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Original Article

Penetrating Head Injury by Stones: A Case Series and Review of the Literature Based on the Type of Injury

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BACKGROUND: Low velocity penetrating head injury (PHI) is uncommon. PHI due to a stone is rare and we report a case series with a systematic review of the literature.

OBJECTIVE: The aim of this study was to evaluate the clinical grade, grade of injury, type of injury and clinical outcome following penetrating head injury with stones.

PATIENTS AND METHODS: We included 4 patients from this series and 21 patients from the literature review. They are grouped into 7 patients with type I injury and 18 patients with type II injury, based on the mode of injury. Type I injury is when the stone hits the head and type II injury is when the head falls on the stone and gets injured. The severity of PHI was graded into 6 grades (grade 0 to grade 5) based on depth of injury. The clinical outcome was assessed based on Glasgow outcome scale.

RESULTS: The mean age was 22.6 years and 84% were males in the total 25 patients. The commonest cause of injury was road traffic accident (40%) and the commonest site of injury was the frontal region (60%). Most patients presented with mild head injury. Grade 4 was the most common grade of injury. There was a statistically significant difference noted in the clinical grade Glasgow coma scale (GCS) and outcome (p=0.03) between the two groups.

CONCLUSION: From the review of the literature, two types of PHI by stones can be concluded. Type I injuries were less common, more severe in the coma scale, injury grade, and had poor outcome compared to type II injuries.

KEYWORDS: Penetrating head injury, Grading of head injury, Head injury by stones.

INTRODUCTION

High-velocity penetrating head injury (PHI) is commonly seen with ballistic armed weapons. The primary pathology in high-velocity PHI is shock waves and cavitation due to high kinetic energy along with tissue laceration. The permanent cavity formed from high velocity PHI is generally greater than the projectile diameter. They are associated with a high rate of complications like infection, abscess, vascular injuries and mortality.[1]

Low-velocity PHIs are less common compared to high-velocity PHI and are commonly seen in self-inflicted wounds, accidents, assaults or at the workplace. The various foreign bodies reported to cause PHI are metallic, wooden, plastic objects and others. The primary pathology in low-velocity PHI is only tissue laceration, the size of which matches that of the projectile diameter. The outcome of these patients is better than high-velocity PHI.

Low-velocity PHI by a stone is even rare. Only a few case reports have been published till now.[2-6] We report a series of 4 patients with PHI due to stones along with a systematic review of the literature.

PATIENTS AND METHODS

We did a retrospective case study of all the patients with PHI due to stones at our institution from April 2014 to September 2019. The penetrating head injuries due to foreign bodies other than stones were excluded. The case records were studied for age, gender, time from injury to presentation, mode of injury, clinical grade based on GCS, size of the stone, location of the injury, computed tomography (CT) scan details of the injury, treatment given, operative findings and outcome, and all these details were tabulated.

All the patients were operated on, the wound was thoroughly washed with hydrogen peroxide and then povidone-iodine solution and was explored and the foreign body was removed. The depressed fracture fragments were taken out. Small bone pieces were discarded while large pieces were washed and replaced. Only one patient had a dural laceration and brain contusion. The contusion was evacuated. After haemostasis, the dural repair was done and scalp laceration was sutured. Post-operatively they were given intravenous antibiotics ceftriaxone and amikacin for 7 days.

A literature search was done in online pubmed search and Google search with the keywords "low-velocity penetrating craniocerebral injury", "low velocity penetrating head injury" and "penetrating head injury with stones". Relevant case reports were noted. We searched the cross references from those articles and finalized the total number of reported cases till now. The patients with PHI due to stones were taken from 4 case series excluding other patients with PHI caused by other objects. We could find out 21 patients from 17

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articles published till now, who had PHI due to stones. We have documented the same details as noted for our patients, according to the availability in the text. The four patients from our series were included and the results of the total 25 patients were analysed. Institutional ethical committee approval was taken, and consent was taken from all patients.

