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Anesthetic Management for Dental and Sinus Surgery

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Introduction

Most adult horses have 36–44 teeth by the time they reach 5 years of age. In general, the dental arcades are composed of 12 incisors, 12 premolars, and 12 molars (some horses will also have additional teeth including canine and wolf teeth). Due to the grinding nature of eating, horse teeth must continue to grow at approximately 1/8" per year until the individual horse reaches old age where teeth can then be completely shed. Throughout the maxillary and frontal areas of the skull, air-filled sinus cavities developed to allow for a large number of premolar and molar teeth without adding significant weight. The linings of the sinuses are rich in vasculature and may play a role in thermoregulation. Significant disease requiring surgical intervention can occur in the teeth or sinus.

Relevant Anatomy

The nasal cavity is a voluminous cavity divided by the nasal septum and vomer bone (Hillmann 1975). The nasal cavity contains the reserve crowns of the maxillary cheek teeth and a portion of the paranasal sinuses of which the major clinically significant sinuses are the

frontal and maxillary sinuses (Hillmann 1975). Two major nasal conchae in each nasal cavity divide the nasal passage into the dorsal, middle, ventral, and common meatus.

The frontal sinus has a large communication with the dorsal conchal sinus, and thereby both are known as the conchofrontal sinus (Hillmann 1975). The ventral conchal sinus communicates with the rostral maxillary sinus over the infraorbital canal and is separated from the caudal maxillary sinus by a thin osseous sheet, the caudal bulla of the ventral conchal sinus. The conchae (or turbinates) are delicate scrolls of bone that are attached laterally in the nasal passage and contain the conchal sinuses (Hillmann 1975).

The maxillary sinus is divided by a thin septum into rostral and caudal compartments or rostral and caudal maxillary sinuses, respectively (Hillmann 1975). The rostral maxillary sinus contains the root of the maxillary first molar and the caudal maxillary sinus contains the roots of the second and third molars (Dixon 2005). The caudal maxillary sinus is partially divided by the infraorbital canal, which may be distorted by a disease process within the sinus. The caudal and rostral maxillary sinuses have separate openings into the middle nasal meatus and the caudal maxillary

sinus communicates with the frontal sinus through the large frontomaxillary opening (Hillmann 1975).

Diagnostic Techniques

Complete history and physical examination of the horse, including assessment of mental status, cardiopulmonary functions, hydration status, and body temperature are mandatory prior to sedation, anesthesia, and/or local anesthetic techniques for dental and sinus surgery. Frontonasal and maxillary bone flaps are indicated to remove of a wide variety of lesions that may develop in the paranasal sinuses or turbinates, such as paranasal sinus cysts, neoplasia, progressive ethmoid hematomas, and apical infections of maxillary cheek teeth (Nickels 2012). The lesions typically cause unilateral epistaxis or mucopurulent nasal drainage, in contrast with diseases of the pharynx or lungs in which the drainage is typically bilateral. However, appropriate diagnostic techniques are indicated to rule out concurrent diseases of the pharynx and lungs that may affect patient management either under general anesthesia or under standing sedation.

On endoscopy, narrowed nasal meati, purulent material, masses, or blood can be seen in

the nasal passage and/or draining from the sinus openings (Nickels 2012). Radiography of the skull may reveal free fluid lines, radiodense masses, paranasal sinus cysts, and lucency and/or proliferation associated with dental disease (Figure 1.1). Sinocentesis can be used to obtain fluid sample for culture and cytological examination. Sinuscopy with the horse standing and sedated is useful for the examination, diagnosis, and treatment of some disorders of the paranasal sinuses (Nickels 2012).

Local Anesthetic Techniques for the Equine Teeth and Sinuses

Locoregional anesthesia can be performed prior to many dental and surgical procedures for horses under both standing sedation and general anesthesia. It is routinely accomplished using either lidocaine 2% or mepivacaine 2% solutions with mepivacaine providing a longer duration of action compared to lidocaine (two to four hours versus one to two hours). It is generally advisable to infuse a small amount (1–2 ml) of local anesthetic into the skin at the site of the nerve block to desensitize the skin prior to attempting the locoregional block. This is especially important under standing sedation conditions. Approximately 5–10 minutes should

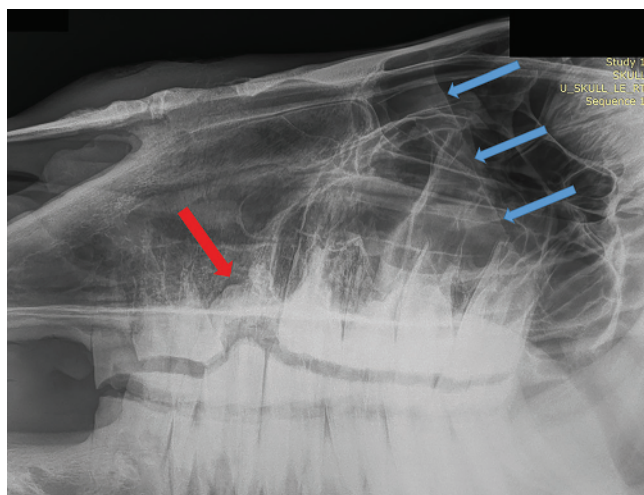


Figure 1.1 Lateral radiograph of a horse skull showing a fluid line (blue arrows) running through the caudal maxillary sinuses. The horse's nose was angled downward resulting in the gravity-dependent fluid line being parallel to the ground. The sinusitis likely resulted from a periapical infection of a cheek tooth (red arrow). Maxillary nerve blockade can be used to desensitize the area for surgical removal of the tooth and drainage and lavage of the sinus.

be allowed to elapse after administration of the local anesthetic to achieve desensitization of the region.

