Equine Veterinary Education

EQUINE VETERINARY EDUCATION
Equine vet. Educ. (2019) **31** (8) 432-440
doi: 10.1111/eve.12757

Review Article

Local anaesthetic techniques for the equine head, towards guided techniques and new applications

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Keywords: horse; anaesthetic; head; perineural nerve blocks; ultrasound

Summary

Perineural nerve blocks are often used in equine practice, especially since the use of diagnostic and surgical procedures in the standing sedated horse have expanded over recent decades. The purpose of this review is to discuss the different perineural nerve blocks for the equine head. The review starts with the currently most used blind approaches as described in textbooks and scientific studies. In human medicine, the role of guided techniques, such as ultrasound guidance, advanced imaging guidance and nerve stimulator guided techniques, is very extensively described. These techniques are promising to use in equine medicine as well. The first studies that describe these techniques in equine cases are also discussed in this review, as well as the possibilities for neuromodulation in equine pain syndromes like equine trigeminus-mediated headshaking and the role of perineural nerve blocks in diagnosing this syndrome.

Introduction

In modern equine veterinary practice, surgical and diagnostic procedures in the standing sedated horse are expanding, especially with the growing interest in minimally invasive surgery (Dixon *et al.* 2005; Coomer *et al.* 2011; De Linde Henriksen and Brooks 2014; Menzies and Easley 2014). Reliable and stable sedative planes are very important and various studies have been performed to assess the effects of sedative and analgesic pharmaca (Ringer *et al.* 2013; Marly *et al.* 2014). Both in the sedated horse and in the horse under general anaesthesia, the beneficial effects of locoregional techniques (diminished levels of sedation or anaesthesia, prevention of harmful reflexes and pre-emptive analgesic effects) are clearly described (Ong *et al.* 2005; Oel *et al.* 2014). Furthermore, in the standing equine patient it is especially important to provide a reliable local anaesthetic block regarding the safety of the horse, the veterinary surgeon and animal handlers.

Previous reviews have very extensively described the use and anatomical landmarks for all relevant local anaesthetic techniques for the equine head (Tremaine 2007; Labelle and Clark-Price 2013). Experience of the performer is very important in the success rates of local anaesthetic techniques, as was shown by Wilmink *et al.* (2015) for the perineural block of the maxillary nerve. Although blind techniques used to be the gold standard, nowadays ultrasound-guided techniques are quickly being adopted. They are broadly used in human medicine where there has been a rapid development in different ultrasound-guided approaches in recent years (Helayel *et al.* 2007). Ultrasound-guided local anaesthetic techniques enhance both the quality and duration of peripheral-nerve blockade and reduce the incidence of complications. Meta-analyses comparing ultrasound-guided local anaesthetic techniques to blind techniques in man have shown that ultrasound guidance reduces complication rates and improves quality of the block (both for sensory and motor blocks); the technique further reduces performance time and results in quicker onset of the block in peripheral nerve blockade in adult humans (Walker *et al.* 2009; Lewis *et al.* 2015). Furthermore, ultrasound guidance reduces the incidence of local anaesthetic systemic toxicity (neuro- and cardiotoxicity consequent to unintended intravascular injection or delayed tissue uptake; El-Boghdadly and Chin 2016; Neal 2016) and unintended paresthesias (Soeding *et al.* 2005). For infants, a recent systematic review by Guay *et al.* (2016) showed that ultrasound guidance improved the success rate and duration of perioperative neuraxial and peripheral local blocks. Additional data are required to assess the potential effect of ultrasound guidance on reducing the rate of inadvertent puncture of blood vessels. Besides these advantages, ultrasound guidance was found to improve the learning curve of clinicians and it has been stated that the technique should have a role in future training (Marhofer *et al.* 2005). To date, the role of ultrasound-guided techniques and advanced imaging is still limited in the performance of local nerve blocks in the equine patient.

This review discusses the perineural nerve blocks for the equine head and describes blind approaches as well as those guided by ultrasound, nerve stimulation, or advanced imaging techniques and compares human and equine literature. As perineural techniques can also have diagnostic and therapeutic value, the possibilities for neuromodulation in equine pain syndromes such as equine trigeminus-mediated headshaking and the role of perineural nerve blocks in diagnosing this syndrome are also discussed.