To note the severity of injury in all these patients, we followed a simple wound grading scale as documented in **Table 1.** The wound was graded as per the scale from the operative findings noted. The clinical grade of the patient was classified according to the Glasgow coma scale score as either severe (GCS 3–8), moderate (GCS 9–12), or mild (GCS 13–15). The outcome of the patient was noted based on the Glasgow outcome scale (GOS) at the end of the 6-month follow-up. GOS 4,5 were considered as good outcomes and GOS 1 to 3 were considered as poor outcomes.

The patients were divided into two groups based on mode of injury, one group consisted of the patients where the stone had hit the head, type I injury. The other group included the remaining patients where the head fell on the stone, type II injury. The clinical grade (GCS), size of the stone, grade of injury and outcome were compared between the two groups. The patients with injury grades 1, 2 and 3 were grouped into one group and grade 4 into another group for comparison. A chi-square test was done to analyse all these categorical variables. The p-value of < 0.05 was considered significant.

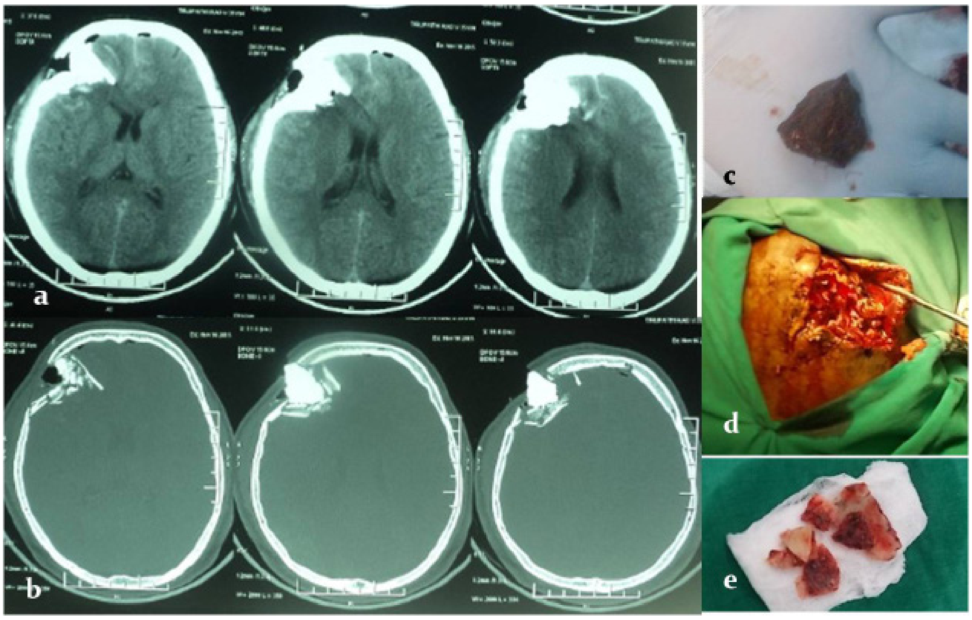

Fig 1: (A) CT Brain of patient 1 showing right frontal depressed fracture with foreign body insitu. (B) CT bone window of the same patient. (C) The foreign body was a stone. (D) It was taken out during surgery where debridement and elevation of depressed fracture was done. (E) The depressed bone fragments were shown.

