Patterns of Anterior Spinal Canal Involvement by Neoplasms and Infections

Dieter Schellinger

PURPOSE: To show that retrovertebral extension of neoplastic and infectious disease proceeds in a predictable manner, with the anatomic superstructure determining the shape of the advancing process. METHODS: We examined 58 patients who had neoplastic (n = 44) and infectious (n = 14) processes that caused canal compromise. In total, 140 levels were examined by means of MR imaging only (48 patients), CT only (1 patient), CT plus MR imaging (3 patients), and MR imaging plus CT myelography (6 patients). RESULTS: At 136 levels, the retrovertebral disease process took the shape of a smoothly margined, bilobulated mass that was broad-based against the posterior surface of the vertebra. Various degrees of mass effect were observed: symmetric on 108 levels and asymmetric on 28 levels; on 4 levels, expansion of the anterior epidural space was unilobar, reflecting unilateral canal invasion. With advanced stages of canal invasion, this bilobulated pattern was maintained but there was a tendency toward detachment of the midline septum (20 levels). CONCLUSION: The observed patterns are determined by the particular anatomy of the anterior epidural space. The shape of the mass is imposed by the posterior longitudinal ligament and by the attached lateral membranes, with the central tether produced by the attached midline septum. The two compartments expand independently.

Index terms: Spine, anatomy; Spine, infection; Spine, neoplasms


Retrovertebral extension of osseous disease processes and associated spinal canal compromise are common. Malignant tumors and bone/disk infection are the most frequent offenders. Propagation into the spinal canal presents a potential threat to the spinal cord and nerve roots and must be carefully monitored to prevent irreversible damage (1–4). Expansion of disease into the spinal canal follows existing anatomic pathways. Our observations suggest that patterns of disease advancement are repetitive and predictable. The anterior epidural space represents the territory most readily invaded. We have previously redefined this anatomic region on the basis of new anatomic concepts (5). Subsequent to these earlier observations, we noted that tumoral and infectious processes exhibit an expansion pattern that is dictated by the anatomy of the anterior epidural space and is frequently limited to this space. Potentially confusing patterns of canal compromise can be understood if these anatomic concepts are brought into play.

Subjects and Methods

This study was based on the findings in 58 patients with canal compromise due to disease extension, usually from the vertebrae and in some cases from disks. In total, there were 285 diseased vertebrae; retrovertebral disease extension was seen at 140 levels (cervical, 15; thoracic, 87; lumbal, 38) and was associated with varying degrees of spinal canal compromise. Levels showing total obliteration or destruction of the spinal canal were excluded from this analysis.

Among these 58 patients were 44 who had neoplastic processes (Table). Diseases included metastases (n = 33), lymphoma (n = 5), hemangioma (n = 3) and others (n = 3). The remaining 14 patients had epidural abscesses, which emanated from infected disks and/or vertebrae. Of the 33 patients with metastatic disease, only 9
had had a specific diagnosis made as to disease origin. In 24 patients, the diagnosis of metastatic disease was based on the multifocality of involvement and on the destructive nature of the disease process. A definitive tissue diagnosis was not available in these patients. In the context of this study, the primary site appeared unimportant, as we were mainly interested in defining retrovertebral growth patterns irrespective of tumor type. In the remaining patients, the diagnoses were as listed in the Table.

In 48 patients, magnetic resonance (MR) imaging was the only imaging method used; in 3 patients, both computed tomography (CT) and MR imaging were used for analysis; in 6 patients, MR imaging was paired with CT myelography as the data source; and in 1 patient, CT was the only study used. CT scans were obtained on a General Electric (Milwaukee, Wis) 8800 or 9800 scanner. Usually, a series of 1-mm to 5-mm contiguous sections were produced.

The MR studies were obtained on a 1.5-T Siemens (Iselin, NJ) Magnetom unit. They usually comprised T1-weighted (600/15/2 [repetition time/echo time/excitations]) and T2-weighted (2200/20,70/2) sagittal sequences. The axial sections were obtained with T1-weighted (800/15/2) and T2-weighted (510/12/2; flip angle, 15) gradient-echo sequences. Other imaging parameters included a sagittal section thickness of 3 mm, an axial section thickness of 5 mm, a 10% intersection gap, a 192 × 256 matrix, and a 20-cm field of view. Sagittal precontrast and postcontrast (10 mL of gadopentetate dimeglumine) MR studies were obtained in most cases.

### Results

Among 140 levels with retrovertebral disease, 121 had disease processes that originated in adjacent vertebrae. At 19 levels, an anterior epidural abscess propagated from infected disks and involved adjacent vertebrae.

At 136 levels, the retrovertebral disease process took the shape of a smoothly marginated bilobulated mass (symmetric in 108, asymmetric in 28) that was broad-based against the posterior surface of the vertebra. The various presentations are shown in Figure 1. Low-grade (Fig 2) and more advanced invasion can result in a bilobulated pattern. More progressive canal compromise frequently exhibited detachment of the midline septum from its bonding site at the vertebral body. This was observed at 20 levels (Fig 3).

