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Surgical Neurology International

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SNI: Trauma

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Case Report

Traumatic penetrating head injury by crossbow projectiles: A case report and literature review

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Received: 09 July 2023
Accepted: 16 December 2023
Published: 09 February 2024

DOI
10.25259/SNI_574_2023

Quick Response Code:

ABSTRACT

Background: Low-energy penetrating head injuries caused by arrows are relatively uncommon. The objective of this report is to describe a case presentation and management of self-inflicted intracranial injury using a crossbow and to provide a relevant literature review.

Case Report: A 31-year-old man with a previous psychiatric history sustained a self-inflicted injury using a crossbow that he bought from a department store. The patient arrived neurologically intact at the hospital, fully awake and oriented. He was not able to verbalize due to immobilization of the jaw as well as fixation of his tongue to his hard palate secondary to the position of the arrow. The trajectory of the object showed an entry point at the floor of the oral cavity and an exit through the calvarium just off the midline. The oral and nasal cavity, along with the palate and, the skull base of the anterior cranial fossa, and the left frontal lobe, were all breached. No vascular injury was identified clinically or in imaging. The arrow was surgically removed in the operating room after establishing an elective surgical airway. The floor of the mouth, tongue, and palate was repaired next. A planned delayed cerebrospinal fluid leak repair was performed. The patient made a substantial recovery and was discharged home in good functional status. A systematic literature search was done using Medline for cases with intracranial injuries related to crossbows to review and appraise the available literature.

Conclusion: A thorough assessment in a multidisciplinary trauma center and the availability of a subspecialty care team, including neurosurgery and otolaryngology, are paramount in such cases. The vascular imaging should be done before and after any planned surgical intervention. Emergent and elective surgical airway management should be considered and made available throughout the stabilization and care of the acute injury. Surgical management should be planned to remove the object with adequate exposure to facilitate visualization, removal, and the possible need for further intervention, including anticipating aerodigestive and vascular injuries on removal. Finally, access to weapons and the relation to psychiatric illness should not be overlooked, as many reported cases are self-harming in nature.

Keywords: Crossbow, Neurotrauma, Penetrating head injury, Projectile, Traumatic brain injury

INTRODUCTION

Traumatic intracranial injury caused by penetrating foreign objects is a rare entity, representing 0.4% of all head injuries.[3] Most penetrating head injuries are caused by high-velocity firearms such as handguns and hunting rifles. Although considered rare, penetrating injuries caused by low-velocity weapons are considered rare. However, recent reports indicate a possible increase in the incidence of this mechanism of injury.[3] A unique pattern of low-velocity injuries is one caused by crossbow arrows penetrating the head, which has been described in several accidental[13] and non-accidental cases.[16]

Historically, a crossbow was a notable weapon used in the Middle Ages for hunting, self-defense, and in times of war. In modern times, its use is mainly related to recreational and hunting activities. This weapon can be defined as a bow that is attached to a trigger device to release the string, with or without a mechanism to tense the bow.[6] As opposed to conventional bows, crossbows provide a longer range a higher penetrative power, and they are easier to operate.[19] In addition, they are relatively easy to obtain compared to other high-velocity weapons due to fewer legal restrictions.[19] Penetrating crossbow injuries are typically of lower energy and, therefore, often associated with better functional status at presentation.[1,22] Removal of the foreign body to preserve function is, therefore, often a greater consideration than with more devastating high-speed projectiles. Surgical removal requires meticulous preoperative and intraoperative planning and coordination with a multidisciplinary team, with appropriate imaging to guide the choice and sequence of procedures.

In this report, we present a systematic review of the literature as well as a case of crossbow-inflicted intracranial injury secondary to a suicide attempt with a special focus on the importance of multidisciplinary teamwork and vascular imaging.

MATERIALS AND METHODS

This study was performed in accordance with ethics and regulations adopted by the Declaration of Helsinki, ethics standards, and the University of McMaster and Hamilton Health Sciences, with no formal ethics board approval required.

