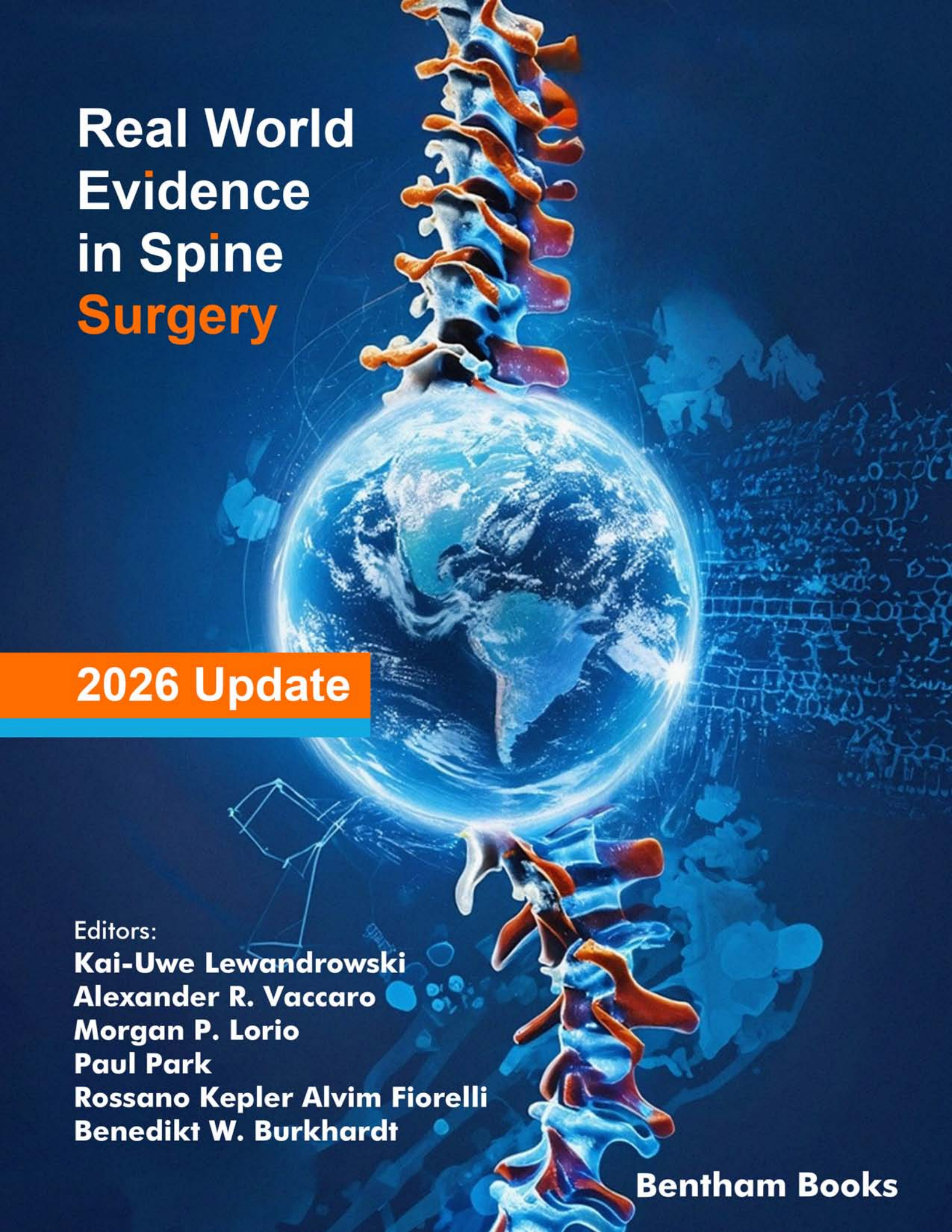




Real World Evidence in Spine Surgery

2026 Update

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Real World Evidence in Spine Surgery-2026 Update

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PREFACE

The field of spine surgery has witnessed extraordinary advancements over the past few decades, driven by relentless innovation, rigorous research, and the pursuit of better outcomes for patients suffering from painful spinal disorders. As the discipline evolves, the dichotomy between evidence-based medicine—anchored in systematic reviews and randomized controlled trials (RCTs)—and real-world clinical practice has become increasingly apparent to many. This book series, *Real World Evidence in Spine Surgery – 2026 Update*, embarks on an ambitious journey to explore this critical intersection, offering insights that promise to redefine how we evaluate and implement spine care in the future.

