CASE REPORT

Lightning Strike in Pregnancy With Fetal Injury

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Injuries from lightning strikes are an infrequent occurrence, and are only rarely noted to involve pregnant victims. Only 13 cases of lightning strike in pregnancy have been previously described in the medical literature, along with 7 additional cases discovered within news media reports. This case report presents a novel case of lightning-associated injury in a patient in the third trimester of pregnancy, resulting in fetal ischemic brain injury and long-term morbidity, and reviews the mechanics of lightning strikes along with common injury patterns of which emergency providers should be aware.

Key words: lightning strike, lightning injury, electrical injury, pregnancy, fetal injury, third-trimester injury

Case Report

PREHOSPITAL COURSE

After a Fourth of July fireworks show in the Southwestern United States, a family was packing up because of a distant but rapidly approaching thunderstorm, when witnesses described a sudden bright flash followed by an earth-shaking boom. Two of the family members dropped unconscious to the ground. In the background, a car horn apparently began blaring as a result of electrical system damage caused by the lightning power surge. A bystander called 911, noting that both victims were unconscious but still breathing. The local fire engine and fire rescue were finishing up another response less than 1.6 km away when the call came in.

The engine was the first to arrive on the scene, with the paramedics close behind. A quick assessment of the scene revealed no immediate hazards or fire, with 2 patients on the ground, both slightly slow to respond but awake, alert, and oriented to person, place, time, and situation. The first patient was a 22-year-old woman, 37 weeks 5 days pregnant, gravida 4, parity 3 (0-1-2), with mild patchy erythematous lesions to her chest and a 5-mm circular lesion at the tip of her left thumb, with no additional visible trauma. Her only complaint was lower back and bilateral calf pain; she had no other complaints on further review of systems, and no past medical history. The second patient was a 32-year-old man

complaining of left ear pain and hearing loss, numbness and tingling in his arms and legs, and pain in both feet. Examination demonstrated erythema and singed hair of the chest, along with mild erythema of the right flank and calf, and mild drainage from the left ear canal. He reported no past medical history. Both patients were rapidly transported to a level-1 trauma center to prevent further additional injury and exposure from continued rain and thunderstorms. En route to the hospital, more detailed evaluation revealed no additional injuries or burns, and vital signs were normal with the exception of mild tachycardia in both victims. The man's initial electrocardiogram (ECG) demonstrated sinus tachycardia at a rate of 102 beats/min without any ectopy or arrhythmia, and the woman's ECG also demonstrated sinus tachycardia of 105 beats/min, with no evident abnormalities.

EMERGENCY DEPARTMENT AND HOSPITAL COURSE

On arrival at the emergency department at 2220 hours, the female patient's primary survey revealed a patent airway with normal phonation. Breath sounds were equal bilaterally, with mild tachypnea at 22 breaths/min but no respiratory distress. Circulatory assessment revealed tachycardia at 116 beats/min with normal cardiac tones and symmetric distal pulses throughout, with well-perfused skin. Evaluation for disability revealed a Glasgow Coma Score (GCS) of 15 and symmetric movement of all 4 extremities. On exposure, there was no evidence of gross deformities, and the patient's skin was mildly damp from the rain. A detailed secondary

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survey was performed. Head, eyes, ears, nose, and throat examination was unremarkable, with normal pupils, normal nares, and normal oropharynx. There was no evidence of tympanic membrane rupture, including no hemotympanum or otorrhea. The neck was atraumatic and nontender. The chest was atraumatic with normal breath sounds bilaterally. The patient's abdomen was notable for a gravid uterus above the level of the umbilicus, and was soft and nontender throughout. The pelvis was stable and nontender. The skin was mildly damp but warm, and initially had no rash or lesions. The extremities were nontender with a full range of motion without any discomfort. Neurologic examination revealed intact cranial nerves, 5/5 motor strength with intact sensation in all 4 extremities, and 2+ deep tendon reflexes in all 4 extremities. Bedside fetal ultrasound revealed a well-developed fetus with a heart rate of 155 beats/min, after which the obstetrics and gynecology service was immediately consulted. During the subsequent hour, the patient's skin developed Lichtenberg figures ("ferning") on her right flank and right lateral thigh.