At four levels, there was a variant pattern, in which the retrovertebral mass was limited to one half of the posterior vertebral surface and appeared as a unilobulated mass that did not extend beyond the midline (Fig 4). This extension was seen in cases in which osseous involvement was more advanced in, or limited to, one half of the vertebral body.

Retrovertebral disease extension at cervical and thoracic levels was similar to that observed in the lumbar region (Fig 5). The abnormalities were best recognized on T2-weighted (Figs 2–4) and on contrast-enhanced T1-weighted (Figs 6 and 7) MR images. They were less distinct on unenhanced T1-weighted images.

### Neoplastic or infectious disease processes in 58 patients

<table>
<thead>
<tr>
<th>Disease</th>
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<tbody>
<tr>
<td>Metastases (n = 33)</td>
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<tr>
<td>Unknown primary</td>
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<tr>
<td>Breast</td>
<td>3</td>
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<td>Lung</td>
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<td>Prostate</td>
<td>2</td>
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<td>Lymphoma</td>
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<td>Germinoma</td>
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<td>Histiocytoma</td>
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<tr>
<td>Hemangioma</td>
<td>3</td>
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<tr>
<td>Osteosarcoma</td>
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<td>Infections/abscess (n = 14)</td>
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<tr>
<td>Infected disks and/or</td>
<td></td>
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<tr>
<td>osteomyelitic vertebrae</td>
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<td>Infected disks only</td>
<td>6</td>
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At 27 levels, both anterior epidural space involvement and perivertebral disease extension were noted. In 14 cases, the expansile process represented inflammatory tissue and originated from neighboring infected disks. Here, the infected disk showed broad-based posterior displacement, similar to annular bulging but with associated contrast enhancement and/or T2 prolongation (Figs 6A and 7A). When the infection extended rostrally or distally to a position directly behind a vertebral body, the disease substrate took the shape of the anterior epidural...

Fig. 2. A, Schematic drawing shows neoplastic/infectious process extending from vertebral body into the anterior epidural space, with demonstration of midline septum/posterior longitudinal ligament complex and attached membranes.

B, Axial T2-weighted MR image of lumbar vertebra in patient with multifocal bone metastases shows intact midline septum/posterior longitudinal ligament complex with biconvex displacement pattern similar to Figure 1A.

C, T2-weighted MR image in a different patient, in whom lumbar vertebra is permeated with metastatic disease, shows the anterior epidural space is invaded and the midline complex remains attached. Symmetric, linear deflection of membranes is similar to Figure 1C.

Fig. 3. T2-weighted images show detached midline septum (arrow in A and B), caused by advanced invasion of the anterior epidural space by metastases to lumbar vertebrae. Right and left portions of the anterior epidural space communicate.

A, Lateral membrane displacement pattern is similar to Figure 2C, but midline septum is detached.

B, Displacement pattern is similar to Figure 1D, but midline septum is detached. Note kissing membranes in midline.

C, Displacement pattern is similar to Figure 1F. Lateral membranes and posterior longitudinal ligament constitute leading edge of advancing tumor mass (arrows). Note mild umbilication in midline, between arrows.
space and became bilobulated (Figs 6B and 7B).

Discussion

Previously, we have used MR imaging and CT to examine ex vivo specimens of the anterior epidural space, and have defined this territory as one that is clearly separate from the remaining epidural space (5). We showed that the internal structure of the anterior epidural space imposes certain constraints to migrating disk fragments. It is postulated here that the same anatomic demarcations also influence distribution patterns of advancing neoplasms and infectious processes.

The traditional anatomic concept has the epidural fat space surround the thecal sac like a continuous layer of insulation. It has the posterior longitudinal ligament bowstrung freely across the concavity side of the posterior vertebral surface, with firm attachment of the posterior longitudinal ligament noted only at the level of a disk, where it is affixed to the outer layers of the annulus fibrosus (6–9). In this anatomic concept, the left and right portions of the anterior epidural space should communicate freely under the posterior longitudinal ligament, and
the perithecal epidural space should be a continuum of the anterior epidural space.

We now recognize the anterior epidural space as a separate compartment, defined by the posterior longitudinal ligament with laterally attached membranes and with a midline septum that is firmly connected to the posterior longitudinal ligament and that anchors it anteriorly to the posterior surface of the vertebral body (Figs 1 and 2A). The midline septum and the posterior longitudinal ligament together constitute the attachment complex. The midline septum divides the anterior epidural space into two portions. Previously, we identified the midline septum as a fibrous structure that consists of lamellae of compact collagen that connects dorsally with the posterior longitudinal ligament and ventrally with the thickened cortex of the vertebral body. In a relaxed state, the midline septum appears flat and measures approximately 2 mm in thickness. In the stretched mode, it measures 1 mm or less. The lateral membranes were discussed by Fick (10) and were later briefly referenced by Schmorl and Junghanns (11). They bridge between the free edges of the posterior longitudinal ligament and the anterolateral laminae. At the level of the exit foramina, the anterior epidural space communicates freely with the perivertebral space. Disease in the anterior epidural space can easily extend via the intervertebral foramina into spaces outside the vertebral canal. Neoplasms and infectious processes frequently follow this path of extension. Upon direct inspection, the lateral membranes are thin, translucent structures. With a thickness of less than 1 mm, they can be easily torn. Their histologic composition has not been analyzed.

