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Penetrating Paediatric Traumatic Brain Injury: Lessons From The Surgical And Medical Management Of Penetrating Cranial Injuries With Wood In Rural Kenya

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ABSTRACT

BACKGROUND: Penetrating cranial injury with wood is a rare injury that can be difficult to detect and has few treatment guidelines. Cases in rural Africa face limited access to the specialized care required to avoid adverse outcomes. Two pediatric cases emphasize the value of neurosurgical expertise in surgical and medical management of this complex and uncommon injury. **OBSERVATIONS**: In these cases, the nature and severity of the injuries were missed by family members (case 1) or clinicians (case 2) until several days after the injury. Wood is known to harbor numerous microorganisms due to its porosity, and is considered a contaminated foreign body. Thus, direct inoculation of the cranium by wood and debris led to the delayed formation of abscesses despite prophylactic antimicrobial therapy and extraction of wood fragments in both cases. **LESSONS**: Penetrating traumatic brain injury from wood requires special attention due to the risk of delayed presentation and recurrent infection despite initial surgical washout and foreign body removal. Surgeons should anticipate the possibility of polymicrobial infection requiring multiple washouts before definitive infection control is achieved and continue monitoring the patient with clinical and imaging follow-up. There is value in exploring specific treatment algorithms with appropriate antimicrobial regimes.

KEYWORDS: pediatric, penetrating-traumatic-brain-injury, wood foreign body, delayed presentation.

INTRODUCTION

Penetrating traumatic brain injury from wood is uncommon. It is of particular interest in the developing world, where it can occur in pediatric patients after a fall from a tree. It is challenging to manage due to delayed presentation, need for collateral history, the

subtle imaging appearance of wood fragments and recurrent abscess formation after surgical intervention. Literature from the developed world on penetrating traumatic brain injury mainly emphasizes metallic projectiles such as; - bullets, shrapnel, knives, nails and other such missile/metallic objects (Table 1).

Penetrating injury from wood provides greater clinical complexity than metal as it is known to harbor a myriad of microorganisms due to its porosity[9,10]. There is little guidance in the literature for appropriate antimicrobial regimes for cases of intracranial wood penetration. In these case studies, we share our experience managing two patients from a rural hospital in Kenya elucidating the presentation, strategies for management, prognosis and clinical course.

ILLUSTRATIVE CASES

Case 1

A 9-year-old boy presented with a mild neck stiffness, headaches, mild photophobia and fever for one week. Patient reports falling from a tree and landing on a sharp piece of wood one week ago (Fig 1b). He also presented with a clear liquid dripping from his nose, clinically determined to be cerebrospinal fluid (CSF) rhinorrhea. He underwent computed tomography (CT) of the brain without and with contrast which showed a foreign body containing air density in the anterior cranial fossa extending into the left frontal lobe with a fracture of the left cribriform plate (Fig 1a, b). The presumed mechanism of injury was sudden forceful cranially-directed penetration of a wood fragment through the nasal cavity. This fractured the ethmoid sinus and cribriform plate, terminating in the left frontal lobe (Fig 1c). The lack of a clear superficial injury contributed to the delayed presentation, as the patient's family did not readily appreciate the severe nature of the intranasal injury.

The patient was started on intravenous broad-spectrum antimicrobials and taken to the operating room for transnasal endoscopic extraction of the foreign body (Fig 2b) with autologous duroplasty by the neurosurgical team. For the first 10 days, the patient had an improving post-operative course, but headaches returned with increased irritability and lethargy. A repeat head CT without and with contrast revealed a large left frontal abscess with surrounding edema resulting in midline shift and compression of the anterior horn of the lateral ventricles (Fig 3a, b). He was subsequently taken in for a left supraorbital craniotomy with drainage of the abscess and repeat duroplasty. Intraoperatively, greater than 20 mL of purulent material containing one small piece of wood and two bony fragments were drained. The cultures were negative. After drainage, he completed a six-week course of intravenous ceftriaxone, metronidazole and vancomycin, as an inpatient. A repeat CT scan without and with contrast on day 60 revealed post treatment inflammatory changes without a recurrent abscess (Fig 3c).

