

Crossbow Bolt Penetrating the Neck Removed with the Assistance of an Endovascular Approach: A Case Report and Literature Review

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Abstract

Penetrating neck injury by a crossbow bolt is extremely rare and can be life-threatening. When removing a crossbow bolt from the neck, it is necessary to protect against fatal bleeding from the carotid vessels. We report removing a crossbow bolt penetrating the neck, with an endovascular approach. A 49-year-old woman was shot in the neck by a crossbow and was transferred to our hospital. On presentation, the crossbow bolt totally penetrated the neck from right to left. Her level of consciousness was clear, with no significant neurological deficits except for right peripheral facial palsy. Neck contrast-enhanced computed tomography revealed the crossbow bolt in contact with bilateral external and internal carotid arteries and that the bolt caused dissection of the left main trunk of the external carotid artery. Under general anesthesia, the crossbow bolt was removed under fluoroscopy with the assistance of an endovascular approach. First, we performed coil embolization for the dissected external carotid artery. Second, we prepared for fatal bleeding from the carotid arteries during crossbow bolt removal under protection using guiding catheters placed in bilateral common carotid arteries. The bolt was removed successfully without significant bleeding, and no complications occurred during the procedure. We report the successful removal of a crossbow bolt penetrating the neck. When removing a crossbow bolt penetrating the neck, endovascular assistance may be feasible to protect against fatal bleeding from the carotid arteries.

Keywords: crossbow, removal, penetrating neck injury, endovascular, bleeding

Introduction

Arrow injuries have been previously reported in some developing countries, such as Nigeria and Papua New Guinea.^{1,2)} However, penetrating head and neck injuries by a crossbow bolt are very rare in developed countries.³⁻⁷⁾ Penetrating neck injuries by a crossbow bolt can be life-threatening because the bolt can injure crucial vessels, such as the carotid or vertebral arteries and jugular veins.^{3,5-7)} Furthermore, this injury may involve the trachea, larynx, pharynx, esophagus, hypoglossal and vagal nerves, or the spinal cord.⁸⁾ Hence, the strategy for removing a crossbow bolt should be considered seriously according to the insertion course of the crossbow bolt and the damaged organs. We describe a case of penetrating neck injury by a

crossbow bolt that was successfully removed with the assistance of an endovascular approach and literature review of penetrating neck injury by a crossbow bolt. To the best of our knowledge, this is the first report of successful removal of a crossbow bolt under fluoroscopy with the assistance of an endovascular approach.

Case Report

A 49-year-old woman was shot in the neck by a crossbow and was transferred to our hospital. On presentation, the bolt completely penetrated the patients' neck from right to left (Fig. 1A). Her vital signs were stable, the level of consciousness was clear, and no significant neurological deficits were apparent except for right peripheral facial

