

T-LCP Fixation of a cranial mid-body fracture of the axis in an adult horse

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Abstract

Cranial mid-body fractures of the axis in horses result from hyperflexion of the neck and are most commonly associated with lateral bending falls over showjumping or steeple chase fences. In the authors' experience, conservative treatment of mild to moderately displaced cranial mid-body axis fractures has been unsuccessful. This case report describes surgical management of a cranial mid-body fracture of the axis in an eight-year-old warmblood gelding that sustained the injury during a showjumping course. Following reduction, a five hole 4.5mm equine compression T-plate was contoured to fit the ventral aspect of the axis and used as an internal fixator. The horse was turned out starting 2 months after surgery and training was gradually resumed. No lameness, ataxia or decrease in cervical range motion were reported after surgery. Check-up radiographs at 5 months post-op showed complete healing of the fracture. T-LCP fixation is a promising treatment option for cranial mid-body fractures of the axis with a good prognosis for athletic function.

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Summary

Cranial mid-body fractures of the axis in horses result from hyperflexion of the neck and are most commonly associated with lateral bending falls over show jumping or steeple chase fences. In the authors' experience, conservative treatment of mild to moderately displaced cranial mid-body axis fractures has been unsuccessful. This case report describes surgical management of a cranial mid-body fracture of the axis in an eight-year-old warmblood gelding that sustained the injury during a show jumping course. Following reduction, a five hole 4.5mm equine compression T-plate was contoured to fit the ventral aspect of the axis and used as an internal fixator. The horse was turned out starting two months after surgery and training was gradually resumed. No lameness, ataxia or decrease in cervical range motion were reported after surgery. Check-up radiographs at five months post-op showed complete healing of the fracture. T-Locking Compression Plate (T-LCP) fixation is a promising treatment option for cranial mid-body fractures of the axis with a good prognosis for athletic function.

Keywords: Horse, Axis, Fracture, Internal Fixation, T-Plate

Introduction

Cranial mid-body fractures of the axis in horses result from hyperflexion of the neck and are associated with lateral bending falls or impact into fixed objects (Nixon 2020). These fractures propagate transversely through the body of the axis, at the level of the cranial physis, and enter the vertebral canal near the cranial vertebral foramen. Dorsal displacement of the body of the axis in relation to the cranial fracture fragment and mild lateromedial displacement are common (Nixon 2020). The literature on management of

equine cranial mid-body axis fractures is scarce. One case series reports successful conservative treatment in four of five horses diagnosed with odontoid process fractures (Vos *et al.* 2008). The four horses that returned to athletic activity presented with a cranial mid-body fracture of the axis, referred to in the case series as a Type II odontoid fracture (Anderson and D'Alonzo 1974), whereas the fifth horse, euthanized several hours after admission, due to severe and deteriorating neurological symptoms, was diagnosed with an avulsion fracture of the odontoid process' also referred to as a Type I odontoid fracture (Anderson and D'Alonzo 1974, Vos *et al.* 2008). All horses but one showed swelling at the level of the axis, signs of neck pain and neurological compromise upon presentation (Vos *et al.* 2008). In the authors experience, conservative treatment of mild to moderately displaced cranial mid-body axis fractures has been unsuccessful. Out of three cases, one case was clinically sound but was retired eight months after initial presentation because of persisting severe neck stiffness, one case was euthanized three and a half months after injury because of acute neurological deterioration, and another became tetraplegic four days after fracture diagnosis and was euthanized. Following this personal experience, the authors recommended surgical treatment for an 8-year-old warmblood gelding admitted to the hospital with a cranial mid-body axis fracture. The authors report successful reduction and stabilization of the fracture using a 4.5mm locking compression T-plate.

