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**Autopsy case of a penetrating wound to the left cerebral hemisphere caused by an
accidental shooting with a crossbow**

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Abstract

A crossbow is a bow that shoots an arrow when a gun-like trigger is pulled. Deaths caused by accidental crossbow shootings are extremely rare. Here we describe an autopsy case of a penetrating wound to the left cerebral hemisphere caused by an accidental shooting with a crossbow. A man in his early 60s who lived with his wife and had used crossbows for 20 years as his hobby was found early one morning in the shed of his house, collapsed and bleeding from the head and neck. He was taken to hospital and died after approximately 3 days of conservative treatment. At autopsy, a penetrating wound between the upper part of the left anterior neck and the left frontoparietal region was evident. Traumatic intracerebral hematoma was observed in the left frontal lobe and severe traumatic subarachnoid hemorrhage was present throughout the brain. Cerebral contusion and hematoma without any organization were noted around the penetration. The cause of death was determined to be cerebral contusion and intracerebral hematoma due to the penetrating wound by the crossbow arrow. He was probably trying to load an arrow into the crossbow by placing it on the floor, pointing upward, and made a mistake in its operation that resulted in the shooting of the arrow. This case is unique because it was a rare accidental death caused by a

crossbow arrow, and a detailed histopathological examination was performed.

Keywords: crossbow, accidental shooting, penetrating brain injury, arrow, trajectory,
forensic pathology

Introduction

A crossbow is a bow that shoots an arrow when a gun-like trigger is pulled. Of the 22 cases of fatal crossbow deaths reported in the literature¹⁻²², nine were suicides, 12 were homicides, and only one case² was accidental; therefore, deaths caused by accidental crossbow shootings are extremely rare. We describe an autopsy case of a penetrating wound to the left cerebral hemisphere caused by an accidental shooting with a crossbow.

Case

A man in his early 60s who lived with his wife and had used crossbows for 20 years as his hobby was found by his wife early one morning in the shed of his house, collapsed and bleeding from the head and neck. A 42-cm segment of the front end of the arrow was found on the floor to the left of his body (Fig. 1). He was taken to hospital by ambulance, where computed tomography identified another piece of the arrow in his brain.

Hospital findings

At hospital admission, wounds were found to the left neck and the parietal region of the head, with continuous, gushing-type bleeding from the mouth. Blood pressure was maintained. The Glasgow Coma Scale score was E1V1M4. Slight movement of the limbs was observed in response to stimulation. In the oral cavity, a pipe-like foreign object was found penetrating from the left posterior pharynx towards the cranial base. The airway was first secured by orotracheal intubation (later changed to tracheostomy), and then locating the bleeding source was attempted. To control bleeding, the wound to the left neck was extended towards the back and the external carotid artery was ligated at its origin. At this point, the neurological prognosis was determined to be hopeless even if the patient's life was saved. Conservative treatment was selected after his family members discussed and rejected removal of the hematoma and foreign object via craniotomy. An intracranial pressure monitor was inserted and the patient was observed. Vital signs gradually deteriorated and death was eventually confirmed after approximately 3 days of conservative treatment.

Hospital findings (computed tomography) (Fig. 2)

A fracture was observed in the left parietal region. A stick-like structure of 9 mm in

diameter extended from the fracture site into the skull, through the left frontal and temporal lobe to the area behind the left maxilla. Cerebral contusion was noted in the area around the penetration, accompanied by subarachnoid hemorrhage. Computed tomography showed extravasation from the left external carotid artery, a foreign object penetrating from the left lower jaw through the left middle skull base to the left frontal bone, hematoma that extended from the left temporal lobe to the frontal lobe, and a skull fracture caused by the exit of the foreign object (Fig. 2). The M1 segment of the middle cerebral artery (MCA) was damaged by the penetration and the end of the MCA was completely indistinguishable. Infarction was noted in almost the entire left MCA area. The marked edematous changes in the left hemisphere were considered to be secondary to the infarction. Midline shift was also observed. The inferior horn of the left lateral ventricle was displaced by edema and was almost invisible.

