Thoracolumbar intervertebral disk disease (IVDD) is a broad term, encompassing disk degeneration and clinical neurologic disease due to disk herniation. Canine IVDD is the most common cause of thoracolumbar myelopathy with paraspinal hyperesthesia.\textsuperscript{1,2} A thorough understanding of diagnostic modalities, prognosis, and treatment options is crucial to medical decision making and comprehensive care.

**Diagnostic Evaluation**

The preanesthetic evaluation of dogs with suspected disk herniation should include a complete blood cell count, serum chemistry panel, urinalysis, and thoracic radiography in geriatric dogs to evaluate cardiovascular structures and rule out pulmonary metastatic nodules. A urine culture should be obtained in dogs with urine retention, regardless of whether pyuria is present.\textsuperscript{3–5} Radiographic signs suggestive of intervertebral disk herniation include narrowing or wedging of the disk space, decreased size of the intervertebral foramen, reduced space between articular facets, and mineralized disk material in the vertebral canal or overlying intervertebral foramen\textsuperscript{6} (FIGURE 1). Spondylosis deformans, while potentially associated with disk protrusion, is not seen with increased frequency at sites of disk extrusion.\textsuperscript{8} Survey radiography does not confirm the presence of spinal cord compression or localize lesions accurately enough for surgery. Surgical localization must be established by myelography, computed tomography (CT), or magnetic resonance imaging (MRI). Because these tests are expensive, require anesthesia, and may have side effects, they are generally performed only when other tests fail to confirm the presence of spinal cord compression and are necessary before spinal surgery.\textsuperscript{7}

At a Glance

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**Abstract:** Thoracolumbar intervertebral disk disease (IVDD) is a common, important cause of paraspinal hyperesthesia, pelvic limb ataxia, paraparesis, paraplegia, and urinary and fecal incontinence in dogs. A companion article reviewed pathophysiology, epidemiology, physical examination, and emergency medical therapy. This article addresses the diagnosis, prognosis, and treatment of dogs with thoracolumbar IVDD.

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Myelography

Myelography has been the mainstay of localization of spinal cord compression caused by intervertebral disk herniation in veterinary medicine. Myelographic and surgical findings have a strong correlation, with myelography correctly identifying the site of intervertebral disk herniation in 85.7% to 98% of cases. Myelography also aids in determining the lateralization of disk extrusions causing myelopathy. Compressive lesions may be seen on myelography in dogs with back pain alone as a clinical sign of intervertebral disk herniation. Compared with CT and MRI, myelography is relatively inexpensive and does not require specialized equipment. The major disadvantages of myelography are side effects and artifacts caused by epidural contrast injection. Myelographic contrast media can cause asystole, seizures, and renal failure and aggravate spinal cord dysfunction. Artifacts that can confound the evaluation of myelograms include epidural, central canal, and subdural filling and direct parenchymal injection. In a comparison of CT, survey radiography, and myelography for the evaluation of vertebral and spinal cord tumors, myelography outperformed CT in classifying intradural lesions. Myelographic findings suggestive of extradural spinal cord compression secondary to disk herniation include dorsal deviation of the ventral subarachnoid contrast column and thinning of the dorsal contrast column dorsal to a disk space on the lateral view. In acute cases, an intramedullary pattern secondary to severe cord swelling may mask the radiographic signs of disk extrusion, causing attenuation of both contrast columns on the lateral and ventrodorsal projections. In these situations, careful evaluation for slight axial deviation of a contrast column or comparison with the survey radiographs may indicate the origin of the disk extrusion. In addition, oblique radiographic projections (left ventral–right dorsal and right ventral–left dorsal) are useful when the lateral and ventrodorsal projections only...
show cord swelling. If the disk material is located significantly lateral to midline, oblique views may show a classic extradural pattern, whereas the traditional views may only show attenuation of the contrast columns.\(^\text{24}\)

**Computed Tomography**

CT allows for assessment of extradural spinal cord compressive lesions.\(^\text{25}\) Herniated disk material appears on CT images as a heterogeneous, isodense-to-hyperdense extradural mass, depending on the mineral content of the herniated disk material.\(^\text{25,26}\) With chronicity, herniated disk material may become more homogenous and hyperdense as the mineral content increases.\(^\text{25,26}\) (FIGURE 4). Epidural hemorrhage typically appears slightly more attenuating than the spinal cord. CT is not very effective at differentiating structures within the dura.\(^\text{25}\)

CT may be combined with myelography to allow visualization of the subarachnoid space, improve accuracy in differentiating intramedullary from extradural causes of spinal cord swelling, and definitively determine the location of herniated disk material. The advantages of CT include few side effects and the ability to view reformatted images. CT is useful in demonstrating gross morphologic changes in the disk, such as mineralization, but is not helpful in assessing subtle changes suggestive of disk degeneration.\(^\text{27}\)