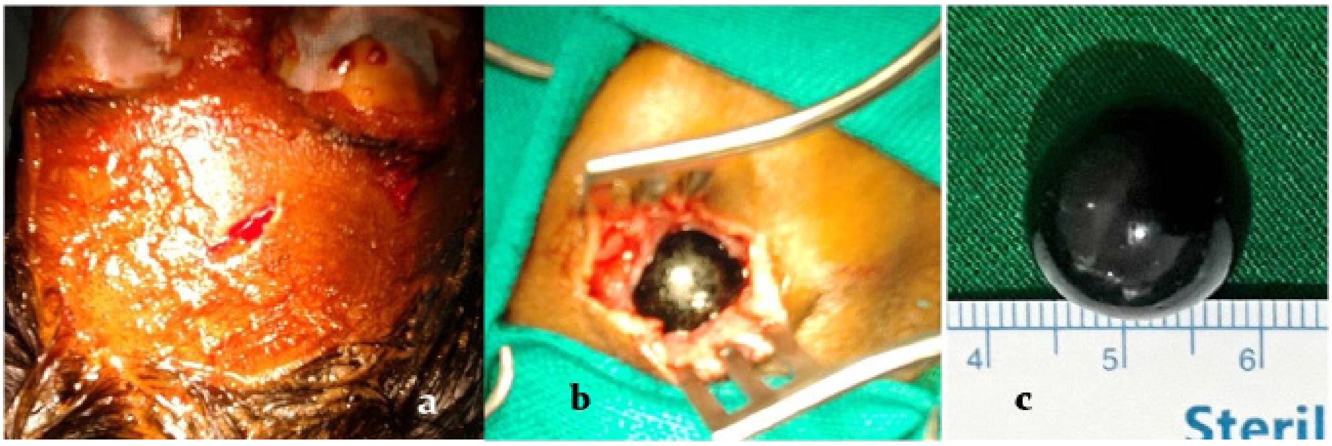

Fig 2: (A) A 7 year old boy (patient 3) had a fall while playing and presented with laceration on the forehead. (B) Exploration of the wound revealed a marble underneath the fractured frontal bone. (C) The marble was removed.

RESULTS

Present series:

The details of the four patients in this series are noted in **Table 2**. All the patients fell on the ground and landed on the stone which was the cause of the penetrating injury. The CT scan and operative pictures of patient 1 are shown in **(Fig. 1)** and those of patient 3 in **(Fig. 2)**.

The size of the stones which were the cause of the injury ranged from 1.2 to 4 cm. An underlying depressed fracture of the skull was noted in all patients. Only one patient had a dural laceration with underlying brain contusion (grade 4) and presented with GCS 14/15. All the remaining patients presented with GCS 15. All patients were operated by exploration, debridement and removal of the foreign body. All the patients did well and their wounds healed well. They were kept on regular follow up. No patient developed any complications. The mean follow-up period was 14 months.

Review of literature including the present series:

A total of 25 patients with PHI due to stones were included in the analysis. The age range was 2 to 70 years (mean 22.6 ± 15.37 years). Nine patients were in the pediatric age group (under 18 years). Twenty-one of them were males (84%) and only 4 were females (16%). The type I injury group consisted of 7 patients (28%) and the type II group included 18 patients (72%). The details of the patients with type I injuries were noted in **Table 3** and type 2 injuries in **Table 4.**

The cause of injury was road traffic accidents (RTA) in 10 patients (40%), fall on the ground in 8 patients (32%), workplace accident in 4 patients and assault, stone propelled from truck wheel, and slingshot in 1 patient each. The size of the stone that caused the injury ranged from 8 mm to 6.2 cm. The injury was noted on the right side in 13 patients, the left side in 9 patients and the midline in 3 patients. The location of injury was noted on the frontal region in 15 patients (60%), parietal region in 5 patients, temporal region and vertex region in 2 patients each, and suboccipital region in 1 patient. Out of the 15 patients with frontal region injuries, 6 patients had injuries on the forehead.

Out of a total of 25 patients, 17 patients (68%) presented with mild head injury, 2 patients with moderate and 3 patients with severe head injury. Two patients were brought dead to the health care centre. No information on clinical status was there regarding one patient. When the clinical grade (GCS) was compared between the two groups using a chi-square test, the result was statistically significant (p=0.03). Nearly 43% of type I injury patients presented in severe clinical grade compared to only 6% of type II injury patients **(Table 5).**

The severity of PHI was graded into 6 grades (grade 0 to grade 5) based on depth of injury **(Table 1).** All the reviewed patients had 0 to 4 grades of injury. Grade 4 was noted in 11 patients, grade 3 in 4 patients, grade 2 in 8 patients, grade 1 and grade 0 in 1 patient each. No patient had a grade 5 injury. Five of the 7 patients with type I injuries had grade 4 injuries (71%), whereas only 6 out of 18 patients with type II injuries had grade 4 injuries (33%). There was no significant correlation between type of injury and grade of injury (p=0.10). **(Table 5).**

Twenty patients underwent surgery and there was good outcome in 19 patients. One patient who underwent surgery died due to respiratory failure following aspiration pneumonia. Four patients did not undergo surgery, out of which two patients were brought dead to the hospital. One patient died in the emergency room and another patient died due to complication from PHI due to stone. Information regarding surgery was unknown in another patient.

