3-20-2022

Tangential Cranial Gunshot Wound in an Infant in Historical Context: Illustrative Case

Jeffrey Campbell

Joseph Piatt

JOURNAL OF NEUROSURGERY:
Case Lessons

J Neurosurg Case Lessons 3(11): CASE227, 2022
DOI: 10.3171/CASE227

Tangential cranial gunshot wound in an infant in historical context: illustrative case

Jeffrey Campbell, MD, MS, MBA,[1–3] and Joseph Piatt, MD, MAS[1–3]

[1]Division of Neurosurgery, Nemours Children's Hospital Delaware, Wilmington, Delaware; and Departments of [2]Neurological Surgery and [3]Pediatrics, Sydney Kimmel Medical College, Thomas Jefferson University, Philadelphia, Pennsylvania

BACKGROUND Military neurosurgeons have long known that tangential cranial gunshot wounds can be associated with intracranial complications out of proportion to the external appearance of the injury. This phenomenon seems not to have been described in infancy.

OBSERVATIONS An infant suffered a massive, acute subdural hemorrhage from a contralateral tangential gunshot wound that did not facture the skull.

LESSONS Similar to adults, infants are subject to catastrophic intracranial injury from gunshots that do not penetrate the skull. The nature of the injury in this case reflected distinctive aspects of the tissue characteristics and proportions of the infant head.

https://thejns.org/doi/abs/10.3171/CASE227

KEYWORDS cranial; firearm; gunshot; infant; tangential; subdural hematoma

Trauma is the leading cause of childhood mortality after the first year of life, and firearm injuries are now the second most frequent cause of childhood trauma mortality.[1] Estimations of trends in the incidence of pediatric firearm injuries vary based on data sources, epochs of study, and intentionality, but firearm injuries remain a clinical challenge for pediatric trauma care.[2–5] Unintentional injuries predominate in early childhood, as expected, but although the incidence may be falling among younger White children, unintentional firearm injuries appear to be increasing in frequency among younger Black children.[4,6,7] Case series of cranial gunshot injuries in childhood are few, and few distinctive wounding patterns or clinical management considerations have been defined by these publications.[8–12] We report here a case, unique in the literature so far as we can tell, that illustrates the response of the infant head to a tangential gunshot wound, and we place it in the context of the history of wartime neurosurgery.

Illustrative Case

Emergency medical services (EMS) were called to the scene of a shooting. A 9-month-old male child had suffered a gunshot wound to the head. In the emergency department there was no eye opening or vocalization and the left pupil was dilated. There was a sagittally oriented 8 cm laceration just to the right of the midline with a bridge of intact scalp at the midpoint, associated with grooving of the underlying calvaria but no penetration (Fig. 1). After immediate intubation, an expedited computed tomography (CT) scan revealed a large, hyperacute, left convexity subdural hematoma with midline shift (Fig. 2A and B). There was no skull fracture (Fig. 2C). With transfusion in progress, the patient reached the operating room 1.5 hours after EMS had arrived at the scene, where he underwent a left frontoparietotemporal decompressive craniectomy with evacuation of most of the subdural, care being taken not to disturb the clot near the sagittal sinus. The dura was left open, and the cranial flap was frozen for later reimplantation. His pupils were equal immediately after surgery and the patient was extubated within 24 hours. He made a rapid recovery, transitioning to inpatient rehabilitation for a total hospitalization of 2 weeks before discharge to outpatient therapy. His cranial flap was replaced 6 weeks after the injury without incident. The patient returned to his neurological baseline within a month of the injury and remains well.

Discussion

Historical Background

From the time of the First World War onward, military neurosurgeons have viewed tangential gunshot wounds of the head with suspicion. They have recognized that the focal, concussive force of a tangential projectile could cause intracranial mischief in the absence of calvarial penetration or even fracture. In the exhaustive

ABBREVIATIONS CT = computed tomography; EMS = emergency medical services.

INCLUDE WHEN CITING Published March 14, 2022; DOI: 10.3171/CASE227.
SUBMITTED January 5, 2022. **ACCEPTED** February 2, 2022.

