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A Case of Penetrating Head Wound Due to Helicopter Rotor Blade Injury in a 34-Year-Old Naval Helicopter Pilot Who Returned to Active Service 5 Years Later

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Patient: Male, 34-year-old
Final Diagnosis: Trauma
Symptoms: Coma • fracture
Medication: —
Clinical Procedure: Craniotomy
Specialty: Neurosurgery • Surgery

Objective: Unusual clinical course

Background: Head trauma, defined as damage to the brain, skull, or scalp when the head is hit by an external force, is a major cause of mortality in military personnel. Therefore, we report a novel case involving a naval helicopter pilot who sustained a helicopter propeller rotor blade injury.

Case Report: We describe a case involving a pilot struck on the head by a helicopter rotor blade. He received care from medical staff shortly after the injury and was en route to the nearest trauma center. Cranial computed tomography (CT) scans revealed a comminuted fracture of the right occipital bone, with bone fragment retention in the right cerebral hemispheres. We performed an emergency right occipital craniotomy. The visual field patterns demonstrated right homonymous hemianopia when the patient was discharged. The patient underwent delayed titanium mesh cranioplasty about 3 months after the right occipital craniotomy. From discharge to 5 years, the patient had performed rehabilitation exercise for at least 3 days every week. The patient's continued recovery was confirmed at the 5-year follow-up in 2019. The bilateral visual acuity was 20/20, and the right homonymous hemianopia problem also disappeared. In the same year, after a physical and psychological assessment by an aviation doctor, he was able to resume flying.

Conclusions: This report has shown that despite safety regulations for military and civilian helicopter personnel, which include the wearing of helmets, helicopter rotor blade injuries still occur and can have long-term consequences due to the severity of head injury.

Keywords: Acupuncture • Advanced Trauma Life Support Care • Craniotomy • Military Personnel • Occipital Bone • Pilots

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Background

Head trauma, defined as damage to the brain, skull, or scalp when the head is hit by an external force, is a major cause of mortality in military personnel. Impacts, explosions, punctures, and/or severe accelerations or decelerations induce demonstrable head and/or cranial nerve damage [1]. The damage induced by an event of head trauma can be divided into 2 types: primary and secondary. The former refers to the immediate injury caused by the event, and the latter refers to subsequent injuries attributable to a variety of individual or confounding factors [2]. The initial assessment and management of traumatic brain injury (TBI) starts with the Advanced Traumatic Life Support (ATLS) [3]. The outcome and prognosis of head trauma are affected by the type and site of skull fracture as well as the associated intracranial hemorrhage [2]. Penetrating injuries of the skull usually lead to the formation of secondary projectiles (bone and major projectile fragments) that cause permanent cavities, increasing internal pressure in the already limited space of the cranium [4]. The kinetic energy (strictly related to the velocity of the bullet) is transferred to the surrounding tissues, causing damage even far from the primary bullet path due to progressive pulsations and contractions. They seldom have the energy to produce a significant secondary cavity, while they produce multiple “permanent cavities” (primary wound channel caused by the tissue damage due to the physical bullet passage through the body). However, several cases have shown that even if an injury is extremely serious and the risk of death is high, adequate and timely critical care treatment as well as a complete and efficient evacuation of the patient can lead to survival of the patient and may possibly even allow for a return to pre-trauma quality of life [2,5,6]. This report is of a case of penetrating head wound due to helicopter rotor blade injury in a 34-year-old naval helicopter pilot who returned to active service 5 years later.

Case Report

In December 2014, a 34-year-old Navy helicopter major pilot performed an exercise mission on the apron of Zuoying Naval Base. When the helicopter he was riding in was refueling on the thermal engine on the tarmac when he left the helicopter to check the refueling process, he failed to maintain a safe distance, causing the right side of his helmet to be hit by the tail rotor, and he immediately lost consciousness. The medical staff at the scene immediately took off the safety helmet, following emergency procedures and a collar was placed on the patient's neck to provide protection. His right parietal lobe and occipital lobe area had irregular lacerations of 4 to 6 cm with sensitive brain tissue and hemorrhage controlled by direct pressure. Since the patient was not breathing and had no pulse, the medical staff immediately performed



Figure 1. A head computed tomography image of the depressed skull fracture in a 34-year-old naval helicopter pilot with a penetrating head wound due to helicopter rotor blade injury.

cardiopulmonary resuscitation (CPR). Spontaneous circulation resumed 10 min after cardiopulmonary resuscitation. Subsequently, the patient was transferred to an ambulance near the helipad and taken to our hospital near the barracks (formerly known as the Naval General Hospital). The estimated travel time was 10 min.