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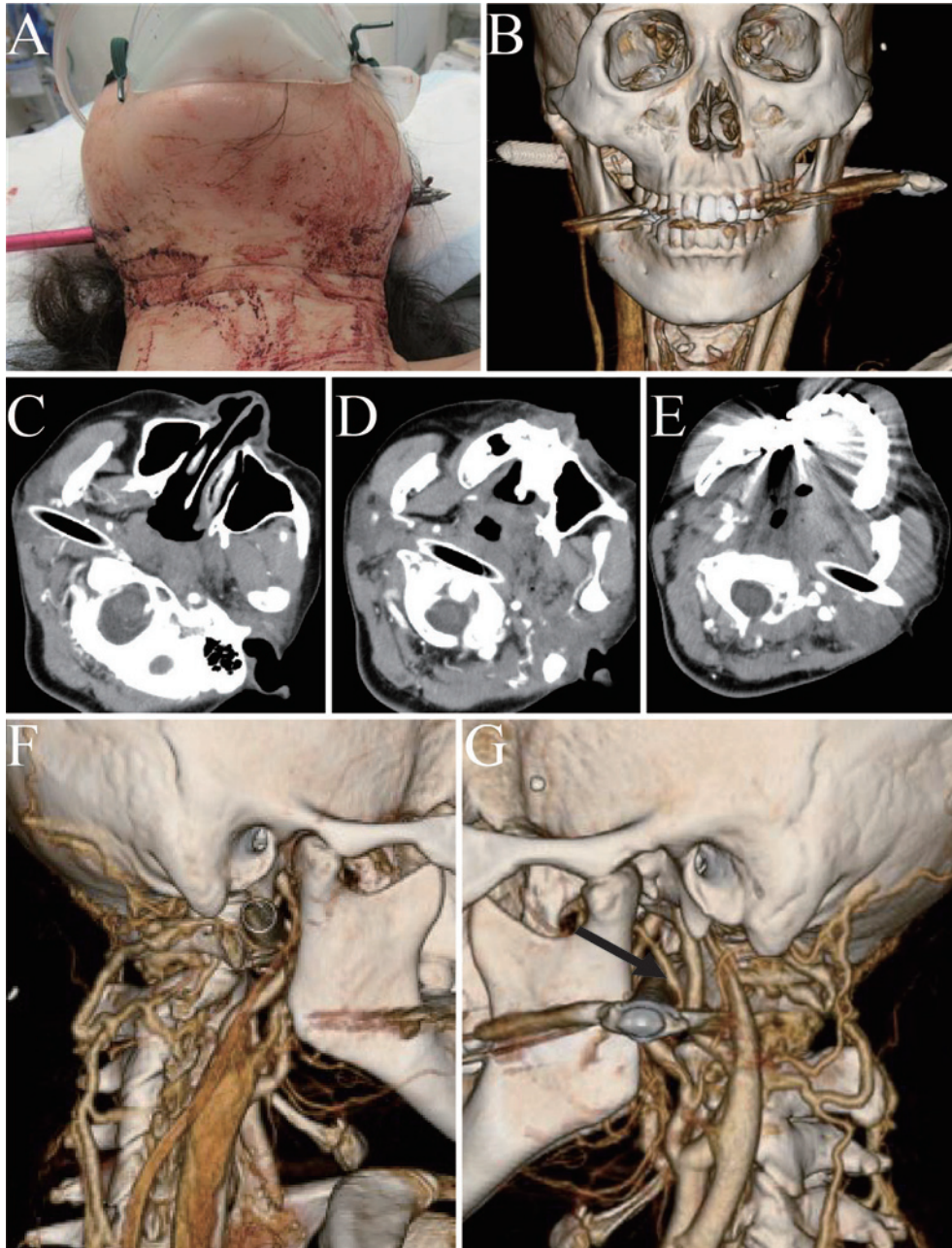


Fig. 1 Preoperative imaging (A: overview of the patient, B–G: computed tomography angiography (CTA)).

A. The patient's neck was totally penetrated from right to left.

B. Three-dimensional (3D) reconstruction of brain CTA showing the crossbow bolt totally penetrating the neck from right to left after penetrating the dermis.

C, D, E. Brain CT showing that the crossbow bolt pierced the right parotid gland, the gap between the right mastoid tip and the mandible (C), the retropharyngeal space, and was in contact with the anterior arch of the atlas (D), and the gap between the left mastoid tip and the mandible (E).

F, G. 3D reconstruction of brain CTA showing the crossbow bolt in contact with bilateral external and internal carotid arteries and the internal jugular vein (F) and that the crossbow bolt caused left external carotid artery dissection (arrow) (G).

palsy. The arrowhead of the crossbow bolt was a conical field tip, and it was exposed outside the skin on the left side. First, the tail of the crossbow bolt was cut away to obtain a computed tomography (CT) imaging (Fig. 3A).