**Magnetic Resonance Imaging**

MRI allows early recognition and classification of disk degeneration with minimal intraobserver and interobserver variability.\(^\text{28,29}\) The normal canine intervertebral disk has a clear demarcation between the annulus fibrosus and nucleus pulposus, with the nucleus pulposus on T2-weighted images appearing as an ovoid area of high signal intensity compared with the relatively hypointense annulus fibrosus (FIGURES 5 AND 6). The signal intensity of the nucleus pulposus on T2-weighted images correlates directly with proteoglycan concentration.\(^\text{30}\) T1- and proton-density−weighted images have a high signal-to-noise ratio and are useful for showing anatomic detail.\(^\text{26}\)

The appearance of a dark cleft in the nucleus pulposus in humans correlates with a mild increase in collagen content and a mild decrease in water content, but it may not correlate with histopathologic degeneration in dogs.\(^\text{30,31}\) In one study, MRI was 100% sensitive and 79% specific for detecting disk degeneration in nonchondrodystrophic dogs compared with histopathology.\(^\text{31}\) The lack of specificity was caused by MRI findings suggesting nuclear and annular degeneration in a few histologically normal disks. As disk degeneration almost always precedes disk herniation, normal MRI findings generally confirm the absence of disk herniation at that site.\(^\text{28}\)

MRI is helpful in the classification of disk herniation as extrusion, protrusion, or bulge.\(^\text{28,32}\) Disk extrusion (Hansen’s type I IVDD) is defined as complete rupture of the annulus fibrosus with translocation of the nucleus pulposus into the vertebral canal.\(^\text{28,32}\) Disk protrusion (Hansen’s type II IVDD) is caused by rupture of the inner layers of the annulus fibrosus, partial displacement of the nucleus into the disrupted annulus, and annular hypertrophy.\(^\text{28,32}\) Disk bulge is defined as symmetrical hypertrophy of the annulus fibrosus.\(^\text{28,32}\) Additional MRI findings suggesting intervertebral disk herniation include fragmentation of disk material and displacement of the adjacent epidural fat.\(^\text{51}\) Intravenous (IV) contrast material can be used to help differentiate scar tissue, granulation tissue, and residual disk material in dogs with previous surgery.\(^\text{26}\)
MRI has several advantages in the diagnosis of intervertebral disk herniation. In addition to demonstrating subtle degenerative changes in the intervertebral disk, it provides more detailed localization of extruded disk material than myelography. It also allows for assessment of soft tissue structures such as the spinal cord parenchyma and ligaments, helping to determine prognosis. Another advantage of MRI is the avoidance of complications associated with myographic contrast agents. Disadvantages include limited availability and high cost.

Cerebrospinal Fluid Evaluation
Cerebrospinal fluid (CSF) evaluation can rule out meningomyelitis before myelography or surgery. Disk herniation can be an incidental finding in neurologically normal animals or those with myelitis. Additionally, myelography may exacerbate neurologic abnormalities in dogs with meningomyelitis. The mild changes typically seen with disk herniation are generally not helpful in differentiating among possible causes of noninfectious, noninflammatory, focal central nervous system disease. Elevations in CSF leukocyte counts are most pronounced in acute, severe cases of disk herniation at 5 days or fewer after onset, but even in these cases it is rare to see counts greater than 5/μL or protein values exceeding 29.75 mg/dL in samples acquired from the cerebellomedullary cistern. Both leukocyte counts and protein levels are usually higher in samples acquired from the lumbar cistern than in those from the cerebellomedullary cistern. Median CSF leukocyte counts and protein levels after lumbar cistern sample acquisition in dogs with acute, severe myelopathy secondary to intervertebral disk herniation have been reported at 5/μL and 419 mg/dL, respectively. CSF samples are usually obtained in conjunction with myelography and are seldom associated with serious side effects.

Definitive Treatment
Nonsurgical Management
The traditional cornerstone of nonsurgical treatment of IVDD is strict cage confinement for 4 to 6 weeks. Owner compliance is critical if conservative management is to succeed. Strict cage rest should be clearly defined, and owners should be advised of the risks of failure to follow instructions. Owners must also monitor for dysuria or progressive neurologic signs. Appropriate analgesia is important. Severely, acutely affected dogs are not ideal candidates for nonsurgical treatment but may recover if IV fluid therapy and injectable analgesics are used with cage rest during hospitalization. Oral analgesics (e.g., tramadol) are beneficial for at-home management. Antiinflammatory doses of prednisone or NSAIDs may also be helpful in keeping the dog comfortable and minimizing disk inflammation. Acupuncture has been described but has not been proved beneficial.

