RESEARCH PAPER

Maxillary nerve blocks in horses: an experimental comparison of surface landmark and ultrasound guided techniques

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Authors' contributions

Stephanie Stauffer: Analysis and interpretation of data, drafted article, revision of article for intellectual content, approved final version

Becky Cordner: Conception and design, acquisition of data, analysis and interpretation of data, approved final version
Jonathon Dixon: Study design, CT image acquisition and interpretation of images, approved final version

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Abstract

Objective The aim of this preliminary proof of concept study was to evaluate and compare the success and complication rate of infiltration of the maxillary nerve of cadaver heads using previously described surface landmarks, standard ultrasound and a novel needle guidance positioning ultrasound system (SonixGPS).

Study Design Prospective anatomical method comparison study

Animals Thirty-eight equine cadaver heads

Methods Twenty-six veterinary students performed the three methods consecutively on cadaver heads with an 18 gauge, 3.5-inch spinal needle and 0.5 mL iodinated contrast medium. Computed tomography was used to quantify success (deposition of contrast in contact with the maxillary nerve), and complication rate (contrast identified within surrounding vasculature or periorbital structures) associated with each method.

Results Perineural injection of the maxillary nerve was attempted 76 times, with an overall success rate of 65.8% (50/76), and complication rate of 53.9% (41/76). Success rates were 50% (13/26) with surface landmark, 65.4% (17/26) with standard ultrasound guidance and 83.3% (20/24) with SonixGPS guidance approaches (Fisher's exact p=0.046). No significant difference in complication rate was found between the three methods.

Conclusion Ultrasound guided maxillary nerve blocks were significantly more successful than surface landmark approaches when performed by inexperienced operators, and the highest success rate was achieved with GPS needle guidance.

Clinical relevance Local anaesthesia of the equine maxillary nerve in the fossa pterygopalatina is frequently used for diagnostic and surgical procedures in the standing sedated horse. Due to vague superficial landmarks with various approaches and the need for experience via ultrasound guidance, this block remains challenging. GPS guidance may improve reliability of maxillary and other nerve blocks, and allow a smaller volume of local

anaesthetic solution to be used, thereby improving specificity and reducing the potential for side effects.

Keywords equine, maxillary nerve, perineural anaesthesia, trigeminal nerve, ultrasound guidance positioning system

Introduction

Many surgical procedures of the equine head can be performed in the standing position with the use of sedation and regional anaesthesia (Young & Taylor 1993; Johnston et al. 1995; Mee et al. 1998). The maxillary branch of the trigeminal nerve provides sensory innervation to the ipsilateral maxillary cheek teeth, the nasal cavity and paranasal sinuses, and is commonly desensitized for dental surgery, or to facilitate the diagnosis of head shaking in horses (Newton et al. 2000). The maxillary nerve is accessible at the pterygopalatine fossa, ventral to the periorbita, between the foramen rotundum and the maxillary foramen, in a location where the nerve is surrounded by multiple large arteries and veins. In close proximity lie the deep facial vein, the periorbita, which includes the intraperiorbital compartment, and the maxillary artery that branches into the infraorbital artery, the descending palatine artery and the buccal artery (Tremaine 2007; Staszyk et al. 2008). Complications have arisen from inadvertent puncture of these structures, and it is important to minimize these risks in clinical practice.

Complications range in severity from transient retrobulbar haematomata and facial swellings, to variable exophthalmos and potentially prolapse of the globe (Archer 2011). Horner’s syndrome, exophthalmos and ocular muscle paralysis have been reported with excessive volumes of local anaesthetic (Tremaine 2007). More severe complications including collapse, blindness, retrobulbar infection and meningitis have been reported in horses (Staszyk et al.

2008; Simhofer 2013), and convulsions, neurological deficits and cardiac arrest have been reported in other species (Rubin 1995; Pearce et al. 2003; Staszyk et al. 2008;). Some of these reports specifically described complications even when the procedure was performed by experienced clinicians (Bardell et al. 2010).

