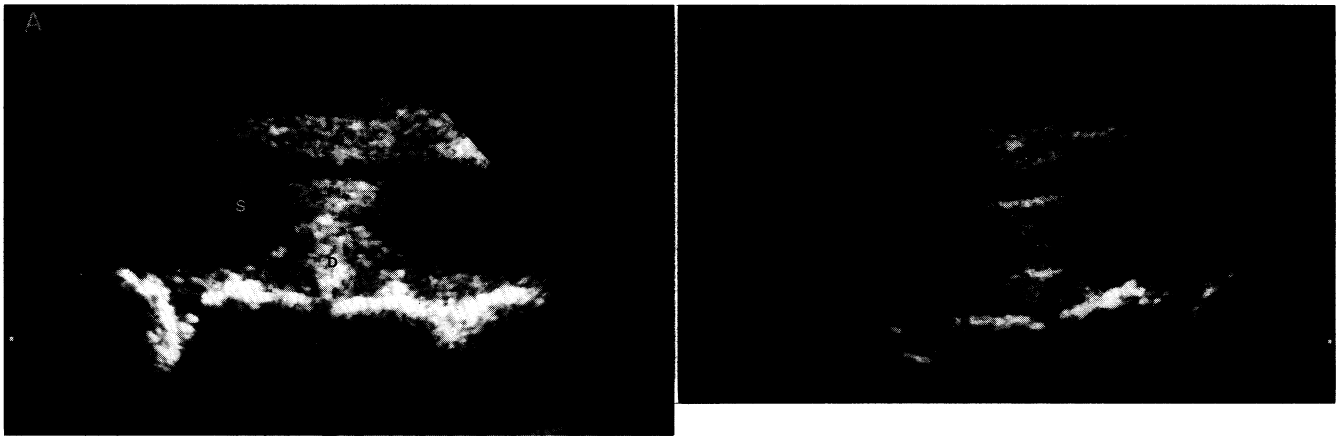

FIG. 5. (A) Longitudinal sonogram of a disk herniation (D) impinging on the spinal cord (S). (B) After removal of disk tissue, the cord compression is improved.

ABNORMALITIES OF THE BONY SPINAL COLUMN

If spinal fracture fragments project into the spinal canal or impinge the cord, intraoperative spinal sonography can assist in location and removal of the bony fragments. After Harrington rod placement, the adequacy of spinal cord decompression can be assessed; in one recent report[3] 60% of patients had inadequate decompression after placement of Harrington rods, and intraoperative spinal sonography aided additional decompression.[3]

Intervertebral disk herniation may be a result of acute trauma or chronic degenerative disease. Herniated disk material appears as an extradural solid mass of echogenic material with smooth margins arising from the intervertebral disk space (Fig. 5). Bright punctate echoes within the mass indicate areas of calcification. The herniated disk material is easier to visualize if it lies in the midline; lateral herniations may be obscured by overlying or adjacent bone. After surgical removal of the herniated material (discectomy), intraoperative spinal sonography can be used to evaluate whether the surgical removal is complete; in 25% of such cases, intraoperative spinal sonography indicates that additional tissue removal is necessary.[3,8,9]

The spinal canal may be narrowed due to osteophytes arising from the facet joints or intervertebral disks (spinal stenosis). Intraoperative spinal sonography can be used to monitor the surgical removal of these bony projections into the spinal canal.[3,8,9]

DISCUSSION

Intraoperative spinal sonography is a valuable surgical tool that assists the neurosurgeon in locating and treating many lesions of the spinal cord and surrounding structures. When operating on the spinal cord, neurosurgeons use microscopes and tiny microsurgical instruments. The surgical procedures are delicate and time consuming. Placement of a single suture to secure a shunt tube in a syrinx may take 30 minutes. The use of intraoperative spinal sonography can minimize the time required for these procedures, minimize surgical cord trauma, and insure that the procedure is completed.

REFERENCES

1. Quencer RM, Montalvo BM. Normal intraoperative spinal sonography. *AJR* 1984;143:1301–1305.
2. Quencer RM, Montalvo BM. Time requirements for intraoperative neurosonography. *AJR* 1986;146:815–818.
3. Montalvo BM, Quencer RM. Intraoperative sonography in spinal surgery: current state of the art. *Neuroradiology* 1986;28:551–590.
4. Kochan JP, Quencer RM. Imaging of cystic and cavitary lesions of the spinal cord and canal: the value of MR and intraoperative sonography. *Radiol Clin North Am* 1991;29: 867–911.
5. Platt JF, Rubin JM, Chandler WF, et al. Intraoperative spinal sonography in the evaluation of intramedullary tumors. *J Ultrasound Med* 1988;7:317–325.
6. Sklar E, Quencer RM, Green BA, et al. Acquired spinal subarachnoid cysts: evaluation with MR, CT myelogra-

phy, and intraoperative sonography. *AJR* 1989;153:1057–1064.
7. Donovan Post MJ, Quencer RM, Montalvo BM, et al. Spinal infection: evaluation with MR imaging and intraoperative US. *Radiology* 1988;169:765–771.
8. Eismont FJ, Green BA, Berkowitz BM, et al. The role of intraoperative ultrasonography in the treatment of thoracic and lumbar spine fractures. *Spine* 1984;9:782–787.
9. Montalvo BM, Quencer RM, Brown MD, et al. Lumbar disk herniation and canal stenosis: value of intraoperative sonography in the diagnosis and surgical management. *AJR* 1990;154:821–830.