Surgical Treatment
Surgery decompresses the spinal cord and removes herniated disk material. This is accomplished by a dorsal or dorsolateral approach to the vertebra and hemilaminectomy, pediculectomy, or dorsal laminectomy. Advanced imaging (myelography, CT, or MRI) and surgery are generally performed during the same anesthetic period. Meaningful comparisons among surgical procedures have not been performed. Hemilaminectomy involves the removal of the articular facets, lamina, and pedicle. Dorsal laminectomy typically involves removal of the spinous process, lamina, and (poten-
Pediculectomy is the removal of the pedicle with preservation of the articular facets. Pediculectomy has also been described as minihemilaminectomy and modified lateral decompression.

Hemilaminectomy offers a few potential benefits over dorsal laminectomy. Herniated disk material may be more accessible for removal. Formation of a laminectomy membrane (cicatrix) may be less likely, although this occurred in only two of 187 dogs treated by dorsal laminectomy in one study. One report comparing hemilaminectomy with dorsal laminectomy for the treatment of disk extrusion in dachshunds found a significantly improved outcome with hemilaminectomy. Survey radiography, with or without myelography, was used for surgical localization. Forty of 47 dogs (85%) treated with hemilaminectomy and 24 of 51 dogs (47%) treated with dorsal laminectomy underwent prior myelography, an inconsistency that makes it difficult to interpret the differences between treatment groups. This study highlights the need for advanced imaging to confirm the location of disk herniation.

Lateral corpectomy has been described as a treatment for chronic disk herniation in dogs. This involves the creation of a slot in the vertebral body, ventral to the intervertebral foramen. The slot is 25% of the length of each vertebra, centered over the disk. The width is about 50% of the vertebra, and the depth is about 50% of the height of the vertebral body. The pedicle and lamina remain intact. Possible advantages of this technique include enhanced removal of herniated disk material with minimal spinal cord manipulation. Disadvantages include possible destabilization, fractures, and the technical expertise required. A successful outcome was reported in 14 of 15 chronically affected dogs treated by lateral corpectomy. We view this technique with caution, as benefit compared with traditional techniques has not been assessed, and biomechanical evaluation was not performed to determine potential instability, particularly when combined with facetectomy as the investigators suggest.

Other Techniques

Durotomy has been shown experimentally to improve functional spinal cord recovery when performed immediately after spinal cord trauma. The potential therapeutic benefit of durotomy was lost after 2 hours postinjury in experimental models. Several surgeons have performed durotomy in dogs with absent deep nociception for potential therapeutic and prognostic benefit. It has been shown experimentally in dogs that adhesions are formed between the durotomy site and the spinal cord 16 weeks postoperatively, but the clinical significance of this finding is unknown. A recent study comparing deep nociception–negative dogs treated with hemilaminectomy alone versus those treated with hemilaminectomy plus durotomy found no difference in outcomes. The prognostic value of durotomy remains uncertain. To our knowledge, there are no data comparing gross surgical findings of myelomalacia with histopathology or clinical outcome.

A number of materials have been applied to the laminectomy site as a barrier to prevent adhesion formation. Autologous fat grafts have been demonstrated to be more effective than absorbable gelatin foam, cellulose mesh, trimacinolone suspension, polyethylene oxide/polybutylene terephthalate copolymer, and untreated controls for preventing epidural and peridural adhesions. One study found that...
both free fat grafts and cellulose membranes were partially effective in preventing laminectomy membrane formation. This study, which used a dog dorsal laminectomy model, also found a significant increase in neurologic deficits and spinal cord compression on histopathology in the sites treated with fat grafts; this was thought to be caused by migration of the fat graft into the spinal canal during the first 6 postoperative hours. However, there does not seem to be a benefit to using a pedicle versus a free fat graft. Early evaluation of a hyaluronic acid sheet is promising, and this product seems superior to absorbable gelatin foam and hyaluronic acid gel.

Autologous olfactory glial cell transplantation may benefit both human and canine spinal cord injury patients in the future. It has been shown that intraspinal transplantation of autologous olfactory glial cells in dogs is safe and reliable. These cells were harvested from the olfactory bulb using a transnasal approach and grown in cell culture for 3 weeks before transplantation into the spinal cord via dorsal laminectomy, midsagittal myelotomy, and injection of cell culture medium containing suspended cells. Similar procedures have been shown to improve functional outcome in rats following experimental spinal cord injury.

Fenestration
Fenestration is the excision of the nucleus pulposus through a surgically created window in the annulus. This is usually done at the time of decompressive surgery. Fenestration can be performed at the site of decompression and other sites throughout the vertebral column. Fenestration has been used for both therapeutic and prophylactic therapy, and is accomplished via ventral, dorsal, or lateral approaches. The efficacy of fenestration may vary with the amount of nucleus removed, which depends on patient factors and surgical technique. A recent retrospective study found that herniation recurrence at sites of fenestration was decreased. However, there was no decrease in overall recurrence rates, and the authors concluded that fenestration could have a destabilizing effect and promote disk herniation at adjacent sites. Indeed, in a cadaver model, fenestration significantly destabilized the vertebral column in response to lateral bending.