Desensitization of the maxillary nerve at the pterygopalatine fossa is well described using surface landmarks for guidance, but these are vague, making the block difficult and potentially unreliable, which is of particular concern when being used diagnostically (Schumacher & Perkins 2005; Staszyk et al. 2008; Bardell et al. 2010). An ultrasound-guided approach has been described to minimize the risks and visualize optimal needle placement (O'Neill et al. 2014). This appears to be beneficial, however, to our knowledge, no direct comparison has been made between the surface landmark and ultrasound-guided approaches. In addition, ultrasound-guided approaches require a high level of operator skill, and a good understanding of the regional sonographic anatomy, or the potential for complications and inaccuracies may be anticipated.

A novel tool has been developed for training and clinical application, utilizing a needle guidance positioning system (GPS) to aid practitioners in developing and applying the skill of ultrasound-guided nerve blocks (Tang et al. 2014; Tielens et al. 2014). The GPS system (SonixGPS, Ultrasonix Medical Corporation, BC, Canada) calculates and displays a needle's position and trajectory, allowing visualization of the needle trajectory during both in and out-of-plane techniques. This technology therefore has potential advantages over conventional ultrasonography where the whole needle and its trajectory is only visible during an in-plane approach and during the out-of-plane approach only the needle tip is visible as it crosses the ultrasound plane

The objective of this method comparison study was to compare two previously described approaches to maxillary nerve infiltration (surface landmark and ultrasound-guided) with a novel needle guidance positioning system, and to quantify the success and complication rates of each method when performed by inexperienced operators. We hypothesized that the ultrasound-guided approaches would result in significantly greater success, defined as successful deposition of contrast in contact with the maxillary nerve, with fewer complications, defined as inadvertent penetration of vascular and periorbital structures, than the surface landmark approach and that the needle guidance positioning system would result in significantly greater success with fewer complications than regular ultrasound.

Materials and Methods

This study was authorised by the Ethics and Welfare Committee of the Royal Veterinary College (local approval reference number 2014/S35).. Informed consent was obtained from all study participants.

Three preliminary cadaver heads were used to pilot protocols for quantifying infiltration of the maxillary nerve using the three injection techniques. Injection of 0.5 mL Iohexol radiopaque contrast solution (Omnipaque, GE Healthcare, UK) provided the best balance for assessment of needle placement and contrast diffusion pattern. Computed tomography (CT) (GE Lightspeed Pro 16, GE Medical Systems, UK) indicated that the soft tissue structures of the pterygopalatine fossa, including the maxillary nerve, were most clearly visualized with CT settings of 120 kV, 300 mA and slice thickness of 2.5 mm. The three pilot cadaver heads were bilaterally dissected to confirm normal anatomy and variations and were not included in the statistical analysis.

Thirty-eight cadaver heads from adult Warmblood-type horses were sourced from an abattoir. All horses had no known history and showed no obvious external signs of abnormalities of the head. The heads were sectioned at the level of the atlanto-occipital junction and were each placed on a table to imitate the position of a standing, sedated horse. Sample size was derived from the maximum number of students available to participate in this study during the study time frame.

Twenty-six clinical veterinary students between their third and fifth (final) year of training and with no previous experience of maxillary nerve blocks volunteered to participate in the project. Informed consent was obtained from all participants. Each student operator was provided with access to literature describing the surface landmark and ultrasonographic approaches, as well as a protocol with a standardized description of the three methods, with no additional verbal guidance provided. Each operator performed all three injection techniques consecutively in the order outlined below. The order of techniques was not randomized because any knowledge derived from ultrasound examination of the regional anatomy would impact on the success of the surface landmark technique.

For all three techniques, an 18 gauge, 3.5-inch spinal needle was used to inject 0.5 mL iodinated contrast solution (Omnipaque) into the pterygopalatine fossa to simulate the injection of a local anaesthetic agent.