At the heart of this 2026 Update lies a compelling premise: the standards of care defined by the highest levels of clinical evidence often diverge from the realities of day-to-day surgical practice. While RCTs and meta-analyses provide invaluable data, they frequently operate within rigid parameters that may not capture the complexity of real-world patient populations, the nuances of surgical decision-making, or the variability in surgeon expertise and proficiency. Conversely, the collective wisdom gained from years of clinical experience, patient interactions, and procedural innovation often remains underrepresented in the literature.

Real World Evidence in Spine Surgery series bridges this gap by systematically comparing state-of-the-art published research with data derived from the real-world experiences of spine surgeons. Through an innovative methodology incorporating psychometric survey data and advanced Rasch analysis, this book sheds light on how surgeons perceive best practices, highlighting areas of agreement and disagreement with established evidence. It provides a platform for open discourse, aiming to reconcile these differences and, in doing so, advance the field.

This book's scope is as ambitious as it is necessary. From spinal anatomy, biomechanics, deformities, and trauma to minimally invasive techniques and motion preservation, each chapter explores the most pressing topics in spine surgery. By using the PICO framework to guide systematic reviews and aligning these with carefully constructed survey questions, the book ensures a balanced, objective examination of each subject. The editorial team, comprising leading experts from diverse backgrounds and disciplines, has crafted a comprehensive resource that will be invaluable not only to surgeons but to healthcare decision-makers, researchers, and policymakers.

The work presented here is groundbreaking in its ability to address fundamental questions: How do we define success in spine surgery? How can we reconcile clinical evidence with the practical realities of patient care? How can we use real-world data to refine our understanding of high-value procedures, ensuring the sustainability of spine surgery in an era of increasing demands and constrained resources?

As the reader explores this book, the editors invite you to embrace its spirit of inquiry and reflection. It challenges conventional wisdom and invites physicians involved in the delivery of spine care to engage in a critical dialogue about the future of our field. The editors are confident that the insights gained from this work will not only inform clinical practice but also inspire further research and innovation.

It is with great admiration for the editors, contributors, and all those who have brought this project to fruition that our editorial team commends Real World Evidence in Spine Surgery to

its readers. May it serve as a valuable resource in our collective mission to improve spine care for the patients we are privileged to serve.

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8032 Zurich, Switzerland

ENDORSEMENTS

Asociación Mexicana de Cirujanos de Columna, A.C. (AMCICO)

As President of the Asociación Mexicana de Cirujanos de Columna, A.C. (AMCICO), I am honored to endorse *Real World Evidence in Spine Surgery: 2026 Update*. This publication represents an important contribution to contemporary spine surgery and offers a timely perspective on the role of endoscopic techniques in modern clinical care.

What distinguishes this volume is its effort to connect scientific evidence with the realities of day-to-day surgical practice. Through focused PICO-based chapters, updated literature reviews, and surgeon survey data analyzed using Rasch methodology, the editors provide a thoughtful and clinically grounded approach to understanding how evidence is interpreted and applied in the treatment of spinal disorders.

Particularly valuable is the book's willingness to revisit accepted treatment pathways within a real-world context. Rather than assuming that current standards should remain unchanged, it considers whether ongoing technological advances and improved insight into disease mechanisms justify refinement of existing protocols.