The study entails a narrative analysis and a detailed description of the clinical presentation, management, and decision-making processes of a self-inflicted head injury using a crossbow. This is supplemented with a comprehensive literature review of previously reported cases. The search was done in Medline using the keywords Crossbow, arrows, head, injury, penetrating, trauma, and brain. We included English literature that provided an adequate description of a crossbow or classical arrow-related injury that extends into the intracranial compartment, regardless of the trajectory. No specification of date of publication, age group, treatment modality, or outcome was used to filter the search results. We excluded cases of arrow-related head injury where intracranial penetration was not confirmed.

Variables and data selection

Selected papers were screened for the number of patients, type of weapon, entry point, the final position of the tip, vital structures injured, timing and modality of vascular imaging, clinical outcome, and need and mechanism of surgical removal.

Data management

Three independent reviewers performed the online search separately using the keywords mentioned above and search engines. Screening was performed by evaluating the study title and abstract with full-text review as needed. The conflict was resolved by consensus. Duplicates were eliminated, and the reference lists of selected papers were screened for additional related evidence. Three independent reviewers performed data extraction. Data was then pooled and collected into a data collection table that reflects the collective work of the group.

CASE REPORT

A 31-year-old man with a history of depression and recent discharge from an inpatient psychiatry service purchased a crossbow at a sporting goods store and subsequently attempted suicide by firing the weapon superiorly through the central submental region. The crossbow projectile entered just at the left side of his chin, coursing superiorly through his floor of mouth, tongue, palate, anterior sphenoid sinus, and subsequently intracranially through the frontal lobe, exiting through the calvarium. This resulted in a compound skull fracture with the tip of the arrow projecting out through the scalp. Paramedics brought him in, and the trauma service was notified urgently. The patient had a Glasgow Coma Scale of 15 on arrival; he was awake, alert, and obeying commands in all four extremities with no obvious neurological deficits on assessment. However, he was not able to speak, given the crossbow arrow traversing his tongue and palate structures. A computed tomography (CT) scan/CT angiogram was obtained, which revealed that there were no major intracranial hemorrhages and no intracranial or extracranial vascular injuries from the penetrating object [Figures 1-3]. The patient was taken to the operating room for removal of the foreign body with otolaryngology/head and neck surgery, initially planning for an awake tracheostomy and repair of aerodigestive injuries. Conscious sedation and local anesthesia were initially administered, and an awake tracheostomy was then performed. Once airway access was secured, the patient was induced under general anesthesia and placed in the Mayfield head holder in a supine position with the neck neutral.

A coronal skin incision (involving the crossbow exit site) was made to expose the compound skull fracture. A bifrontal

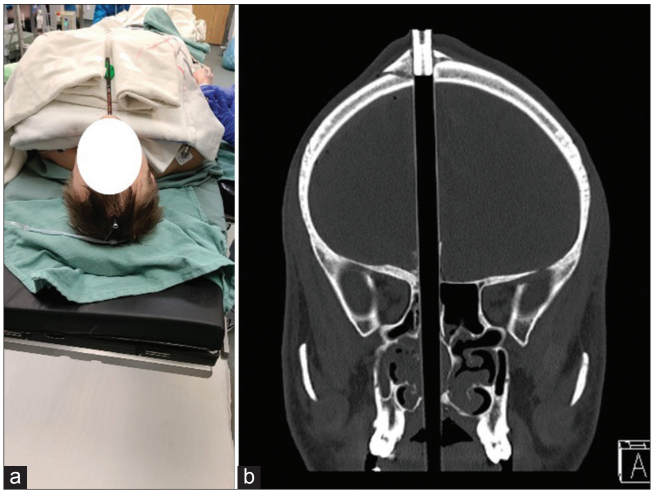

Figure 1: Penetrating head injury. Suicidal attempt in a 31 Y male. (a) A gross photograph of the patient showing the arrow as it enters through the floor of the oral cavity and exits through the calvarium on the right side. (b) A computed tomography scan (bone window) shows the bony defect in the skull base and the frontal bone fracture at the site of exit.

craniotomy was performed to devise a flap between the fractured bone segments and the projectile exit site. The bone was removed in a piecemeal fashion to liberate the arrow from the frontal bone and to have vascular control of the superior sagittal sinus in the event of injury. Once the dura was exposed from sites surrounding the arrow shaft, a careful dural incision was extended to allow for access around the defect. Coagulation around the arrow shaft was avoided to prevent energy transmission to surrounding neural structures. The sharp arrow tip was previously removed before surgery by the emergency medical service team, as it screwed onto the shaft. Following the dural opening, inspection around the shaft of the arrow demonstrated no active hemorrhage and no tissue entanglement. Following this assessment, the arrow was pulled out gently from the entry site (floor of the oral cavity), as the fins on the tail of the arrow were not removable.

