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Surgical enlargement of the nasomaxillary aperture and transnasal conchotomy of the ventral conchal sinus: Two surgical techniques to improve sinus drainage in horses

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Abstract

Objective: To evaluate 2 surgical techniques for establishing and/or improving paranasal sinus drainage in cadaver heads and horses with sinusitis and evaluate the feasibility of postoperative transnasal sinus endoscopy.

Study design: Ex vivo study (equine cadaver heads) and case series.

Sample population: Nine adult equine cadaver heads and 8 horses with recurrent sinusitis.

Methods: For the ex vivo study, the following procedures were performed on 9 cadaver heads: preoperative and postoperative computed tomography (heads 1–6), endoscopy-guided transnasal conchotomy of the ventral conchal sinus (TCVCS) and surgical enlargement of the nasomaxillary aperture (SENMAP) on opposite sides (heads 1–3), combined TCVCS and SENMAP on both sides (heads 4–9), evaluation of sinus drainage before and after surgery (heads 7–9), and postoperative transnasal endoscopy (heads 4–9). For the case series, 8 horses with secondary sinusitis were treated in standing position with SENMAP and/or TCVCS and postoperative transnasal endoscopy.

Results: Sinonasal communications were successfully created in all cadavers and affected live horses. Transnasal endoscopy of all sinuses except the middle conchal sinus was possible in heads 4–9 and in all clinical cases. Sinus drainage was improved ($P = .028$) by combining techniques. Blood loss in live horses ranged from 0.5–5.5 L (1.95 ± 1.5) per horse. Sinusitis resolved in all affected horses during follow-up of 3.2–25.5 months (13.5 ± 8.5).

Conclusion: Transnasal conchotomy of the ventral conchal sinus and SENMAP consistently created large sinonasal communications, facilitating sinus endoscopy and improving sinus drainage.

Clinical significance: Transnasal conchotomy of the ventral conchal sinus and SENMAP are viable options to treat horses with sinusitis and anatomical obstructions of the sinonasal communications.

1 | INTRODUCTION

Sinus drainage in horses with sinusitis can be compromised by infection-induced thickening of the mucous membranes or accumulation of inspissated pus in the sinuses and/or the sinonasal canals, eventually resulting in chronic sinus empyema, facial deformation, and/or permanent occlusion of the sinonasal canals.[1,2] Sinonasal drainage can also be affected by congenital deformations, dental diseases, traumatic insults, space-occupying lesions (eg, sinus cysts, progressive ethmoidal hematoma, and neoplastic disease), and combinations of these conditions.[1,2] Minimally invasive or transnasal surgical techniques recently developed to improve sinus drainage include balloon catheterization of the nasomaxillary opening[3] and laser vaporization of the ventral and dorsal conchal sinuses.[4–6] Fenestration of the dorsal conchal sinus limits access and drainage to the caudal sinus compartments consisting of the caudal maxillary (CMS), conchofrontal (CFS), middle conchal (MCS; ethmoidal), and sphenopalatine (SPS) sinuses. In contrast, fenestration of the ventral conchal sinus (VCS) permits access only to the rostral sinus compartment, consisting of the rostral maxillary sinus (RMS) and the VCS.

The objective of this study was to evaluate transnasal conchotomy of the ventral conchal sinus (TCVCS) and surgical enlargement of the nasomaxillary aperture (SENMAP). These techniques can be performed separately or combined to meet individual requirements for postoperative transnasal sinus endoscopy and lavage and to establish/improve sinus drainage in horses with chronic or recurrent sinusitis and/or obstructions of the sinonasal canals.

We hypothesized that these techniques could be combined to establish and improve drainage of the ipsilateral sinus compartments. We also hypothesized that postoperative transnasal sinus endoscopy (sinoscopy) of the rostral and most of the caudal compartments and transendoscopic sinus lavage would be feasible through the surgically created sinonasal communications.

2 | MATERIAL AND METHODS

2.1 | Cadaver heads and animals

Nine adult equine cadaver heads (2 female, 7 male; 12–22 years old [median, 15.9 ± 4]) were obtained from horses with no sinonasal disease that had been euthanized for reasons unrelated to the study. The clinical animal group consisted of 8 horses with recurrent sinusitis (5 female, 3 male; 8.4–24.8 years old [median, 14.6 ± 7.2]).

2.2 | Methods

Computed tomography (CT) examination of cadaver heads 1–6 was performed with a 16-slice helical scanner (Somatom Emotion 16; Siemens, Erlangen, Germany) before and after surgical intervention. The heads were fixed in ventral recumbency, with the hard palate held in horizontal orientation by a positioning device. Transverse, 0.8-mm-thick slices with a 0.5-mm reconstruction interval were acquired (130 kV, 140–205 mA) by using a soft tissue and high-frequency bone algorithm. The CT images were analyzed by 2 experienced radiologists using a DICOM (Digital Imaging and Communications in Medicine) viewer (JiveX Diagnostic Advanced; VISUS Health IT, Bochum, Germany) by using both soft tissue and bone window multiplanar reconstructions.

Transnasal conchotomy of the ventral conchal sinus[7,8] was subsequently performed on the right side of each of the first

FIGURE 1 Conchotomes with a 5-mm ball tip (1), a 5-mm blade (2), and a 6-mm blade with moderately bent tip (3) were used in this study

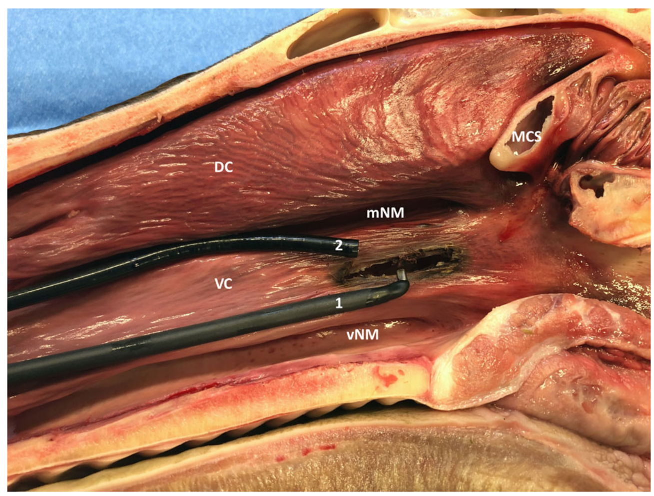

FIGURE 2 The positions of the conchotome (1) near the vNM and of a 5.9-mm endoscope (2) in the mNM during conchotomy. The area of the medial wall of the VC overlying the VCS was cauterized prior to conchotomy of the VCS. DC, dorsal concha; MCS, middle conchal sinus; mNM, middle nasal meatus; VC, ventral concha; VCS, ventral conchal sinus; vNM, ventral nasal meatus