From the perspective of AMCICO, this type of analysis is highly relevant. Progress in spine surgery depends not only on innovation itself, but also on careful evaluation of when new techniques should complement, modify, or replace established approaches. In that sense, this work supports more informed surgical judgment, more responsible adoption of emerging technologies, and a stronger commitment to patient-centered care.

The editors—Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt—deserve recognition for preparing a scholarly and internationally relevant volume that promotes critical thinking and continued advancement in spine surgery.

Sincerely,
Carlos Sauri, MD
President

Asociación Mexicana de Cirujanos de Columna, A.C. (AMCICO)

Asociación Argentina de Cirugía Minimamente Invasiva de Columna (ARMISS)

As President of Asociación Argentina de Cirugía Minimamente Invasiva de Columna (ARMISS), I am proud to endorse *Real World Evidence in Spine Surgery: 2026 Update*, a book whose international perspective and methodological rigor are especially meaningful to spine surgeons working across diverse healthcare environments.

This international relevance is reinforced by the topics selected: perioperative risk, neuromonitoring, 3D-printed implants, robotics and navigation, tubular and endoscopic decompression, transforaminal techniques, and cervical endoscopic applications. These are precisely the areas where global adoption often outpaces guideline certainty, and where regional experience matters.

It speaks to surgeons who must adapt innovation thoughtfully rather than simply import it uncritically.

I am confident that this book will be especially valuable to the international spine community, including surgeons, trainees, researchers, and leaders working across diverse systems of care. I congratulate the editorial team on a text that is rigorous, current, and genuinely global in outlook.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
Marisa Perez Solis, MD
President
Asociacion Argentina de Cirugia Minimamente Invasiva de Columna (ARMISS)
Argentina

Brazilian Spine Society (SBC)

I am pleased, on behalf of the Brazilian Spine Society (SBC), to support Real World Evidence in Spine Surgery: 2026 Update. The volume stands out because it does not treat evidence as abstract; instead, it tests how well published conclusions align with the choices spine surgeons make in actual practice.

One of the volume's strongest features is its refusal to flatten complex questions into simple recommendations. Instead, it highlights discrepancy analysis, decision quality, and the practical meaning of evidence when treating real patients in real systems.

The result is a volume that is both academically serious and immediately readable for busy clinicians.

Because of that breadth and methodological seriousness, I believe the volume will have long-term value for both day-to-day practice and future academic discussion. I warmly commend the editorial team for this thoughtful contribution to the field.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
Alexandre Fogaca Cristante, MD, PhD
President
Brazilian Spine Society (SBC)
Brazil

International Society for Minimal Intervention in Spinal Surgery (ISMISS)

As President of the International Society for Minimal Intervention in Spinal Surgery (ISMISS), I am honored to endorse *Real World Evidence in Spine Surgery: 2026 Update*, a substantial and timely contribution to the literature of contemporary spine care.

The chapter selection is broad without being diffuse. Topics such as wound drains in routine ACDF, obesity and perioperative risk, intraoperative neuromonitoring, 3D-printed implants, robotics and navigation, and both tubular and endoscopic decompression strategies make the book relevant across the full spectrum of modern spine surgery.

Its usefulness lies in helping readers interpret variation rather than pretending variation does not exist.

I expect this book to become a durable reference for surgeons, trainees, researchers, and society leaders who want a more complete understanding of what constitutes meaningful evidence in spine surgery. The editors and contributors are to be congratulated for an important and timely accomplishment.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
Benedikt W. Burkhardt, MD
 President
 International Society for Minimal Intervention in Spinal Surgery (ISMISS)
 International

International Society of Endoscopic Spine Surgery (ISESS)

On behalf of the International Society of Endoscopic Spine Surgery (ISESS), I am pleased to express my support for *Real World Evidence in Spine Surgery: 2026 Update*. This volume is particularly important because it addresses spine surgery as it is actually practiced: a field shaped not only by formal evidence, but also by experience, evolving techniques, patient selection, and the realities of clinical decision-making.

