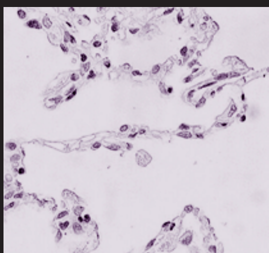

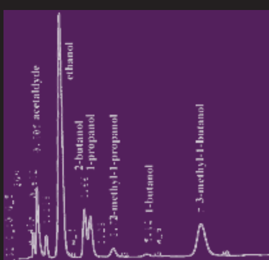

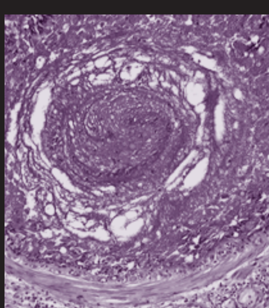

Forensic Pathology Reviews

Volume 4

Edited by

Michael Tsokos, MD

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Dedication

To my son Titus, once again

—Michael Tsokos, MD

Series Introduction

Over the last decade, the field of forensic science has expanded enormously. The critical subfield of forensic pathology is essentially based on a transverse, multiorgan approach that includes autopsy, histology (comprising neuropathological examination), immunohistochemistry, bacteriology, DNA techniques, and toxicology to resolve obscure fatalities. The expansion of the field has not only contributed to the understanding and interpretation of many pathological findings, the recognition of injury causality, and the availability of new techniques in both autopsy room and laboratories, but also has produced specific new markers for many pathological conditions within the wide variety of traumatic and nontraumatic deaths with which the forensic pathologist deals.

The *Forensic Pathology Reviews* series reflects this expansion and provides up-to-date knowledge on special topics in the field, focusing closely on the dynamic and rapidly growing evolution of medical science and law. Individual chapters take a problem-oriented approach to a central issue of forensic pathology. A comprehensive review of the international literature that is otherwise difficult to assimilate is given in each chapter. Insights into new diagnostic techniques and their application, at a high level of evidential proof, will surely provide helpful guidance and stimulus to all those involved with death investigation.

It is hoped that this series will succeed in serving as a practical guide to daily forensic pathological and medicolegal routine, as well as provide encouragement and inspiration for future research projects. I wish to express my gratitude to Humana Press for the realization of *Forensic Pathology Reviews.*

Michael Tsokos, ***MD***

Preface

Never before has so much information on current criminal cases and the associated forensic pathological matters been so readily available to so many people. The media seem to carry an increasing number of crime stories that touch detail nearly every day. The Internet provides widespread and virtually unlimited access to information (and misinformation) on all types of forensic pathological and medicolegal scenarios.

More than ever, there is a need for fixed points of reference by which both common forensic pathological entities and specific pathological conditions that are only rarely encountered in the autopsy room can be judged based on expert review, evaluation, and recommendation. The *Forensic Pathology Reviews* series has the goal of increasing a point of reference.

Of course, solving forensic pathological problems effectively requires a strong base of knowledge of pathology combined with personal experience and critical appraisal skills. Successful forensic pathologists and medical examiners weigh the importance and validity of the data they collect from the victims of homicide, suicide, and accidents as well as from those who expire from natural causes using sound reasoning based on probabilities, and a broad knowledge of the pathological and clinical features presented by these fatalities, in order to generate a thoughtful, convincing, and appropriate approach to establishing the cause and manner of death and the reconstruction of events. Encountering and solving problems in forensic pathology—particularly challenging cases—continues to be a source of great professional satisfaction.

It is a pleasure to express my gratitude to the many colleagues from all around the world who have so generously contributed to the *Forensic Pathology Reviews* series by making their scientific and practical knowledge accessible to the broad international readership of this series.

Michael Tsokos, *MD*

Contents

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Death From
Environmental Conditions

1

Pathological Features of Death From Lightning Strike

Stephan Seidl, MD

Contents

Summary

Lightning strikes cause more deaths in the United States than other natural disasters, such as hurricanes, tornadoes, volcanoes, and floods. Lightning is a transfer of an electrical charge and results from the sudden environmental discharge of static electricity. The power of lightning is estimated to be between 10,000 and 200,000 A of current, with estimated voltage ranging from 20 million to 1 billion V. The effects of lightning on the human body depend on a number of features, such as the intensity of the current, the time it spends passing through the body, the pathway involved, the activity and position of the person at the time of the event in relation to the ground, and the kind of strike (direct strike, contact voltage, side splash, ground strike, or wire-mediated lightning). Lightning strikes result in multisystem dysfunction, and survivors may experience prolonged disability following recovery from the initial insult.

