Radiography and ultrasound of the equine neck

Diagnostic imaging of the equine neck is undertaken for a wide variety of conditions. In many cases, radiography is the principal imaging modality, often complemented by ultrasound examination. Common conditions encountered include osteoarthritis, articular process joint osteochondral fragmentation, cervical vertebral malformation ('wobbler'), fractures and numerous soft tissue lesions. The complex three-dimensional anatomy of the region limits interpretation of planar images and, in some cases, cross-sectional imaging (such as computed tomography) may be required. However, careful use of radiography and ultrasound can help clinicians to achieve a diagnosis in many cases, often from combining conventional and lesion-orientated projections with a thorough clinical examination.

https://doi.org/10.12968/ukve.2021.5.4.142

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Key words: nerve | spinal cord | wobbler | osteoarthritis | facet | cervical spine

Lateral radiographs of the neck are relatively easily obtained with a high-powered portable X-ray generator, typically 70 kilovoltage peak (KvP) and 0.15 seconds. However, images of the base of the neck and oblique views may require a higher-powered, ceiling mouted generator, up to 90kVp and 45 milliampere seconds.

Acquisition of laterolateral views of the neck in the standing horse is straightforward. The horse should be stood squarely on a firm level surface, with the neck straight relative to the body and the head resting on a head stand or shavings bale. Tilting of the head or bending of the neck results in cervical spine obliquity, limiting the diagnostic quality of the radiographs. Sedation is required to prevent the horse being startled by equipment and blinkers may be useful. A rope halter should be used for projections encompassing the poll. A plate-holder and a generator stand should be used to ensure radiation doses to personnel are minimised. A grid can be beneficial, as this reduces scattered radiation and improves image quality. However, unless this is in a fixed 'Bucky' system, it can be challenging to maintain the x-ray beam perpendicular to the grid, which is essential for image acquisition. Modern digital radiography systems may include digital noise suppression, which may improve image quality without the need for a grid.

Laterolateral views should be acquired with the most cranial view encompassing the caudal occiput and extend caudally as far as possible on the detector. Ideally three vertebrae should be included on each sequential view, with slight overlap between images. It is sometimes helpful to place markers (metal or wood) on the skin surface to ensure that there is adequate overlap of the images. Three or four views are usually required to assess all cervical vertebrae, from the occiput to the cervicothoracic junction, adequately. Images should be dorsoventrally collimated to include the trachea ventrally and a minimal amount of soft tissues dorsal to the cervical vertebrae, to minimise scatter. Careful assessment of the positioning of the vertebrae is required to ensure the views are not oblique (*Figure 1*).

Ventrolateral to dorsolateral oblique views of the neck from both the left and right are useful for assessing articular and transverse processes without superimposition (Withers et al, 2009). Use of a higher-powered X-ray generator is recommended, as these require high exposures and tight collimation reduces the effect of scatter radiation. The X-ray generator is positioned ventrally and angled 45–55 degrees dorsally; often a 'steeper' angle is required for the more caudal projections. The plate is positioned dorsolateral to the neck, angled perpendicular to the X-ray primary beam. The articular process joints closest to the detector are projected ventrally in the radiograph and those at the side of the generator are projected dorsally. This may allow determination of lesion laterality in cases of asymmetrical pathology. Careful labelling of the radiographs, to depict laterality or method of image acquisition, is vital as these are occasionally obtained using a dorsolateral-ventrolateral primary beam orientation, which can be confusing with anatomical depiction. A successful oblique radiograph should allow visibility through the articular space of the articular processes closer to the detector and silhouette the articular processes closest to the X-ray generator without extensive superimposition. If the articular space cannot be defined between the cranial and caudal articular processes, there is likely image obliquity.

Common pitfalls to radiographic interpretation typically include movement artefact associated with the equid or equipment, image obliquity meaning that lesions are obscured, or underexposure leading to incomplete evaluation (particularly at the cervicothoracic junction).

Radiographic anatomy

The first cervical vertebra (C1) or atlas has no 'body' or articular processes, though the cranial fovea articulate with the occipital condyles, and has a flattened shape caudocranially, with two well-defined lateral 'wings'(Butler et al, 2017).