TABLE 1 Gross anatomical and CT measurements of incision distances of SENMAP-TCVCS and combined techniques

	Left SENMAP		Right TCVCS	
Head No.	Maximal rostrocaudal distance, mm	Minimal distance to base VCS, mm	Maximal rostrocaudal distance, mm	Minimal distance to base VCS, mm
1	37	5.7	50*	8*
2	42	5.7	45*	23*
3	28	4	45*	15*
	TCVCS and SENMAP combined			
4	45	0	40	0
5	45	0	43	0
6	47	5	48	0

CT, computed tomography; SENMAP, surgical enlargement of the nasomaxillary aperture; TCVCS, transnasal conchotomy of the ventral conchal sinus; VCS, ventral conchal sinus.
*Gross anatomical measurements.

3 heads (see detailed description below). Surgical enlargement of the nasomaxillary aperture[8] was performed on the left side of each of the first 3 cadaver heads. In heads 4–9, both procedures were combined and performed bilaterally.

2.3 | Transnasal conchotomy of the ventral conchal sinus

Electrosurgical conchotomes used in this study consisted of 450-mm-long, 6-mm-circular steel shafts with (1) a 5-mm-diameter ball tip, (2) a 5-mm spatula-shaped blade, and (3) a 6-mm spatula-shaped blade with a moderately bent tip (Figure 1). All shafts were insulated with rubber tubing, and all had a port for connection to the electrocautery device at their bases. The settings of the electrosurgical device were 80 W for coagulation and 50 W for cutting. A ground plate was attached to the forehead of each cadaver head.

A flexible, 5.9-mm video endoscope (60 511 PKS/NKS; Karl Storz, Tuttlingen, Germany) was inserted into the middle nasal meatus. The location for conchotomy of the VCS (ie, 10–50 mm rostral to the caudal end of the ventral concha and 15–20 mm dorsal to its ventral border) was identified. Coagulation of an area of approximately 50 × 15 mm of the caudomedial ventral conchal wall was performed under

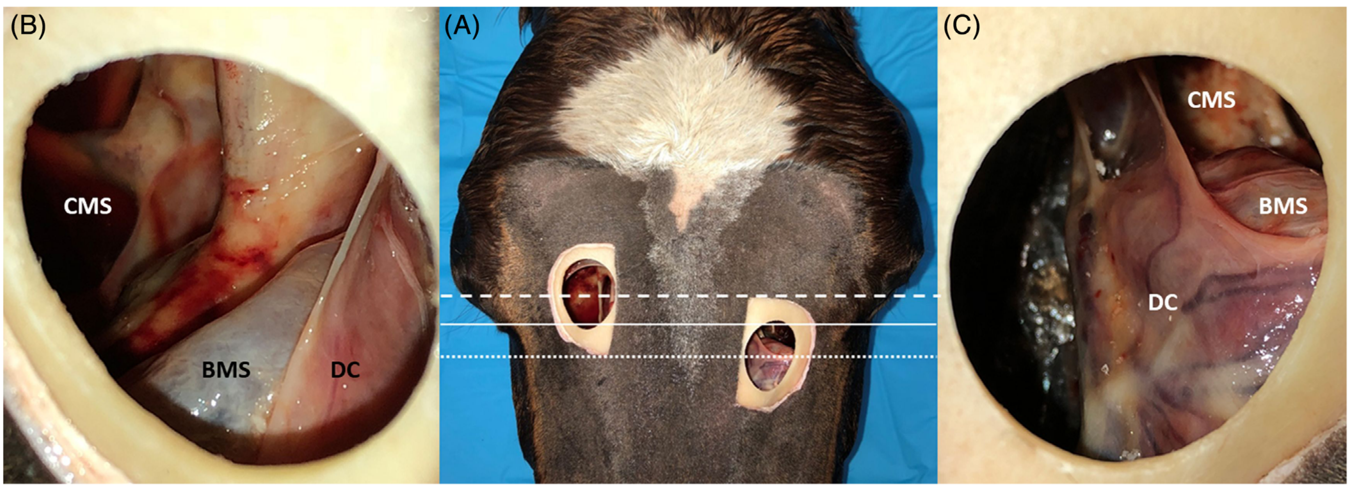

FIGURE 3 Comparison of 2 surgical trephination sites for SENMAP. **A,** A line connecting the medial left and right canthi (continuous line, 1) served as base line. **A,B,** A 30-mm trephination was performed, centered approximately 2 cm dorsal to the base line (dashed line) on the right side. **A,C,** On the left side, an identically sized trephination was performed, centered on a line 15 mm rostral to the base line (dotted line). Visibility of and access to the surgical field, surveyed at a 90% angle to the horizontal plane, are significantly improved through the rostrally centered trephination portal on the left side (**C**). BMS, bulla of the maxillary septum; CMS, caudal maxillary sinus; DC, dorsal concha; SENMAP, surgical enlargement of the nasomaxillary aperture