Infraorbital Block

The infraorbital block desensitizes the maxillary teeth to the level of the first molar, the maxillary sinus, the skin from the lip nearly to the medial canthus, and the rostral nose as well as the roof of the nose (Skarda et al. 2010) (Figure 1.2). The infraorbital canal is palpated as the midpoint on a line between the nasoincisive notch and the rostral most aspect of the facial crest (Rice 2017). The levator labii superioris muscle must be manually elevated to facilitate placement of the needle into the canal (Rice 2017). For local anesthesia of the upper lip and nose, a 20 gauge, 2.5cm needle can be advanced perpendicularly to the skin at the opening of the infraorbital canal using 5 ml of local anesthetic (Skarda et al. 2010). For

blockade of the maxillary teeth and sinus, a 25–20 gauge, 3.8–5cm needle should be advanced into the canal and 3–5ml of local anesthetic should be injected (Rice 2017; Skarda et al. 2010).

Maxillary Nerve Block

Blocking the maxillary nerve within the pterygopalatine fossa results in blockade of the maxillary teeth, the paranasal sinus, and the nasal cavity (Woodie 2013) (Figure 1.3). Multiple techniques have been described for performing this block, owing in part to relatively vague surface landmarks for injection. The first involves the injection of local anesthetic into the extraperiorbital fat body (Staszuk et al. 2008). This technique uses a 18 gauge, 3.5" spinal needle to inject approximately 10ml of local anesthetic into the fat body surrounding the maxillary nerve (Staszuk et al. 2008). The injection site is made



Figure 1.2 The infraorbital block in the horse. The yellow circle indicates the location of the infraorbital canal, and stippling indicates the area of desensitization following administration of local anesthetic.



Figure 1.3 The maxillary nerve block in the horse. The yellow circle indicates the location of the infraorbital canal, and stippling indicates the area of desensitization following administration of local anesthetic.

perpendicular to the skin at a point located 10mm ventral to the zygomatic arch transverse to the plane between the middle and caudal 1/3 of the eye and the needle is advanced until it pops through the masseter muscle for a total depth of approximately 4.5–5 cm (Staszuk et al. 2008). The technique was used in horses under standing sedation using a 20 gauge, 3.5" spinal needle and reported generally successful blockade with no reaction of mechanical or thermal stimulus with mild chewing, bleeding, swelling, and turgor at the injection site as the only complications (Rieder et al. 2016a). Another study evaluating the volume of lidocaine necessary to produce anesthesia with the extraperiorbital fat body technique and found that 2ml/100 kg of body weight should result in sufficient local anesthesia while minimizing side effects (Rieder et al. 2016b).

Another technique involves the use of a 19 gauge, 2.5" spinal needle with an injection site along the ventral border of the zygomatic arch at the narrowest point of the arch (Newton et al. 2000). The needle is inserted into the skin on a rostromedial and ventral angle and is directed along this angle toward the 6th cheek tooth on the contralateral side to a depth of approximately 2" at which 5 ml of local anesthetic is injected (Newton et al. 2000). At a landmark slightly rostral to that described by Newton, an injection can be made perpendicular to the skin, ventral to the zygomatic process at a point on the skin found on the line running perpendicular to the dorsal head contour and through the temporal canthus of the eye (Bemis 1917). These two techniques were compared using cadaver heads and new methylene blue dye and failed to elucidate a significant difference between the two, with both techniques resulting in at least partial success in "blockade" of the maxillary nerve approximately 80% of the time (Bardell et al. 2010). It is worth noting that the authors reported inadvertent deposition of dye into the deep facial vein on two instances (Bardell et al. 2010). This reinforces the need to aspirate the needle at the

injection site prior to injection for any local anesthesia technique.

Another approach to locoregional anesthesia of the maxillary nerve is accomplished by directing a long (8–9 cm, 21–19 gauge) Touhy spinal needle through the infraorbital canal, using the landmarks described previously and injecting 10 ml of local anesthetic (Nannarone et al. 2016). This technique was evaluated using CT of cadaver heads and contrast medium and noted that the needle placement and injection were reasonably easy and that the contrast medium reached the maxillary nerve sufficiently such that it would be expected to result in blockade of the nerve (Nannarone et al. 2016).

