Management of cancers affecting the axial skeleton (i.e. the skull, vertebral column or pelvis), can prove challenging. Due to the proximity of vital structures, it can prove difficult to achieve an appropriate oncologic boundary about the mass necessary for a curative resection.

The advent of coaxial imaging has greatly improved our ability to manage these tumours. By being able to visualise the tumour in three dimensions, surgical planning can be completed with more confidence.

The potential functional impact of surgery needs to be considered alongside the surgical plan. Remarkably, there is good tolerance for considerable resections of the mandible maxilla and calvarium with often only mild to moderate clinical impact. For tumours of the pelvis, the functional impact will be determined by whether amputation is necessary as part of the resection. If amputation is required, clinical function following hemi-pelvectomy should be similar to that following a hindquarter amputation and will be influenced by patient size, fitness and agility. Larger patients may benefit from some supportive walking for the first 3-4 days until they gain confidence and coordination. Surgery may be inappropriate for very large or obese patients, or those with comorbidities affecting limb function in other legs.

There is a compelling argument for the use of customised prosthetics for specific neoplastic conditions of the axial skeleton to allow the potential for functional loss to be overcome. This is particularly true for tumours affecting the mandible, sternum and pelvis. However, case experiences are currently limited in the dog. In humans, customized prosthetics have been used to enable complete en-bloc resection of vertebral tumours.

Other technologic advances that will assist management of axial tumour include stereotactic radiosurgery (SRS). This allows a curative-intent dose of radiation to more precisely delivered to the target, with a reduced risk of injury to adjacent vital structures.

Preoperative planning
Many of the tumours affecting the axial skeleton will have a metastatic potential. Complete staging tests such as three-view thoracic radiographs, complete blood count, serum biochemistry profile, regional lymph node examination is recommended in all cases.

Coaxial imaging with either computed tomography (CT) or magnetic resonance imaging (MRI) is recommended in all cases because they provide superior detail and the cross-sectional perspective aids in planning the surgical approach and resection. Magnetic resonance imaging can provide better soft tissue detail than CT, but there are no currently studies to determine whether either modality is superior for surgical planning.

Surgical Preparation
Major resection of structures about the axial skeleton pose the potential for significant hemorrhage. Severe hemorrhage requiring transfusion or aggressive volume support may arise despite anatomical knowledge and sound surgical technique being followed due to the proximity to large vessels. Preparation of the patient for a potential blood transfusion should be made prior to surgery by performing a cross-match or blood typing as appropriate for blood bank facilities available in the hospital.

Anesthesia management should include consideration for multi-modal preemptive analgesia. This may include systemic opioids, in combination with either a morphine and/or lidocaine epidural. Non-steroidal anti-inflammatory drugs may be used at the discretion of the surgeon and patient co-morbidities. Local
nerve blocks (with bupivacaine) at the time of transection may also be considered. Finally, placement of a wound diffusion catheter may allow provision of local pain relief in the immediate post-operative period.

1 Skull

Skull tumors are uncommon in dogs and very rare in cats. In dogs, the most common skull tumors are malignant and include osteosarcoma and multilobular osteochondrosarcoma (MLO). However, tumors affecting the oral cavity are common, accounting for approximately 6% of canine cancer, and is the fourth most common cancer overall. A variety of benign and malignant tumor types may occur in the mouth. Histological definitions can be confusing, and at times, controversial. In the dog, the following malignant tumors have been described: fibrosarcoma, malignant melanoma, squamous cell carcinoma and osteosarcoma. Benign tumors present the greatest controversy with respect to nomenclature. The term epulis is generally considered a descriptive term, and refers to any tumor or tumor-like lesion on the gingiva.

Surgical excision is the cheapest, most economical and usually most successful treatment modality for tumors of the skull and oral cavity. Management of even benign lesions such as peripheral odontogenic fibroma and peripheral ameloblastoma/acanthomatous epulis requires an aggressive (bone-removing) technique, since simple excision of the gingival epulis alone will be associated with recurrence. Margins of at least 2cm are required about malignant tumours such as squamous cell carcinoma and malignant melanoma, and a compartmental resection should be attempted for fibrosarcoma. Careful surgical planning is required to ensure surgery can be completed safely without compromise to vital organs.

Canine and feline patients usually tolerate extensive resections of large sections of the skull extremely well, with little disruption to quality of life. Despite the fairly radical nature of some of the procedures, clinical recovery is usually rapid with animals generally eating the evening following surgery. Long-term function is excellent, and cosmetics are usually acceptable to the owners. Various commissure advancement and reconstructive techniques are used in some cases to improve the cosmetic appearance.