Furthermore, this vector avoided the entrainment of oral/nasal contaminants further into the intracranial space. Vital signs were closely monitored as well as evaluation of entry and exit sites to detect any new hemorrhage, change in vitals, or tissue resistance. The object was completely removed with no ensuing adverse events. The dura was reinforced using a synthetic dural replacement material. The bone fragments were examined, debrided, and realigned with plates, bur hole covers, and screws and then placed back to close the defect. There was no cerebrospinal fluid leak (CSF) or rhinorrhea evident at this time; however, the patient was monitored continually for future CSF leaks. Within the same surgery, the otolaryngology team repaired the floor of the mount, tongue, and palate, taking advantage of a distally located surgical airway. Postoperative CT angiogram of the head demonstrated no evidence of vascular injury. The patient spent an uneventful 24 h course in the intensive care unit and was extubated the next morning after ensuring an adequate airway.

Repair of skull-base defect

During the same admission, the patient developed clear, watery rhinorrhea and was taken to the operating room to repair a skull base defect through an endoscopic endonasal approach. The skull base team consisting of otolaryngology/rhinology and neurosurgery located the defect in the roof of the right ethmoid cavity. After performing a right-sided anterior and posterior ethmoidectomy and sphenoidotomy, the team then identified the site of the leak using direct visualization and confirmed with the image guidance system. The edges of the CSF fistula were freshened by removing mucosa from the defect circumferentially and then utilizing an infraumbilical fat graft and ipsilateral nasoseptal flap based on the sphenopalatine artery for closure and sealing of the CSF leak. Intraoperative confirmation of watertight seal with a valsalva maneuver was conducted at the end of the procedure.

Results of the literature review

A total of 24 cases of penetrating head injuries with crossbows have been identified in the literature [Table1].[1-4, 6-15, 18-22] The vast majority (20/22) were male, and most of the cases were suicidal (17/24). In addition, 15 cases survived the injury. Two of them made a full recovery with no disabilities. Involvement of the face and/or oronasal cavity is common (18/24). Six cases required surgical airway secondary to upper airway involvement. Significant intracranial vascular injuries were seen in 7/24 cases. Dedicated vascular imaging was done in 9 cases where data were available. In addition, a CSF leak was noted in 6/24 cases secondary to the injury. Finally, surgical removal of the arrow was done in 11 cases with available data on who made it alive to the hospital.

DISCUSSION

Low-energy penetrating head injuries caused by arrows are relatively uncommon in trauma/neurosurgical practice. The paucity of data available in the current literature reflects two important aspects of the topic. First, the data are scarce, and no clear consensus on a treatment protocol has been established. Second, the reports are spaced over a protracted period so that differences in technology, treatment approaches, and decision-making process are evident.

Relation to psychiatric illness

Forensic studies have demonstrated that lethal crossbow injuries are now rarely encountered. A literature review has

Table 1: Summary of studies describing penetrating head injuries with Crossbow.

