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CASE REPORT

Neuroanesthesia Management in Pediatric with Traumatic Brain Injury Due to Gunshot Wound

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Abstract: Traumatic brain injury (TBI) in the pediatric population is a major cause of morbidity and mortality. Between various etiologies of TBI, gunshot wounds occupy a unique characteristic and apprehensive place. We report a clinical case of a TBI due to a gunshot wound in Indonesia. A 4-year-old girl complained of a painful head and vomiting after sustaining a gunshot wound to the head. The patient was presented with a pediatric Glasgow Coma Scale (pGCS) score of E3V4M5 and was hemodynamically stable Multislice computerized tomography (MSCT) revealed a bullet lodged in the left temporal lobe, a subdural hematoma in the left frontoparietal-temporooccipital, an intracranial hemorrhage in the left temporoparietal region, and a midline shift to the right by 0.7 cm. The patient underwent craniotomy for subdural hematoma evacuation and bullet evacuation. Stable hemodynamics and brain relaxation conditions were achieved during surgery. Postoperative recovery in the pediatric intensive care unit (PICU) was uneventful, and the patient was discharged with improved neurological status (pGCS E4V5M6) without complications. The case highlights the successful management of a pediatric patient with traumatic brain injury due to a gunshot wound through a multidisciplinary and tailored approach focusing on hemodynamic stability, intracranial pressure management, early posttraumatic seizure, and infection prophylaxis to ensure a positive outcome. Given the scarcity of reported cases in low- and middle-income settings, this report provides valuable insights into the optimal management of pediatric gunshot-related TBIs.

Keywords: gunshot wound, neuroanesthesia, pediatric, traumatic brain injury

Introduction

In low- and middle-income countries, pediatric traumatic brain injury is the leading cause of death and disability, making it a worldwide health concern.[1,2] Among the various etiologies of traumatic brain injury, gunshot wounds occupy a special and concerning place because of their sudden and often severe nature. A thorough and cautious approach is necessary for the anesthetic management of pediatric patients with traumatic brain damage from gunshot wounds, taking into account the unique physiological and anatomical needs of children as well as the complexity of the trauma they have experienced.[3]

Neuroanesthesia management requires a thorough understanding of intracranial dynamics, especially in maintaining optimal intracranial pressure and cerebral perfusion.[4] Children have different physiological reservations compared to adults, including smaller blood volume, different hemodynamic responses, and a higher risk of changes in intracranial pressure due to head trauma.[5] Therefore, the anesthetic approach must be adjusted to minimize the risk of increased intracranial pressure and maintain hemodynamic stability. The management of neuroanesthesia in children suffering from gunshot wounds-related traumatic brain injury will be presented in this case study.

Case

A 4-year-old girl weighing 20 kilograms and 120 cm tall complained of headache after being shot by a rifle about 2 hours before being taken to the hospital. The patient did not faint but complained of vomiting once with brownish vomit mixed with rice. Currently, the patient's consciousness tends to be sleepy 30 minutes after being shot in the head. The patient did not complain of cough and runny nose. The patient has not previously been afflicted by any diseases.

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The patient was found apathetic upon physical examination with a pediatric Glasgow Coma Scale (pGCS) E3V4M5. Blood pressure was measured at 84/52 mmHg, pulse and respiration rates were 72 and 20 beats per minute, respectively, and the patient's body temperature was 36.6 °C with 99% oxygen saturation (SpO2) on room air. The airway was clear and the neck movement was possible. Mesocephalic head size, no lumps. In the eyes, there was no anemic conjunctiva or icteric sclera, the diameter of the right and left pupils was 3mm, and light reflexes and corneal reflexes were positive in both eyes. Physical examination of the nose, mouth, neck, lungs, heart, abdomen, and extremities revealed no abnormalities. The patient had a urinary catheter installed with a product of > 0.5 mL/kg/hour.

