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Electric Burn Injury and Cardiac Autonomic Function

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ABSTRACT

Electrical injuries are a common form of mechanical trauma that can cause significant damage to the skin and underlying tissues, as well as potentially affect other systems of the body, including the cardiovascular system. Electric burn injury can affect cardiac autonomic function, potentially leading to arrhythmias and heart failure.

The autonomic nervous system plays a critical role in regulating cardiac function, acting as the primary regulator of heart rate and contractility. The balance between the two systems, sympathetic and parasympathetic, is essential for optimal cardiovascular function and can be assessed through measures of cardiac autonomic function. The most commonly utilized method is using the electrocardiogram (ECG) in combination with the impedance cardiogram (ICG). The pre-ejection period (PEP) can be extracted from ECG during the left ventricular ejection as a measure of cardiac sympathetic control, and the respiratory sinus arrhythmia can be extracted from ECG during respiration as a measure of cardiac parasympathetic control.

This literature review explores the current understanding of how electric burn injury affects cardiac autonomic function and its potential influence on cardiac function. It also emphasize the need of further research to understand the precise mechanisms involved in the effects of electric burn injury on cardiac autonomic function and to develop effective treatment strategies to prevent adverse cardiovascular outcomes.

KEYWORDS: electric burn injury, cardiac autonomic function, sympathetic nervous system, parasympathetic nervous system, heart rate variablity, pre-ejection period, respiratory sinus arrhythmia.

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INTRODUCTION

Electrical injuries, a relatively common form of mechanical trauma, can occur as a result of lightning, low-voltage, or high-voltage injury, and are often associated with high morbidity and mortality.[1-4] In the United States, there are approximately 1000 deaths per year, as a result of electrical injuries. Of these, approximately 400 are due to high-voltage electrical injuries, and lightning causes 50 to 300. There are also at least 30,000 shock incidents per year that are non-fatal. Each year, approximately 5% of all burn unit admissions in the United States occur as a result of electrical injuries.Approximately 20% of all electrical injuries occur in children. The incidence is highest in toddlers and adolescents. In adults, these injuries occur mostly in occupational settings and are the fourth-leading cause of workplace-related traumatic death, whereas, in children, electrical injuries occur most often at home.[1-7] In Indonesia, one study from Cipto Mangunkusumo National Central General Hospital in 2019 revealed burn injuries admissions were about 11.7% of all burn injury admissions during the 5 year span from 2014-2019.[8]

A person may get an electrical injury at home, such as a shock from a wall outlet, extension cable, or small appliance, but these injuries are very rarely accompanied by serious harm or consequences. Children may experience a low-voltage injury without associated loss of consciousness or arrest by biting or chewing on an low voltage electrical cord. Adults who work on workplace or home appliances or circuits could sustain similar accidents. Similar to high-voltage current, low-voltage electrical current can cause significant harm depending on the duration of exposure (for instance, if there is prolonged muscular tetany), the person's size, and the cross-sectional area in contact with the electrical source.[5-7]

Nearly all electrical injuries are unintentional and frequently avoidable. Even if not immediately lethal, electrical injury damage can cause various tissues or organs to malfunction.[1-

[4] Electric burn injuries can cause significant damage to the skin and underlying tissues, as well as potentially affect other systems of the body, including the cardiovascular system. One area of interest in electric burn injury research is the impact of such injuries on cardiac autonomic function, which refers to the balance between the sympathetic and parasympathetic nervous systems that regulate heart rate and other cardiovascular functions. In this literature review, we will explore the current understanding of how electric burn injury affects cardiac autonomic function and its potential influence on cardiac function.

Sympathetic and parasympathetic nervous system and cardiac autonomic function

The autonomic nervous system plays a critical role in regulating cardiac function. It acts as the primary regulator of heart rate and contractility.[9] The autonomic nervous system achieves control over cardiac function by modulating the activity of the sinoatrial node, which is considered the natural pacemaker.[10] The autonomic nervous system is divided into two branches: the sympathetic nervous system and the parasympathetic nervous system.[11] The sympathetic nervous system is responsible for the "fight or flight" response, which leads to an increase in heart rate, contractility, and cardiac output.[12] These changes occur due to the release of norepinephrine from sympathetic nerve endings, which binds to β1-adrenergic receptors on cardiac cells, resulting in increased calcium influx and subsequent myocardial contraction.[13] On the other hand, the parasympathetic nervous system is responsible for the "rest and digest" response.[11] This leads to a decrease in heart rate, contractility, and cardiac output.[12] These changes occur due to the release of acetylcholine from parasympathetic nerve endings, which binds to muscarinic receptors on cardiac cells, resulting in decreased calcium influx and subsequent myocardial relaxation.[14] The balance between the sympathetic nervous system and parasympathetic nervous system is crucial to maintaining optimal cardiac function. Dysfunction in the autonomic nervous system can lead to a variety of cardiac-related disorders, such as arrhythmias and heart failure.The balance between these two systems is essential for optimal cardiovascular function and can be assessed through measures of cardiac autonomic function.[15-17]