The second vertebra (C2) or axis has a well-defined cranial projection called the dens. This is formed as a separate ossification centre in young animals, fusing at approximately 7 months of age. Care must be taken to differentiate this from a fracture in the juvenile. Either side are cranial articular processes that oppose the atlas. The large dorsal spine of C2 usually has a smooth contour with mild irregularity of the cranial and caudal edges. Occasionally, an osseous spur is superimposed on the dorsal-caudal epiphysis of the vertebral body. This is a normal finding, caused by superimposition of a transverse process and does not project into the vertebral canal (Butler et al, 2017).

The third, fourth and fifth cervical vertebrae (C3, C4 and C5) are similar in size and shape. The two sides of the vertebral arch, the dorsal lamina and the vertebral body form the borders of the vertebral canal, housing the spinal cord. Cranial and caudal articular processes project from the borders of the vertebral arches and articulate with the adjacent vertebrae, forming synovial articular process joints (APJs). The intervertebral junctions (or intercentral joints) between vertebral bodies are formed between the curved cranial surface of the vertebral end plate and the corresponding concave caudal surface of the more cranial vertebral body. These are interposed by a fibrocartilage intervertebral disc. Small cranial transverse processes of each vertebral body partially superimpose over the intervertebral disc space. The sixth cervical vertebra (C6) is shorter than C5 and has an additional ventral portion of the transverse process projecting caudoventrally. This is a useful feature for identification (*Figure 1*), but it should be noted that this can occasionally be transposed to C7. The C7 vertebra is normally shorter than C6 and may have a small spinous process dorsally, which should not be confused with new bone associated with the articular processes (Butler et al, 2017).

Figure 1. Laterolateral composite radiographs of the cervical vertebral column of a normal adult horse. The similar size and shape of C3–C5 can be appreciated. The normal additional ventral lamina of the C6 vertebra can be appreciated (white arrows). There is good exposure of the cervicothoracic junction. The transverse processes of C3 are well superimposed indicating good laterality, with slight obliquity noted at C5–C6.

Figure 2. Laterolateral radiograph of the caudal neck of a 16-year-old Warmblood gelding. There is moderate enlargement of the articular process joints at C5–C6 (white arrowheads) and C6–C7 (black arrowheads) with the ventral margin of the C6–C7 articular process joint extending ventrally to the level of the dorsal border of the corresponding vertebral body. There is a vestigial spinous process of C7 (white arrow) which should not be mistaken for additional periarticular new bone. The ventral process of C6 is highlighted with an asterix.

Common findings

Articular process joints: osteoarthropathy

Enlargement of the cervical APJs is a common finding in the caudal aspect of the neck (*Figure 2*). Care must be taken to ensure that the images are not oblique, resulting in artefactual enlargement. Assessment of the size of the APJs can be challenging and a good 'rule of thumb' is to assess how close the ventral aspect of the articular processes are to the dorsal margin of the vertebral body, to compare the APJ to those cranial and caudal to it, and to assess the margins of the APJ for irregularity or osteochondral fragments. Enlargement of the caudal APJs can occur as a consequence of ageing and may be related to higher level of athletic use (Down and Henson, 2009; Espinosa-Mur et al, 2020), so assessing the clinical relevance of enlargement of the caudal APJs can be challenging. The presence of enlarged APJs does not necessarily infer clinical relevance as a solitary finding.

Articular process joints: osteochondrosis or osteochondral fragmentation

Fragmentation of the APJs, consistent with osteochondritis dissecans or osteochondral fragments, has been reported in increasing numbers (Gough et al, 2020; Tucker et al, 2020). The presence of fragments may lead to osteoarthropathy of the APJs. Cases may present with a history of ataxia, neck stiffness or potentially be clinically silent. Osteochondral fragments may be detected on laterolateral radiographs (*Figure 3*), but oblique views or cross-sectional imaging may be required for definitive diagnosis. Fragmentation should be considered a differential diagnosis in cases of horses with ataxia and abnormally enlarged APJs, especially in very young horses.

