Author’s response to reviews

Title: Delayed Oesophageal Perforation following Lightning Strike.

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Delayed Esophageal Perforation following Lightening Strike:

A Case report & review of the literature

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ABSTRACT

INTRODUCTION:
Lightning is the second most common storm-related cause of death. The mortality following lightning strike is 10-30%, a large proportion of whom suffer cardiopulmonary arrest at the time of the strike. Much less commonly, solid organ injuries occur from either primary or secondary blunt force trauma.

CASE PRESENTATION:
This is the first case-report in the literature of a 79 year-old Caucasian male with an isolated esophageal rupture caused by lighting strike blunt-force trauma.

CONCLUSIONS:
1. Solid organ injuries are often under appreciated in lightening strikes.
2. Blast injury to patients by lightening strikes should prompt clinicians to search for occult organ injury.
INTRODUCTION:

Lightning is the second most common storm-related cause of death, exceeded only by flash floods. The mortality following lightning strike is 10-30% with a bias towards the reporting of fatalities. A large proportion of victims suffer either ventricular fibrillation or an asystole cardiopulmonary arrest at the time of the strike. The injuries seen in survivors include neurological phenomenon, cardiac dysrhythmia, vasospasm, burns, and tympanic and ocular damage [1]. Much less commonly, solid organ injuries occur from either primary or secondary blunt force trauma. To our knowledge, this is the first case in the literature of an isolated esophageal rupture caused by lightning strike blunt force trauma.

CASE PRESENTATION:

The patient was a 79 year old white male who was hit by the ground current of a lightning strike while holding onto the metal railing of his veranda. He was thrown back 2 meters and suffered a fractured right humerus but never lost consciousness. He was admitted to a regional hospital for observation with casting of his fractured arm and subsequently discharged. Four days later the patient complained of acute upper abdominal pain followed by an episode of hematemesis. At representation he was hemodynamically unstable and hypoxic requiring intubation. A CT-chest and abdomen demonstrated bilateral hydrothorax with esophageal rupture and hence bilateral chest drains were inserted. He was transferred to our institution for surgical opinion and management of his septic shock with multi-organ failure.
Trans-esophageal echocardiogram showed normal LV size and function but markedly dilated right-sided chambers with severe tricuspid regurgitation, no aortic dissection. Because of hemodynamic instability and uncertainty of survival, it was elected to treat the patient non-surgically. He was managed with inotropic support, broad-spectrum antibiotics, further pleural space drainage, total parental nutrition and renal replacement therapy. On the 12th day of admission, a CT-gastrograffin swallow demonstrated a persistent distal esophageal rupture into the pleural space. A total esophagectomy with decortication of the right pleural space and insertion of a jejunostomy feeding tube was performed on the 21st day. Unfortunately, the patient’s condition worsened and he passed away 8 days after surgery.

**DISCUSSION:**

Lightning cannot be classified as either a direct or alternating current, its physics are extremely complex and differ from generated electricity. It can release >1 million volts of energy and can generate currents of >200,000 A. The damage caused is determined by the strength of the current (which is directly proportional to the source voltage and inversely proportional to the resistance of the conducting medium) and the duration of the application of the energy. The pathway that a current follows determines the type of injury, the tissues involved, and the extent of conversion to heat energy.

In contrast to high voltage electrocution injuries, severe burns and solid organ injuries are unusual because of the very short duration (2 milliseconds) of current flowing through the body and a phenomenon known as flashover where the majority of the energy flows
externally over the body. Injuries caused by lightning strike are thought to occur by five
different mechanisms; direct strike, contact injury, side splash, ground current and blunt
trauma [2,3].

1. **A direct strike** occurs when the lightning hits the person directly, usually on or
   near the head. However, a proportion of the energy may enter orifices such as
   the ears and flow internally mostly through the neurological and vascular systems.

2. **Contact** injury occurs when the victim touches an object within the lightning
   pathway.

3. **Side splash** injury occurs when lightning jumps from the primary strike site on to
   the victim.

4. **Ground current** injury occurs when a lightning strike hits the ground, spreads
   radially, and enters the victim’s feet.

5. **Blunt trauma** can either be primary or secondary (for example falls, airborne
   debris, or infrastructure collapse). Primary blunt force trauma can be caused by
   two mechanisms. Firstly, the current flow may cause muscular contraction
   throwing the patient, and secondly a blast wave may be produced with massive
   and sudden fluctuations in temperature. Air surrounding and within the victim is
   very rapidly super-heated to temperatures as high as 27,760 °C (50,000°F), and
   almost instantaneously expands and contracts, creating a shockwave that can
   throw the victim and/or cause blast wave injuries. Examples of blast wave injuries
   include myocardial and pulmonary contusions, ruptured lung, shearing of large
   vessels, ruptured tympanic membrane, ocular damage, and intestinal rupture.
   These types of injuries are well described and reproducible in bomb blasts and
experimental models [4]. Our patient’s severe right heart abnormalities are likely attributable to the blunt force contusion injury.

Whilst tympanic rupture and ocular damage are well documented in lightning strike victims (up to 50% - may also be caused by direct current entry or secondary blunt force trauma); there is limited literature on solid organ blast wave injuries caused by lightning. There are two case reports describing patients with a lightning-related severe blast injury to the lungs, and a third describing an isolated pneumomediastinum presumably secondary to alveolar rupture [5-7]. Post-mortem studies of lightning strike victims have shown a significant proportion of blast injuries, and the same group demonstrated blast injuries to the lungs and other solid organs using artificial lightning in animal models [8]. The reader may wonder if our patient had an occult injury that is known to be associated with esophageal injury, for example, cervical spine fracture or Boerhaave’s syndrome [9,10]? Neither by history nor diagnostic imaging could we identify any other injury. Furthermore, esophageal rupture tends to present acutely with pain, like in the instance of our patient four days later. Esophageal rupture is a rare, difficult diagnosis to make and even a more challenging syndrome to treat. Highly specialized institutions spend decades collecting data to achieve modest case series [12,13]. Various medical, surgical and minimally invasive procedures exist that are beyond the scope & purpose of this case report [11,14]
CONCLUSION:

Based on this case and our review of the available literature, it would seem prudent to have a high index of suspicion of blast injury in victims of lightning strike, and the presence of one such injury should prompt careful examination for others. Blast injury is an important cause of morbidity and mortality in lightning strikes.
Consent

Written informed consent was obtained from the patient’s family for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-chief of this journal.

Competing Interests

The authors declare that they have no competing interests.

Author’s contributions

GA and PF contributed equally to the final manuscript. All authors read & approved final manuscript.
REFERENCE LIST:

FIGURES

1. Intubated patient showing esophageal rupture during gastrograffin swallow.

2. Same gastrograffin series, posterior view.