METHODIST DEBAKEY CARDIOVASCULAR JOURNAL

Vascular Robotics in the Era of Intelligent Surgery

ISSUE INTRODUCTION

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KEYWORDS:
robotic surgery; vascular intervention; robotics; advanced imaging; artificial intelligence

TO CITE THIS ARTICLE:
Corr SJ, Lumsden AB. Vascular Robotics in the Era of Intelligent Surgery. Methodist DeBakey Cardiovasc J. 2025;21(5):1-4. doi: 10.14797/mdcvj.1699

The field of vascular intervention is entering a new era defined by the convergence of robotics, advanced imaging, and artificial intelligence (AI)—a paradigm increasingly referred to as "intelligent surgery." In this context, robotics provides precision and dexterity, imaging supplies dynamic anatomical and physiological insight, and data-driven analytics offer predictive and adaptive guidance. Together, these technologies are reshaping the practice of vascular surgery and interventional medicine, enabling procedures that are safer, more efficient, and more personalized than ever before.

This unique edition on vascular robotics in the era of intelligent surgery brings together a diverse set of contributions that highlight both the current state of the art and the trajectory of innovation in this space. Articles in this issue explore intraoperative data analytics and the concept of smart surgical suites, underscoring the growing importance of integrated, real-time decision-support systems. They also reveal the evolving role of robotic systems in cardiovascular interventions as well as the clinical application and technical skill assessment of robotic-assisted vascular procedures. Complementing these perspectives are reviews on remote and telerobotic ultrasound imaging, innovations in MRI and AI for peripheral artery disease, and a forward-thinking overview into the fusion of robotics with imaging modalities for enhanced surgical guidance.

We begin this exploration with a review Alan Lumsden and I have authored with our colleagues titled "From Data to Decision: A Comprehensive Review of Real-Time Analytics and Smart Technologies in the Surgical Suite." We explain how recent advancements in intraoperative data acquisition and analytics—combined with physiological monitoring, medical imaging, instrument motion data, surgical video, and environmental metrics—are transforming next-generation operating rooms. We also discuss the challenges that arise when managing data, system interoperability, regulatory compliance, and privacy.

In "Robotic Systems in Cardiovascular Interventions," authors Srikanth Reddy Mandhumula and Ali Tavallaei provide a comprehensive survey of 19 commercial and emerging robotic systems, describe the barriers to widespread adoption of existing platforms, and offer valuable insights into current capabilities, limitations, and potential future directions for advancing robotic technologies.

From a cardiovascular surgeon's viewpoint, "Robotic-Assisted Vascular Surgery" by Charudatta Bavare, Alan Lumsden, and Jacob Watson imparts a comprehensive clinical perspective on robotic-assisted vascular surgery. To unlock its full potential, the vascular community must invest in specialized training, develop dedicated robotic instruments, and define the role of robotic techniques in future clinical practice.

Taking a deeper dive, authors Marcia O'Malley, Jacob Laughlin, and colleagues explore "Technical Skills Assessment in Robotic Surgery," focusing on four categories, including structured rubrics, skill-based metrics, crowd-sourcing techniques, and automated assessment models. They propose that the effort to integrate task- and movement-based assessment into procedure-level evaluations may lead to more data-driven and objective assessment methods that eventually improve surgical training and patient outcomes.

Expanding beyond surgical applications to additional technologies, "Remote and Telerobotic Ultrasound Imaging" by Stephen Seslar, Wayne Monsky, and coauthors shows the intersection of telehealth, robotics, and imaging, describing how telerobotic ultrasound systems—assisting a sonographer at a site far from the patient—can control a robotic arm to perform a remote patient exam. While the potential impact is profound, important logistics must be addressed before widespread adoption can be achieved.

In "Innovations in MRI and AI Integration for Vascular Plaque Evaluation and Overview of Deep Learning Techniques in Peripheral Vascular Disease," authors Trisha Roy, Eniko Pomozi, and colleagues review the current state of integrating AI with magnetic resonance vascular imaging. With a focus on peripheral artery disease, they offer insights into their research approach, which represents a step toward more objective, reproducible, and clinically interpretable tools that bridge high-fidelity imaging with AI-driven analysis.

"The Fusion of Robotics and Imaging: A Vision of the Future" by Alan Lumsden, myself, and colleagues shares our views on how surgical applications may evolve, based on recent advances in AI, computer vision, and machine learning. Clearly, we are poised for immense changes to come.

A special "Points to Remember" column offers a glimpse of what's required to implement a technology-centric approach when establishing a new hospital. In "Building a Smart Hospital Cardiovascular Surgery Program: Lessons from the Ground Up," authors Caroline Mascarenhas, Bridgette Enamait, and colleagues outline the foundational strategies and technological integrations that shaped a cardiovascular surgery program before opening a new hospital in March 2025. Early data indicates improved surgical outcomes and optimized patient care using advanced AI-driven systems and real-time data integration.