Routine hematology laboratory results, coagulation function, kidney function, and electrolytes were within normal limits (Table 1). Thoracic imaging showed no abnormalities in the heart and lungs. A subdural hematoma was discovered in the left frontoparietal-temporooccipital region on March 30, 2024, during the latest non-contrast Multislice Computerized Tomography (MSCT) examination of the head. The lesion appeared to be pressing and narrowing both the anterior and posterior horns of both of the lateral ventricles, causing a midline shift to the right by 0.7 cm, as well as an intracranial hemorrhage in the left temporoparietal region. The MSCT examination of the head (Figure 1) showed a picture of a bullet foreign body in the left temporal lobe with an entrance wound in the left parietal bone with an estimated distance from the entrance wound measuring 6.14 cm × 3.75 cm (sagittal - coronal). The patient was identified as having subdural hematoma, vulnus-sclopetorum of the left parietal region, and moderate traumatic brain injury. A craniotomy for subdural hematoma evacuation and bullet corpus evacuation was planned.

The patient was preoxygenated and airway patency was maintained. An arterial line was inserted under local anesthetic on the right radial artery to measure arterial blood pressure in real-time after given a light sedation. Additionally, pulse oximetry, end-tidal carbon dioxide (EtCO2), and a 5-lead electrocardiogram (ECG) were used to monitor the patient. The patient was induced using midazolam 0.05 mg/kg, dexamethasone 0.1 mg/kg, fentanyl 1.5 µg/

Table 1 Preoperative and Postoperative Blood Test Results

Variables	Preoperative (30 March 2024)	Postoperative (31 March 2024)
Hb (g/dl)	10.6	10.5
Ht (%)	30	29
Leu (10^3/mm^3)	15.6	13.7
Plt (10^3/mm^3)	298	255
AE (10^3/mm^3)	3.95	3.57
PT (second)	16.6	–
APTT (second)	29.0	–
INR	1.220	–
Ur (mg/dl)	15	–
Cr (mg/dl)	0.3	–
Na (mmol/L)	143	137
K (mmol/L)	4.2	4.3
Cl (mmol/L)	110	109

Abbreviations: Hb, Hemoglobin; Ht, Hematocrit; Leu, Leukocytes Count; Plt, Platelets Count; AE, Erythrocytes Count; PT, Prothrombin Time; APTT, Activated Partial Thromboplastin Clotting Time; INR, International Normalized Ratio; Ur, Ureum; Cr, Creatinine; Na, Natrium; K, Potassium; Cl, Chloride.

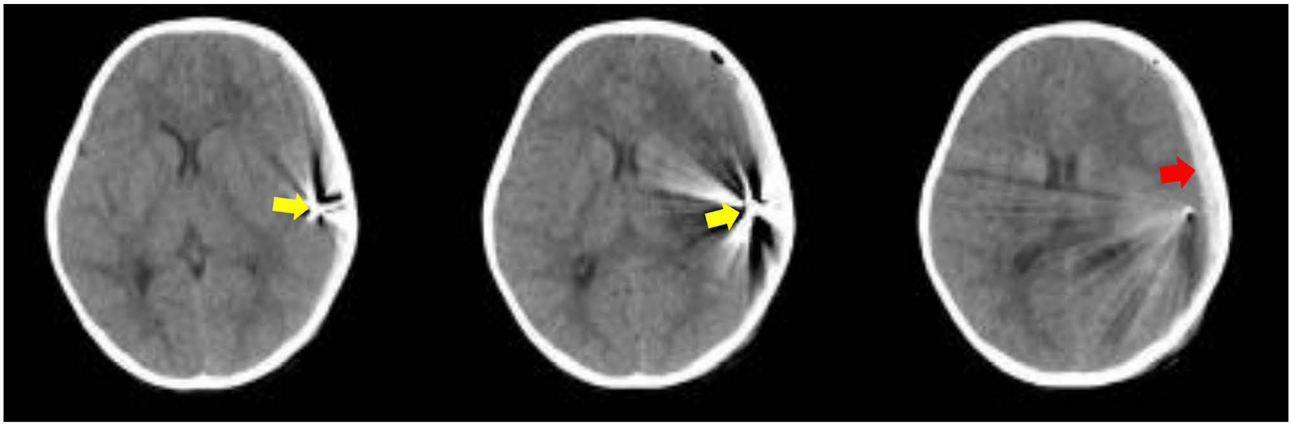

Figure 1 Multislice computed tomography revealed a bullet foreign body in the left temporal lobe (yellow arrow) and subdural hematoma (red arrow).