The biconvex appearance of the anterior epidural space is best observed under conditions of pathologic expansion; inflation of this space demarcates the midline septum and the lateral membranes to better advantage. Under normal conditions, the anterior epidural space is shallow, and the various anatomic constituents cannot be recognized. In obese patients, and at the L-5 to S-1 level of normal-sized patients, there is increased fat content in the anterior epidural space, and the lateral membranes as well as the midline septum can be clearly identified. Because of their usual inconspicuousness in the average patient, any disruption of these structures cannot be seen.

The bilobulated appearance of the anterior epidural space in cases of retrovertebral tumor/infectious process extension is determined by the firmly anchored midline attachment complex and by the laterally affixed lateral membranes. Each invaded portion of the anterior epidural space expands posteriorly like an inflated tent. If there is equal invasion, right and left, the anterior epidural space expands symmetrically (Figs 1, 2, 3A and B, and 5). Asymmetric involvement results in asymmetric anterior epidural space expansion (Figs 1B, 4, and 6).

In more advanced cases of retrovertebral anterior epidural space invasion, the posterior displacement of the lateral membranes can result in medial abutment of the membranes (Figs 1D, 3B, and 5B). The posterior displacement of the
lateral membranes may also lead to more linear, leaflike deflection and produce a pie-shaped appearance (Figs 1C, 2C, and 3A), with the apex located at the attachment of the midline septum.

In some cases, there is obvious destruction of the midline septum with left-to-right extension of the pathologic process (Figs 1E and F, 3, and 4) within the anterior epidural space. While this diminishes the midline tethering and flattens the figure-of-three shape, central umbilication is still often suggested (Fig 3C). Since the posterior longitudinal ligament is still connected to the vertebral body rostrally and distally, the septum can wedge the anterior epidural space mass in midline, owing to the bowstring effect.

Even advanced retrovertebral extension tends to keep the lateral membranes intact (Figs 1D–F, 3B and C, 4, 5B, and 6B). The pathologic process adapts to the shape of the anterior epidural space, and the delicate lateral membranes cap the advancing tumor without being penetrated. The notion that a paper-thin membrane may control the shape of an advancing neoplasm without being destroyed in the process may appear illogical. However, we surmise that the elasticity of this structure provides enough flexibility to evade destruction.

At a disk level, the posterior longitudinal ligament is firmly and broadly affixed to the outer layers of the annulus fibrosus. Therefore, an anterior epidural space does not exist at this site. The anterior epidural space begins directly above and below the disk. With diskitis, the posteriorly displaced, infected disk displaces the posterior longitudinal ligament but does not detach from it. Infectious material may spill into the anterior epidural space above and below where it produces the usual expansion pattern (Figs 6 and 7).

The 140 levels examined and described in this article invariably showed expansion patterns similar to those portrayed in Figure 1. In rare cases of advanced posterior tumor extension, the described types of tumor containment could no longer be identified. Levels with such advanced and therefore disorganized tumor extension were not included in this article.

This retrovertebral process extension was discussed in a previous communication (D. Schellinger, C. A. Cammarata, L. M. Levy, et al, “Patterns of Tumor Growth in the Anterior Epidural Space of the Spinal Canal” presented at the 29th Annual Meeting of the American Soci-

ety of Neuroradiology, Washington, DC, June 9–14, 1991) and was later also recognized by another investigator (J. M. Provenzale, “Clinical Features and Neuroradiologic Findings in Spinal Epidural Abscess,” presented at the 30th Annual Meeting of the American Society of Neuroradiology, St Louis, Mo, May 31–June 5, 1992), who observed the figure-of-three appearance in cases with epidural abscesses. The work of other authors who observed retrovertebral extension of epidural abscesses (12–14) or metastases (1, 15–17) did not focus on epidural extension patterns.

What are the potential benefits of this new anatomic concept? Recognition of distinct anatomic spaces typically leads to a more dynamic understanding of disease distribution. In modern head and neck radiology, mapping of facia-defined anatomic areas has dramatically changed the diagnostic approach. It is hoped that improved understanding of the anterior spinal canal infrastructure may also lead to a better grasp of disease behavior within this space.

In summary, extension of tumors and/or infectious processes from the vertebrae into the spinal canal follows certain predictable patterns. The intrinsic anatomic architecture of the anterior epidural space is the primary determinant influencing this growth pattern.

References


