Interdisciplinary Neurosurgery: Advanced Techniques and Case Management 25 (2021) 101203

Contents lists available at ScienceDirect

Interdisciplinary Neurosurgery: Advanced Techniques and Case Management

journal homepage: www.elsevier.com/locate/inat

Case Reports & Case Series

Unintentional penetrating brain injuries caused by air rifles in teenagers: Two case report

Muhammad I. Rahmatullah, Muhammad Arifin Parenrengi, Wihasto Suryaningtyas *

Department of Neurosurgery, Universitas Airlangga Faculty of Medicine - Dr. Soetomo General Academic Hospital, Surabaya, Indonesia

ARTICLE INFO

Keywords:
Air rifles
Penetrating brain injury
Gunshot wound
Surgery
Complication

ABSTRACT

Pellet guns are non-powder guns but their related injuries have been reported worldwide. They represent a significant cause of injury especially among children and teenagers. We present two cases of non-powder firearms. First case was a 13-year old male with a chief complaint of headache following gunshot accident towards his head. The bullet's entry point was from the buccal region, going upwards fracturing the orbital roof, hitting the inner table of the frontal skull and ricocheted towards the parietal region. Second case was a 14-year old male who presented with cerebrospinal leakage, pulsating at the bullet's entry point in the frontal area. Despite several opinions existed for these type of injuries, aggressive management for surgical extraction of the foreign body is the largely accepted treatment. The leaded bullet had to be extracted to avoid future damage from the metal's known neurotoxicity. Often under-appreciated, we found difficulties in our experience for increasing the understanding and awareness for potentially fatal outcome regarding the gunshot wound brain injury. This obstacle often hinders the patient of consenting to surgical intervention in our population.

1. Introduction

Pellet guns are non-powder guns but their related injuries have been reported worldwide. They represent a significant cause of injury especially among children and teenagers. As oppose to gun-powder firearms, non-powder firearms, such as air rifles, resulted in different progression and injuries with different understand of its mechanism of injury.[1] This firearm has now been an increasing concern due to the potential of producing significant injury.[2,3]

The head is the most commonly penetrated part of the body, and the orbit is the most common part of the skull resulting in cerebral injury. The majority of fatal incidents were reported involving children and adults. Pellets have entered through the eyes, temple or forehead, and then penetrated the brain.[2,3]

The consideration of whether applying the same aggressive management with the high-kinetic gunshot injury to non-powder firearms is an intriguing question by itself. Here we report two interesting cases of air rifle accident causing multi intracranial lesion.

2. Case presentation 1

We present a first case of 13-year old male who came to our emergency department with a chief complaint of headache. Pain was felt dominantly on the left side. The patient was shot in the face by an air rifle 19 h prior to admission. The bullet went through his left cheek with an upward trajectory and could not be found anywhere else. Patient vomited one time before seeking medical helps. No loss of consciousness or seizure were seen following the incidence.

Patient came with stable vital signs and neurological examination was unremarkable. Physical findings were pertinent for bullet entry wound in the left bucal region with a clean round shape and a diameter of 2 mm. No active bleeding was seen from the wound. Left palpebral edema and ecchymosis was observed (Fig. 1a).

Skull x-ray showed radiopaque foreign body, lodged into the parietal region. Head CT showed the bullet as a hyperdense lesion with scatters in the left parietal lobe. Secondary tract was seen along the frontoparietal lobe in a right angle. Intracerebral hemorrhage (ICH) was seen along the primary and secondary tract. The bullet also produced thin subdural hemorrhage (SDH) on the left temporoparietal region. (Fig. 1b

Abbreviations: ICH, Intracerebral Hemorrhage; CSF, Cerebrospinal Fluid; CT, Computed Tomography; Mg, Milligram; SDH, Subdural Hemorrhage; TBI, Traumatic Brain Injury; PBI, Penetrating Brain Injury; ICP, Intracranial Pressure.