In type I injury, 43% mortality (3 out of 7 patients) was observed compared to 6 % mortality (1 out of 16 patients) in type II injuries. Two patients were excluded during the evaluation of the outcome. One patient met with a fatal gunshot injury to the C2 cord followed by a fall on the ground and sustained PHI by stone. Another patient was excluded as the information regarding the outcome was unknown. There was a statistically significant correlation between the type of injury and the outcome when tested by a chi-square test (p=0.03) **(Table 5).**

There was a strong correlation between the clinical grade (GCS) and the outcome of the patient. This was confirmed when the data was analysed with a chi-square test (P=0.0008) **(Table 5).** When the size of the stone and the grade of the injury were correlated with the chi-square test as per the available data of 18 patients (p=0.06), the stones larger than 3 cm caused more number of grade 4 injuries **(Table 5).**

Table 1: Grade of penetrating head injury based on the depth of injury

Grade	Injury
0	Only scalp injury
1	Outer table of skull injured, inner table intact
2	Skull fracture (both outer and inner table involved)
3	Dural injury, Dural bleeds
4	Brain parenchymal injury
5	Intraventricular haemorrhage or intracranial vascular injury

Table 2: Details of all the patients in our series

No.	Age in years and gender	Time from injury to presentation	Foreign body	Location of injury	Details of injury	Surgery	Outcome
1	37, Male	3 hrs	Stone	Right Frontal	Depressed #, brain contusion	Exploration, debridement, removal of stone, elevation of depressed fracture	Good
2	35, Male	7 hrs	Stone	Temporo parietal	Depressed #, intact dura	Exploration and removal of the stone	Good
3	7, Male	2 hrs	Marble	Forehead (midline)	Depressed #, intact dura	Exploration and removal of the marble	Good
4	28, Famle	3 weeks	Stone	Forehead (left frontal)	Fracture of the outer table of frontal bone	Exploration and removal of the stone	Good

Table 3: Details of the patients in the literature with type 1 injury, where the stone hits the head

No.	Patient	Age in years, Gender	Mode of injury	Size of the stone (cm)	Clinical grade (GCS)	Grade of injury	Outcome
1	Bhootra and Bhana[4]	24, Male	Slingshot	2.2	Mild	4	Died
2	Chattopadhyay et al[5]	7, Female	Stone propelled from rear wheel of truck	2.6	Brought dead	4	Died
3	Balak et al[3]	9, Male	Stone from 7th floor fell on head	3	Mild	4	Good
4	Satyarthee et al[6]	28, Male	Knife sharpening stone broke during work	6.2	Severe	4	Good at 6 months
5	Moussa & Abbas pt 2 [7]	36, Male	Assault	NA	Mild	2	Good
6	Moussa & Abbas pt 4 [7]	20, Male	During construction	NA	Severe	4	Died
7	Kahveci et al[8]	10, Male	Whetstone broke during work	6	Mild	3	Good

NA – not available, pt - patient

Table 4: Details of the patients in the literature (including present series) with type 2 injury, where the head falls on the stone