What makes this work especially compelling is its balanced perspective. It does not treat innovation as inherently beneficial simply because it is new, nor does it dismiss progress because long-term data are still developing. Instead, it offers a thoughtful framework for assessing, refining, and integrating emerging approaches into patient care.

This perspective is highly relevant to endoscopic spine surgery, where rapid technical advancement must always be matched by careful evaluation, sound judgment, and attention to outcomes. The book reflects the understanding that meaningful progress in surgery depends not only on technological capability but also on appropriate indication, disciplined assessment, and continued learning from real-world clinical practice.

For these reasons, I believe this volume will serve not only as an important reference but also as a valuable contribution to the broader discussion of quality, innovation, and evidence in

modern spine care. It is a timely and substantial work that will benefit surgeons, researchers, and the broader spine community.

The editors—Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt—are to be congratulated for producing a volume that will strengthen informed surgical judgment, encourage critical appraisal of evolving technologies, and support higher-quality care for patients worldwide.

Sincerely,
Prof. Zhen Zou Li
International Society of Endoscopic Spine Surgery (ISESS)

Korean Minimally Invasive Spinal Surgery Society (KOMISS)

As President of the Korean Minimally Invasive Spinal Surgery Society (KOMISS), I am delighted to endorse *Real World Evidence in Spine Surgery: 2026 Update*, a forward-looking work that addresses one of the central questions in modern spine care: how to reconcile formal evidence hierarchies with the realities of minimally invasive surgical practice.

Across chapters on ACDF wound drains, obesity and perioperative risk, intraoperative neuromonitoring, robotics and navigation, and competing decompression strategies, the volume repeatedly asks the right question: what happens when formal evidence is tested against routine surgical reality? That is precisely the question minimally invasive spine surgeons confront every day.

Its emphasis on discrepancy analysis is especially useful in procedures where published evidence and surgeon experience do not always align neatly.

I am confident that this book will serve as an important resource for surgeons, trainees, investigators, and professional societies seeking to define best practice in minimally invasive spine surgery. The editors are to be congratulated for a work of both intellectual rigor and practical value.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
Cheol Wong Park, MD, PhD
President
Korean Minimally Invasive Spinal Surgery Society (KOMISS)
Korea

Korean Research Society of Endoscopic Spine Surgery (KOESS)

It is a privilege, in my capacity as President of the Korean Research Society of Endoscopic Spine Surgery (KOESS), to endorse *Real World Evidence in Spine Surgery: 2026 Update*.

The editors have assembled a work that moves beyond promotional narratives and instead examines how endoscopic techniques perform, evolve, and are adopted in the real world.

Its chapter architecture is particularly effective: focused PICO questions and updated literature reviews are paired with surgeon survey data analyzed through Rasch methodology, allowing the reader to see not only what the literature reports, but also how spine surgeons actually navigate decompression choices, endoscopic indications, and evolving cervical and lumbar techniques.

The text is especially persuasive in showing that endoscopic surgery should be assessed through longitudinal practice patterns, not only through isolated trial snapshots.

This volume deserves wide circulation among surgeons, educators, researchers, and decision-makers involved in the future of endoscopic spine surgery. I congratulate the editors on a book that is methodologically serious, clinically grounded, and internationally relevant.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
Dong Chan Lee, MD, PhD
 President
 Korean Research Society of Endoscopic Spine Surgery (KOSESS)
 Korea

Korean Society for the Advancement of Spinal Surgery (KOSASS)

I am pleased, on behalf of the Korean Society for the Advancement of Spinal Surgery (KOSASS), to support *Real World Evidence in Spine Surgery: 2026 Update*. The volume stands out because it does not treat evidence as abstract; instead, it tests how well published conclusions align with the choices spine surgeons make in actual practice.

One of the volume's strongest features is its refusal to flatten complex questions into simple recommendations. Instead, it highlights discrepancy analysis, decision quality, and the practical meaning of evidence when treating real patients in real systems.