Study	No. of cases	Age (Sex)	Etiology	Mortality	Projectile entry	Projectile tip position	Important structures injured	Surgical airway	Vascular injury	Timing and modality of vascular imaging		Complication	Surgical treatment
										Preoperative	Postoperative		
Kulwin *et al.*, 2018[15]	2	–*	Suicide	No	Optic foramen	Intracranial, with in the occipital bone	Mesial temporal lobe injuries	None	Transverse sinus occlusion by arrow	CTA	CTA	No major vascular injury	None
		–	Suicide	No	Submental area	Intracranial, lateral to the inion bone	Oropharynx, cerebellar peduncle, falx, occipital lobe, vertebral artery stenosis	Yes	Significant compression of vertebral artery	CTA	CTA	-	Manual removal (outside the operating room)
Panata *et al.*, 2017[19]	1	40 (M)	Suicide	Yes	Suprahyoid area	Extracranial, through left parietal bone	Tongue, middle fossa, left temporal lobe	-	-	-	-	CSF leak (Extensive subdural and subarachnoid bleeding)	-
Aljuboori *et al.*, 2022[1]	3	36 (M)	Suicide	No	Left mandible	Extracranial, lateral to the SSS	Left anterior lobe.	No	None	CTA/CTV+DSA	DSA	CSF leak, subarachnoid hemorrhage	Arrow removal and endoscopic CSF repair
		22 (M)	Suicide	No	The floor of the oral cavity	Extracranial, through cranial vault and forehead	Anterior skull base	No	None	DSA	-	CSF leak, subarachnoid hemorrhage	Arrow removal and endoscopic CSF repair
		67 (M)	Suicide	No	The floor of the oral cavity	Extracranial, through cranial vault near the vertex on the right side	Anterior skull base	No	Right ACA occlusion, filling defect of SSS	CTA	DSA	CSF leak, intraparenchymal hemorrhage, subdural hemorrhage, IVH, sphenoidal fracture	Craniotomy around the arrow, endoscopic CSF leak repair (POD3)
Zyck *et al.*, 2016[22]	1	12 (M)	Suicide	No	Upper lip at the midline	Extracranial, through left parietal calvarium	Maxilla, left sphenoid, left pons, temporal bone, left parieto-occipital region, left CN3 compression	none	Cavernous sinus, cavernous ICA stenosis, left PCA pseudo-aneurysm.	CTA	DSA+CTA	intraparenchymal hemorrhage, IVH, high postoperative ICP	Required through two simultaneous craniotomies (parieto-occipital and pterional)
Byard *et al.*, 1999[2]	2	18 (M)	Suicide	Yes	Behind the right orbit	Intracranial, left parietal lobe immediately above the the Sylvian fissure	Diencephalon, left thalamus, right middle cranial fossa, left cerebral hemisphere.	-	-	-	-	Extensive subarachnoid hemorrhage	-
		27 (M)	Suicide	Yes	The midportion of the tongue	Intracranial, posterior portion of the corpus callosum	Posterior palate, basilar portion of the occipital bone, optic chiasm, left basal ganglia, left cerebral hemisphere, clinoid process of the sella turcica	-	-	-	-	Extensive subarachnoid hemorrhage, traumatic cerebral parenchymal damage and hemorrhage	-
Franklin *et al.*, 2002[4]	1	15 (M)	Suicide	No	Oral cavity	Intracranial, within the occipital bone	oral pharynx, sphenoid bone, Sella turcica, occipital lobe.	Yes, emergent cricothyroidotomy	-	-	-	Multicompartmental hemorrhage, right-sided hemiparesis.	The arrow was removed under direct visualization.
Ishigami and Ota 2017[9]	1	25 (M)	Suicide	No	Right pterion	Extracranial, left temporal bone	right medial frontal lobe	-	Pericallosal artery aneurysm (POD 35)	3D rotational angiography	CTA POD 1 and 35	-	Bifrontal craniotomy and manual removal

(*Contd...*)

Table 1: (*Continued*)