Perineural nerve blocks for the equine head: classic approach

The most commonly used local anaesthetic techniques for the equine head are well described in various review articles (Tremaine 2007; Labelle and Clark-Price 2013) and veterinary textbooks (Easley *et al.* 2011; Gilger 2011). Perineural nerve blocks are often used in equine dentistry and equine ophthalmology. **Figure 1** shows the four anatomical locations for the techniques most often used in equine dentistry: the

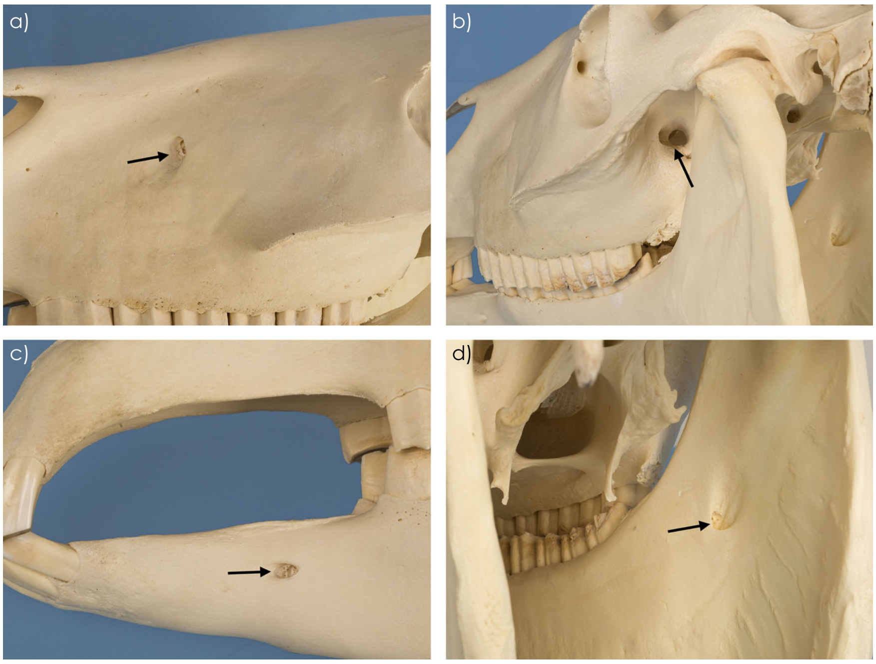

***Fig 1:** Most important anatomical structures for nerve blocks used in equine dentistry. a) Infraorbital foramen for infraorbital nerve block, b) caudal entrance of infraorbital canal for maxillary nerve block, c) mental foramen for mental nerve block and d) mandibular foramen for inferior alveolar nerve block.*

maxillary, mandibular, infraorbital and mental nerve blocks with their relevant anatomical foramina. The infraorbital and mental nerves are desensitised outside the infraorbital and mental foramina for procedures involving the mandibular and maxillary soft tissues, such as treatment of soft tissue trauma in these areas. For painful procedures involving the incisor teeth (such as extraction in equine odontoclastic tooth resorption and hypercementosis), mandibular or maxillary fractures of the incisive (premaxillary) bone or extraction of the first cheek teeth, the infraorbital or mental nerve should be desensitised inside the respective foramina because of branching nerves to these structures. **Figure 2a** shows the localisation of the infraorbital foramen, relative to the surrounding structures (rostral edge of the facial crest and nasoincisive notch).

Maxillary nerve block

Several techniques for the maxillary block have been described in various studies: Bardell *et al.* (2010) described two approaches for the maxillary nerve block in equine cadavers with different orientations of the needle (perpendicular vs. angled needle placement in relation to the skin). Staszyk *et al.* (2008) compared a superficial approach (superficial advancement of the needle into the extraperiorbital fat cushion underneath the masseter muscle) to a deep approach (deep advancement of the needle into the pterygopalatine fossa of the palatine bone). The advantage of the superficial technique is the decreased risk of haemorrhage, because the major vascular structures (infraorbital artery, deep facial vein and descending palatine artery) are located close to the palatine bone.

Nannarone *et al.* (2016) described a retrograde maxillary nerve perineural injection within the infraorbital canal towards the maxillary foramen using a Tuohy needle, thereby avoiding the periocular region and possibly the described complications (Tremaine 2007; Staszyk *et al.* 2008).

For surgical procedures involving the paranasal sinuses and the nasal cavity, a maxillary nerve block will in some instances not be sufficient due to sensory innervation of these structures by the ophthalmic branch of the trigeminal nerve

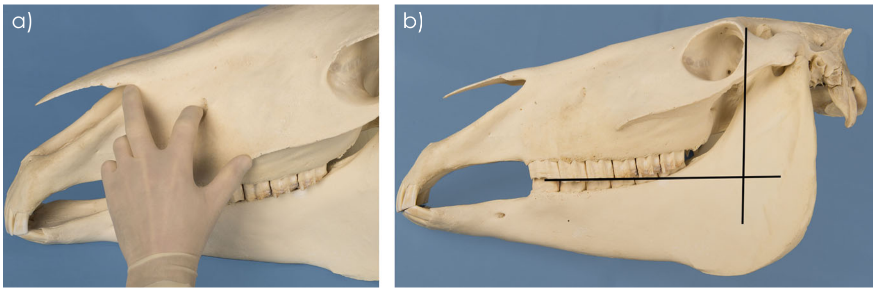

***Fig 2:** Anatomical localisation of the infraorbital and mandibular foramen. a) Anatomical structures (rostral edge of the facial crest and nasoincisive notch) and handsetting to determine the infraorbital foramen. b) Determination of position of the mandibular foramen using perpendicular lines through occlusion of the maxillary and mandibular cheek teeth and the lateral canthus of the eye.*

