A long-term study of sinoscopic treatment of equine paranasal sinus disease

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A long-term study of sinoscopic treatment of equine paranasal sinus disease: 155 cases (2012-2019)

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Running title: Sinoscopic treatment of sinus disorders

Summary

Background: There is little objective information concerning the intra- and post-operative complications or the long–term outcome of sinoscopic treatment of equine sinus disorders.

Objectives: To document the long–term outcome, including intra-operative complications, reasons for treatment failure and other complications, in horses undergoing standing sinoscopic treatment of sinus disorders.

Study design: Retrospective clinical study.

Methods: Records of sinus disease cases presented to The University of Edinburgh Veterinary School between January 2012 and July 2019 were reviewed. Follow-up information was obtained from clinical records and a telephone questionnaire.

Results: Long-term follow up for 155 cases treated sinoscopically showed that 108/155 (69.7%) fully responded to their initial treatment. Concurrent intranasal lesions were identified in 37.4% of cases. Sinusotomy was later required in 10 cases to improve surgical access or sinonasal drainage. Reasons for failure to fully respond to the initial treatment (n=47) included: intra-sinus bone sequestra (n=9), inspissated exudate (n=6) or insects (n=2); similar material and/or infected conchal bullae in the middle meatus (n=7); persistent oro-maxillary fistulae (n=4), misdiagnosed dental apical infections (n=4); impaired sinonasal drainage (n=4), progressive ethmoid haematoma regrowth (n=3) and undiagnosed causes (n=5). Further treatment of 43 of these cases (67% as outpatients) showed 34/43 cases fully responding to their second treatment. Only 4/155 cases (2.6%) required sinonasal fenestration. In the long term, 149/155 cases (96.1%) showed full and 2/155 cases (1.3%) showed partial improvement. Sinoscopy portal wound infection occurred in 9 cases.

Main limitations: The length of time between treatment and obtaining follow-up information in some cases. Advances in knowledge and techniques over the duration of the study.

Conclusions: Sinoscopic treatment is a minimally-invasive technique causing minimal morbidity and was successful in 96.1% of cases. Meticulous care should be taken to ensure that bony sequestrae and inspissated exudate are fully removed from the sinuses and nasal cavity during sinoscopic treatments.

Introduction

Equine paranasal sinus disorders ("sinusitis") are usually chronic diseases where it can be difficult to establish the precise cause [1-5] and sometimes to effectively treat [6, 7]. Sinusitis can be termed 'primary' when no underlying cause is identified for the sinus inflammation. Sinusitis is termed 'secondary' when underlying causes including cheek teeth apical infections, oro-maxillary fistula (OMF), sinus cysts, intra-sinus progressive ethmoid haematoma (PEH) and tumours, or sinus trauma are identified [1-5]. Recent

studies have highlighted the occurrence of concurrent ipsilateral nasal disease with sinusitis, including the presence of sino-nasal fistulae, inspissated exudate or bone sequestrae [2,3,4,8,9] and infected nasal conchal bullae (NCB) [5,8,10].

Equine sinusitis was traditionally treated by osteotomy flaps under general anaesthesia with attendant risks of morbidity, mortality, haemorrhage and higher costs; and later by sinusotomy under standing sedation which reduced some of these risks and costs [4,6,7]. More recently, sinusitis has been investigated and treated using sinoscopy through frontal bone portals [4,7, 8,9,11-12]. No long-term study has specifically examined the intra- and post-operative complications or reasons for treatment failure associated with sinoscopic treatments.

The aims of this study were to accurately document: 1) the intra-operative problems that can occur during sinoscopy, 2) reasons for failure to respond to sinoscopic treatment, 3) other post-operative complications that can occur following sinoscopic treatment and 4) some brief comparisons with sinusotomy treated horses. Such information may help clinicians considering surgical treatment options for sinus disorders and improve success in future cases.

Materials and methods

Cases

The clinical records of horses referred for treatment of sinus disease at The University of Edinburgh Veterinary School Equine Hospital between 1 January 2012 – 31 July 2019 were reviewed (Supplementary Item 1). Short-term information on response to treatment was obtained for some horses from clinical records at requested routine revisits 2-4 weeks following their initial treatment and/or from revisits because of continuing sinusitis or other post-operative complications. Longer-term follow-up information was later obtained in each case from clinical records if later re-examined at our hospital, and by a telephone questionnaire (Supplementary Item 2). Clinical details of post-operative problems in horses not re-examined by us were obtained from the referring veterinarian.

Cases were subdivided into two groups based on whether they were treated initially by sinoscopy or sinusotomy (Supplementary Item 1). The emphasis of this study was sinoscopic treatment. Sinusotomy treatments have been extensively reported [1, 2, 4, 6, 7,9] and limited details of cases treated initially by sinusotomy are presented in this study (Supplementary Item 3).

Clinical and imaging examinations

Following admission, all horses underwent full clinical examinations, including oral endoscopy for the presence of dental lesions such as occlusal pulpar exposure and dental fractures that could indicate the presence of maxillary cheek teeth apical infection, or deep diastemata possibly indicative of oro-maxillary fistula. Diagnostic head imaging including radiography and/or standing head computed tomography (CT) were also performed when indicated. Cases of primary sinusitis were subdivided into subacute cases, i.e. of <2 months duration and chronic cases i.e. of >2 months duration [2].

Nasal endoscopy

Nasal endoscopy (9 mm external diameter videoendoscope [a] [Olympus Evis Lucera]) was performed in every case to assess for evidence of sinus disease, i.e. the presence of exudate at the sino-nasal ostia or swelling of the nasal conchae and of the 2nd ethmoturbinate (by distension of the underlying sinuses). Following transendoscopic lavage of the middle meatus with 10 – 20 mls of 2.0% lignocaine with adrenaline [b] (Lignol), it was examined for abnormalities that may have caused or contributed to the presenting clinical signs including: inspissated exudate, sino-nasal fistulae, bone sequestrae, mycotic plaques or infected NCB [2,3,4,7-10]. Following pressurised (using a motorised pump) transendoscopic lavage of exudate with lukewarm water to allow examination of the underlying structures. Detected sequestrae were removed using transendoscopic forceps that were also used to disrupt inspissated exudate and to retrieve hard fragments of exudate.