History

An eight-year-old 550kg warmblood gelding was referred for surgical management of an axis fracture sustained during a 1.30m show-jumping course. The horse fell over a fence and landed on the ground with a hyperflexed neck. The owner reported that the horse shows signs of ataxia immediately after getting up. The animal was transported to the nearest equine hospital for further examination. At admission, the horse was depressed. Swelling, although more pronounced on the right side, was apparent on both sides of the neck, at the level of the first cervical vertebrae (C1-C3). Palpation of that region was painful. The horse held its head and neck in an extended position and was reluctant to turn to the left. When walked in a circle to the right, the horse showed uncoordinated movement of the hindlimbs. The observed ataxia was assigned a grade 3 (Mayhew system – Mayhew 1978). Further neurological tests were not performed. Following the clinical examination, latero-lateral radiographs of the cervical spine were obtained. A cranial mid-body axis fracture, propagating transversely through the body of the axis, at the level of the cranial physis, and entering the vertebral canal near the cranial vertebral foramen, was diagnosed. Mild ventral displacement of the cranial fracture fragment (odontoid process) was observed. A dorsoventral radiograph of the axis was obtained to evaluate latero-lateral displacement of the fracture. No obvious displacement was recorded in the latero-lateral plane (**Figure 1**). Standing CT was considered for further diagnostics but was finally not performed as it was not available on site. The patient received anti-inflammatory medication (dexamethasone IV 0.1mg/kg and flunixin meglumine IV 1.1mg/kg) and was placed in a sling. Considering the authors' disappointing results with conservative management, internal fixation was recommended. The horse remained in the sling for eight days before being transported to a referral hospital for surgical management. In the meantime, the anti-inflammatory medication was continued (flunixin meglumine IV 1.1mg/kg BID). Hay was fed loosely at shoulder height. The horse's comfort improved significantly within the first two days. Neck stiffness remained but the horse did not show any signs of pain in the box. The patient was stabled in a sling and continued receiving anti-inflammatory medication (flunixin meglumine IV 1.1mg/kg BID) at the referral hospital before undergoing surgery.

Surgery

Procaine Penicillin (22 000 IU/kg IM), gentamicin sulfate (6.6 mg/kg IV) and flunixin meglumine (1.1mg/kg IV) were administered preoperatively. The horse was sedated with detomidine hydrochloride (0.1mg/kg IV) and morphine (0.1mg/kg IV). General anaesthesia was induced with diazepam (0.02mg/kg IV) associated with ketamine (2.2 mg/kg) and maintained with isoflurane. The horse was positioned in dorsal recumbency with the head and neck extended. A custom-made wedge was placed at the level of C3-C4 to stabilize the neck in a strict sagittal position with good alignment of the cranial cervical vertebrae. The head was fixed to a separate small table that could be adjusted independently from the surgery table to create additional extension at the level of the atlantoaxial joint (**Figure 2**). This enabled to improve the alignment of the two

main fragments and reduce the fracture. Radiography was used to determine the amount of head extension needed.

After routine aseptic preparation and appropriate draping, a 20cm-skin incision was made, centred over the axis. The cutaneous colli muscle was bluntly dissected, and the sternohyoid and sternothyroid muscles were separated at the midline to expose the trachea. Dissection was then continued dorsally along the right side of the trachea until the longus colli muscles were reached. The trachea was retracted towards the left and two self-retaining retractors were placed to gain access to the ventral aspect of the axis: A Ricard-Begoin retractor was placed at the cranial end of the wound and a modified Beckman retractor at the caudal end. The atlantoaxial and C2C3 joints were localized using radiography. The aponeurosis of the longus colli muscles was incised from the cranial to the caudal border of C2. Mayo scissors and a periosteal elevator were used to divide the longus colli muscles. An Inge retractor was placed in between the separated longus colli muscles to expose the ventral surface of C2. The fracture line through the cranial mid-body of the axis was palpated and visualized. Palpation and radiography confirmed correct alignment of the axis and fracture reduction. The ventral spinous process of the axis body was slightly flattened using a curved osteoma. A 4.5mm five-hole T-LCP plate was contoured to fit the ventral aspect of the axis. The first standard combi-hole was used as a landmark for plate positioning and placed just caudal to the fracture line. The plate was fixed to the cranial fragment using three locking head screws in the stacked combi-holes. The screw lengths had been determined preoperatively but even so, radiographs were taken strategically during the procedure to make sure that the spinal canal was not entered during drilling or screw placement. The caudal fragment was grasped with bone forceps while a fourth locking head screw was placed through the second standard combi-hole. The third, fourth and fifth standard combi-holes were also filled with locking head screws. Finally, a 4.5mm cortical screw was placed through the first standard combi-hole, instead of a locking head screw, to avoid crossing the fracture line (**Figure 3**). The wound was flushed abundantly with sterile saline solution. The longus colli muscles and cutaneous colli muscles were apposed with a simple continuous 2-0 polyglactin 910 suture. The skin was closed with interrupted horizontal mattress 0 polydioxanone sutures and staples. The wound was protected with a stent bandage and an antimicrobial adhesive drape. Recovery was assisted with a single tail rope system and was uneventful. A head and neck bandage was placed over the stent and the horse was put back in the sling after recovery.