The result is a volume that is both academically serious and immediately readable for busy clinicians.

Because of that breadth and methodological seriousness, I believe the volume will have long-term value for both day-to-day practice and future academic discussion. I warmly commend the editorial team for this thoughtful contribution to the field.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
Seok Woo Kim, MD, PhD
President
Korean Society for the Advancement of Spinal Surgery (KOSASS)
Korea

Korean Society for the Advancement of Spine Surgery (KOSASS)

I am pleased, on behalf of the Korean Society for the Advancement of Spinal Surgery (KOSASS), to support Real World Evidence in Spine Surgery: 2026 Update. The volume stands out because it does not treat evidence as abstract; instead, it tests how well published conclusions align with the choices spine surgeons make in actual practice.

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Sincerely,
Seok Woo Kim, MD, PhD
President
Korean Society for the Advancement of Spinal Surgery (KOSASS)
Korea
Co-President of KOSASS
Jae Taek, Hong, M.D., Ph.D.
Chang Nam Kang, M.D., Ph.D.

Korean Society of Minimally Invasive Spine Surgery (K-MISS)

From the standpoint of the Korean Society of Minimally Invasive Spine Surgery (K-MISS), Real World Evidence in Spine Surgery: 2026 Update is an especially valuable contribution. It approaches contemporary spine surgery not as a static set of procedures, but as a rapidly changing field in which experience, patient selection, and implementation science matter alongside trial data.

This text is particularly persuasive because it avoids simplistic binaries. It recognizes that minimally invasive surgery advances through careful iteration, nuanced patient selection, and

continuous comparison between what published studies recommend and what practicing surgeons actually encounter.

The volume recognizes that less invasive surgery is not defined by incision size alone, but by the quality of decision-making, the durability of the outcome, and the appropriateness of the indication.

For that reason, I believe the book will have enduring relevance not only as a reference text, but also as a framework for future discussion about quality, innovation, and value in spine surgery. I commend the editorial team for this substantial contribution.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
Hyung-Yeon Seo, MD, PhD
 President
 Korean Society of Minimally Invasive Spine Surgery (K-MISS)
 Korea

Minimally Invasive Spine Association of Bharat (MISSAB India)

From the standpoint of the Minimally Invasive Spine Association of Bharat (MISSAB India), *Real World Evidence in Spine Surgery: 2026 Update* is an especially valuable contribution. It approaches contemporary spine surgery not as a static set of procedures, but as a rapidly changing field in which experience, patient selection, and implementation science matter alongside trial data.

This text is particularly persuasive because it avoids simplistic binaries. It recognizes that minimally invasive surgery advances through careful iteration, nuanced patient selection, and continuous comparison between what published studies recommend and what practicing surgeons actually encounter.

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Sincerely,
Kartik Kailash, MD
President
Minimally Invasive Spine Association of Bharat (MISSAB India)
India

MISABCON India

I am pleased to offer my endorsement of *Real World Evidence in Spine Surgery: 2026 Update* on behalf of MISABCON India. The book captures the practical intelligence of minimally invasive spine surgery while preserving a disciplined commitment to evidence-based analysis.

The book's methodological design is one of its greatest strengths. By pairing PICO-driven reviews with surgeon survey data analyzed using Rasch methods, this approach creates a framework for understanding not only efficacy in the literature but also implementation, variation, and value in everyday clinical care.

It is rare to find a book that speaks equally well to experienced surgeons and to those helping define the next generation of minimally invasive standards.

This is the kind of book that helps a field mature. It offers guidance without oversimplification and innovation without hype. I am pleased to endorse it and expect it will be widely useful to the minimally invasive spine community.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
Ajay Krishnan, MD
President
MISABCON India
India

Sociedad Interamericana de Cirurgia de Columna Minimamente Invasiva (SICCFMI)

As President of Sociedad Interamericana de Cirurgia de Columna Minimamente Invasiva (SICCFMI), I am pleased to endorse *Real World Evidence in Spine Surgery: 2026 Update*, a comprehensive and highly relevant reference for orthopaedic spine surgeons who must evaluate both evidence quality and practical applicability.