Sinoscopic technique

Horses were administered procaine benzylpenicillin [10mg/kg], neomycin [5mg/kg] q24 h, I.M. (Neopen)[c] and flunixin meglumine (Finadyne)[c] 1.1mg/kg q24 h, I.V. for three days followed by 25 mg/kg bwt sulfadiazine and 5 mg/kg trimethoprim (Norodine)[d] q24 h, P.O. and phenylbutazone (Equipalazone)[b] 2.2mg/kg q12 h, P.O. Following sedation, skin preparation and local subcutaneous anaesthesia with 3-5mls of lignocaine[b] at a frontal trephine site, a 4 -5 cm vertical skin and periosteal incision was made, midway between the orbit and midline, with its ventral aspect at a line joining the medial aspects of the orbits [4,10] (Fig 1). Two 5mm diameter bone trephine openings were made using a customised drill bit (Fig 1), circa 10 mm from the rostral and caudal incision margins. These openings were enlarged with a 13-14 mm diameter, customised hand drill (Fig 1). Irregular areas of bone were removed with bone rongeurs and the edges of the now conjoined openings (large enough to accommodate Ferris Smith rongeurs and endoscope together) were smoothed with a round bone file to prevent endoscope damage. Silver sulfadiazine cream 1.0% (flamazine)[e] was applied over the trephined bone in many cases as a physical barrier to reduce bone contamination with the sinus contents.

A suction pump (Olympus KV5 suction unit)[b] and a 5 mm diameter, 25cm long, rigid plastic catheter, with a 5cm long, 40 degree angled tip (modified mare insemination catheter) were used if the caudal sinuses

contained liquid exudate. The conchofrontal sinus (CFS), caudal maxillary sinus (CMS) and entrance to the sphenopalatine sinus (SPS) were sinoscopically examined. Most cases of mycotic sinusitis were diagnosed at this stage. Under endoscopic guidance, the maxillary septal bulla (MSB) was transendoscopically sprayed with 10-20 mls of lignocaine[b] and fenestrated using 17.8 cm long Ferris Smith rongeurs with different angled heads. Haemorrhage during fenestration of inflamed MSBs was aspirated by suction if necessary. Following MSB fenestration, the rostral maxillary sinus (RMS) and ventral conchal sinus (VCS) were endoscopically examined and detected exudate and bone sequestrae were removed using transendoscopic lavage, and trans-endoscopic biopsy and basket forceps.

If cases (especially those without pre-existing sino-nasal fistulae) showed poor sino-nasal drainage during trans-endoscopic lavage at a flow rate of approximately 2.5 litre/min, the lavage fluid was concurrently aspirated to prevent it egressing from the sinoscopy portal. Sino-nasal fistulation was not performed at this stage, in the expectation that sino-nasal drainage would improve with resolution of sinus mucosal inflammation. Following sinus debridement and lavage, approximately 5cm of a 150cm long indwelling soft plastic, 5mm internal diameter lavage tube[f] (Kruuse uterus flushing tube) was placed through the sinoscopy portal and sutured to the skin circa 5 cm caudal to the sinoscopy portal with monofilament nylon using a finger trap pattern. The remainder of the tube was taped to the mane.

The sinuses were lavaged 2-4 times daily (dependant on the amount of inspissated exudate present) with 5L of lukewarm water/homemade physiological saline solution. If sinuses had effective drainage (i.e. did not overflow when being lavaged as above), a 0.1% povidone iodine solution lavage was used (in less than 10% of cases). These included horses that had malodorous exudate and as an additional treatment for cases of mycotic sinusitis. It was not used in the other horses in case it further inflamed the sinus mucosa and potentially caused further sino-nasal drainage obstruction.

Following the initial sinoscopic treatment, the catheter tip was temporarily withdrawn from the sinus each day. The sinuses were then sinoscopically re-examined, especially for the presence of any remaining inspissated exudate in the rostral sinus compartments, that if identified was broken up and aspirated along with any blood clots (usually present at first re-examination). Most cases had good sinonasal drainage during sinus lavage by the 2nd or 3rd day post initial sinoscopy, as evidenced by all lavage fluid exiting via the nasal passages. Once good drainage was present and all sinus compartments appeared to be endoscopically free of exudate, sequestrae or fungal plaques, treatment was discontinued, although inflamed sinus mucosa was usually still present at this stage. The sinus lavage catheter was removed, and the sinoscopy skin incision was sutured closed. Rarely, inflamed sinoscopy portals that had been open for >4 days, with non-mobile adjacent skin, had a dressing applied instead and were allowed to heal by

secondary intention. After discharge from the hospital, horses continued on the previously described 5-7 day course of oral sulfadiazine/trimethoprim and phenylbutazone.

In addition to the above sinoscopic treatment, cases of dental sinusitis had the infected teeth extracted, orally when possible. OMF were treated by debridement of fistulae and the use of polymethyl methacrylate prostheses. PEH lesions were treated by sinoscopic intra-lesional formalin injection close to their sinus wall attachments, followed by rongeurs and suction debulking of larger lesions. Mycotic lesions were transendoscopically debrided with biopsy forceps and their sites sprayed with enilconazole[g] (Imaverol) solutions. Sinoscopy was only performed in traumatic sinus injuries with open wounds to remove debris, loose bone fragments and blood clots.

Duration of initial hospitalisation was compared between sinoscopic and sinusotomy treated groups using a Wilcoxon signed rank test (variable not normally distributed when assessed graphically and using a Shapiro-Wilks test). All statistical analyses were performed using Stata (12) StataCorp LLC, College Station, Texas.

Results

Complete clinical and follow up data were available for 197 horses, mean age 11.7 years (range 2-25 years) treated for sinus disease (Supplementary Item 1). Prior to referral, 123/197 cases (62.4%) had antibiotic therapy, 14/197 (7.1%) had sinus lavage and 8/197 (4.1%) had sinus surgery (and sinus lavage). Clinical signs included nasal discharge in 193/197 (98.0%) that was unilateral in 181 (91.9%), bilateral in 12 (6.1%); purulent/mucopurulent in nature in 178/197 (90.4%) and haemorrhagic in 15/197 (7.6%). Facial swelling was present in 35 (17.8%) cases and epiphora in 20 (10.2%) cases.