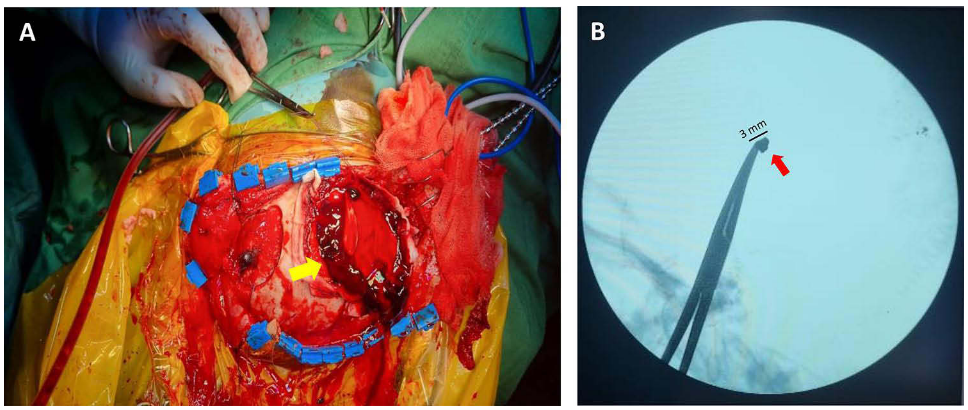

Figure 2 Intraoperative clinical findings showed subdural hematoma (yellow arrow) due to gunshot wound (**A**). Image of bullet (red arrow) viewed through the C-arm (**B**).

kg, and propofol 1 mg/kg intravenously. Neuromuscular blockade was achieved with rocuronium 15 mg. Intubation was performed using a reinforced endotracheal tube (ETT) no. 5.0 with a depth of 16 cm.

The patient was in a left oblique and reverse Trendelenburg 30° position. The anesthesia was maintained with 50% O_2, air bar, sevoflurane, and rocuronium 10 μg/kg/min. Additional fentanyl was administered 10 μg before scalp incision and cranium drilling. About 20 minutes before the end of the surgery, ondansetron 0.1 mg/kg and metamizole 15 mg/kg were given intravenously. The surgery lasted for 3 hours. Total fluid input was 572 mL (drugs 21 mL, fluids 350 mL, packed red cells 201 mL), while total fluid output was 500 mL (urine 250 mL, and bleeding 250 mL). Surgical findings showed a bullet corpuscle in the left temporoparietal (Figure 2), then corpus extraction, subdural hematoma evacuation, and decompression were performed. The patient's hemodynamics were stable during surgery (Figure 3). Hemodynamics during surgery were blood pressure 90–100/50–70 mmHg, pulse 90–110 beats/minute, SpO2 100% on ETT 5.0 depth 16 cm, on Ventilator SIMV PCG-VG, PEEP 4 FiO2 60%, VT 130, Psupp 7, rate 16. The patient was moved to the pediatric intensive care unit (PICU) while intubated.

Postoperative care was carried out in the PICU for two days. Postoperative medication used tranexamic acid 200 mg q8h, metamizole 300 mg q8h, ranitidine 20 mg q12h, mannitol 50 mg q8h, and phenytoin 50 mg q12h. During the two days of PICU care, the pGCS improved, no seizures, neurological deficits, and other complications were observed. The patient was admitted in the ward for three days without any complications and then discharged with pGCS E4V5M6.

