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CASE REPORT

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Surgical treatment of headshaking by removal of a paracondylar process fragment via modified hyovertebrotomy approach: A detailed anatomical and surgical description in an adult horse

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Abstract

Objective: To describe, in detail, the relevant anatomy and surgical approach to access the paracondylar process (PCP) and report its application in a clinical case of headshaking.

Animal: A seven-year-old, mixed breed mare.

Study design: Experimental study/case report.

Methods: A seven-year-old mixed breed mare was presented for investigation of acute onset progressing violent headshaking, resulting in the horse falling on multiple occasions. The horse was highly reactive to palpation over the right PCP. Standing computed tomographic (CT) investigation and ultrasonographic examination of the head detected a fracture of the right PCP. Five equine heads of mixed breeds and sizes were dissected to demonstrate the relevant anatomy surrounding the PCP with regard to surgical access. A modified hyovertebrotomy approach was used to remove the fracture fragment under general anesthesia.

Results: The anatomy surrounding the PCP was described. The fragment was successfully removed resulting in gradual resolution of clinical signs. The horse recovered well postoperatively and was back into light levels of work with no signs of headshaking present two and a half years following surgery.

Conclusion: The caudal meningeal artery and vein as well as the glossopharyngeal and hypoglossal nerves are adjacent to the PCP and must be avoided during dissections. The modified hyovertebrotomy approach allows safe surgical access to the PCP. Surgical excision of a PCP fragment can result in complete resolution of clinical signs of headshaking. Computed tomography and ultrasonography are valuable diagnostic tools to identify a fracture of the PCP.

1 | INTRODUCTION

The paracondylar process (processus paracondylaris [PCP]) is an extension of the occipital bone and projects as a linear bony structure from the base of the occipital condyle in a ventrolateral direction, acting as an apophysis for the musculature of the head and neck.[1] The digastric muscle attaches to the PCP together with the occipitohyoideus muscle which support opening of the mouth and ventral movement of the larynx, respectively. The antagonistic muscles of the atlanto-occipital joint, the lateral straight muscle of the head (m. rectus capitis lateralis, flexor) and the oblique capitis cranialis muscle (m. obliquus capitis cranialis, extensor), also insert onto the PCP. The lateral ligaments of the atlanto-occipital joint bridge the joint space between the medial aspect of the PCP and the wing of the atlas.[2] The temporal bone (pars petrosa) releases the facial nerve (cranial nerve VII) via the foramen stylomastoideum in close proximity and rostral to the PCP.[1] Fracture of the PCP has previously been reported[3–5] and was associated with facial nerve paralysis,[3,4] headshaking,[4,5] and poor performance.[4] Resolution of clinical signs was achieved with conservative management in three out of five horses.[4,5] However, two cases required surgical intervention. The objective of this study was to describe in detail the relevant anatomy and a surgical approach tailored to the purpose of accessing the PCP and report its application in a clinical case.

2 | MATERIALS AND METHODS

2.1 | Case history

A 7-year-old, 515 kg mixed breed mare was presented to the Royal Veterinary College Equine Referral Hospital, UK, for investigation of an acute onset of headshaking. The mare was used for low-level dressage and eventing. The headshaking was first noted one month prior to presentation and was observed when ridden, turned out in the field, or exercised on the lunge, sometimes associated with stumbling. On two occasions the horse fell over whilst being lunged and turned out due to the intensity of the headshaking. The horse became incapable of tolerating normal basic activities (such foot trimming) without falling over due to severe head movements. Focal and frequent sweating around the head was noted by the owner. No traumatic event had been witnessed to explain the sudden onset of clinical signs.