Head radiography was performed in 114/197 cases (57.9%), head CT in 121/197 (61.4%) (42 horses had both) and 4/197 cases (2%; OMF and mycotic sinusitis cases) had neither.

Long-term (median 18; range 2-84 months post-treatment) follow-up information was available for 155 horses with sinus disease (unilateral in 149, bilateral in 6) where sinoscopic treatment was performed initially. Table 1 lists the diagnosed cause of the sinus disease.

Nasal endoscopy

Nasal endoscopy at the initial examination showed abnormalities in the caudal aspect of the ipsilateral middle meatus, usually accompanied by inspissated exudate in 55/155 (35.5%) horses with sinus disease. These included infected NCB (n=17); sino-nasal fistulae (n=13); sino-nasal fistulae and infected NCB (n=16) and inspissated exudate with conchal bone sequestrae and/or mycotic plaques (n= 9). These nasal

abnormalities were present in 2/15 (21.4%) cases of subacute (<2 months duration) primary sinusitis; 16/42 (38.1%) chronic (>2 months duration) primary sinusitis; 28/74 (37.8%) of dental sinusitis; 3/6 (50%) of OMF; 6/9 (66.7%) of mycotic sinusitis and none in sinus cyst, traumatic sinusitis or PEH cases.

Response to initial sinoscopic treatment

Long-term follow-up information demonstrated a full clinical response in 108/155 (69.7%) horses following their initial treatment, with horses taking a mean of 7.7 days (median 4; range 1-42 days) following discharge from hospital to become free of clinical signs. Mucoid unilateral nasal discharge occurred in two cases for up to 6 weeks post treatment. Cases having sinoscopic treatment only were hospitalised for a mean of 3.9 days (median 3, range 1-12 days) at their initial treatment.

1) Intraoperative problems

Failure to sinoscopically access the two rostral sinus compartments satisfactorily

Sinoscopically, it was not possible to access the RMS and VCS fully at the initial treatment for two separate reasons:

a. Thickening and/or distortion of the MSB (n=7)

Gross thickening of the MSB bone due to osteitis [13] and thickening of its overlying mucosa (Fig 1) and/or the absence of any caudal protrusion of the MSB, was recognised during attempted MSB fenestration in seven horses. MSB thickening was sometimes accompanied by a sinusitis-related infra-orbital canal osteitis and enlargement (Figs 1, 2) that prevented satisfactory MSB fenestration (without risking infraorbital canal damage). This in turn, prevented adequate endoscopic access to the RMS and less commonly to the VCS.

Horses presenting with rostral maxillary bone swellings (i.e. distension of the lateral wall of the RMS) in the absence of intra-sinus masses (n=4) (Fig 2), consistently had a thickened MSB and maxillary septum. These were the most difficult cases to treat sinoscopically.

The aforementioned 7 cases were treated by sinusotomy (N=5); an additional RMS sinoscopy (n=1) and by blind lavage using a narrow catheter forced into the RMS (n=1) (Supplementary Item 4). Long-term follow-up (median 42.5; range 5-66 months) showed a full response (n=5), partial response (n=1) and no response (n=1).

b. Dorsal nasal concha too close to the infraorbital canal (n=3*)*

A less common reason for inability to adequately access the VCS in 3/155 (1.9%) horses was when the ventro-medial aspect of the dorsal nasal conchus was located close to the infra-orbital canal at the MSB fenestration site (Fig. 3). Sinusitis-related infraorbital canal osteitis and swelling exacerbated this obstruction in two cases. Sinoscopically-guided resection of the protruding dorso-medial aspect of the ventral concha using rongeurs to gain access to the VCS was unsuccessful due to severe haemorrhage (n=2).

Treatment was by resection of the DCS floor and then of the MSB via nasofrontal sinusotomy (n=2) or an enlarged (20mm wide) frontal sinoscopy portal (n=1), thus conjoining the DCS, VCS and CMS that successfully allowed VCS debridement. Follow up information (15, 17, 60 months later) showed full resolution in all horses.

2) Failure to respond to the initial treatment (n=47)

The sinusitis in 47/155 cases (30.3%), including 42/146 cases (28.8%) that had sinoscopic treatment only (9/155 cases initially treated sinoscopically also required a sinusotomy), did not respond fully to their initial treatment (Table 2). These cases had continuing muco-purulent/purulent nasal discharge (n=44); discharging facial tract (n=1); or epistaxis (n=3 EIPH cases). The authors performed re-examination in 41 of these 47 non-responding cases (29 as outpatients). Repeat sinoscopy through the original (now partly fibrosed) frontal trephine site was performed in all cases, with the MSB having to be partly or fully re-fenestrated in some horses. Sinoscopy was usually crucial in establishing reasons for the ongoing sinusitis (Table 2).

Inadequate drainage of the rostral sinuses due to MSB sclerosis

Details of two cases of MSB sclerosis and thickening that did not fully respond to treatment due to inadequate rostral sinus drainage have been presented above.

Presence of extraneous solid material within the sinuses:

Bone sequestra (n=9)

The most common finding in cases not responding to their initial treatment was the presence of intra-sinus bony sequestrae (along with exudate) in 9/47 cases (19% of complications) (rostral two sinuses n=8; CMS n=1). These included lacelike pieces of bone (n=7) (Fig 4) likely from the VCS wall or MSB. Smaller, thicker pieces of bone (n=2) were believed to be from thickened, sclerotic MSB or maxillary septa that were loosened during the initial surgical fenestration.

Inspissated exudate (n=6)

The second most common finding in non-responsive cases was the presence of pieces of inspissated exudate within the rostral two sinuses (n=6) and additionally in the CFS (n=1). Three of these cases additionally had NCB infection/inspissated exudate in their ipsilateral middle nasal meatus (Fig 4).