Method 1: Surface landmark guidance

Operators had the option of using either of two surface landmark-guided approaches previously described (Bardell et al. 2010). The needle could be inserted either ventral to the facial crest perpendicular to the skin on a line running perpendicular to the dorsal contour of the head to the lateral canthus of the eye, or ventral to the zygomatic process of the temporal bone at the narrowest part of the zygomatic arch pointing rostromedially and ventrally towards the contralateral sixth maxillary cheek tooth.

Method 2: Ultrasound-guidance

Following the recently described approach, an 8 cm^2 area was clipped ventral to the zygomatic arch and caudal to the facial crest (O’Neill et al. 2014). A linear ultrasound transducer (L14-5/38, SonixTablet; Analogic Corporation, MA, USA), operating at 6 MHz, was used to examine the area. Initially positioning the probe vertically with the dorsal aspect of the probe immediately ventral to the zygomatic arch, the probe was swept rostrally and caudally to visualize the bony landmarks of the pterygopalatine fossa. The epiperiorbital fat body was appreciable, within which cranially it was possible to image the maxillary nerve entering the maxillary foramen. The periorbital cone and extraocular muscles were appreciable immediately dorsal to the nerve. Once confident with the location of the maxillary nerve, operators were given the option of performing an in-plane injection, introducing the needle ventral to the probe, recognizing the needle as a hyperechoic line as it advanced through the musculature and periorbital fat or performing an out-of-plane injection, introducing the needle caudal to the probe, recognizing the needle tip as it ultimately crossed the ultrasound beam.

Method 3: Guidance positioning system (GPS)

Preparation, ultrasound settings and probe were as for method 2. A 0.55 mm needle sensor was inserted into the needle and a system accuracy test was performed. Operators were again given the option of performing an in-plane or out-of-plane injection. For the in-plane approach, the approach was similar to that described above, however the SonixTablet monitor displayed orientation bars (Fig. 1) to guide hand and needle position. An insertion point was chosen in the middle of the transducer for precise alignment and the insertion angle of the needle was adjusted to reach the target. When using GPS-guidance, orientation bars were superimposed on the ultrasound image and turned green to indicate when the needle was in the correct position and direction, and then the needle could be seen beneath the transducer. Advancing the needle, the projection was shown as a red outline, and a further green line extended to the target. The out-of-plane approach relied on the guidance positioning system to display an ‘X’ on the ultrasound image (Fig. 2) at the point at which the needle was predicted to intersect the plane of the ultrasound beam. This enabled optimal needle positioning before piercing the skin and a direct advancement towards the target position.

After both maxillary nerves were injected each cadaver head was imaged using CT as described above. Images were analyzed blindly by a single observer (BC). The observer had been trained in the regional anatomy, in the use of image viewing software (OsiriX MD, Pixmeo, Switzerland) and in particular distance measurement callipers. The scans were reviewed in all planes. The CT scans were reviewed for success and complications. Injections were defined as successful if contrast was in direct contact with the maxillary nerve or within 3 mm in any plane (Fig. 3) or unsuccessful if contrast was more than 3 mm from the nerve in any plane (Fig. 4). Injections were defined as having a complication if contrast was identified within the periorbital structures or within the vasculature (Fig. 5). Data were numerically coded in excel and statistically analysed using SPSS (IBM SPSS Statistics, version 21.0, IBM Corp, NY, USA). Fisher's exact tests were performed to assess the association of injection technique with the binary outcomes of success or complication.

Results

The objective of this study was to compare the three approaches for maxillary nerve infiltration. Perineural injection of the maxillary nerve in the pterygopalatine fossa was attempted 76 times. Twenty-six injections were performed using surface landmark guidance, 26 with ultrasound-guidance and, due to technical difficulties relating to software licensing, 24 with needle GPS. Successful perineural contrast deposition was achieved in 65.8% of injections overall (50/76). Complications were identified in 53.9% of injections (41/76).