Postoperative care

The stent was removed two days postoperatively and the bandage changed every forty-eight hours. Antimicrobial therapy was continued for five days and anti-inflammatories for another fourteen days at decreasing dosage. The horse also received omeprazole (2mg/kg once daily) and probiotics during hospitalization. After three days, the horse was walked outside of the box for the first time since surgery. Postoperative radiographs showed satisfying reduction of the fracture and implants in situ (**Figure 4**). As the patient did not show any signs of ataxia, the sling was removed. Food and water were placed at chest level for another two weeks. The horse continued showing mild signs of neck stiffness after surgery. A mild seroma developed at the incision site but resolved spontaneously within two weeks. The horse was discharged after suture and staple removal three weeks after surgery. The owner was instructed to keep the horse on box rest for an additional four weeks and begin hand walking at approximately two months post-surgery.

Clinical outcome and Follow-up

As the horse was getting very restless in the box and when walked by hand, it started to be turned out in a small grass paddock (15x15m) at two months post-surgery. The horse did not show any signs of lameness or ataxia and the cervical range of motion did not appear to be decreased. The horse was turned out several hours per day for one more month and then started additionally being worked on long-reins in walk and trot for another two months. The owner reported mild stiffness on the right lead that improved gradually with exercise. Check-up radiographs taken five months after surgery showed complete healing of the fracture(**Figure 5**). The horse resumed canter work after the five-month check-up. As the owners gradually increased the canter work, they noticed a respiratory noise at exercise. The horse was diagnosed with a right-sided laryngeal hemiplegia grade 3. The horse was turned out every day in a grass field with another horse

and continued light exercise until upper airway surgery was performed seven months following axis fracture repair. A bilateral transendoscopic laser ventriculocordectomy and a right-sided laryngeal reinnervation using the spinal accessory nerve were performed. Following the mandatory six-week rehabilitation time after upper airway surgery, training was resumed. At ten months post-surgery, the horse is back to normal flatwork and gradually increasing the level of the jumping training.

Discussion

Cranial mid-body axis fractures associated with a disruption of the vertebral canal can be fatal injuries. Due to the relatively confined nature of the vertebral canal through the axis, mild displacement is sufficient to result in spinal cord damage and neurological deficits (Nixon 2020). Although plain radiography remains the most appropriate screening examination for acute injuries of the cervical spine, CT enables more accurate evaluation of fracture displacement and spinal cord impingement (El-Khoury *et al.* 1995). Standing CT examination should therefore be considered if the procedure can be carried out safely despite the patient's likely neurological symptoms.

In human medicine, fractures of the axis involving the odontoid process have been classified by Anderson and D'Alonzo in three categories (Anderson and D'Alonzo 1974). Type I fractures involve the proximal tip of the odontoid process. Type II fractures occur at the junction of the dens and the C2 vertebral body. Type III fractures extend into the vertebral body (Niemeier *et al.* 2018).

Treatment of odontoid fractures aims to re-establish anatomical alignment and provide adequate stabilization of the fracture to enable bone healing. Both surgical and conservative management are common in human medicine (Shears and Armitstead 2008). Surgical management of odontoid fractures includes posterior C1-C2 fusion techniques and anterior screw fixation of the odontoid process itself (Shears and Armitstead 2008). Conservative approaches include the application of a cervical collar (with or without prior traction) and the use of an external fixation device (Halo device) (Shears and Armitstead 2008). Conservative management is only advised for non- or minimally displaced odontoid fractures (displacement inferior to 4mm). Axis fractures with a displacement superior to 6mm have a very high non-union rate when treated conservatively (86%). Consequently, internal fixation is always preferred over conservative management for cases with obvious displacement (Greene *et al.* 1997). Overall, results from meta-analysis studies have shown that internal fixation results in a higher fusion rate compared to external immobilization (Nourbakhsh *et al.* 2009).