* Corresponding author at: Department of Neurosurgery, Universitas Airlangga Faculty of Medicine - Dr. Soetomo General Academic Hospital, Surabaya, Indonesia.
E-mail address: wihasto-s@fk.unair.ac.id (W. Suryaningtyas).

https://doi.org/10.1016/j.inat.2021.101203
Received 12 November 2020; Received in revised form 17 March 2021; Accepted 28 March 2021
Available online 31 March 2021

– 1 g) Angiography study did not show any vascular lesion. (Fig. 1h – 1i)

Patient was diagnosed with mild TBI with thin SDH of the left fronto-temporo-parietal region and ICH due to penetrating brain injury. Ophthalmology consultation resulted in closed glove injury of the left orbita with complication of traumatic optic neuropathy and left palpebral edema and hematoma. Patient was admitted for close observation and non-operative management due to his refusal despite of repeated informed consent. Methylprednisolone was administered with a dose of 250 mg every 6 h for 3 days due to traumatic optic neuropathy. Metamizole was given as analgetic every 8 h. Ceftriaxone was given with a dose of 1 g twice daily for 7 days. Phenytoin was prescribed as prophylaxis anticonvulsant with a loading dose of 700 mg and a maintenance dose of 100 mg every 8 h. Patient did not show any deterioration during hospital care. Patient discharge from the hospital with fully oriented, GCS 15 and no neurological deficite. Patient was given antibiotic cefixime 100 mg twice daily for 7 days after discharge from the hospital.

3. Case presentation 2

We present a second case of a 14-year old male who came to our emergency room with a chief complaint of wound on the head after being shot accidentally by an air rifle 10 h prior to admission. Nobody witnessed the incident and knew the whereabouts of the rifle shot. The patient was completely conscious and didn't complain of anything in particular, such as headaches, nausea, vomiting, and seizures.

Patient came with stable vital sign and GCS 15 neurological examination was unremarkable. Physical findings showed a clean round-shaped open wound on the left frontal region consistent with a bullet entry wound. Bone was visible and showed a round-shaped discontinuity, egressing pulsatile clear fluid following the patient's heart rate (Fig. 2a).

Head CT scan was performed and showed a hyperdensity with the same density as bone tissue in the left lateral ventricle indicating a foreign body. There was an area of air density in the left ventricle following the trajectory of the bullet shot indicating left frontal lobe and both lateral ventricles pneumocephalus (Fig. 2b – 2c). Other additional examinations weren't of any important significance.

The patient was diagnosed with left lateral ventricular foreign body (bullet) with left frontal lobe and bilateral lateral ventricular pneumocephalus and cerebrospinal fluid (CSF) leakage. Surgery was planned for debridement and foreign body exploration with c-arm guidance and extraventricular drain installment at right Keen point. A left temporo-frontal incision was performed and frontal craniotomy using 3 burr-holes was made (Fig. 2d). A cross incision was made on the dura and c-arm guided foreign body extraction was performed (Fig. 2e). The foreign body suspected as an air rifle bullet was successfully extracted (Fig. 2f).

Post-operative head CT for evaluation was performed and showed no foreign body residual (Fig. 1g). Post-operative medications administered include intravenous Metamizole 1-gram thrice a day and Phenytoin 500 mg every eight hours. Ceftriaxone was given with a dose of 1 g twice daily for 7 days. Patient did not show any deterioration during hospital care and follow-ups. Patient discharge from the hospital with fully oriented, GCS 15 and no neurological deficite. Patient was given antibiotic cefixime 100 mg twice daily for 7 days after discharge from the hospital.

4. Discussion

Two cases discussed above are illustrations of gunshot wound injury that had been surprisingly underreported in in Indonesia. The understanding of the danger with firearms had not been fully comprehend by the people. The complication itself regarding potential life-threatening injury, in our case brain injury, had been under-respected. It reflected by refusal of the first patient for surgery while the second patient agreed to surgery.