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Electrical energy causes muscular spasm and necrosis, thrombosis, blood vessel tears, unconsciousness, and motor and sensory function abnormalities. Most deaths after lightning strikes occur either because of primary cardiac arrest or hypoxia-induced secondary cardiac arrest. If multiple persons are struck, attention at the scene should be directed first to those who appear dead, because they may be in respiratory arrest and in urgent need of immediate cardiopulmonary resuscitation that can be successful in lightning strike victims for far longer than would seem reasonable in other types of injury.

Key Words: Lightning strike; lightning injuries; direct strike; ground strike; contact voltage; side splash; side flash; wire-mediated lightning; flashover; Lichtenberg figures; burns.

1. Introduction

Lightning is a transfer of electrical charge resulting from the sudden environmental discharge of static electricity sandwiched between an upper negative-charged region, such as thunderheads, and a lower positive area *(1)*. When voltage between two oppositely charged fields exceeds atmospheric resistance, discharge occurs *(2)*. The most common types of lightning strikes are intracloud (the majority of discharges) and cloud-to-ground (some 20%), with ground-to-cloud and cloud-to-cloud lightning occurring only rarely *(2–4)*. However, a lightning strike may occur under fair weather conditions from a clear sky, far from any thunderstorm clouds *(5-8)*. Cherington and colleagues *(9)* discussed a case where the discharge originated in a cumulonimbus cloud that was approx 10 miles away and that was obscured by mountains. They called this phenomenon a "bolt from the blue."

The power of lightning is estimated to be between 10,000 and 200,000 A of current, with estimated voltage ranging from 20 million to 1 billion V *(10-12)*. A strike produces an intense burst of thermal radiation of up to 30,000 K within milliseconds and is accompanied by a shock wave of up to 20 atm that can contuse or perforate human organs *(10,11,13,14)*. Electrical energy follows the path of least resistance. Because tissues that have a low water and electrolyte content have a higher resistance, tissue resistance decreases in the following order: bone, fat, tendon, skin, muscle, blood vessel, and nerve *(4,11,15,6)*. The most important resistor to the flow of current is skin. Skin resistance varies from 1000 ohms on a sweaty palm to 1 million ohms on a dry, calloused hand *(11)*. The phenomenon of current traveling on the surface of wet skin without much penetration to deeper tissues is called "flashover" *(1-3,14)*. If it is raining or the person is perspiring, the water can vaporize with such force that the clothes are shredded and the shoes are blown off *(2,14)*.

Estimates reveal that there are approx 50,000 thunderstorms and 8 million lightning flashes per year worldwide *(17)*. Surprisingly, despite the vast amounts of energy involved, the overall mortality rate following lightning injury is only 30% *(8,18)*. The morbidity rate in survivors, however, is close to 70% *(2,19)*. Lightning strikes, although uncommon, still reportedly cause more deaths in the United States than other natural disasters, such as hurricanes, tornadoes, volcanoes, and floods *(16,18,20,21)*. In the United States, several thousand people are struck by lightning but survive, and approx 100 to 600 people die from lightning injuries *(2,4,8,10,14,17–19,22)* each year. These deaths occur primarily from May to September, between 3 and 6 PM, and mostly affect a young, active group less than 40 years of age *(8,18,19)*. The effects of lightning on the human body depend on a number of features, including the intensity of the current, the time it spends passing through the body, the pathway actually involved, and the activity and position of the person at the time of the event in relation to the ground *(1,10,13)*. In addition to these, a factor of major importance is the kind of strike, as a person may be hit by lightning in several ways *(4)*.

2. The Different Forms of Lightning Strikes

2.1. Direct Strike

Lightning may strike a person directly, usually entering through the head or an outstretched arm *(1,12,18,23,24)*. The current is then transferred to the body, and, in most of these cases, the exit pathway is through the soles of the feet because the lightning victim is normally standing, earthing him or herself through the ground *(12,14)* (Fig. 1). A direct lightning strike is the most damaging because the current discharges directly through the body and causes extensive thermal injuries and barotrauma *(2,12,19,23,25)*.

2.2. Contact Voltage

The difference between a direct strike and a side splash is the contact voltage. It occurs if people are wearing or carrying something metal, such as an umbrella, golf club, or a weapon *(2,23,26)*. If lightning strikes this metal object, the current will flow to the body of the victim, if this pathway is the way of least resistance *(23)*.

2.3. Side Splash

A side splash or side flash strike occurs when lightning discharges—after a primary strike to an adjacent object such as a tree—to a victim who has no