The prognosis for all benign tumours is excellent, provided a complete margin is obtained. Conservative surgery may result in tumour recurrence, and the need for further surgery.

For dogs with MLO, the prognosis is better for dogs with low histologic grade tumors and complete excision. In one study, 47% of the dogs developed local recurrence at a median time of 797 days and 56% developed metastasis (primarily to the lungs).

2. Vertebrae

A variety of primary tumour types are reported to develop within the bones of the vertebral column. The most common primary tumours are mesenchymal, and include osteosarcoma, chondrosarcoma or fibrosarcoma. Round cell tumours can also develop, with plasmacytoma or multiple myeloma representing about 4% of all vertebral tumours. The vertebrae can also be a site for metastatic bone tumours to develop, particularly for osteotrophic tumours such as carcinoma (mammary, urothelial, prostatic) and osteosarcoma. Multiple vertebral involvement is reported in 25% dogs.

Most dogs will present with evidence of pain and exercise intolerance. The source of pain can be difficult to localise, and may be referred to a limb due to para-spinal pain. Compression of the spinal cord may lead to development of neurological signs of a transverse myelopathy in some patients. Progression is usually slow for a compressive lesion, but acute deterioration may be seen if the vertebrae is sufficiently lytic to be unstable or for a pathologic fracture to develop.

As with other tumours of the axial skeleton, a CT or MRI scan can be essential for surgical planning and staging purposes. Plain radiographs may underestimate the degree of neoplastic involvement and soft tissue extent of the tumour, and will not allow assessment of any spinal cord compression.
Treatment options for vertebral tumours will be influenced by the tumour biology, and include surgery, radiation therapy, and chemotherapy. These treatments may be combined in certain cases. For radiation, careful planning and hyper-fractionated protocols will be required to allow for protection of the spinal cord.

The options for surgical resection will be based on the degree of tumour involvement. Complete, curative-intent resection will be limited by the ability to preserve structural integrity of the vertebrae. Stabilisation may be required, and the strategies for this will need to be carefully planned. In humans, vertebral resection and reconstruction is proving more successful with the advent of customised printed prostheses.

The prognosis for vertebral tumours will be influenced by the neurological status on presentation, and also the neurological tolerance of the resection. Euthanasia will usually be considered due to the disability and pain associated with the local effects of the tumour. In most studies, median survival times of just 3-4 months is reported.

For radiation therapy, outcomes are significantly longer for dogs treated with curative-intent radiation therapy compared to palliative radiation therapy (150 days v 15 days).

3. Pelvis

For the management of tumors affecting the pelvis or soft tissues of the thigh, some variant of hemipelvectomy may be required. Pre-operative surgical planning will help identify which specific anatomical components of the pelvis and associated musculature are affected by the neoplastic process. Amputation is not necessarily required in every case, and functional sparing surgery should be considered wherever appropriate.

Prognosis

Canine patients: Metastatic disease was a common cause of death after hemipelvectomy, occurring in 39/83 (47%) dogs. Taken overall, only about 50% of dogs with malignant mesenchymal tumors (i.e. hemangiosarcoma, osteosarcoma, chondrosarcoma, soft tissue sarcoma) remained alive 1 year after surgery suggesting patient selection and staging is important. On multivariate analysis, there were no factors of significance that were predictive of improved survival or DFI. The median survival times for chondrosarcoma (1232 days), osteosarcoma (533 days) and soft tissue sarcoma (373 days) were not statistically different, with high rates of metastatic disease or local recurrence influencing long-term outcome for all malignant tumors.

Feline tumors. There is limited data on survival of cats following hemi-pelvectomy. In one study, outcomes for 16 cats were reported. Cats had a significantly longer survival time compared with dogs (HR 0.3; \( P = .03; \) 95% CI: 0.11, 0.88) with 75% survival at 1 year. No statistical difference in survival was found between cats with chondrosarcoma, osteosarcoma and soft tissue sarcoma, but individual numbers of each tumour type were low. Clean resection margins were associated with statistically significant improved mean ST (1965 days vs. 198 days, \( P = 0.003 \)). Metastatic disease was less common than in the dog, developing or being suspected in only 2 (12.5%) cats, both with osteosarcoma. The median DFI for local recurrence for all tumour types was 105 days (95% CI: 9, 210 days).