Gun-powder firearms are heavily regulated in Indonesia and cannot be readily accessed by common people. In the opposite, non-powder firearms are unregulated. Given the ease of access for this type of guns made its use fairly popular and often gives the impression of false safety

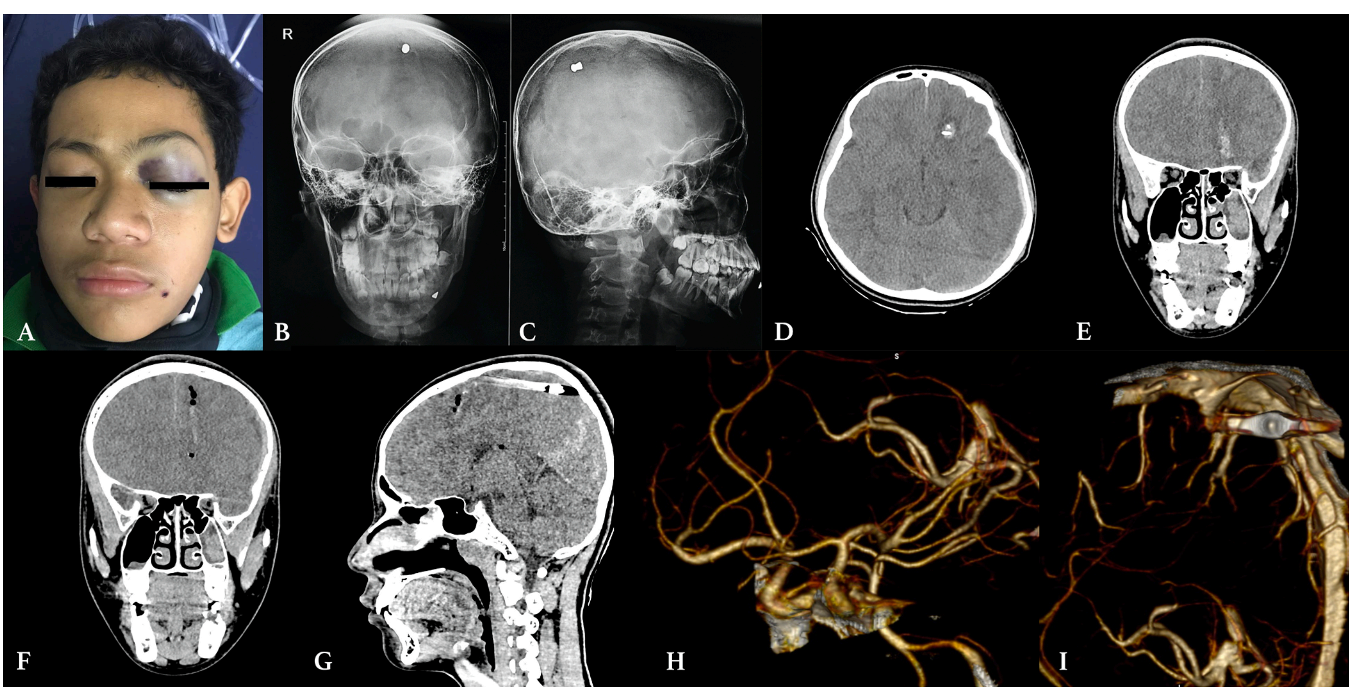

Fig. 1. Clinical findings showed palpebral edema and hematoma due to the bullet penetrated the orbital cavity before entering the intracranial space. Entry wound was seen as a clean round shaped on the left buccal area (a). Radiological studies showed foreign body in the intracranial space, cranial x-ray showed radiopaque bullet in the parietal region (b-c). Intracerebral and thin subdural hematoma was seen on the frontal and frontotemporoparietal region (d-e) Intracranial lesion was seen resulting from the bullet trajectory along its pathway. The bullet went through the roof of maxillary sinus and orbital roof showing as fracture in bone window CT (f-g). CT angiography did not show vascular disruption. (b-c) the bullet was not in contact with major blood vessels (h-i).