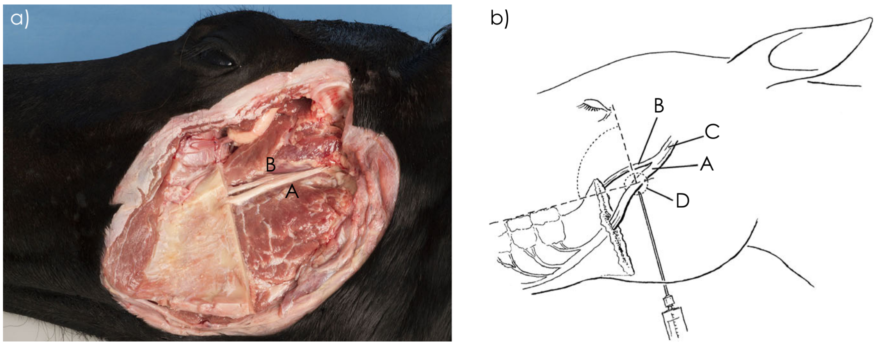

Fig 3: Localisation of the lingual and inferior alveolar nerves. a) In-situ anatomical orientation of inferior alveolar nerve (A) and lingual nerve (B). The latter branches off the mandibular nerve (C) before it enters the mandibular foramen (D) as the inferior alveolar nerve. b) Schematic orientation of both nerves. Figure 3b reproduced with permission by Caldwell and Easley (2012).

and an additional block of the nerve in addition to the maxillary nerve block can be beneficial in these cases. Caruso III *et al.* (2016) described a technique to desensitise the ethmoidal nerve. The ethmoidal nerve branches off the nasociliary nerve, which proceeds as the infratrochlear nerve. The ethmoidal nerve is blocked at the rostromedial aspect of the supraorbital fossa and the technique has proven to be reliable and simple.

Inferior alveolar nerve block

The mandibular or inferior alveolar nerve block has been described in various studies. Harding *et al.* (2012) described two extraoral approaches (vertical vs. angled technique), while Henry *et al.* (2014) described an intraoral technique. In the latter, a custom-made device inserted into the mouth is used to anaesthetise the inferior alveolar nerve with a relatively small volume of local anaesthetic (5 mL). This alternative technique could decrease the risks of side-effects of this block such as self-inflicted trauma of the tongue due to accidental desensitisation of the lingual nerve that branches off the mandibular nerve very close to the mandibular foramen (**Fig 3**). Several cases of this self-inflicted tongue trauma after bi- and unilateral inferior nerve blocks have been described by Caldwell and Easley (2012). Localisation of the mandibular foramen on the medial side of the mandible can be realised using the perpendicular lines passing through the occlusal surface of the maxillary and mandibular cheek teeth and the lateral canthus of the eye (Tremaine 2007; **Fig 2b**). Harding *et al.* (2012) determined the accuracy of this technique of localising the mandibular foramen using radiography, revealing that the mandibular foramen was consistently located in close proximity to the intersection of these perpendicular lines. The described topographical landmarks were found to be accurate in locating the mandibular foramen (Harding *et al.* 2012). The relative position of the lingual and the inferior alveolar nerves is shown in **Figure 3**.

Ophthalmic nerve blocks

For ophthalmic procedures, various blocks can be used to enable minor and major surgical procedures in the standing horse or in the horse under general anaesthesia. The retrobulbar block (Tremaine 2007; Labelle and Clark-Price 2013) can effectively be used in surgical procedures such as enucleation and for minor procedures such as intraocular injection of tissue plasminogen activator in cases with recurrent uveitis with fibrin formation in the anterior chamber or for episcleral placement of cyclosporin implants. With the retrobulbar block, the oculomotor, trochlear and abducens nerves are desensitised, resulting in paralysis of all the straight and oblique ocular muscles, and the retractor bulbi muscles, which leads to a stable forward-positioned eye. Additionally, the ophthalmic and maxillary branches of the trigeminal nerve and the optic nerve are blocked, providing desensitisation of the eye and ocular adnexa. **Figure 4** shows the ‘diamond block’, which comprises the supraorbital, lacrimal, infratrochlear and zygomaticofacial nerves. This block results in desensitisation of respectively the medial two-thirds of the superior eyelid, the temporal canthus of the eye, nasal eye canthus and the temporal 75% of the inferior eyelid. The block is useful for surgical repair of eyelid lacerations or several diagnostic procedures of the eye.