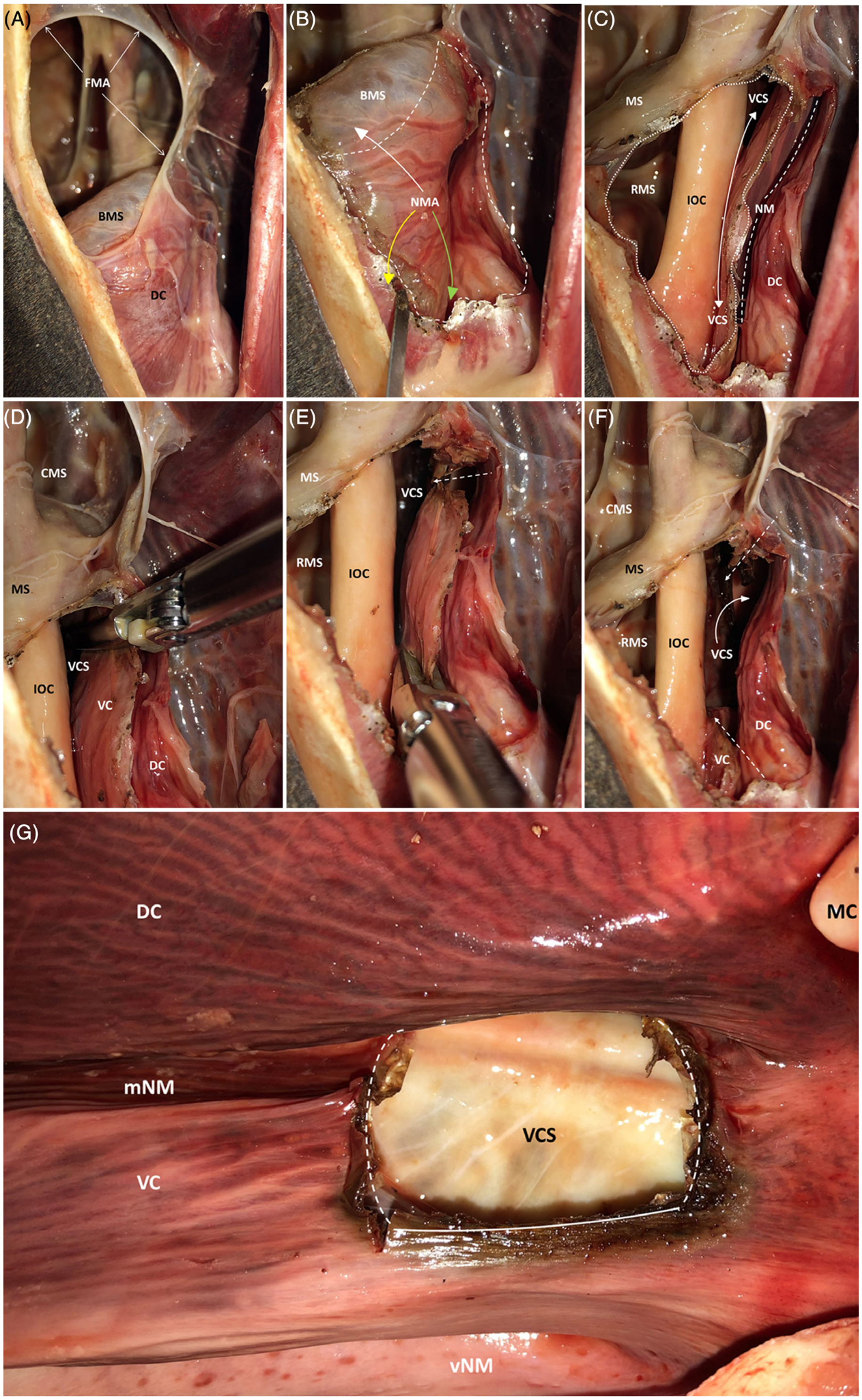

FIGURE 4 Dorsal (**A-F**) and medial (**G**) views of SENMAP performed on the right side of a cadaver head. The frontal and nasal bones have been partially removed to improve visualization. **A,** White arrows, borders of the FMA. **B,** Dashed white line, resected area of the ventral lamella (floor); white arrow, orientation of the caudal sinonasal canal; yellow arrow, orientation of the rostral sinonasal canal; green arrow, opening toward the mNM. **C,** Dotted white line, resected portion of the BMS; white arrows, extension of the VCS; dashed white line, common NM. **D,** CMS and VC. **E,** Dashed white arrow, caudal resection site of the medial conchal wall. **F,** Dashed white arrows, caudal and rostral resection sites of the medial ventral conchal wall; curved white arrow, communication into the nasal meatus. **G,** MC and mNM. BMS, bulla of maxillary septum; CMS, caudal maxillary sinus; DC, dorsal concha; FMA, frontomaxillary aperture; IOC, infraorbital canal; MC, middle concha; mNM, middle nasal meatus; MS, maxillary septum; NM, nasal meatus; NMA, nasomaxillary aperture; RMS, rostral maxillary sinus; SENMAP, surgical enlargement of the nasomaxillary aperture; VC, medial wall of ventral concha; VCS, ventral conchal sinus; vNM, ventral nasal meatus

endoscopic control by using the ball-tipped conchotome. A blade-tipped conchotome was then positioned at the caudal end of the coagulated portion of the conchal wall. The conchal wall was penetrated with the tip of the blade by using cutting currents. A 43–50-mm long, full-thickness linear incision was created by pulling the conchotome rostrally (Figure 2, Table 1).

2.4 | Surgical enlargement of the nasomaxillary aperture

Surgical access to the CFS was created with a 30-mm Galt trephine (Erbrich Instrumente, Tuttlingen, Germany). In heads 1–3, the trephination was centered on the intersection of a line that was parallel to the long axis of the head and 60% of the distance from the midline to the medial canthus of the eye to a line 0.5 cm caudal to a line joining both medial canthi (Figure 3A,B).[9] In heads 4–9, the conchofrontal trephinations were performed approximately 20 mm farther rostrally (Figure 3A,C).

A portion of the ventral lamella of the dorsal concha approximately 30–45 mm long and 30 mm wide that was located rostromedially to the frontomaxillary aperture was identified. The mucosal lining at the intended resection edges was cauterized (80 W, coagulation mode) with an electrothermal scalpel (Figure 4A,B). The solid bony lamella was cut along the cauterized lines with a chisel and was removed with hemostat forceps (Figure 4B), exposing the underlying bulla of the maxillary septum (BMS). The dorsal aspects of the BMS were cauterized and removed (Figure 4C). An electrothermal bipolar tissue sealing system (MarSeal Slim IQ; KLS Martin, Tuttlingen, Germany) was used to perform 2 vertical, approximately parallel incisions of the medial wall of the ventral concha (VC) at the rostral and caudal aspects of the resection lines of the BMS (Figure 4D,E). The tissue between the incisions was bluntly removed with forceps.

2.5 | Combined TCVCS and SENMAP

A combination of both procedures was performed bilaterally in cadaver heads 4–9, starting with TCVCS and followed by SENMAP. The incisions created for SENMAP were aligned with the rostral and caudal borders of the incisions created during TCVCS. Thus, clearly defined incisions and a controlled disruption of conchal tissue were obtained (Figure 4F,G).