2.2 | Clinical and diagnostic findings

On presentation, the mare was bright and alert with unremarkable vital parameters. No headshaking was observed at rest. When lunged, the horse occasionally demonstrated a vertical and rotational headshaking. The horse was highly and reproducibly reactive to palpation over the right PCP; no reactivity was noted on the left side (Video S1). Both neurological and ophthalmic examinations were unremarkable. Upper respiratory tract (including both guttural pouches) and oral endoscopic examination revealed no significant findings. Standing computed tomographic (CT) examination (GE Medical Systems Light Speed Pro 16, with 1.25 mm slice thickness and 1.25 mm interval, 120kVp, X-ray tube current 400 mA) of the head and cranial cervical spine was performed under standing sedation. Images were reconstructed using sharp and smooth kernel, with a slice thickness of 0.6 and 0.3 mm interval and 3.75 and 1.5 mm, respectively. This revealed an irregular, but mainly smoothly marginated complete hypodense line running in craniocaudal and slight ventrocaudal direction at the dorsoventral mid-level of the right PCP (Figure 1A, B). The adjacent aspects of the bone were moderately thickened. These findings were consistent with a chronic, complete, minimally displaced, transverse fracture of the right PCP with fibrous union. Ultrasonographic examination (10–15 MHz linear probe) of the cranial cervical region[6] could also identify the fracture of the right PCP with associated bony remodeling (Figure 2B).

Given that only moderate clinical signs were observed upon presentation, conservative management as a first-line treatment was offered. The owner, however, was concerned about the horse's welfare and safety, after witnessing falls due to violent episodes of headshaking and elected for surgical removal of the fracture fragment.

2.3 | Anatomical dissections

Five frozen equine heads of mixed breeds were obtained from a local abattoir. The heads were thawed and dissected to demonstrate the relevant in situ anatomy surrounding the PCP with regards to surgical access.

2.4 | Surgical technique

Perioperatively, the mare was administered oxytetracycline (8 mg/kg IV, twice daily) and flunixin meglumine (1.1 mg/kg IV, twice daily). She was anesthetized and positioned in left lateral recumbency. The surgical site was aseptically prepared and draped. Right dorsolateral to left ventrolateral radiographic views outlining the right PCP were obtained (Figure S1). A 10–15 MHz linear ultrasound transducer was used to map the extents of the fracture