Insects (n=2)

Two cases had continuing nasal discharge following treatment during the summer. One had rubbed its sinoscopy sutures out and the other had displaced a sinoscopy wound dressing. Sinoscopy showed unidentified dead black and yellow flies, circa 15mm long (n=2 and n=1) (Fig 4) in the CMS of both horses, along with mucopurulent exudate.

Treatment of 17 non-responsive cases with intrasinus extraneous solid material

All cases were treated as outpatients. Inspissated exudate, sequestrae and insects were removed using transendoscopic forceps and suction. Following endoscopy of all compartments to ensure no solid, foreign material remained, the sinuses were lavaged with 5L of lukewarm saline/water and the sinoscopy wounds were re-sutured. Three cases with concurrent intra-nasal sequestrae/inspissated exudate also had this material removed *per nasum.*

Long-term information (median 16; range 2-60 months) following their second treatment showed 15/17 cases to fully respond to a single sinoscopic re-treatment by a median of 2 days (0-42 days). One of the non-responsive cases (chronic primary sinusitis) responded to two further similar treatments. The remaining (chronic primary sinusitis) case only partly responded, with continuing low-volume, non-odorous nasal discharge (after its second treatment) with further investigation declined.

Continuing nasal discharge fully due to nasal disorders (n=7)

Nasal endoscopy of seven other non-responsive cases (chronic primary n=3: dental sinusitis n=4) found no exudate emanating from the sinonasal ostia, but inspissated exudate/sequestrae (n=6) or fungal plaques (n=1) were present in the middle meatus (Fig 4d-f). Thin bony sequestrae (Fig 4e) protruded from the scrolls of the ventral conchus (n=4) or dorsal conchus (n=1) due to previous NCB infection and destruction. None of these cases had nasal lesions identified at their initial treatment. These cases were treated as described earlier.

Follow-up information (median 24; 2-60 months) following treatment showed that all seven cases responded to treatment after a median of 14 (0-28 days). However, one of these cases had a recurrence of unilateral nasal discharge 11 months later. Nasal endoscopy (its third visit) then showed a bone sequestrum

with fungal plaque (not identified at the previous visit) protruding from beneath the ventral conchus at the ventral NCB site. Following its removal, the nasal discharge fully resolved (follow-up 26 months).

Misdiagnosis of dental sinusitis (n=4)

Three cases of sinusitis without definitive radiographic or clinical evidence of dental apical infection were initially treated for primary sinusitis but did not respond to treatment. Unusually, a further case had equivocal CT changes present in tooth 109 (i.e. limited endodontic changes but no detectable alveolar changes) at the initial examination and also did not respond to sinoscopic treatment. CT imaging subsequently showed infected teeth in all four cases. All responded to exodontia and further sinoscopic treatment (follow up median 11; range 2-62 months).

True sinonasal drainage obstruction (n=4)

Re-examination of four non-responsive cases showed distended sinuses, with intermittent mucopurulent, non-odorous exudate (n=3); minimal or no drainage visible at the sinonasal ostia; intra-nasal distension of the conchal sinuses (n=4), bulging skin at the sinoscopy site (n=1), and a distended common sinus lumen on sinoscopy and CT imaging (Fig 5). These cases were the only 4/155 cases (2.6%) diagnosed as having anatomical sino-nasal drainage obstruction.

Treatments of sino-nasal obstruction

Treatments of four cases of sino-nasal obstruction (Fig 5) included *per nasum* transendoscopic diode laser fenestration of a relatively avascular distension of the VCS into the nasal cavity in one case. Another case temporarily responded to a similar treatment (with marked epistaxis) and later had a sino-nasal fistula created via a naso-frontal sinusotomy. The third case had sinoscopically-guided disruption of the relatively avascular rostral VCS wall with a rigid probe followed by insertion of a 10mm diameter plastic catheter that was sutured to the external nostril, with the proximal, fenestrated 10 cm of catheter lying free in RMS. This catheter was left in place for 6 weeks to allow the sino-nasal opening to epithelialise (Figs 5e f). The 4th case had sinoscopic DCS wall fenestration into the nasal cavity that was then extended ventrally to include some of VCS wall. Follow-up information (median 16; range 4-54 months after last treatment) showed complete resolution in all cases.

Unknown reason for continuing presence of intrasinus liquid exudate (n=5)

Sinoscopy of one horse with continuing sinus empyema and effective sino-nasal drainage showed intra-sinus liquid exudate. No underlying reason (such as solid extraneous material) was found within the sinuses or nasal cavity. The sinus was lavaged Q8h for 3 days with lukewarm water.

Two other non-responsive cases were found to have MSB thickening and distortion (apparently exacerbated by the initial MSB fenestration) at their second visit, that now required sinusotomy to debride their rostral compartments that contained liquid exudate.

Two other cases had continuing nasal discharge within 3 weeks of their initial treatment at this hospital. A referring veterinarian isolated *Staphylococcus* and *Streptococcus* spp in one case. Both cases responded to short courses of trimethoprim sulphonamides, indicating that persistent sinusitis of unknown reasons with intra-sinus liquid exudate was present in both. Long-term information (median 12: range 7-96 months) confirmed complete resolution in all 5 cases

Continuing oro-maxillary fistulae (n=4)

Oro-maxillary fistulae did not respond to their initial treatment in four cases, with three cases requiring 1, 3 and 6 similar treatments for a response (follow-through 4, 10, 18 months). A 25-year-old horse with pituitary pars intermedia dysfunction and a chronic, pre-existing oro-maxillary fistula had continuing signs for >2 years following our single treatment, with further treatment declined.

Recurrence of benign intrasinus growths (n=4)

Three cases of intra-sinus PEH (two unilateral, one bilateral) had further epistaxis following their initial treatment, including on the contralateral side (n=2). One case was treated with intra-lesional formalin injection on 6 occasions (including in the contra-lateral sinus) over 25 months, but continued to have epistaxis. One case was treated on 4 occasions over 37 months, before eventually responding (19 months follow-up following last treatment). The third case was not treated further and had continuing epistaxis 2 years later.

One horse re-presented with continuing nasal discharge 5 weeks following laser and rongeurs resection of unusual, intra-sinus and intra-nasal cyst-like lesions. A large, exudative granulomatous lesion, at the site of the resected CMS lesion was excised using transendoscopic basket forceps and laser excision with a complete response (follow-up 9 months).