Taken together, the articles here illustrate how vascular robotics is moving beyond incremental advances to become a cornerstone of intelligent surgery. They showcase how robotics, imaging, and data analytics are beginning to intersect in ways that extend surgical reach, reduce operator burden, and expand access to care across geographic and resource boundaries. The lessons and insights presented here not only define the current landscape but also chart the path forward for clinicians, engineers, and researchers committed to advancing the next generation of vascular interventions.

GUEST EDITOR BIOGRAPHIES

The editorial team of the *Methodist DeBakey Cardiovascular Journal* extends a heartfelt thanks to Stuart Corr, PhD, and Alan Lumsden, MD, for their ongoing insight, guidance, and dedication while curating this visionary issue on vascular robotics in the era of intelligent surgery.

STUART J. CORR, PHD

Stuart Corr, PhD, has over 20 years of experience in research and innovation, documented through 50 peer-reviewed publications, 16 grants and awards (including NIH and NSF funding), several patents, and numerous conference proceedings. Trained as an electrical engineer, Dr. Corr began his career at Rice University developing analytical tools for nanomaterials research before earning his MSc and PhD in engineering from Dublin City University. He returned to Rice as a postdoctoral fellow and later joined University of Texas MD Anderson Cancer Center as a postdoc, then instructor, then joined Baylor College of Medicine as an assistant professor of surgical research, where his work on noninvasive cancer hyperthermia contributed to the development of the VectRx™ system (NeoTherma Oncology).

Shifting toward translational innovation, Dr. Corr founded the Interdisciplinary Surgical Technology and Innovation Center (INSTINCT), advancing technologies ranging from microsuturing tools for fetal surgery to low-cost laparoscopic devices and imaging systems for vascular disease. In 2020, he joined Houston Methodist to help build the Institute for Robotics and Image-Guided Navigation

(MIRIN), the work of which has led to the creation of a new initiative called **The Bookout Center**—a unique environment for medical innovation, simulation, and emerging technology dedicated to advancing the future of health care. Focused on the fusion of robotics, imaging, and digital surgery, it brings together cutting-edge technology and hands-on training to equip medical professionals with the skills and tools needed to revolutionize patient care.

Dr. Corr currently serves as an associate professor in the Department of Cardiovascular Surgery, and director of innovation engineering for the Bookout Center at Houston Methodist.

ALAN B. LUMSDEN, MD

Alan Lumsden, MD, is the Walter W. Fondren III Presidential Distinguished Chair, Houston Methodist DeBakey Heart & Vascular Center, and chair of the Department of Cardiovascular Surgery at Houston Methodist. His academic career began in 1989 at Emory University in Atlanta, Georgia, where he completed his postdoctoral training and served as a collaborative scientist in the Division of Pathobiology and Immunology at the renowned Yerkes Primate Center. He remained at Emory for several years, rising to the rank of associate professor and chief of the Division of Vascular Surgery. In 2002, Dr. Lumsden joined the faculty at the Baylor College of Medicine in Houston, Texas, as professor and chief of the Division of Vascular Surgery and Endovascular Therapy. He assumed his current positions at Houston Methodist in 2008.

Dr. Lumsden has developed an international reputation as a leader in the field of endovascular surgery. He has clinical and research expertise in stent graft treatment of thoracic and abdominal aortic aneurysms, stenting and endarterectomy in carotid arterial disease, renovascular hypertension, aortoiliac occlusive disease, and mesenteric vascular and minimally invasive therapy in venous disease. Dr. Lumsden also conducts FDA-mandated training for surgeons nationwide in a carotid stenting simulator housed at the Houston Methodist DeBakey Heart & Vascular Center.

Dr. Lumsden's research interests include developing novel minimally invasive methods of therapy and preventing restenosis. His research has been funded by the National Institutes of Health, and he has contributed more than 200 papers to the medical literature as well as numerous abstracts, books, and book chapters.

COMPETING INTERESTS

Dr. Lumsden conducts research on behalf of W. L. Gore & Associates; consults for Siemens, Boston Scientific, and W.L. Gore & Associates; and has an ownership interest in Hatch Medical, Egg Medical, and Brijjit. Dr. Corr has no competing interests to declare.

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Corr SJ, Lumsden AB. Vascular Robotics in the Era of Intelligent Surgery. Methodist DeBakey Cardiovasc J. 2025;21(5):1-4. doi: 10.14797/mdcvj.1699

Submitted: 26 August 2025 **Accepted:** 26 August 2025 **Published:** 07 October 2025

Methodist DeBakey Cardiovascular Journal is a peer-reviewed open access journal published by Houston Methodist DeBakey Heart & Vascular Center.

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