Peripheral Nerve Sheath Tumors (NST)
Peripheral nerve sheath tumors (PNST) have a low incidence in dogs. PNST are benign or malignant mesenchymal tumors and they originate from periaxonal schwann cells (schwannoma) and fibroblasts (neurofibroma/neurofibrosarcoma). PNST terminology includes neurinoma, schwannoma, neurofibroma, neuro(fibro)sarcoma, neurilemmoma, neurogenic sarcoma, and neurofibromatosis. PNST may occur in every large or small nerve in the body but will only receive attention from the orthopedic surgeon or the neurosurgeon when the spinal cord, cauda equina or main peripheral nerves of limbs are involved. Although most PNST grow outside the spinal canal they may extend along the pathways of the nerve roots via the intervertebral foramen into the spinal canal where they may develop an extradural or intradural component (Figure 1). Clinical signs include severe, unexplained, and intractable pain, thoracic or pelvic limb lameness, profound isolated muscle atrophy, monoparesis, ataxia and proprioceptive deficits. Early diagnosis and surgery enables complete tumor resection sparing the limb. PNST have a high rate of recurrence, and the overall prognosis is considered poor. Since PNST usually lead to lower motor neuron dysfunction, electromyography is very useful to identify the nerve roots involved.

At the Utrecht University nine dogs were diagnosed with nerve sheath tumor. The dogs (3 Golden Retrievers, 2 German Shepherd dogs, English Cocker Spaniel, Bouvier, Irish Terrier, Labrador Retriever) ranged in age from 14 months to 10 years and were referred for limb lameness, monoparesis, severe muscle atrophy, and (periodic) severe limb or axillary pain unresponsive to medical treatment. Pain was localized in the upper cervical area (1 dog), in the lower cervical area and axillary region (4 dogs), in the lower back region (2 dogs), and in the distal limb (2 dogs). Electromyography was performed in 4 dogs and showed denervation potentials of the muscles of the affected limb. In all dogs radiography was not diagnostic. Computed tomography (CT) was performed in 5 dogs, magnetic resonance imaging (MRI) in 4 dogs, and ultrasonography in 2 dogs. Imaging revealed a left paravertebral NST at C1-C2 (1 dog), a brachial plexus tumor at C6-C7-T1 (4 dogs), a spinal nerve S1 tumor (2 dogs), a tibial nerve NST (1 dog) and a median nerve NST (1 dog). Seven dogs underwent surgical exploration and tumor resection sparing the limb. Histopathological examination of surgical specimens revealed a schwannoma (spinal cord, brachial plexus), a low-malignant neurofibrosarcoma (S1 nerve root, median nerve) and a myxosarcoma (tibial nerve). Follow up examination showed a recurrence in 3 dogs at 2 to 5 months after surgery. The dogs that underwent resection of NST of median nerve and tibial nerve showed no significant neurological deficits following surgery due to overlapping innervation of other distal limb nerves.

Spinal Cord Tumors
Spinal cord tumors become a significant differential diagnosis once the more common problems such as disc disease and trauma have been eliminated. Clinical signs may begin as nonspecific discomfort, followed by progressive neurological deficits and evidence of spinal pain. Marked muscle atrophy is often present caudal to the lesion. Sudden deterioration in neurological status or sudden increase in spinal pain is possible. In case of extradural or intradural spinal cord tumors, the tumor mass may grow slowly which gives unaffected spinal parenchyma time to compensate. Therefore clinical signs may only become apparent when considerable tumor mass has already filled up the spinal canal, especially in the cervical spine. PNST involving the brachial plexus or lumbosacral plexus may present first as progressive unilateral lameness, and later with spinal cord dysfunction when the vertebral canal is invaded. Diagnosis of spinal cord tumors relies on electromyography, radiography, myelography, and advanced imaging techniques such as (spiral) CT and/or MRI. Electromyography may be helpful to determine the neurological localization for further imaging. Survey radiographs rule out discospondylitis or may show metastasizing tumors to vertebral bodies. In most cases of spinal neoplasia radiographs result in negative findings. Myelography provides information about the location of the tumor and also its position in the vertebral canal relative to the dura mater (extra- or intradural). A cerebrospinal fluid (CSF) sample taken when a myelogram is performed may occasionally identify neoplastic cells. In case the spinal cord tumor is within reach, a needle aspiration biopsy may be attempted.

CT and especially MRI are the imaging tools of choice for spinal cord neoplasia. CT and MRI allow direct assessment of the spinal cord itself instead of indirect visualization, like with myelography. CT and
MRI also allow for differentiation between normal spinal cord parenchyma and the neoplastic tissue. Based on the CT and MR images, neurosurgery can be planned using the best approach and exposure for precise dissection between unaffected spinal cord parenchyma and spinal cord neoplasia. Based on imaging findings, spinal cord tumors are classified in extradural tumors, intradural-extramedullary tumors and intramedullary tumors (Figure 1). Extradural tumors lie outside the dura mater, i.e., vertebral body neoplasia (osteosarcomas, fibrosarcoma, chondrosarcoma, myeloma) and metastasized extradural tumors (carcinoma, sarcoma, melanoma). In cats, the most common extradural tumor is lymphoma that may also affect the spinal cord itself (intradural localization). Intradural-extramedullary tumors lie within the dura mater but outside the spinal cord parenchyma. The most common are meningiomas and nerve sheath tumors (neurofibroma, neurofibrosarcoma, schwannoma). Intradural tumors (glioma, astrocytoma, ependymoma or metastasizing tumors, e.g., lymphosarcoma) occur within the spinal cord parenchyma.

Surgical intervention in primary spinal cord neoplasia may be considered 1) to collect tissue for histopathological diagnosis or 2) to improve spinal cord function by tumor removal and decompression. Surgical treatment is considered appropriate in meningiomas and nerve sheath tumors. In case of intramedullary tumors there is usually not a sharp border between neoplastic tissue and normal spinal cord parenchyma and surgical resection is considered palliative. Surgical approaches must be tailored to the location of the tumor and, ideally, are planned using the information available by CT and MRI. Dorsal laminectomy is recommended in most patients with a spinal cord neoplasia in the cervical (C1-C7), thoracic (T1-T10) and thoracolumbar (T11-L3) area. The ‘ventral slot’ approach in the cervical area is not useful since access to the spinal cord and nerve roots is limited. Also, the venous sinuses hamper an undisturbed, dry surgical field. In the thoracolumbar (T11-L3) area dorsal laminectomy will lead to instability, therefore following tumor removal, the vertebral stability must be restored using internal fixation techniques such as Lubra plates or spinal plates. In the caudal lumbar region (L4-L6) and lumbosacral region (L6-S3) a dorsal laminectomy can be performed without additional stabilization. However, if facetectomies are required to gain better access to the spinal canal, spinal fixation is required afterwards. The intradural localization of meningiomas necessitates a durotomy and often also a partial durectomy. The use of surgical magnification (loupes or operating microscope) makes identification of tumor margins easier. Methylprednisolone is administered preoperatively (2-5 mg/kg) to minimize the effects of spinal cord manipulation. Often the neurosurgeon has to weigh the advantages of complete tumor removal including a margin against potential damage to the spinal cord leading to worsening of neurological deficits. Therefore spinal cord neoplasia removal may not be complete and other therapies (chemotherapy and radiation) should be considered as follow up treatment.

Further Reading
Figure 1 1) Extradural, 2) intradural-extramedullary, and 3) intradural-intramedullary localization of nerve sheath tumor and spinal cord neoplasia.