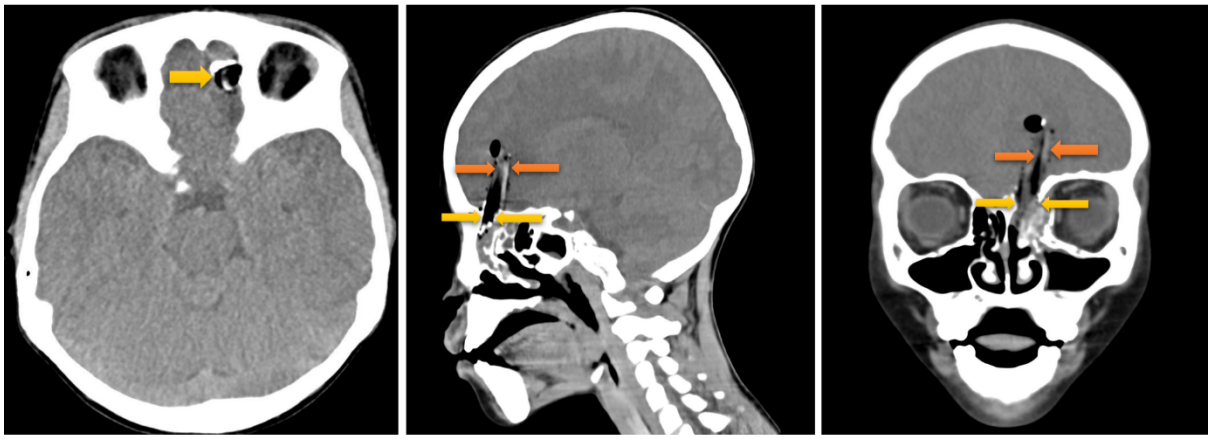

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Fig 1a; Axial CT of the head performed at presentation showing a penetrating injury of the anterior skull base with a foreign body extending into the left frontal lobe (yellow arrow). The foreign body has mixed density with areas of both low and intermediate attenuation, as well as surrounding densities related to bone fragments. Fig 1b; The sagittal CT image at presentation illustrates the trajectory and extent of the injury, showing the foreign body (orange arrows) fracturing through the left ethmoid air cells (yellow arrows) and cribriform plate and extending into the left frontal lobe. Fig 1c; The coronal CT image from presentation shows the foreign body (orange arrows) has fractured through the ethmoid air cells, medial orbital wall, and cribriform plate (yellow arrows).

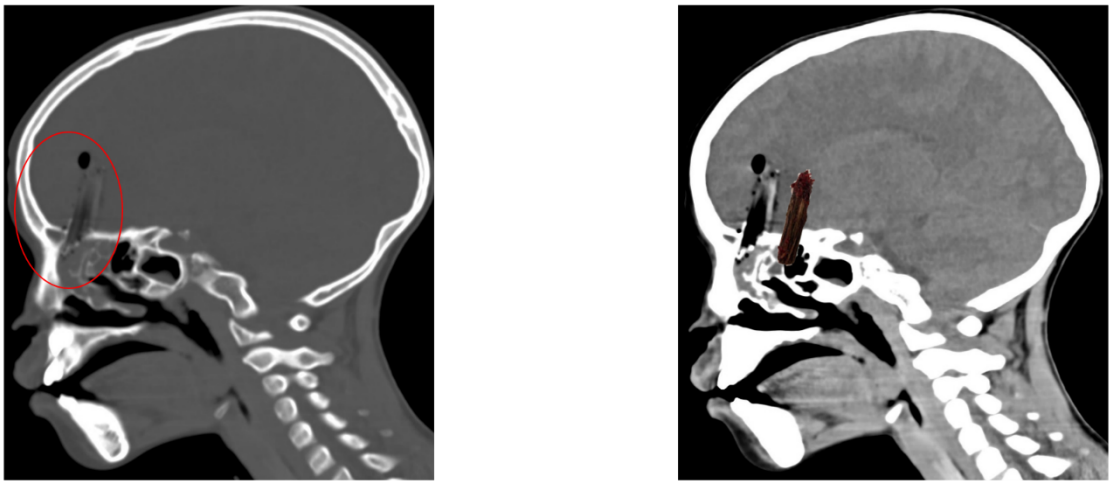

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Fig 2a; Sagittal CT image at presentation with bone windows help us to see the injuries of the sinus and anterior skull base (circle). Note the areas of near-air-density in the foreign body and small areas of pneumocephalus related to sinus injury. Fig 2b; Sagittal CT image at presentation with overlying photo of the gross pathology correlation. The gross specimen wood fragment correlates with the CT image illustrating the orientation of the wood fibers and near-air density that is characteristic of wood on CT.

