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Editors

Noninvasive Vascular Diagnosis

A Practical Textbook for Clinicians

Fifth Edition

With 653 Figures and 99 Tables

Springer

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To the memory of my father and mother, Lenny and Marcia, who sacrificed so much so that I could pursue my dreams and from whom I learned so much, and who set the example of hard work and ethics I have always tried to follow; and to my wife Patti and my children Rachel and Mason, for their patience, understanding, and support throughout my career.

Bruce Perler

To the memory of my parents to whom I owe so much for their unconditional support and encouragement, and who also taught me the value of hard work and sacrifice; to my wife Marion and my children Zachary, Chelsea, and Joseph, for their patience, understanding, and support not only while working on this book but throughout my career.

Ali AbuRahma

To our Vascular Laboratory families at Charleston Area Medical Center/Johns Hopkins, an incredible group of talented sonographers who always give so much for the benefit of patients, and especially during the past 2 years of the pandemic have performed in the most selfless and professional fashion in the most difficult times of all of our careers.

Ali AbuRahma
Bruce Perler

Foreword

As the internet has become the most commonly used source of medical information for patients and physicians alike, very few textbooks retain their relevance; however, *Noninvasive Vascular Diagnosis: Practical Textbook for Clinicians*, in its fifth edition, is an exception. It retains its relevance by covering a huge field, noninvasive vascular diagnosis, where the technology for many vascular diagnostic devices has been developed by many medical specialties, in addition to vascular surgery, so publications related to their value are spread throughout medical and engineering journals. It would take a lifetime to collect and read all the information included in this textbook.

As diagnostic and treatment options have become minimally invasive and procedures can now be done in an outpatient center or office by many specialties, a textbook like *Noninvasive Vascular Diagnosis: Practical Textbook for Clinicians* has value to physicians and nurses from many specialties who diagnose or treat a range of vascular diseases in either outpatient or inpatient sites.

From Drs. Ali AbuRahma and Bruce Perler, senior editors, to associate editors Drs. Dennis Bandyk and Jan Brunkwall, each has organized their part anatomically and reported on the diagnostic techniques for the wide spectrum of vascular diseases in their anatomic region. The authors in each part represent the acknowledged experts in their respective fields, as well as being on the cutting edge of research; each is published widely on their topic, making each chapter both relevant and including the most up-to-date information.

The basic principles of vascular disease evaluation and diagnosis have remained the same for many years – most patients require only a carefully conducted history and physical exam to make a vascular disease diagnosis; however, noninvasive vascular diagnostic testing is often required to confirm the diagnosis and objectively document it. As Eugene Strandness, one of the pioneers of vascular ultrasound, often said, duplex ultrasound is the "eyes and ears" of the vascular specialist. Noninvasive imaging is often also useful in helping decide on the best treatment option, as well as guiding the treatment and assessing its impact. Vascular imaging and physiologic testing also help determine when a treatment is failing, allowing intervention before complete failure.

The book takes the reader through a process, from learning the principles of vascular physics, hemodynamics, and ultrasound to systematically organized parts and chapters that teach about each region of the body, first for arterial

disease, followed by venous disease, and lastly addressing unusual vascular diseases, such as vascular malformations, that also benefit from noninvasive testing.

The first part, Vascular Laboratory Operations, discusses the principles in setting up a vascular lab and developing a quality program, as well as the qualifications of physicians who should interpret vascular lab studies.

The editors have then organized their parts using an anatomic approach, starting with cerebrovascular disease, where they cover the most important imaging techniques, including duplex ultrasound for screening, criteria for diagnosis of stenoses, assessing proximal arch vessels, and using transcranial Doppler during carotid stenting.

The next part discusses the multiple physiologic and anatomic methods of diagnosing and monitoring lower and upper extremity arterial vascular disease. Although anatomy is important, the physiologic impact of arterial diseases is emphasized in this part, as well as correlating arterial disease with symptoms and the degree of limb ischemia.

The next part focuses on diagnostic techniques to evaluate and treat venous disease, including the use of plethysmography, duplex ultrasound, and cross-sectional imaging for diagnosis and during venous procedures, including ablation, placement of filters, stents, and closure of venous malformations.

The final anatomic part addresses vascular diseases of the abdominal and visceral vessels, including the diagnostic criteria for aneurysms, visceral occlusive diseases, and uncommon diseases of the abdominal arteries and veins.

