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Review Article

# Keraunoparalysis: What a neurosurgeon should know about it?

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## Abstract

Keraunoparalysis or transient weakness in limbs following a lightning strike has been well described in literature. Many times, neurosurgeons encounter patients with paraparesis secondary to trauma in the setting of a lightning strike. In these cases, it becomes imperative to find out the true cause behind such weakness in lower limbs because the prognosis differs significantly depending on the etiology. We report a case of keraunoparalysis affecting both lower limbs in a 50-year-old male, where he recovered within 48 hours of the impact. As far as our knowledge is concerned, this is the first case of keraunoparalysis reported from India. We also review the available literature and discuss the physics of lightning, its mechanism, other clinical presentations, and management strategy in the light of our case. These patients must be investigated for other possible causes of paraparesis secondary to trauma and keraunoparalysis should rather be a diagnosis of exclusion, only to be confirmed on imageology. Awareness regarding similar cases will make neurosurgeons notice this entity early, avoiding unnecessary investigation, and hence they will be able to prognosticate in the most efficient manner.

**Key words:** Keraunoparalysis, lightning strike, paraparesis, transient

## INTRODUCTION

Lightning injuries are relatively common in rural setups and they involve a myriad of presentations. Chiefly, they present as burn injury, along with multisystemic involvement in the form of cardiovascular, renal, and neurological abnormalities. However, if the mode of injury is a direct one, entry and exit wounds also may be noticed and the patient may even die of a sudden cardiac arrest. Multiple traumatic fractures and secondary injuries are also common. Neurological involvement may occur in various ways and keraunoparalysis is one of them. We discuss here the epidemiology, physics of lightning, mechanisms of injury, clinical presentations, and the phenomenon of keraunoparalysis in the light of our case and its associated diagnostic dilemmas.

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### Epidemiology

Lightning strikes the earth more than 100 times each second or 8 million times per day.[1] It is considered as the second leading cause of weather-related mortality. However, it is found to be heavily under-reported, as pointed out by some authors.[2] In India, July–September is the most common period where lightning strikes are encountered. It is seen in hilly areas and areas with rapidly changing temperatures. Most commonly, young males, mostly farmers are the ones affected owing to their predominant outdoor activities.[3,4] The usual response of a lightning strike is to take shelter under a tree or a metallic roof and this tendency usually accounts for more number of casualties.

### Physics of lightning

The physics of lightning is little confusing. Lightning develops due to the formation of voltage difference between the cloud and the

ground. The severity of the strike depends upon the strength of the energy transferred, voltage, and resistance to current flow, along with duration of contact with the current source. The electric current is usually in the Direct Current (DC) format in order of 30,000–50,000 A and the duration is in milliseconds. This creates release of heat in large magnitudes which causes the formation of "thermoacoustic blast wave or thunder."[1] These thunderstorms are created by vertical updrafts in the region of mountains, cold terrains, sea and lakes, and heating of warm, moist air. There is an uneven distribution of charges within the clouds due to the continuous movement of this warm air mixing with the cold air above. These charges keep on separating till anvil-shaped thundercloud is formed. The bottom part of this thundercloud is usually negative and the earth is also usually negatively charged. But once this thundercloud moves above the ground, the earth acquires a positive charge and then the current starts to flow via trees, buildings, and people.[5] Lightning can take the form of a streak or sheet (shapeless flashes of light between the clouds). Bead and ball types of lightning have also been described.

## Mechanisms of injury

Ritenour *et al.*[1] have described the following modes of injury by lightning:

- Direct strike: Usually are fatal
- Contact injury: When the patient is touching some metal object struck by lightning
- Side flash: When lightning gets diverted from a nearby object
- Ground current: Lightning strikes directly at the ground and passes underneath to enter into patient's body
- Blast injury: Either caused directly resulting in tympanic membrane rupture or indirectly due to resultant falls

## Clinical presentation

The clinical presentation can be varied and involves cutaneous, cardiovascular, renal, ophthalmological, otologic, and neurological manifestations. Neurosurgeons/neurologists rarely encounter lightning patients as they present with cutaneous and metabolic derangements first. Early detection and prompt treatment can help them recover aptly, if a multisystemic approach is employed.