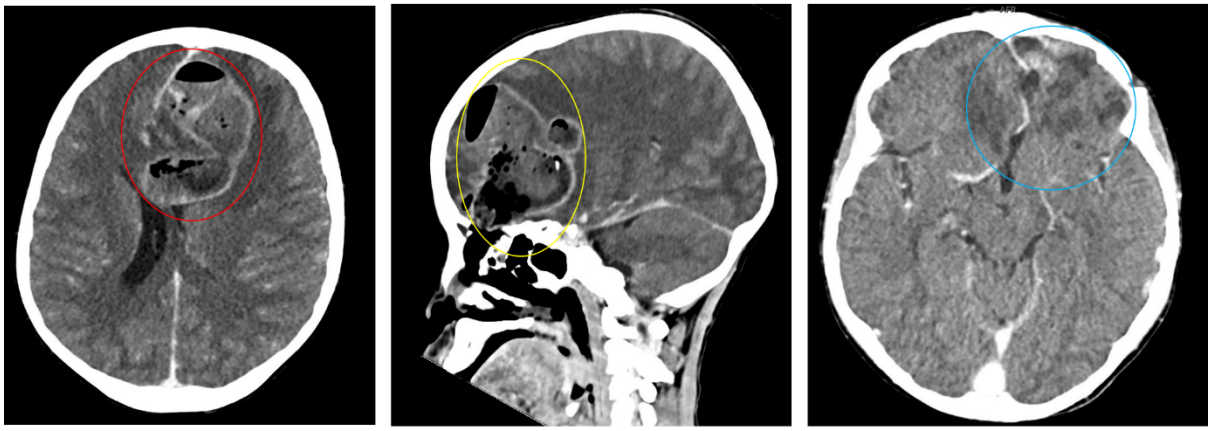

Fig 3a; On day 10, the patient underwent repeated head CT with contrast. This axial image shows a large (6.5 cm) left frontal abscess with a thick, enhancing wall and fluid, debris, and air within (circle). There is surrounding edema and mass effect on the falx and ventricles. Fig 3b; Sagittal CT image with contrast from day 10. The location of the new large abscess (circle) corresponds to initial location of the foreign body (Figs 1b). Fig 3c; Axial CT of the brain with contrast on day 60. Following drainage and antibiotic therapy, the patient had near complete resolution of the abscess. There is some residual edema and enhancement in the left frontal lobe and anterior skull base likely related to the treated abscess (circle), but no collections remain.

Case 2

A 10-year-old boy presented to our Emergency Department (ED) with a few episodes of non-projectile emesis and worsening confusion. He was assaulted with a sharp rugged piece of wood on his right temporal region five days prior. He first sought care at a peripheral facility where they washed-out a laceration. No imaging was performed at the peripheral facility.

At our ED, a shot of tetanus toxoid and analgesics were given. He was subsequently started on cefazolin, metronidazole and gentamicin. A CT scan of the head without and with contrast was performed and revealed a right temporal open depressed skull fracture with traumatic durotomy (Fig 4). No radiopaque foreign bodies or densities were identified. He was subsequently taken to the operating room for debridement and skull fracture elevation, with intra-operative findings revealing devitalized brain tissues, a 1.0 cm-long piece of a wood, tree branch debris, and a 3 cm dural defect. After the washout, he began two weeks of intravenous broad-spectrum antimicrobials (ceftriaxone, metronidazole, vancomycin), with the plan to switch to oral broad-spectrum for an additional month.

One week later, however, he started oozing a small amount of pus from the inferior border of the incision site. He did not have any new neurological symptoms. A repeat CT scan without and with contrast revealed a massive right sided temporal abscess with midline shift (Fig 5a). He was taken to theatre for an urgent craniectomy with drainage of 15 mL of purulent material. Cultures were negative. After surgery the patient continued with the same course of antimicrobials but was noted to have had a recurrence of the peri-incisional purulence two weeks later. He was taken in for a repeat washout with drainage of 5 mL of

purulent materials (Fig 5b). He did well after this third operation with no further wound concerns. One week later, he was switched to oral antimicrobials (flucloxacillin, levofloxacin and metronidazole) and discharged home continuing this therapy. He had a normal neurological exam and normal inflammatory markers on his two-week follow-up outpatient visit.