Ultrasound-guided local anaesthetic techniques for the equine head

In modern human and veterinary clinical anaesthesiological practice, ultrasonography is becoming a more important technique that improves accuracy and safety of local anaesthetic techniques. Ultrasound can help to determine the exact location of the needle placement relative to the anatomical landmarks and the peripheral nerve that is aimed for. By means of ultrasound guidance, the amount of local anaesthetic needed to desensitise a nerve can be minimised due to the close proximity of the needle in relation to the peripheral nerve. The resultant influence on volume and concentration of the local anaesthetic at the level of the nerve improves the anaesthetic block quality in terms of time of onset and duration of effect. Ultrasound can also help to determine anatomical structures such as adjacent blood vessels, hence reducing the risk of side-effects such as haemorrhage from puncturing a vessel or inadvertent injection of the nerve. On ultrasound, nerves appear as single or multiple round or oval hypoechoic areas surrounded by a relatively hyperechoic area in the transverse scanning orientation (Alexander and Dobson 2003). In the longitudinal view, the nerve presents as a hyperechoic band characterised by multiple discontinuous hypoechoic stripes separated by hyperechoic lines, creating a fascicle pattern

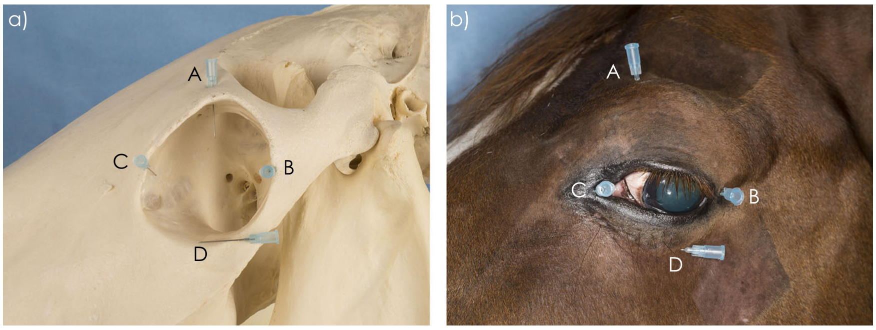

***Fig 4:* Diamond block. Needle setting on a) skull and b) head for diamond block (A, supraorbital nerve; B, lacrimal nerve; C, infratrochlear nerve; D, zygomatofacial nerve).**

(Beukers *et al.* 2016). The hyperechoic structures are the fascicles of the nerves; the hypoechoic background reflects the connective tissue between neuronal structures. The nerve's image is sensitive to the angle of insonation because of the presence of fat (Re *et al.* 2016).

Maxillary nerve block

Ultrasound guidance for the maxillary nerve block has been described both in man (Bouzinac *et al.* 2014) and in horses (O'Neill *et al.* 2014). In the study by Bouzinac *et al.* (2014) efficacy of the block was not tested by pinpricks since the patients were under general anaesthesia, but ultrasound guidance allowed for accurate placement of the needle by visible spreading of the local anaesthetic into the pterygopalatine fossa. O'Neill *et al.* (2014) described the technique both in equine cadavers and in a number of clinical cases in a standing procedure. Ultrasound permits identification of the bony landmarks of the pterygopalatine fossa that can guide the needle towards the maxillary nerve and determination of the position of the needle relative to the greater vascular structures accompanying the maxillary nerve (deep facial vein, infraorbital artery, descending palatine artery). Puncturing of these vascular structures can cause serious side-effects such as temporary blindness, haemorrhage and severe swelling. Ultrasonography can be very helpful in improving the safety and efficacy of maxillary nerve blocks (**Fig 5**) and has proven to be an accurate and precise technique without any complications in clinical cases (O'Neill *et al.* 2014), compared to the blind technique (Bardell *et al.* 2010). Colour flow Doppler can be very useful