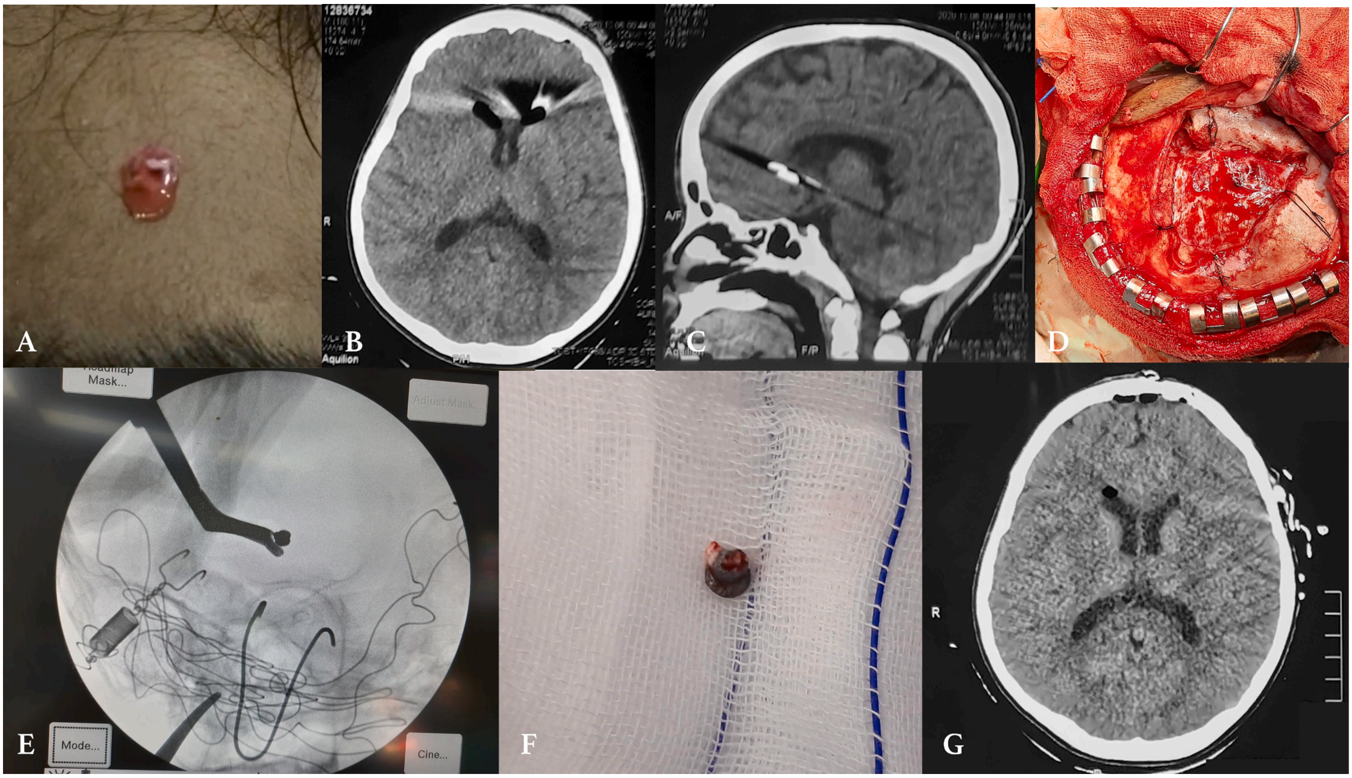

Fig. 2. Round-shaped open wound on the left frontal region showing bone discontinuity and pulsatile egression of clear fluid, following the heartbeat (a). Head CT showed a hyperdense lesion with the same density of bone tissue in the left lateral ventricle indicating a foreign body and its trajectory along the frontal lobe. Pneumocephalus in the left frontal lobe and bilateral lateral ventricles. Trajectory of bullet showing the bullet lodged just by the head of caudate nucleus (b-c). Intraoperative craniotomy and dural exposure (d). C-arm guided foreign body extraction. Extraction was done through bullet's trajectory into the site (e). Foreign body extracted (f). Post-operative evaluation with head CT scan of axial view view showed complete removal of bullet with no postoperative hemorrhages (g).

due to being labeled as 'not real weapon'. Study showed over 70% of the non-powder firearm injury for pediatric cases were unintentional. The US alone stated in to 2013 that there were sixteen thousand incident with the majority of its victims being under 19 years old.[4] The importance of acknowledgement of its potential to cause serious injuries seems yet to not be coming to people. Indonesia on the other hand, did not have the same level of national system with the US for centralized database. Several non-powder firearm reports that were published were case report and small studies.[5–7] Darmadipura, *et al.*, had previously published a study of 16 cases from our institution.[7] It somewhat showed the under-respected danger of this type of weapon.