In an attempt to minimize complications, including inadvertent puncture of vascular structures in the pterygopalatine fossa, a technique for ultrasound-guided perineural injections of the maxillary nerve has been described (O'Neill et al. 2014). Using a 6 mHz ultrasound probe facilitated visual identification of all relevant anatomical structures, allowing the operator to position the 18 gauge, 3.5" spinal needle tip in close proximity to the maxillary nerve (O'Neill et al. 2014). In cadavers injected with new methylene blue, ultrasound guidance resulted in successful staining of the maxillary nerve with all injections while cutaneous desensitization of the ipsilateral nose was achieved in all live horses injected with mepivacaine (O'Neill et al. 2014).

Lastly, a recent study evaluated veterinary students performing contrast injection maxillary nerve blocks using the Bemis (1917) or Newton et al. (2000) techniques for surface landmark locations with O'Neill's et al. (2014) ultrasound-guided technique and a technique using a new needle guidance tool (SonixGPS) (Stauffer et al. 2017). Compared to a success rate of 50% with surface landmark techniques, ultrasound guidance resulted in 65.4% success and the GPS tool increased the success rate to 83.3%; however, there was no difference in complication rates between the three (53.9%) (Stauffer et al. 2017).

It is important to note that both the infraorbital and maxillary nerves arise from the trigeminal nerve and are responsible for sensation. However, the facial nerve supplies motor function to the muscle of the face, and branches can run in proximity to the infraorbital and maxillary nerves. Inadvertent blockade of the facial nerve can result in paralysis of the levator labii superioris, levator nasolabialis, and levator anguli oris muscles. As a result, a horse may lose the ability to “flair” its nostrils during inspiration and can even result in nasal collapse during inspiration leading to upper airway obstruction, particularly if blockade is bilateral. Short endotracheal tubes or cut syringe cases can be inserted into the nostrils to provide stenting of the nasal passage until the nerve blockade wears off and normal nerve function resumes.

Mental Nerve Blocks

Blockade of the mental nerve at the mental foramen results in desensitization of the lower lip while advancement of a needle into the mandibular canal results in blockade of the mandibular alveolar nerve leading to desensitization of the ipsilateral incisors and premolars (Skarda et al. 2010; Rice 2017) (Figures 1.4 and 1.5). The block is achieved by elevating the depressor labii inferioris muscle and depositing

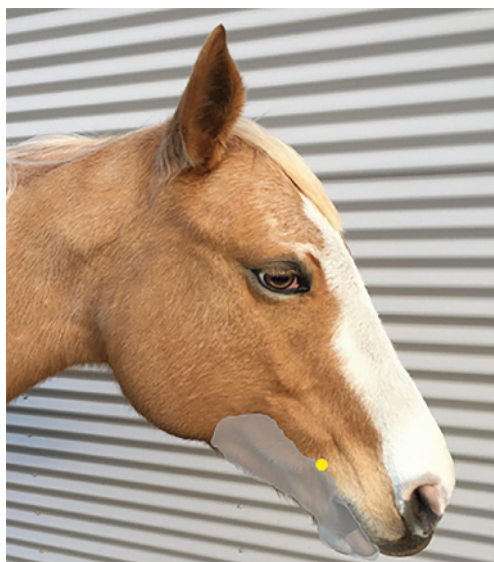
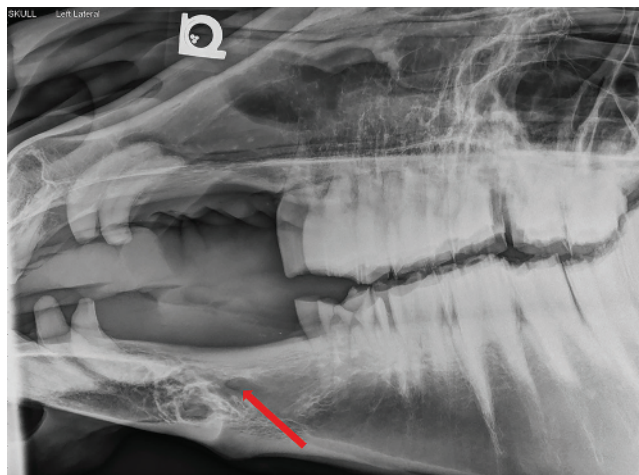


Figure 1.4 The mental nerve block in the horse. The yellow circle indicates the location of the infraorbital canal, and stippling indicates the area of desensitization following administration of local anesthetic.

approximately 5 ml of local anesthetic with a 22 gauge, 1" needle at the palpable ridge along the mandible at approximately the middle of the interdental space (Skarda et al. 2010). A 25–20 gauge, 1–2.5" needle and 3–10 ml of local anesthetic is described blockade of the mandibular alveolar nerve within the mandibular canal (Skarda et al. 2010; Rice 2017).

Figure 1.5 Lateral radiograph of a horse skull with severe dental disease. The mental foramen (red arrow) can be seen where the mental nerve exits to innervate the rostral aspect of the mandible. Mental nerve blockade can be used to desensitize the mandible rostral to the mental foramen to the level of the mandibular symphysis.