Successful contrast deposition in contact with the maxillary nerve was seen with the anatomical surface landmark-guided approach (Method 1) in 50% of injections (13/26), with conventional ultrasound (Method 2) in 65.4% (17/26) and with GPS ultrasound (Method 3) in 83.3% (20/24). There was a statistically significant association between injection method and success (Fisher's exact test, $p = 0.046$).

Complications were seen in 61.5% (16/26) of surface landmark-guided injections, and 50% of both ultrasound-guided (12/24) and GPS-guided injections (13/26). There was no statistically significant association between injection method and complication rate (Fisher's exact test, $p = 0.467$).

Discussion

Significantly higher success rates were observed with the SonixGPS system compared to the ultrasound-guided or surface-guided techniques. There was no statistically significant difference in the complication rates, although fewer complications were observed with the GPS ultrasound approach. Visualization of deep structures such as bony landmarks seemed to have a positive influence on successful needle placement. The ultrasound probe and settings were the same between the GPS and conventional ultrasound techniques, so higher success with the GPS-guidance was likely related to the improved needle visualization with this technique. Successful needle placement offers important advantages for clinical cases, in particular the ability to deliver a small injectate volume precisely.

Surface landmark success rates (50%) were slightly higher when compared to those previously reported (40%) (Wilmink et al. 2015). Both studies reported success rates for veterinary students performing the injections, however, study design differences make direct comparison difficult, notably the use of differing contrast medium volumes (0.5 mL in this study compared to 0.1 mL), and different outcome measures (direct hit and miss used in this study compared to a zonal system) (Wilmink et al. 2015). Higher success rates of up to 80% have been seen with more experienced operators, when performing the surface landmark-guided technique (Bardell et al. 2010; Wilmink et al. 2015), however smaller volumes (0.25 mL and 0.1 mL) of methylene blue dye were used in these studies and successful injection was defined by dissection rather than three dimensional imaging (Bardell et al. 2010).

Ultrasound-guided success rates were lower in this study (65%) compared to those (100%) previously reported with more experienced operators (O'Neill et al. 2014). Extrapolating from the results of previous studies it is likely that operator experience is a major factor in the lower success rates for ultrasound in the current study. There may also be a difference in diffusion pattern between the contrast used in this study and the methylene blue used in other studies (O'Neill et al. 2014). The key element in ultrasound-guided anaesthesia is visualization of the needle. The two most common errors of inexperienced users are failure to view the needle before advancement and moving the ultrasound transducer unintentionally.

Additionally, the five quality-compromising patterns of behaviour are identified as failure of recognizing the maldistribution of local anaesthesia, failure to recognize an intramuscular location of the needle tip before injection, fatigue, failure to correctly correlate the sidedness of the patient with the sidedness of the ultrasound image, and poor choice of needle-insertion site and angle in relation to the probe preventing accurate needle visualization (Sites et al. 2007). Therefore, increasing experience of needle control may substantially improve operator's performance and success rate of regional anaesthesia. Naïve operators were selected to ensure uniformity of experience level in a study population of a suitable size.

There were insufficient numbers to draw any conclusions regarding the influence of student year and outcome, however this would be an avenue for future studies.

In a phantom study, GPS was demonstrated to shorten execution time and reduce needle repositioning maneuvers (Tielens et al. 2014). The system has also been evaluated in human medicine for spinal injections, brachial plexus block and thoracic paravertebral block but to our knowledge this is the first publication of an application of the technology in veterinary medicine (Brinkmann et al. 2013; Kaur et al. 2013; Tang et al. 2013). In our study, GPS injection of the maxillary nerve had the highest success rate (83.3%) compared to surface landmark and standard ultrasound approaches.