Neck contrast-enhanced CT showed the crossbow bolt totally penetrating from right to left sides after entering the dermis (Fig. 1B). The bolt pierced the right parotid gland, the gap between the right mastoid tip and the mandible,

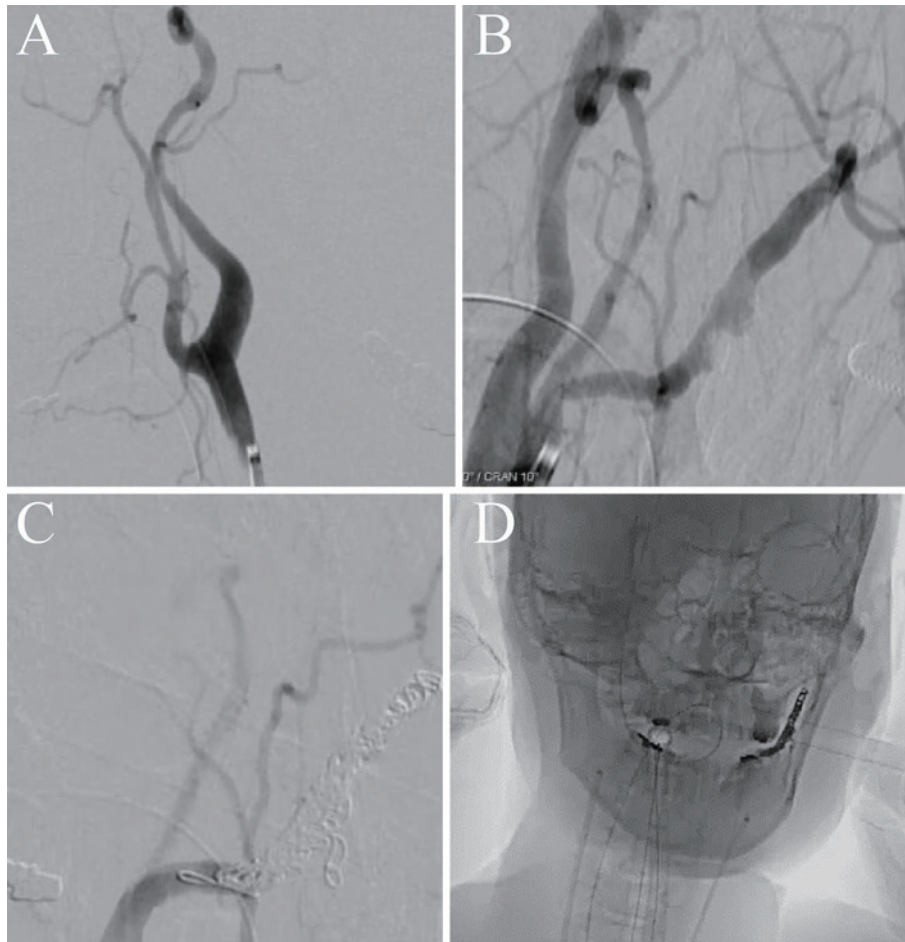


Fig. 2 Angiogram of endovascular therapy.

A. Right common carotid artery angiography (CCAG) showing no arterial bleeding or abnormal arterial changes.

B. Left CCAG showing dissection of the main trunk of the left external carotid artery (ECA).

C. Postoperative left CCAG showing complete embolization of the ECA, including the dissection lesion.

D. We prepared for possible fatal bleeding while withdrawing the crossbow bolt under protection using balloon guiding catheters placed in bilateral common carotid arteries. Crossbow bolt removal was accomplished without bleeding by checking bilateral CCAG images.

the retropharyngeal space, and was in contact with the anterior arch of the atlas, and the gap between the left mastoid tip and the mandible (Fig. 1C-E). Regarding the vascular structures, the bolt was in contact with bilateral external and internal carotid arteries and the internal jugular vein and caused left external carotid artery (ECA) dissection (Fig. 1F and G). There was no evidence of injury to the trachea, larynx, pharynx, and esophagus. Thus, we could safely intubate the patient under general anesthesia.