2.6 | Evaluation of sinus drainage

Heads 7–9 were fixed on head stands at a 20° angle to the horizontal plane, and bilateral trephinations of the CFS (as in heads 3–6) were performed. Each BMS was perforated (approximately 1 cm^2) to enable unobstructed fluid flow from the caudal to the rostral sinuses. An extension set attached to a fluid pump (Storz Laparomat; Karl Storz) was inserted into each trephination site, and sinus lavage with tap water at 300 mm Hg was initiated. Flow rates were increased until constant fluid levels could be maintained under visual control without water emanating from the trephination sites. This steady-state flow rate was maintained, and draining fluids were collected from the equilateral nostril for 60 seconds. Fluid volumes were recorded as baseline drainage (mL/min) for the left and right paranasal sinuses of each cadaver head.[3] Transnasal conchotomy of the ventral conchal sinus-SENMAP was subsequently performed bilaterally in heads 7–9 as previously described, and sinus lavage was repeated. Drainage rates exceeded the conveying capacity of the pump, and tap water was instilled into the trephination sites via a garden hose. Flow rates were gradually increased until constant fluid levels in the caudal maxillary sinuses could be maintained. Drainage rates (mL/min) before and after TCVCS-SENMAP were recorded and are presented as minimum-maximum (mean ± SD) and in Table 2. The results were compared by using a Wilcoxon signed-rank test, with a $P < .05$ considered significant.

2.7 | Transnasal sinoscopy

Transnasal sinoscopy with a 5.9-mm flexible video endoscope (60 511 PKS/NKS; Karl Storz) was performed bilaterally in heads 4–9 to evaluate the accessibility of the ipsilateral paranasal sinus compartments (VCS, RMS, CMS, CFS, SPS, MCS). Video recording of the sinoscopy and radiographic documentation of the positioning of the endoscope during sinoscopy were performed in head 9.

2.8 | Imaging

Postoperative CT was performed for heads 1–6 as previously described. After the above procedures, heads 1–6 were deep frozen (−18°) and sectioned longitudinally along the nasal septum by using a band saw (CT-400; Bertsch-Laska, Vienna, Austria). The nasal septum was removed, and the cadaver heads were transversely sectioned at the midorbit level and rostral to the 2nd premolars. Surgical sites were photographed. The maximal rostrocaudal distances of the TCVCS incisions and the minimal distances from the incisions to the ventral aspect (base) of the VCS were measured with a ruler. In heads 4–6, the maximum distance between the rostral and caudal incisions of the medial ventral conchal wall and the minimum distance from the TCVCS incision to the ventral aspect (base) of the VCS were measured on reformatted CT images (Figure 5A-C). To further image the procedure, 3-dimensional (3D) reconstructions of head 6 were performed before and after the surgery (Figure 6A-I) in AmiraTM software (Thermo Fisher Scientific, Hillsboro, Oregon).

TABLE 2 Sinus lavage flow rates before and after TCVCS/SENMAP

Flow rate	Head 7 left	Head 7 right	Head 8 left	Head 8 right	Head 9 left	Head 9 right
Flow rate prior to TCVCS/SENMAP, mL/min	420	240	120	130	300	1040
Flow rate after TCVCS/SENMAP, mL/min	8800	6200	3500	3300	12 900	13 200

SENMAP, surgical enlargement of the nasomaxillary aperture; TCVCS, transnasal conchotomy of the ventral conchal sinus.

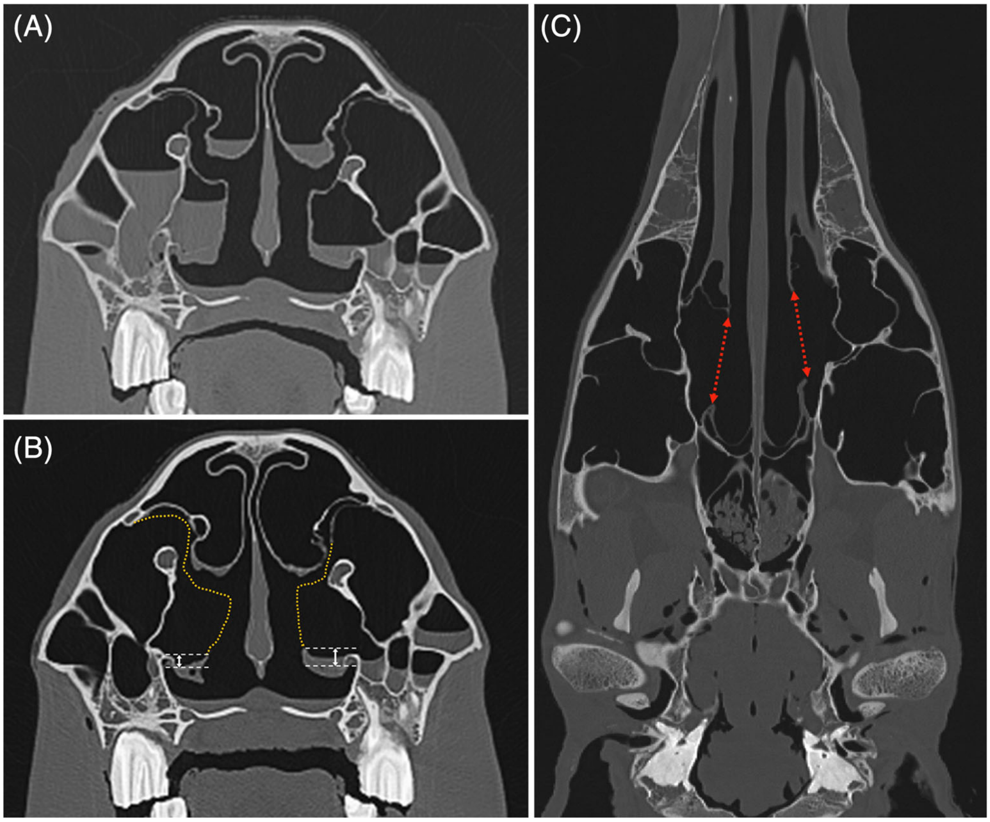

FIGURE 5 Transverse (**A,B**) and coronar (**C**) computed tomography images before (**A**) and after (**B,C**) performing combined TCVCS and SENMAP in head 8. The resected portions of the bulla of the maxillary septum and the medial wall of the ventral concha are indicated with yellow dotted lines (**B**). Two-tipped white arrows, distance measured from the incised medial conchal wall to the bony base of the ventral conchal sinus (**B**). Two-tipped red arrows, distance measured from the rostral to the caudal SENMAP incisions of the ventral conchal wall (5C)

2.9 | Short case series

Both techniques were performed and evaluated in 8 adult horses (Table 3) including horses with sinusitis secondary to dental disease (n = 6) or sinusitis secondary to facial bone fractures (n = 2). Chronic sinusitis with sinus empyema developed in 2 horses (1, 8) with facial bone fractures after surgical fracture management (wound debridement, repositioning of depressed fracture fragments, sequestrectomy, sinus lavage) and postoperative treatment with antimicrobial drugs and non-steroidal anti-inflammatory drugs (NSAID). Prior to referral, all 6 horses (2–7) with sinusitis secondary to dental disease were repeatedly but unsuccessfully treated with various antimicrobial drugs and NSAID. All affected cheek teeth were extracted orally with forceps prior to performing TCVCS and/or SENMAP (Table 3).