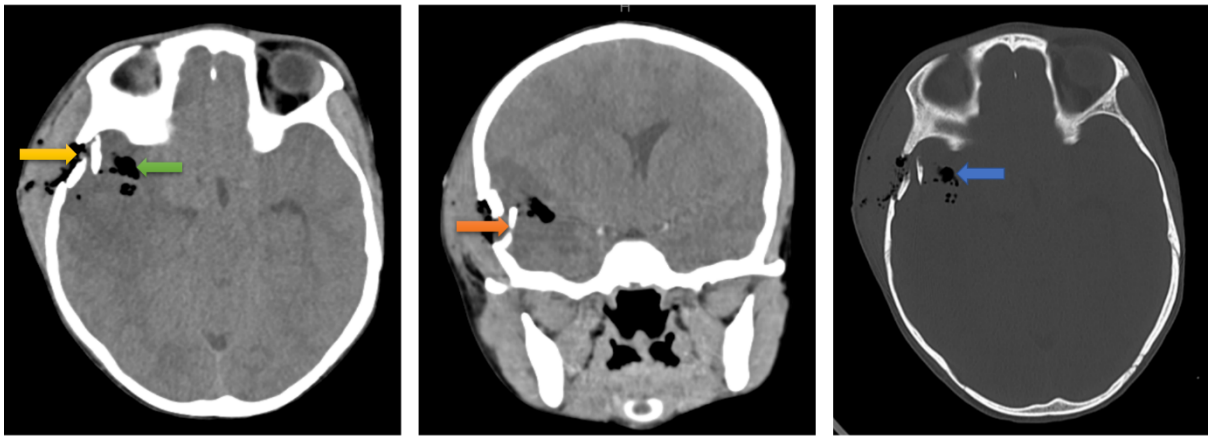

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Fig 4a; Axial CT image in brain window at presentation revealing the depressed fracture of the right temporal bone (yellow arrow) into the temporal lobe, with air density in the temporal lobe that is a combination of pneumocephalus and wood fragments (Green arrow). Fig 4b; Coronal CT at presentation illustrates the trajectory of injury through the temporal bone with depressed, comminuted fracture (orange arrow). Fig 4c; Axial CT image in bone window in bone window illustrates the fractured temporal bone along the trajectory of injury (blue arrow).

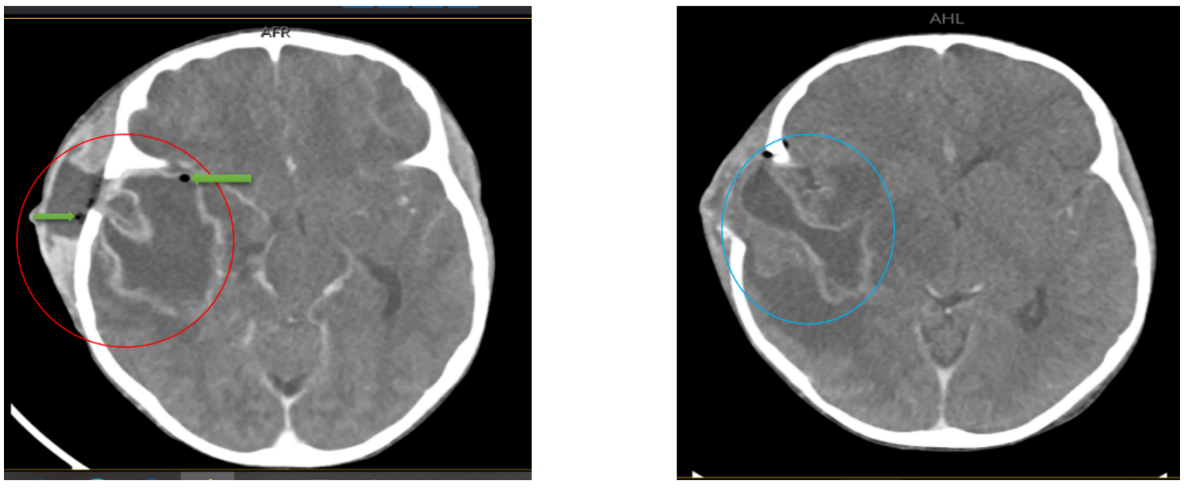

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Fig 5a; Axial CT image with contrast one week post washout revealing a large right temporal lobe ring-enhancing lesion with a central fluid density with a component extending through the temporal bone defect into the scalp, indicating a large abscess (circle) with some gas(green arrows). Fig 5b; Axial CT image with contrast two weeks after the repeat washout demonstrates recurrence of the abscess with surrounding vasogenic edema(circle).