Around 0130 hours, the patient was taken for an emergency cesarean section because of decreasing fetal activity with nonreassuring fetal heart tracings that demonstrated tachycardia and minimal variability, and a biophysical profile score of 2/10. A 2.8-kg female infant with Apgar scores of 4 and 7 was transferred to the neonatal intensive care unit with respiratory distress and depressed neurologic status. The neonate experienced periodic episodes of shaking and was initiated on fosphenytoin owing to concerns of seizure activity. Electroencephalogram (EEG) on the first day of life revealed abnormal burst suppression and diffuse cerebral dysfunction. This was further compounded by a magnetic resonance image on day 2 of life demonstrating bilateral symmetric areas of ischemia involving the posterior limbs of the internal capsules. Although there was some improvement in the level of cortical dysfunction noted on a repeat EEG 2 weeks later, the patient was ultimately diagnosed with diffuse cortical injury. All 10 previous prenatal care visits, including 3 fetal ultrasounds, had revealed no evidence of abnormalities, and there was no history of congenital aberrancies in the siblings or extended family. One month later, the neonate required placement of a gastrostomy tube for failure to thrive. On follow-up at 1 year, the child had marked developmental delays and was unable to sit up, crawl, or swallow food adequately. The patient still requires a feeding tube for nutrition.

The mother was discharged home on postoperative day 4 without any complications, although she continued to experience muscle spasms in her lower back and bilateral calves on reassessment 1 week after the event. She presented with new-onset depression 3 weeks later.

The male patient was found to have an isolated ruptured left tympanic membrane, and was discharged home 2 days later with persistent mild symptoms. On reevaluation 1 week later, he had yet to regain any hearing in the left ear, and required a cane for stabilization secondary to bouts of vertigo.

Discussion

LIGHTNING INJURY PATTERNS

Skin findings in lightning burns most commonly present in 4 patterns: linear, punctate, Lichtenberg figures, and thermal. Linear burns are generally first- to secondary-degree burns between 1 and 4 cm wide, and are caused by vaporization of sweat or rain.^{1,2} Punctate burns generally present as multiple subcentimeter lesions too small to require invasive treatment. Lichtenberg figures, also known as flowering, feathering, or ferning, are pathognomonic of lightning. These are transient skin findings that resolve within minutes to hours, and are not actually burns, as there is no damage to the skin and no evidence of histologic changes.³⁻⁶ It is thought that the slightly palpable pattern, pink to brown in color, is caused by the electron current path during flashover. Thermal burns from clothing or metal objects touching the skin result when the object becomes superheated during the extreme current flow.² Victims may exhibit one or more combinations of the different burn types. Because of the minor and superficial nature of many lightning burns, they may take several hours to manifest clinically.⁷ Patients with burn patterns to the head and face have a higher mortality rate.⁸

Lightning injuries should not be treated like other high-voltage injuries owing to many factors. Most notably, lightning exposure is on the order of milliseconds, whereas typical high-voltage injuries tend to involve a more sustained connection with an electrical source. Per Joule's law ($\text{energy} = \text{current}^2 \times \text{resistance} \times \text{time}$), the total energy is proportional to the length of exposure to a current source. The brief energy exposure from lightning results in flashover, in which the electrical current rapidly flows over the external surface of the victim's body, potentially vaporizing moisture on the skin, which can blast apart clothes and shoes. Flashover spares most lightning victims from sustaining more than minor burns. Discrete entry and exit points are rare in mild to moderate lightning injury because of the limited amount of time of exposure to the current, and fasciotomy is rarely required in victims of lightning strike.⁷ Sustained exposure from other high-voltage sources can result in skin breakdown and secondary flow of current within the body, resulting in greater internal burns. In contrast to other types of high-voltage injuries, lightning

injuries rarely result in tissue breakdown leading to myoglobinuric renal failure as a result of the extremely rapid time of exposure, and therefore victims do not typically require aggressive fluid boluses. Lightning injuries also differ from more common residential and industrial high-voltage injuries in that the impulse current of lightning is most similar to generated direct current (DC) electricity, whereas most modern electrical grids are powered by alternating current (AC). The oscillating nature of AC exposure results in tetanic muscle contraction, often when a hand contacts an electrical wire, potentially leading to prolonged exposure to the electrical source and further injury. In contrast, high-voltage DC currents tend to result in a single muscle contraction, which can propel the victim from the source, resulting in a greater risk for blunt trauma.⁹

Up to two-thirds of severely injured lightning victims may experience lower extremity paralysis (keraunoparalysis) secondary to vasospasm and sympathetic instability; diminished or absent pulses, more commonly in the lower extremities, may also be noted.¹⁰ These symptoms generally resolve over the course of a few hours.