We planned to remove the crossbow bolt under fluoroscopy with the assistance of an endovascular approach. Under general anesthesia, 7-Fr sheaths were placed into right and left femoral arteries. A 7-Fr balloon guiding catheter (Optimo; Tokai Medical Products, Aichi, Japan) through the right femoral sheath was advanced into the right common carotid artery (CCA), and 4000 U of systemic heparin was administered. Right common carotid artery angiography

(CCAG) showed no arterial bleeding or abnormal arterial change (Fig. 2A). Next, a 6-Fr balloon guiding catheter (Optimo; Tokai Medical Products) through the left femoral sheath was placed into the left CCA. Left CCAG showed dissection of the main trunk of the left ECA (Fig. 2B).

Initially, we performed parent artery occlusion with coils for the dissected left ECA. A microcatheter (Excesior1018; Stryker Neurovascular, Kalamazoo, MI, USA) was placed in the ECA proximal to the internal maxillary artery and superior temporal artery beyond the dissection lesion using a microguidewire (CHIKAI 14; ASAHI INTECC, Nagoya, Japan). Although fibered platinum coils would be more effective in parent artery occlusion of extracranial vessels, we used the conventional platinum coil that we are familiar with. Then, we successfully embolized the ECA, including the dissection lesion, using eight coils (Target XL360 soft 4 mm × 120 mm; Stryker Neurovascular) (Fig. 2C).