In this study, complication rates were high with an overall rate of 53.9%. A complication was defined as contrast medium identified within the periorbital cone or the surrounding vasculature, as determined in three dimensions by CT. Complication rates of 0 and 3% have previously been reported using methylene blue injections (Bardell et al. 2010; O’Neill et al. 2014). The differences in complication rate may be due to different study methodology, with the current approach detecting subtler infiltration of non-target structures. Indeed, during preliminary work for this study infiltration small vessels could not be detected using methylene blue rather than contrast CT.

Complication rates were not significantly different between the two ultrasound-guided approaches. This may be due to the difficulty in imaging vasculature using Doppler assessment in cadavers on ultrasound, and the inability to aspirate blood following direct vessel puncture (Bardell et al. 2010). In live clinical cases visualization of blood flow within vessels is likely to further reduce the likelihood of inadvertent puncture of blood vessels and resulting complications such as inadequate blockade, haematoma, abscess formation and meningitis (Staszyk et al. 2008; Archer 2011; Simhofer 2013; O’Neill et al. 2014). Direct nerve puncture can also be minimized with direct visualisation, thereby avoiding peripheral nerve damage and induction of paraesthesia, a complication which has been well documented in the medical literature (Chambers 1992). Further study is required to assess the complication rates in live horses and the effects of the use of ultrasound and GPS-guidance.

Limitations of this study include the non-random sequential nature of the nerve blocks. Each student performed surface landmark first, followed by ultrasound-guided then GPS-guided. Each injection was performed on a different side of the head or a new head and no feedback was given to each operator between injections. The relevant literature was provided for all three blocks at the beginning to minimize the effects of learning from one block to another. This methodology was based upon previous literature, which has described learning operators to be statistically similar to completely inexperienced operators, when performing maxillary nerve blocks (Wilmink et al. 2015). Teaching material was standardized throughout the trial and no feedback was given until after the three injections had been performed and questionnaires completed, in order to prevent bias. There are indications that any previous experience of inexperienced operators may not have an effect while participating in a phantom study (Tielens et al. 2014; Whittaker et al. 2013), which is comparable to our study model with cadaver heads. More concentrated training on ultrasound imaging would have provided results in favour of navigation assistance, which would be in accordance with the extensive training effect seen by users of video games and flight simulators (Tielens et al. 2014).

Post-hoc power calculation indicated that at least 94 students were required to detect a statistical difference in success rate between surface landmark (50%) and GPS ultrasound (83%) techniques assuming 80% power and 5% type I error rate. Likewise, 718 students would be required to demonstrate a difference in complication rate between surface landmark (61%) and either of the two ultrasound techniques (50%). Each student required 1.5 heads to complete the three techniques making such numbers impractical. Although underpowered this study provides useful preliminary data and prompts further hypotheses. For example, further studies should be performed to assess the time to perform the injection, number of needle redirections and to compare in-plane and out-of-plan techniques.

Conclusion

The Sonix GPS system enabled more successful infiltration of the maxillary nerve, and ultrasound-guidance proved significantly more accurate than surface-guided landmark approaches. No significant difference was seen in complication rate and further research is warranted to investigate potential benefits of the GPS system such as smaller injectate volume, shorter duration of injection procedure and reduced needle repositioning. The technique is likely to be suitable for other local peripheral nerve analgesia.

References

Archer M (2011) Regional anaesthesia of the equine head and body. Proceedings of the ACVS Equine and Small Animal Symposium, 580-584.

Bardell D, Iff I, Mosing M (2010) A cadaver study comparing two approaches to perform a maxillary nerve block in the horse. Equine Vet J 42, 721-725.

Brinkmann S, Tang R, Sawka A, Vaghadia H (2012) Assessment of a real time ultrasound guided spinal technique using SonixGPS in human cadavers. Can J Anaesth 59, 1156–7.

Chambers WA (1992) Peripheral nerve damage and regional anaesthesia. Br J Anaesth 69(5), 429-230.

Johnston GM, Taylor PM, Holmes MA, Wood JLN (1995) Confidential enquiry of perioperative equine fatalities (CEPEF-1): preliminary results. Equine Vet J 27, 193-200.