The primary cause of death in lightning strike victims is immediate cardiopulmonary arrest; if this does not occur, it is rare for victims to die from another condition in the acute setting.⁸ Primary cardiac arrest is generally asystolic, and may be temporary if adequate cardiopulmonary resuscitation (CPR) is implemented. Secondary cardiac arrest occurs as a result of stunning of the respiratory drive in the medullary respiratory center, leading to hypoxia and subsequent development of ventricular dysrhythmias. Because these patients require immediate cardiopulmonary support until the spontaneous return of respiratory drive or cardiac automaticity, “reverse triage” applies in a lightning-associated mass casualty incident.⁸ This refers to the immediate provision of maximal medical efforts, including CPR, to victims in cardiopulmonary arrest who would normally be considered “nonsalvageable” and triaged as “deceased/expectant” (black tag) under other circumstances. Patients who do not regain pulses within 20 to 30 minutes are unlikely to survive. Cardiac insult after lightning strike can potentially manifest with T-wave changes on ECG suggestive of ischemia, lasting for several days and in some cases months, or QT interval prolongation.^{10–12}

Lightning can have multiple adverse effects on the nervous system. Anterograde amnesia and confusion frequently occur among lightning strike victims, and they may be unable to assimilate new memories for minutes to days. Transient paresthesias, dysesthesias, and muscular spasm are also common.¹³ Patients may

experience posttraumatic headaches that generally resolve after a few months. Chronic conditions including peripheral neuropathy, fine motor skills dysfunction, chronic pain syndromes, sleep disorders, and neuropsychological symptoms (ie, depression, posttraumatic stress disorder) may also occur.^{14–16} Travel of electrical current through the brain can result in epidural hematoma, subdural hematoma, or intraventricular hemorrhage. Intracranial injury or cardiopulmonary arrest-induced hypoxia can result in focal or diffuse seizures that generally improve during a period of months. Conversely, children are prone to experiencing a delayed onset of seizures.

Blunt trauma, from either fall or blast injury, can cause orthopedic injury and subtle internal bleeding. Thus, patients need to be diligently evaluated for fracture or hemorrhagic shock. Blast injury commonly causes transient deafness, with almost 50% of victims having ruptured one or both tympanic membranes.¹⁷

LIGHTNING INJURY IN PREGNANCY

A review of the current medical literature describes only 13 previous cases of pregnant lightning strike victims—our report brings the total to 14.^{18–23} In all reported cases, the mother survived. Five of the cases report intrauterine fetal demise, with an additional case of newborn death a few hours after delivery. Of the 8 newborn survivors, this paper is the first to describe sequelae evident in the first month of life. Previous reports indicated no apparent long-term morbidity in the surviving newborns. The available evidence suggests that the third trimester carries the greatest risk of adverse outcomes including intrauterine fetal death, risk of uterine rupture, or induction of labor. These patients need to be rapidly evaluated in the emergency department to assess both the mother and the fetus. This includes fetal monitoring. Until comprehensive testing can be performed in the hospital by an obstetrician, stabilizing and optimizing the mother’s health is the best way to improve the outcome of the fetus.

As it is possible that many pregnant lightning strike victims are not reported in the medical literature, it is difficult to gather detailed information on this rare occurrence. An evaluation of the major broadcast news media in the United States yielded 7 additional cases online. In 6 of the 7 available cases, both the mother and fetus demonstrated no lasting dysfunction; the fetal gestational ages ranged from 14 to 36 weeks, with the majority being in the second trimester.^{24–29} One mother and her fetus did die while taking shelter under a tree in a rural location.³⁰ Although this data set is obviously limited, it potentially indicates that lightning-associated

morbidity and mortality may actually be lower than that reported in the medical literature.

Conclusions

In this case, the injury patterns of the adult patients were consistent with those typically seen with lightning strikes, including skin lesions, paresthesias, muscular spasms, tympanic membrane rupture, and subsequent development of depression. The development of diffuse ischemic brain injury to the fetus is the first reported in the medical literature, and the relatively minor injuries sustained by the mother would make a direct trauma mechanism a less likely cause. The possibility of uterine or umbilical vasospasm could be considered as potential etiologies, as could direct effects of electrical exposure on the fetal brain. Previous data indicate that lightning injuries during the third trimester carry the highest risk of fetal mortality, although the underlying cause of this mortality is unclear. The potential dangers of lightning injury to an unborn fetus are further supported by the long-term morbidity suffered by the neonate in this case, and highlight the importance of rapid fetal assessment and monitoring.