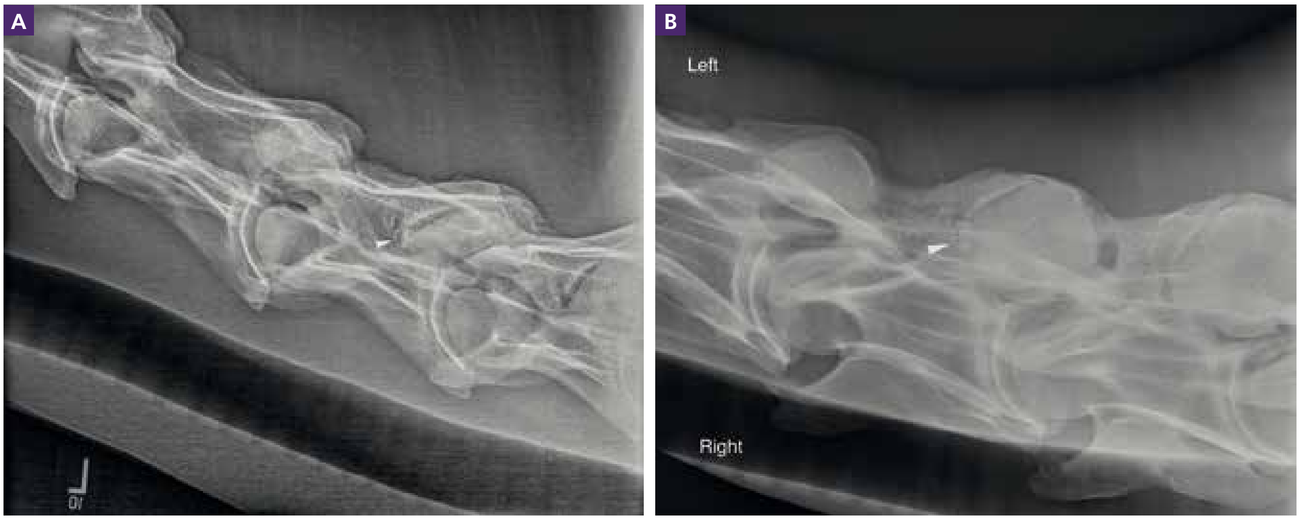

Figure 3. (A) Laterolateral and (B) left ventral-right dorsal oblique views of the mid-cervical vertebrae of a 6-year-old thoroughbred gelding presenting with ataxia. A rounded osseous fragment is visible at the cranioventral aspect of the left C4–C5 articular process joint, with mild to moderate enlargement of the joint and smoothly irregular periarticular new bone formation present.

Figure 4. Laterolateral (A) and left ventral-right dorsal oblique (B) views of the neck of a 6-year-old thoroughbred racehorse presenting with neck stiffness following a fall on the right side. In the laterolateral view, a focal linear lucency can be seen within the transverse process of the C5 vertebra. The oblique view reveals a comminuted fracture of the right transverse process of C5 (white arrowheads) with minimally displaced fractures of the transverse processes of C4 (black arrows) and C3 (black arrowheads).

Fractures

Fractures are most often traumatic (from a fall or collision) and occasionally pathological, secondary to neoplasia. Various locations of fracture are reported, and the prognosis for recovery is dependent on the extent and location. The clinical signs may vary based on pain and potential neurological compromise:

- Transverse process fractures are commonly seen following a fall on the side. These usually present with neck stiffness without any ataxia because of the peripheral location. Care needs to be taken when evaluating laterolateral radiographs, as subtle signs of a fracture can be easily missed. Oblique radiographs may be required to assess the full extent of the lesions (*Figure 4*).
- Articular process fractures are less common but not rare and are also typically traumatic. These are commonly minimally displaced and may present with neck pain with or without ataxia, depending on the location. Oblique views are vital for complete fracture assessment, as these typically involve the articular surfaces.
- Vertebral body fractures are uncommon. Fractures of the axis at the level of the dens may be associated with a poor prognosis. Horses with vertebral body fractures usually present with severe ataxia and imaging may be challenging initially. Radiographs should be carefully evaluated for the presence of radiolucent lines, the presence of displaced fragments impinging on the vertebral canal and the presence of subluxation of the APJs. Instability can also be associated with vertebral luxation or subluxation.