A concluding part addresses less commonly used techniques such as TCPO2 and 3-D ultrasound, which are currently not part of many vascular labs, as well as chapters on competing technologies such as CT and MR scanning. Lastly, there is a chapter on the management of a successful vascular lab.

Noninvasive Vascular Diagnosis: Practical Textbook for Clinicians retains its relevance by providing the foundation for understanding vascular disease diagnosis. It helps the well-motivated vascular specialist diagnose a broad range of vascular diseases and also assists by providing the diagnostic criteria for delivering the most appropriate, cost-effective care. In addition, it is a great resource for residents in training and practicing physicians to pass certifying exams, which enable their participation in accredited noninvasive vascular labs.

Read it from cover to cover or when you have a challenging diagnostic vascular problem, in either case, you will not be disappointed!

Preface to the Fifth Edition

This fifth edition of the popular textbook, *Noninvasive Vascular Diagnosis: Practical Textbook for Clinicians*, highlights further new advances in noninvasive vascular diagnostics. The format of this new edition follows the same practical methodology of previous editions, comprehensively covering various noninvasive methodologies in diagnosing vascular diseases, region by region. Each part is closed with a chapter covering the clinical implications of these noninvasive vascular methods with emphasis on unusual clinical topics that are not covered in separate chapters. This book covers the entire spectrum of vascular noninvasive diagnosis issues, including all necessary technology, details of laboratory operation, accreditation, and the totality of clinical applications. As such, this book should serve as an unparalleled resource for vascular trainees and experienced clinicians alike across all specialties who care for vascular patients, as well as those who manage vascular laboratory operations.

All chapters have been updated, including references, with new authors added to some chapters, based on their most recent interests and areas of expertise. This new edition also contains several new chapters with new authors, covering several topics of special interest to the vascular specialist. For example, new chapters were added to cover: "Ergonomics and Vascular Lab," "Correlation of Doppler PSV >230 c/s to Positive Predictive Value in Predicting >70% and >80% Carotid Stenosis," "Incidence of Subclavian Steal as Detected by Carotid Duplex Ultrasound and Its Clinical Implications," "Duplex Ultrasound Surveillance After Carotid Endarterectomy," "Role of Follow-Up Duplex Ultrasound Post Deep Vein Thrombosis," "Role of Duplex Ultrasound Screening/Surveillance in High-Risk Deep Vein Thrombosis Patients," "Duplex Ultrasound of Renal Transplants," "Clinical Validation of 3-Dimensional Ultrasound for Diagnosis of Abdominal Aortic Aneurysm," "Duplex Ultrasound Screening for Abdominal Aortic Aneurysm," and "Role of CT Angiography in Pre- and Postabdominal Aortic Aneurysm Endovascular Grafts."

A new associate editor, Dr. Jan Brunkwall of University of Cologne, Germany, was also assigned to Part II, Vascular Hemodynamics and Basic Vascular Physics, and Part VII, Miscellaneous, based on his interests and expertise.

As in previous editions, Dr. Robert Zwolak, a nationally recognized expert in coding and reimbursement for vascular laboratory testing, provided a

comprehensive updated chapter, which is extremely critical for many of the independent vascular laboratories and their reimbursement.

The editors and associate editors would like to express their most sincere appreciation to all contributors to this new edition, for without their help, this edition would not have been possible.

Charleston, WV, USA — Ali F. AbuRahma
Baltimore, MD, USA — Bruce A. Perler
February 2022

Preface to the Fourth Edition

This 4th edition of this popular textbook, *Noninvasive Vascular Diagnosis*: *Practical Textbook for Clinicians*, will highlight further advances in noninvasive diagnostic methods of vascular diseases. As you will notice, the format of this new edition follows the same practical methodology of previous editions, comprehensively covering various noninvasive methodologies in diagnosing vascular disease, region by region; and each part is closed with a chapter covering the clinical implications of these noninvasive methods with emphasis on unusual topics that are not covered in separate chapters.

Most, if not all, chapters have been updated, including references, with new authors added to some chapters, based on their most recent interests and areas of expertise. This new edition also contains some new chapters with new authors, covering several topics of special interest to the vascular specialist. For example, new chapters were added: "Carotid Duplex Consensus Criteria on Interpretation of Carotid Duplex Ultrasound," "Color Duplex Ultrasound for Diagnosis of Peripheral Artery Aneurysms (Lower and Upper Extremity)," "Color Duplex Scanning of Superior Mesenteric and Celiac Artery Stenting," "Computed Tomographic Angiography in the Diagnosis of Peripheral Arterial Disease," and "Magnetic Resonance Angiography in the Diagnosis of Peripheral Arterial Disease."

