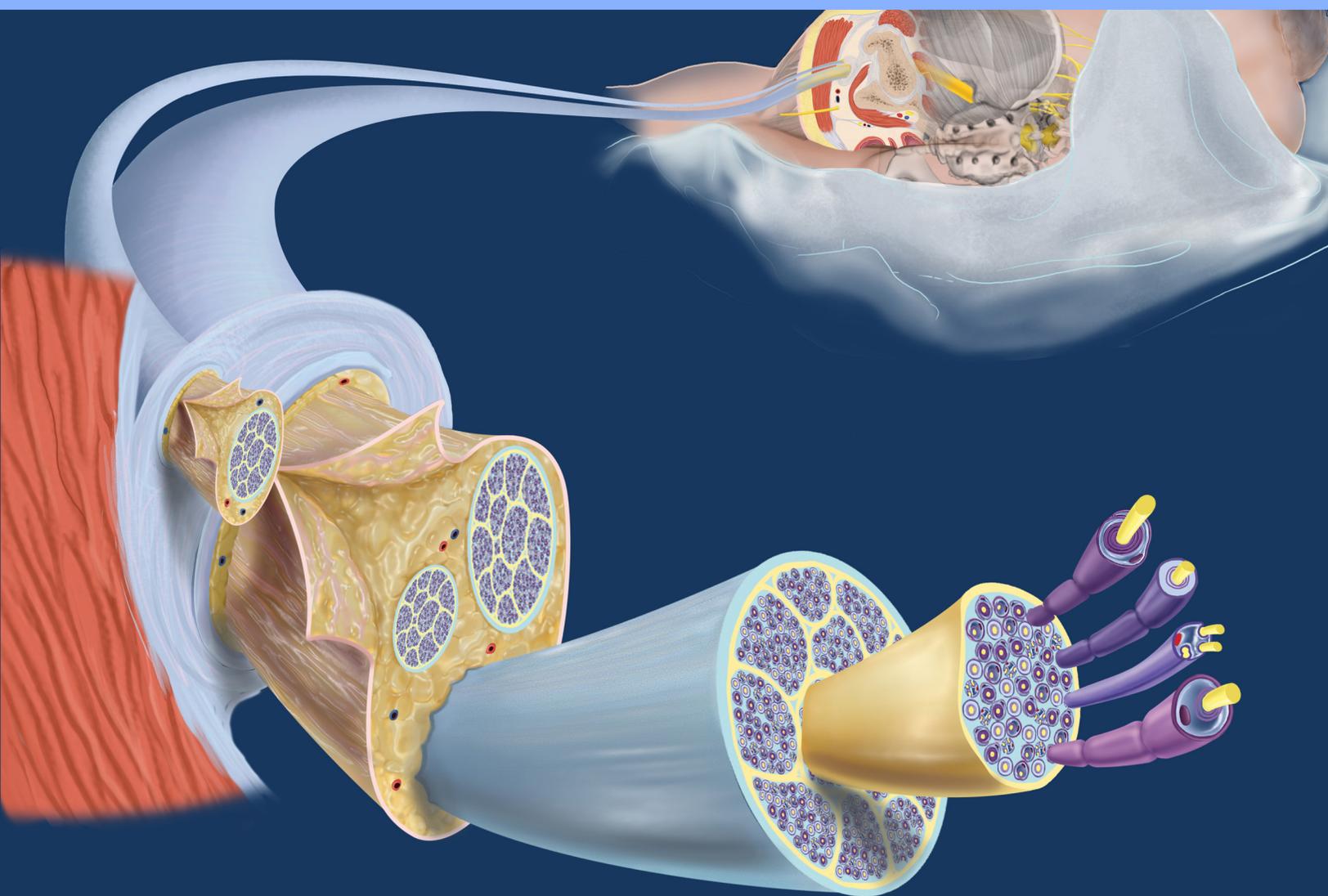


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THE ANATOMICAL FOUNDATIONS OF REGIONAL ANESTHESIA AND ACUTE PAIN MEDICINE