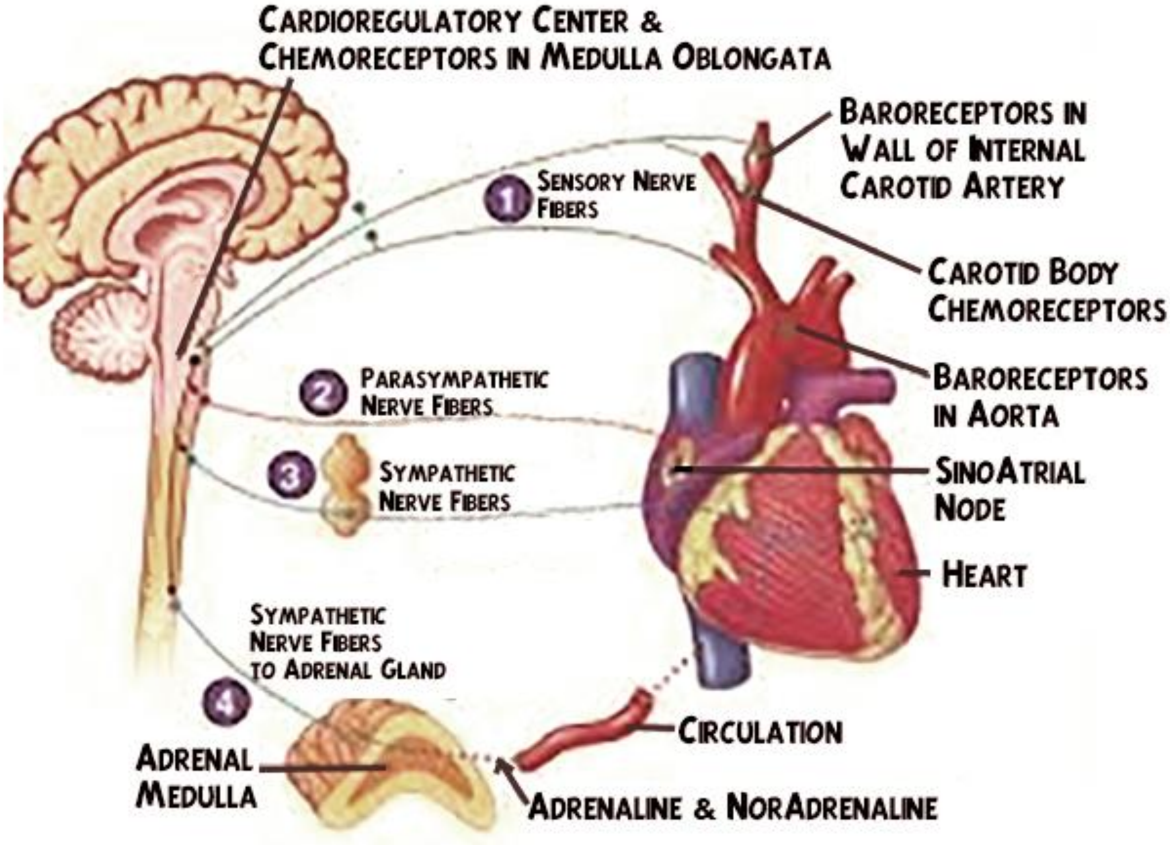

Figure 1. Autonomous Nervous System of the Heart

Measuring cardiac autonomic function

The autonomous nervous system activity can be measured invasively, for instance by radiotracer techniques or microelectrode recording from superficial nerves, or it can be measured non-invasively by using changes in an organ's response as a proxy for changes in the autonomous nervous system activity, for instance of the sweat glands or the heart. Invasive measurements have the highest validity but are very poorly feasible in large scale samples where non-invasive measures are the preferred approach. Autonomic effects on the heart can be reliably quantified by the recording of the electrocardiogram (ECG) in combination with the impedance cardiogram (ICG), which reflects the changes in thorax impedance in response to respiration and the ejection of blood from the ventricle into the aorta. We can extract the pre-ejection period (PEP) from ECG during the left ventricular ejection as a measure of cardiac sympathetic control, and we can extract the respiratory sinus arrhythmia from ECG during respiration as a measure of cardiac parasympathetic control. As ECG and ICG recording is mostly performed in laboratory settings, however, having the subjects report to a laboratory greatly reduces ecological validity, inot always doable in large scale epidemiological studies, and can be nerve-wracking for children. An ambulatory device for ECG and ICG simultaneously resolves these challenges.[18]

