Article published online: 2024-09-16

A Strike from the Air: Cerebral Hemorrhage after a Lightning Strike

Mojsije Radovic[1] Mirko Micovic[2,3] Bojana Zivkovic[2,3] Vladimir Bascarevic[2,3]

[1] Department of Neurosurgery, General Hospital Cuprija, Cuprija, Serbia
[2] Neurosurgical Clinic, University Clinical Center of Serbia, Belgrade, Serbia
[3] Faculty of Medicine, University of Belgrade, Belgrade, Serbia

Address for correspondence Vladimir Bascarevic, MD, PhD, Faculty of Medicine, University of Belgrade, Dr. Koste Todorovica 4, Belgrade 11000, Serbia (e-mail: klinikazaneurohirugijuukcs@gmail.com).

Indian J Neurosurg

Abstract

Lightning strikes pose a rare but catastrophic risk for a variety of injuries, including damage to the central nervous system. We present the case of a 79-year-old farmer who survived a lightning strike directly in the chest resulting in an intracerebral hemorrhage in the region of the left basal ganglia. The patient was initially comatose with right-sided paralysis and central facial palsy but displayed gradual improvement with supportive medical therapy. This unique case highlights the potential for lightning strikes to cause rare and severe neurological complications, including intracerebral hemorrhage. A review of the literature proposes possible pathophysiology of lightning-induced intracerebral hemorrhage, but the exact mechanism is yet to be found. Early diagnosis, classification, and treatment of neurological symptoms are crucial for optimal patient outcomes following lightning strikes. This case report adds valuable information to the limited body of literature on lightning strike-induced central nervous system injuries, emphasizing the importance of prompt medical intervention and multidisciplinary care for lightning strike survivors. Further research is needed to better understand the mechanisms underlying lightning-induced intracerebral hemorrhage and to develop optimal treatment strategies for these rare but potentially devastating events.

Keywords

- basal ganglia hemorrhage
- brain injury
- intracranial hematoma

Introduction

Almost every ancient civilization had a deity responsible for thunder or lightning. Due to its terrible power and the fact that it comes straight from the sky above us, lightning is inevitably associated with the wrath of the gods and intended as a punishment for mankind's evil deeds. The voice of the thunderstorm forges menacing melodies that devastate the world:

"*The Wind begun to rock the Grass*
With threatening Tunes and low
He threw a Menace at the Earth
A Menace at the Sky"
Emily Dickinson, 1864: A Thunderstorm

The physical concept defines lightning as a naturally occurring electrostatic discharge in which two oppositely charged locations, either in the atmosphere or on the ground, momentarily neutralize and release a tremendous amount of energy. About 80% of lightning discharges end between the clouds. The remaining 20% represents a lightning strike and poses a potential risk for a variety of injuries.[1] The most serious injuries from lightning strikes affect the cardiovascular and central nervous systems (CNS).[2]

We report an exceptional case of a man who experienced a direct lightning strike to the chest, leading to intracerebral hemorrhage, yet remarkably survived this harrowing event.

DOI https://doi.org/10.1055/s-0044-1790534.
ISSN 2277-954X.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Case Report

A 79-year-old farmer who was suddenly struck by lightning in an open field was first examined at the local hospital. The estimated travel time from the accident scene to the nearest primary health care facility was 30 minutes. The initial physical examination classified the patient's condition as a medical emergency, cardiopulmonary stable with vital signs within normal limits (heart rate of 105 beats per minute and blood pressure of 125/75 mm Hg), and neurologically assessed as comatose (Glasgow Coma Scale [GCS] 7). He underwent rapid assessment, sedated, and orotracheal intubation before an urgent transfer to a tertiary referral hospital. The emergency department described the initial electrocardiogram examination upon arrival as normal. Upon arrival at the emergency center in Belgrade, the patient underwent a detailed examination by a trauma team. There were no visible head injuries upon admission. Several superficial lacerations were discovered in the area of the left knee and hip. A local examination revealed that the point of entry for electric current was on the chest (►**Fig. 1**). There were no typical Lichtenberg figures, but an irregular-shaped skin erythema (the first-degree burn) surrounded the point of entry, further extending in the right upper and lower quadrants of the abdomen, through the right hip and right leg, and ending in the right heel (►**Fig. 1**). A noncontrast head computed tomography (CT) showed an acute cerebral hemorrhage in the left basal ganglia with surrounding vasogenic edema, followed by intraventricular hemorrhage with no midsagittal plane shift (►**Fig. 2**). Cerebral CT angiography showed no presence of vascular anomalies. The physical and neurological examination, as well as the finding of the CT scan, prompted us not to carry out surgical treatment, but to continue supportive medical therapy.

Throughout the period of hospitalization, our patient went through a multidisciplinary treatment involving anesthesiologist, neurosurgeon, cardiologist, and plastic surgeon. The anesthesiology team consistently monitored the patient during his hospital stay, promptly addressed any biochemical imbalances, and ensured sufficient pain relief and sedation. A cardiologist also examined the patient for short-term pressure spikes that occurred during the first and second days of hospitalization. A plastic surgeon took daily care of the burns, which all completely healed within 3 weeks without local infection.