MACROANATOMY; MICROANATOMY; SONOANATOMY; FUNCTIONAL ANATOMY



Editor:
André P. Boezaart

Illustrated by Mary K. Bryson

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**The Anatomical Foundations of Regional
Anesthesia and Acute Pain Medicine**
Macroanatomy
Microanatomy
Sonoanatomy
Functional anatomy

Editor

André P. Boezaart

*Departments of Anesthesiology and Orthopaedic Surgery and
Rehabilitation*

Division of Acute and Perioperative Pain Medicine

University of Florida College of Medicine

Gainesville, Florida

USA

Illustrated by Mary K. Bryson

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subscriptions@benthamscience.org



DEDICATION

I dedicate this book with love and gratitude to my lifelong companion Karin, our children Kim, Ted and Johke and our grand children Dihan, Mila, André, Zani and Sebastian who enrich our lives far beyond their possible understanding.

I also dedicate this book to all my mentors, especially to Alon Winnie, Dannie Moore, Dag Selander and Gale Thompson who taught me that if I understood where a nerve lives, and what membranes and fascia barriers it lives in, and how to find it, I could do any known or unknown nerve block safely and successfully. All left for me was to be a Doctor, and care for patients. That teaching inspired the creation of this textbook.

André P. Boezaart

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FOREWORD

I have often used the quote, attributed to my dear friend, the late Alon P. Winnie, one of the "Founding Fathers" of the American Society of Regional Anesthesia, that "*regional anesthesia is nothing more than applied anatomy.*" This quote and approach to regional anesthesia has been the foundation of much of my career as a military anesthesiologist. I was therefore flattered and enthusiastic when my friend and colleague, André P. Boezaart, MD, PhD, asked me to provide a forward to this masterful work, "*The Anatomical Foundations of Regional Anesthesia and Acute Pain Medicine.*"

André and I have both turned to the potential of regional anesthesia in time of war to provide safe, compassionate, and logistically sound anesthesia and analgesia to soldiers wounded in combat. André served in the South African Defense Force in 1975 during the Angola War as the only anesthesiologist for the Forward Surgical Unit. Clutching a worn copy of Daniel Moore's 1967 4th edition textbook, "Regional Block," he quickly applied the lessons therein to many war casualties in long operating room sessions. In an effort to improve efficiency and avoid repeated axillary blocks for soldiers with upper extremity wounds that required further surgery or dressing changes, André performed axillary artery cut-downs and then passed central line catheters cephalad next to the artery to where the plexus crosses the first rib to provide continuous access to the brachial plexus for re-block and continuous analgesia of the arm. These catheters would remain in place for weeks and were used for frequent dressing changes and debridements common to war wounds. André's experience likely represents the first utilization of a continuous peripheral nerve block during war. Many years later, in 2003, employing far better equipment and the same love of anatomy, I would place the first continuous peripheral nerve block in a United States soldier evacuated from Iraq after sustaining near fatal injuries that included a traumatic amputation of his left leg below the knee. As in André's experience, these continuous regional techniques provided excellent operating room anesthetic conditions, remarkable perioperative analgesia, and greatly enhanced the wounded soldiers comfort during long evacuation flights without the nausea and respiratory depression associated with the exclusive (and at the time far too common) use of morphine for pain management. I am pleased to say that regional anesthesia and continuous nerve blocks are now routine practice in American military and civilian medicine. There are few situations in medical practice that are more unforgiving and difficult than the management of polytrauma casualties in austere battlefield conditions. The "discovery" of the utility of regional anesthesia by two (much younger at the time) anesthesiologists on two very different battlefields, separated by decades, is a testimony to the power this technique affords the anesthesiologist willing to invest the time necessary to acquire the essential anatomical knowledge required to apply these techniques safely, successfully, and consistently.