Cervical vertebral malformation

Cervical vertebral malformation (CVM) is the most common cause of ataxia in horses in Europe and Australasia, and is usually

Figure 5. Laterolateral image of the caudal cervical region of a 7-year-old thoroughbred horse with cervical vertebral malformation. The vertebral canal is moderately narrowed and funnel shaped at the cranial extent of C6 (black arrows) with moderate caudal extension of the dorsal laminae of C4 and C5 (asterisks). There is moderate caudal epiphyseal flaring of C5 (white arrows). The articular process joint of C6/C7 is slightly enlarged when compared with the C5/C6 articular process joint. There is a moderate ventral step in the vertebral canal at the level of C6/C7. The intra-vertebral ratio of C5 was 0.44, and intervertebral ratio of C6/C7 was 0.45.

Figure 6. Laterolateral view of the cranial cervical region of a 2-year-old miniature pony with occipitoatlantoaxial malformation. The first cervical vertebra (atlas) is fused to the occiput (white arrowheads). There is moderate angulation of the vertebral column with dorsal subluxation of the dens at the C1/C2 articulation (white arrow). The C2 vertebra is abnormally long, with a central lucency, which is consistent with fusion of the second and third cervical vertebrae. The lucency is considered likely the vestigial intervertebral foramen (black arrow).

developmental in origin. Radiographic assessment is one of the key methods of diagnosis, so acquisition of good quality radiographs is paramount. Radiographic assessment is both subjective and semi-objective. Subjective assessment includes the alignment and dorsoventral height of the vertebral canal, flaring of the caudal vertebral epiphysis and the caudal extension of the dorsal lamina of the vertebra. Semi-objective assessment includes calculation of the inter- and intra-vertebral ratios of the vertebral bodies. A ratio of <0.485 at any vertebral location is indicative of narrowing of the vertebral canal (Hahn et al, 2008), potentially warranting further evaluation (*Figure 5*).

Not all horses with suspected CVM will have definite radiographic stenosis of the vertebral canal, as we can only assess dorsoventral dimensions using laterolateral image, typically in a neutral standing position. Additionally, the dimensions of the vertebral canal do not necessarily reflect direct compression of the spinal cord itself (which cannot be delineated on a plain radiograph), nor lateral or dorsolateral vertebral canal narrowing. Further imaging, such as myelography or ideally computed tomography (CT) myelography, may be required to confirm the diagnosis of CVM (Gough et al, 2020; Lindgren et al, 2020).

Vertebral malformations

Congenital malformations are infrequent. The most common is occipito-atlantoaxial malformation, with a breed predilection in Arabians (Watson and Mayhew, 1986), but occasionally seen in other breeds (*Figure 6*). Other congenital malformations, such as vertebral fusion, do occur but are uncommon. Trauma-induced lesions with intervertebral disc space collapse are also possible (*Figure 7*). Horses with these malformations may be asymptomatic unless the spinal cord becomes compromised , so these can be diagnosed in adult life.

Neoplasia

Cervical vertebral neoplasia is rare, but has been reported. Signs are typically of ataxia, neck pain or neck stiffness. Depending on the origin of the lesion, the radiographic signs may differ. A mottled ill-defined opacity of the vertebral body may indicate neoplastic invasion of the bone. This has been reported in tumours such as haemangiosarcoma, lymphosarcoma and myeloma (*Figure 8*). Less commonly, nerve root tumours may cause widening of the intervertebral foraminae and cavitation of the vertebral arch.

Figure 7. Laterolateral view of the caudal neck of a 16-year-old Warmblood dressage horse with ataxia. There is fusion of the C5/C6 vertebra, with a central intervertebral foramen (white arrowhead). The transverse process of the C5 vertebra (white arrow) and that of the C6 vertebra can be clearly seen. There is marked osteoarthritis and sclerosis of the C6/C7 articular process joint (black arrowheads) and narrowing or collapse of the C6/C7 intervertebral junction.

Figure 8. Laterolateral view of the first to third cervical vertebrae of a 24-year-old pony with sudden onset ataxia. There are multifocal radiolucencies within the body of C2 (white arrowheads) with disruption of the dorsal border of the vertebral body (white arrows). Post-mortem examination confirmed a vertebral body haemangiosarcoma.