On arrival at the hospital, the patient was evaluated in the Emergency Department according to the ATLS guidelines, showing that he was actively bleeding from the right occipital region. He was found to have multiple contusions, with an abrasion to the trunk and extremities and extensive laceration with depressed skull fracture in the right occipital region. The patient's airway was intact; therefore, he was intubated. His blood pressure was 121/93 mmHg, pulse was 93 beats/min, and body temperature was 37.5°C. He had a normal sinus rhythm, and O₂ saturation of 96% on 100% FiO₂. The Glasgow Coma Scale (GCS) score was 6 (E1V1M4) and both pupils were reduced in size (3 mm, left; 3 mm, right). Cranial CT scans revealed a comminuted fracture over the right parietal and occipital bone, with bone fragment retention in the right cerebral hemispheres consistent with intraparenchymal contusion, subarachnoid and intracranial hemorrhage, and subdural hematoma (SDH) beneath the fracture site (**Figure 1**). The patient was, therefore, subjected to emergency right parietal and occipital craniotomy and removal of the retained bone fragment as well as intracranial pressure (ICP) monitoring. The following findings were observed intraoperatively: 3 large head laceration wounds (17×2 cm, 5×1 cm, 3×1 cm) with



Figure 2. The intra-operative appearance of the head, showing scalp, skull, and brain injury of a 34-year-old naval helicopter pilot following a helicopter rotor blade injury.

brain tissue exposure in the right occipital region (**Figure 2**), a skull defect at the right occipital paramedian adjacent to the transverse sinus, irregular laceration of about 20 cm in length from the suboccipital to the parietal lobes, a dural defect of approximately 4×3 cm in size with brain tissue exposure and protrusion from the skull surface, and a moderate amount of paramedian skull bone fragment retention adjacent to the transverse sinus. The most significant tear wound extended from the right posterior neck up to the occiput and top, and the position was more medial to the midline, from the occipital bone across the lambdoid suture to the parietal bone. The position of the minor wound was more outward than the position of the most significant wound, from the occipital bone spanning the lambdoid suture to the parietal bone. The smallest wound was only in the parietal bone, which was located on the upper edge of the outer side of the head.

No obvious penetration of bone fragments into the sinus was noted during removal (about a third of the total number of bone fragments). The remaining bone fragments were deep-seated and were located close to the midbrain and sinus and, thus, were difficult to identify. The brain was not swollen. The patient's ICP was monitored, and the brain surface was covered with a Duraform® dural graft implant (Codman Neurovascular, Raynham, MA, USA). The removed skull fragments constituted a total area of 6×5.5 cm (**Figure 3**). The entire operation time was about 3.5 h and the total blood loss was about 100 cc.



Figure 3. Removal of the foreign body. The total area of the multiple skull fragments removed from the patient's neural tissue was 6×5.5 cm.

The patient was later admitted to the Neurologic Intensive Care Unit. The ICP level normalized on hospital day 3 (from 18 mmHg to 13 mmHg), and the patient was extubated the following day. However, he developed right homonymous hemianopia, bradykinesia, dystonia, muscular dystrophy, and resting tremor. A neurological examination revealed decreased motor strength and reflexes throughout his right upper and lower extremities, and he was able to move his upper and lower extremities and dorsiflex and plantarflex his feet. The plantar reflex was bilaterally equivocal. He was alert and oriented to person, place, and time and had no cranial nerve deficit. His temperature was normal, and his skin was dry. He received inpatient therapy, including acupuncture, occupational therapy, and physical therapy for 1 month. Acupuncture was performed to strengthen his nerve function and improve visual field defects. He was discharged on hospital day 30 and home rehabilitation was continued, after which he returned to work in a limited capacity. He underwent delayed titanium mesh cranioplasty about 3 months after the right occipital craniotomy. One year after the first craniotomy, his vision in the right eye was 15/20, and the left eye was 20/20 and corrected. But visual field patterns demonstrated right homonymous hemianopia. Visual field patterns showed congruous right homonymous hemianopia with vertical meridian and sparing fixation. His pupils are equal, round, responded to light, and had no defects in the afferent pupils. The movement of the extraocular muscles was smooth and full. The intraocular pressure of was 15 mmHg in the right eye and 16 mmHg in the left eye as measured by applanation. We used diopter lenses and a binocular indirect ophthalmoscope to perform a mydriatic fundus examination. The examination showed that the retinal pigment epithelium of the 2 eyes did not change, and there were no obvious holes, tears, or detachments near the retina. From discharge to 5 years, the patient had performed 30 min of rehabilitation exercise at least 3 days every week, including acupuncture treatment. The patient's continued recovery was confirmed at the 5-year follow-up in 2019. His bilateral visual acuity was 20/20, and the right homonymous hemianopia problem also had disappeared. Results of other eye examinations were the same as the previous results. Following a

physical and psychological evaluation by the aeronautical doctor, he was able to return to full-qualification training.