Inferior Alveolar (Mandibular) Nerve Blocks

Desensitization of the inferior alveolar nerve prior proximal to its entrance into the mandibular canal results in blockade of the entire hemi-mandible including teeth, mandibular bone, skin, and gingiva (Figures 1.6 and 1.7). Due to the close anatomical proximity of the lingual branch of the trigeminal nerve, it is also possible to inadvertently desensitize the tongue, potentially resulting in self-trauma on recovery (Caldwell and Easley 2012; Harding et al. 2012). Smaller volumes of local anesthetic may minimize this risk (Harding et al. 2012). Much like the maxillary nerve, multiple techniques have been proposed to achieve desensitization of this nerve in the horse. The earliest was by Bemis who suggested that a vertical line be drawn from the lateral canthus of the eye ventrally to the mandible and a horizontal line be drawn from the occlusal surface of the mandibular molars caudally to the ramus of the mandible with the mandibular foramen located on the medial aspect of the mandible at the junction of the two lines (1917). The technique suggested inserting a spinal needle 3 cm ventral to the temporomandibular junction and advancing it medially to the mandibular foramen (Bemis 1917). Modifications of this technique include approaching the foramen



Figure 1.6 The inferior alveolar/mandibular nerve block in the horse. The yellow circle indicates the location of the infraorbital canal, and stippling indicates the area of desensitization following administration of local anesthetic.

from the ventral border of the ramus and inserting a long spinal needle along the imaginary horizontal line from the caudal aspect of the vertical ramus, medially along the mandible to a depth of 9 cm and injecting

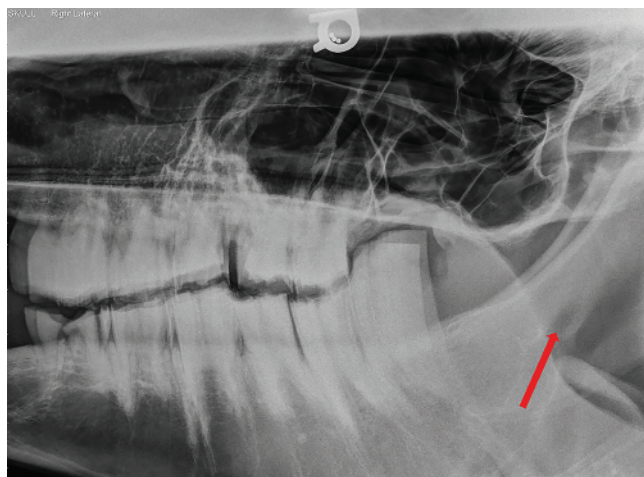


Figure 1.7 Lateral radiograph of a horse skull with severe dental disease. The mandibular foramen (red arrow) can be seen where the mandibular nerve enters on the medial aspect to innervate the entire hemi-mandible. Mandibular nerve blockade can be used to desensitize the entire hemi-mandible.

10ml of local anesthetic (Fletcher 2004; Harding et al. 2012).

A recent cadaver study compared inferior alveolar nerve blocks performed using the landmarks suggested by Bemis and advancing an 18 gauge, 20cm spinal needle either from the ventral border of the vertical ramus at Bemis' imaginary vertical line to the mandibular foramen or rostradorsal from the angle where the horizontal and vertical rami meet the foramen (Harding et al. 2012). The study reported successful dye staining of the nerve in 59% of the vertical injections and 73% of the angled injections; however, there was no significant difference between the two techniques (Harding et al. 2012).

Lastly, another recent study has described the use of an intraoral approach to the inferior alveolar nerve block in the horse. The intraoral approach is used quite frequently in other species; however, the anatomy and relatively narrow gape of the horse make manual palpation of the mandibular foramen impossible. The study described the use of a custom-made tool that was essentially a 20-gauge needle attached to a length of extension tubing and secured to a bent metal rod to allow the needle to be directed through the mouth and to the medial mandibular location of the foramen (Henry et al. 2014). In the study, a total of 51 blocks using 5ml of 2% mepivacaine were administered and procedures including endodontics, mucosal elevation, and dental extractions were performed successfully following all blocks (Henry et al. 2014). One horse was reported to develop an abscess in the pterygoid fossa two weeks after the procedure (Henry et al. 2014).

Dental Extractions and Repulsions

Extractions and repulsions of teeth can be done either with standing sedation and local anesthesia techniques or under a general anesthetic. The choice is a matter of the horse's personality and health status, the perceived invasiveness of the procedure, as well as the

surgeon's preference; however, the obvious benefit of performing the procedure in a standing horse is the avoidance of the inherent risk and complications associated with general anesthesia. In addition, standing sedation avoids having an orotracheal tube in the mouth where it may obstruct the surgeon's view and/or make access to the tooth with extraction equipment difficult. Multiple studies have described the successful use of a combination of standing sedation and local anesthesia blocks in order to accomplish oral extraction or sinus repulsion of both retained fragments and intact teeth (MacDonald et al. 2006; Coomer et al. 2011; Dixon et al. 2005). There are no procedure-specific considerations when choosing a general anesthesia protocol for dental procedures in the horse. To facilitate adequate access to the oral cavity, a total intravenous (TIVA) protocol such as "triple-drip" (guaifenesin, ketamine, xylazine) can be used while supplementing oxygen via a nasotracheal tube. TIVA techniques should be reserved for procedures in healthy horses lasting less than 45 minutes to 1 hour. During the general anesthetic, care should be taken when positioning the horse for the extraction or repulsion to avoid pressure on the contralateral facial nerve. Lastly, recovery should be facilitated with either a nasotracheal or orotracheal tube left in place to maintain the airway and partially guard the airway against any remaining bleeding from the procedure.

