Volume 8

Advances in Plastic and Reconstructive Surgery®

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Advances in Plastic and Reconstructive Surgery®

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A Special Message From the Editor

I am sure that those who follow up *Advances in Plastic and Reconstructive Surgery*® realize that the *Advances* always appears to be ready to be reviewed by the subscribers and all those interested at the time of the American Society of Plastic and Reconstructive Surgeons meeting. However, this year, we were faced with a very unusual situation with the war that took place in the Persian Gulf. Some of us had to be called up for active duty, including your Editor-in-Chief, and had to put our lives, activities, and patients "on hold" in order to be trained and prepared for deployment. Some of us were deployed to the Middle East, some to Germany, and some were used in the United States for deployment to different posts and also as back-fills. That disruption in our usual routine activities caused some of the delays in manuscripts, reviews, and other aspects that eventually showed its toll in the delays in the publication of the *Advances in Plastic and Reconstructive Surgery*®, volume 8.

However, with the superb support and activities from the publisher, we were able to catch up in a way and get all the manuscripts reviewed, prepared, and ready to go by the time the war was over. I hope our readers will excuse us for the delay this year, and that we will be able to catch up with our routines by the next volume.

We were also faced with another aspect in that the meeting at which we usually released the book, which is the ASPRS meeting, was moved earlier this year.

We are all looking forward to a nice and peaceful future so we can complete our first anniversary and our silver anniversary in the coming years.

Mutaz B. Habal, M.D., F.R.C.S.C.
Editor-in-Chief

Statement of Purpose

The eighth volume of *Advances in Plastic and Reconstructive Surgery*® offers another series of new and innovative topics and introduces these advances to the practicing plastic surgeon.

Time has passed so fast since we started our first series almost 10 years ago. At that time, we felt that we would be going over some topics that were new and controversial two or maybe three times. However, we are still seeing more and more advances coming our way in plastic and reconstructive surgery. Some of these will be noted in this volume and others will be forthcoming in future volumes.

As the surgical specialty is getting more and more focused into regions, techniques, and procedures, the scope continues to widen for the plastic surgeon. There is a wide variety of techniques and the process is still fascinating and exciting. It is of utmost importance that even though we now have specialized people in our specialty of plastic and reconstructive surgery, we still thrive on being able to perform a wide variety of plastic and reconstructive surgery and yet have the ability to focus into one area and excel, which is almost a must for every plastic surgeon who is just starting out in the field now.

In this issue, as we have promised in the past, even though most of the chapters are invited authors, we are still open for those who may feel they have something of interest which they would like to present. The process is the same: a short abstract is written and reviewed, and then a chapter is formulated and also peer-reviewed before it is accepted for publication. We have one such chapter selected in this issue and we hope that in the future we will always have a mix between those invited and those that are authored by this selective process of strict peer review by the editorial board.

It is also of interest to note that in striving for excellence, we continue to be a "matrix" specialty, crossed with many other specialties for different treatment modalities. In this issue, it is well noted in the embolization chapter where the skill of a plastic surgeon and a radiologist helped alleviate some of the problems that patients encounter with large vascular malformations.

Whether in basic science or clinical application, *Advances in Plastic and Reconstructive Surgery* will exhibit such advances that will continue to be placed under one cover as a forum of communication in the future.

If a topic is very controversial, we will have a point/counterpoint presentation and leave the final judgment of which method, technique, or treatment plan to use to the practicing plastic surgeon's experience.

Mutaz B. Habal, M.D., F.R.C.S.C.
Editor-in-Chief

Preface

This year, *Advances in Plastic and Reconstructive Surgery*®, volume 8, brings to us a variety of topics that are of interest to the practicing plastic surgeon. Specifically, the topics are a mixture of clinical and also basic science with its applications. The basic science data is of importance to most of us dealing with thermal injury.