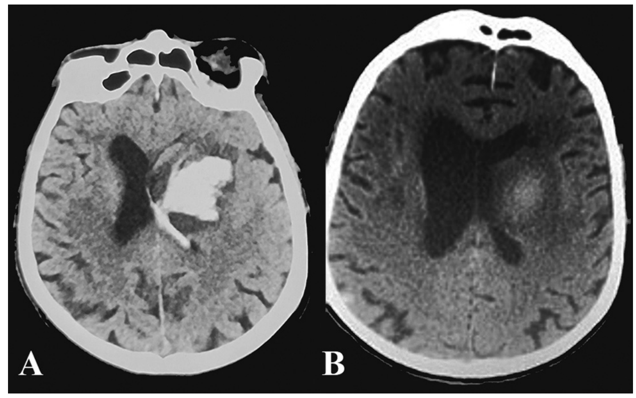

Fig. 2 (**A**) A noncontrast head computed tomography (CT) shows an acute deep cerebral hemorrhage in the left basal ganglia with surrounding vasogenic edema, followed by an intraventricular hemorrhage with no midsagittal plane shift. (**B**) The follow-up CT scan showed significant resorption of the basal ganglia hematoma.

Due to the expected prolonged intubation, an open surgical tracheostomy was performed. The neurological examination remained unchanged until the eighth day of hospitalization, when the patient occasionally began to follow commands and open his eyes on request. The follow-up CT scan showed significant resorption of the basal ganglia hematoma (►**Fig. 2**). After a total of 54 days of hospitalization, the patient was awake with a normal pupillary response and able to communicate through eye contact, hand gestures, and facial expressions. The right central facial palsy persisted, as did the right hemiplegia. However, the patient was able to sit unaided and perform a

Fig. 1 (**A**) Local examination revealed that the point of entry for electric current was on the chest. (**B** and **C**) Further extension of the burn occurred in the right upper and lower quadrants of the abdomen through the right hip and right leg, ending in the heel.

full range of motion with his left extremities. Early rehabilitation began within 7 days of the stroke. The discharge examination revealed that the patient's vital signs were stable and within normal limits, and he was eventually transferred to a rehabilitation center.

The patient's condition significantly improved upon follow-up examination 6 months after release. The patient was able to walk with the help of a walking aid, and there was a noticeable improvement in his facial palsy. The patient had the ability to fully close his eyelids. Nevertheless, the buccal and peripheral mandibular branches' paralysis did not improve.

Discussion

It is not possible to determine the exact number of deaths from lightning, but the estimated number is almost 24,000 deaths per year worldwide, whereas nonfatal injuries are approximately 10 times more common, resulting in 220,000 to 250,000 injuries per year.[3] The most common cause of lightning injuries is an indirect lightning strike (95–97%).[3] In the past 10 years, an average of 27 lightning strike fatalities were reported in the United States per year.[3] Direct lightning strikes usually end fatally.[3] Lightning strikes have a lifetime chance of 1/15,300. More than 80% of victims are men, with most deaths occurring among 20 to 45 year olds.[4] Estimates place the electrical lightning current at 10,000 to 200,000 A, and the voltage at 20 million to 1 billion V.[5] Due to the sporadic nature of lightning, the literature consists of only a few articles, mostly single-case reports.[2,6] Most cases reporting intracranial hemorrhage occur after a direct lightning strike to the head with a subsequent brain injury.[2,6] Furthermore, cerebral hypoxic-ischemic encephalopathy is the most common brain injury, closely followed by diffuse cerebral edema resulting from cardiac or respiratory arrest. Cerebral hemorrhage is an extremely rare complication with a tendency to occur in the area of the basal ganglia.[2] The pathophysiology of hemorrhage in the basal ganglia after a lightning strike is still unclear. The suggested hypothesis of these injuries includes either direct mechanical or thermal damage to the nervous tissue or indirect delayed effects that occur as a result of complex pathophysiological mechanisms.[5] These theories are still in their early stages of development and encompass:

(1) The electrical current directly induces vascular spasm and ischemia in the tissues supplied by the damaged vessels. After the initial injury, chronic ischemia slowly and steadily harms the tissue it supplies and causes a chronic inflammatory reaction of vascular endothelial cells due to free radicals resulting from oxidative stress.[7]

(2) Direct electrical damage is inducing electrostatic separation of tissues, and electroporation of cells (opening of the pores in the cell membranes using a pulse of electricity, causing functional deterioration).[7]

(3) Denaturation of proteins, deoxyribonucleic acid, and lipids due to electrical current, thus producing free radicals from oxidative stress, leading to demyelination.[8]

(4) Under the influence of the electrical current, circulating substances are released and are carried in the blood stream, having an effect in different tissues. It is suggested that elevated cortisol levels in trauma lead to hyperstimulation of glutamate receptors, which in turn increases the release of destructive free radicals, which are extremely elevated in a lightning injury.[9]