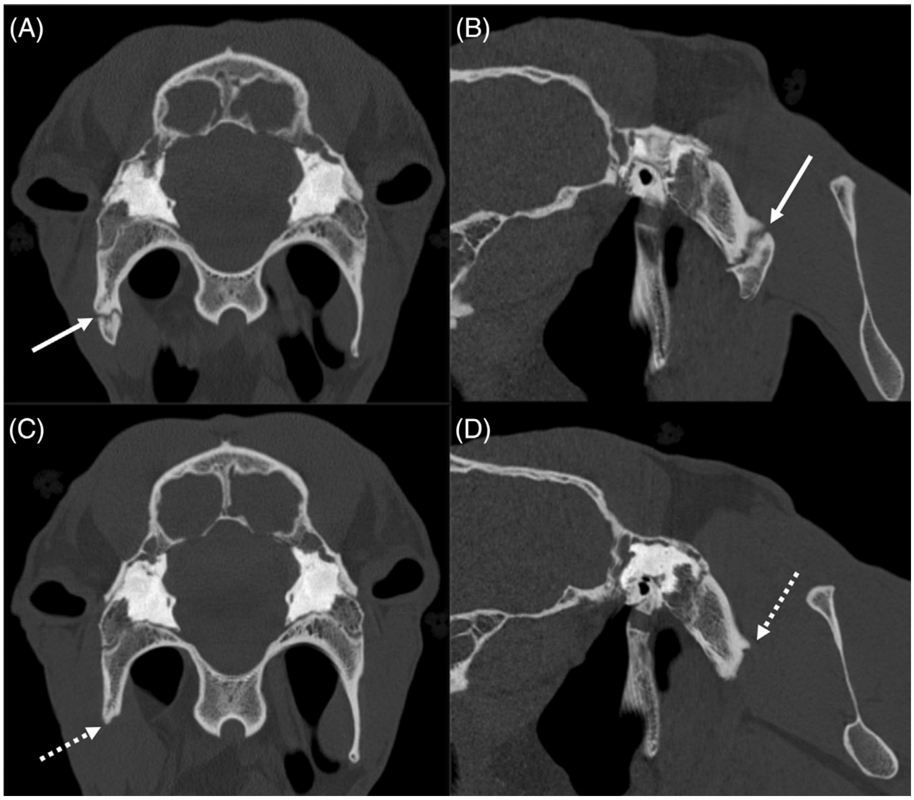

FIGURE 1 Transverse (A, C) and parasagittal (B, D) computed tomographic images at the level of the right paracondylar process. The patient's right side (A, C) and the rostral side (B, D) is on the left of the images (respectively). In the preoperative images (A, B) an irregular hypodense line is running through the right paracondylar process (arrows) with irregular thickening of the adjacent bone margins, consistent with a chronic fracture. Absence of the ventral fracture fragment (dashed arrows) is noted and the remaining bone is mainly smoothly outlined in the postoperative images (C, D).

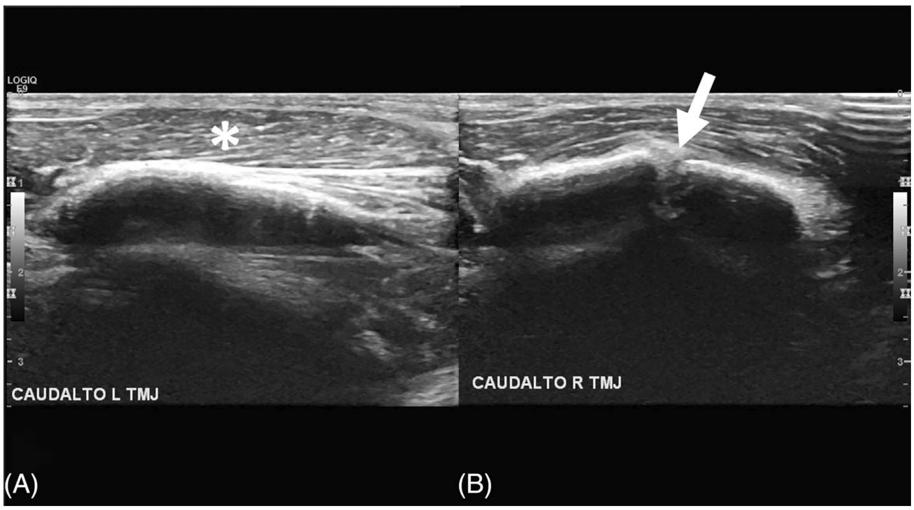

FIGURE 2 Longitudinal ultrasonographic images of the left (A) and right (B) paracondylar process, covered by the cranial obliquus capitis muscle (asterisk). Dorsal is to the left. The bone surface echo of the left paracondylar process is smooth and regular. The fracture line in the right paracondylar process can be easily seen (arrow).

fragment. Stainless steel staples were used as markers. A 5 cm dorsoventral skin incision was made, centered over the fracture fragment, approximately 4 cm ventral to the base of the right ear, and parallel with, but 4 cm caudal to, the caudal border of the right mandibular ramus. After the dense parotid fascia was incised, the parotid gland and overlying parotidoauricularis muscle were reflected cranially using Langenbeck retractors. Care was taken to avoid damage to the caudal auricular vein coursing along the caudal aspect of the parotidoauricularis muscle. Bipolar electrocautery was used to achieve appropriate hemostasis. Blunt dissection was used to separate fascial planes. The cranial obliquus capitis muscle was reflected caudally exposing the underlying right PCP. The fracture plane could be palpated and seen. The intact periosteum was incised longitudinally, and the fragment was carefully exposed using periosteal elevators (Figure 3). The caudal meningeal artery and vein coursing along the caudal aspect of the PCP were reflected caudally. The attachments of the digastric muscle rostral and the lateral rectus capitis muscle caudal to the fragment were sharply transected. A small osteotome and mallet were used to gently enlarge the fracture gap and transect remaining fibrous attachments to the parent bone, allowing removal of the