FIG. 1. There was a sagittally oriented 8 cm laceration just to the right of the midline with a bridge of intact scalp at the midpoint, associated with grooving of the underlying calvaria but no penetration.

report of his experiences with the British Expeditionary Force, Harvey Cushing defined nine grades of head wounds, in the first four of which a projectile lacerated the scalp but failed to gain entrance to the cranial cavity.[13] He devoted 46 pages to the description of such injuries. Trephination of the skull in the absence of a fracture was not his practice at the time, but in retrospect he remarked that half of such cases in his series might have benefitted even from

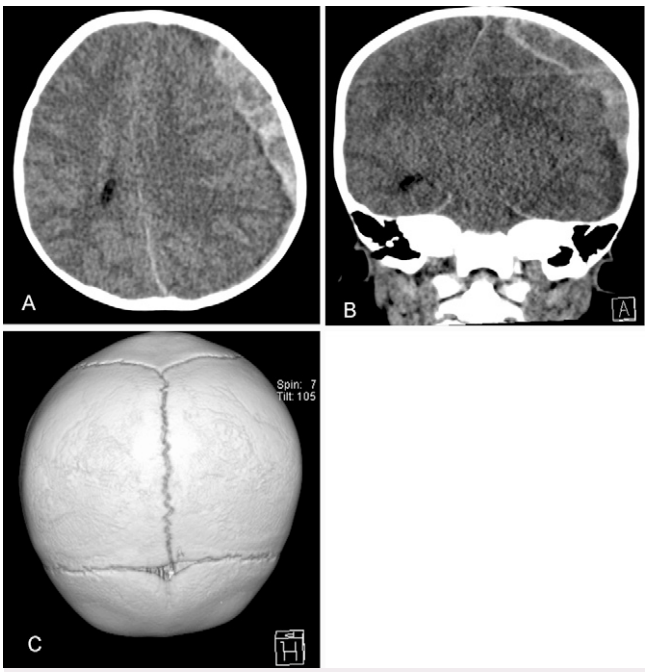

FIG. 2. Axial (**A**) and coronal (**B**) CT images show a large, mixed-density, acute subdural hematoma over the left convexity with midline shift and effacement of the ventricular system and the basilar cisterns. A prone, vertex view from a three-dimensional reconstruction (**C**) confirms the absence of a fracture at the site of the wounding.

intradural exploration, as they exhibited focal neurological symptoms and signs likely reflecting contusion or hemorrhage. He believed that evacuation of clot and "disorganized" brain tissue expedited recovery, but for contaminated wounds hours or days old, the risk of infection incurred by opening the dura placed a heavy burden on the judgment of the surgeon. Whether to open the dura was a question addressed by other contemporary authors as well.[14,15] Geoffrey Jefferson's work in France confirmed Cushing's descriptions of focal neurological findings corresponding to tangential scalp wounds with intact skull, although he was even more reluctant to explore them by trephination.[16] The prevalence of focal symptoms and signs corresponding to the site of nonpenetrating missile injuries was a concern for military neurosurgeons in the Second World War,[17,18] the Korean conflict,[19,20] and the Vietnam War[21] as well. Management of tangential injuries evolved little over these decades with the possible exception of increasing determination, fortified by shorter time intervals to definitive care and by the introduction of antibiotics, to explore below intact dura. CT entered clinical practice too late for impact in the last major American conflict, and for all subsequent military engagements it has destroyed the mystique of tangential projectile wounds. Nevertheless, in his magisterial 1984 treatise *Penetrating Craniocerebral Trauma*, Meirowsky[22] prescribed opening of the dura, evacuation of subdural hemorrhage, debridement of devitalized brain, search for subcortical hematoma, and water-tight closure. Contemporary writers continue to stress the importance of brain imaging for victims of apparently trivial tangential wounds.[23–25]

Clinical Background

Massive subdural hemorrhage in infancy is most commonly due to abusive head trauma. Subdural hemorrhage can derive from laceration or contusion of the brain itself, but in infancy it is attributed in most cases to rupture of bridging veins draining into the dural venous sinuses.[26] The older term for abusive head trauma, shaken baby syndrome, has fallen out of use because of its excessive specificity, but it created a vivid picture of the brain lagging behind an abruptly accelerated skull with stretching of the veins that connect the two structures beyond their tolerances. Whether adults shaking infants can actually create sufficient acceleration to cause the effects attributed to it has been a topic of conversation in the pediatric literature.[27–29] Clinical and postmortem observations have established that impacts are more common than suggested by the external appearance of the head or by radiography and, conversely, that serious injuries can be unaccompanied by clinical, radiological, surgical, or postmortem evidence of impact.[28,30–33]