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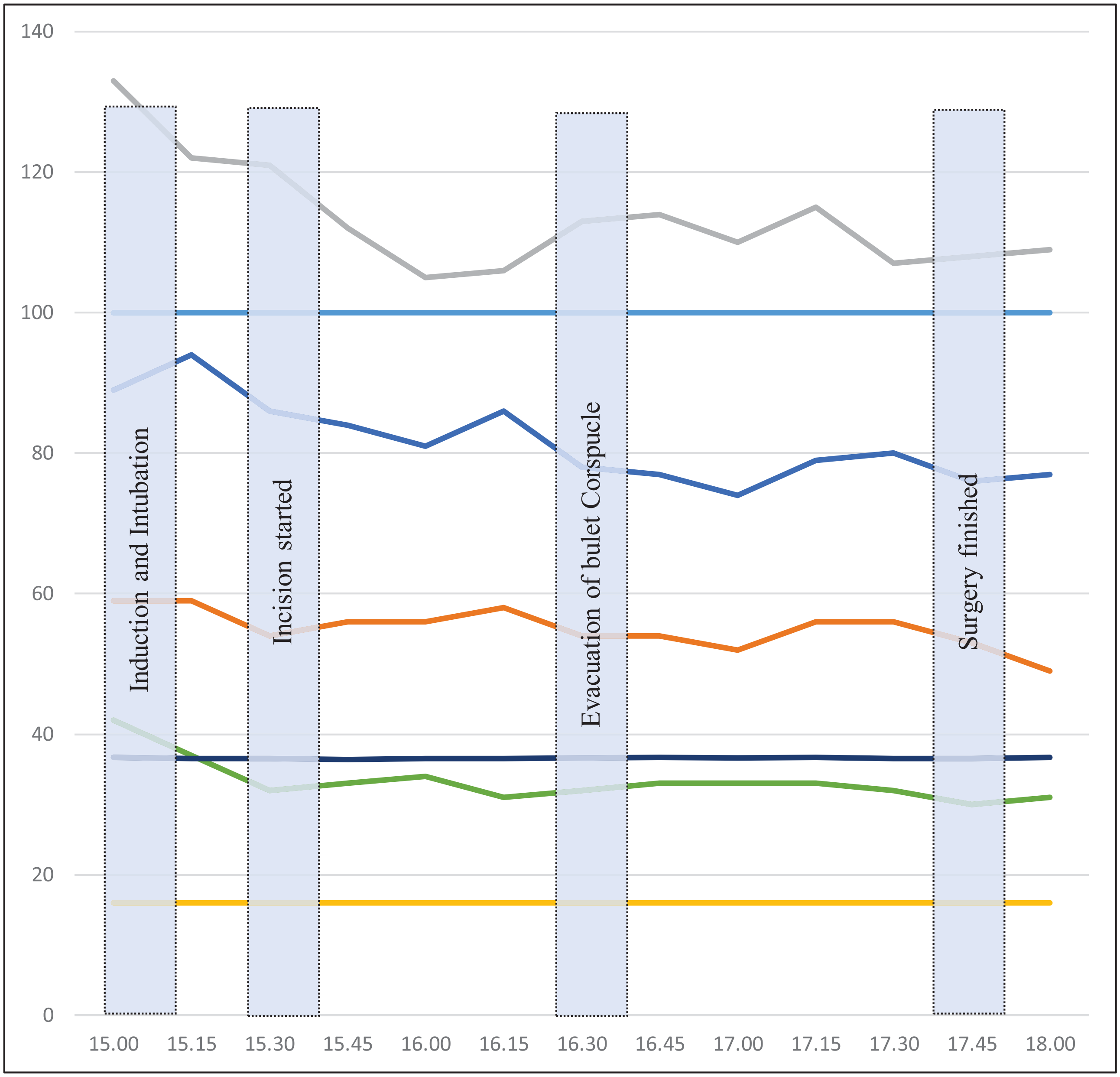

Figure 3 Intraoperative vital sign monitoring, encompassing parameters such as systolic blood pressure (blue line), diastolic blood pressure (Orange line), heart rate (grey line), respiration rate (yellow line), peripheral capillary oxygen saturation (light blue line), end tidal CO2 (green line), and temperature (dark blue line).

Discussion

Children between the ages of one and eighteen are at a heightened risk of death and impairment due to traumatic brain injury (TBI). This disorder is a result of a mechanical blow to the head impairing normal brain function. According to the Glasgow Coma Scale (GCS), traumatic brain injury is categorized as mild, moderate, or severe and can be lethal. Gunshot wounds to the head have a high mortality rate of over 90% in adults and a lower rate of about 65% in children. Prior to hospitalization, the highest death rate is between 70–90%, and half of the survivors pass away during emergency department resuscitation. As a result, due to a lack of training and research, neurosurgeons and anesthesiologists find it extremely difficult to treat penetrating gunshot head injuries, particularly in pediatric patients.[5] Until now, there have only been few reports of penetrating gunshot head injuries in children in Indonesia.