Kaur B, Tang R, Vaghadia H, Sawka A (2013) Ultrasound guided thoracic paravertebral block using the SonixGPS system in human cadavers. Can J Anaesth 60, 331-2.

Mee AM, Cripps PJ, Jones RS (1998) A retrospective study of mortality associated with general anaesthesia in horses: elective procedures. Vet Rec 142, 275-276.

Newton SA, Knottenbelt DC, Eldridge PR (2000) Headshaking in horses: possible aetiopathogenesis suggested by the results of diagnostic tests and several treatment regimes used in 20 cases. Equine Vet J 32, 208-216.

Rubin AP (1995) Complications of local anaesthesia for ophthalmic surgery. Br J Anaesth 75, 93-96.

O'Neill HD, Garcia-Pereira FL, Mohankumar PS (2014) Ultrasound-guided injection of the maxillary nerve in the horse. Equine Vet J 46, 180-184.

Pearce SG, Kerr CL, Bouré LP, Thompson K, Dobson H (2003) Comparison of the retrobulbar and Peterson nerve block techniques via magnetic resonance imaging in bovine cadavers. J Am Vet Med Assoc 223, 852-855.

Schumacher J, Perkins, J (2005) Surgery of the paranasal sinuses performed with the horse standing. Clinical techniques in equine practice 4, 188-194.

Simhofer H (2013) Local anaesthesia for dental and maxillofacial surgery in equines. In: European Veterinary Conference Voorjaarsdagen.

Sites BD, Spence BC, Gallagher JD, Wiley CW, Bertrand ML, Blike GT (2007) Characterizing novice behaviour associated with learning ultrasound-guided peripheral regional anesthesia. Reg Anesth Pain Med 32, 107-15.

Staszyk C, Bienert A, Bäumer W, Feige K, Gasse H (2008) Simulation of local anaesthetic nerve block of the infraorbital nerve within the pterygopalatine fossa: anatomical landmarks defined by computed tomography. Res Vet Sci 85, 399-406.

Tang R, Sawka A, Vaghadia H, Umbarje K (2013) SonixGPS needle tracking system for out-of-plane brachial plexus block in human cadavers. Acta Anaesthesiol Scan 57, 398–9.

Tang R, Sawka A, Vaghadia H (2014) SonixGPS - the role of operator experience. Anaesthesia 69, 1060-1061.

Tielens LK, Damen RB, Lerou JG, Scheffer G-J, Bruhn J (2014) Ultrasound-guided needle handling using a guidance positioning system in a phantom. Anaesthesia 69, 24-31.

Tremaine WH (2007) Local analgesic techniques for the equine head. Equine Vet Educ 19, 495-503.

Whittaker S, Lethbridge G, Kim C, Keon Cohen Z, Ng I (2013) An ultrasound needle insertion guide in a porcine phantom model. Anaesthesia 68, 826-829

Wilmink S, Warren-Smith CM, Roberts VL (2015) Validation of the accuracy of needle placement as used in diagnostic local analgesia of the maxillary nerve for investigation of trigeminally mediated headshaking in horses. Vet Rec 176, 148.

Young SS, Taylor PM (1993) Factors influencing the outcome of equine anaesthesia: a review of 1,314 cases. Equine Vet J 25, 147-151.

Figure Legends

Figure 1 In-plane maxillary nerve block injection technique using GPS-guidance (guidance positioning system). The ultrasound image is overlain with orientation bars on each end of the probe. The orientation bars turn green to indicate needle is in-plane with the ultrasound beam and amber or red if the needle moves out-of-plane (not detailed here).