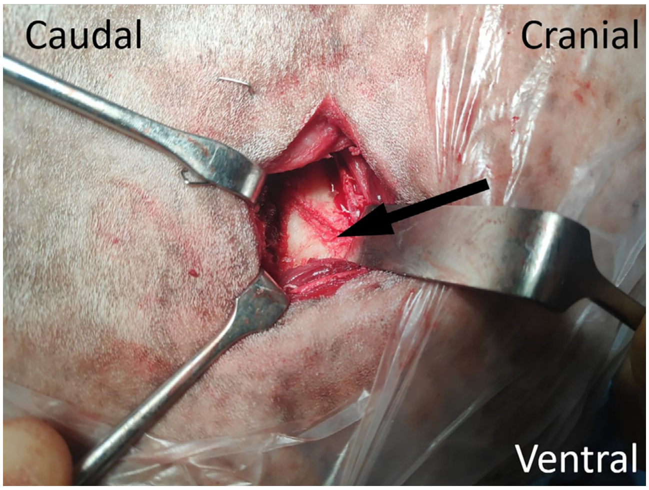

FIGURE 3 Intraoperative image of the exposed right paracondylar process. The periosteum had been reflected cranially and caudally. The fracture line (arrow) is easily appreciated.

fragment. Smooth fracture edges were noted on the remaining PCP. The incision was lavaged with 100 mL sterile saline. Intraoperative radiographs confirmed successful complete removal of the fragment. The fascia of the cranial obliquus capitis muscle was closed using USP 2–0 poliglecaprone 25 suture material in a simple continuous suture pattern. The parotid fascia and subcutaneous tissues were then apposed using the same suture material and pattern. Stainless steel staples were used to close the skin. Sterile swabs were folded and used as a stent bandage to cover the incision and secured with USP 0 polyamide suture in a cruciate suture pattern. The horse recovered well from general anesthesia using head and tail rope assistance.

3 | RESULTS

3.1 | Anatomical dissections

Step-by-step anatomical dissections to access the PCP are provided (Figure 4–7).

3.2 | Outcome

Shortly after recovery from general anesthesia, the horse developed a firm, 10 cm in diameter, circular swelling over the left masseter muscle. Cold packing and twice daily topical application of a heparin/levomenthol/hydroxyethyl salicylate gel (Compagel gel for horses, Boehringer Ingelheim, UK) was initiated, which resulted in gradual resolution of the swelling. The horse was