DISCUSSION

Pediatric injury as a result of falling from a tree is an important mechanism to recognize in rural Africa[1,2,3]. The injury is most commonly an extremity or pelvic fracture[4]. The incidence of penetrating brain injuries in the pediatric population remains largely unknown[6]. Penetrating injury from wood, and specifically penetrating traumatic brain injury with a wood fragment, is uncommon and often unexpected by both the victim and treatment team[5]. As with many cases of penetrating trauma, the external signs often underestimate the degree of internal injury.

In the first case, as a result of both the uncommon nature of the injury and lack of clear external signs of trauma, the injury was not detected by the family until after several days resulting in a delayed presentation. Direct inoculation of a contaminated foreign body (wood and debris) may lead to the delayed formation of an abscess despite prophylactic antimicrobial therapy and removal of the wood fragment.
Most literature on penetrating traumatic brain injury emphasizes missile/metallic injuries (table 1). Very little is written on wood which is known to harbor a myriad of microorganisms both pathogenic and non-pathogenic due to its porosity, despite the known innate antimicrobial properties [7,9,10].

Wooden foreign bodies can create a diagnostic challenge and be hard to differentiate due to their “near-air” density on CT scan. Zhigang Lan et al. found that 16.2% of patients with retained wood were not identifiable on the CT imaging and were discovered intraoperatively[9]. Wood can often be of similar density to air and blend in with the other foci of air introduced from the penetrating trauma. They advocate that when there is a high clinical suspicion of a wooden foreign body, an MRI should be done when the presence of metal fragments is excluded by the initial CT scan and if patient’s condition is relatively stable.

Infection is the main complication of penetrating skull base injury, with a reported overall rate of 64-70% and a mortality rate of 14-57%[11]. Organic foreign bodies such as wood are not only the carriers but also a potent media for infection. Patients are more prone to infection with concomitant cerebrospinal fluid (CSF) leaks, air sinus injuries, trans-ventricular injuries, or injuries in which the object crosses the midline[9]. Staphylococcus aureus is the most common infectious organism. The administration of broad-spectrum antimicrobials is deemed necessary in all patients with all types of penetrating brain injuries and should be started as soon as possible. Cephalosporins (e.g., ceftriaxone) are the most favorable antimicrobials among most trauma physicians. There is no single standard of care regarding the selection and timing of antimicrobials, length of antimicrobial course, and whether prophylactic antimicrobials lead to more resistant bacterial strains.

Radical surgical debridement was the standard of care for penetrating TBI patients throughout World Wars I and II, the Korean and Vietnam wars[10]. In 1980s; during the Israeli-Lebanon conflict, however, a shift was made towards conservative debridement in an effort to preserve as much cerebral tissue as possible. The results were similar[10]. These injuries require a multidisciplinary approach to management with prompt surgical attention and removal of an accessible foreign body within 12 hours (and preferably within 1 hour of arrival), when possible[8]. If removal is performed more than 12 hours after the initial injury, there is an increased risk of infectious complications[10]. When considering the surgical plan, organic foreign bodies should be totally retrieved, if possible, while other

deep seated foreign bodies such as metal or bone fragments can be left as these harbor less bacteria and total extraction may cause more damage[10].

Table 1: Review of cases from literature review on penetrating traumatic brain injury