In summary, 43 of the 47 cases not initially responding to their initial treatment, including due to misdiagnosis (4 dental sinusitis cases) had further treatment. This was by the referring veterinarians in 2 cases and by the authors in 41 cases, with 25/29 cases treated as outpatients fully responding to their 2nd treatment. Overall 33/43 cases fully responded to their second treatment and following further treatments, 41/47 showed full and 2/47 showed partial improvement, with four cases not responding.

3) Other Post-operative Problems

Sinoscopy portal complications (n=10)

Sinoscopy portal infections developed within one week of sinoscopy in 9/155 (6.2%) horses. These infections included localised, soft tissue infections that quickly resolved (n=6) and frontal bone osteomyelitis (n=3), with *Bacteroides*, *Proteus* and *Pseudomonas* spp isolated in individual cases. The osteomyelitis was localised (n=2) and with an adjacent naso-frontal suture infection (n=1). All were treated by curettage and systemic antibiotic therapy. A further case developed a localised hard swelling (possibly a naso-frontal suturitis) of the healed sinoscopy site circa 6 months post sinoscopy that later spontaneously resolved. Follow-up information (median 14 months; range 2-60 month following last treatment) showed resolution in all 10 cases.

Two other horses dislodged their sinoscopy sutures by head rubbing and had their wounds re-sutured by the referring veterinarians without any recorded problem.

Sinusotomy wound infection (n=2)

Two of 10 cases requiring sinusotomy developed sinusotomy wound infections; one taking < 1 week, the other, 12 weeks to heal.

Discussion

This study shows that sinoscopic treatment through a frontal sinus trephine portal is effective in the majority of sinus disease cases with 149/155 cases (96.1%) showing full and 2/155 cases (1.3%) showing partial long-term improvement. The procedure was associated with few complications. Some specific challenges to sinoscopic treatment included:

Failure to access the rostral compartments

Sinusitis-related osteitis of the MSB with bone thickening and sclerosis [13] and with thickened mucosa on both its surfaces was present in some cases of sinusitis. Additionally, marked anatomical variation of the MSB (mainly the absence of a protruding area) was present in some affected horses. The presence of these two features prevented MSB fenestration in seven horses at their initial sinoscopy and so prevented access to the rostral sinus compartments. MSB bone and mucosal thickening also developed following post-fenestration in another two horses. A cadaver study on normal equine heads found that atypical MSB morphology prevented its fenestration in 10% [11]. The use of longer or different fenestration instruments, narrower endoscopes, or an additional maxillary portal for MSB fenestration could have allowed some of these cases to have effective rostral compartment sinoscopy. A minority of horses with a chronic distension of their RMS and overlying maxillary bone along with osteitis and thickening of their maxillary septum and MSB may be more suitable for sinusotomy than sinoscopy treatments.

Additionally, in a minority of horses, where an enlarged infraorbital canal lay close to the nasal concha, it was not possible to enter the VCS with a 9 mm diameter endoscope following MSB fenestration. Unless a very narrow (<4mm diameter) endoscope is available, such cases may also be more suitable for sinusotomy than sinoscopy.

Failure to respond to treatment

The intra-sinus sequestrated bone present in some horses at their initial examination was believed to originate from the VCS wall and/or MSB possibly due to gross distension of the rostral sinus compartments with exudate, with resultant bone necrosis. Some intra-sinus sequestrae present at revisits appears to have been caused by further MSB or maxillary septum bone sequestration following damage associated with surgical fenestration (Fig 4). Some intra-sinus sequestrae may have been overlooked at the initial treatment due to mucosal swelling or were hidden in diverticulae of the rostral sinuses. It appears advisable that all damaged or mobile flaps of MSB caused by fenestration should be removed at the initial treatment and also that a large (i.e. 3-4cm diameter) fenestration is made to prevent it from healing over with scar tissue.

It is also unclear if the intra-sinus inspissated exudate found in some cases at re-visits (Fig 4) had reformed since the initial treatment due to ongoing sinus inflammation or alternatively, had been missed at the initial treatment. In this study, horses had sinoscopic treatment and lavage for a mean of 3.9 days, but in view of the above finding, horses with very inflamed sinus mucosa and continuing mucopurulent discharge, may benefit from some additional days of sinus lavage combined with antibiotic and non-steroidal anti-inflammatory treatment.

In retrospect, it seems likely that some of these intra-sinus complications could have been avoided. Meticulous sinoscopic examination of all compartments for solid material should be performed prior to the completion of treatment. It is also recommended that owners ensure sinoscopy wounds remain sealed by sutures or dressings, to prevent the ingress of flies or other foreign material.

The prevalence of pre-existing middle meatus lesions in 38%-67% of horses with empyema caused by chronic primary, dental and mycotic sinusitis and OMF is much higher than previously recorded (15%) [2]. This is likely due to increasing awareness of these middle meatus lesions, the use of CT [13] and more careful endoscopic examination of this area. A recent multicentre CT study of 300 horses found an overall prevalence of NCB lesions (infection or loss) in 56% of horses with sinus disease [5].

Overall, 45.2% of chronic primary sinusitis and 43.2% of dental sinusitis cases had concurrent nasal lesions. It is pertinent that none of the seven cases where intra-nasal lesions alone caused non-response to treatment, had intra-nasal lesions detected at their initial treatment. It is possible that intra-nasal lesions were present but not detected at that stage. It is also possible that intra-nasal sequestra or inspissated

exudate, not originally visible, were dislodged during sinus lavage. It therefore appears advisable to also examine the middle meatus at the *end* of sinoscopic treatment.

In the past, most sinusitis cases had complete clinical remission after treatment [9] . However, those treatments usually involved sinusotomy and nasal fistulation, that along with prolonged sinus lavage, likely dislodged inspissated exudate and sequestrae from the middle meatus or NCB, as well as from the sinuses, thus resolving any concurrent nasal problem. The presence of complete loss of NCB with distortion and adjacent nasal conchal changes in some horses with sinusitis [5] indicates that some infected NCBs are fully lost, thus allowing resolution of the nasal middle meatus inflammation.