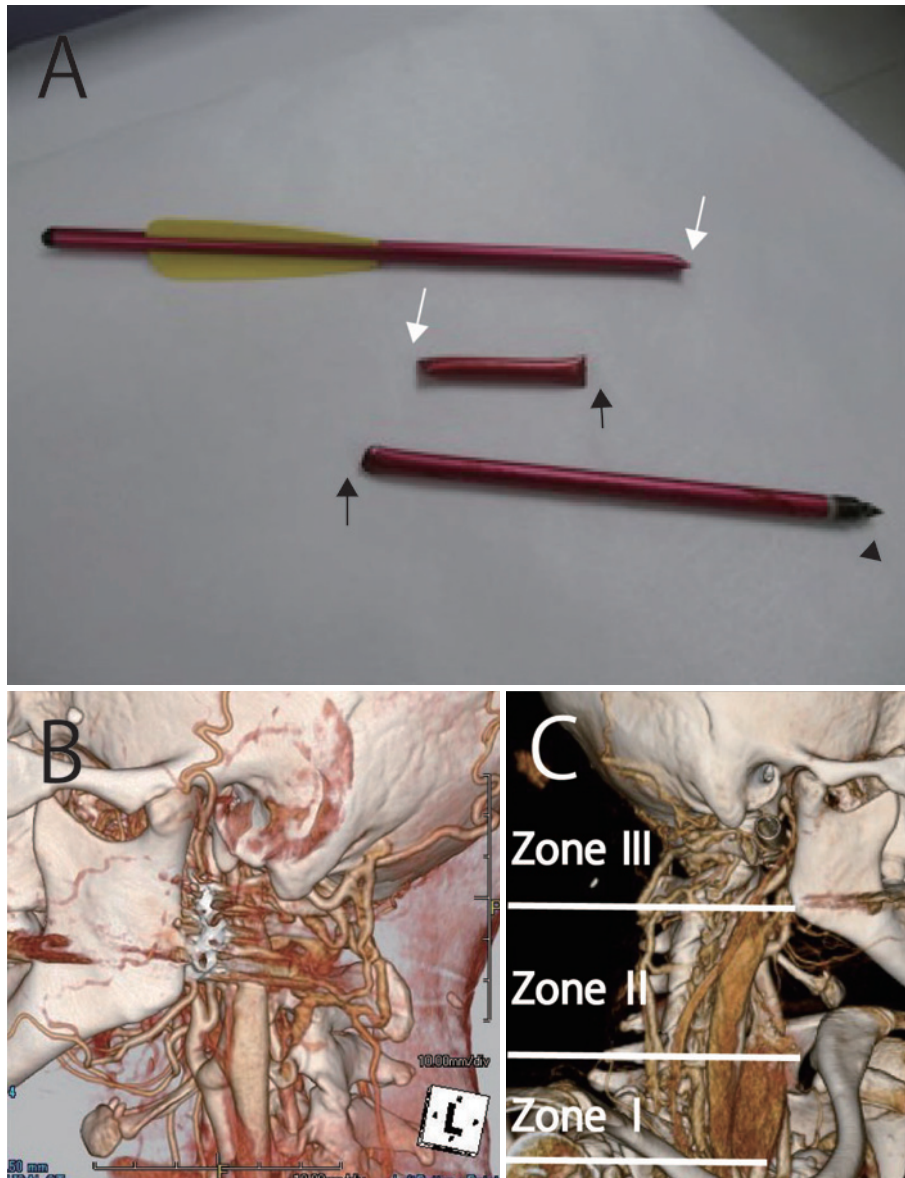


Fig. 3

A. The overview of the crossbow bolt that was removed from the patient.

The arrowhead of the crossbow bolt was a conical field tip (*arrowhead*). First, the tail of the crossbow bolt was cut away to obtain a CT imaging (*white arrow*). The shaft of the crossbow bolt was cut short across the skin to shorten its length through the patient's neck as much as possible before removal (*black arrow*). Then, residual crossbow bolt (from *black arrow* to *arrowhead*) through the neck was pulled out gently from the left side.

B. Postoperative neck computed tomography angiography (CTA) (left side).

CTA revealed no abnormal vascular changes and coil mass into left ECA.

C. Anatomical classification of neck trauma (Zones I–III).

Zone I is from the clavicle to the cricoid cartilage, which is the thoracic outlet. Zone II is from the cricoid cartilage to the mandibular angle, which includes the internal and external carotid arteries, jugular veins, pharynx, larynx, esophagus, recurrent laryngeal nerve, thyroid, parathyroid, and spinal cord. Zone III is from the mandibular angle to the skull base and is protected by the skull bones. A direct surgical approach was difficult due to these structures. In the present case, the injury occurred in Zone III.

The shaft of the crossbow bolt was cut short across the skin to shorten its length through the neck as much as possible. To safely remove the crossbow bolt, we prepared for possible fatal bleeding while withdrawing the bolt un-

der protection using the balloon guiding catheters placed in bilateral common carotid arteries (Fig. 2D). The crossbow bolt was pulled out gently from the left side (Fig. 3A). After the right stump of the crossbow bolt passed the right

Table 1 Summary of reports about penetrating neck injury by a crossbow bolt

First author and year	Number	Age	Year	Country	Cause of injury	Tip type of crossbow bolt	Site of impaction	Penetrating	Blood vessels in contact	Treatment	Endovascular assist	Complication	Outcome
Chang, 2010 ³⁾	1	24	Male	New Zealand	Accident	Broad-head tip	Left supraclavicular fossa	-	Carotid artery	Removing gently	-	None	Survival
Kovari, 2016 ⁷⁾	2	57	Male	Hungary	Suicide	Broad-head tip	From mouth to his posterior neck	+	N/A	Direct surgery	-	Bleeding	Survival
Omura, 2017 ⁵⁾	3	49	Male	South Africa	Suicide	Conical field tip	Left anterolateral neck	-	Internal jugular vein, common carotid artery, vertebral artery	Direct surgery	-	None	Survival
Kondo, 2018 ⁶⁾	4	60	Male	Japan	Accident	Broad-head tip	From the posterior pharynx to the cranial base	+	External carotid artery	Conservative	-	None	Death
Present Case, 2022	5	49	Female	Japan	Homicide	Conical field tip	From right to left sides of neck	+	Bilateral external and internal carotid arteries, internal jugular vein, left external carotid artery	Removing gently with endovascular assistance	+	None	Survival