For orthopaedic spine surgeons, this book is particularly useful because it speaks to the questions that most influence daily practice: implant strategy, obesity-related risk, neuromonitoring, navigation and robotics, decompression choice, and the interpretation of procedure-specific outcomes in the context of actual surgical workflows.

It offers the kind of structured reflection that is essential when evaluating procedure selection in contemporary orthopaedic spine practice.

I expect the book to be of lasting value to orthopaedic spine surgeons, neurosurgeons, trainees, clinical researchers, and professional societies interested in evidence translation and responsible adoption of new techniques. I gladly lend it my endorsement.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
João Bergamaschi, MD
President

Sociedad Interamericana de Cirurgia de Columna Minimamente Invasiva (SICCMi)

Singapore Spine Society (Endoscopic Focus Group)

On behalf of the Singapore Spine Society (Endoscopic Focus Group), it is our privilege to endorse *Real World Evidence in Spine Surgery: 2026 Update*. This volume represents a meaningful and methodologically robust contribution to the ongoing evolution of spine surgery, particularly in the domain of endoscopic techniques.

The editors have developed a work that goes beyond conventional summaries of the literature. Through a structured framework built on focused PICO questions, contemporary evidence synthesis, and surgeon-reported data analyzed using Rasch methodology, the text offers a balanced and practical perspective. It not only captures what is known from the literature but also reflects how spine surgeons are currently interpreting and applying these techniques in real-world settings.

A notable strength of this volume is its emphasis on longitudinal practice patterns. By examining how endoscopic approaches are adopted, refined, and integrated into clinical workflows, the book provides insights that extend beyond isolated clinical trials and more accurately represent everyday surgical decision-making.

This text will be of considerable value to surgeons, educators, researchers, and healthcare leaders seeking to critically evaluate emerging technologies and improve patient outcomes. Its international scope and analytical depth make it highly relevant to both regional and global spine communities.

We commend the editors—Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt—for producing a volume that advances evidence-based practice, supports critical appraisal, and contributes to the continued progress of spine care.

Sincerely,
Pang Hung Wu, MBBS, FRCS
Past President,
Endoscopic Focus Group
Singapore Spine Society

Sociedad de Neurocirugía de Chile

On behalf of the *Sociedad de Neurocirugía de Chile*, I am pleased to express my support for *Real World Evidence in Spine Surgery: 2026 Update*. This volume makes an important contribution by recognizing that contemporary spine surgery is shaped not only by published evidence, but also by clinical judgment, patient selection, evolving techniques, and the realities of everyday practice.

What gives this work particular value is its balanced and thoughtful perspective. It does not reduce progress to simple assumptions about innovation, nor does it frame surgical advancement in overly rigid terms. Instead, it presents spine care as a discipline that advances through careful evaluation, practical experience, and ongoing comparison between research findings and real-world outcomes.

The book is especially relevant because it acknowledges that quality in spine surgery is not defined solely by technical execution, but also by sound indication, durability of results, and responsible adoption of new methods. In that respect, it offers a meaningful framework for both present practice and future discussion.

For these reasons, I believe this volume will serve as more than a reference text. It will also contribute to broader conversations about quality, evidence, and innovation in spine surgery across the international neurosurgical community. The editorial team is to be commended for assembling such a timely and significant work.

The editors—Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt—are to be congratulated for producing a volume that will support informed surgical decision-making, encourage critical assessment of evolving technologies, and promote higher-quality care for patients throughout the spine community.