The repeat treatment of most non-responsive cases in this study was usually relatively straightforward and performed on an outpatient basis in 29 of the 41 cases treated at this clinic. The resolution of clinical signs within a median of 2 days in 22/24 cases (92%) following removal of solid material from the sinuses or middle meatus confirms that this material most likely caused the ongoing sinusitis.

Only 4/14 sinus cysts (all smaller cysts) were treated sinoscopically, 10 other larger cysts being excised via sinusotomy. Because of the very poor prognosis with sino-nasal tumours [12] that can usually be identified and biopsied (often orally), none were referred during the period of this study. The recurrence of PEH lesions is not unusual, but surgical PEH excision has shown better results than found in this study [14].

The 4 cases diagnosed with dental sinusitis after initial unsuccessful treatment for primary sinusitis emphasises the usefulness of CT. However, care is required in interpreting CT images. Some cases with CT evidence of maxillary cheek teeth endodontic disease but with minimal periodontal or alveolar changes may be less likely to be associated with sinusitis. It is sometimes possible to identify such endodontic changes in cheek teeth outwith an affected sinus.

Sino-nasal drainage obstruction

It was previously believed that many cases of sinusitis had permanent anatomically compromised sinonasal drainage that was of aetiological importance and sino-nasal fenestration was routinely performed [1]. Many of the current cases had restricted sinonasal drainage at initial presentation. However, following 1-3 days of the described treatments, sinus drainage improved greatly in almost all cases indicating that drainage impairment was due to inflammation of the sinonasal drainage pathway mucosa, rather than to a permanent anatomical obstruction. Only 4/155 cases (2.6%) required sino-nasal fenestration, that is a relatively invasive procedure, usually associated with marked haemorrhage, and thus it should not be performed unless there is a clear indication to do so.

Other postoperative problems

The creation of sinoscopy (or sinusotomy) portals allows bacterial contamination (from sinus contents) of the frontal bone and possibly the nasofrontal suture line (depending on individual anatomical variation and positioning of the sinoscopy site). The presence of sinoscopy site infections (including six self-resolving soft tissue infections) in 9/155 horses is therefore not surprising. The excellent drainage at this frontal bone site, the small surgical wound and absence of bone flaps may explain why sinoscopy portal infections 9/155 (6%) were less common with 6/9 self-resolving than sinusotomy infections in this study. In contrast, 22% of sinusotomy cases had wound infections taking a median of 2.3 treatments and 12 weeks to resolve (Supplementary information 3). Creating a physical barrier between the exposed bone and intra-sinus contents by applying antiseptic ointment, or using a modified syringe case, after trephination and at further endoscopies may be beneficial.

Conclusion

Sinoscopic-assisted treatments are minimally invasive and effective for sinus disorders. The presence of bony sequestrae or inspissated exudate within the sinuses or the ipsilateral nasal cavity were the main reasons for non-response to these treatments. If meticulous care is taken to ensure that such solid material is fully removed from the sinuses and the nasal cavity during sinoscopic treatments it should be possible to decrease the prevalence of these complications. Surgical sino-nasal fenestration is not required in the vast majority of cases and sinus drainage usually improves with lavage, non-steroidal anti-inflammatory drugs and time. Concurrent intra-nasal lesions are so common with sinus disorders that the term sino-nasal disorders seems more appropriate for these disorders.

Authors' declaration of interest

No competing interests have been declared.

Ethical animal research

The study received approval from the Veterinary Ethical Review Committee of The Royal (Dick) School of Veterinary Studies and The Roslin Institute.

Informed consent

All owners gave written permission for information on their horses to be used in approved studies.

Data accessibility statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Authorship

The study was designed by P.M. Dixon who had full access to all data, study execution by all authors, data analysis and interpretation by R. Reardon and P.M. Dixon. Preparation of the manuscript by P.M. Dixon, R. Reardon and S. Barakzai. All authors approved the final manuscript.

Manufacturers' addresses

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[c]MSD Animal Health, Milton Keynes, Buckinghamshire, UK.

[d]Norbrook Laboratories Ltd, Corby, Northamptonshire, UK.

[e]Smith-Nephew PLC, Watford, Herfordshire, UK.

[f]Kruuse, Langeskov, Denmark.

[g]Elanco Animal Health, Basingstoke, Hampshire, UK.

Figure Legends

Fig 1: Left) Customised drills with flanges to prevent excessive sinus penetration and ethmoturbinate damage. Middle) Use of a customised hand drill to enlarge the ventral pilot opening in the frontal bone. Right) CT image showing left-sided (dental) sinusitis with the MSB thickened and sclerotic due to osteitis

and with swollen mucosa on both sides (vertical arrow), and grossly thickened maxillary bones (horizontal arrow).

Fig 2: left) Horse with a localised rostral maxillary swelling (arrow) caused by a 209 apical infection and dental sinusitis: Middle) Transverse CT image showing gross maxillary bone osteitis and soft tissue swelling (arrow), distension of the RMS (star) and empyema of the VCS. Right) slightly more caudal CT image showing similar features including infraorbital canal osteitis and enlargement. The RMS (star) and DCS contain inspissated exudate.

Fig 3: Left) CT image showing the dorsal nasal conchae bilaterally lying adjacent to the infraorbital canals (IOC) in a horse with left VCS and RMS empyema (star). Right) a 5mm diameter plastic catheter has been forced between the nasal concha and the IOC into the VCS in order to blindly lavage it.

Fig 4: Sinoscopic images from six non-responsive sinusitis cases. a) Following trans-sinoscopic lavage, a bone sequestrum is identified in the CMS. b) A small mass of inspissated exudate is identified during VCS transendoscopic lavage. c) An unidentified yellow and black fly lying in an inflamed CMS. d) Retrieval of a necrotic bone fragment (arrows) from the middle meatus. e) Bone sequestrum protruding from beneath the ventral nasal concha (likely from ventral NCB infection). f) Caudal aspect of the middle meatus showing inspissated pus partially covering a fistula into the VCS.