A new associate editor, Henrik Sillesen, was assigned to Part II, Noninvasive Diagnosis of Abdominal/Visceral Arteries, and Patrick A. Stone was assigned to Part VII, Miscellaneous, based on their interests and expertise.

You will also notice in this new edition that Dr. Robert Zwolak, a nationally recognized expert in coding and reimbursement for vascular laboratory testing, provided a comprehensive updated chapter, which is extremely critical for many of the independent vascular laboratories and their reimbursement.

The editors and associate editors would like to express their most sincere appreciation to all contributors to this new edition, for without their help, this edition would not have been possible.

Charleston, WV, USA — Ali F. AbuRahma

Acknowledgments

This new edition owes much to our colleagues, who have contributed a great deal, and without their expertise and guidance, this volume would not have become a reality. I would like to thank the technical staff for their support, particularly Samantha Mullins in Charleston, West Virginia, for assisting in transcribing and revising chapters, editing, and maintaining contact with contributing authors regarding guidelines and deadlines. I also appreciate the effort of some of my vascular laboratory technologists, particularly Jennifer Sloan and Cristyn Caron. My thanks to editorial assistant, Eleanor Gaffney, and senior editor, Grant Weston, and the entire Springer Nature team for their invaluable support and guidance.

Contents

Volume 1

About the Editors

Ali F. AbuRahma is a tenured Professor of Surgery, Chief of Vascular and Endovascular Surgery, Director of the Vascular Surgery Fellowship and Residency Programs of West Virginia University, Charleston. He also serves as Medical Director of the Vascular Laboratory and Co-director of the Vascular Center of Excellence at Charleston Area Medical Center. He attended Alexandria University Medical School and completed his general surgery residency at the State University of New York and West Virginia University and his vascular fellowship at Arizona Heart Institute. He is certified by the American Board of Surgery, Vascular Surgery Board, and Royal College of Surgeons of Canada in Vascular Surgery.

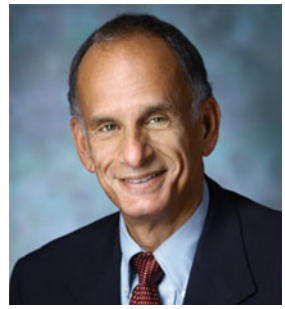
His contributions to the SVS/regional vascular societies in our specialty are numerous. As noted in the next few paragraphs, his scholarly endeavors have led to active membership in over two dozen professional vascular/surgical societies, for example, Society for Vascular Surgery (since 1991) (Distinguished Fellow), American Surgical Association, Southern Surgical Association, Southern Association for Vascular Surgery, Eastern Vascular Society, and International Society of Endovascular Specialists. He has served in many of these societies on the regional/national level: President (2014–2015) of the Southern Association for Vascular Surgery, President of the Eastern Vascular Society (2010–2011), the Board of Directors of the Intersocietal Commission for the Accreditation of Vascular Laboratories (2006–2012), SVS Membership Chairman (2009–2010), Advisory Board to the President of

the SVS (2005–2006) and Chairman of the SVS Foundation Development Committee (2013–2015), Board of Directors of SVS and SVS Foundation (2013–present). Additionally, Dr. AbuRahma served as the Secretary of the Society for Vascular Surgery from 2016 to 2019, Vice President from 2019 to 2020 and as President-Elect from 2020 to 2021. He is currently serving as President and his term runs from 2021 to 2022. He has served/is serving on the editorial board of the *Journal of Vascular Surgery*, *Annals of Vascular Surgery*, *Journal of Endovascular Therapy*, *Journal of Vascular and Endovascular Surgery*, and *Vascular Specialist*; he is the Associate Editor of the journal, *Vascular*, and a reviewer for several other medical journals.

Dr. AbuRahma has an avid interest in vascular surgery and has dedicated his life to research, earning him a national and international reputation for his contributions in this field. As a result, he has published over 275 articles in peer-reviewed journals, over 200 abstracts, 125 book chapters, and eight textbooks in vascular surgery (seven in noninvasive vascular diagnostics and one vascular/endovascular surgery combat manual). He is also Associate Editor of the eighth, ninth, and tenth editions of *Rutherford's Vascular Surgery and Endovascular Therapy*. He has also made presentations at over 560 national and international medical meetings, including many named distinguished lectures (e.g., Rutherford lecture at John Hopkins, John Bergan lecture at Northwestern University, Yale lecture, W. Andrew Dale lecture at Vanderbilt, James M. Seeger lecture at the University of Florida, Gainesville, William H. Baker lecture at Loyola, etc.). He also serves on the advisory and scientific committees of the Veith Symposium since 2014.