Discussion

Head trauma-induced brain damage is not limited to the impact and exit sites and associated radial cracks [4,7]. The depressed fracture can be divided into 2 types: open and closed. Our patient had an open depressed fracture. A depressed skull fracture is a focal fracture of the bone that is pushed inward at the point of impact, resulting in permanent partial depression of the skull; it is usually caused by a blunt object with a small surface hitting the head [5,8]. In addition, the direct or indirect external force increases internal pressure, fracturing the base of the skull, which is the weakest part of the skull [2,4]. The long-term effects of TBI include disability of the extremities, epilepsy, and irreversible, permanent disability [1,2,4,5,8-11]. Many deaths and morbidities are attributable to head wounds. While the head accounts for just 9% of traumatic events, 20% and 50% of penetrating injuries and combat injuries involve head injury [2,10,12]. Because high-velocity fragments are the leading cause of injury, helmets are designed to prevent fragments from protruding from the skull following injury [10,13]. While high-speed bullets are the most common cause of helmet perforation [2], the speed and kinetic energy of a high-speed rotating propeller can be far more harmful to the human body than high-speed bullets or broken projectile fragments. Although the rotating blade severed the helmet worn by the case we report, the helmet still had a protective effect, preventing fatal injuries.

Over the last century, measures have been developed to mitigate damage, prevent infection, and facilitate early intervention in cases of possible brain damage [10,14]. In the absence of a neuroprotective agent for TBI and increasingly prioritized human security, brain damage management relies heavily on improved management and the experience gained [10,14]. In addition to the type of injury, pre-hospital, paramedic, and critical care interventions influence patient survival [14]. Up to 90% of deaths occur before the patient reaches a medical facility [3,6]. During intensive care, surgery, and rehabilitation, less than 10% of TBI patients with penetrating TBI survivors have a low GCS score [15,16]. Although the mechanisms underlying the various causes of head trauma cannot be directly compared, survival rates and prognostic evaluations provide relatively objective means of comparison [17]. The prognosis of our patient was better than indicated in many research reports.

Helicopter central rotor blade and tail rotor damage are not common in civil and military operations. Nevertheless, in the past 60 years, there have been many articles published on head injuries and deaths caused by rotor blades [13,16-18].

Crowley et al [18] pointed out in a 1993 article that rotor blade damage is an inherent hazard in helicopter operation. Among them, head injuries accounted for 65% of the people injured. We believe that head injuries are the most frequent because when the helicopter stays on the ground, the rotor blades are still in high-speed operation, and the person does not maintain a safe distance, resulting in head injuries. Our case was a severe head injury caused by not keeping a safe distance. In addition, flight crews and passengers accounted for 78% of the victims, ground crews accounted for 14%, and bystanders accounted for 8% [18]. This shows that ground crews still have nearly a 15% chance of head injury when performing ground tasks. In addition, in 1997 Gibbons et al [6] published a study analyzing 24 blade injuries, of which 45% (9/20) of head injuries were related to tail rotors [6]. Approximately 63% of casualties were flight crews or ground crews. Equally important, 91.6% (22/24) of the incidents occurred during the day, as in the case we reported. The primary helicopter pilot was a tall man. He raised his head into the tail rotor tunnel and was hit when he left the cockpit to check the refueling process. Despite being cut by the rotating blade, the helmet had a protective effect, preventing fatal injuries. However, even a blow injury can be serious, and all relevant personnel should be instructed in helicopter safety. The rotor blades are a threat to all on-site personnel, and they should fully understand the situation disembarking or boarding the helicopter [11,17]. The helicopter crew must maintain situational awareness when the blades are turning. Professional training alone cannot guarantee that the rotating blades will not injure personnel. These air crews and ground crews have also received helicopter training, but there are still personnel who fail to implement the safety regulations. All flight crews and ground crews must be reminded of the danger of rotating blades. The helmet does provide some protection and should be worn under operating conditions. In some cases, protective helmets help reduce injuries, but it is still not the safest protective measure. The strongest guarantee of safety is that personnel strictly follow safe operation regulations and maintain a safe distance.

Conclusions

This report shows that despite safety regulations for military and civilian helicopter personnel, which include the wearing of helmets, helicopter rotor blade injuries still occur and can have long-term consequences due to the severity of head injury.

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