All TCVCS and SENMAP were performed in standing, sedated, and locally anesthetized animals in a single or in 2 consecutive procedures. Maxillary nerve blocks under sterile conditions,[10] subcutaneous infiltration of the surgical sites, and transendoscopic topical anesthesia of the nasal mucous membranes were performed with mepivacaine (2%) in all horses prior to surgery. Transnasal conchotomy of the ventral conchal sinus and SENMAP were performed on separate days when the total sedation time for performing dental extractions and TCVCS/SENMAP would have exceeded 3 hours or when TCVCS alone provided insufficient sinus drainage. Age, sex, diagnosis, laterality, technique of local anesthesia, procedure performed, blood loss for each procedure, total blood loss, surgery time, requirement for postoperative sinus packing, follow-up times, and the outcome of each case were documented.

2.10 | Data analyses

Descriptive statistical analysis was performed in Excel 2016 (Microsoft, Redmond, Washington). Data (incision sizes and distances of TCVCS and SENMAP in cadaver heads; surgery time, blood loss per individual procedure, total blood loss and follow-up time in clinical cases) are reported as range (minimum-maximum mean ± SD).

3 | RESULTS

3.1 | Transnasal conchotomy of the ventral conchal sinus in cadaver heads

Transnasal conchotomy of the ventral conchal sinus was performed, avoiding laceration of adjacent anatomical structures and thermal injury to mucous membranes apart from the surgical sites in all cadaver heads. Transnasal conchotomy of the ventral conchal sinus incisions were difficult to measure on the reformatted CT images but were subsequently directly measured. The rostrocaudal dimensions of the TCVCS incisions ranged between 45 and 50 mm (46.7 ± 2.9). The distances from the ventral aspect of the incision to the bony base of the VCS varied between 8 and 23 mm (15.3 ± 7.5 mm; Table 1).

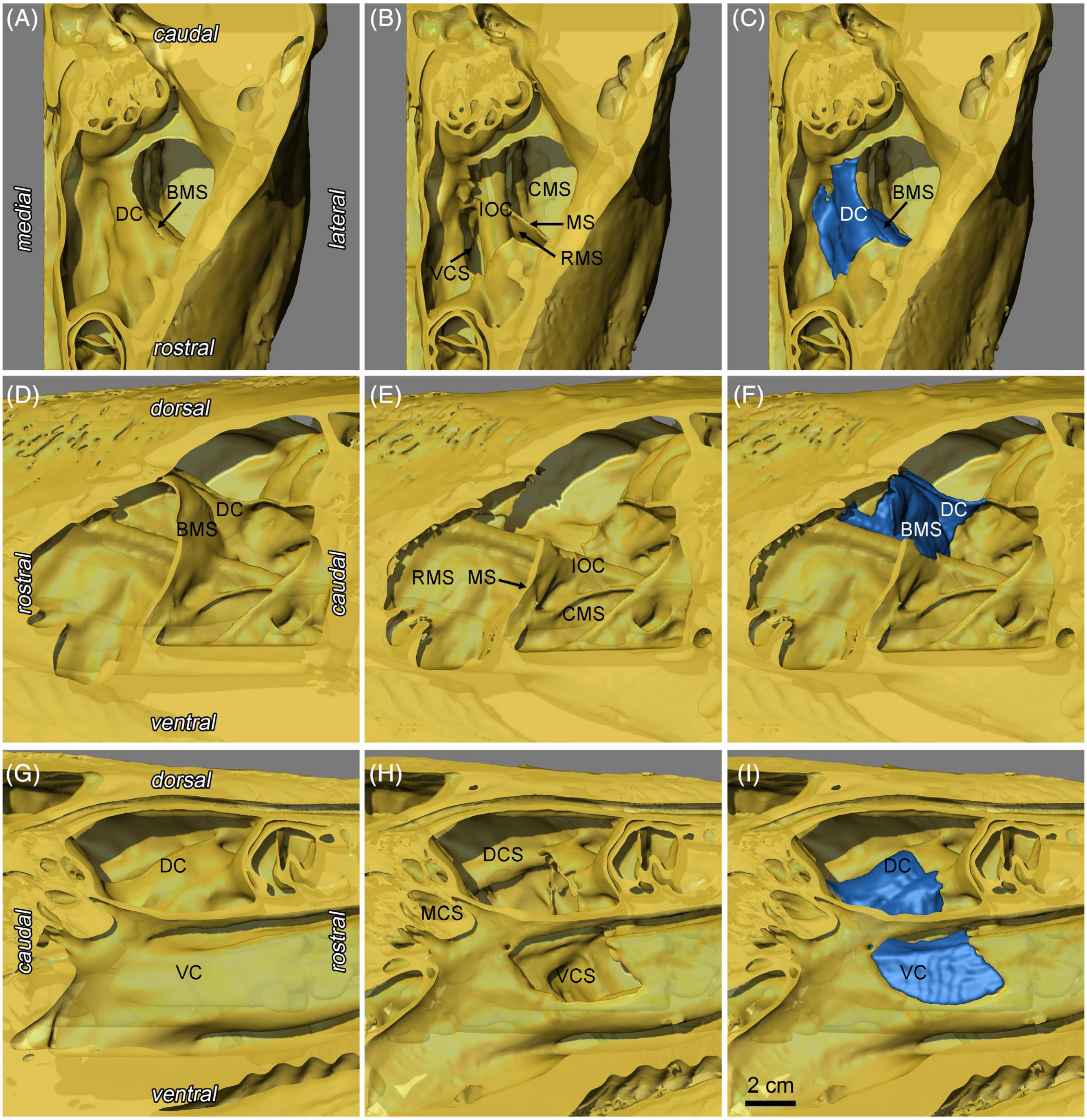

FIGURE 6 Reformatted 3-dimensional dorsal (**A-C**), lateral (**D-F**), and medial (**G-I**) computed tomography views of the left side of head 6 before (**A,D,G**), and after (**B,E,H**) combined TCVCS-SENMAP. The resected portions of the dorsal and ventral concha are highlighted in blue (**C,F,I**). BMS, bulla of the maxillary septum; CMS, caudal maxillary sinus; DC, dorsal concha; DCS, dorsal conchal sinus; IOC, infraorbital canal; MS, maxillary septum; RMS, rostral maxillary sinus; SENMAP, surgical enlargement of the nasomaxillary aperture; TCVCS, transnasal conchotomy of the ventral conchal sinus; VC, ventral concha; VCS, ventral conchal sinus. Scale bar = 2 cm