Nonetheless, arguments for fenestration include a potentially decreased likelihood of recurrence. Arguments against fenestration include lack of proven efficacy in decreasing overall recurrence rates, longer operative time (increasing client cost, risk of wound infection, and anesthesia-related side effects), iatrogenic vertebral column instability, and numerous other possible complications.

Percutaneous alternatives to surgical disk fenestration have been reported, including chemonucleolysis with collagenase, partial percutaneous diskectomy, and percutaneous laser ablation with a holmium:yttrium–aluminum–garnet laser. None of these procedures has demonstrated efficacy in a controlled clinical trial, and they have limited availability and occasional complications.

Prognosis
Nonsurgical Management
Little is known about IVDD prognosis with conservative therapy, and many studies on this subject are older and used questionable treatment modalities (e.g., parenteral vitamin E, selenium) and research methods. One report described successful outcomes (ambulation, urinary continence) in nearly 50% of conservatively treated paraplegic dogs; the nociception status was not noted. Another report described success (ambulation) in about 40% of paraplegic dogs with absent nociception. The remaining 60% of patients died or were euthanized, and return of ambulation without deep nociception (“spinal walking”) was not described. One study reported a 51% success rate for medical management of intervertebral disk herniation in nonambulatory dogs compared with 82% for surgical management.

Surgical Treatment
Patients with Intact Deep Nociception
Successful surgical outcomes in dogs with intact deep nociception range from 72% to 100%. Dogs with back pain alone have an excellent prognosis: in one report, 24 of 25 dogs with back pain alone improved following fenestration and (in most cases) decompressive surgery. Extensive epidural hemorrhage may be an indication for extensive surgical decompression but does not seem to negatively affect outcome. Two
recent studies found no difference between dogs with lesions causing upper and lower motor neuron pelvic limb signs.85,86

In a report describing the prognostic value of MRI in paraplegic dogs, 65% of dogs with intact deep nociception did not have an area of spinal cord parenchymal hyperintensity greater than the length of the second lumbar (L2) vertebra on T2-weighted images (a finding that indicates spinal cord edema).34 All of these dogs had successful surgical outcomes. In addition, 13 of 17 dogs (76%) with intact deep nociception and an area of spinal cord parenchymal hyperintensity greater than the length of L2 on T2-weighted MRI had positive outcomes. The overall surgical success rate for dogs with intact deep pain perception was 92%. Another report found that the height and length of intervertebral disk extrusion as measured on MRI had no prognostic value.33 Extruded disk material may lie immediately adjacent to the disk or migrate cranially or caudally in the epidural space, and the degree of dispersion does not seem to affect preoperative neurologic status or surgical outcome.35

Mean time from surgery to ambulation in nonambulatory dogs has been reported at 10 to 13 days in study populations of small-breed dogs with intact deep nociception.11,82 Another study population composed entirely of large-breed dogs (93% of which had intact deep nociception) had a mean time to ambulation of 7 weeks.10 Most of these dogs (62%) were walking within 4 weeks of surgery.10 Another 50% were walking within 12 weeks of surgery.10 Time to ambulation increased with patient weight and age.10 The time to recovery of pelvic limb function was similar in 33 nonambulatory paraparetic dogs and 19 paraplegic dogs with intact deep nociception.85 All of these dogs (regardless of group) were weight-bearing with protraction (forward advancement) of the pelvic limbs more than 50% of the time within 12 weeks of surgery.85

Patients Without Deep Nociception
Paraplegic dogs in which deep nociception is absent have a 25% to 78% chance of recovery to ambulation.13,42,55,56,86–88 This wide range probably reflects different means of assessing deep nociception, low case numbers, different exclusion criteria, and different criteria for a successful outcome. A recent report describing surgical success in 78% of paraplegic dogs without deep nociception evaluated deep nociception by applying hard finger pressure to the digits; in our view, this method only tests superficial nociception.86 Other studies required the application of hard pressure with forceps or a similar instrument to digital or metatarsal bones and reported lower percentages of recovery to ambulation.13,55,88

Several recent studies reported recovery to ambulation in 58% to 64% of surgically treated, deep nociception–negative dogs.13,34,87,88 About 33% of such dogs that return to ambulation have intermittent fecal or urinary incontinence.88 Even with agreement on testing methods, assessment of nociception in dogs remains subjective.86

It has been postulated that imaging findings suggesting myelomalacia may correlate with a poor outcome.34,89 Myelographic evidence of myelomalacia includes spinal cord swelling and contrast medium infiltration into the spinal cord.90 The appearance of contrast medium within the spinal cord is not pathognomonic for myelomalacia; it may be iatrogenic or represent chronic pathology (e.g., syringohydromyelia).90