The first chapter, by Lee and associates, shows us the biophysiology, pathophysiology, mechanics, and physics behind electrical thermal injuries. As this becomes more evident on the scientific level, discussions of the treatment and treatment plans followed.

Bob Flowers and his associates bring us Bob's experience of many years in eyelid reconstruction. Even though the early part of his experience was working on aesthetic eyes, the various uses and techniques used in eyelid reconstruction with the new advances are all noted. It is of great interest to note that when eyelid surgery was initially performed, it was merely an excision of redundant skin with primary closure. Now, it is extensive, artistic work with muscle physiology and plastic surgery to give the patient the best possible outcome.

Jim Carraway, who also has vast experience on this topic, brings us both his experiences and the advances made.

Steve Sohn has a profound interest in cosmetic surgery. He started working many, many years ago with Dr. Skoog and ended up with his practice in Boston. He brings us some of the ancillary points in cosmetic surgery.

Mustoe and Khori bring us new advances in scar therapy. The application is the same, however their experience is well demonstrated through different parts of the text, and the future of such modalities and applications will be dependent on how long they stand the test of time.

Kawamoto demonstrates to us the application of craniofacial surgical techniques in aesthetic surgery, stressing the importance of knowing the anatomy of the skeleton well for application of patient treatment.

Rapperport and his colleagues bring us their experience with direct modalities of iontophoresis in the treatment of patients with extensive topical and extensively localized infection by regional application. An example is the improvement of a well known modality with widening of its application.

So, we now progress in our knowledge and application, continuing to follow the Osler dogma of utilizing our knowledge from reading, experience, and teachings for application in patient care to pursue excellence and achieve the best possible outcome with the highest standard of care available.

Mutaz B. Habal, M.D., F.R.C.S.C.
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Contents

Pathophysiology and Clinical Manifestations of Tissue Injury in Electrical Trauma

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The high-voltage electrical burn is often a thoroughly devastating injury. Extensive skeletal muscle, neural and vascular tissue injury may occur, and the damage is characteristically scattered in its distribution along the current path. The victim frequently suffers permanent disability. The pathogenic mechanisms underlying electrical trauma have not been well understood. Recent research indicates that strong electric fields damage tissues by more than heating alone, involving direct damage to cell membranes. Despite recent progress, there are many unresolved questions. This review will focus on the current state of biophysical and clinical understanding of electrical trauma as well as touch on aspects of clinical management.

Background Physiology and Biophysics

Electrical Conduction

Although in metallic conductors current is carried by electrons, the charge carriers in aqueous solutions are mobile ions. During electric shock, electrons are converted to ions by electrochemical reactions across the metal-

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skin interface (Fig 1). This generates heat and toxic chemical by-products that alter tissue oxygen and pH and may contribute to local tissue injury.

Pure water is tenfold more resistant to electrical current than is physiologic saline. The addition of salt provides mobile ions to carry the current, which raises conductivity to approximately 1 siemens*/m for physiologic saline. Because saline is such a good electrical conductor, the body in contact with a 60-Hz source behaves like a pure resistive load.

When current passes through the body, the epidermal layer and the metal-skin surface contact impedances dominate the initial resistance. The epidermis is very thin, typically a 100- to 500-μm thick layer of fused squamous epithelial cells that covers the body surface, forming a thin electrically insulating closed shell. Depending on its state of hydration, the resistance of 1 cm^2 of epidermis may range from 50,000 to 500,000 Ω. In the palms of the hands and soles of the feet, the epidermis can build up to double or triple that thickness, resulting in two or three times greater resistance. There is little difference in the measured resistance between adja-

$$^{*}1 \text{ siemens} = \frac{1}{\text{ohm } (\Omega) \times \text{volt } (V)}$$