Standing sedation protocols have been reviewed elsewhere in this book; however, it is worth highlighted a recent study describing the use of romifidine-based standing sedation for cheek tooth extraction (Müller et al. 2017). The authors evaluated the use of a romifidine continuous rate infusion alone (0.05 mg/kg/h) and in combination with butorphanol (0.04 mg/kg/h), midazolam (0.06 mg/kg/h), or ketamine (1.2 mg/kg/h). All drugs received appropriate loading doses (romifidine 0.03 mg/kg; butorphanol 0.02 mg/kg; midazolam 0.02 mg/kg; ketamine 0.5 mg/kg) prior to commencement of the CRI and lidocaine-based maxillary or

mandibular nerve blocks. The protocol achieved sufficient sedation for completion of the extractions in all groups other than group receiving romifidine alone. The combination of romifidine with midazolam produced substantial ataxia compared to combination with ketamine although both produced good surgical conditions. Combination with butorphanol resulted in a reduced cortisol stress response (Müller et al. 2017). The study concludes that romifidine should not be used alone for standing sedation for dental extractions (Müller et al. 2017).

Surgical Diseases of Paranasal Sinuses

Primary Sinusitis

Primary sinusitis is caused by an upper respiratory tract infection (most commonly, *Streptococcus* species) that has involved the paranasal sinuses, and secondary sinusitis is caused by an apical infection of maxillary cheek teeth (Tremaine and Dixon 2001a). Systemic antibiotic therapy is very effective but sinus lavage once or twice daily with an indwelling catheter introduced into the infected sinus through a trephine opening may be clinically necessary to fully resolve the infection or remove inspissated pus. The skin over the trephination site is locally infiltrated with 2–3 ml of 2% mepivacaine prior to surgery (Tremaine 2007).

Paranasal Sinus Cysts

Paranasal sinus cysts are single or loculated fluid-filled lesions that typically develop in the maxillary sinuses and ventral concha and can extend into the conchofrontal sinus (Woodford and Lane 2006). The etiology and pathogenesis are unknown (Tremaine et al. 1999); however, extirpation of the cyst and the involved conchal lining through a frontonasal or maxillary bone flap is curative (Woodford and Lane 2006).

Ethmoid Hematoma

Ethmoid hematoma is a progressive and locally destructive idiopathic mass that may arise from the ethmoid labyrinth or the floor of the paranasal sinuses. These lesions are characterized by endoturbinate or a sinus submucosal hemorrhage and concurrent stretching and thickening of the mucosa that becomes the capsule of the hematoma (Tremaine et al. 1999). Ethmoid hematomas can extend into the frontal sinus, the maxillary sinus, the nasal cavity, or the sphenopalatine sinus by disrupting the tectorial plate (Nickels 2012). If the ethmoid hematoma extends into one of the paranasal sinuses, a frontonasal bone flap is indicated to remove the lesion, but it can be associated with profuse intraoperative hemorrhage (Nickels 2012). Typically, ethmoid hematoma causes mild and spontaneous intermittent epistaxis; however, anemia is very rare.

Neoplasia

Neoplasia in the nasal cavity or paranasal sinuses are uncommon (Tremaine and Dixon 2001a). Squamous cell carcinoma is the most common neoplasia of the paranasal sinuses; however, other types of sarcoma tumors (osteogenic sarcoma, lymphosarcoma, poorly differentiated carcinoma, fibrosarcoma, hemangiosarcoma, and adenocarcinoma) have been reported.

Surgery of the Paranasal Sinuses

Sinoscopy

Sinoscopy of the paranasal sinuses is usually performed with the horse standing and adequately sedated. The examination is performed with a flexible endoscope using portals created with a 15-mm Galt trephine following local infiltration of 3–4 ml of 2% mepivacaine at the surgery sites. The endoscopic portal for the **conchofrontal sinus** is located 60% of the distance from midline toward the medial canthus and 0.5 cm caudal to the medial canthus of the

eye, whereas the endoscopic portal for the maxillary sinuses is located 2 cm rostral and 2 cm ventral to the medial canthus of the eye (**caudal maxillary sinus**) or 50% of the distance from the rostral end of the facial crest to the level of the medial canthus and 1 cm ventral to a line joining the infraorbital foramen and the medial canthus (**rostral maxillary sinus**).