Autopsy findings

Height was 168 cm and weight was 75 kg. Sharp trauma, including incision wounds that are considered to be defensive in nature, was not noted on either hand. A penetrating wound was observed between the upper part of the left anterior neck and the left frontoparietal region

(Fig. 3); the entrance of the wound in the upper part of the left anterior neck was approximately 3 cm long vertically (Fig. 3A). The edges of both ends of the wound were sharp. The wound tract went backwards into the inferior border of the anterior belly of the left digastric muscle and into the left anterior region of the palate. It then passed through the left maxilla and the anterior end of the left middle cranial fossa into the cranial cavity. It further extended into the left temporal pole to the left frontal lobe in the left cerebral hemisphere, followed by the calvaria of the left frontoparietal region. The exit wound was in this region and was approximately 3 cm long (Fig. 3B). The wound tract was approximately 22 cm long. The rear end of the shaft of a black arrow remained (approximately 16.2 cm in length and approximately 0.8 cm in diameter), penetrating the left cerebral hemisphere. The rear end of the arrow was exposed in the posterior left region of the palate (Fig. 3C). The broken end was located in the calvaria of the left frontoparietal region. Traumatic intracerebral hematoma was observed in the left frontal lobe and severe traumatic subarachnoid hemorrhage was present throughout the brain (Fig. 4). The cut surface of formalin-fixed brain tissue showed midline shift and cerebral contusion around the penetration was noted (Fig. 5A, B).

The heart weighed 409 g. Left ventricular hypertrophy and subendocardial

hemorrhage were observed from the left ventricle to the ventricular septum. The cardiac muscle was extremely pale.

Histological findings

Cerebral contusion was noted in the area around the penetration. Vascular breakage was found in the hematoma and small fragments of bone were also observed. The hematoma was fresh without any organization. Berlin blue stain was negative. Cerebral interstitial edema was observed histologically. Neither hypoxic neuronal change nor diffuse axonal injury around the trajectory were observed (Fig. 5C, D).

Toxicological findings

The femoral vein blood alcohol concentration was 0.01 mg/mL (postmortem). No information was available about whether the deceased had been drinking alcohol or the volume of alcohol consumption when the wound was inflicted. Blood drug analysis by LC–MS/MS using femoral vein blood revealed a negative result.

Cause of death

Based on the autopsy results, the cause of death was determined to be cerebral contusion and intracerebral hematoma due to the penetrating wound caused by the crossbow arrow.

Discussion

The crossbow was used for hunting and fighting as a projectile weapon before guns were developed, and has a long history¹. With changes in the way crossbows are manufactured, they have become very dangerous weapons that can cause fatal injuries^{7, 14, 15}. Suicides, homicides, and accidental injuries from crossbows have been reported sporadically in Western countries²⁻²². However, cases involving crossbows are rarely experienced in forensic autopsy practice¹. In Japan, there have been few reports of crossbow injuries, and we identified only one previous report of suicidal death caused by a crossbow in Japan¹.

The gun-like base of the crossbow makes it easy to aim. High leverage is used to pull the bowstring and therefore the arrow can be shot with great force, making crossbows highly lethal^{1, 7, 14, 15}. Because arrows can be shot across long distances simply by pulling the trigger, the crossbow became widely prevalent in Europe and were frequently used in hunting and fighting from the 10th to the 15th centuries⁸. After

the invention of guns, crossbows were used only for competition or hunting and not as weapons⁸.

Crossbows marketed in Japan are classified as heavy crossbows¹. They are usually 60 to 100 cm long, 50 to 70 cm wide and weigh about 3 to 10 kg^{7,14}. On average, the effective range is 40 to 80 m, the maximum range is 100 to 425 m, and the maximum speed is as high as 60 m/s^{7,14}. While crossbows are mainly used for competition and hunting in other countries, in Japan their use in hunting is prohibited¹.

Crossbow injuries are caused mainly by direct passage of the arrow³. If the arrow remains in the wound, the etiological classification of crossbow injuries is straightforward and clear-cut. In most cases, it is no problem to determine the trajectory of the arrow⁷. Forensic investigation of crossbow injuries can be quite difficult, especially when the arrow has been removed from the body. As most victims show some survival time after the injury, it is possible that the arrow may be removed by the victim themselves⁸. Despite their low kinetic energy (compared with projectiles from guns), crossbow arrows have a high penetration force, and may be sufficient to enable penetration of the skull at short range, as in the current case²⁰. The cutting edge of the arrow is extremely sharp, facilitating penetration of tissue⁴.