No.	Patient	Age in years, Gender	Mode of injury	Size of the stone (cm)	Clinical grade (GCS)	Grade of injury	Outcome
1	Cina et al[9]	18, M	Fall onto ground	0.8	Brought dead	0	Victim of gunshot
2	Kiymaz and Yilmaz[10]	5, M	RTA	1.8	Moderate	3	Good
3	Sharma et al[11]	NA, M	Fall from running train	NA	NA	4	NA
4	Alafaci et al[2]	19, M	RTA	5	Mild	4	Good
5	Kataria et al pt 1 [12]	2, M	Fall from height	2.6	Mild	3	Good
6	Kataria et al pt 2 [12]	5, M	Fall from height	2	Mild	3	Good
7	Patibandla et al [13]	35, M	RTA	3	Mild	2	Good
8	Bhat et al[14]	4, M	Fall from height	1	Mild	2	Good
9	Moussa & Abbas pt 1 [7]	27, M	RTA	NA	Mild	2	Good
10	Moussa & Abbas pt 3 [7]	23, M	RTA	NA	Mild	4	Good
11	Jha et al [15]	22, F	RTA	3.5	Mild	4	Good
12	Triphati et al[16]	32, M	RTA	1.8	Mild	2	Good
13	Chowdhury et al [17]	40, F	Accidental fall	NA	Moderate	4	Good
14	Koko & Lasseini pt [18]	70, M	RTA	NA	Severe	2	Poor
15	pt 1 (present)	37, M	RTA	4	Mild	4	Good
16	pt 2 (present)	35, M	RTA	3	Mild	2	Good
17	pt 3 (present)	7, M	Fall while playing	1.5	Mild	2	Good
18	pt 4 (present)	28, F	Fall on the ground	1.2	Mild	1	Good

NA – not available, RTA – road traffic accident, pt - patient

Table 5: Statistical results of different categorical variables compared by Chi-square test

Variable		Type I injury (missile type)	Type 2 injury (non missile type)	p- value
Clinical grade (GCS) (n=23) †	Mild -moderate	4	15	**0.03**
	severe	3	1	
Grade of PHI (n=24)	1 to 3	2	12	0.08
	4	5	6	
Outcome based on GOS (n=23) †	Good	4	15	**0.03**
	Poor	3	1	
		Good outcome	**Poor outcome**	
Clinical grade (GCS) (n=23) †	Mild-moderate	18	1	**0.0008**
	severe	1	3	
		Injury grade 1 to 3	**Injury grade 4**	
Size of stone (n=18) *	≥3 cm	3	5	0.06
	<3cm	8	2	

† the data was not there in one patient and another patient excluded as he died from gunshot injury

* The data regarding the size of the stone was not known in 7 patients.

DISCUSSION

Commonly the injury occurres due to a fall of the patient on to a stone lying on the ground during a road traffic accident or fall while playing or working. This was noted in all the patients of our series. The other mode of injury noted was an accident at workplace, fall of an object from a height, slingshot, assault by stone, etc. So it was either stone hitting the head or the head hitting the stone. The type of injury is important to note as the severity of the injury and outcome depend on it.

We propose two types of PHI by stones based on the type of injury. The low-velocity PHI where a stone hits the head is termed type I (missile) injury which are less common and more severe in grade. The stone is the moving object in the type I injury. A missile is an object which is forcibly propelled at a target, either by hand or from a mechanical weapon. We can consider type I injury as a missile type. The injuries where the head falls on the stone are called type II (non-missile) which are more common and less severe. The head is the moving object in type II injury.

The kinetic energy (KE) is directly proportional to the velocity and the weight of the object. The KE of an object depends more on its velocity than its weight as per the formula KE=1/2mv2. The velocity of the moving stone in the type I injury is more than the velocity of the moving head in the type II injury. The more kinetic energy of the missile stone is responsible for the severe injury in type I injury. The potential energy which is dependent on the weight of the object (head) is more important than the kinetic energy in type II injury.[14] The same result is reflected in the outcome as 43% of type I injury patients had mortality compared to less than 6% of type II injury patients. The factors responsible for the severity of the PHI are kinetic energy, velocity of moving object, weight, shape of the object, depth of penetration, infective nature of the foreign body, etc.[14,19]