Observations

Structural differences between infant and adult skulls may have ramifications for the effects of tangential injuries. For example, the absence of a diploe eliminates the possibility of what Cushing called grade III injuries, characterized by cracking of the outer table but fragmentation of the inner table with laceration of the dura and the brain. A tangential gunshot causes an extremely sharp acceleration of the head as well as focal deposition of energy at the site of the impact. Tangential bullet grazing of the skull has been studied by high-speed photography,[34] but actual measurements of induced energy transfers do not seem to have been reported. The relatively thin infant skull may sustain greater degrees of deformation without fracture and may thus favor focal contusion over global acceleration. However, this effect may be counterbalanced by the relative

craniocerebral disproportion present in many infant heads that render them more susceptible to out-of-phase accelerations and shearing forces. Acceleration of the head is implicated in the current case, as the hemorrhage was contralateral to the wounding. In the absence of developmentally stratified laboratory studies, only clinical observations can be brought to bear on these speculations, and published clinical observations are sparse. The absence of a fracture in the present case and the presence of massive subdural hemorrhage typical of abrupt acceleration of skulls that are bigger than the enclosed brains may define a pattern of injury to be anticipated in the setting of tangential wounding.

Lessons

Similar to adults, infants are subject to catastrophic intracranial injury from gunshots that do not penetrate the skull. The nature of the injury in this case reflected distinctive aspects of the tissue characteristics and proportions of the infant head.