Frontonasal and Maxillary Bone Flap Technique

A frontonasal bone flap approach is used to gain access to the **conchofrontal** and **caudal maxillary sinuses** and, by additional steps, the rostral maxillary and ventral conchal sinuses. If there is bilateral disease, a tracheotomy should be performed prior to induction and the horse should be intubated through the tracheostomy incision; the animal is otherwise intubated routinely. In addition, sufficient analgesia of the cheek teeth and sinus is a prerequisite for procedures performed on standing horses under chemical sedation. To provide anesthesia of the paranasal sinuses and maxillary cheek teeth, the maxillary branch of the trigeminal nerve in the pterygopalatine fossa should be desensitized using one of the locoregional maxillary nerve block techniques described in the previous section. This block should be performed regardless of whether the surgical procedure is done under standing sedation or general anesthesia.

The frontonasal or maxillary bone flap procedure consists of incising the skin, periosteum, and bone on three sides. For a frontonasal bone flap, the caudal margin is a line drawn at right angle to the dorsal midline and midway between the supraorbital foramen and the medial canthus of the eye, the lateral margin is a line 2.5 cm medial to the medial canthus of the eye that runs slightly dorsal to another line from the medial canthus to the nasoincisive notch, and the rostral margin is caudal to the point at which the nasal bones become parallel. For a maxillary bone flap, the rostral margin of the maxillary bone flap is a line drawn

from the rostral end of the facial crest to the infraorbital foramen, the dorsal margin is a line from the infraorbital foramen to the medial canthus of the eye, the caudal margin is a line (parallel to the rostral margin) from the medial canthus of the eye to the caudal aspect of the facial crest, and the ventral margin is the facial crest (Nickels 2012). The bone flap is then elevated, the affected cheek teeth are repelled by placing a dental punch onto the roots or the lesion (paranasal cyst, ethmoid hematoma, neoplasia, etc.) and removed while controlling intraoperative bleeding.

Following a frontonasal or maxillary bone flap, a surgical opening into the nasal cavity is created and then saline-soaked rolled gauze is inserted immediately into the sinus and nasal passages to control hemorrhage and the end of the gauze is pulled through the sinuses and out the nostril. The packing is removed at 48–72 hours after surgery. Historically, frontonasal and maxillary bone flaps have been associated with profuse hemorrhage so that having a potential blood donor identified by cross-match is recommended. However, in recent publications of the surgical procedure this complication was infrequent (Tremaine and Dixon 2001a, b; Woodford and Lane 2006; Hart and Sullins 2011).

Surgical Diseases of the Nasal Cavity

Nasal Septum Deformity

Although it is clinically infrequent, nasal septum resection is indicated for treatment of malformations, cystic degeneration, fungal infections, traumatic thickening secondary to septal fracture, and neoplasia among others (Valdez et al. 1978; Watt 1970; Doyle and Freeman 2005; Schumacher et al. 2008). The cartilage of the nasal septum responds in an exaggerated fashion to trauma and heals with deformity, thickening, and deviation which produces decreased airflow or complete unilateral obstruction and

nasal stertor. Diagnosis can generally be made with endoscopic and radiographic examination. The abnormality may be rostral enough to palpate digitally; however, advanced diagnostic imaging may be useful in some cases to plan the surgical treatment (Auer 2012).

Campylorhinus Lateralis (Wry Nose)

Campylorhinus lateralis is a congenital abnormality consisting of dysplasia of one side of the maxilla and premaxilla that results in deviation of the maxillae, premaxillae, nasal bones, vomer, and the nasal septum to the dysplastic side (Schumacher et al. 2008). The deviation usually results in malocclusion of the incisors of the mandible and maxilla. Depending on the degree of deviation foals may have difficulty breathing and stridor due to progressive airway obstruction secondary to deviation of the nasal septum to the convex side of the deformity (Schumacher et al. 2008). Radiography supports the clinical diagnosis; however, computed tomography may be useful to assess if there is rotational component in the deviation (Auer 2012). Slight nasal deviation may straighten with growth, but horses with moderate or severe deviation require surgical treatment to resolve respiratory obstruction and to improve incisor occlusion and cosmetic appearance (Auer 2012).

Choanal Atresia

This is a rare maxillofacial malformation in which one or both nasal cavities fail to communicate with the nasopharynx due to persistence of the buccopharyngeal septum, which separates the nasal cavities from the nasopharynx during the embryonic development (James et al. 2006; Hogan et al. 1995). Although there are multiple theories proposed for its embryological origin, it appears that buccopharyngeal membrane persistence is due to misdirection of mesodermal flow caused by errors in neural crest migration in the nasal cavities during embryogenesis.

Affected animals may have partial (unilateral atresia) or complete (bilateral atresia) airflow obstruction through the nasal cavity (James et al. 2006; Hogan et al. 1995; Richardson et al. 1994). Given that horses are obligate nasal breathers, bilateral choanal atresia in foals can cause immediate asphyxia upon birth unless an airway is immediately established by a temporary tracheostomy (James et al. 2006). When the atresia occurs unilaterally, foals exhibit loud respiratory noise, exercise intolerance, and asymmetry of airflow from the nostrils can be detected (James et al. 2006; Hogan et al. 1995; Richardson et al. 1994). The diagnosis is typically made by endoscopic examination but other modalities such as skull radiography, contrast radiography, and computed tomography can be helpful to plan the surgical approach (Gerros and Stone 1994; Nykamp et al. 2003). The treatment is resection of the buccopharyngeal membrane.