It is against this background that André has produced an anatomical text that focuses on the macro-, micro-, sono-, and functional anatomy that is vital for success in the field of regional anesthesia and acute pain medicine. So much of our teaching was, and regrettably still is, focused on how to find the nerves (ultrasound, nerve stimulation, paresthesia), and by far not enough on where these nerves are and what tissues and membranes surround them. This book gives equal weight to all three of these matters. The anatomical focus and approach to regional anesthesia provided in this text is refreshingly unique and much needed. Certainly, ultrasound technology in regional anesthesia has been revolutionary in terms of our ability to place needles and deposit local

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anesthetics in appropriate spaces around target nerves. Unfortunately, some have leaned too heavily on this technology as a crutch to overcome a poor grasp of basic anatomy. I predict that, like André's worn copy of Daniel Moore's "*Regional Block*" saved the lives and reduced suffering of many hundreds of wounded soldiers during the 1975 Angolan War, "*The Anatomical Foundations of Regional Anesthesia and Acute Pain Medicine*" will become a cherished companion of countless anesthesiologists who desire the virtues of regional anesthesia and understand that they must apply these foundations safely and with the confidence that is borne from a detailed knowledge of human anatomy.

It is my great honor to be the first to congratulate André Boezaart on this masterful effort that is the product of, and was inspired by, a truly remarkable career in anesthesiology. André does all of us, new and old acute pain specialists and regionalists alike, a great service with this refreshing look at the modern practice of regional anesthesia and acute pain medicine based on the timeless application of gross human anatomy, also now studied through modern microscopic lenses, by ultrasound beams and defining the nerve functions with electrical stimulation – macro-, micro-, sono- and functional anatomy.

Chester 'Trip' Buckenmaier

Defense and Veterans Center for Integrative Pain Management (DVCIPM.org)

Professor Anesthesiology

Department of Military Emergency Medicine

Uniformed Services University, USU '92

USA

PREFACE

Many thousands of high quality anatomy textbooks have been written over the centuries, and this textbook does not attempt to replace any of these or to improve on any of them. As a matter of fact, many of those texts were used as source material for this book. Those books remain essential parts of our fundamental study of Medicine. They contain beautiful photographs and drawings of carefully prepared dissections of anatomical specimens. However, to make the anatomy pictures beautiful and understandable the fascia and tissue barriers that surround tissue and organs (nerves in this case) had to be removed to illustrate the structures clearly; these textbooks were written to explain the gross macroanatomy to surgeons and other physicians.

But anatomy for regional anesthesia and acute pain medicine is different. Local anesthetic agents do not readily cross over anatomical barriers, and if they did they would be highly toxic. They therefore have to be deposited in the correct spaces surrounding nerves to allow diffusion to nerve axons without harming them. To describe these spaces, the authors of this textbook make liberal use of modern microscopic and electron microscopic studies of nerves as well as new ultrasound technology to explain, not only where the nerves are, but also what structures, membranes and barriers surround them and what the functions of the nerves are. Local anesthetic agents can only be effective if they reach the axons of nerves and they can only reach the axons if they were injected into the correct tissue compartment close enough so that it can readily diffuse to the axons, while the nerve axons are still protected from its potential toxic effects.

This textbook is also not a regional anesthesia or acute pain medicine textbook. It does not attempt to instruct on the techniques or style of performing nerve blocks and the authors tried to refrain from expressing opinions, but rather reflect on the anatomical facts, as we now know them. Its quest is to teach where the nerves are (macroanatomy), what tissue membranes and barriers surround them (microanatomy), what their functions are (functional anatomy), and how to find them (sonoanatomy). If these are known and understood, any nerve block, known or unknown to us, should be easy to accomplish effectively and safely.

Some of our new understanding of the microanatomy has become apparent in only the past few years, especially the circumneural (paraneural) sheath/space, and most of the “newer” knowledge basically served to validate and emphasize our previous knowledge from the days of Keys and Retzius some 150 years ago. For the old and new understanding the authors would like to pay tribute to the contributions and influences that the groundbreaking work of Gale Thompson, Dag Selander, Daniel Moore, Henning Anderson, Manoj Karmakar, and Miguel Reina and their colleagues, among many others, had on the creation of this textbook. We finally realized that what we for many years have simply called the “sweet spot of the nerve,” the place where regional anesthesiologists of yesteryear coined the phrase “*no paresthesia, no block*” for, is nothing else but the subcircumneural (subparaneural) space. It also explains why some secondary blocks work well while others fail.