### Cutaneous manifestations

Lightning can cause six types of burns, namely, feathering, linear, punctuates, thermal, contact, and flash burns.[6] Characteristic features like ferning or feathering having an arborescent pattern is almost diagnostic for lightning strikes (keraunographic markings or Lichternberg figures). These figures are actually pseudo-burns which occur due to extravasation of red blood cells from the capillaries secondary to the electric discharge. They disappear on their own. Linear burns are 1-4 cm wide, and occur beneath the areas of heavy sweating, including beneath the breasts, mid-axillary regions, and chest. Punctate burns can be seen at the entry and exit points. Thermal burns essentially happen due to heat generated if the victim stays in touch with any metallic object.

### Cardio-pulmonary manifestations

Cardio-pulmonary manifestations form the most common cause of lightning-related mortality.[5] Cardiac arrest can be the primary cause of death. However, the intrinsic electric activity leads to depolarization and resumption of heart beat. Hence, young patients can easily come out of the arrest.[7] On the contrary, the chief cause of mortality is the respiratory arrest due to medullary involvement. Resultant hypoxia leads to arrhythmias and secondary cardiac arrest. ST segment elevations and elevated cardiac enzymes are also seen at times. Taussig *et al.* have stressed on the fact that patients who look apparently dead need to be resuscitated first, as they generally respond well to the treatment and ventilatory support.[8]

### Renal manifestations

Myoglobinuria and resultant acute renal failure (ARF) can also occur secondary to lightning.[9] Massive muscular contraction following electric shock may lead to release of myoglobin leading to ARF. Constant diuretic and fluid therapy may help to reverse the ARF, while fasciotomy may be needed to treat compartment syndrome secondary to muscle trauma.

### Ophthalmological and otologic manifestations

Lightning cataracts and tympanic membrane ruptures have been commonly associated with lightning strikes.[10,11] Secretory otitis media, transient dizziness may follow such events. Ocular manifestations may include corneal burns, intravitreal hemorrhage, uveitis, choroido-retinits, and iridocyclitis.

### Neurological manifestations

Cherington has classified neurological lightning injuries into the following:[12]

Class I: Immediate and transient

Class II: Immediate and prolonged/permanent

Class III: Delayed Neurological syndromes

Class IV: Secondary injuries from trauma/blasts

*Group I* injuries include immediate and transient deficits in the form of loss of consciousness, confusion, amnesia, weakness, or keraunoparalysis. *Group II* injuries are immediate but prolonged ones, such as intracerebral hemorrhage (more in the basal ganglia and brainstem) and infarction associated with hypoxic encephalopathy. Paraplegia, hemiplegias are as common as cognitive deficits like memory impairments and judgment difficulties. *Group III* injuries involve prolonged syndromes like motor neuron disease, amyotrophic lateral sclerosis, Parkinsonism, and focal dystonias, while *Group IV* injuries are traumatic injuries secondary to falls and blasts. This transient weakness in lower limbs must be differentiated from group IV set of injuries, and hence imageology becomes quintessential.

### Miscellaneous manifestations

These include features of post-traumatic stress disorders, endocrine – sexual dysfunctions, hematologic manifestations in the form of disseminated intravascular coagulation (DIC), etc., The overall management of a lightning injury patient has to be multipronged involving many subspecialities. This is briefly summarized in Figure 1.

We encountered a similar case a few days back, which actually

prompted us to review the existent literature and highlight this for the neurosurgical fraternity.