Fig. 5 a, b: Transverse head CTs of a horse with chronic mucoid to mucopurulent nasal discharge (had a sinusotomy before referral) showing a large common sinus distended with fluid (stars), VCS atrophy and bone remodelling of the previous surgical site. c) A further case of sino-nasal obstruction shows an enlarged CMS, partially filled with mucoid to mucopurulent type secretions (iatrogenic haemorrhage at margins from sinoscopy). d) A further case of sinonasal obstruction following laser excision of a VCS protrusion causing immediate drainage of mucopurulent exudate – that later sealed over. e, f) At sinoscopy a plastic tube has been inserted through the rostral VCS wall and ventral NCB into the middle meatus with its tip later sutured to the nostril for 6 weeks.

Supporting Information

Supplementary Item 1: Flow diagram of cases

Supplementary Item 2: Questionnaire from The Equine Hospital, The University of Edinburgh Veterinary School

Supplementary Item 3: Details of sinusotomy treatments

Supplementary Item 4: Treatment of cases with thickened MSB.

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Table 1. Diagnosed causes of sinusitis initially treated by sinoscopy or sinusotomy

* 4 primary sinusitis cases were later found to be misdiagnosed dental sinusitis cases

Cause of sinus disease	**Initially treated sinoscopically No. of cases (%)**	**Initially treated by sinusotomy No. of cases (%)**
Dental sinusitis	*74 (47.7)	11 (26.2%)
Subacute primary sinusitis	15 (10.0)	3 (7.1%)
Chronic primary sinusitis	*42 (27.1)	12 (28.6%)
Mycotic sinusitis	9 (5.8)	1 (2.4%)
Oro-maxillary fistula (OMF)	6 (3.9)	1 (2.4%)
Intra-sinus PEH	4 (2.6)	4 (9.5%)
Sinus cyst	4 (2.6)	10 (23.8%)
Traumatic sinusitis	1 (0.7)	0
Total no of cases	**155**	**42**

Table 2. Reasons for non-response to initial treatment in 47 of 155 cases initially treated by sinoscopy

Reasons for non-response to initial treatment in 47 horses	Number (%)
Bone sequestrae and exudate in sinuses	9 (19.1)
Inspissated exudate in sinuses	6 (12.8)
Foreign bodies (flies) in sinuses	2 (4.3)
Inspissated exudate, sequestrae or fungal plaques in nasal cavity only	7 (14.9)
Continuing liquid exudate in sinuses unknown cause	5 (10.6)
Misdiagnosed apical infection	4 (8.5)
Anatomical sino-nasal drainage obstruction	4 (8.5)
Continuing oro-maxillary fistula	4 (8.5)
PEH regrowth	3 (6.4)
Intra-sinus granuloma following polypectomy	1 (2.1)
Continuing sinusitis post RMS sinusotomy	1 (2.1)
Continuing sinusitis post RMS blind lavage	1 (2.1)
Total	**47 (100)**

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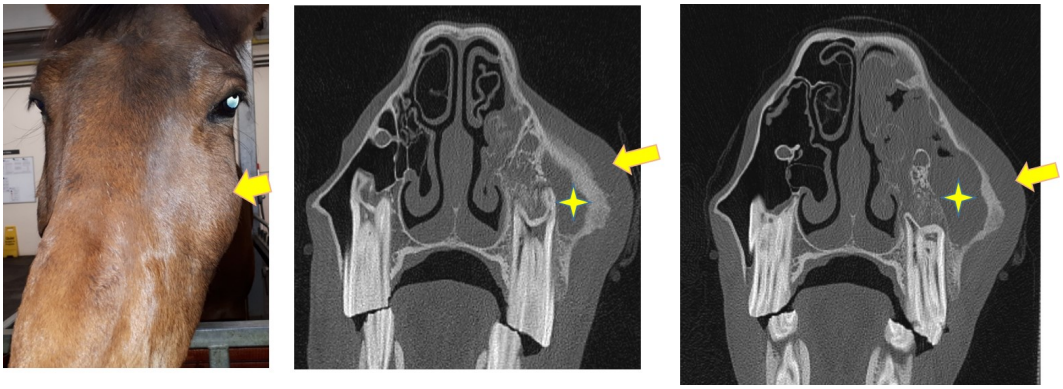

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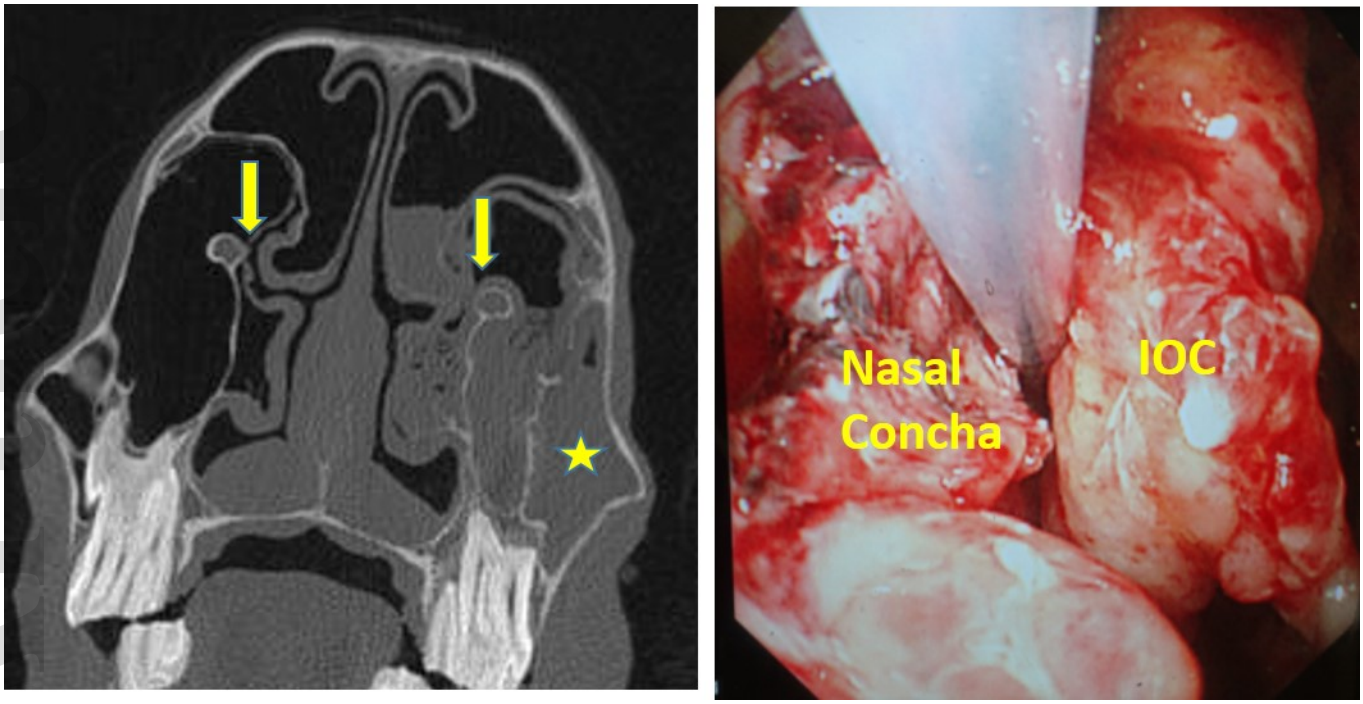