References

1. Cunningham RM, Walton MA, Carter PM. The major causes of death in children and adolescents in the United States. *N Engl J Med.* 2018;379(25):2468–2475.
2. Avraham JB, Frangos SG, DiMaggio CJ. The epidemiology of firearm injuries managed in US emergency departments. *Inj Epidemiol.* 2018;5(1):38.
3. Eber GB, Annest JL, Mercy JA, Ryan GW. Nonfatal and fatal firearm-related injuries among children aged 14 years and younger: United States, 1993-2000. *Pediatrics.* 2004;113(6):1686–1692.
4. Fowler KA, Dahlberg LL, Haileyesus T, Gutierrez C, Bacon S. Childhood firearm injuries in the United States. *Pediatrics.* 2017;140(1): e20163486.
5. Hatchimonji JS, Swendiman RA, Goldshore MA, et al. Pediatric firearm mortality in the United States, 2010 to 2016: a National Trauma Data Bank analysis. *J Trauma Acute Care Surg.* 2020; 88(3):402–407.
6. Carter PM, Cook LJ, Macy ML, et al. Individual and neighborhood characteristics of children seeking emergency department care for firearm injuries within the PECARN network. *Acad Emerg Med.* 2017;24(7):803–813.
7. Patel SJ, Badolato GM, Parikh K, Iqbal SF, Goyal MK. Sociodemographic factors and outcomes by intent of firearm injury. *Pediatrics.* 2021;147(4):e2020011957.
8. Bandt SK, Greenberg JK, Yarbrough CK, Schechtman KB, Limbrick DD, Leonard JR. Management of pediatric intracranial gunshot wounds: predictors of favorable clinical outcome and a new proposed treatment paradigm. *J Neurosurg Pediatr.* 2012;10(6): 511–517.
9. Coughlan MD, Fieggen AG, Semple PL, Peter JC. Craniocerebral gunshot injuries in children. *Childs Nerv Syst.* 2003;19(5-6):348–352.
10. Deng H, Yue JK, Winkler EA, Dhall SS, Manley GT, Tarapore PE. Pediatric firearm-related traumatic brain injury in United States trauma centers. *J Neurosurg Pediatr.* 2019;24(5):1–11.
11. Levy ML, Masri LS, Levy KM, et al. Penetrating craniocerebral injury resultant from gunshot wounds: gang-related injury in children and adolescents. *Neurosurgery.* 1993;33(6):1018–1025.
12. Miner ME, Ewing-Cobbs L, Kopaniky DR, Cabrera J, Kaufmann P. The results of treatment of gunshot wounds to the brain in children. *Neurosurgery.* 1990;26(1):20–24, discussion 24-25.
13. Cushing H. A study of a series of wounds involving the brain and its enveloping structures. *Br J Surg.* 1918;5:558–684.
14. Horrax G. Observations on a series of gunshot wounds of the head. *Br J Surg.* 1919;7:10–54.
15. Roberts JEH. The treatment of gunshot wounds of the head, with special reference to apparently minor injuries. *BMJ.* 1915;2(2857): 498–500.
16. Jefferson G. Gunshot wounds of the scalp, with special reference to the neurological signs presented. *Brain.* 1919;42:93–112.
17. Cairns H. Gunshot wounds of the head in 1940. *J Army Med Corps.* 1941;76:12–22.
18. Russell WR. Transient disturbances following gunshot wounds of the head. *Brain.* 1945;68:79–97.
19. Dodge PR, Meirowsky AM. Tangential wounds of scalp and skull. *J Neurosurg.* 1952;9(5):472–483.
20. Lewin W, Gibson RM. Missile head wounds in the Korean campaign: a survey of British casualties. *Br J Surg.* 1956;43(182):628–632.
21. Jacobs GB, Berg RA. Tangential wounds of the head. *J Neurosurg.* 1970;32(6):642–646.
22. Meirowsky AM. Tangential wounds of scalp and skull. In: *Penetrating Craniocerebral Trauma.* Charles C Thomas; 1984:98–111.
23. Anglin D, Hutson HR, Luftman J, Qualls S, Moradzadeh D. Intracranial hemorrhage associated with tangential gunshot wounds to the head. *Acad Emerg Med.* 1998;5(7):672–678.
24. Robles LA. High-velocity gunshot to the head presenting as initial minor head injury: things are not what they seem. *Am J Emerg Med.* 2012;30(9):2089.e5–7.
25. Stone JL, Lichtor T, Fitzgerald LF, Gandhi YN. Civilian cases of tangential gunshot wounds to the head. *J Trauma.* 1996;40(1): 57–60.
26. Choudhary AK, Bradford R, Dias MS, Thamburaj K, Boal DK. Venous injury in abusive head trauma. *Pediatr Radiol.* 2015;45(12): 1803–1813.
27. Duhaime AC, Gennarelli TA, Thibault LE, Bruce DA, Margulies SS, Wiser R. The shaken baby syndrome. A clinical, pathological, and biomechanical study. *J Neurosurg.* 1987;66(3):409–415.
28. Salehi-Had H, Brandt JD, Rosas AJ, Rogers KK. Findings in older children with abusive head injury: does shaken-child syndrome exist? *Pediatrics.* 2006;117(5):e1039–e1044.
29. Stray-Pedersen A, Strisland F, Rognum TO, Schiks LAH, Loeve AJ. Violent infant surrogate shaking: Continuous high-magnitude centripetal force and abrupt shift in tangential acceleration may explain high risk of subdural hemorrhage. *Neurotrauma Rep.* 2021;2(1):224–231.
30. Alexander R, Sato Y, Smith W, Bennett T. Incidence of impact trauma with cranial injuries ascribed to shaking. *Am J Dis Child.* 1990;144(6):724–726.
31. Hadley MN, Sonntag VK, Rekate HL, Murphy A. The infant whiplash-shake injury syndrome: a clinical and pathological study. *Neurosurgery.* 1989;24(4):536–540.
32. Hahn YS, Raimondi AJ, McLone DG, Yamanouchi Y. Traumatic mechanisms of head injury in child abuse. *Childs Brain.* 1983;10(4):229–241.
33. Sieswerda-Hoogendoorn T, Robben SG, Karst WA, et al. Abusive head trauma: differentiation between impact and non-impact cases based on neuroimaging findings and skeletal surveys. *Eur J Radiol.* 2014;83(3):584–588.
34. Thali MJ, Kneubuehl BP, Zollinger U, Dirnhofer R. A high-speed study of the dynamic bullet-body interactions produced by grazing gunshots with full metal jacketed and lead projectiles. *Forensic Sci Int.* 2003;132(2):93–98.

Disclosures

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

Author Disclosures

Conception and design: both authors. Acquisition of data: Campbell. Analysis and interpretation of data: Campbell. Drafting the article: both authors. Critically revising the article: both authors. Reviewed submitted

version of manuscript: both authors. Approved the final version of the manuscript on behalf of both authors: Piatt. Administrative/technical/material support: Piatt. Study supervision: Piatt.

Correspondence
Joseph Piatt: Nemours Children's Hospital Delaware, Wilmington, DE. jpiatt@nemours.org.