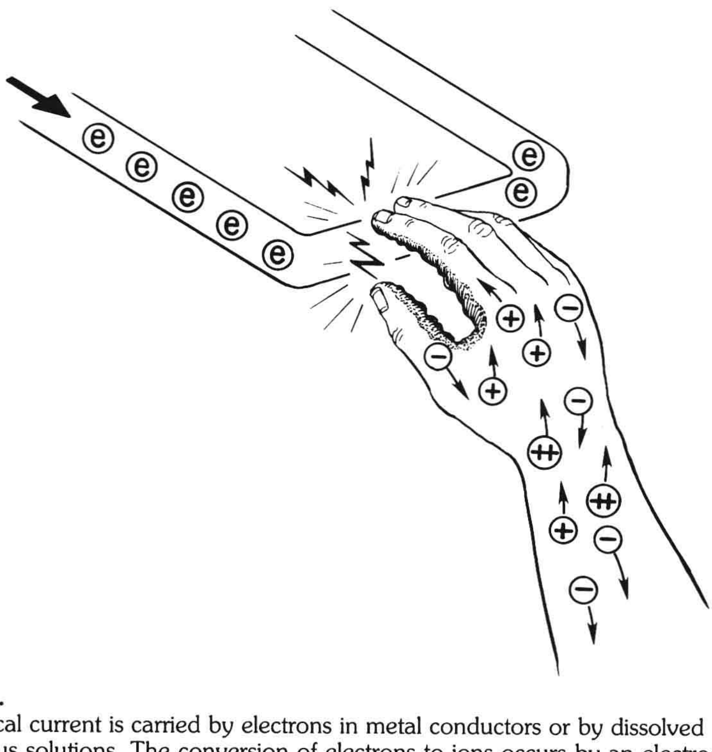

FIG 1.
Electrical current is carried by electrons in metal conductors or by dissolved ions in aqueous solutions. The conversion of electrons to ions occurs by an electrochemical process that causes pH changes and heat generation.

cent fingers on one hand and between two fingers on opposite hands because the epidermis dominates the electrical resistance to current passage through the body.

Conduction of current in tissues is altered by the presence of cells. Cell membranes are very insulating, thus the current tends to pass around and between them. In effect, this reduces the tissue area available for ion flux. The result is that tissue conductivity is less than that of physiologic saline and varies according to cell density, cell size, and cell orientation. For example, the conductivity of muscle parallel to the long axis of the muscle cells is greater than the conductivity perpendicular to the major axis. Table 1 lists the electrical conductivity of the most abundant human tissues.

Dielectric Breakdown: Arcing

When the electric field strength within a material exceeds the critical value above which the force on atoms in the field pulls the electrons out of their orbital shells, the material becomes very conductive. This event is called dielectric breakdown and is manifested by a bright flash (arc) as electrons give off photons. The dielectric strength of a material is the maximum electric field strength a material will withstand before breakdown. For air, it is roughly 2×10^6 V/m; for other materials it has a different value (Table 2).

The temperature of the arc is roughly in the range of 3,000° C. Arc burns frequently occur on the skin of victims of high-voltage shock. How-

TABLE 1.
Electrical and Thermal Properties of Viable Human Tissues

Tissue	Electrical Conductivity (siemens/m)*	Thermal Conductivity (W/m° C)	Heat Capacity (J/m³° C)
Saline	1.3	0.59–0.66	4.13×10^6
Skin (dry)	$\sim 10^{-4}$	0.2	3.2×10^6
Skin (normal)	0.038	0.5–0.6	3.6×10^6
Fat	0.05	0.1–0.4	1.98×10^6
Muscle	0.4 (L) 0.14 (T)	0.385	3.8×10^6
Major nerve	0.47–0.72 (L) 0.083 (T)	—	—
Bone cortex	0.054	2.2	4.13×10^6
Bone marrow	0.180	0.385	$\sim 4.14 \times 10^6$
Blood	0.65	0.53	$\sim 4.14 \times 10^6$
Glycerine	10^{-8}	0.28	3.5×10^6
Mercury	10^6	8.0	1.9×10^6

*L = longitudinal to the long axis of the fibers, T = Transverse to the long axis of the fibers.