Information regarding the relationship between myelographic findings of spinal cord swelling and prognosis is conflicting. In two studies,13,87 spinal cord swelling was measured by calculating a ratio of the length of the loss of myelographic contrast column to the length of the second lumbar vertebra (L2). A ratio of more than 5 was significantly related to poorer prognosis in one study, but no difference was seen in the other. These studies differed in exclusion criteria and outcome measures. The study that showed a significant difference included only dogs with clinical signs of less than 24 hours in duration, and a positive outcome was defined as return of voluntary motor function.87 The other study included dogs with clinical signs that exceeded 24 hours in duration, and it defined a successful outcome as restoration of nociception, ambulation, and urinary continence.13

MRI provides important prognostic information for dogs with absent nociception.34 Parenchymal hyperintensity on T2-weighted images suggests spinal cord edema, whereas parenchymal hypointensity on T2-weighted gradient echo (T2*) images is suggestive of spinales.85

Canine Thoracolumbar IVDD: Diagnosis

QuickNotes
Survey radiography is helpful in ruling out diagnostic differentials such as diskospondylitis, vertebral fracture, luxation, infection, or neoplasia.
nal cord hemorrhage, particularly in dogs with absent nociception. These findings—located diffusely, cranially, and caudally to a compressive extradural lesion—may correlate grossly to ascending/descending myelomalacia. In a study in which 46% of deep nociception-negative dogs did not have an area of spinal cord parenchymal hyperintensity greater than the length of L2 on T2-weighted MRI, all of the patients had successful outcomes. In contrast, only 31% (five of 16) of deep nociception-negative dogs with an area of spinal cord parenchymal hyperintensity greater than the length of L2 on T2-weighted MRI had successful outcomes. In this study, dogs with an area of T2 hyperintensity in the spinal cord had increased odds of an unsuccessful outcome compared with dogs lacking T2 hyperintensity in the spinal cord (odds ratio: 29.87; 95% confidence interval: 3.47 to 256.95). One dog in another study did not have MRI findings suggesting spinal cord edema but subsequently developed myelomalacia.

Other prognostic indicators in deep nociception-negative dogs have been studied. Longer duration between loss of deep nociception and surgery seems to correlate with poorer prognosis, but definitive evidence is lacking. The surgeon usually does not know when deep nociception was lost, and the functional outcome of dogs treated surgically more than 48 hours after the loss of deep nociception has not been rigorously studied. Therefore, aggressive diagnostic measures are warranted in dogs in which nociception is absent for longer than 48 hours. In one study, dogs that deteriorated to nonambulatory status in less than 1 hour had poorer outcomes compared with dogs that deteriorated more slowly. Other investigators have found that dogs that regain deep nociception within 2 weeks after surgery have a good prognosis. The converse is also true: dogs that do not recover deep nociception within 2 weeks after surgery are less likely to recover. Subdural hemorrhage seen at surgery may be associated with a negative outcome. As in dogs with intact deep nociception, increased age and body weight may prolong recovery to ambulation.

Recurrence
Early reports probably underestimated the recurrence of disk herniation due to short duration of follow-up and reliance on owner surveys instead of neurologic examination. A report of postsurgical recurrence with a mean follow-up duration of 44.8 months suggests that about 20% of dogs exhibit pain and neurologic deficits. Dachshunds may have higher postsurgical recurrence rates of disk herniation than other breeds. The number of opacified intervertebral disk spaces increased the risk of recurrence by 1.4 times in non-dachshund breeds. Thus, dogs with five or six opacified disks at the time of surgery had a recurrence rate of 50%. Reported recurrence rates in nonsurgically managed dogs are as high as 40% over the ensuing 4 years.

Postoperative Care
The goals of postoperative care are to decrease the likelihood and severity of concurrent disease processes. In addition to urinary bladder management, priorities of postoperative care include maintaining appropriate analgesia and hydration status, avoiding diseases of recumbency (e.g., pressure sores), monitoring the surgical wound, and treating myelography-associated seizures. Many clinicians use gastroprotective drugs, although their efficacy in minimizing corticosteroid-induced gastroenteritis is unclear. Ice can be applied to the wound, at least for the first postoperative day. Any dog that deteriorates neurologically during the postoperative period should be viewed as a candidate for further imaging studies to determine whether additional surgery is indicated.

Physical rehabilitation offers potential benefits in the functional recovery of the dog with thoracolumbar intervertebral disk herniation. A five-step protocol has been suggested for patients with thoracolumbar myelopathy. Overzealous physical rehabilitation can be detrimental to dogs with vertebral column instability or unresolved spinal cord compression, causing further spinal cord injury. The protocol initially calls for cold-packing the surgical incision, passive range-of-motion exercises, and massage of affected limb muscles (step 1). Once the patient is able to bear weight, standing exercises and neuromuscular stimulation are recommended (step 2). As limb motion returns, weight-shifting exercises, walking (assisted and/or treadmill), and swimming can be incorporated (step 3). Steps 4 and 5 include sit-to-stand exercises, balance and coordination activities, and increased intensity of walking and swimming.
Swelling and discharge are the most common surgical wound complications, occurring in 7.5% and 5.3% of dogs, respectively, in a retrospective study. Other complications (occurring in 1.5% of cases each) included bleeding from the incision, seroma formation, and partial or complete dehiscence. These complications generally did not warrant antibiotic use or surgical wound closure, although two of 264 dogs required surgical wound management.