Figure 9. Laterolateral view of the caudal head and cranial neck of a 3-year-old Warmblood gelding found in the field with an abnormally extended and rotated head. The horse was diagnosed with atlantoaxial subluxation. The dens of C2 is caudoventrally displaced (black arrowhead), with a reduction of the space between the dorsal aspect of the atlas and axis (white arrows). The atlas is abnormally angled ventrally.

Luxation

Subluxation of the atlanto-occipital or atlanto-axial joints occur rarely in foals and adult horses. Clinically, these horses present with a history of acute onset of unusual head carriage and occasionally the head being 'stuck' tilted to one side or the neck extended. The Dens of the axis may be displaced dorsally or ventrally, but in the author's experience, caudoventral displacement is more common (*Figure 9*). Successful closed reduction has been reported (Licka, 2002) although there are many factors which may influence the success of attempted reduction, so rapid referral is advised once the horse is stable.

Subluxation of the caudal cervical vertebrae is occasionally seen in mature horses with poor performance and low-grade ataxia. Dorsal subluxation is most common, but ventral subluxation can occur. Osteoarthropathy of the APJs may occur simultaneously.

Infection

In foals, haematogenous spread of bacteria can lead to localisation of infection in vertebral bodies or synovial articulations, which may be challenging to detect. Clinical signs may include in neck stiffness and recurrent pyrexia. Focal radiolucencies are often the first identifiable radiographic change but, following treatment, areas of increased opacity may occur. Joint effusion may be identified ultrasonographically or potentially with CT.

Discospondylitis is rare in horses and is usually associated with infection, although it may be of unknown or traumatic aetiology.

Non-infectious intervertebral disc disease or collapse is also rarely encountered. Clinical signs of both manifestations may include neck stiffness, ataxia and, less commonly, forelimb lameness if a caudal neck lesion is present. Lesions are characterised by narrowing to collapse of the intervertebral disc space, with endplate remodelling of the adjacent vertebrae. Focal or more diffuse radiolucencies

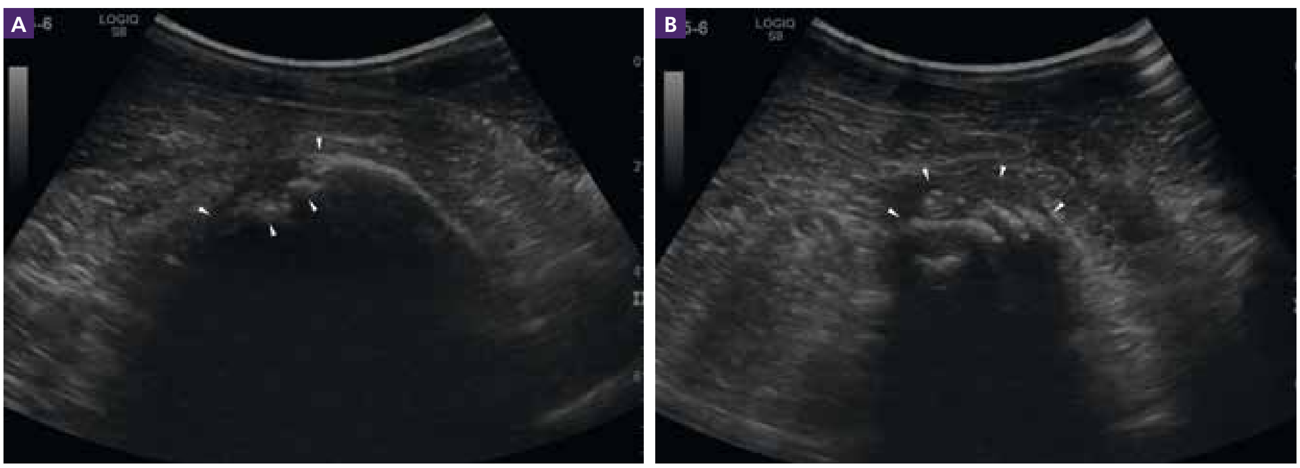

Figure 10. A) Transverse ultrasound images of the left C5/C6 articular process joint, with white arrows indicating enlargement and marked irregularity of the articular process margins at the level of the joint space, with fragmentation in image B. (B) Normal articular processes in this orientation should have smooth margins with a convex contour.

and variably increased opacity may be seen within the endplates. Ultrasound examination may be useful to identify abscessation.