3.2 | Surgical enlargement of the nasomaxillary aperture in cadaver heads

All SENMAP and combined procedures were performed as planned. However, the localization of the trephination sites in heads 1–3 provided a suboptimal view of the surgical field, so further instrument handling was difficult. The maximum rostrocaudal incision distances in SENMAP varied between 28 and 42 mm (35.6 ± 7.1), and the distances from the ventral aspect of the incision to the base of the VCS ranged from 4 to 5.7 mm (5.1 ± 1).

TABLE 3 Clinical cases treated with SENMAP and/or TCVCS in sedated, standing position under local anesthesia

Horse No.	Age, y	Sex	Diagnosis/reason for surgery	Side	Local anesthesia	Teeth extracted, Triadan No.	Procedure performed	Surgery time, min	Blood loss per individual procedure, L	Total blood loss, L	Sinus packing	Follow up, mo	Outcome
1	21.4	F	Open comminuted, depressed facial fracture	Right	Topical	None	TCVCS	15	1.3	1.3	No	25.5	Healed
					MNB, ISS		SENMAP	95	<0.5				
2	8.4	F	Recurrent secondary (dental) sinusitis	Left	Topical	209	TCVCS	20	5	5.5	Yes	23.4	Healed
					MNB, LISS	210	SENMAP	105	<0.5		No		
3	16.4	G	Recurrent secondary (dental) sinusitis	Left	Topical	208	TCVCS	15	2	2.5	Yes	14.4	Healed
					MNB, LISS	209	SENMAP	90	0.5				
4	8.9	F	Recurrent secondary (dental) sinusitis	Left	Topical	209	TCVCS	25	1	1.5	No	17.8	Healed
					MNB, LISS		SENMAP	95	0.5				
5	18.6	F	Recurrent secondary (dental) sinusitis	Right	Topical	109	TCVCS	10	1.5	2.3	Yes	13.2	Healed
					MNB, LISS		SENMAP	85	0.8				
6	24.8	G	Recurrent secondary (dental) sinusitis	Right	MNB, LISS	109	SENMAP	90	<0.5	0.5	No	7.0	Healed
7	15.1	G	Recurrent secondary (dental) sinusitis	Right	MNB, LISS	109	SENMAP	90	<0.5	0.5	No	3.6	Healed
						110							
8	3.5	F	Open comminuted, depressed facial fracture	Right	Topical	None	TCVCS	15	1.5	1.5	No	3.2	Healed
					MNB, LISS		SENMAP	95	< 0.5		No		

F, female; G, gelding; LISS, local infiltration of surgical site; MNB, maxillary nerve block.