There are no significant pathological differences among suicidal, homicidal, and accidental fatal crossbow injuries in the literature. With regard to the site of injury in fatal crossbow deaths, of two accidental cases, including the current case, the site of injury was the head. Of nine suicide cases, five were an arrow shot to the thorax and four cases were an arrow shot to the head. For homicide, an arrow was shot to the thorax in six cases, to the head in three, the abdomen in one, and the upper extremities in two. For homicidal shootings, while the thorax was the most frequent site of injury, other sites were hit with an arrow, possibly because of the resistance and movement of the victim.

Penetrating brain injuries can be divided into categories of missile or non-missile injuries. Missile injuries have an impact velocity of greater than 120 m/s. Injuries caused by a crossbow arrow are categorized in non-missile injuries because the maximum speed of the crossbow arrow is 60 m/s ²⁴.

Penetrating head injuries result in the most severe traumatic brain injuries, which carry a high incidence of morbidity and mortality, and account for 0.4% of all head injuries²³. Although injuries caused by handguns, hunting rifles, and other high-velocity objects have been well-described, events caused by low-velocity objects are particularly uncommon. When transcranial penetration by a low-velocity object

does occur, the most common routes are through areas of thin bone such as the temporal squama, skull base foramina, and orbit. Consequently, direct damage to brain tissue occurs with possible vascular laceration or occlusion. Further complications related to penetrating traumatic brain injuries include hematoma, aneurysm, pseudo-aneurysm, carotid-cavernous fistula, meningitis, abscess, seizures, and pneumocephalus²⁴. For hematoma and hemorrhage, the arrow itself has a protective tamponade effect¹⁰.

In the current case, the arrow was considered to have entered from the lower part of the left anterior neck and penetrated the left frontoparietal region. The patient did not have any motive for committing suicide. It is thought he was probably trying to load an arrow into the crossbow by placing it on the floor, pointing upward, and made a mistake in its operation that resulted in the shooting of the arrow. The deceased's family said that they were always anxious about his careless use when dealing with crossbows. Furthermore, the safety equipment was used contrary to the manufacturer's instructions (there being no effective catch of the string to keep it secure). Although the deceased was very experienced with crossbows, it is suggested that he was probably negligent at the time of the incident. The

front end of the arrow is thought to have broken when the patient lost the ability to act and fell to the floor.

This case is unique because it was an accidental death caused by a crossbow arrow, and a detailed histopathological examination of the penetrating brain injury was performed.

Conflict of interest

None.

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Figure legends

Figure 1 Photograph of the crossbow used by the deceased

The front end of the arrow that broke after penetration is indicated by the red arrow.

Figure 2 Head computed tomography following hospital admission

Computed tomography demonstrating the trajectory of the arrow penetrating the left middle skull base to the left frontal lobe, and hematoma in the left frontal lobe and infarction in the left middle cerebral artery area.

Figure 3 Photographs of entry and exit wounds

A: Entrance of the arrow, B: exit of the arrow, C: rear end of the arrow exposed in the posterior left region of the palate, D, E, F: trajectory of the arrow between the upper part of the left anterior neck and the left frontoparietal region. The direction of the arrow is indicated by red arrows.

Figure 4 Macroscopic images of the brain

A, B: left side view, C: basal side view. Diffuse subcutaneous hemorrhage was

observed. The broken end of the arrow is indicated by the red arrow in A.

Figure 5 Macroscopic and histological images

A, B: Macroscopic and C, D: histological images of the brain (after fixation). A, B: midline shift was observed. Cerebral contusion in the left temporal lobe around the penetration is indicated by the white arrow. The direction of the arrow is indicated by the red arrows. C: cerebral contusion around the penetration and hematoma is apparent. D: interstitial edema is apparent.