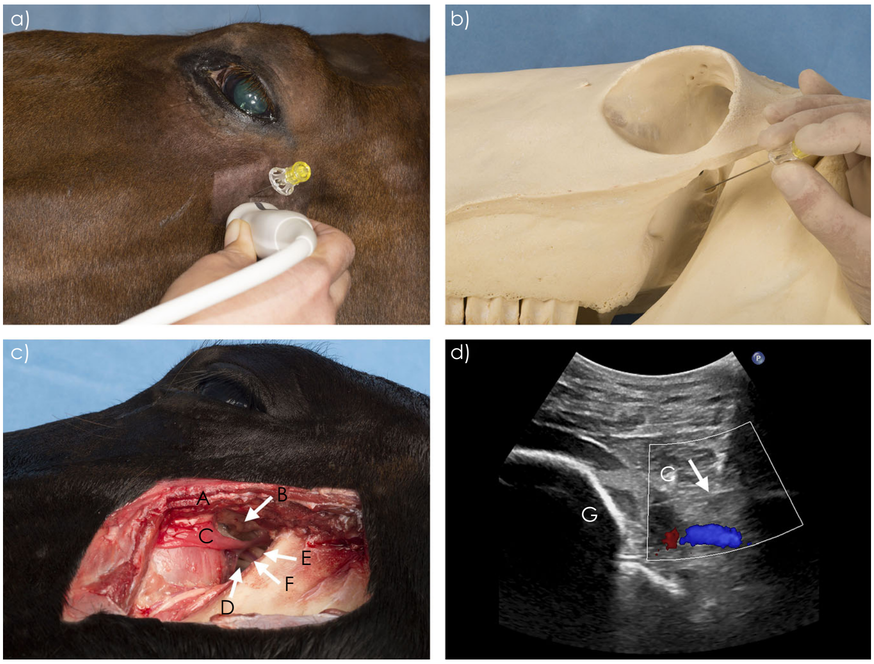

***Fig 5:* a) and b) relative positioning of the ultrasound probe and the needle for ultrasound-guided maxillary nerve block. c) masseter muscle (A) and underlying extraperiorbital fat tissue (B) with the deep facial vein (C) embedded in the extraperiorbital fat tissue and the maxillary nerve situated deeper (D), in close proximity of the infraorbital artery (E) and the descending palatine artery (F). d) Ultrasound with colour Doppler image showing the maxillary nerve at the needle tip (white arrow) and associated vascular structures (C, deep facial vein, red and blue Doppler traces are infraorbital artery and the descending palatine artery; G, tuberosity of the maxillary bone).**

as well to identify vascular structures and is often used in human patients (Marhofer *et al.* 2005), although blood flow or pulsation can often easily be identified in horses without the use of colour flow Doppler (O'Neill *et al.* 2014).

Inferior alveolar nerve block

In man, the use of ultrasound guidance has been described for the desensitisation of the inferior alveolar nerve block (Hannan *et al.* 1999; Chanpong *et al.* 2013). In order to visualise the inferior alveolar nerve that runs medial of the mandibular ramus, the ultrasound probe is placed intraorally medial to the mandibular ramus (Hannan *et al.* 1999; Chanpong *et al.* 2013). Introduction of the technique has substantially improved outcome compared to the formerly used blind technique (Chanpong *et al.* 2013), of which failure rates were as high as 60% (Montagnese *et al.* 1984) and this position of the ultrasound probe helps to determine the inferior alveolar nerve. In literature, failure rates of up to 62% for the inferior alveolar block have been described in older human studies (Montagnese *et al.* 1984), greatly caused by anatomical variation and blind needle placement. Ultrasound guidance may improve the outcome of the inferior alveolar nerve blocks (Chanpong *et al.* 2013) and, at the same time, it could decrease the risk of potential side effects such as vascular punctures. This technique seems rather impractical in the equine head because of the long mouth, but, alternatively, ultrasound guidance could potentially be applicable in the equine head as well with a modified approach from the ventromedial aspect of the mandibular ramus. This technique has not yet been described in the horse and may prove impractical due to the deep location of the nerve.

Retrobulbar block

In man, ultrasound-guided retrobulbar blocks have been described by Luyet *et al.* (2008). They used a cranial approach and ultrasound guidance allowed the needle tip to be advanced up to 2 mm from the optic nerve. No side effects such as contrast injection into the eyeball or into the optic nerve were seen. For ultrasonography of the retrobulbar space by the transbulbar approach, curvilinear array transducers are most suitable at low to intermediate frequencies of 3–8 MHz. Phased array or linear array transducers can be used, but produce a less optimal image for needle guidance. Two indices, thermal index (TI) and mechanical index (MI), are denotive of heat and mechanical agitation that are generated by every ultrasonographic transducer. Low TI- and MI-values are preferred for ultrasonography of the eye (Morath *et al.* 2013). For the human eye, the maximally allowed TI is 1.0 and the maximally allowed MI is 0.23 (these values are much lower for the eye compared to other tissues).

In the horse, the technique of the ultrasound-guided retrobulbar block has been explored in a cadaver study by Morath *et al.* (2013). The effect of the volume that was injected was assessed, as was desensitisation of the orbital fissure after both intra- and extraconal injection of contrast medium. The study used a caudal (supraorbital) approach (comparable to the technique shown in **Fig 6**) and the spread of contrast medium was evaluated by computed tomography (CT). Needle placement within the cone formed by the retractor bulbi muscles was found to lead to a more effective spread of the injected fluid towards the orbital fissure and the subjective evaluation of ultrasound performance appeared to correlate well with the results of