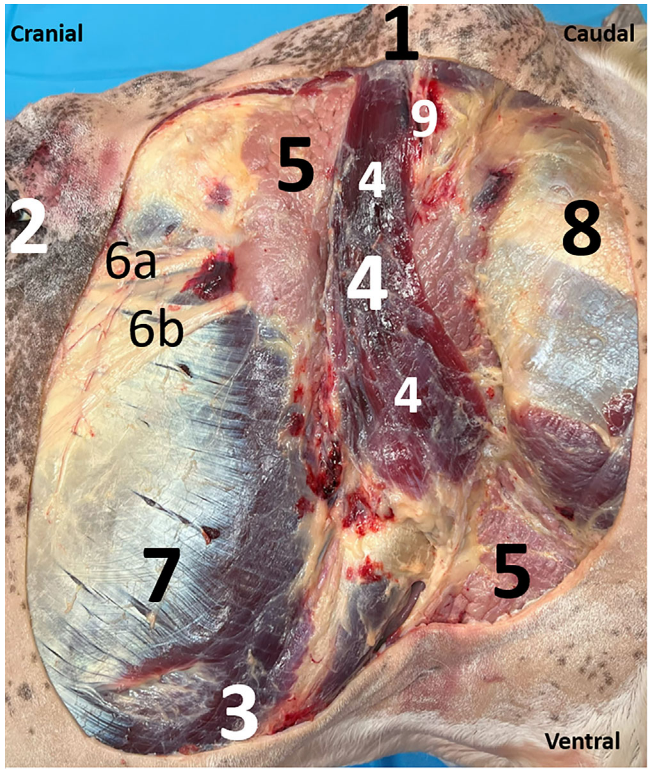

FIGURE 4 Left lateral view of structures presented on the superficial dissection of the cranio-dorsal region of the neck, skin dissected. 1) Base of the left ear, 2) Temporal angle of the left eye, 3) Angle of the left mandible, 4) M. parotidoauricularis - Parotidoauricular muscle, 5) Glandula parotis - Parotid gland, 6) N. facialis - Cranial nerve VII (Facial nerve), 6a)Dorsal buccal branch of facial nerve, 6b)Ventral buccal branch of facial nerve, 7) M. masseter, pars superficialis partially exposed- Superficial part of the masseter muscle, 8) Tendinis musculi longissimi capitis – Tendon of the longissimus capitis muscle, 9) V. auricularis caudalis - Caudal auricular vein, 10) M. obliquus capitis cranialis - Cranial obliquus capitis muscle, 11) M. obliquus capitis caudalis – Obliquus capitis caudalis muscle, 12) M. digastricus, venter rostralis – Digastric muscle, rostral portion, 12') M. digastricus, pars occipitomandibularis – Occipitomandibular part of the digastricus muscle, 13) Stylohyoideum – Stylohyoid bone, 14) M. occipitohyoideus – Occipitohyoid muscle, 15) Ligamentum laterale articulatio atlantooccipitalis – Lateral atlantooccipital ligament, 16) Processus paracondylaris – Paracondylar process, 17) M. rectus capitis lateralis – Lateral rectus capitis muscle, Dashed Line) Processus transversus ala atlantis – Transverse process of the wing of atlas, Black Arrow) A./V. meningea caudalis – Caudal meningeal artery and vein, White Arrow) N. glossopharyngeus – Cranial nerve IX (glossopharyngeal nerve), White Arrowhead) N. hypoglossus – Cranial nerve XII (hypoglossal nerve), White Diamond) Diverticulum tubae auditivae – Guttural pouch

maintained on intravenous antimicrobials for a total of five days. Two days after surgery, the stent bandage was removed and there was no heat or swelling of the surgical site. NSAID treatment was changed from intravenous

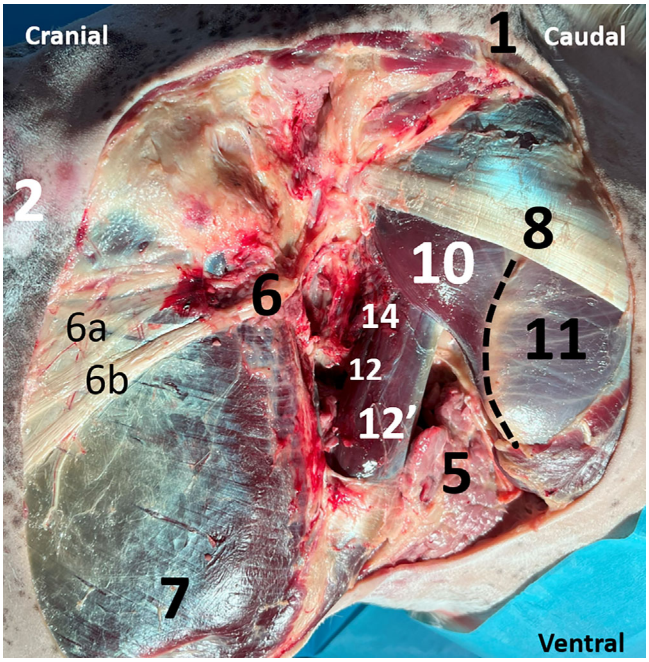

FIGURE 5 Left lateral view of structures presented on the deep dissection of the neck with parotidoauricularis muscle and parotid gland (partially) excised.