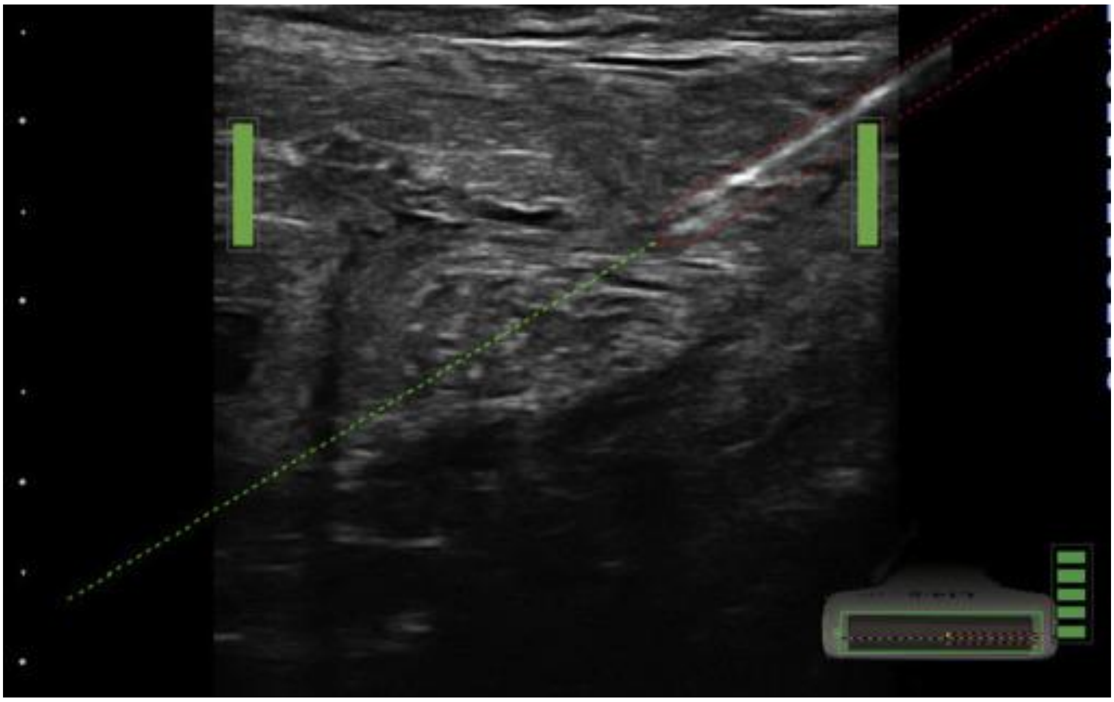

Figure 2 Out of plane maxillary nerve block injection technique using GPS-guidance (guidance positioning system). The ultrasound image is overlain with an outline of the direction of travel of the needle (dashed red lines) and a white cross ('X') indicating the point at which the needle will intersect the ultrasound beam.