With the recent introduction of ultrasound technology to our practice, we realized its tremendous value. Unfortunately, ultrasound works best when we need it least, for example, when looking at superficial nerves, and *visa versa*. Furthermore, until high-definition ultrasound is universally and readily available, the membranes and connective tissue barriers surrounding nerves will continue

not to be clearly “visible” by regular ultrasound. Ultrasound scanning is dynamic, and the way to fully appreciate the image looked at is to follow a structure, a nerve for example, to see where it comes from and where it is going to, or to see pulsations of arteries, compression of veins, or shimmering of lung tissue, *etc.* For this reason, the authors present the sonoanatomy not only as still images, but also as video productions to express a particular structure’s dynamic view.

Finally, the book deals with the functional anatomy of every nerve that lends itself to high yield regional block. For that we describe the motor response these nerves have to electrical stimulation, and also through video productions demonstrating the motor responses by percutaneous nerve stimulation using a human model with the surface anatomy painted on her.

The design of this textbook is such that by viewing the figures and reading their legends, together with the viewing the video productions, practitioners should gain a high level of a working knowledge of the anatomical foundations required to practice safe and effective regional anesthesia and acute pain medicine. Should the student wish to learn more, there is ample supportive text and references to study the fundamental concepts further.

André P. Boezaart

Departments of Anesthesiology and Orthopaedic Surgery and Rehabilitation
Division of Acute and Perioperative Pain Medicine
University of Florida College of Medicine
Gainesville, Florida
USA

CONTRIBUTORS

- André P. Boezaart** Departments of Anesthesiology and Orthopaedic Surgery and Rehabilitation, Division of Acute and Perioperative Pain Medicine, University of Florida College of Medicine, Gainesville, Florida, USA
- Paul E. Bigeleisen** Department of Anesthesiology, University of Maryland, Baltimore, Maryland, USA
- Donald S. Bohannon** Department of Anesthesiology, Division of Acute and Perioperative Pain Medicine, University of Florida College of Medicine, Gainesville, Florida, USA
- David A. Edwards** Vanderbilt University Medical Center, Department of Anesthesiology, Nashville Tennessee, USA
- Barys V. Ihnatsenka** Department of Anesthesiology, Division of Acute and Perioperative Pain Medicine, University of Florida College of Medicine, Gainesville, Florida, USA
- Linda Le-Wendling** Department of Anesthesiology, Division of Acute and Perioperative Pain Medicine, University of Florida College of Medicine, Gainesville, Florida, USA
- Anastacia P. Munro** Department of Anesthesiology, Division of Acute and Perioperative Pain Medicine, University of Florida College of Medicine, Gainesville, Florida, USA
- Johan P. Reyneke** Department of Maxillofacial and Oral Surgery, University of the Western Cape, South Africa; Centre for Orthognathic Surgery, Cape Town Mediclinic, Cape Town, South Africa; Department of Maxillofacial and Oral Surgery, University of the Western Cape, Cape Town, South Africa; Division of Oral and Maxillofacial Surgery, Universidad Autonoma de Nuevo Leon, Monterrey, Mexico; Department of Oral and Maxillofacial Surgery, University of Oklahoma College of Dentistry, Oklahoma City, Oklahoma, USA and Department of Oral and Maxillofacial Surgery, University of Florida College of Dentistry, Gainesville, Florida, USA
- Yury Zasimovich** Department of Anesthesiology, Division of Acute and Perioperative Pain Medicine, University of Florida College of Medicine, Gainesville, Florida, USA

Applied Macroanatomy of the Upper Extremity Nerves Above the Clavicle

André P. Boezaart^{1,*} and Paul Bigeleisen²

¹Departments of Anesthesiology and Orthopaedic Surgery and Rehabilitation, Division of Acute and Perioperative Pain Medicine, University of Florida College of Medicine, Gainesville, Florida, USA and ²Department of Anesthesiology, University of Maryland, Baltimore, Maryland, USA