ICA and ECA, right CCAG was performed and showed no arterial bleeding or abnormal arterial change. After the right stump of the crossbow bolt passed the left ICA and ECA, left CCAG was performed again and revealed no arterial bleeding or abnormal arterial change. The bolt was removed intact, and no complications occurred during the procedure. Cefazolin 1 g, Tetanus Toxoid 0.5 mL, and Tetanobulin 250 units were intravenously administered. The wound was flushed sufficiently with saline and closed with 2-0 nylon. Postoperative computed tomography angiography (CTA) showed no bleeding or abnormal vascular change and no damage to any crucial organs (Fig. 3B).

Blood test showed no anemia (hemoglobin at pre-procedure, post-procedure day 1, and post-procedure day 15 were 12.5 g/dL, 10.2 g/dL, and 11.3 g/dL, respectively). No complications also occurred in the wound. Right pe-

ripheral facial nerve palsy, presumably related to directly damaging the facial nerve by the crossbow bolt, had improved, only remaining subjective discomfort. The patient was discharged on postoperative day 19 with a modified Rankin Scale score of 1.

Discussion

A crossbow is a bow that releases an arrow (= a crossbow bolt) by pulling a gun-like trigger. We described a rare case of a penetrating neck injury by a crossbow bolt. Many cases of penetrating neck injury by a foreign body such as gunshot have been reported,^{1,9-12)} but there were only four cases of penetrating neck injury by a crossbow bolt in the literature (Table 1).^{3,5-7)} The neck injury in the present case was caused by an attempt to homicide. In these previous

cases, there were two cases of accident and others were suicide. Previous reports have indicated that there is no difference in the pathological characteristics of injuries caused by suicide, accident, and homicide.⁶⁾ The overall survival rate was 80% (4/5 cases) according to the previous reports.^{3,5-7)} Regarding the reason for death, it was considered to be caused by the site of injury rather than differences in the mechanism of injury (e.g., the main cause of death was brain injury in Kondo's report).⁶⁾ Among them, a case of removal of a crossbow bolt under fluoroscopy with the assistance of an endovascular approach has not been reported. In 75% of these cases, the blood vessels were in contact with a crossbow bolt. Therefore, it is necessary to watch for bleeding, when removing a crossbow bolt. There are two main types of crossbow bolt tips that are a broad-head tip and a conical field tip. Although the broad-head tip is commonly used in hunting because of resulting in hemorrhage, the conical field tip is commonly used to practice shooting.¹³⁾ In the present case, the crossbow bolt tip was conical field tip (Fig. 3A) (Table 1). Removing of the broad-head tip is more difficult and usually requires large skin incision to open a tract to pull the crossbow bolt out along the trajectory of its entry. The conical field tip makes an entry wound that is either oval or circular with abraded skin edges. In usual, the damage is caused by direct tissue penetration and cutting by the tip.¹⁴⁾ Unlike gunshot wounds, cavitation does not form due to the low kinetic energy in such injuries.¹⁵⁾ Moreover, bleeding from the wound is uncommon because the elastic surrounding soft tissue is narrow and closes the wound trajectory, accordingly acting as an incomplete tamponade.¹⁴⁾ In other words, in the case of penetrating injury by a crossbow bolt, although external injuries are limited to minimal entry and exit wounds, the major injuries are commonly internal. Therefore, the management of penetrating neck injury of crossbow bolt differs from that of gunshot or other foreign bodies.