Traumatic brain injury is the result of energy being transferred from an object to the human skull and underlying brain. The penetrating object has kinetic energy that is proportional to the projectile equal to the mass times the square of its velocity (Ek = 1/2mv2). Most non-bullet penetrating objects, such as nails or knives, impart less damage to the skull and brain because they have less kinetic energy to transfer on impact. Bullets tend to have less mass, but travel at higher velocities, though bullet velocities can vary based on a number of factors, such as the muzzle velocity, travel through the air, and travel through the impacted target. Injuries associated with penetrating and perforating injuries include cerebral contusions, hematomas, CSF leaks, pseudoaneurysms and arteriovenous fistulas. Projectiles may penetrate the skull and brain and ricochet off the inner aspect of the skull. This occurs most often with low-velocity projectiles and creates a new wound tract in otherwise uninjured brain tissue. Immediate intracranial injury occurs as the result of neuronal and vascular destruction caused by the projectile traveling through intracranial tissues. Once the projectile strikes the head and transfers its kinetic energy to extra and intracranial tissues, destruction occurs in tissue both in the projectile's path as well as in distant tissues outside the projectile's trajectory. Permanent cavitation occurs in tissues directly in the projectile's path, but sonic waves followed by pressure waves of as much as 30 atmospheres produce temporary cavitation. Expansion and retraction of the temporary cavities cause distant punctate hemorrhages and neuronal membrane disruption. The result is a rapid rise in intracranial pressure (ICP) as hematomas enlarge, and cerebral edema increases as early as 30 min after the initial injury. Concurrently, cerebral perfusion pressure decreases and infarction can follow. , Herniation can occur in a severe injury.[8]

Our first patient presented himself to our hospital with full consciousness despite having a lead foreign projectile causing intracranial lesions. It was a given clinical presentation considering the intracranial lesion were small hemorrhages along its track, thin subdural hemorrhage, and small pneumocephali. The bullet itself entered through the buccal region with an upward trajectory into the maxillary sinus. It then continued upwards making a slight dorsal angle into the orbital cavity and went into the intracranial space through the orbital roof into the frontal lobe. The bullet made a direct straight track and hit the inner table of the frontal skull. The impact caused ricochet of the bullet and a secondary track in an acute angle was formed with the bullet ended in the parietal lobe. Kazim, et al. recommended cerebral angiography in patient with penetrating brain injury (PBI) where there is an increased risk of vascular injury.[9] In this patient angiography study did not show any vascular lesion. The impact disrupted the vasculature in the subdural space causing a small amount of bleeding on the Frontotemporoparietal subdural region. The hemorrhages were not indicative for evacuation.

Craniotomy was planned to extract the bullet for both cases. In the first case, the patient was in relatively good clinical condition but the bullet was seen to be a diabolo-style shape and known to be made from lead. Lead itself is neurotoxic and could produce further injury to its surrounding structure. Tindel, *et al.* showed destruction of the neural structures from implanted lead fragments.[10] Fibrosis will occur in the adjacent neuronal structure surrounding the metal fragments as a reaction while the toxicity of lead will produced histological changes. These changes will occur for all metal bullet fragments on brain tissue with different severity depending on the type of the metal.[10–12] Unfortunately, the first patient refused surgery despite repeated informed consent.