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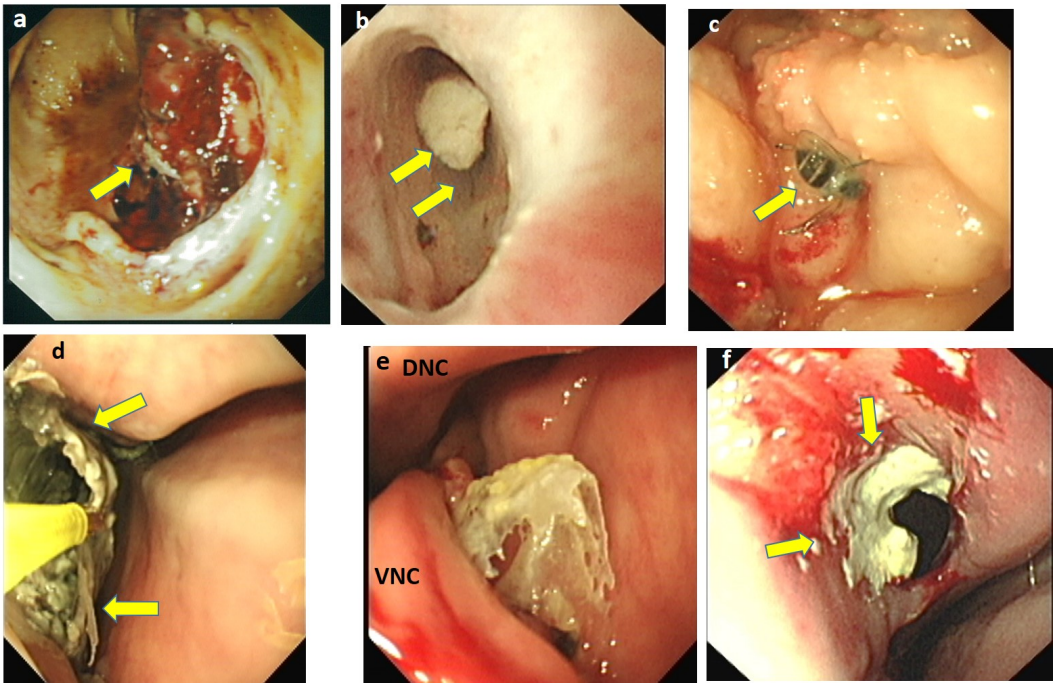

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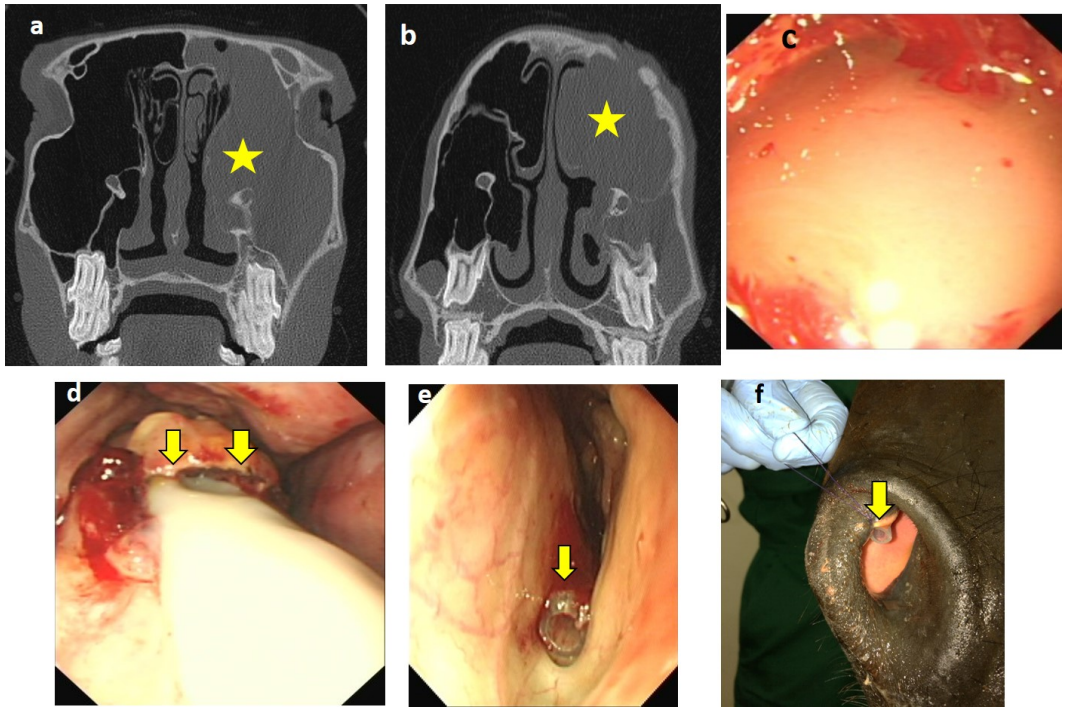

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