Case(year)	Sex	Age(yrs)	Material	Retained	Surgery	Culture	Antibiotics Choice	Route	Duration	complications
Ruhong et al,2018	M	60	nail	Yes	Yes	no report	Ceftazidime/vancomycin	IV	2wks	None
Ruhong et al,2018	M	57	nail	Yes	Yes	no report	Ceftazidime/vancomycin	IV	2wks	None
Ruhong et al,2018	F	49	Nail	Yes	Yes	no report	Ceftazidime/vancomycin	IV	2wks	None
Evangelos et al,2017	F	4	glass	Yes	Yes	no report	Vancomycin/ceftriaxone/metronidazole	IV	2wks	None
Evangelos et al,2017	M	6	fish hook	Yes	Yes	no report	Not mentioned/broad spectrum	PO	1wk	None
Evangelos et al,2017	M	6	wood	Yes	Yes	no report	Not mentioned/Broad spectrum	IV	5 days	None
Evangelos et al,2017	M	14	spear	Yes	Yes	no report	Vancomycin/ceftazidime	IV	10 days	None
Evangelos et al,2017	F	3	Metal	No	No	no report	Metronidazole/Cefepime	IV	15 days	None
Stephanie et al,2016	M	12	Arrow	Yes	Yes	no report	Not mentioned/Broad spectrum	IV	30 days	None
Stephanie et al,2016	M	37	knife	Yes	Yes	no report	Not mentioned/broad spectrum	IV	14 days	None
Stephanie et al,2016	M	46	nail	Yes	Yes	no report	Not mentioned/broad spectrum	IV	21 days	abscess
Danfeng et al,2017	F	75	bamboo stick	Yes	Yes	no report	Not mentioned/Broad spectrum	IV	14 days	None
Danfeng et al,2017	M	32	metal	Yes	Yes	no report	Not mentioned/Broad spectrum	IV	14days	None
Michael Young et al,2020	M	34	knife	Yes	Yes	no report	Ceftriaxone/Metronidazole	IV	14 days	None
Michael Young et al,2020	M	37	Nail	Yes	Yes	no report	Ceftriaxone/Metronidazole	IV	14 days	None
Michael Young et al,2020	M	31	Nail	Yes	Yes	no report	Ceftriaxone/Metronidazole	IV	14 days	None
Zhigang Lan et al,2018	M	22	metal rod	Yes	Yes	no report	Ceftriaxone/Metronidazole	IV	7 days	None
Zhigang Lan et al,2018	M	44	wood	Yes	Yes	no report	Ceftriaxone/Metronidazole	IV	7 days	None
Zhigang Lan et al,2018	M	1.5	bamboo stick	Yes	Yes	α-Hemolytic streptoc	Ceftriaxone/Metronidazole	IV	21 days	abscess
Elad Avraham et al,2020	M	71	wood	Yes	Yes	Enterobacter spp	Ceftriaxone	IV	14 days	None
Quri Savitri et al, 2020	M	34	wood	Yes	Yes	no report	cefixime/metronidazole	IV	42days	abscess

OBSERVATIONS

The two illustrative cases emphasize the challenges regarding the treatment of pediatric penetrating traumatic brain injury that exist in various neurosurgical centers around the world, particularly those in LMICs. These injuries require interdisciplinary input (microbiology, infectious disease, radiology, and neurosurgical). No clear guidelines exist covering penetrating wood injury per se. Most literature in higher income countries regarding penetrating traumatic brain injury is in reference to metallic objects, with fewer insights into how to best manage those from an organic wooden object.

Our cases also illustrate the ongoing challenges faced by the neurosurgical team in managing delayed complications. The term 'late presentation' may also need to be better defined with regards to the different types of penetrating traumatic brain injury, and have corresponding management recommendations based on a greater expected complication rate. Centers without neurosurgery may benefit from earlier referral to centers with neurosurgical expertise.

LESSONS

Penetrating traumatic brain injury from wood is an uncommon injury, with a challenging management due to delayed presentation and abscess formation even after initial surgical intervention. These illustrative cases emphasize the value of neurosurgical expertise in providing adequate ongoing surgical and medical management of these complex and unusual injuries. Despite these challenges, prognosis can be excellent with appropriate management.

LIMITATIONS

As two case reports of relatively uncommon injuries, it can be difficult to broadly generalize the lessons learned and management recommendations to other settings. Both patients had a delayed presentation, which may have resulted in a higher complication rate. Additionally, we lacked adequate data on bacterial and fungal cultures and sensitivities by virtue of being in a lower-resource hospital setting, which influenced our antimicrobial therapy selection.

ETHICAL CONSIDERATIONS

We obtained informed consent from the respective parents in a bid to have the cases written up and promised to maintain confidentiality. In the course of treatment, both the patients and the families were well updated and we have maintained patient contact.

CONCLUSION

A neurosurgeon should expect the need for repeat debridement/washout when encountering these injuries, and perform careful clinical and imaging follow-up accordingly. The presentations are commonly delayed and under-recognized, and likely more so in rural Africa. There is value in continuing to explore the appropriate antimicrobial regimes in penetrating traumatic brain injury especially in rare cases such as wood penetration.

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