In general, patients with PHI due to stones had less number of complications compared to PHI patients due to other causes. No early complications of seizures and infection were noted after surgery in this review however late complications cannot be ruled out as there was no long-term data on these patients. The incidence of late-onset epilepsy following PHI rises with an increase in follow-up. This was noted by Salazar et al., in their study of epilepsy after PHI, that the overall seizure occurrence was 34% at 5-year follow-up and increased to 53% at 15-year follow-up.[20]

Intracranial infection was one of the most common complications in penetrating head injuries resulting in poor outcome in certain patients. The incidence of the infection varies with the nature of the foreign body, the presence of associated organic material like skin, hair, mucosa, etc., crossing of the air sinuses, and associated cerebrospinal fluid (CSF) fistula. The incidence was noted to be highest, up to 50%, in the patients of PHI with wood.[21] Even though the penetrating object was non-organic (knife, nail etc.,), the incidence was as high as 33% noted in the study by Abdelhameid and Saro.[22] In the present study, there were 2 out of 25 patients who developed infection, the incidence being 8%. This incidence was among the least in low-velocity PHI. Prophylactic broad-spectrum antibiotics were advised by many authors for 1-2 weeks postoperatively to prevent infection.[22]

Vascular injuries which were reported in PHI by various sharp objects were not noted in this review. They were unlikely to be seen in PHI by stones as stones were relatively blunt and might not cause too deep injuries. In the study of 42 patients of PHI with wood by Miller et al, the overall mortality was 25% and surgical mortality was 10%.[21] In our review, overall mortality was 16% (4 out of 25 patients) and surgical mortality was 5% (1 out of 20 operated patients). Out of 4 deaths, 3 patients were of severe head injury and 1 patient was of mild head injury.

The recognition of the foreign body in the wound was missed by the primary health care physician who had done suturing in two patients of our series. This was noted in other studies also.[4,13,15,16] They had serious consequences ranging from wound infection to mortality.[4,16] The treating physician should have high degree of suspicion to identify the foreign body particularly in seemingly simple scalp wounds. This was highlighted by Fowler et al., in their case report.[23] So the wound has to be reopened, debrided and washed thoroughly if there is any suspicion in the radiographs taken, even if the already sutured wound appears good.

Even if the wound appears clinically as an isolated scalp injury, either already sutured or not, with no history of loss of consciousness or vomiting or seizures and no neurological deficit, it is always advised to do at least X-ray skull anteroposterior and lateral views. They help to rule out any foreign bodies, gravel particles, and sometimes small and subtle penetrating injury. Generally, the basic investigation of any head injury is X-ray skull AP and lateral views for the sake of the medicolegal aspect in the court of law. It is obvious to do a straight away CT scan head in case of a gross wound with suspected underlying fracture irrespective of GCS.

Limitations: As the data was retrieved retrospectively in some patients, there were irregularities in the uniformity of data. Many of them were corrected by following a protocol like a grading scale for injury. There was some missing data in the previously reported articles which interfered with the data analysis. Overall the number of patients was less, due to the rarity of the cause. The shape of the stone, weight and velocity of the object can not be studied as the information was unavailable in many papers.

CONCLUSION

The low-velocity PHI due to stones are rare, we reported a series including four patients of PHI by stones. From the review of the literature, two types of PHI by stones can be concluded. Type I (missile type) injuries were less common, more severe in GCS, injury grade and have poor outcome compared to type II (non-missile type) injuries.

List of abbreviations

CT: Computed tomography.
CSF: Cerebrospinal fluid.
GCS before GOS.
GCS: Glasgow coma scale.
GOS: Glasgow outcome scale.
KE: Kinetic energy.
PHI: Penetrating head injury.
RTA: Road traffic accident.

Disclosure

The authors report no conflict of interest in the materials or methods used in this study or the findings specified in this paper.

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REFERENCES

1. Ozkan U, Kemaloglu S, Ozates M, Aydin MD. Analysis of 107 civilian craniocerebral gunshot wounds. *Neurosurg Rev*. 2002;25(4):231–236.

2. Alafaci C, Caruso G, Caffo M, et al. Penetrating head injury by a stone: Case report and review of the literature. *Clin Neurol Neurosurg.* 2010;112(9):813-816.