The differing anatomy of the child's brain making them more susceptible to damage from trauma. Open fontanels and undivided sutures provide some flexibility against increased intracranial pressure but also make the brain more vulnerable to severe injury. However, the small cranial volume makes children more susceptible to brain herniation once compensation is exhausted. The smaller brain mass and larger ratio of head surface area to body volume also contribute to an increased risk of primary and secondary brain injury.[6] Secondary brain injuries are often more devastating than primary brain injuries and require immediate medical intervention to prevent further brain damage.[7]

Traumatic brain injury due to bullet trauma is one of the complex forms of brain injury. Gunshot wounds to the head can cause extensive brain damage due to the high kinetic energy of the bullet which causes extensive tissue damage, including hemorrhage, edema, and necrosis. Management of this case requires a multidisciplinary and very careful approach to increase the chances of survival and recovery of the patient. Peak death from craniocerebral gunshot wounds typically happens at the scene of the wound or in the first three hours following the wound.[8]

Ballistic characteristics such as kinetic energy, projectile mass, velocity, shape, angle of approach, properties of the tissue passed through, and the formation of secondary projectiles such as metal or bone fragments determine an object's capacity to enter the brain and cause primary brain injury.[8] Air rifles are categorized as low-velocity missiles (<300 m/s), but they can penetrate the skull. The bullets fired tend to have a smaller mass, so they have greater kinetic energy and higher velocity that can significantly impact brain tissue. Arteriovenous fistulas, cerebral contusions, pseudoaneurysms, and cerebrospinal fluid leaks are all linked to penetrating and perforating brain traumas. Gunshot wounds will result in permanent cavitation of the brain tissue directly in the path of the projectile, exacerbated by sonic waves followed by pressure waves that cause temporary cavitation. Expansion of this temporary cavity causes hemorrhage and disruption of the neural membrane. As a result, intracranial pressure will increase along with the enlargement of the hematoma and increasing edema. The presence of a higher water content in the child's brain renders them more susceptible to brain edema.[9,10]

When a bullet passes through tissue, it causes immediate distension and subsequent tissue rupture, which is known as direct injury. The creation of a cavity along the projectile's path that corresponds to the damaged tissue's core region happens next. Without direct contact between the bullet and the tissue, indirect injury arises in the form of a shock wave and stretch cavity. The tissue around the bullet tunnel is temporarily damaged by the radial stretching of that tissue, which also damages nearby tissue. As the bullet travels through the body, the bullet's leading edge, where the point of maximum pressure is located, creates a pressure wave that moves quickly ahead.[11]

Gunshots that enter the dura and skull without leaving an exit wound are referred to as penetrating wounds; in contrast, a perforation-type missile enters the dura and skull and leaves by leaving an exit wound. When a missile strikes the skull at an oblique angle, it can only lacerate the scalp or stay under it, resulting in elevated or depressed fractures. Bone fragments that are forced into the brain parenchyma can cause cortical bruises, dural violations, and extradural or subdural hematomas.[8]

MSCT head examination is commonly utilized to assess cases involving penetrating head trauma, particularly when there is suspicion of bullet fragments remaining in the brain parenchyma. This type of examination has significantly enhanced the ability to identify missile fragments and bones, characterize projectile trajectories, assess the extent of brain injury, and detect existing intracranial hematomas. When dealing with acute craniocerebral gunshot trauma, it is generally not advisable to perform a magnetic resonance imaging examination due to its time-consuming nature and potential risk when dealing with retained ferromagnetic objects that may cause movement due to magnetic torque.