Study	No. of cases	Age (Sex)	Etiology	Mortality	Projectile entry	Projectile tip position	Important structures injured	Surgical airway	Vascular injury	Timing and modality of vascular imaging		Complication	Surgical treatment
										Preoperative	Postoperative		
Kondo *et al.*, 2018[13]	1	60S (M)	Accidental	Yes	Left lower jaw.	Extracranial, through left frontal bone	Left posterior pharynx, left middle skull base, left frontal lobe	Yes	The object damaged the left M1.	None	None	Multicompartmental hemorrhage, left MCA infarction.	None
Liebelt *et al.*, 2015[16]	1	50 (M)	Suicide	No	Oral cavity	Intracranial, right of the vertebrobasilar junction	Inferomedial to the junction of the petrous and lacerum segment of internal carotid artery, right clivus	Yes, emergency tracheostomy	No significant vascular injury	CTA	-	CSF leak 2 days postoperative, pneumocephalus.	Surgical removal and endoscopic CSF leak repair
Grellner *et al.*, 2004[6]	2	38 (M)	Suicide l	Yes	Oral cavity	Extracranial, through right calvarium	Clivus, the pons, the right occipital lobe	None	Basilar artery injury	None	none	Slight subdural and subarachnoid hemorrhage	None
		31 (M)	Accidental	No	Right upper eyelid	Extracranial, through left occipital bone	Right orbit, the brain/corpus callosum, right basal ganglia, right lateral ventricle, occipital area	None	None	None	None	Right leg weakness, CSF leak, meningitis.	Surgical removal of the eyeball.
Handlos *et al.*, 2019[7]	1	Young (M)	Homicide	Yes	Left temporal bone	Extracranial, through the right temporal bone	Left temporal lobe, midbrain, right temporal lobe	-	-	-		-	Surgical removal of the arrow.
Joud *et al.*, 2015[11]	1	37 (-)	suicide	No	Oral cavity	Intracranial, in the brainstem above the vertebrobasilar junction	Clivus	Salvage tracheostomy under local anesthesia	None	CTA	-	Left hemiparesis, dysphagia, meningitis, brain abscess, left arm weakness	Surgical removal of the arrow, brain abscess, aspiration
Opeskin and Burke 1994[18]	1	44 (M)	suicide	Yes	1st arrow: penetrated between the left eye and the nose. 2nd arrow: went through the right lower lip	1st arrow: Intracranial, base of the left frontal lobe 2nd arrow: Intracranial, right parietal parasagittal region	1st arrow: base of the left frontal 2nd arrow: hard palate, middle cranial fossa, right temporal lobe	-	-	-	-	-	-
Hengzhu *et al.*, 2014[8]	1	22 month (F)	Accidental	No	Left temporal	Extracranial, through right frontal regions	Right frontal regions	None	-	-	-	ICH, SAH, right side weakness	None
Salam *et al.*, 1990[21]	1	24 (M)	Accidental	No	Right temporal bone	Intracranial, brainstem	Right temporal lobe; brainstem.	Yes	None	None	None	None	None
Joly *et al.*, 2002[10]	1	42 (M)	Suicide	No	Oronasal cavity	Extracranial, through left frontal bone	None	No	None	-	-	None	Surgical removal of the arrow
Karger *et al.*, 2004[12]	1	35 (M)	Homicide	Yes	Left eye	Intracranial, left temporal lobe	Left temporal lobe.	None	None	None	None	None	None
Krukemeyer *et al.*, 2006[14]	1	31 (M)	-	No	Right Eye	Extracranial, through left occipital bone	The right eye, corpus callosum, lateral ventricles.	No	None	None	None	CSF leak	CSF leak repair, surgical removal of the arrow
Pomara *et al.*, 2007[20]	1	54 (M)	Homicide	Yes	Left occipital bone.	Intracranial, left frontal lobe	Left occipital lobe, basal ganglia and frontal lobe	None	None	None	None	None	No

(-): Data not available in the original report. CTA: Computed tomography angiogram, CTV: Computed tomography venogram, DSA: digital subtraction angiography, CSF: cerebrospinal fluid leak, ACA: anterior Cerebral artery, IVH: Intraventricular hemorrhage, POD: Postoperative day, SSS: Superior sagittal sinus, MCA: Middle cerebral artery, ICH: Intracerebral hemorrhage, SAH: Subarachnoid hemorrhage, ICP: Intracranial pressure, ICA: Internal carotid artery, PCA: Posterior carotid artery

Khayat, *et al.*: Crossbow injuries

not shown a clear difference in the pattern of tissue injury between accidental and non-accidental injuries.[13] Most of the reported cases represent accidental injuries or suicidal attempts rather than assault. In fact, 17 out of 24 cases identified in the literature with crossbow-related head injury represented suicidal attempts. Like gun-related suicide, most of the self-inflected crossbow injuries occur in the context of psychiatric illness or substance abuse.[19] Due to relatively easy access and ability to operate these weapons with no special training or licensing requirement, many victims preferred to use them over more demanding and less easily accessible tools such as guns. The case discussed has a protracted psychiatric history of active treatment with recent admission to a psychiatric health facility for personal safety and protection purposes. The patient was able to obtain the device from a nearby department store, where it is sold for recreational activity. This raises the issue of considering stricter controls similar to guns and the management of related psychiatric illness in such cases.