References

1. Andrews CJ, Cooper MA, Darveniza M, et al. *Lightning Injuries: Electrical, Medical and Legal Aspects* Boca Raton, FL: CRC Press; 1992:192.
2. Cooper MA. Emergent care of lightning and electrical injuries. *Semin Neurol*. 1995;15:268–278.
3. Golde RH, Lee WR. Death by lightning. *Proc Inst Electr Eng*. 1976;123(10R):1163–1180.
4. Hocking B, Andrews C. Fractals and lightning injury. *Med J Aust*. 1989;150:409–410.
5. Bartholome CW, Jacoby WD, Ramchand SC. Cutaneous manifestations of lightning injury. *Arch Dermatol*. 1975;111:1466–1468.
6. Cherington M, Olson S, Yarnell PR. Lightning and Lichtenberg figures. *Injury*. 2003;34:367–371.
7. O'Keefe Gatewood M, Zane RD. Lightning injuries. *Emerg Med Clin North Am*. 2004;22:369–403.
8. Cooper MA. Lightning injuries: prognostic signs for death. *Ann Emerg Med*. 1980;9:134–138.
9. Pinto DS, Clardy PF. Environmental and weapon-related electrical injuries. *Up To Date*. <http://www.uptodate.com/contents/environmental-and-weapon-related-electrical-injuries>. Accessed May 20, 2014.
10. Jex-Blake AJ. Death by electric currents and by lightning. The Ghoulistonian Lectures, lecture III. *BMJ*. 1906;11:548.
11. Bernstein T. Theories of the causes of death from electricity in the late nineteenth century. *Med Instrum*. 1975;9:267–273.
12. Andrews CJ, Colquhoun DM, Darveniza M. The QT interval in lightning injury with implications for the “cessation of metabolism” hypothesis. *J Wilderness Med*. 1993;4:155–166.
13. Cannell H. Struck by lightning: the effects upon the men and the ships of HM Navy. *J R Nav Med Serv*. 1979;65:165–170.
14. Cooper MA. Post electrocution syndrome—long term effects of lightning injury. In: Proceedings at the Foudre et Montagne, Chamonix-Mont Blanc, France, June 1994.
15. Copper MA, Andrews CJ. Neuropsychological aspects of lightning injury. In: Proceedings of the 9th International Conference on Atmospheric Physics, St. Petersburg, Russia, June 1992.
16. Primeau M, Engelstatter GH, Bares KK. Behavioral consequences of lightning and electrical injury. *Semin Neurol*. 1995;15:279–285.
17. Qureshi N. Indirect lightning strike via telephone wire. *Injury*. 1995;26:629–630.
18. Pierce MR, Henderson RA, Mitchell JM. Cardiopulmonary arrest secondary to lightning injury in a pregnant woman. *Ann Emerg Med*. 1986;15:597–599.
19. Rees WD. Pregnant woman struck by lightning. *BMJ*. 1965;1:103–104.
20. Chan YF, Sivasamboo R. Lightning accidents in pregnancy. *J Obstet Gynaecol Br Commonw*. 1972;79:761–762.
21. Guha-Ray DK. Fetal death at term due to lightning. *Am J Obstet Gynecol*. 1979;134:103–105.
22. Weinstein L. Lightning: a rare cause of intrauterine death with maternal survival. *South Med J*. 1979;72:632–633.
23. Flannery DB, Wiles H. Follow-up of a survivor of intrauterine lightning exposure. *Am J Obstet Gynecol*. 1982;142:238–239.
24. ABC News. Fiancé Killed by Lightning During Surprise Wedding Proposal. June 9, 2010. Available at: <http://abcnews.go.com/Health/Media/fiancee-killed-lightning-wedding-proposal/story?id=10860008>.
25. ABC News. Pregnant Ohio Woman Struck by Lightning. Available at: <http://www.abc57.com/story/27298242/pregnant-ohio-woman-struck-by-lightning>. Accessed March 8, 2016.
26. CBS Denver. Newborn Healthy After Mom Struck By Lightning While Pregnant. Jan. 18, 2012. Available at: <http://denver.cbslocal.com/2012/01/18/newborn-healthy-mom-struck-pregnant/>. Accessed March 8, 2016.
27. Pregnant Woman Felt Shock During Lightning Storm at Busch Gardens Tampa Bay Times. Available at: <http://www.tampabay.com/news/publicsafety/pregnant-woman-felt-shock-during-lightning-storm-at-busch-gardens/1179466>. Accessed March 8, 2016.
28. Fox News Pregnant Woman and Her Two Children Survive Lightning Strike. Aug. 8, 2004. Available at: <http://foxnewsinsider.com/2012/08/04/pregnant-woman-and-her-two-children-survive-lightning-strike>. Accessed March 8, 2016.
29. NBC Philadelphia, Lightning Strikes Pregnant Woman Four Wildwood. Aug. 1, 2012. Available at: <http://www.nbcphiladelphia.com/news/breaking/Lightning-Strikes-Pregnant-Woman-Four-Wildwood-164613126.html>. Accessed March 8, 2016.
30. Huffington Post, Mary Yoder, Pregnant Amish Woman, Killed By Lightning On Due Date. July 25, 2012. Available at: http://www.huffingtonpost.com/2012/07/25/mary-yoder-pregnant-amish_n_1700500.html. Accessed March 8, 2016.