3. Balak N, Aslan B, Serefhan A, Elmaci I. Intracranial retained stone after depressed skull fracture: Problems in the initial diagnosis. *Am J Forensic Med Pathol.* 2009;30(2):198-200.

4. Bhootra BL, Bhana BD. An unusual missile-type head injury caused by a stone: Case report and medicolegal perspectives. *Am J Forensic Med Pathol.* 2004;25(4):355-357.

5. Chattopadhyay S. Accidental low velocity atypical missile injury to the head. *Am J Forensic Med Pathol.* 2008;29(4):334–336.

6. Satyarthee GD, Borkar SA, Tripathi AK, Sharma BS. Transorbital penetrating cerebral injury with a ceramic stone: Report of an interesting case. *Neurol India.* 2009;57(3):331-333.

7. Moussa WM, Abbas M. Management and outcome of low velocity penetrating head injury caused by impacted foreign bodies. *Acta Neurochir. (Wien)* 2016;158(5):895-904.

8. Kahveci R, Gokce EC, Ozdek R. Penetrating head injury by a knife whetstone. *World J Surg Surgical Res.* 2018;1:1005.

9. Cina SJ, Gelven PL, Nichols CA. A rock in a hard place. A brief case report. *Am J Forensic Med Pathol.* 1995;16(4):333-335.

10. Kiymaz N, Yilmaz N. Penetrating intracranial stone. *Pediatr Neurosurg.* 2005;41(3):145-157.

11. Sharma A, Diyora B, Shah S. Stone in the brain. *Indian J Neurotrauma*. 2006;3:149.

12. Kataria R, Singh D, Chopra S, Sinha VD. Low velocity penetrating head injury with impacted foreign bodies in situ. *Asian J Neurosurg.* 2011;6(1):39–44.

13. Patibandla MR, Thotakura AK, Panigrahi MK, Paniraj GL. Traumatic calvarial stone: A rare case report and review of the literature. *Neurol India.* 2011;59(6):938-940.

14. Bhat R, Raswan US, Kirmani AR, Choudhary NK, Sarmast AH. Reverse-penetrating head injury caused by falling on sharp-edged stone: A case report. *Indian J Neurotrauma.* 2015;12(1):80–83.

15. Jha AK, Kumar J, Harsh V, Kumar A. Penetrating injury of the posterior cranial fossa by a stone. *Neurol India.* 2016;64(5):1081-1082.

16. Triphati A, Singh A, Verma SR, Srivastava A, Chaudhary P. Low velocity penetrating frontal bone injury with a stone: *An interesting case report. Indian J Anat Surg Head, Neck Brain.* 2016;2(4):110-111.

17. Chowdhury FH, Haque MR, Hossain Z, et al. Nonmissile penetrating injury to the head: Experience with 17 cases. *World Neurosurg.* 2016;94:529-543.

18. Koko AM, Lasseini A. Impalement brain injury: Report of five consecutive clinical cases. *Egypt J Neurosurg.* 2020;35:35.

19. Kazim SF, Shamim MS, Tahir MZ, Enam SA, Waheed S. Management of penetrating brain injury. *J Emerg Trauma Shock*. 2011;4(3):395–402.

20. Salazar AM, Jabbari B, Vance SC, Grafman J, Amin D, Dillon JD. Epilepsy after penetrating head injury, I. Clinical correlates: A report of the Vietnam Head Injury Study. *Neurology.* 1985;35(10):1406-1414.

21. Miller CF, Brodkey JS, Colombi BJ. The danger of intracranial wood. *Surg Neurol.* 1977;7(2):95-103.

22. Abdelhameid AK, Saro A. Non-missile penetrating brain injuries: Cases registry in Sohag University Hospital. *Egypt J Neurosurg.* 2019;34:24.

23. Fowler TR, Crellin SJ, Greenberg MR. Detecting foreign bodies in a head laceration. *Case Rep Emerg Med.* 2015;2015:801676.