Initial assessment of damage and involvement of a multidisciplinary team

Rapid transfer of the patient to a trauma center with neurosurgical and otolaryngology availability is paramount. The clinical presentation depends on the extent of tissue penetration/injury and the involvement of vital structures along the object's trajectory. However, due to the low-energy nature of the injury and the limited extent of tissue damage, some patients may retain full consciousness and remain relatively asymptomatic.[1,22]

Ballistic studies showed that crossbows can travel at a speed of up to 100 m/s, generating about 135 Joules/s of kinetic energy. This amounts to one-third of the typical energy associated with a 9-mm bullet, which is sufficient to penetrate the skull bone and cause damage to neurovascular structures and surrounding tissues.[1] However, the low-speed nature of this injury and the relatively low kinetic energy are associated with better outcomes. The damage caused by a crossbow is often comparable to the low-speed, non-missile type of penetrating injuries (e.g., stabbing).[22] Most of these injuries occur around the areas where the skull base is relatively thin and thus easier to penetrate. The temporal bone, occipital bone, orbital region, and oro-palato-nasal structures are prime examples.[13] The damage is generally caused by direct disruptive and tearing forces of the penetrating object itself rather than the secondary blast effect that is seen with high-speed objects.[19] In addition, the crossbow arrow is often embedded in soft tissue in the majority of cases which act to tampon surrounding tissue and to slow down bleeding.[19] This explains how patients can arrive at the hospital in stable condition as long as the arrow did not cause a lethal injury along the trajectory. It also explains how some victims can present with a double self-inflected injury.[18] The pattern of injury as seen on the victim is highly dependent on the device used, especially the tip of the arrow which can dictate the morphological appearance of the wound. The involvement of a multidisciplinary team is important to provide the necessary care in a timely fashion.[1] A thorough examination of the patient to determine the trajectory, entry, and exit wound is important along with a full trauma assessment.[22] CT scan of the head and neck, or the involved region is crucial to determine the extent of tissue damage and to serve as a reference for future follow-ups. CT angiogram is needed to assess the proximity and involvement of critical vascular structures to the projectile.[22]

The need for a surgical airway

Self-harm attempts using arrow-type projectiles often involve the upper aerodigestive tract. Our review of the literature revealed that facial and oronasal involvement was seen in 75% of the cases reported with crossbow-related penetrating head injuries. As such, securing the airway in such cases should be prioritized with consideration of potential surgical airway (e.g., awake tracheostomy) if required. Our review of the literature showed that 6/17 patients with orofacial involvement ended up needing a tracheostomy at some point in their care. In our described case, the patient maintained a patent airway until surgery even though oronasal intubation was not possible. Preparedness and close monitoring are needed in these cases to detect early airway complications, such as hemorrhage or edema. A planned awake tracheostomy was undertaken in our case to proceed with general anesthesia without access to the nasal and oral airways.

Vascular imaging: Timing and modality

According to current literature, the rate of vascular injury following penetrating head injury ranges from 5% to 40%.[22] Among the 24 cases identified in the literature with crossbow-related head injuries, we found seven patients with vascular injuries. Features that increase the risk of vascular injury include orofacial or pterional involvement, the presence of intracranial hemorrhage, as well as proximity to dural venous sinuses.[17] Vascular imaging should thus be performed as soon as it is safe to proceed, preferably before surgical intervention. Repeat vascular imaging should be planned immediately after the removal of the foreign object to ensure that there is no occult bleeding. The literature does, however, report a variety of routines/requirements for postoperative imaging (see index). In addition, reported intracranial injuries related to crossbows include direct damage to brain tissue with associated vascular laceration or occlusion.[22]

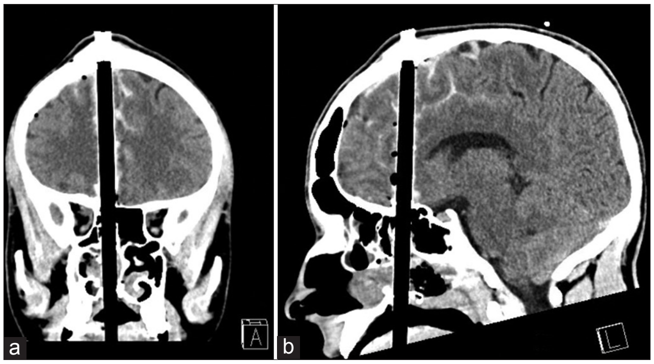

Figure 2: Radiological findings. Coronal (a) and sagittal (b) computed tomography scans of the brain show the degree of tissue damage by the projectile. Sulcal subarachnoid hemorrhage, as well as a subdural hematoma adjacent to bony fractures, are noted.