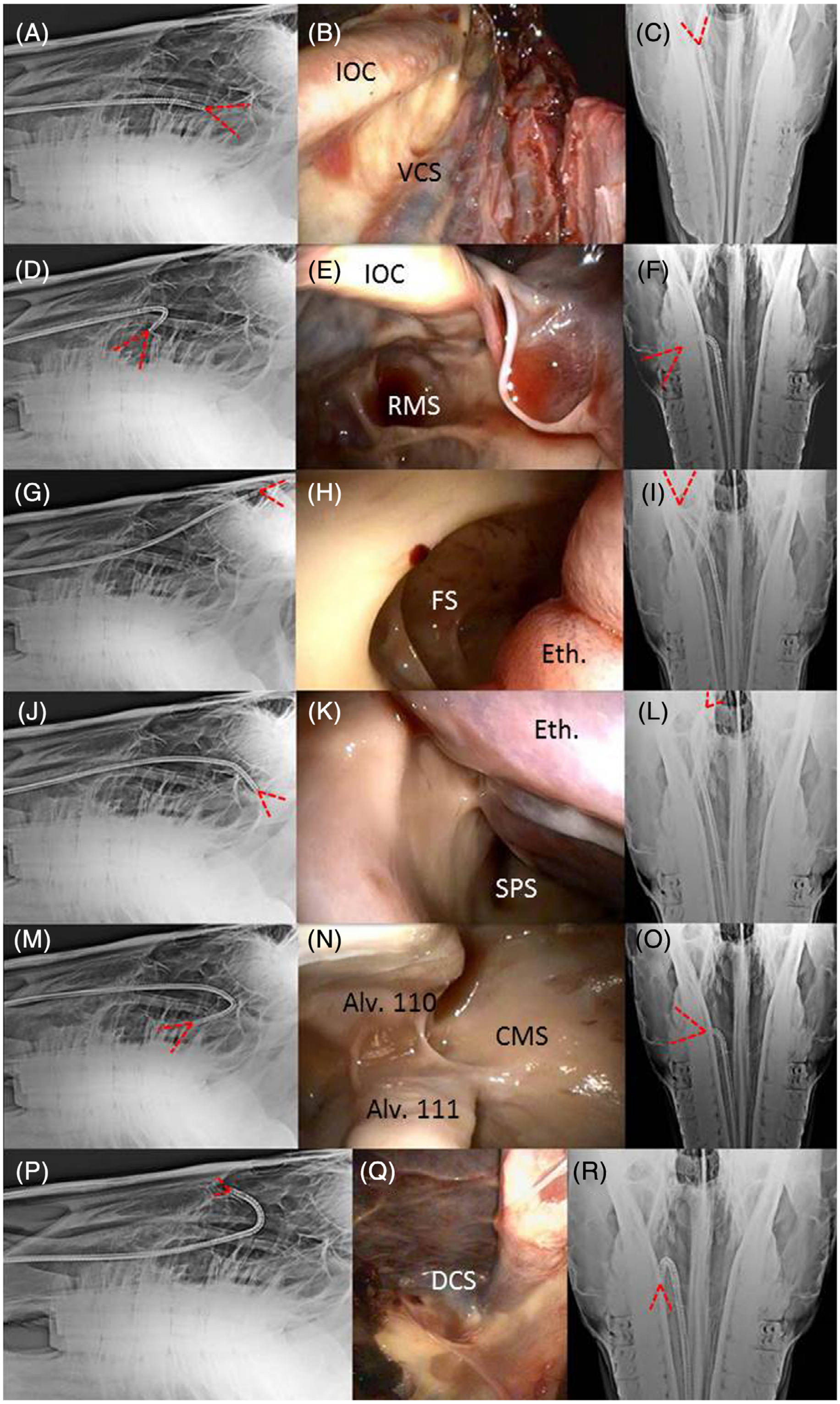

FIGURE 7 Sinoscopy of the right paranasal sinuses in head 9. From left to right, laterolateral radiographic projections, endoscopic views, and frontomandibular radiographic projections of the respective sinuses. The approximate endoscopic field of view is indicated by red dotted lines on the radiographs. Endoscopy of the ventral conchal sinus (VCS, **A-C**), rostral maxillary sinus (RMS, **D-F**), frontal sinus (FS, **G-I**), rostral portion of the sphenopalatine sinus (SPS, **J-L**), caudal maxillary sinus (CMS, **M-O**), and dorsal conchal sinus (DCS, **P-R**). Alv. 110, alveoli of Triadan 110; Alv. 111, alveoli of Triadan 111; Eth., ethmoid; IOC: infraorbital canal

3.3 | Combined TCVCS and SENMAP in cadaver heads

The trephination portals were centered approximately 20 mm farther rostrally in heads 4–9 to improve surgical site visualization and instrument handling. The maximum rostrocaudal incision distances for the combined procedures varied between 40 and 48 mm (44.6 ± 2.9), and the distances from the ventral aspect of the incision to the base of the VCS ranged from 0 to 5 mm (0.8 ± 1.9). Postoperative visual examination, CT images, 3D reconstruction, and endoscopy clearly revealed the extent of the surgical interventions and the improved draining of the treated sinuses.

3.4 | Evaluation of postoperative sinus drainage in cadaver heads

Drainage was increased ($P = .028$) through the surgically created sinonasal communications (combined TCVCS-SENMAP) in heads 7–9 (Table 2).

3.5 | Transnasal sinoscopy

The rostral sinus compartments (VCS and RMS) and the 2 large caudal sinus compartments (CMS, CFS) on both sides were visualized in all heads with combined TCVCS-SENMAP (heads 4–9) and in all 8 live horses (Figure 7A-R). Endoscopic visualization of the SPS was limited to its rostral portion, and the MCS could not be endoscopically accessed in any of the heads or clinical cases (see Supporting Information Video Clip 1: Postoperative sinoscopy of head 9 and Video Clip 2: Postoperative sinoscopy of clinical case 7).

3.6 | Transnasal conchotomy of the ventral conchal sinus and/or SENMAP in affected horses

Transnasal conchotomy of the ventral conchal sinus and/or SENMAP was successfully performed in 6 horses with secondary dental sinusitis and in 2 horses with sinusitis secondary to facial fractures (Table 3). Combined TCVCS and SENMAP was performed on separate days in horses 1, 2, and 8 and in a single session in horses 3, 4, and 5. All TCVCS and/or SENMAP were well tolerated by the standing, sedated, and locally anesthetized horses. However, occasional head movements during conchotomy did occur in some horses. In these cases, repeated transendoscopic topical application of mepivacaine (2%) proved effective in sufficiently desensitizing the surgical area of the medial ventral conchal wall.

Surgical enlargement of the nasomaxillary aperture was modified in horses 6 and 7; the tissues of the medial wall of the ventral concha between the rostral and caudal SENMAP incisions were fully thermally coagulated and then repeatedly transected in vertical direction by using the cutting function of the electrosurgical device (MarSeal Slim IQ; KLS Martin). The coagulated portions of the medial ventral conchal wall were subsequently removed with forceps, rendering TCVCS unnecessary in these cases. Blood loss during both procedures was <500 mL and the conchal fenestrations were of similar size to those created using combined procedures.

The duration of TCVCS in live horses varied between 10 and 25 minutes (16.6 ± 4.7), and the duration of SENMAP varied between 85 and 105 minutes (93.1 ± 5.9; Table 3). Blood loss ranged from 1 to 5 L (2.1 ± 1.4) during TCVCS and from 0.5 to 0.8 L (0.54 ± 0.1) for SENMAP. Total blood loss varied between 0.5 and 5.5 L (1.95 ± 1.5). Endoscopic monitoring during TCVCS was only occasionally compromised by bleeding and was quickly resolved by cleaning the tip of the endoscope in all cases. Sinus packing was required in only 3 horses.

Transnasal sinoscopy and transendoscopic sinus lavage were performed in all live horses at 2-day intervals until signs of sinusitis had improved. Owners interviewed by phone 3.2–25.5 months (13.5 ± 8.5) after discharge from the hospital indicated that sinusitis had resolved in all horses.

4 | DISCUSSION

The VCS was incised successfully and without laceration of adjacent structures in all TCVCS performed in this study. All SENMAP were successfully performed, despite the suboptimal positioning of trephination portals in heads 1–3. Combining procedures improved the visualization of and access to the surgical site when the trephination was centered approximately 20 mm more rostrally than the positioning that was used in heads 1–3. All combined procedures were performed satisfactorily and resulted in large sinonasal communication, thereby improving sinus drainage. Transnasal conchotomy of the ventral conchal sinus and/or SENMAP was successfully performed in 8 horses with sinusitis. Surgical enlargement of the nasomaxillary aperture was modified in 2 horses, eliminating the requirement for TCVCS. Sinusitis resolved in all 8 horses. Postoperative transnasal endoscopic examination of all ipsilateral sinus compartments (except the middle conchal sinus) was possible in all heads with combined procedures and in all 8 clinical cases.