A complex interaction among electric current, glutamate, cortisol, free radicals, and vessel walls may be responsible for the delayed and distant effects of electrical injuries on the CNS and the peripheral nervous system.[8] There was no head injury in our case, we can rule out the direct mechanical damage as the cause of hemorrhage. Also, we ruled out the presence of brain aneurysms or arteriovenous malformations. The most probable explanation in our case is either that the intracerebral hemorrhage was caused by a transient increase in arterial blood pressure or caused by a complex combination of humoral factors in correlation to the last hypothesis. Only one published case reported an isolated intracerebral hemorrhage that did not coincide with an electrical current entry point in the head. In this case, the patient had massive intracerebral hemorrhage in the left basal ganglia, followed by massive pulmonary hemorrhage, leading to immediate fatality.[8]

Our patient's neurological examination revealed a comatose state, with a GCS score of 7. The patient's altered neurological condition warranted neuroimaging, but given the absence of head trauma and a chest entry point, along with the development of an intracranial bleed, it would be prudent to consider a CT scan in all lightning strike cases to avoid overlooking this severe complication.

An intracranial hematoma could be the cause of the patient's poor neurological state, but since there was no significant midline shift, there could also be a second cause, such as the previously mentioned complex disturbance and interaction between cortisol, glutamate, and an increase in free radicals, or some other as-yet-unknown disturbance of neuronal function related to electric current.

Medical assistance and immediate care for an injured person can be two of the most important factors affecting survival. In our case, the response to supportive drug therapy was excellent, so our patient did not require surgical treatment. According to the recommendation of the European Union Stroke Initiative blood pressure was maintained below 150/100 mm Hg.[10] Also, according to the most of the recommendation for the treatment of the patients with stroke, early mobilization was undertaken, to preserve or restore musculoskeletal strength and function and potentially improve overall functionality.[11] Early cardiovascular control and stabilization, along with rapid resuscitation, can play a key role in preventing cerebral ischemia.[12] Additionally, a health center treating these patients should have the necessary equipment, experience, and multidisciplinary staff to handle the full spectrum of challenging multisystem disturbances and complications that can occur.

To treat lightning-related injuries more effectively, we must comprehend the precise pathophysiology of these injuries; in the meantime, we should focus on prevention and educating people on how to lessen their risk of lightning strikes.

Conclusion

To our knowledge, this is the first published report of a patient who sustained a lightning strike to the thorax, suffered an intracerebral hemorrhage, and survived. About a third of lightning strikes result in death. The possibility of damage to the CNS depends on the type of lightning injury (direct strike, stride potential, or side flash), the intensity and duration of the current, the path of the current within the body, and injuries to the brain secondary to cardiac arrest and hypoxia or from physical trauma. The pathogenesis of basal ganglia hemorrhage following a lightning strike remains unclear, but the most likely cause in our case seems to be an intense peripheral vasoconstriction leading to an abrupt increase in intracranial arterial pressure. Lightning injury survivors suffer from a variety of neurological, psychiatric, and social issues. Early diagnosis, classification, and treatment of neurological symptoms are essential for these patients.

Funding
This investigation is supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (grant no. 200110).

Conflict of Interest
None declared.

References

1 National Weather Service. National Oceanic and Atmospheric Administration. Accessed August 24, 2024 at: https://www.weather.gov/safety/lightning-struck
2 Ozgun B, Castillo M. Basal ganglia hemorrhage related to lightning strike. AJNR Am J Neuroradiol 1995;16(06):1370–1371
3 Holle LR. Annual Rates of Lightning Fatalities by Country. Presented at: 20th International Lighting Detection Conference;. 2008
4 National Weather Service. National Oceanic and Atmospheric Administration. Accessed August 24, 2024 at: https://www.weather.gov/safety/lightning-ods
5 Yiannopoulou KG, Papagiannis GI, Triantafyllou AI, et al. Neurological and neurourological complications of electrical injuries. Neurol Neurochir Pol 2021;55(01):12–23
6 Aggarwal A, Salunke P. Bolt from the blue: basal ganglion bleed following lightning strike. Surg Neurol Int 2011;2:170
7 Andrews CJ, Reisner AD. Neurological and neuropsychological consequences of electrical and lightning shock: review and theories of causation. Neural Regen Res 2017;12(05):677–686
8 Stanley LD, Suss RA. Intracerebral hematoma secondary to lightning stroke: case report and review of the literature. Neurosurgery 1985;16(05):686–688
9 Bailey DM, Bärtsch P, Cooper MA. Electron paramagnetic resonance spectroscopic evidence of increased free radical generation and selective damage to skeletal muscle following lightning injury. High Alt Med Biol 2003;4(03):281–289
10 Goldstein JN, Gilson AJ. Critical care management of acute intracerebral hemorrhage. Curr Treat Options Neurol 2011;13(02):204–216
11 Arias-Fernández P, Romero-Martin M, Gómez-Salgado J, Fernández-García D. Rehabilitation and early mobilization in the critical patient: systematic review. J Phys Ther Sci 2018;30(09):1193–1201
12 Sances A Jr, Myklebust JB, Szablya JF, et al. Current pathways in high-voltage injuries. IEEE Trans Biomed Eng 1983;30(02):118–124