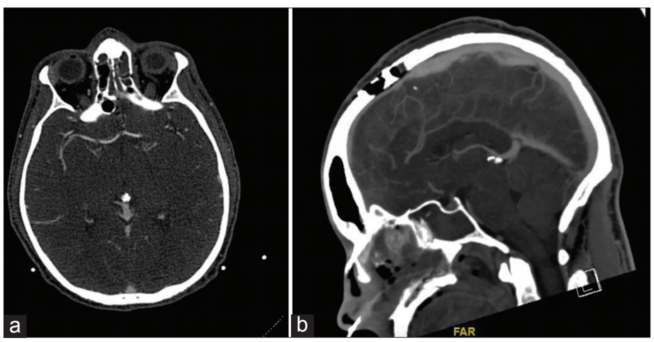

Figure 3: Vascular imaging. (a) Preoperative computed tomography (CT) angiogram showing no intracranial vascular injury, and (b) a postoperative CT venogram showing normal filling of the superior sagittal sinus underneath the craniotomy site. A computed tomography angiogram done in a postoperative setting (not shown here) was also negative for vascular injury.

Indication for surgical removal and venue of intervention

As opposed to other penetrating head injuries with small fragments retained within the tissues, large crossbows need to be removed as soon as possible.[15] Decompression of neurovascular structures, removal of foreign body and bone fragments, hemostasis, and debridement of the wound with meticulous surgical closure are key goals of the surgery.[22] Although there is a 10% mortality risk associated with surgical management of these types of injuries, mortality rates increase to 60% if the projectiles are not removed.[5] Most low velocity penetrating cranial foreign bodies in the literature were removed in the operating room. However, recent data have suggested doing such a procedure in a radiologic setting.[15] The rationale behind this approach is to allow rapid and timely diagnosis of any possible bleeding following the removal of the foreign body with enhanced ability of source determination. Therapeutic intervention could also be performed in such a setting.[15] Blind and open removal are both reported in the previous literature. When craniotomy is an option, pterional, frontal, and transnasal approaches have been reported.[15] In the index case, open removal was planned for two reasons. First, the presence of a comminuted skull fracture along with lodgment of the object into the bone makes the removal of this object difficult and risks a tractional displacement of bone fragments, resulting in further tissue or vascular injury. Second, the open approach was needed to enhance visualization of nearby structures, including the superior sagittal sinus, and to facilitate intervention in case of bleeding. We opted to use a modified bifrontal approach where exposure of both sides of the midline around the arrow was achieved to include the fracture fragments, enhance visualization of the sinus, and dissect the arrow from the bone.

Postoperative monitoring and complication

Complications related to penetrating traumatic brain injuries include hematoma, aneurysm, pseudo-aneurysm, carotid-cavernous fistula, meningitis, abscess, seizures, CSF leak, and pneumocephalus.[22] By reviewing the literature, we found that 25% of crossbow-related head injuries developed CSF leaks as a result. Skull base involvement is a major risk factor. Close monitoring and surveillance are important in diagnosing and treating such a complication.

CONCLUSION

In crossbow-related head injuries, it is crucial to do a complete examination in a multidisciplinary trauma center. It has access to a specialized care team that includes neurosurgery and otolaryngology. In addition, the ideal timing for vascular imaging is before and after any scheduled surgical operation. Throughout the stabilization and treatment of the acute injury, emergency, as well as elective surgical airway management, should be taken into consideration and made available. The object should be removed surgically with sufficient exposure to allow for visualization, removal, and the potential need for additional intervention, as well as to account for potential vascular and aerodigestive damage that may occur during removal. Furthermore, since many reported cases involve self-harm, it is important to consider controlling access to such tools and to appreciate their relationship to mental illness.