When it comes to the acute management of pediatric gunshot head injuries, the first step involves basic stabilization using a resuscitation protocol, which includes assessing and managing the airway, breathing, and circulation. It is imperative to achieve and sustain perioperative hemodynamic stabilization in pediatric patients with TBI, as the narrower range of cerebral blood flow (CBF) autoregulation renders them more vulnerable to hemodynamic deterioration. Moreover, higher cerebral metabolic rate of oxygen ($CMRO_2$) levels in pediatrics increase the risk of brain ischaemia, particularly in the absence of adequate oxygen supply. An immediate resuscitation with bleeding control and management of increased intracranial pressure is necessary, along with four steps in the care process: debridement of contaminated, macerated, or ischemic tissue to prevent infection; prevention of meningococcal scarring to preserve nerve tissue; and restoration of the anatomical structure by creating an airtight seal on the dura and scalp layers.[8] When the patient arrived at the emergency room, resuscitation was started, and it was decided that a craniotomy was required as part of comprehensive patient treatment in order to remove the bullet and clear the subdural hematoma. The

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administration of drugs with neuroprotective properties was utilized. The titration of dosage, the employment of drug combinations, and arterial blood pressure monitoring serve to further mitigate the impact of hemodynamic deterioration.

Irrigation, debridement of devitalized cell tissue, and removal of hematoma, infiltrated bone, and accessible bullet pieces are among the surgical techniques that can be used.[8] Infants and children with head traumas may benefit from decompressive craniectomy as a first and last resort. Local debridement and watertight closure can be used to treat penetrating injuries if there is little or no cerebral mass effect.[10] In this instance, a bullet foreign body was discovered in the area where the gunshot wound-induced a subdural hemorrhage in the left temporoparietal region.

Broad-spectrum antibiotics should be used when a patient has been shot in the head. The presence of foreign bodies, bone fragments, infected skin, and hair in the projectile's path increases the likelihood of cerebral infection in gunshot brain injuries. Antimicrobial medicines used for prophylaxis in penetrating brain trauma vary widely; according to a survey conducted by American Neurosurgical Practice, 87% of neurosurgeons took cephalosporins, 24% had chloramphenicol, 16% used penicillins, and 12% took aminoglycosides.[12] A lower rate of subsequent cerebral infection was linked to antibiotic prophylaxis in patients receiving shrapnel removal, wound debridement, and watertight dural closure. In this case, the patient was given an Ampicillin Sulbactam injection of 25 mg/kg as a prophylactic antibiotic and an Ampicillin Sulbactam injection of 25 mg/kg q6h as a postoperative antibiotic.

Approximately 30 to 50% of patients with penetrating brain trauma experience seizures, approximately 4–10% of whom experience their first seizure within the first week and 80% within the first two years, but the risk decreases over time. Anticonvulsant drugs in the first week after penetrating brain trauma in pediatrics are recommended due to the heightened risk of early post-traumatic seizure (PTS), attributable to the immaturity of inhibitory neurotransmitters.[2] Prophylactic treatment with anticonvulsants after the first week after penetrating brain trauma has not been proven to prevent the development of new seizures and is not recommended. Previous study had not shown a significant correlation between remaining fragments and post-traumatic epilepsy.[13] In this case, Phenytoin (5 mg/kg q12h) was given as seizure prophylaxis, and no seizures were found in the perioperative period.

After surgery, the patient underwent two days of care in the PICU. The patient was extubated 12 hours after surgery. During the treatment period, there were no complications such as decreased consciousness, postoperative nausea and vomiting, seizures, and other neurological disorders. After extubation and the patient was fully conscious, a consciousness examination, neurological examination, hemodynamic monitoring, and periodic pain scale examination were performed. The patient was discharged after three days of hospitalization without any additional complaints or neurological deficits.

Conclusion

The successful management of the pediatric patient with traumatic brain injury due to gunshot wound highlights the importance of a multidisciplinary approach and requires a tailored approach, considering their unique physiological and anatomical characteristics. The anesthetic and surgical strategies employed-focusing on hemodynamic stability, intracranial pressure management, early posttraumatic seizure, and infection prophylaxis proved essential in ensuring a favorable postoperative outcome. Given the rarity of pediatric gunshot-related traumatic brain injuries, this case contributes valuable insights into optimal perioperative care, emphasizing the importance of rapid resuscitation, meticulous surgical planning, and vigilant postoperative monitoring.

Ethics and Consent Statement

An institutional review board approval is not required for publishing the case details.

Informed Consent

Written informed consent was obtained from the patient (her parents) for anonymized information to be published in this article.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, execution, analysis and discussion, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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