Sincerely,
Dra. Jacqueline Lacrampette Gajardo
President
Sociedad de Neurocirugía de Chile

Sociedad Colombiana de Columna (SOCCOL)

On behalf of Sociedad Colombiana de Columna (SOCCOL), I am delighted to support *Real World Evidence in Spine Surgery: 2026 Update*. Its global orientation is one of its major strengths, particularly for regions where local practice patterns, resource constraints, and training pathways may differ from those reflected in conventional trial literature.

For surgeons practicing in heterogeneous environments, the book is valuable because it respects both scientific rigor and contextual reality. It recognizes that evidence must ultimately be interpreted through the lens of patient population, resource availability, training culture, and system-level constraints.

That orientation is especially important in regions where high-level evidence may not fully capture local practice realities or access-related decision pathways.

For those of us committed to raising standards while respecting regional differences in practice, this book offers an important model. I am pleased to endorse it and believe it will stimulate thoughtful discussion across the Americas and beyond.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
Fernando Medina, MD
President
Sociedad Colombiana de Columna (SOCCOL)
Colombia

Sociedad Mexicana de Endoscopia de Columna (SOMEEC)

As President of Sociedad Mexicana de Endoscopia de Columna (SOMEEC), I am pleased to endorse *Real World Evidence in Spine Surgery: 2026 Update*, an ambitious and timely volume that gives endoscopic and minimally invasive spine care the kind of rigorous, practice-facing analysis our field urgently needs.

What makes this book distinctive is its willingness to examine the full pathway from evidence generation to real-world adoption. The chapters on tubular versus endoscopic lumbar decompression, transforaminal endoscopic lumbar decompression, cervical endoscopic surgery, and anterior/endoscopic cervical indications are especially relevant to societies like ours because they address implementation, training, and practice variation rather than merely technical enthusiasm.

The chapters devoted to lumbar and cervical endoscopic strategies are likely to be particularly influential for surgeons refining indications and training pathways.

For these reasons, I believe this book will be of lasting value to spine surgeons, trainees, researchers, and policy leaders interested in how endoscopic and minimally invasive procedures should be evaluated and implemented. I commend the editorial team for producing a work that is rigorous, current, and genuinely useful to the global spine community.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,
Roberto Aaron Cantu Longoria, MD
President
Sociedad Mexicana de Endoscopia de Columna (SOMEEC)
Mexico

Brain Mapping and Therapeutics (SBMT)

On behalf of the Society for Brain Mapping and Therapeutics (SBMT), I am pleased to endorse *Real World Evidence in Spine Surgery: 2026 Update*. This volume is especially valuable because it approaches innovation not as a slogan or assumption, but as something that must be tested, compared, and validated through real clinical practice.

At a time when new technologies often enter surgical care more quickly than traditional evidence pathways can fully mature, the book provides a thoughtful and balanced framework for distinguishing what is promising, what is established, and what still warrants careful evaluation. That perspective is both timely and necessary.

A particular strength of this work is its measured tone. Rather than celebrating novelty for its own sake, it emphasizes the importance of disciplined assessment when emerging tools are introduced into patient care. This is exactly the kind of perspective the spine community needs as technology continues to reshape clinical decision-making.

For these reasons, I am pleased to recommend this book broadly to the international spine community. It is a mature, relevant, and well-balanced contribution to the ongoing discussion of technology-enabled surgical care and evidence-based innovation.

The editors—Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt—are to be congratulated for producing a volume that will strengthen informed surgical judgment, encourage critical appraisal of emerging technologies, and support higher-quality patient care across the spine field.

Sincerely,
Namath Hussain, MD
President

Society for Brain Mapping and Therapeutics (SBMT) International

Sociedad Venezolana de Cirugía de Columna (SVCC)

On behalf of the Sociedad Venezolana de Cirugía de Columna (SVCC), it is our honor to endorse *Real World Evidence in Spine Surgery: 2026 Update*. This publication makes an important and timely contribution to spine surgery, especially in its examination of endoscopic methods in contemporary clinical settings.