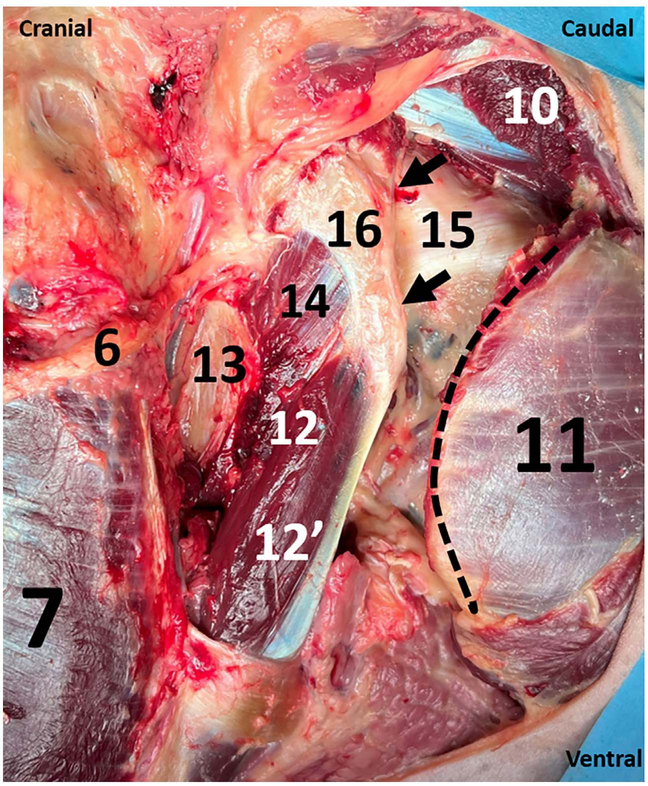

FIGURE 6 Left lateral view of structures presented on the deep dissection of the neck with the tendon of the longissimus capitis muscle and cranial obliquus capitis muscle (partially) resected.

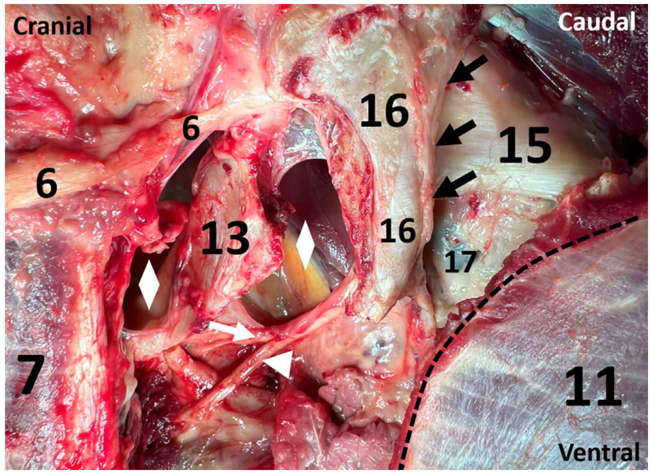

FIGURE 7 Left lateral view of the left paracondylar process of the occipital bone with the surrounding anatomical structures presented on the deep dissection of the neck. The occipitohyoid and digastric muscles have been removed.

flunixin meglumine to 1 g (1.9 mg/kg) phenylbutazone given orally once daily. No headshaking was observed in the postoperative period. The horse was discharged from the hospital six days postoperatively. Treatment with phenylbutazone was continued by the owner for a total of five days. Two weeks box rest with daily hand grazing, followed by four weeks of turnout before reintroduction of lunging and gradual return to ridden work was recommended.

3.3 | Follow-up

The horse returned nine months after surgery for a follow-up examination. The owner reported a significant improvement after surgery. The head shaking had completely resolved; the horse no longer fell over when exercised and trimming of the feet could be performed without any problems. The general behavior of the horse was back to what it had been before the headshaking started. However, some degree of imbalance appeared to persist according to the owner. On examination, the previously observed reaction to palpation over the right PCP could no longer be elicited. When lunged, there was an intermittent and mild horizontal movement of the head on both reins. Repeat neurological examination was unremarkable. Computed tomographic examination of the head and cranial cervical spine under standing sedation was repeated and showed minimal remodeling at the surgical site (Figure 1C, D). Radiographic examination of the cervical and thoracolumbar spine was performed and identified mild to moderate enlargement of the articular process joints of C5/6 and C6/7. Ultrasonographic examination of the cervical spine revealed periarticular remodeling of the left and right C6/7 process joints with mild joint distension. The left and right articular process joints of C5/6 and C6/7 were medicated aseptically under ultrasonographic guidance with 20 mg methylprednisolone acetate per site. The horse was discharged with the recommendation to resume work after two weeks of turnout. Follow-up information obtained two and a half years after surgery via telephone interview with the owner revealed that the horse had been turned out in the field for 12 months at the owner's discretion. When the horse was brought back into light work, no headshaking signs or other issues were noted.