Ultrasonography

Percutaneous ultrasonographic examination of the cervical region is less frequently performed, compared to radiography. However, it is a valuable technique and is underutilised in the authors' opinion. It can be performed both in a field and hospital setting, as the relatively superficial location of the majority of the regions of interest allows for their evaluation.

Patient preparation is important to optimise evaluation. Clipping, cleaning and application of alcohol followed by ultrasound coupling gel is advised. Comparative images of both left and right sides assist with image interpretation when evaluating unfamiliar regions. Use of a linear, curvilinear or microconvex transducer is recommended, with the frequency selection as high as possible whilst still achieving adequate depth of penetration to visualise the regions of interest. Combining different transducers can be helpful for assessment of deep and superficial structures.

Some structures that can be readily evaluated include APJ's (*Figure 10*), transverse processes, the nuchal ligament and cranial nuchal bursae, occiput, atlanto-occipital joints (*Figure 11a*), musculature, peripheral nerves and the spinal cord focally at the atlanto-axial junction (*Figures 11b–d*). In the absence of severe pathology, the remainder of the spinal cord cannot be assessed ultrasonographically because of the osseous vertebral canal encircling the whole structure. Typical planes of examination include transverse and longitudinal ultrasonographic windows, but as with radiography, lesion-orientated imaging can be useful. In addition, some structures can be evaluated not only from a lateral site, but from dorsal or ventral along the skin surface.

An additional benefit of ultrasound examination is the ability to guide needle placement or lesion sampling without the need for ionising radiation. In-plane techniques (needle path aligned with the long-axis of the transducer), such as ultrasound-guided synoviocentesis or medication of the APJs can be mastered with practice and in the authors' opinion, these should be routinely performed. Ultrasound-guided techniques have been shown to