Fig. 1

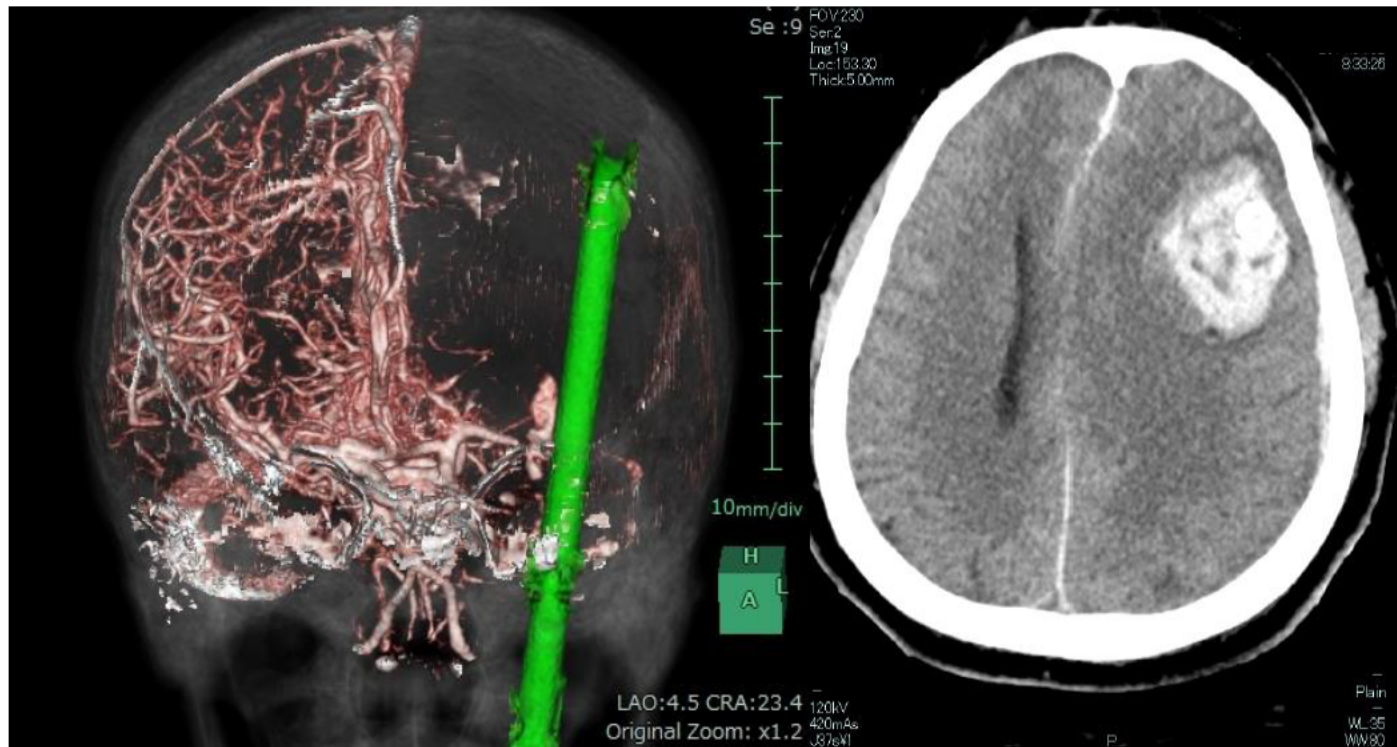


Fig. 2