4 | DISCUSSION

In this case report, a fractured PCP resulting in severe clinical signs of headshaking was treated by surgical removal of the fracture fragment with an excellent outcome. The inflammation and associated swelling following bone fractures are speculated to irritate surrounding structures, including nerves, which may have resulted in the clinical signs of headshaking. The nerves most likely affected, given the close anatomical proximity are branches of the facial (cranial nerve VII), glossopharyngeal (cranial nerve IX), vagus (cranial nerve X), accessory (cranial nerve XI), or hypoglossal nerve (cranial nerve XII). Facial nerve paralysis as a result of PCP fracture has been previously reported.[3,4] In this case, no distinct signs of nerve damage were appreciated. The main clinical complaint was headshaking (vertical and rotational movements of the head), which has been observed in other horses with this condition[4,5] and could be elicited by gentle digital pressure on the fractured process. Other causes of excessive head movements, including trigeminal-mediated head shaking[7] or dental disease[8] do not usually result in clinical signs as severe as those described by the owner of this case. They included falling over during exercise, turnout, or foot trimming due to the severity of the rotational movements of the head. Lischer et al.[4] also described one horse with PCP fracture that became unsafe to ride due to the severity of the clinical signs. The reason why these horses can show such an extreme form of headshaking remains speculative. Given that multiple muscles attach to the PCP and have a role in feed processing, airway function, and head posture, it seems logical that contractions of these muscles may result in local tissue irritation and pain in the presence of a fracture. The continuous motion complicates fracture healing, resulting in nonunion or pseudarthrosis. In this case, the periosteum was found to be intact during surgery. Human periosteum has been shown to contain nerves exhibiting substance P-like immunoreactivity, mediating the sensation of pain.[9] If the periosteum is intact, the edges of a fracture fragment will result in pain sensation. Similar to other (e.g., third metatarsal/metacarpal condylar) fractures, pain might be severe as long as the fracture is not or only mildly displaced and the periosteum remains intact, but comfort might improve once the fracture completely displaces and the periosteum is disrupted. This may explain the differences in severity of clinical signs observed in horses with fracture of the PCP. Why clinical signs were less obvious when the horse was eating remains unclear, as contractions of the digastric and occipitohyoideus muscles during mastication are expected to place force on their insertions onto the PCP.

Given the reported good outcomes with removal of the fracture fragment alone, internal fixation of the PCP seems to be unnecessary but could be considered if acute fractures with large fracture fragments occur.

It appears that fractures of the PCP are difficult to accurately diagnose on standard radiographs.[4,5] In our facility, horses presenting for headshaking usually undergo CT examination of the head and cranial cervical spine, which readily identified the fracture as reported before.[4,5] When using radiography during and after surgery, it became evident that obtaining diagnostically conclusive radiographs of the PCP is challenging. In a description of the ultrasonographic examination of the upper cervical region, Rathmanner and Rijkenhuizen were able to evaluate all ($n = 30$) PCPs without difficulties.[6] We performed ultrasonography after the CT examination; therefore, we had prior knowledge of the presence of the fracture and were able to readily identify it.

Resolution or improvement of clinical signs with conservative management alone is reported.[4,5] In our case, the clinical signs progressed despite reduced exercise to an extent that there was a severe risk to the safety of the horse and handlers. Therefore, the owner elected for immediate surgical intervention. The hyovertebrotomy approach[10] describing surgical access to the guttural pouch was modified to facilitate access to the PCP. The main modifications were the orientation of the incision with the mandible rather than the wing of the atlas, and a smaller, more dorsally centered incision. Based on intraoperative ultrasonography and palpation, the PCP appeared almost parallel to the caudal border of the mandibular ramus[6] but in an acute angle to the wing of the atlas, making orientation on the less positioning-dependent mandible more appropriate. Ultrasonographic assessment was essential to guide the incision precisely in line with the PCP and screen for adjacent blood vessels using color doppler. Careful dissection is crucial to avoid damage to adjacent structures such as the parotid gland or the caudal meningeal artery and vein which run along the caudal margin of the PCP (Figures 6 and 7). The previously mentioned cranial nerves in close proximity to the surgical site are all located deep (axial) to the PCP. These must be taken in consideration when a fragment is manipulated and freed from its attachments as described in this report.