In the second case, cerebrospinal fluid was seen pulsating from the bullet's entry wound so surgery is mandatory and the patient agreed to surgery. We planned the extraction pathway to be using the bullet's trajectory to avoid further injury. The forcep was inserted towards the head of the caudate nucleus where the bullet lodged nearby. The process was guided by C-Arm fluoroscopy and we successfully extracted the bullet. Early surgical intervention is the principal for this type of injury.[1] Other important matter is the high risk of infection that potentially followed the surgery with CSF

Surgical management for missile penetrating brain injury had been largely published.[1] Several opinions exist of gunshot wound penetrating brain injury surgical management, based on its clinical presentation, but metal fragment extraction is key for surgery to alleviate local toxicity effect and permanent neurostructural changes which may develop into permanent neurological deficits. Surgery should be done with a mindset of thorough debridement to remove every pathologic bodies possible. Mass effect found on radiological studies is an indication for surgery itself.[13,14] While surgery is the mainstay treatment, medical treatments has not reached appropriate agreement and therefore acted as the supporting management for these cases.[15]

Infectious complications are not uncommon after PBI, and they are also associated with higher morbidity and mortality rates. The risk of local wound infections, meningitis, ventriculitis, or cerebral abscess are particularly high among PBI patients because of the presence of contaminated foreign objects, skin, hair, and bone fragments driven into the brain tissue along the projectile track. Infectious complications are more frequent when cerebrospinal fluid leaks, air sinus wounds, transventricular injuries or those ones crossing the midline occur. A higher incidence of intracranial infections after PBI is documented in studies on military PBI (4%−11%) as compared to series on civilian PBI (1%−5%).[9] There is a considerable variation in the preference for antibiotic regimen for prophylaxis in PBI patients. Cephalosporins, however, are the most preferred antibiotics. Esposito and Walker have recommended the use of intravenous ceftriaxone, metronidazole, and vancomycin for a minimum of 6 weeks for PBI patients. [9] In this patient both we used ceftriaxone for prophylaxis 1 g twice daily for 7 days and cefixime 100 mg twice daily for 7 days after discharge from the hospital.

The risk of posttraumatic epilepsy after PBI is high probably due to direct traumatic injury to the cerebral cortex with subsequent cerebral scarring. It is reported that the more severe the injury to the brain according to the Glasgow outcome scale (GOS) grade, the higher the risk for the development of posttraumatic epilepsy. About 30%–50% of patients suffering a PBI will develop seizures. It is estimated that up to 10% of them will appear early (first 7 days after the trauma), and 80% during the first 2 years, but about 18% may not have their first seizure until 5 or more years after injury. The initial studies did not confirm the beneficial effect of the prophylactic anticonvulsants administration, more recent ones recommend the prophylactic anticonvulsants use (e.g., phenytoin, carbamazepine, valproate, or phenobarbital) in the first week after an injury.[9]

As a summary, we make some important considerations based on our experience in dealing with cases of penetrating brain injuries caused by non-powder guns. These recommendations are listed in table 1 below.

5. Conclusion

Treatment of penetrating brain injuries caused by non-powder guns requires special attention. The orbital region should be evaluated. Infection as a complication should be avoided. Vascular evaluation is mandatory in any suspicion. Surgery remains as the mainstay for missile penetrating brain injury. Metal fragments of the bullet needs to be removed due to its toxicity to the brain tissue that will produce histopathological changes leading to permanent damages and deficits. Aggressive management is preferred for missile penetrating brain injury despite different opinions.

Table 1
Important Considerations in Managing Penetrating Brain Injuries (PBI) Caused by Air Rifles / Non-Powder Guns.

Assesment:
Orbital region must be evaluated
Workup:
CT Scan still being the best modality for any brain injury cases, including PBI
The angiography study is mandatory in any case of suspicion
Management:
Aggressive surgical treatment is preferred to avoid the toxicity of metal fragments
Prophylactic antibiotic should be given in all case, due to high rate of infection
Prophylactic anticonvulsant administration is reasonable

6. Consent and release

Written informed consent and release was received from patients for publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] N. Syrmos, M. Ganau, A. De Carlo, L. Prisco, L. Ganau, V. Valadakis, K. Grigoriou, C. Iliadis, D. Arvanitakis, Dealing with the Surgical and Medical Challenges of Penetrating Brain Injuries, Case Rep Surg. 2013 (2013) 1–4, https://doi.org/10.1155/2013/209750.