Abstract: In this chapter, the authors present the most common arrangement of the brachial plexus; its five roots of origin, three trunks, anterior and posterior divisions, three cords, and, finally, its terminal branches. The sensory dermatomal and osteotomal innervation of the spinal roots are discussed, as well as the neurotomal distribution of each peripheral terminal branch. Anatomical dissections of the lateral view of the neck and its posterior triangle are presented, as well as trans-sectional anatomical views at the level of the 6th cervical vertebra. Photographs of anatomical dissections of the five scalene muscles are discussed, especially the crossover of the fibers of the anterior and middle scalene muscles, which forms the paravertebral trough, and the seven most commonly found positional anomalies of the muscles with the roots of the cervical ventral rami. Finally, multiple anatomic sagittal sections of the neck, starting from the spine and ending at the mid-clavicular line, show the supraclavicular brachial plexus. These multiple sections are presented in the form of three figures of strategic positions, and also as a movie where these multiple sections have been added together to play sequentially. The authors discuss the innervation of the five joints around the shoulder girdle in some detail in this chapter.

Keywords: Anterior scalene muscle, Brachial plexus, Cervical paravertebral space, Dermatomes, Dorsal middle scalene muscle, Dorsal scapular nerve, Inferior trunk, Long thoracic nerve, Middle trunk Cords, Nerve to levator scapulae, Neurotomes, Osteotomes, Phrenic nerve, Posterior scalene muscle, Scalene minimi muscle, Shoulder joint innervation, Spinal accessory nerve, Spinal roots, Superior trunk, Suprascapular nerve, Ventral middle scalene muscle.

INTRODUCTION

The posterior triangle of the neck refers to the area between the clavicular head of the sternocleidomastoid muscle anterior and the anterior margin of the trapezius

*Corresponding author **André P. Boezaart:** Departments of Anesthesiology and Orthopaedic Surgery, Division of Acute and Peri-operative Pain Medicine, University of Florida College of Medicine, 1600 SW Archer Road, Gainesville, Florida 32610, USA; Tel: 352-846-0913 (Work); Fax: 352-392-7029; E-mail: aboezaart@anest.ufl.edu

André P. Boezaart (Ed)

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muscle posterior; the middle third of the clavicle forms the base of the triangle. For the purposes of this chapter, the triangle extends medially to the paravertebral space, and therefore does not have a “floor.”

As a good understanding of anatomy is essential for performing any regional anesthesia technique or invasive procedure for acute pain medical condition, it follows that one must understand the most fundamental principle of successful acute or perioperative pain control by regional anesthesia, namely, Hilton’s Law of Anatomy [1]. The principles behind Hilton’s Law were first espoused in a series of medical lectures given by John Hilton between 1860 and 1862 [1]. John Hilton (1808–1878) was a British surgeon born in Essex (UK) in 1805. He was appointed demonstrator of anatomy in 1828 at Guy’s Hospital and assistant surgeon in 1845; he was appointed surgeon four years later. Ten years later, he became Professor of Anatomy and Surgery at the Royal College of Surgeons. From 1859 to 1862, he presented a series of lectures in the form of a course on “Rest and Pain” [1]. The “Law of Anatomy”, which has now reached classical status, was revisited and challenged in 2013 using modern technology [2] and was found to be as sound as it was in 1860.

Hilton’s Law of Anatomy states: “The same trunks of nerves whose branches supply the groups of muscles moving a joint furnish also a distribution of nerves to the skin over the insertions of the same muscles; and—what at this moment more especially merits our attention—the interior of the joint receives its nerves from the same source” [2].

Upon reflection, we realize that to move any of the joints of the upper limb, all of the muscles around that specific joint are involved. Furthermore, the skin overlying that area receives sensory innervation from branches of the brachial plexus. Because of these two facts, we know that to effectively block painful stimuli generated from any of the joints of the upper limb, we have to block the entire brachial plexus.

One common misunderstanding that needs our attention, at least in our anatomical understanding, is that if, for example, 60% of the nerves that supply sensory innervation to a joint are blocked, the pain generated from that joint would be 60% less. Through the lessons we have learned over the years, especially in