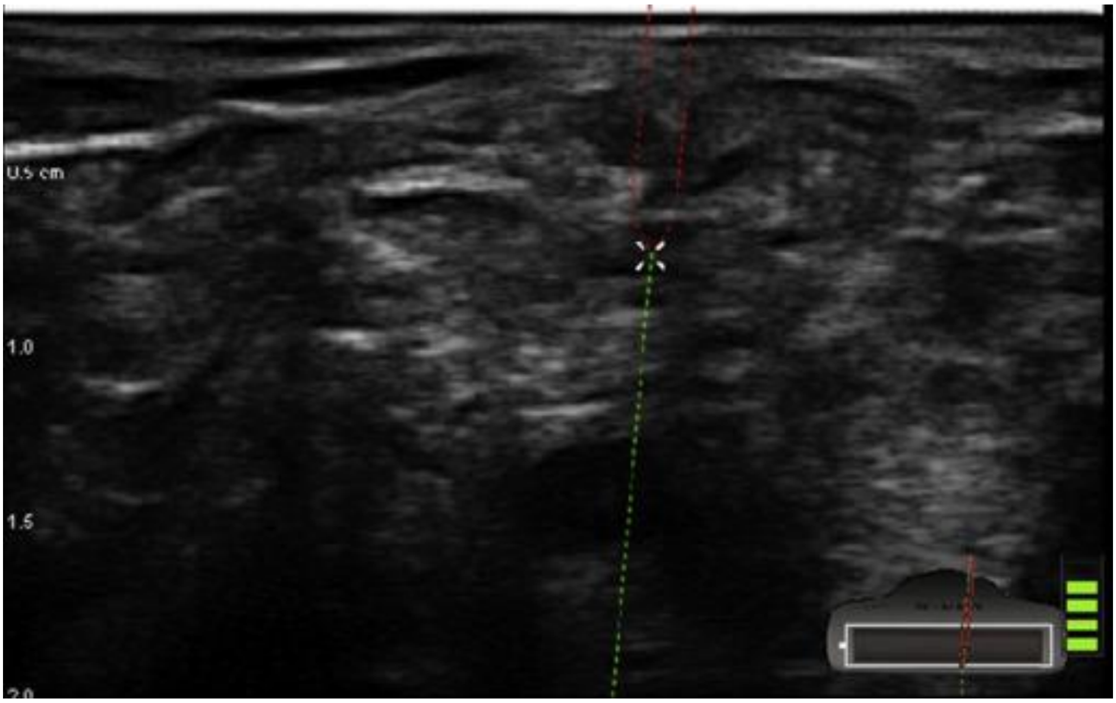

Figure 3 Transverse computed tomography image showing successful injection. Contrast (yellow arrows) has been bilaterally deposited in direct contact with the maxillary nerves (circled in red).

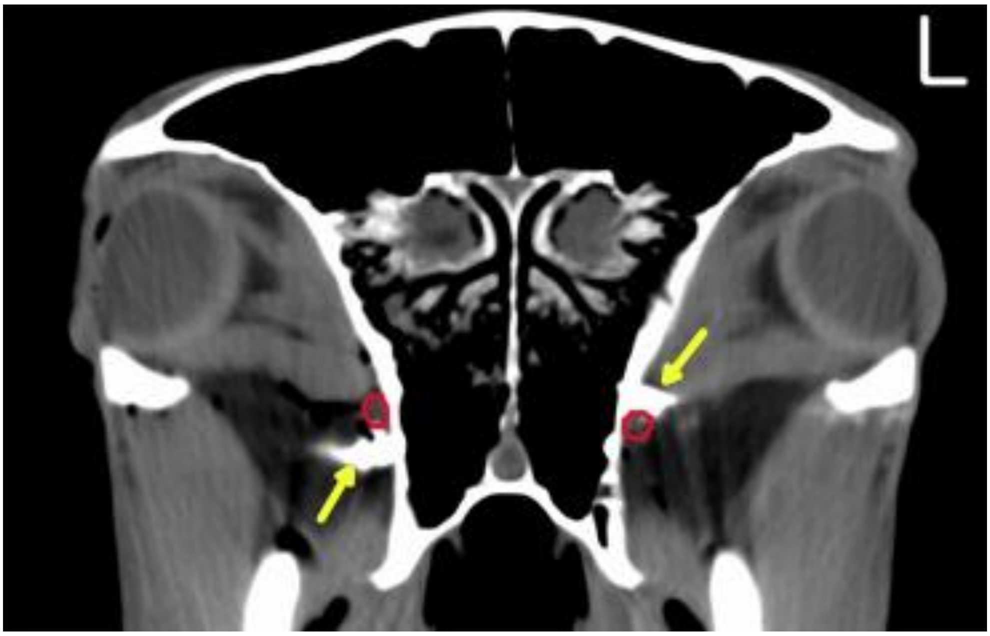

Figure 4: Transverse computed tomography image showing bilaterally unsuccessful injection. Contrast (yellow arrows) has not been deposited in direct contact with the maxillary nerves (circled in red).

Figure 5: Transverse computed tomography image showing an example of complications observed with inaccurate contrast injection. The maxillary nerves are circled in red. Contrast (yellow arrows) has been deposited within the periorbital cone.