## Illustrative case

A 50-year-old man presented to our emergency department with history of lightning strike when he was standing under a tree in the course of a lightning storm. He was unconscious for 15 min, and after he regained consciousness, he was unable to move both his lower limbs with loss of sensations and urinary retention. On examination, tone in both lower limbs was normal. He had grade 0 power in both lower limbs, with a sensory level up to D12. Reflexes were depressed and plantars were equivocal. There was a 30% loss in L1 dermatome downward, which was almost complete in S1 dermatome. On the 2nd day, his power improved to grade III bilaterally which improved to grade IV the very next day so that he was ambulant by now. X-rays were within normal limits. The Magnetic Resonance Imaging (MRI) brain was normal, while spine imaging showed the evidence of ruptured posterior longitudinal ligament (PLL) at D12–L1 level with evidence of hemorrhage [Figure 2]. This could also have been a result of trauma. However, *no signal intensity changes* were seen in the cord at that level. This patient later on developed ARF for which nephrology consultation was taken and he was transferred under their care.

Lakshminarayana *et al.* have reported two cases of lightning injury with long-term follow-up of 5 years.[13] Both patients had features of myelopathy which improved substantially in the next few years so that there was a complete recovery. Our patient had a group I injury where the imageology showed nothing substantial correlating to the pattern of injury, and hence diagnosis of keraunoparalysis was made. Keraunoparalysis, also known as

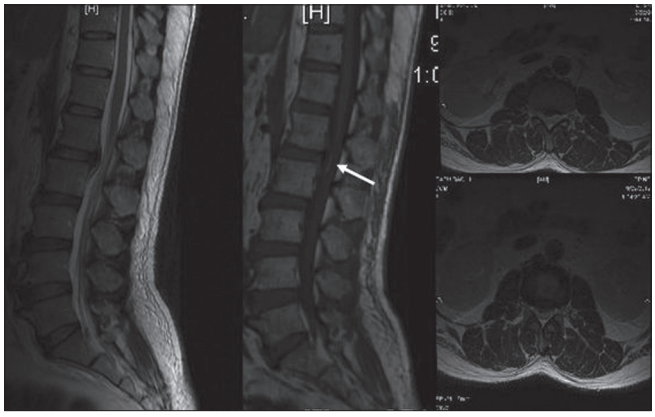

**Figure 1: Sagittal and Axial MRI images of lumbar spine show elevated Posterior Longitudinal Ligament at D12-L1 level with evidence of hemorrhage (arrow). No significant cord signal changes are seen**