Transnasal conchotomy of the ventral conchal sinus and SENMAP may be used separately or combined, depending on the specific disorder. Transnasal conchotomy of the ventral conchal sinus as a sole procedure may suffice in horses with primary chronic sinusitis limited to the RMS and VCS. However, in most sinusitis cases, the caudal sinus compartments are also affected, and some horses display compromised sinus drainage due to partial or complete obstruction of the rostral and the caudal sinonasal canals.[11] In these cases, effective sinus drainage can be established by combining TCVCS and SENMAP to create a large sinonasal communication, causing minimal to moderate hemorrhage. Transnasal conchotomy of the ventral conchal sinus may be performed as the sole surgical interference if the sinus disorder affects only the RMS and VCS. Facial bone osteotomy and the risks for postoperative complications such as severe hemorrhage after the creation of sinonasal communications with conventional instruments not under visual control and suture dehiscence and wound infections,[12] including suture periostitis,[13–15] may be avoided in these cases.

The transversely oriented septum forming the rostral border of the VCS[16–18] can be lacerated during surgery because this structure cannot be visualized during conchotomy. An increased resistance at the tip of the conchotome when extending the incision rostrally indicates the proximity of the conchotome blade to the rostral aspect of the VCS. Attempts to extend the conchotomy beyond this point will cause profuse bleeding in clinical cases[7] and increase the risk for postoperative infection of the ventral conchal recess and bulla[19] located rostrally to the VCS. Limiting the caudorostral distance of the TCVCS incision to approximately 5 cm helped avoid this complication in this study. Trying to fenestrate the VCS more ventrally than described can result in laceration of the large submucosal venous plexus in this area,[17,18] which can cause profuse hemorrhage while failing to create the desired opening into the VCS.[7] Small and/or narrow conchal incisions can heal prematurely and cause recurrence of sinusitis if the conchomaxillary aperture and/or the rostral sinonasal canal remain obstructed.[7] Severe conchal distension that is secondary to sinus cysts, neoplasia, or massive empyema formation can obstruct the nasal meatus to an extent that renders a TCVCS impossible.

The decision to access the CFS with a 30-mm trephination portal and discard the excised bone disc was based on the author's observations of lower complication rates and excellent cosmetic results compared with other sinusotomy techniques.[9,12,20] In this study, the overview of the surgical field and instrument handling improved substantially in heads 4–6 and in all clinical cases by centering the CFS trephination approximately 20 mm farther rostral than had been previously described.[2,9,12,20–22] This approach also avoids the frontonasal suture during osteotomy, reducing the risk for suture periostitis.[13–15]

A conventional resection of the medial wall of the VC without electrothermal coagulation will inevitably result in profuse hemorrhage in clinical cases.[22] In this study, electrosurgical instruments were effectively used to create large sinonasal communications in horses. Transendoscopic conchal fenestration techniques with laser surgery have been described.[4–6] Electrosurgical equipment was favored in this study because of the ease of instrument handling, lower cost, and difficulty of sectioning bone with surgical lasers. Transnasal sinoplasty has been reported as an alternative, less invasive technique to improve sinus drainage in man[23–29] and in horses.[3] In human medicine, balloon dilation techniques of the frontal, sphenoid, and maxillary ostia have also been described[23-29]; however, in equine medicine, there is evidence only for the effective dilation of the caudal sinonasal canal.[3] Technical problems in successfully dilating the rostral sinonasal canal and in improving the drainage of the RMS and VCS have not been resolved to date.[3] In addition, ventral compression of the septal bulla during balloon sinoplasty of the caudal sinonasal canal may cause the stenosis or even occlusion of the conchomaxillary aperture in some horses, which might in turn reduce or impede the VCS drainage. In human balloon sinuplasty studies, the patency failure rate is less than 20%, and the revision rates are between 1% and 3%[26,29]; similar data are not yet available for horses.

Similarly to during the TCVCS, the size of the surgically created sinonasal communications during the SENMAP could influence the success rate of the procedure because conchal fenestrations may stenose after surgery.[3,7] Formation of adhesions between the resection edges of the dorsal and ventral conchal walls or with the infraorbital canal can affect drainage of the individual sinuses or sinonasal canals, causing recurrence of sinusitis. To avoid this complication, the communications between the sinuses and nasal meatus were created as large as reasonably possible. Large sinonasal communications also facilitate the insertion of an endoscope into the equilateral ipsilateral sinuses for sinoscopy. Lack of information concerning morphologic changes at the surgically created sinonasal communications over time is a limitation of this study; this can be addressed in future research.

Establishing the underlying cause of sinusitis[1,2] is of the utmost importance, especially in horses with recurrent signs. Adequate treatment, such as exodontia of infected teeth or surgical removal of necrotic bone associated with facial fractures, is as important as restoring sinus drainage and ventilation for therapeutic success. Less invasive procedures, such as transnasal sinus endoscopy, transendoscopic sinus lavage, or balloon sinuplasty, should be considered as therapeutic options prior to performing TCVCS and/or SENMAP. Although a large percentage of horses with sinusitis can be successfully treated with less invasive methods, TCVCS, SENMAP, or the combined technique might be helpful for the treatment of cases with chronic sinusitis and with persistent obstructions of the nasomaxillary apertures. Studies involving larger samples of horses and long-term follow-up are required to evaluate the long-term outcome in larger groups of horses treated with the described techniques.

Hemorrhage was more pronounced during TCVCS than during SENMAP. Blood loss of almost 5 liters was encountered only in a single TCVCS. Hemorrhage control during all SENMAP was effectively performed with the electrosurgical tissue sealing device, minimizing blood loss to less than 500 mL in 5 of 8 horses. With increasing experience, relevant blood loss might be additionally minimized in future cases. The modified SENMAP (without TCVCS) used in horses 6 and 7 resulted in limited hemorrhage; further evaluation of this technique is warranted.

The transnasal sinoscopic accessibility of all large ipsilateral sinus compartments via the surgically created sinonasal communication represents an additional advantage of SENMAP and the combined technique. Thus, postoperative transnasal and transendoscopic flushing of the sinuses under visual control as well as the removal of hitherto undetected inspissated pus and postoperative debris such as splinters of necrotic conchal bone with endoscopic biopsy forceps was feasible in all clinical cases. Transnasal sinus lavage renders the use of indwelling flushing systems (eg, Foley catheters) unnecessary. This might promote uncompromised primary healing of the external trephination sites and reduce complications such as suture periostitis.[13–15]

In conclusion, SENMAP and TCVCS improved sinus drainage and should be considered in horses with chronic sinusitis. The combination of both methods facilitates the creation of large, presumably permanent sinonasal communications. Drainage of the ipsilateral sinus compartments via these sinonasal communications is improved and postoperative transnasal sinus endoscopy and sinus lavage is facilitated. Indwelling flushing systems can be avoided, which may improve healing of the trephination site.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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