Urinary Bladder Management

Urinary bladder dysfunction is a common preoperative and postoperative problem with IVDD. The nature of the dysfunction depends on lesion location and severity, degree of pelvic limb motor function, and loss of nociception, ranging from mild increases in residual volume to distention with overflow. Consequences of urinary bladder dysfunction include bacterial cystitis, pyelonephritis, bladder atony, and bladder fibrosis with long-term distention.

The canine urinary bladder is innervated by the pelvic, pudendal, and hypogastric nerves. The pelvic nerve arises from the sacral spinal cord segments, supplying the detrusor (smooth) muscle with parasympathetic motor and sensory innervation. Preganglionic and postganglionic parasympathetic neurons synapse at the pelvic ganglia, within the wall of the bladder. The pudendal nerves arise from the sacral spinal cord segments and provide motor and sensory function to the skeletal muscle of the external urethral sphincter, motor function to the perineal musculature, and sensory function to the urethra. The hypogastric nerve arises from the first through fourth lumbar spinal cord segments to provide adrenergic innervation to the internal urethral sphincter, pelvic (parasympathetic) ganglia, and detrusor muscle. Sympathetic input to the pelvic ganglia may inhibit parasympathetic activity during urine storage. The hypogastric nerve also contains sensory fibers from the bladder wall involved in nociception. Descending motor information includes inhibitory and excitatory upper motor neuron input to the detrusor muscle and urethral sphincters.

Normal urine storage and voiding involves both reflexive and conscious input. Urine storage is accomplished by β-mediated detrusor muscle relaxation, α-mediated internal urethral sphincter tone, and cholinergic-mediated external urethral tone. During voiding, adrenergic input to the bladder is decreased, resulting in increased detrusor muscle tone and decreased internal urethral sphincter tone. Cholinergic stimulation via the pelvic and pudendal nerves results in detrusor muscle contraction and external urethral sphincter relaxation.

In upper motor neuron bladder syndrome, the sacral spinal cord segments supplying the pelvic and pudendal nerves remain intact. The communication of ascending and descending information with the brain is decreased or lost. This results in urinary incontinence with increased detrusor muscle and external urethral sphincter tone, which clinically presents as a large, firm bladder that is difficult to express and may overflow as intraluminal pressure overwhelms the urethral sphincters.

Pharmacologic intervention targets relaxation of the urethral sphincters (TABLE 1). Drugs may include α-adrenergic antagonists (e.g., phenoxybenzamine, prazosin), skeletal muscle relaxants (e.g., diazepam, dantrolene) may be helpful in decreasing external urethral tone. In dogs with bladder atony, bethanechol may be used in addition to an α-adrenergic antagonist after therapeutic levels of the latter have been reached. Phenoxybenzamine has a slow therapeutic onset and may take several days to demonstrate clinical efficacy.

In dogs with thoracolumbar intervertebral disk herniation and lower motor neuron bladder syndrome, the sacral spinal cord segments or nerve roots are dysfunctional. The first through fourth lumbar spinal cord segments or hypogastric nerve may remain intact. This results in the loss of local reflexes that maintain detrusor muscle and external urethral sphincter tone during urine storage. Some bladder nociceptive information (via the hypogastric nerve) may remain intact. As with upper motor neuron bladder syndrome, communication with the brain is decreased or lost. This results in decreased detrusor muscle and external urethral sphincter tone, which clinically presents as a large, soft bladder that is easy to express and overflows with minimal intraluminal pressure. Pharmacologic intervention targets the detrusor muscle and may include cholinergic agonists (e.g., bethanechol).

QuickNotes
The presence or absence of deep nociception has important prognostic ramifications; 58% to 64% of dogs treated surgically within 24 hours of the loss of deep nociception recover the ability to walk.
mediated constriction of the internal urethral sphincter may remain intact, an α-adrenergic antagonist may be helpful.2