Generally, penetrating neck injuries can be caused by low- or high-energy external damage, such as by a knife, gun, glass or metal foreign body, or a crossbow bolt. Penetrating neck injuries represent 5%-10% of all trauma cases.¹⁶⁾ The mortality rate is high and is estimated to be as high as 10%.¹¹⁾ Neck trauma is anatomically classified into Zones I-III (Fig. 3C).^{17,18)} Zone I is from the clavicle to the cricoid cartilage, which is the thoracic outlet. Sharp vascular injuries in Zone I have a high complication and mortality rate owing to damage to the large vessels. Zone II is from the cricoid cartilage to the mandibular angle, which comprises the internal and external carotid arteries, jugular veins, pharynx, larynx, esophagus, recurrent laryngeal nerve, thyroid, parathyroid, and spinal cord. Zone III is from the mandibular angle to the skull base and is protected by the skull bones. However, the surgical approach in Zone III is difficult owing to the skull base and mandibular bones.^{17,18)} In the present case, the injury occurred in

Zone III, and a direct surgical approach was difficult (Fig. 3C).

The first reason for the high mortality rate in penetrating neck injuries is that the neck contains vital organs that are essential for survival, such as the trachea, larynx, pharynx, esophagus, and spinal cord. In the present case, the crossbow bolt had avoided the trachea, esophagus, pharynx, and larynx. Since the crossbow bolt penetrated the retropharyngeal space, which is located anterior to the cervical spine and posterior to the esophagus, extends from the skull base to the mediastinum, and is filled with sparse connective fibers, such as fat and lymph nodes,^{19,21)} there was no damage to the vital organs. However, tracheal compression and asphyxia owing to hemorrhage in the retropharyngeal space have been previously reported.^{19,20)} Even if a foreign body penetrating the retropharyngeal space does not damage vital organs, it may be important to check for active bleeding using angiography. In our case, angiography after removing the crossbow bolt showed no bleeding.

The second reason for the high mortality rate in penetrating neck injuries is that this injury can damage crucial vessels, such as the carotid or vertebral arteries and jugular veins. Traumatic vascular injuries to the neck account for 10% of all vascular injuries, and 67% of these are penetrating injuries.²²⁾ Although there are many reports of sharp injuries, such as from gunshot and stab wounds in penetrating neck injuries, there are few reports of crossbow injuries.⁸⁾ Despite that carotid artery injuries account for less than 0.02% of patients requiring hospitalization, carotid injury can cause various complications, such as major hemorrhage, cerebral infarction, and damage to the surrounding organs, such as the esophagus and trachea. Among all carotid artery injuries, the incidence of cerebral infarction is 28%, and the mortality rate is 17%.²³⁾

When removing a foreign body, it is especially necessary to watch for bleeding.¹⁰⁾ In our case, we used an endovascular approach under fluoroscopy when withdrawing the crossbow bolt. First, we embolized the dissection lesion in the ECA to avoid bleeding. If the bleeding from the dissection site of left ECA is uncontrolled, a balloon guiding catheter is required to be placed in the proximal ECA,²⁴⁾ and we considered that a 6-Fr catheter would be easier to place into the left ECA than a 7-Fr catheter due to its smaller size. Therefore, we selected a 6-Fr balloon guiding catheter to treat left side.

Then, we used balloon guiding catheters placed in bilateral carotid arteries to prepare for bleeding when removing the crossbow bolt. If bleeding could not be controlled by the balloon guiding catheters, a microballoon catheter could be navigated or embolization could be added by introducing a microcatheter. Since the crossbow in this case was radiopaque,^{3,4)} we were able to visualize the position of its stump in real time by fluoroscopy, during removal. Fluoroscopy permitted accurately judging the moment

when the bolt passed each carotid artery. We believe that endovascular assistance under fluoroscopy may be feasible to protect against fatal bleeding from carotid arteries when removing a crossbow bolt penetrating the neck.

We report a rare case of a penetrating neck injury by a crossbow bolt and its successful removal. When removing a crossbow bolt penetrating the neck, endovascular assistance under fluoroscopy may be feasible to protect against fatal bleeding from the carotid arteries.

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Informed Consent

Written informed consent for publication of the patient's information and images was provided by the patient.

Conflicts of Interest Disclosure

The authors declare no conflict of interest.

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