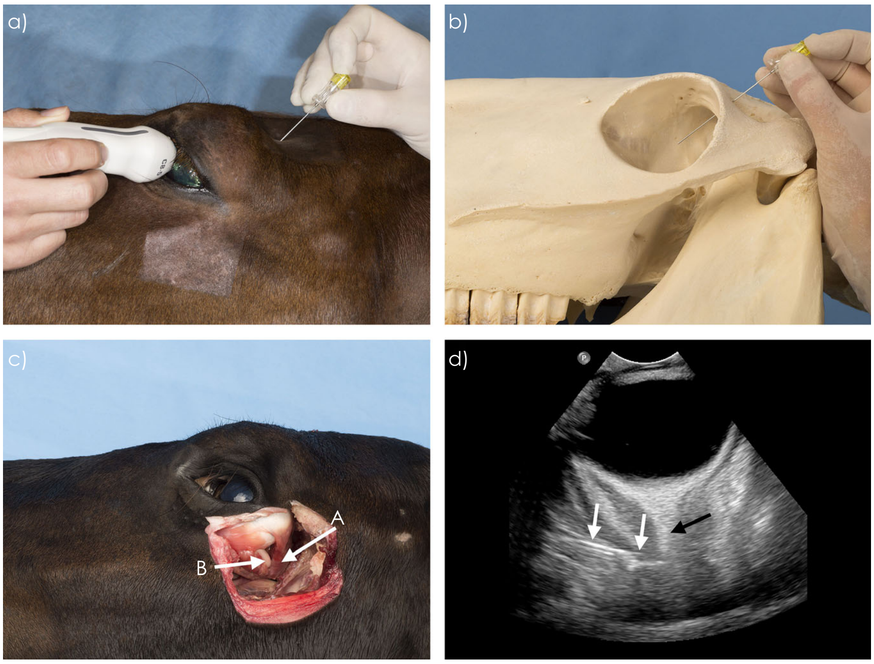

***Fig 6:** Ultrasound-guided retrobulbar nerve block. a) Positioning of the ultrasound probe and the needle on the head. b) Needle placement with respect to the bony landmarks. c) Extrinsic straight eye muscles (A) within the covering fascia (cone) and the optic nerve in the centre of the straight muscles (B). d) Ultrasound image of retrobulbar needle placement and associated structures (white arrows show needle placement with tip at the height of the right arrow, black arrow shows the optic nerve).*

the CT images. Toth and Hollerrieder (2013) also have described an ultrasound-guided retrobulbar block in horses with a similar approach (**Fig 6**), followed by CT assessment of local anaesthetic spread. They describe the use of Tuohy needles to advance a catheter into the retrobulbar intraconal location for repeated injections.

Internal auricular nerve block

To enable otoscopic examination of the equine external ear canal including the tympanic membrane in sedated standing horses, the internal auricular nerve block can be performed. Sommerauer *et al.* (2012) provided a detailed anatomical dissection of the equine external ear canal and its nerve supply and described anaesthesia of the equine external ear canal by desensitising the internal auricular nerve. Ultrasound-guided localisation of the styloid process of the auricular cartilage was described as a reliable landmark for desensitisation of the internal auricular nerve, which is a branch of the facial nerve that provides most of the sensory innervation to the equine external ear canal.

Advanced imaging guided procedures

The role of modern imaging techniques, such as CT and magnetic resonance imaging in equine medicine, has expanded in the last decades and these techniques are becoming more widely available for clinical use. For visualisation of the equine skull and the related perineural anaesthetic techniques, CT imaging can especially be very helpful as has been stressed in various review studies (Porter and Werpy 2014; Manso-Díaz *et al.* 2015). The introduction of sliding gantry CT scanners that allow for standing procedures in sedated horses without exposure of personnel, has further increased the possibilities to use this technique without significant risks for the patient (such as complications related to general anaesthesia). These imaging techniques are very useful for assisting with locoregional techniques as well. This clinical application is still under development and should be explored further.

Tomaszewska *et al.* (2014), used a CT scan to determine anatomical landmarks for localisation of the greater palatine foramen in man. CT scans have been used to compare two different techniques for maxillary nerve blocks in horses and yielded very useful information on anatomical landmarks for these techniques (Staszyk *et al.* 2008). These authors assessed a modified superficial (extra periorbital fat body) technique, in which the needle is not inserted up to the palatine bone (where the maxillary nerve is located) and showed it to be effective and safer than the more conventional palatine bone technique. The cadaveric and CT images from this study provide invaluable information about the regional anatomy of the maxillary nerve in relation to accompanying structures such as blood vessels (**Fig 7**). CT has also been used to aid maxillary nerve block placement in a human