Clinicians commonly use heart rate variability (HRV) as a method for assessing cardiac autonomic function. HRV measures the variation in time between consecutive heartbeats, which reflects the activity of the sympathetic and parasympathetic nervous systems. HRV can be measured in the time domain, frequency domain, or nonlinear methods.[19] In addition, clinicians also have other methods such as baroreflex sensitivity and spectral analysis to assess cardiac autonomic function.[20-25]

Electric burn Injury and cardiac autonomic function

The highly polar interactions of water have a significant influence on the molecular architecture of biological systems. Thus, macromolecules such as proteins that are highly water soluble must be electrically polar. We acknowledge that energy production process required to sustain cellular metabolic activities rely heavily on segregating mobile ions, thus necessitating the use of electrical ion transport barriers like membranes. One consequence of these biological design constraints is vulnerability to injury by electrical forces. Supraphysiological electric forces rupture cell membranes and change the structure of biomolecules, which results in harm to cells and tissues. Additionally, continuous electrical current flow causes damage through thermal mechanisms.[26] However, we focused on the non-thermal impacts of electrical trauma in this review.

Clnicians have studied the impact of electric burn injury on cardiac autonomic function. A group of clinicians in South Korea performed 24-hour heart rate variability (HRV) monitoring in 60 patients with electrical burns, major burns, and minor burns, as well as monitoring 10 healthy participants, and analyzed the HRV in the time and frequency domain. They hypothesized that heart rate variability is a surrogate for autonomic nervous system dysfunction in patients with burn and found out that burn patients showed a sympathetic predominance during daytime and a decreased parasympathetic activity during nighttime, and patients with electric burn injury showed significantly higher heart rate variability than other burn injuries.[27]

Burn experts have not yet fully agreed about the exact mechanisms by which electric burn injury affects cardiac autonomic function. However, they have proposed several potential mechanisms. One possible mechanism is the direct effect of electrical current on cardiac tissue, leading to damage to the nerves and structures that regulate cardiac autonomic function. A broad spectrum of cardiac changes in cases of direct electrical current contact (e.g. electrocution) has been described in the literature, including the break-up of myocardial fibres, cardiomyolysis, haemorrhagic areas, the separation of myofibres and alternating hypercontracted-hyperdistended myocytes.[28] Another proposed mechanism is the release of cytokines and other inflammatory mediators in response to tissue damage, which can disrupt the balance between sympathetic and parasympathetic activity. We acknowledge that severe burn injuries lead to a persistent, hyperinflammatory response that may last up to 2 years after trauma, and this persistent release of inflammatory mediators contributes to end-organ dysfunction. Cytokines promote the inflammatory cascade and promulgate mechanisms resulting in cardiac dysfunction. Such mechanisms triggering the post-burn cardiac dysfunction include the role of tumor necrosis factor α (TNFα), interleukin 1β (IL-1β), interleukin-6 (IL-6), and interleukin-10 (IL-10).29

CONCLUSION

We recognize how electrical burn injuries are known to cause extensive damage to the skin and underlying tissues, but we should not forget that they also have significant impact on vital organs, most importantly the cardiovascular system. Electric burn injuries commonly reduce cardiac parasympathetic activity and increase cardiac sympathetic activity, and an imbalance between the two systems of cardiac autonomous nervous system can lead to a range of cardiac-related complications and increased morbidity and mortality. Various methods of measuring cardiac autonomic function are available, including non-invasive measures such as electrocardiogram (ECG) and impedance cardiogram (ICG) recording. Although the exact mechanisms by which electric burn injury affects cardiac autonomic function are not fully understood, available related-studies and current understanding are still sufficient as the foundation for the proper clinical management of electric burn injury cases and for further studies to elucidate the patophysiology of cardiac autonomous nervous system dysfunction due to electric burn trauma.

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