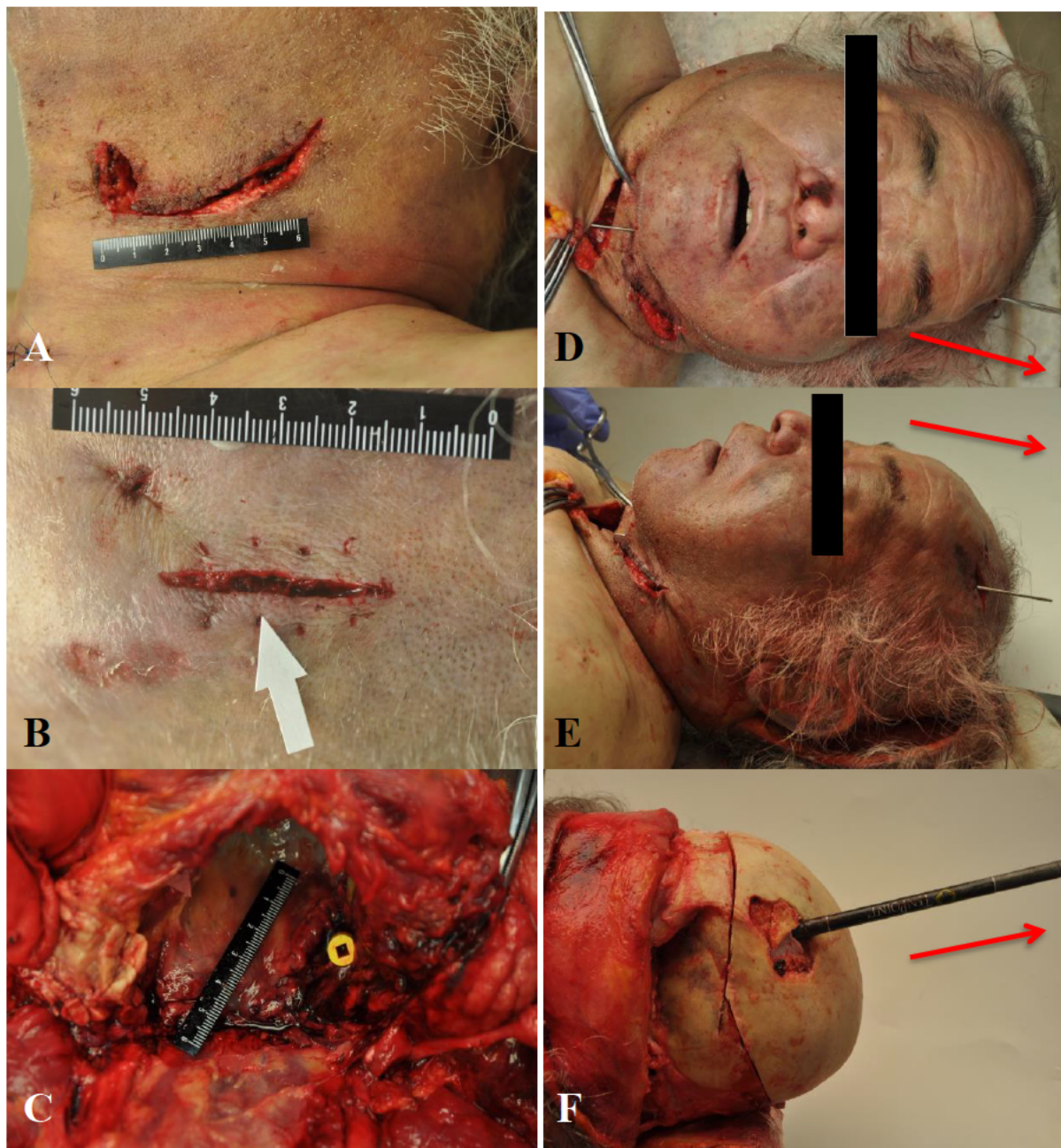


Fig. 3

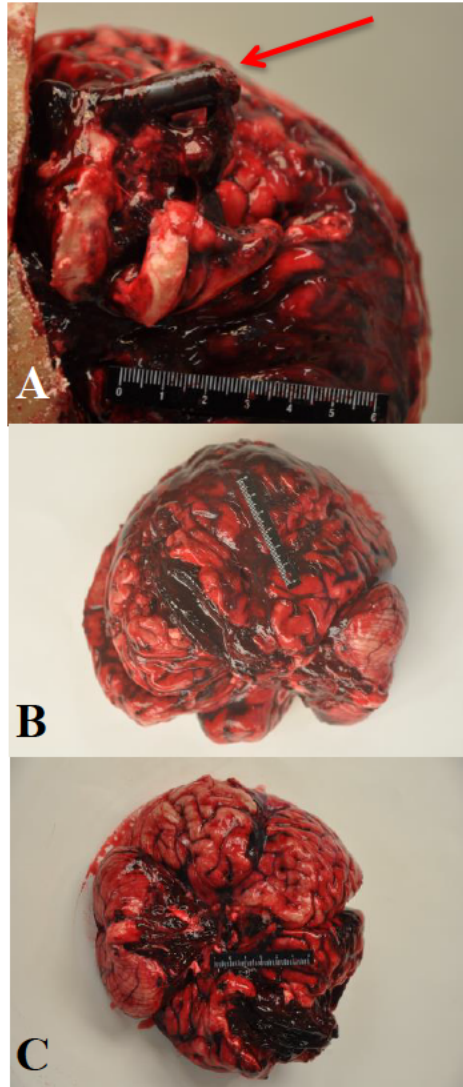