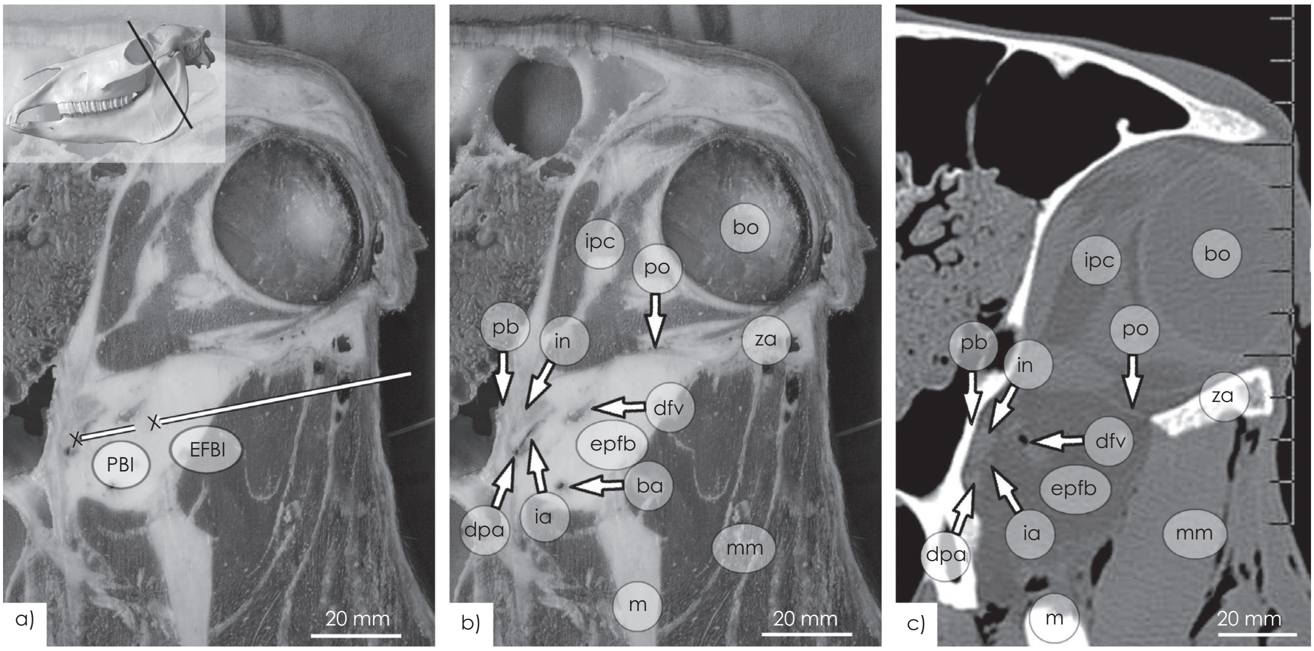

***Fig 7:** Regional anatomy of the maxillary nerve in cadaveric specimens and matching CT scans. a) Transverse section through the left pterygopalatine fossa of a deep frozen specimen, rostral view. The inset indicates the section plane at the level of the caudal third of the eyeball. The lines indicate the position of the tip of the needle for performing a maxillary block (x). The needle was inserted either until its tip touched the palatine bone (PBI: Palatine Bone Insertion) or the needle was inserted only for 15–20 mm into the extraperiorbital fat body (EFBI: Extraorbital Fat Body Insertion). b) The same picture as in (a) to demonstrate selected anatomical landmarks. The transition from the masseter muscle (mm) to the extraperiorbital fat body (epfb) is clearly visible. c) CT image corresponding to (a) and (b). The periorbita (po) separates the extraperiorbital fat body (epfb) from the intraperiorbital compartment (ipc). Note that the infraorbital nerve (in) is located directly next to the palatine bone (pb). The infraorbital nerve is accompanied by the infraorbital artery (ia) laterally and by the descending palatine artery (dpa) ventrally. The deep facial vein (dfv) is embedded in the extraperiorbital fat body (epfb). ba – buccal artery; pb – perpendicular plate of the palatine bone; za – zygomatic arch; m – mandible; bo – bulbus oculi. Reproduced with permission by Staszyk et al. (2008).*

patient with trigeminal neuralgia, in which the classical approach using anatomical landmarks was confounded because of anatomical variations (Okuda *et al.* 2000). A similar approach could be used in equine cases in which anatomical variations impede the use of anatomical landmarks. In cows, magnetic resonance imaging scans were used to compare two different techniques for retrobulbar blocks using contrast medium in cadaveric heads (Pearce *et al.* 2003).

Nerve stimulator guided local techniques for the equine head

Since the inferior alveolar nerve is a sensory nerve with certain motor components as well, it is a very suitable nerve for nerve stimulator guidance when it needs to be desensitised. In various studies, the use of nerve stimulator guidance of the inferior alveolar block in man has been described (Simon *et al.* 2010; Espitalier *et al.* 2012; Kumar *et al.* 2012). Stimulation of the nerve using a lateral extraoral approach results in a motor response of the temporal and masseter muscles, apparent as a jaw jerk.

Cheetham *et al.* (2009) used a peripheral nerve locator to perform a bilateral block of the common trunk of the hypoglossal nerve in 10 horses to determine the role of the hypoglossal nerve in equine nasopharyngeal stability. During this study, no complications were associated with the technique.