In equine, splinting techniques have been described to manage fractures of the cranial articulation of the axis, not involving the odontoid process, in foals (Nixon 2020). For all other axis fracture types, especially in adult horses, external copation does not achieve fracture stabilization (Nixon 2020). Although successful conservative treatment of displaced cranial mid-body axis fractures has been reported, conservative management carries a substantial risk of non-union and remains therefore controversial (Florman *et al.* 2022). Fracture displacement, insufficient stabilization and comminution are amongst the main predisposing factors for non-union (Buckley and Richard 2018). One differentiates between stable and unstable non-unions. Stable non-unions, also referred to as fibrous non-unions, are characterized by the formation of fibrotic tissue that might offer protection from threatening motion (Florman *et al.* 2022). Stable non united fractures are well aligned and immobile on dynamic imaging studies (Florman *et al.* 2022). One must keep in mind, that callus formation is not always a sign of successful bone healing. Radiography can show excess bone at the fracture site but if there is no bridging callus at the bone ends, this is referred to as a hypertrophic nonunion (Buckley and Richard 2018). Non-union fractures with marked malalignment and dynamic instability clearly pose a substantial risk of neurologic catastrophe. Even when non-unions appear to be stable, they still carry the risk of delayed myelopathy caused by an excessive callus formation or a loss of stability (Pommier *et al.* 2020).

An ideal treatment for odontoid fracture in horses should achieve reduction and stable fixation of the fracture to enable bone healing (Vos *et al.* 2008). Surgical repair of odontoid process fractures has been described in foals using compression plating (McCoy *et al.* 1984) and Steinmann pin fixation (Owen and Smith-Maxie

1978). To the best of the authors' knowledge, no successful surgical treatment for cranial mid-body axis fractures in mature horses has previously been reported. Internal fixation has been performed in this case using a 4.5mm equine locking compression T-plate. This implant, recently developed by DePuy Synthes in cooperation with the Large Animal Veterinary expert group of the AOVET foundation, was initially designed for physeal fractures of the proximal tibia in foals (Lischer *et al.* 2018) and has been successfully used for the internal fixation of tarsometatarsal subluxations, tarsometatarsal and distal intertarsal joint arthrodesis, partial carpal arthrodesis and luxation of the atlantoaxial joint (Curtiss *et al.* 2018; Keller *et al.* 2015; Lambert *et al.* 2023; Schulze *et al.* 2019). The equine T-Plate, which incorporates locking technology, is intended to enhance fixation in short fracture segments (Lischer *et al.* 2018). The three stacked combi holes that are arranged in the head of the plate allow insertion of locking head screws with a length of up to 50mm without interference of the screw tips (Schulze *et al.* 2019). This feature of the plate enabled, in this case, to increase bone purchase in the cranial fragment of the axis.

Creating adequate stability is the main concern when performing internal fixation as it is the limiting factor to achieve the ultimate goal of fracture repair: Early and safe mobilization of the injured area and patient as a whole (Mukhopadhyaya and Jain 2019). The 4.5mm T-LCP was used in this case as a bridging “internal fixator”. The authors decided to use almost exclusively locking head screws to privilege construct stability over compression. Locking screws enable angular as well as axial stability, eliminating the possibility for the screw to toggle, slide or dislodge and thereby strongly reducing the risk of postoperative loss of reduction (Wagner 2003). Locking head screws also have better resistance against bending and torsion forces in cancellous and osteoporotic bone compared to cortical screws (Wagner 2003). The second cervical vertebra contains a high amount of cancellous bone (Barone 2009), which supports the use of locking head screws. Since the stability of a locking construct does not rely on compression between the plate and the bone, precise anatomical contouring of the plate is not necessary (Nixon 2020). However, the further the plate is from the surface of the bone, the greater the bending moment on the locked screws, increasing the chance of screw failure and instability (Ahmad *et al.* 2007). Contouring the plate adds an additional advantage in terms of construct stability: it results in divergent and convergent screw directions enhancing the pullout strength of the screws compared to a construct in which all screws have an identical direction (Gautier and Sommer 2003). Furthermore, using an LCP as an “internal fixator” eliminates the risk of a loss of primary reduction: When locking head screws are tightened, they “lock” to the threaded screw hole, stabilizing the fragments without pulling the bone to the plate. Unlike other screws, locking screws make it impossible for screw insertion to alter achieved reduction (Nixon 2020).

Conclusion

Internal fixation using a 4.5 mm T-LCP resulted in successful stabilization and healing of a cranial mid-body axis fracture in an eight-year-old warmblood. The described surgical management enabled the patient to make a prompt and full recovery. Although this technique warrants validation in a larger cohort of horses, it is a promising treatment option with a good prognosis for athletic function.

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