He has also received many regional/national awards, including the Benedum Distinguished Scholar Award in Biosciences and Health Sciences of West Virginia University (which is given to one faculty member annually among all WVU Health Sciences); the William J. Maier, Jr. Health Sciences Education Award, West Virginia University (awarded to the physician who contributed the most to education and research); Honorary Chairman of Annual Vascular Fellows

Award, New York, NY; Honorary Chairman of the Pennsylvania Hospital Vascular Symposium, Philadelphia, PA; and the Society for Vascular Surgery Presidential Citation Award (2016). Recently, Dr. AbuRahma was given an Honorary Membership in the German Vascular Society (2018).



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Dr. Perler received a Bachelor's of Arts degree, Summa cum laude, Phi Beta Kappa, in 1972 from Duke University and his M.D. in 1976 from the Duke University School of Medicine. In 2004 he received a Master of Business Administration from the Johns Hopkins University and received the Outstanding Student Award in the class. He completed his internship and residency at the Massachusetts General Hospital as well as a Clinical and Research Fellowship in Vascular Surgery at the Massachusetts General Hospital and the Harvard Medical School. Dr. Perler joined the faculty of the Johns Hopkins University School of Medicine in 1982 and was named the first recipient of the Julius H. Jacobson II, M.D. endowed Chair in Vascular Surgery. He has served as Director of the Vascular Noninvasive Laboratory at the Johns Hopkins Hospital since 1982. In 1998 he established the Vascular Surgery Fellowship at the Johns Hopkins Hospital and served as Director until 2009. Dr. Perler was named the Chief of the Division of Vascular Surgery and Endovascular Therapy at Johns Hopkins in January 2002. In 2013, he was named the Vice-Chair for Clinical Affairs and Finances for the Department of Surgery and became Chief Emeritus of the Division of Vascular Surgery.

Dr. Perler has edited or co-edited five textbooks, and is currently the Co-editor of *Rutherford's Textbook of Vascular Surgery and*

Endovascular Therapy, ninth edition and tenth edition (in preparation). He has authored more than 250 medical journal articles and textbook chapters on the diagnosis and treatment of the entire spectrum of circulatory diseases. He has served on the editorial boards of the *Journal of Vascular Surgery Vascular and Endovascular Surgery*, *Vascular*, and the *Annals of Vascular Surgery*, and from 2009 to 2016 served as the Senior Editor of the *Journal of Vascular Surgery*, as well as being the co-founder and Senior Editor of the *Journal of Vascular Surgery: Venous and Lymphatic Disorders* and the *Journal of Vascular Surgery Cases.*

He has held many leadership positions in vascular surgery. From 2015 to 2016 he served as President of the Society for Vascular Surgery and from 2016 to 2017 as Chair of the SVS Foundation. He has also served as President of the Southern Association for Vascular Surgery, the Eastern Vascular Society, and the Chesapeake Vascular Society. In 2021 he received the Rudolph Matas Lifetime Achievement Award for the Southern Association for Vascular Surgery.

In 2016 he was selected to serve as the Associate Executive Director of the American Board of Surgery for Vascular Surgery, and in 2019 was named the Vice President of the American Board of Surgery.

Dr. Perler has received the Outstanding Faculty Teaching Award by the surgical house staff at Johns Hopkins. He has delivered more than 350 lectures as a faculty member at national and international symposia and postgraduate courses, and as a Visiting Professor. In addition to his longstanding interest in cerebrovascular disease and especially carotid endarterectomy, and the surgical and endovascular treatment of PAD and limb salvage revascularization, his clinical surgical expertise includes the evaluation and treatment of aortic and peripheral aneurysms and renal and mesenteric occlusive disease. He served from 1989 to 2017 as a Consultant to the Circulatory Devices Panel, Center for Devices and Radiologic Health of the Food and Drug Administration.

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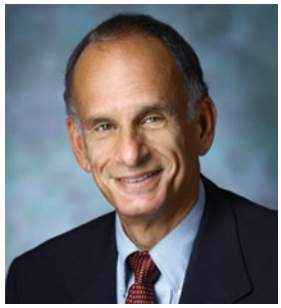

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