The authors elected to perform the procedure under general anesthesia due to the possible risk of diffusion of local anesthetic solutions to adjacent cranial nerves (i.e., vestibulocochlear nerve) and the serious consequences that might result from inadvertent movement of the horse during manipulations.

The owner reported an immediate improvement in the horse's demeanor after surgery, although mild signs persisted. On re-examination, hypersensitivity upon palpation of the right PCP was no longer appreciated but mild and rapid horizontal head movements could be observed occasionally. Cervical articular process joints of radiographically enlarged size were medicated nine months postoperatively to address reported intermittent mild imbalance, although neurological examination remained unremarkable. According to the owner, the signs had completely resolved one year after surgery. It remains speculative, whether the articular process joint medication or time alone resulted in resolution. At the time of follow-up interview two and a half years after surgery, no recurrence of clinical signs was noted, and the mare was back in light work.

The mandibular swelling on the contralateral side to the fracture noted postoperatively was not investigated further as the horse's ability to eat was not impaired. A myositis of the masseter muscle was suspected, presumably due to increased pressure on the head during the procedure. Appropriate positioning and padding as well as using caution when manipulating the head during surgery may have prevented this complication. Whether the swelling was reason for prolonged antimicrobial administration (5 days total) could not be established retrospectively. Due to the prolonged anesthesia time and risk of inadvertent penetration of the guttural pouch, perioperative administration of antimicrobials was considered appropriate; however, the extent appears excessive.

There are parallels between this case and a previously reported case (Lischer et al., case 2)[4] in terms of sensitivity to palpation of the affected area, severity of clinical signs, and improvement after surgical removal of a PCP fragment. Lischer et al. emphasized imaging findings and advantages of CT, limiting the surgical information to referencing the hyovertebrotomy approach for access of the guttural pouch. We focused on a detailed description of a surgical approach specifically to access the PCP to provide a reference for colleagues embarking on operations of this structure.

A limitation of this case report is its single-case character, and consequently the absence of a conservative treatment control. No treatment with nonsteroidal anti-inflammatory drugs alone was attempted before surgery. Although resolution of clinical signs without surgery may have been successful, the immediate, permanent, and significant improvement of severe clinical signs following surgery supports the notion the procedure itself was effective.

In conclusion, the modified hyovertebrotomy approach described here allows safe surgical access to the PCP. The caudal meningeal artery and vein as well as the glossopharyngeus and hypoglossal nerves are adjacent to the PCP and must be avoided during dissections. Surgical extraction of a PCP fragment was effective in resolving clinical signs of severe headshaking and did not result in any functional deficits. Computed tomography and ultrasonography are valuable diagnostic tools to identify a PCP fracture. Ultrasonography can be used to guide the surgical approach.

AUTHOR CONTRIBUTIONS

Spiesshofer P, DVM: Conception of the study, study design, collected the data, data interpretation, primarily drafted and revised the work. Hawkins AE, BSc, BVSc, MVetMed: Study design, data acquisition, and draft revision, performed surgical procedure. Berner, D, Dr med vet, DECVDI: Study design, data acquisition, and draft revision. Previdelli RL, MIMV, MScVetEd, PhD, MRSB, FHEA: Study design, data acquisition, and draft revision. Fiske-Jackson AR, BVSc, MVetMed, FHEA, DECVS (Large Animal): Study design, data acquisition, and draft revision, performed surgical procedure.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest with respect to the research, authorship, or publication of this article.

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SUPPORTING INFORMATION

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

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