Ethical approval

The Institutional Review Board approval is not required.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. Aljuboori Z, McGrath M, Levitt M, Moe K, Chestnut R, Bonow R. A case series of crossbow injury to the head highlighting the importance of an interdisciplinary management approach. Surg Neurol Int 2022;13:60.
2. Byard RW, Koszyca B, James R. Crossbow suicide: Mechanisms of injury and neuropathologic findings. Am J Forensic Med Pathol 1999;20:347-53.
3. Domingo Z, Peter JC, de Villiers JC. Low-velocity penetrating craniocerebral injury in childhood. Pediatr Neurosurg 1994;21:45-9.
4. Franklin, Glen A, Lukan JK. The image of trauma. J Trauma Inj Infect Crit Care 2002;52:1009.
5. Gokcek C, Erdem Y, Koktekir E, Karatay M, Bayar MA, Edebali N, *et al*. Intracranial foreign body. Turk Neurosurg 2007;2:121-4.
6. Grellner W, Buhmann D, Giese A, Gehrke G, Koops E, Püschel K. Fatal and non-fatal injuries caused by crossbows. Forensic Sci Int 2004;142:17-23.
7. Handlos P, Joukal M, Dokoupil M, Uvíra M, Marecová K. Necessary defense or homicide?: The importance of crime scene reconstruction in crossbow injuries. Am J Forensic Med Pathol 2019;40:293-7.
8. Hengzhu Z, Enxi X, Lei S, Xiaodong W, Lun D. A rare case of penetrating brain injury by crossbow in a 22-month-old child. Pediatr Emerg Care 2014;30:421-3.
9. Ishigami D, Ota T. Traumatic pseudo-aneurysm of the distal anterior cerebral artery following penetrating brain injury caused by a crossbow bolt: A case report. NMC Case Rep J 2017;5:21-6.
10. Joly LM, Oswald AM, Disdet M, Ragguenea JL. Difficult endotracheal intubation as a result of penetrating cranio-facial injury by an arrow. Anesth Analg 2002;1:231-2.
11. Joud A, Merlot I, Klein O. Foreign body of the brainstem by penetrating injury: Conservative treatment. Neurochirurgie 2015;61:401-3.
12. Karger B, Bratzke H, Grass H, Lasczkowski G, Lessig R, Monticelli F, *et al*. Crossbow homicides. Int J Leg Med 2004;118:332-6.
13. Kondo T, Takahashi M, Kuse A, Morichika M, Nakagawa K, Tagawa Y, *et al*. Autopsy case of a penetrating wound to the left cerebral hemisphere caused by an accidental shooting with a crossbow. Am J Forensic Med Pathol 2018;39:164-8.
14. Krukemeyer MG, Grellner W, Gehrke G, Koops E, Püschel K. Survived crossbow injuries. Am J Forensic Med Pathol 2006;27:274-6.
15. Kulwin CG, DeNardo A, Khairi S, Payner T. Neurosurgical management of self-inflicted cranial crossbow injury. World Neurosurg 2018;116:69-71.
16. Liebelt BD, Boghani Z, Haider AS, Takashima M. Endoscopic repair technique for traumatic penetrating injuries of the clivus. J Clin Neurosci 2016;28:152-6.
17. Offiah C, Twigg S. Imaging assessment of pene-trating craniocerebral and spinal trauma. Clin Radiol 2009;64:1146-57.
18. Opeskin K, Burke M. Suicide using multiple crossbow arrows. Am J Forensic Med Pathol 1994;15:14-7.
19. Panata L, Lancia M, Persichini A, Scalise Pantuso S, Bacci M. A crossbow suicide. Forensic Sci Int 2017;281:e19-23.
20. Pomara C, D'Errico S, Neri M. An unusual case of crossbow homicide. Forensic Sci Med Pathol 2007;3:124-7.
21. Salam AA, Eyres KS, Magides AD, Cleary J. Penetrating brain stem injury from crossbow bolt: A case report and review of the literature. Arch Emerg Med 1990;7:224-7.
22. Zyck S, Toshkezi G, Krishnamurthy S, Carter DA, Siddiqui A, Hazama A, *et al*. Treatment of penetrating non-missile traumatic brain injury. Case series and review of the literature. World Neurosurg 2016;91:297-307.

How to cite this article: Khayat MA, Khayat H, Alhantoobi MR, Aljoghaiman M, Sommer DD, Algird A *et al*. Traumatic penetrating head injury by crossbow projectiles: A case report and literature review. Surg Neurol Int. 2024;15:35. doi: 10.25259/SNI_574_2023