In literature, use of a nerve stimulator to assist locoregional techniques in the equine head has not been described, but the technique should be feasible and merits further investigation.

Neuromodulation of trigeminal nerve branches in the equine head

Desensitisation of peripheral nerves of the equine head is very important for surgical procedures; however, perineural techniques are used as well in diagnosing peripheral neuropathies in horses (such as headshaking) and neuromodulation of these peripheral nerves can also be of therapeutic value in these cases. Various studies on the technique and reliability of the maxillary nerve block for diagnosing headshakers have been published (Newton *et al.* 2000; Roberts *et al.* 2013; Wilmink *et al.* 2015). Where few horses with idiopathic headshaking showed improvement on anaesthesia of the infraorbital nerve, the majority (13 out of 16 = 81%) showed complete or partial improvement after anaesthesia of the posterior ethmoidal branch of the maxillary nerve (Newton *et al.* 2000). This block is called caudal anaesthesia of the infraorbital nerve by Roberts *et al.* (2013) and caudal nasal nerve block by Dyce *et al.* (2002). This latter nerve branches off the maxillary nerve just proximal to the maxillary foramen and enters the caudal nasal foramen before running towards the dorsal meatus of the nasal cavity to innervate the nasal mucosa.

A recent study by Roberts *et al.* (2016) describes the first results of neuromodulation of the maxillary nerve in equine headshakers, by use of a percutaneous electrical stimulation protocol featuring alternating high (100 Hz) and low (2 Hz) frequency stimulations. The infraorbital nerve was located by ultrasound guidance and the nerve was stimulated for 25 min. Preliminary results show partial or complete remission for a prolonged period in five out of seven cases after several treatments (up to 12–28 weeks after four treatment sessions).

Neurostimulation for the treatment of humans with neuropathic pain has been well described (Papúc and Rejdak 2013; Shaparin *et al.* 2015; Maniam *et al.* 2016). Peripheral stimulation is categorised into transcutaneous electrical nerve stimulation (TENS), peripheral nerve stimulation (PNS) and nerve root stimulation. With TENS, surface electrodes are used while electrodes are percutaneously implanted to directly contact the nerve in PNS. In the study by Roberts *et al.* (2016) in horses, stimulation is realised through needle electrodes that are inserted in close proximity to the nerve, placing this technique more or less between TENS and PNS. After stimulation, the needles are removed in contrast to the practice with PNS in man (in which the electrodes stay in contact).

There are various hypotheses about the working mechanism of peripheral nerve stimulation. Stimulation is thought to produce paraesthesia that spreads along the territory innervated by the stimulated nerve (Abejón and Krames 2009). Exogenous electrical stimulation might also lead to signal modification of intrinsic electrical impulses (Shaparin *et al.* 2015), or stimulation may inhibit central nociceptive transmission or lead to partial sympathetic blockade and local blood flow alterations (Shaparin *et al.* 2015). Papúc and Rejdak (2013) proposed that high frequency stimulation would lead to inhibition exerted by large-size afferents on spinothalamic pathways. Low-frequency stimulation is thought to activate the antinociceptive systems, mediated in part by the opioid system. The gate-control theory by Melzack and Wall (1965), which states that competing nociceptive and innocuous signals influence second-order neurons to transmit pain signals for higher processing, may also be useful for understanding the effect of peripheral nerve stimulation.

Conclusions

Local anaesthetic techniques have been used in equine practice for a very long time, but the use of ultrasound (or nerve stimulator) guided techniques is new and still limited to date in equine cases. Nevertheless, these techniques are very promising and can possibly be of similar benefit as they have been shown to be in human medicine. Ultrasound-guided techniques can also become very prominent in training young professionals in performing various local blocks. As the immediate real-time feedback results in steeper learning curves, the quality and accuracy of the blocks is most likely to improve considerably, as in human medicine. So far, most studies have been performed on equine cadavers with the main aim of describing the technique. Efficacy and safety studies have not been performed in horses yet. For the further development of the techniques and their implementation in practice, clinical studies such as those that are described in the various systematic reviews in humans are needed.

This review shows that guided techniques (both by ultrasound and nerve stimulator) and modern imaging techniques are becoming more important in veterinary practice and have huge potential. Furthermore, the implementation of peripheral nerve stimulation protocols such as described for equine trigeminus-mediated headshaking is a promising development. It is not unlikely that these techniques will become as important in equine pain management as they are in human pain management.

Authors' declaration of interests

No conflicts of interest have been declared.

Authorship

All authors contributed to study execution and preparation of this manuscript and approved the final version of the manuscript.

Acknowledgements

We would like to thank Joop Fama for his help with photography, Jacobine Schouten for her help with dissection of anatomical structures and René van Weeren for critical reading of the manuscript.

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