Surgery of the Nasal Cavity

Nasal Septum Resection

The nasal septum is covered with a highly vascular mucosa, consequently excision of the septum may cause severe intraoperative hemorrhage, hypotension, and hypoxia. Administration of large volumes of intravenous fluids during surgery is recommended to help alleviate the hypotension. However, it is advisable to identify a suitable blood donor and collect 4–8 l of blood before surgery in case a blood transfusion is necessary. A tracheotomy should be performed before surgery for maintenance of ventilation and inhalational agent delivery thereby allowing adequate surgical access to the oral cavity during surgery.

This procedure should be performed under general anesthesia; however, no specific protocol is indicated and, instead, should be chosen based on the needs of the horse. As the horse will be placed in lateral recumbency for the procedure, administration of a bilateral maxillary block can be challenging. The anesthetist should

consider positioning the horse in dorsal recumbency on the surgical table initially to facilitate blockade of the “down” nerve prior to repositioning to lateral recumbency. Alternatively, consideration could be made for performing the bilateral maxillary blocks in the standing horse under sedation/premedication and possibly at the same time as the temporary tracheostomy is performed.

The horse is positioned in lateral recumbency, and the obstetrical wire is passed up one nasal passage. The most commonly used technique involves transecting the nasal septum dorsally, ventrally, and caudally with obstetrical wire and the most rostral incision is made with a scalpel leaving 5 cm of septum to support the nostrils and alar folds (Doyle and Freeman 2005). The mouth is held open with a speculum, a hand passed back into the oral cavity, and the wire is retrieved around the edge of the soft palate. Another wire is introduced in similar manner up the other nasal passage and is also brought out through the mouth. The ends of the wires are connected outside the mouth, and one is drawn back through a nasal passage until the splice is brought out of the nostril. The wires are then disconnected and the one is left in place so that it passes around the ventral edge of the vomer bone and out both nostrils; this wire is used to transect the nasal septum ventrally.

Next, a trephine hole is placed in the nasal bones immediately rostral to the point at which these bones diverge on the face toward the eyes. A Chamber's mare catheter is introduced into the nasal passage to exit through the trephine hole. A length of obstetrical wire is then threaded down this catheter and the catheter is removed so that the wire runs from the trephine hole to exit at the nostril. The catheter is introduced into the other nostril and the same wire is threaded down it so that it loops around the septum at the level of the trephine hole and both ends exit the nostril; this wire is used to transect the septum dorsally.

Another length of obstetrical wire is now passed through the trephine hole and into one

nasal passage, in a direction toward the caudal edge of the soft palate. The mouth is held open with a speculum, a hand passed back into the oral cavity, and the wire is retrieved around the edge of the soft palate. Another wire is introduced in similar manner through the trephine hole into the other nasal passage and is also brought out the mouth. The ends of the wires are then taped together outside the mouth, and one is drawn back through a nasal passage until the splice is brought out of the trephine hole. The remaining wire is left in place so that it passes around the ventral edge of the vomer bone and out the trephine hole; this wire is used to transect the septum caudally. The ventral and dorsal cuts are made simultaneously taking care and completed rapidly once started so that hemorrhage is minimal before packing is inserted. The septum is extracted by grasping it with long forceps at the rostral end and pulling it through one of the nostrils. The nasal cavity is packed similarly as for sinuses following surgery and the horse should be allowed to recover with a temporary tracheostomy tube secured in place. The nasal packing and temporary tracheostomy tube may be removed after 48 or 72 hours.

Wry Nose (*Campylorhinus Lateralis*)

Successful surgical treatment can improve cosmetic appearance and alleviate airway obstruction (Schumacher et al. 2008). This reconstructive surgery is recommended when the foal is two to three months of age to allow the facial bones to gain enough strength to support implant. The foal is anesthetized using a routine protocol and positioned in dorsal or lateral recumbency on the surgery table (Schumacher et al. 2008). The endotracheal tube is inserted ideally through a tracheostomy approach, the cuff is inflated, and the mouth is thoroughly washed. A bilateral maxillary block can be performed at this time; however, there are currently no studies reporting on this technique in foals.

The first step consists of resecting the nasal septum leaving sufficient septum to support the nostrils and alar folds; the section of

septum to be removed is centered on the middle of the bend in the nasal septum. The nasal passages are packed with rolled gauze to control the hemorrhage and the nostrils are sutured closed to retain the packing. The second step consists of transecting the rami of the maxilla at the level of the interalveolar space to allow re-alignment of the maxillae and premaxillae followed by stabilization with bone plates or Steinmann pins. During surgery, symmetry of the upper and lower jaws is maintained by temporarily wiring the incisors of the maxilla and mandible. The third step consists of correcting the nasal bone deviation and stabilize with reconstruction bone plates. Some surgeons use an autogenous cortical bone graft in the form of a rib to fit the gap in the concave side of the premaxilla; therefore, a section of rib can be harvested before straightening the maxillae/premaxillae, with the horse positioned in left or right lateral recumbency, or in dorsal recumbency (Schumacher et al. 2008).