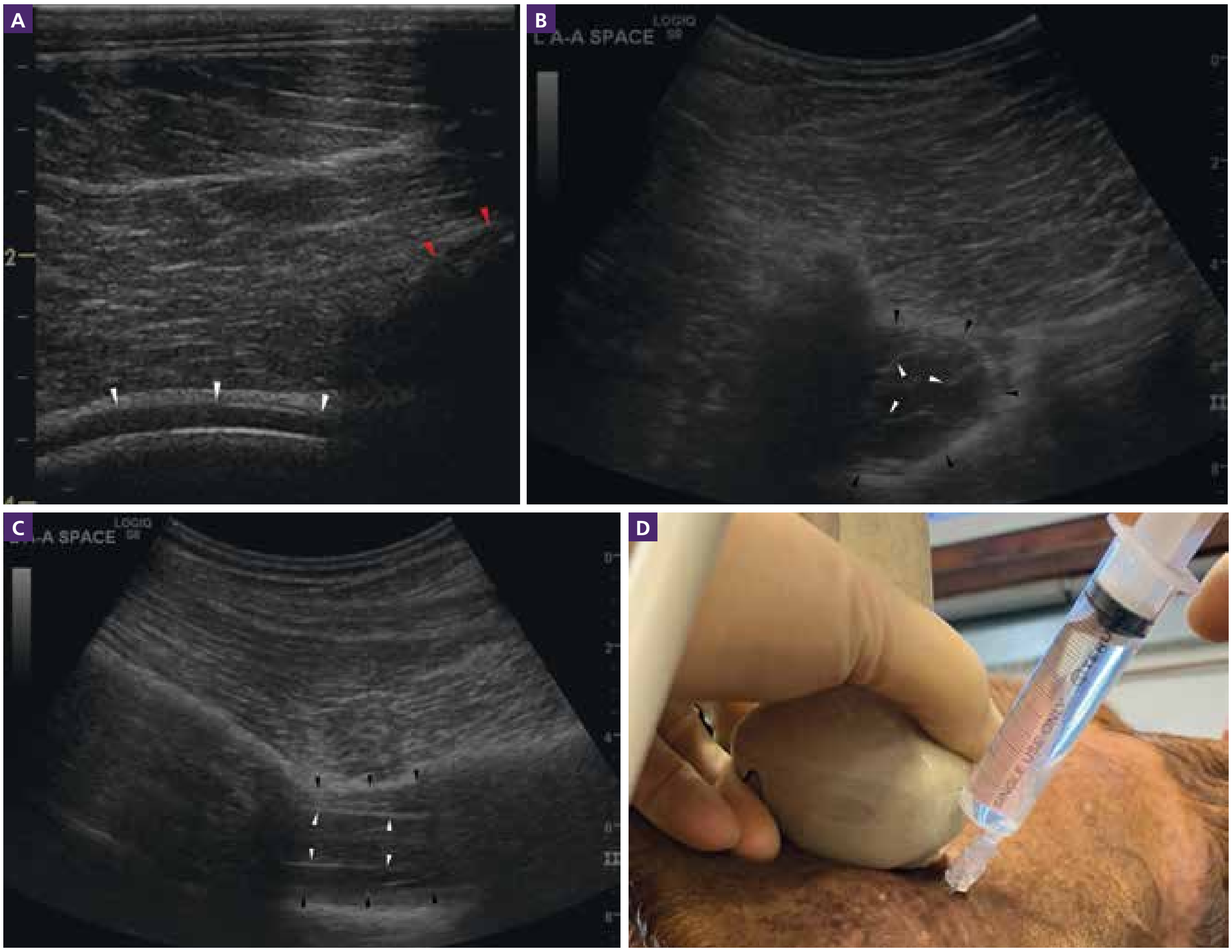

Figure 11. (A) Parasagittal image of the right atlanto-occipital joint, with white arrows indicating articular cartilage on the right occipital condyle, and red arrows the C1 dorsal arch. (B) Transverse image at the atlanto-axial junction, black arrows indicate the dural sac and white arrows the spinal cord margins. (C) Parasagittal oblique at the same level as B, indicating the region of the spinal cord from cranial-caudal which is visible (white arrows) surrounded by cerebrospinal fluid (black arrows). (D) Photograph depicting an in-plane ultrasound guided aspiration of cerebrospinal fluid from the atlanto-axial junction; note the use of a sterile transducer cover.

be associated with a high degree of accuracy of intra-articular or intra-capsular injection (Nielsen et al, 2003) and can also facilitate cerebrospinal fluid collection from the atlanto-axial space (Pease et al, 2011). Ultrasound-guided perineural injection of the spinal nerves (ramus ventralis) has recently been described and may have future clinical benefit (Touzot-Jourde et al, 2020). Out of plane injection techniques (where the needle is orientated perpendicular to the long-axis of the transducer) can be used if the transducer footprint is large and the lesion is small or superficial, but this is technically harder to master. Intraoperative use to guide surgical access, for example to drain abscesses or remove foreign material, can minimise surgical intervention and aid in avoidance of critical vascular structures, reducing patient morbidities.

Assessment of APJ osteoarthropathy or osteochondral fragments is probably the most frequent use of ultrasound of the equine neck. Access to evaluate the dorsolateral, lateral and ventrolateral margins of the APJs is possible from C2 to the T1 junctions. Enlargement can be subjectively assessed, with irregularity often being a sign of osteoarthritis, and small-or-large echogenic fragments with distal acoustic shadowing may be identified. Medially located fragments or osteophytes cannot be seen. In severe cases, fluid effusion of the articular recesses may be identified and when performing ultrasound guided injections, the injectate can often be seen flowing and distending slightly the joint recess.

Ultrasonography of the articular structures is not limited to the APJs and this technique can also be used to examine the atlanto-occipital joint margins, which can be clearly accessed on the left and right using a dorsal window.

Some vital soft tissues of the ventral cervical region can be evaluated with high-frequency linear transducers with relative ease, owing to the superficial location. In particular the larynx, thyroid glands (*Figure 12*), oesophagus, regional lymph nodes, wounds, abscesses, and regional vasculature (such as carotid arteries and jugular veins).