[2] M.H. Nguyen, J.L. Annest, J.A. Mercy, G.W. Ryan, L.A. Fingerhut, Trends in BB/pellet gun injuries in children and teenagers in the United States, 1985–99, Inj Prev. 8 (3) (2002) 185–191, https://doi.org/10.1136/ip.8.3.185.

[3] H. Ceylan, Air weapon injuries: a serious and persistent problem, Arch Dis Child. 86 (4) (2002) 234–235, https://doi.org/10.1136/adc.86.4.234.

[4] S.L. Bratton, M.D. Dowd, T.V. Brogan, M.A. Hegenbarth, Serious and Fatal Air Gun Injuries: More Than Meets the Eye, Pediatrics. 100 (4) (1997) 609–612, https://doi.org/10.1542/peds.100.4.609.

[5] W. Niryana, H. Irawan, I.P.E. Widyadharma, An Intracerebral Penetration of Air Shotgun Pellet in Toddler: A Case without Neurological Sequelae, Open Access Maced J Med Sci. 6 (8) (2018) 1446–1449, https://doi.org/10.3889/oamjms.2018.330.

[6] A.T. Wijaya, I.M.D. Ayusta, I.W. Niryana, Air gun wound: bihemispheric penetrating brain injury in a paediatric patient, BJR|case reports. 5 (2) (2019) 20180070, https://doi.org/10.1259/bjrcr.20180070.

[7] S. Darmadipura, U. Kasan, A. Hafid, A. Turchan, Air rifle injury to the head, J Clin Neurosci. 1 (3) (1994) 188–192, https://doi.org/10.1016/0967-5868(94)90027-2.

[8] D.W. Van Wyck, G.A. Grant, Penetrating Traumatic Brain Injury: A Review of Current Evaluation and Management Concepts, J Neurol Neurophysiol. 06 (06) (2015), https://doi.org/10.4172/2155-9562.1000336.

[9] S.F. Kazim, M.S. Shamim, M.Z. Tahir, S.A. Enam, S. Waheed, Management of penetrating brain injury, J Emergencies, Trauma Shock. 4 (3) (2011) 395–402, https://doi.org/10.4103/0974-2700.83871.

[10] N.L. Tindel, A.E. Marcillo, B.-K.-B. Tay, R.P. Bunge, F.J. Eismont, The Effect of Surgically Implanted Bullet Fragments on the Spinal Cord in a Rabbit Model, J Bone Jt Surgery-American 83 (6) (2001) 884–890, https://doi.org/10.2106/00004623-200106000-00010.

[11] W.P. Sights, R.J. Bye, The fate of retained intracerebral shotgun pellets, J Neurosurg. 33 (6) (1970) 646–653, https://doi.org/10.3171/jns.1970.33.6.0646.

[12] I. Spence, C. Drew, G.A.R. Johnston, D. Lodge, Acute effects of lead at central synapses in vitro, Brain Res. 333 (1) (1985) 103–109, https://doi.org/10.1016/0006-8993(85)90129-5.

[13] H.R. Alvis-Miranda, R. Adie Villafañe, A. Rojas, G. Alcala-Cerra, L.R. Moscote-Salazar, Management of Craniocerebral Gunshot Injuries: A Review, Korean J Neurotrauma. 11 (2) (2015) 35, https://doi.org/10.13004/kjnt.2015.11.2.35.

[14] R. Gutiérrez-González, G.R. Boto, M. Rivero-Garvía, Á. Pérez-Zamarrón, G. Gómez, Penetrating brain injury by drill bit, Clin Neurol Neurosurg. 110 (2) (2008) 207–210, https://doi.org/10.1016/j.clineuro.2007.09.014.

[15] J.F. Annegers, W.A. Hauser, S.P. Coan, W.A. Rocca, A Population-Based Study of Seizures after Traumatic Brain Injuries, N Engl J Med. 338 (1) (1998) 20–24, https://doi.org/10.1056/NEJM199801013380104.