Choanal Atresia

Treatment options for choanal atresia include transendoscopic laser excision of the buccopharyngeal membrane, or via bilateral frontonasal bone flap (if the buccopharyngeal membrane is osseous, or the condition is bilateral), or via laryngotomy with endoscopic assistance to gain access to the obstructed choanae (Aylor et al. 1984; James et al. 2006; Ducharme 2012).

In horses with unilateral choanal atresia, transendoscopic laser excision can be done with the patient standing and seated with detomidine and butorphanol, and topical anesthesia with phenylephrine (2% lidocaine or mepivacaine hydrochloride and 10ml of 0.15% phenylephrine) applied to the buccopharyngeal membrane and nasal cavity. Choanal stenosis is a frequent complication, so the use of stents is mandatory post-operatively to prevent stricture (James et al. 2006). This can be done with a silicone endotracheal tube threaded over the

wire, pushed through the puncture site in the choanal membrane, and left in place to serve as a stent. If resection of the buccopharyngeal membrane via frontonasal bone flap with the animal anesthetized is elected, a temporary tracheostomy should be performed to allow tracheal intubation during surgical manipulations of the head and should be left in place with the cuff inflated during recovery to assure an adequate airway and protect it from surgical site bleeding.

Equine Blood Typing and Transfusion Considerations

As stated earlier in this chapter, significant acute hemorrhage is a potential risk associated with surgical procedures of the nose. Acute blood loss of >20% of the blood volume and/or clinical signs of hypovolemia should be used to assess the need for emergency transfusions as changes in packed cell volume (PCV) or total protein may lag behind by several hours due to splenic contraction (Hardy 2009). Transfusions of whole blood should be reserved for life-saving situations however as transfused red blood cells only last in recipient circulation for two to six days (Hardy 2009; Kallfelz et al. 1978). Transfusion medicine in horses is more complicated than in humans or small companion animals owing to the lack of a universal blood type in horses. Horses have eight different blood groups, A, C, D, K, P, Q, U, and T as well as more than 30 different surface marker factors on the red blood cells. As a result, the likelihood of a perfect match between donor and recipient is estimated to be upward of 1 in 400 000. Fortunately, the vast majority of transfusion reactions are attributable to two specific blood types, Aa and Qa, and horses that possess Ca antigens also pose a theoretical risk (Schmotzer 1985). As stored equine blood samples are only stable for a few weeks, blood banking is not common, and donors must typically be either kept on site or available at short

notice (Mudge et al. 2004). Ideal donors must be healthy adult horses, up to date on vaccines and free from any diseases. Unrelated geldings of the same breed or mares who have never foaled can be chosen for blood donors as long as their PCV is greater than 35% and they test negative for Aa, Qa, and Ca antigens. Related horses or mares who have foaled previously are more likely to possess antibodies that could lead to transfusion reactions. In larger practice settings where donor horses are maintained, blood typing should be performed prior to donation to avoid Aa, Qa, and Ca antigens; however, Quarter horses and standardbreds are reported as breeds less likely to possess Aa or Qa antigens if prior blood typing is not possible (Nolen-Walston, n.d.).

Cross-matching should be performed, if possible, prior to blood transfusion administration. A major cross-match involves combining washed donor red blood cells with recipient serum while a minor cross-match combines donor serum with washed recipient red blood cells. Signs of incompatibility include auto-agglutination and hemolysis.

Donor horses should have a large gauge, short catheter placed aseptically in the jugular vein and connected to a bag containing anticoagulant. Adult horses greater than 450 kg can donate between 15 and 20 ml/kg of whole blood which should be replaced with at least an equivalent volume of crystalloid fluids after donation (Malikides et al. 2001; Nolen-Walston, n.d.).

When estimating the amount of donor blood needed for transfusion, one can calculate with the following general estimate:

$$\text{Donor blood needed} = \frac{\text{Estimated Recipient blood volume}}{\text{Desired PCV\%} - \text{Actual PCV\%} / \text{Donor PCV\%}}$$

A more general estimate assumes that 2–3 ml/kg of whole blood from a donor with a PCV of 40% will raise the recipient's PCV by 1% (Hardy 2009). In general, adult horse's blood volumes can be estimated as 80 ml/kg. The technique for administration of the actual transfusion is not dissimilar to that of small animals or humans where the transfusion is started at a slow rate for the first 15 minutes to closely observe for transfusion reactions after while time the remainder of the volume can be administered at 5–20 ml/kg/h with the goal of completing the transfusion in less than four hours to maintain sterility (Hardy 2009; Nolen-Walston, n.d.). Signs of transfusion reactions include hypotension, skin wheals, sweating, tachycardia, fever, diarrhea, colic, and piloerection (Hardy 2009; Nolen-Walson, n.d.). Transfusions should be stopped if signs of reaction occur and treatment, including fluids and epinephrine if needed, should be instituted. If the transfusion reaction is mild and the signs resolve with discontinuation of the infusion, restarting the infusion at a slower rate can be considered, especially if no other suitable donor is available.

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