Fig. 4

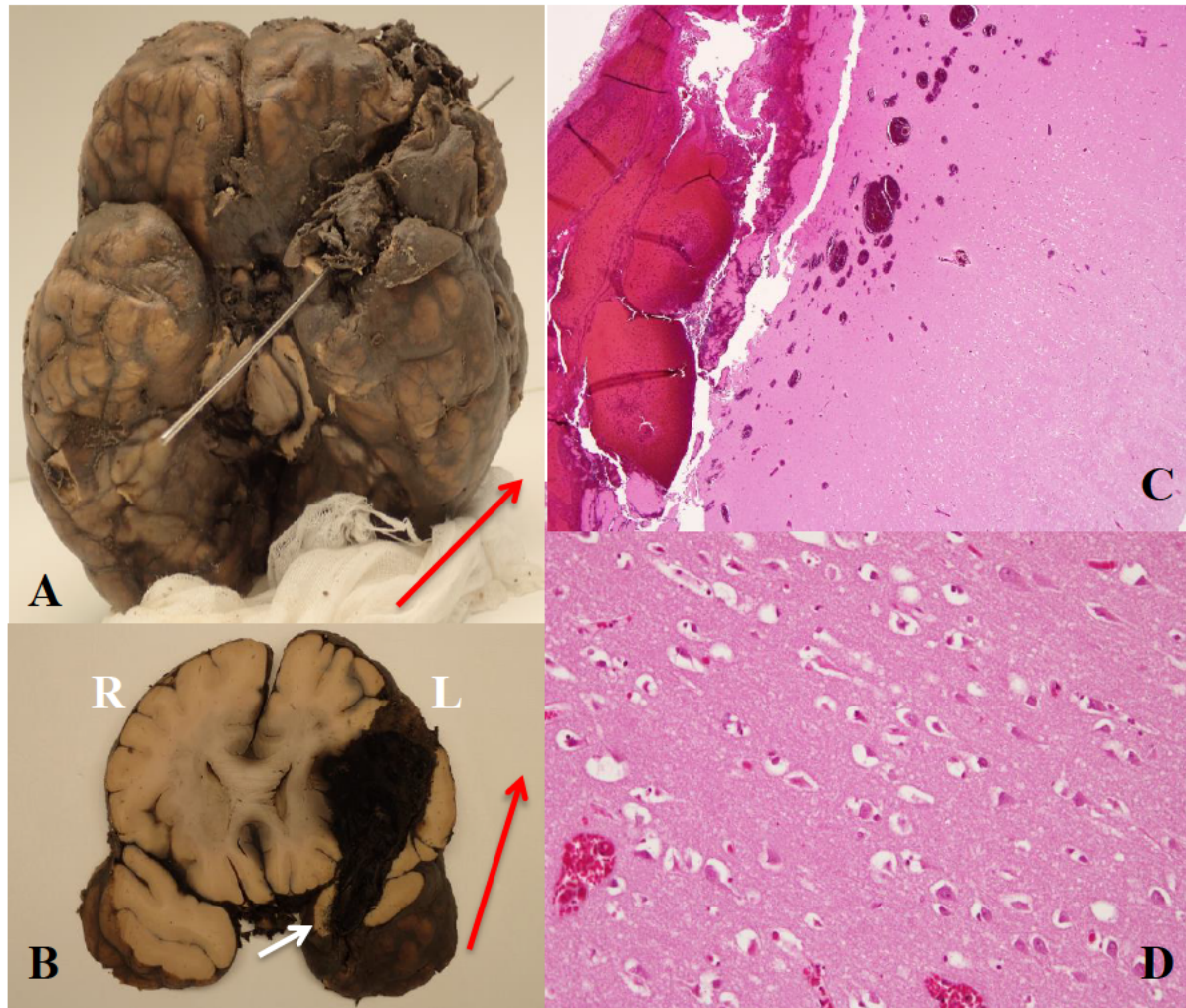


Fig. 5