**Urinary Bladder Evacuation**

Urinary bladder distention must be prevented in dogs with urine retention.36,105 This can be accomplished by indwelling urinary catheter placement, manual expression, or intermittent catheterization.5,96 Intermittent urinary evacuation (via catheter or expression) has been advocated as a means of avoiding the increased risk of urinary tract infection (UTI) resulting from an indwelling urinary catheter.5,96,113−115 The placement of an indwelling urinary catheter is advantageous in dogs not amenable to intermittent urine evacuation. For example, a large, nonambulatory, female dog with a bladder that is difficult to express may be best treated with an indwelling urinary catheter. Other candidates include aggressive dogs and dogs with lower motor neuron bladder syndrome (to prevent leakage and scalding). It may be best to avoid systemic antibiotics in dogs with indwelling urinary catheters, as the risk of acquiring an antibiotic-resistant UTI may be increased.114–116 These dogs should be monitored closely for the development of a UTI. An exception would be a dog with pyelonephritis secondary to urine retention and cystitis. Antiinfective catheter materials, antibiotics, and antiseptic agents do not seem to be effective in the long-term prevention of UTI in the setting of spinal cord injury and urine retention.117 For most dogs, urinary bladder evacuation by expression or intermittent catheterization is feasible and advantageous.3,96 The necessary frequency of evacuation depends on the completeness of the previous evacuation and volume of urine produced.96 It has been suggested that the urinary bladder should be evacuated every 4 to 6 hours initially, with the frequency adjusted as needed.96 We feel that this may be excessive and that bladder expression every 6 to 8 hours may be more appropriate. Ultrasonography can help to determine the optimum frequency and efficacy of bladder evacuation.102 Technical difficulties involved in intermittent catheterization of female dogs preclude widespread use of this technique.3

**Urinary Tract Infection**

Bacterial UTI may predominate in a single site (e.g., kidney, urinary bladder) or multiple sites.4 Predisposing factors for UTI in dogs with spinal cord injuries may include incomplete voiding, elevated intravesical pressure, catheter use, and preexisting medical conditions (e.g., cystic calculi, hyperadrenocorticism, diabetes mellitus).5,118 Dogs may not have any clinical signs of UTI or may develop pollakiuria, stranguria, dysuria, inappropriate urination, hematuria, pyuria, proteinuria, fever, septicemia, abdominal pain, or renal failure.4 Many of these signs overlap with clinical signs of neurogenic bladder dysfunction. UTI is best diagnosed by urine culture and susceptibility testing.4

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**QuickNotes**

Although the prognosis is poorer beyond 24 hours after the loss of deep nociception, some dogs can still recover, warranting the use of aggressive diagnostic measures.

**TABLE 1** Pharmacotherapy for Neurogenic Bladder Dysfunction106,107,110,111

<table>
<thead>
<tr>
<th>Drug</th>
<th>Dosage</th>
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<tr>
<td>Phenoxybenzamine</td>
<td>0.25–0.5 mg/kg PO q12–24h or 5–15 mg (total dose) PO q12–24h</td>
<td>Decreases internal urethral sphincter tone. Therapeutic effects take days. May cause hypotension.</td>
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<tr>
<td>Prazosin HCL</td>
<td>1 mg/15 kg PO q8–24h</td>
<td>Decreases internal urethral sphincter tone. May cause marked hypotension.</td>
</tr>
<tr>
<td>Bethanechol chloride</td>
<td>2.5–25 mg (total dose) PO q8h</td>
<td>Enhances detrusor muscle contraction. May cause vomiting, diarrhea, excessive salivation, and anorexia.</td>
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</table>
Antibiotics are the mainstay of UTI treatment. The antibiotic should reach urine concentrations that exceed the minimum inhibitory concentration by at least fourfold. Route of administration, side effects, and cost are also important considerations. The duration of therapy in dogs with UTI secondary to neurogenic bladder dysfunction should be longer than that recommended for a simple UTI. Some experts advocate a 3- to 6-week course of antibiotics for persistent UTI. We recommend repeating the urine culture 2 to 3 days after the completion of antibiotic therapy. Using antibiotic therapy without addressing predisposing factors is largely unsuccessful, with most UTIs recurring in less than 8 weeks. Therefore, in dogs that do not regain urinary continence, periodic urinalysis and culture should be performed.

A recent study reported an overall UTI incidence of 27% (diagnosed by positive culture) in dogs treated surgically for intervertebral disk extrusion. Interestingly, UTI developed in 12% of dogs that were able to urinate voluntarily. Statistically significant factors associated with an increased likelihood of UTI included female sex, urinary incontinence, nonambulatory status, prolonged hypothermia during anesthesia, and lack of perioperative antibiotic administration. Among dogs that were urinary incontinent or nonambulatory, the prevalence of UTI increased with age. Dogs undergoing intermittent urinary catheterization tended to have a decreased incidence of UTI compared with those evacuated by manual expression. However, no significant differences could be determined between these groups because intermittent catheterization was only performed in male dogs. Method of evacuation had no effect on prevalence of UTI when sex was taken into account.