Soft tissue disruption to the nuchal ligament, including mineralisation, can be identified (*Figure 13*) when scanning dorsal to the vertebral canal, most often associated with the caudal aspect of the occiput and region dorsal to the C1 vertebral body. Infrequently, horses can present with poll region soft tissue swelling, and minimal significant abnormalities on radiography, caused by nuchal bursitis (*Figure 14*). This process can be aseptic or septic and, depending on the chronicity, may also be associated with mineralisation of the regional soft tissues, which can be profound. Ultrasound examination through a dorsal or dorsolateral window, can allow for differentiation of fluid distension and intrathecal hyperechogenic structures (or 'rice bodies') within the cranial nuchal bursae have been described (Hohu et al, 2020).

In the authors' opinion, the utility of ultrasound is extensive and with practice and increasing confidence, can add significant treatment-changing or prognosis-altering information.

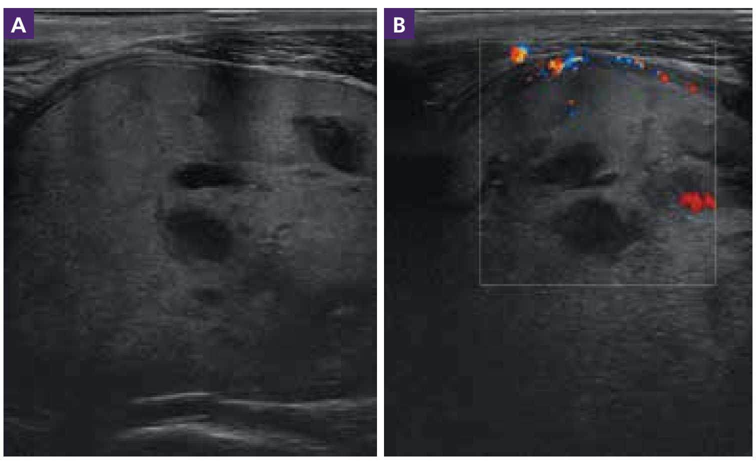

Figure 12. (A) Transverse B-mode ultrasound image of an enlarged and heterogeneous right thyroid gland, representing a thyroid adenoma. B) The colour flow Doppler is applied to determine regional blood vessel presence.

Figure 13. (A) Right laterolateral poll region radiograph, with osseous remodelling on the occiput (black arrowheads) and a large rounded osseous structure (red arrowheads). (B) Parasagittal ultrasound image of the occipital region, the white arrowheads indicate the osseous fragment caudal to the occipital bone (cranial is to the image left).

Some common pitfalls to interpretation come from poor technique (potentially related to frequency and gain settings); misconceptions relating to accessible structures, for example the deeper structures or spinal cord; image artefacts in cases of subcutaneous gas presence and the hugely complex regional anatomy of small neurovascular structures.

Conclusions

Conventional imaging can provide veterinarians with a thorough assessment of the equine neck, and we advocate a complementary use of radiography and ultrasound, however some pathological findings may only be identified with cross-sectional imaging or via post-mortem or histopathology. CT and CT myelography in particular are emerging and evolving techniques that can facilitate a comprehensive evaluation of osseous structures of the equine neck, as well as the spinal cord and related structures. This should especially be considered in cases where the location of the pathology is known, but conventional imaging has failed to document the abnormalities. EQ

Figure 14. (A) Transverse image at the level of the cranial nuchal bursa to the right of midline, note the large fluid cavity with numerous echogenic 'rice bodies' floating within the cavity and thickened synovial lining. (B) The linear echogenic structure represents a needle placed into the cranial nuchal bursa to guide aseptic aspiration for synovial fluid examination.

KEY POINTS

- Cervical radiography is commonly used and can reveal significant pathology, ranging from common to rare conditions, and can be performed both in the field and in a hospital environment.
- Combinations of radiographs, including laterolateral and oblique projections, should be obtained and in some cases, ventro-dorsal or lesion-orientated oblique projections can also be useful.
- Radiography can be complemented by myelography. However, for more comprehensive tomographic evaluation, computed tomography can be considered.
- Ultrasound examination can include evaluation of the articular process joints, nuchal bursae and ligament, spinal nerves and surrounding musculature, and vascular structures.
- Ultrasound can be used to accurately guide needle placement to obtain aseptic cerebrospinal fluid samples, nuchal bursa synoviocentesis and articular process joint or intervertebral foraminal injections.

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