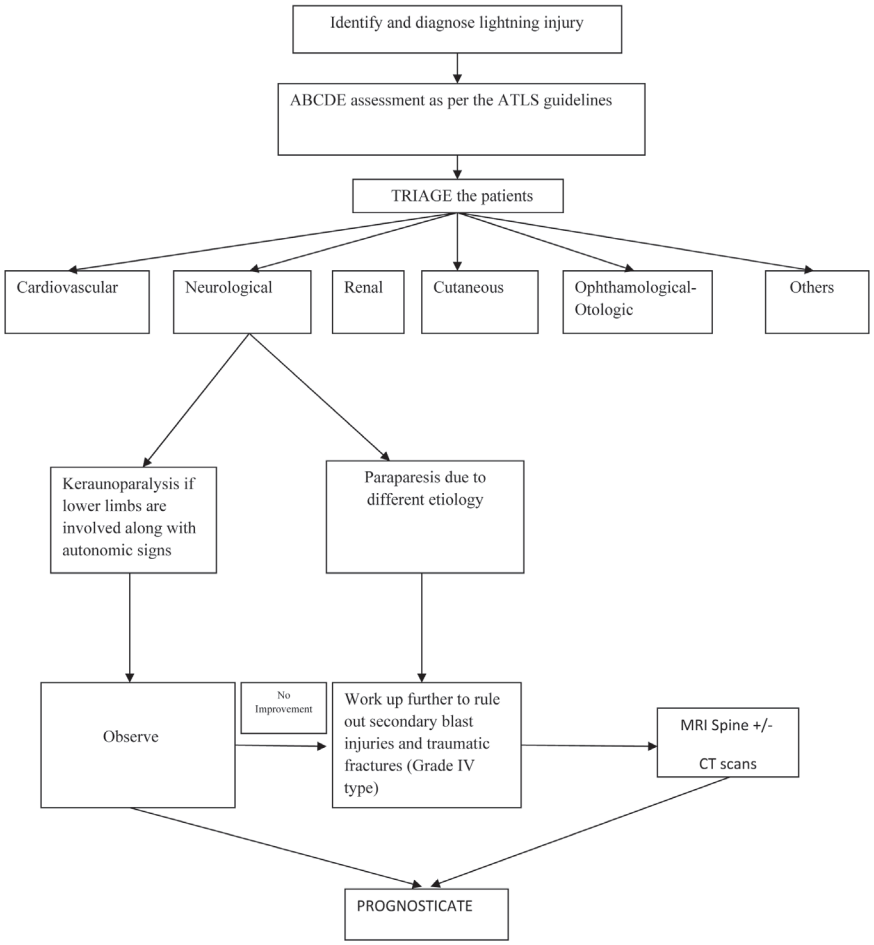


**Figure 2: Management algorithm for a patient with lightning injury**

Charcot's paralysis, involves transient weakness affecting the lower limbs more commonly and automatically reverses in a matter of few hours. The hypothesis behind this is the adrenergic gush and catecholamine release leading to temporary vasospasm of the spinal arteries. This is also accompanied by pallor and intense vasoconstriction in the extremities. Sensory disturbances and coolness of the limbs are also encountered. Charcot was the first one to describe this entity, although the term "keraunoparalysis" was introduced for the first time by Critchley and ten Duis. It has been reported in the past by the neurologists because no intervention is usually sought and neurosurgeons never come into the picture. Whenever a patient of lightening strike presents with paraparesis, a neurosurgeon usually thinks about the secondary trauma being the etiology behind this phenomenon and orders a battery of investigations. The investigations may take time and it may be difficult at times to secure them as early as possible in an emergent setting. This usually leads to anxiety and unnecessary chaos in the Emergency Room (ER). Also, it will prevent unnecessary administration of methyl prednisolone in these subsets of patients. This could prevent steroid-associated complications in patients. Actually in our patient, the presence of hemorrhage substantiates our belief, but reversal of the neurological deficits in due course of time proved otherwise. This incident prompted us to review the literature regarding similar reversible deficits post lightning. Keraunoparalysis is an entity less known to neurosurgeons than plastic surgeons/ neurologists as it does not involve surgical management. As secondary trauma cannot be ruled out completely, it is always a diagnosis of exclusion. However, if we, as a community, are aware of this entity, we can save our energy and may try expectant management in cases where clear and definitive history of lightning strike is there. This will not only reduce our anxiety but also will give us time and help us prognosticate the patients well. If patients recover within hours and no bony fractures are seen on X-rays, MRI of spine may not be required in the emergent setting and can be ordered little late in the course of time when the changes within cord become more apparent.

## CONCLUSION

In order to reduce the lightning injuries, we need to be better educated and aware of the sequelae caused by them. In case of storms with lightning, people should be instructed to take shelters at homes rather than taking shelters under a tree or a metallic roof top, although a completely closed metallic object like a car can be a better option than an open ground. While inside, all the electrical appliances and telephones need to be kept away from contact and in switched off mode.[14] Any lightning injury victim presenting with paraparesis can have etiology of varied types. As far as neurosurgeons are concerned, after a primary survey is over, close observation may be instituted till the patient shows some improvement in the paraparesis and if no other obvious bony injuries are suspected. Better understanding of keraunoparalysis will help us prognosticate our patients in the best suitable manner and will avoid unnecessary therapeutic mismanagement. Most importantly, it may convert a grim situation into more optimistic one. *"What the mind dose not know, eyes never see."* We hope that this article enlightens the minds of many!

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