Although pyelonephritis is rare in dogs with intervertebral disk herniation, it has life-threatening implications. Pyelonephritis was reported in six of 187 dogs in one large retrospective study. Clinical signs include fever, lethargy, anorexia, vomiting, polyuria, polydipsia, and abdominal pain. Clinical pathologic abnormalities consistent with pyelonephritis include neutrophilic leukocytosis, azotemia, pyuria, and isosthenuria. Dogs meeting these criteria may require ultrasonographic evaluation of the kidneys. Because many of these findings are nonspecific (e.g., stress leukogram, prerenal azotemia, corticosteroid-induced isosthenuria), we suspect that pyelonephritis is underdiagnosed in dogs with urine retention secondary to intervertebral disk herniation. It is unclear whether dogs with IVDD benefit from the treatment of asymptomatic bacteriuria, but current recommendations are to treat with antibiotics as for symptomatic UTI. A long-term strategy involving a weekly oral cyclic antibiotic administration program appears promising.

**Surgical Failure**

In the event of an unsuccessful surgical outcome, many pet owners are able to successfully care for a paraplegic dog. Large dogs are more difficult to manage than small dogs because of the increased physical demands of nursing care, the likelihood and severity of pressure sores, and difficulty expressing the urinary bladder. A variety of carts are available to assist in ambulation. Recurrent UTI may become problematic in some dogs. "Spinal walking" has been reported in some dogs that did not regain deep nociception after surgery and that maintained the activity for at least 3 weeks. This involves the use of pelvic limb reflexes, trunk muscles, and any remaining upper motor neurons. Most of these dogs do not recover urinary and fecal continence.

**Conclusion**

Despite recent research, the efficacy of many common therapies remains unknown and controversial. In practices that do not perform spinal surgery, the decision of when to refer is of paramount importance.

**References**

53. Park MA, Jor A. Durotomy and saline perfusion in spinal cord trauma. JAVMA 1975;11:412-413.
1. Which finding suggests intervertebral disk herniation on survey radiography?
   a. widened intervertebral disk space
   b. remodeling of the bone surrounding the intervertebral foramen
   c. mineralized material within the plane of the vertebral canal
   d. widening of the space between the articular facets

2. Which statement is true regarding survey radiography?
   a. It is highly sensitive for disk herniation.
   b. It correlates well with surgical findings.
   c. It can help to rule out diskospondylitis.
   d. It can demonstrate spinal cord compression.

3. A common adverse effect of myelography is
   a. acute hepatic failure.
   b. seizures.
   c. worsening of pancreatic islet cell function.
   d. thrombocytopenia.

4. Myelographic findings suggesting extraspinal cord compression include
   a. widening of the contrast column in a “golf tee” appearance.
   b. contrast medium infiltration into the spinal cord.
   c. a heterogeneous hyperattenuating mass on transverse views.
   d. dorsal deviation of the ventral contrast column on the lateral view.

5. On T2-weighted MRI, the normal canine disk has a
   a. clear distinction between the annulus and nucleus.
   b. symmetric annulus extending dorsally into the vertebral canal.
   c. round area of low signal intensity corresponding to the nucleus pulposus.
   d. hyperintense annulus fibrosus relative to the nucleus pulposus.

6. CSF evaluation is
   a. highly specific for IVDD.
   b. helpful in ruling out meningoymetitis.
   c. expected to show increased protein levels in samples obtained from the cerebellomedullary cistern compared with the lumbar cistern.
   d. an unnecessary risk to the patient with suspected intervertebral disk herniation.

7. Surgical outcome for repair of disk herniation
   a. is good to excellent in dogs with absent deep nociception.
   b. is better for dogs with absent deep nociception that deteriorated to nonambulatory status acutely (in less than 1 hour) than for those that deteriorated more slowly.
   c. is principally related to the presence or absence of the withdrawal reflex.
   d. has a success rate of 58% to 64% in dogs with absent deep nociception.

8. The presence of an area of spinal cord hyperintensity on T2-weighted MRI greater than or equal to the length of the L2 vertebral body
   a. is a negative prognostic indicator.
   b. is seen more commonly in dogs with intact deep nociception than in those with absent deep nociception.
   c. does not provide meaningful prognostic information.
   d. implies an area of altered biomechanical function.

9. Which procedure is most appropriate for the treatment of thoracolumbar disk herniation with severe myelopathy (absent deep nociception)?
   a. partial percutaneous disectomy
   b. acupuncture
   c. hemilaminectomy
   d. chemonucleolysis

10. Which statement regarding urinary bladder physiology is true?
    a. Urine storage is accomplished by α-mediated detrusor muscle relaxation, β-mediated internal urethral sphincter tone, and cholinergic-mediated external urethral tone.
    b. Adrenergic input to the bladder is reduced during voiding, resulting in decreased detrusor muscle tone and increased internal urethral sphincter tone.
    c. Cholinergic stimulation via the pelvic and pudendal nerves results in detrusor muscle contraction and external urethral sphincter relaxation during micturition.
    d. The external urethral sphincter is made up of smooth muscle.