The editors have produced a volume that goes beyond a conventional review of published studies. By combining focused PICO-based chapters, current evidence summaries, and surgeon survey findings evaluated through Rasch methodology, the book presents a practical and well-balanced view of both the scientific literature and day-to-day surgical judgment.

One of its greatest strengths is the attention given to changes in clinical use over time. Rather than relying solely on isolated trial results, the text shows how new procedures are introduced, adapted, and applied across a range of treatment environments, offering a more realistic picture of present-day spine practice.

This book will be highly valuable to surgeons, teachers, investigators, and healthcare leaders who aim to assess new technologies carefully and advance patient care. Its broad international

outlook and strong methodological foundation make it relevant across both regional and global spine communities.

We congratulate the editors—Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt—on preparing a book that promotes thoughtful clinical judgment, careful evaluation of innovation, and continued progress in spine surgery.

Sincerely,
Radovan Sančević Žanko, MD
 Sociedad Venezolana de Cirugía de Columna (SVCC)

Sociedad Venezolana de Neurocirugía (SVNC)

On behalf of the *Sociedad Venezolana de Neurocirugía (SVNC)*, it is our distinct honor to endorse *Real World Evidence in Spine Surgery: 2026 Update*. This publication represents a meaningful and timely contribution to the neurosurgical and spine communities, particularly in its evaluation of endoscopic techniques within real-world clinical practice.

The editors have developed a volume that extends beyond traditional literature summaries. Through a structured approach incorporating focused PICO-based chapters, up-to-date evidence reviews, and surgeon-derived insights analyzed using Rasch methodology, the book offers a comprehensive perspective that aligns scientific data with practical clinical experience.

A notable strength is its systematic reexamination of established surgical protocols within real-world clinical contexts. By assessing whether current practices remain appropriate in light of technological advances and improved understanding of disease biology, the text offers a dynamic perspective that goes beyond static trial evidence.

This work will be a valuable resource for neurosurgeons, spine specialists, educators, researchers, and healthcare leaders seeking to critically assess emerging technologies and improve patient outcomes. Its global perspective and analytical rigor ensure relevance across diverse practice environments.

We commend the editors—Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt—for their leadership in producing a volume that advances evidence-based care, supports thoughtful clinical decision-making, and contributes to ongoing progress in spine surgery.

Sincerely,
Ernesto Luis Carvallo Cruz, MD
 Sociedad Venezolana de Neurocirugía (SVNC)

World Congress of Minimally Invasive Spinal Surgery Techniques (WCMISST)

On behalf of the World Congress of Minimally Invasive Spinal Surgery Techniques (WCMISST), I am pleased to endorse *Real World Evidence in Spine Surgery: 2026 Update*. This volume is distinguished by its clear understanding that progress in spine surgery does not

rest on novelty alone, but on the careful evaluation of techniques, outcomes, patient selection, and real-world application.

A major strength of this book is its balanced and thoughtful approach. Rather than presenting innovation as automatically beneficial, it emphasizes the importance of measured assessment and clinical relevance. In doing so, it reflects the way meaningful advancement in minimally invasive spine surgery actually occurs: through refinement, comparison, experience, and critical interpretation of evidence as it emerges in practice.

This perspective is especially valuable at a time when surgical technologies and techniques are evolving rapidly. The volume offers a practical and intellectually grounded framework for considering not only what is new, but what is effective, reproducible, and appropriate for patient care. That makes it highly relevant to surgeons committed to improving outcomes while maintaining scientific rigor.

For these reasons, I believe this book will be important not only as a contemporary reference, but also as a contribution to the broader discussion of quality, innovation, and value in spine surgery worldwide. It is a timely and substantial work that will serve the global spine community well.

The editors—Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt—are to be congratulated for producing a volume that will support informed surgical judgment, encourage thoughtful evaluation of evolving technologies, and promote higher-quality care for patients across the field of spine surgery.

Sincerely,
Kai-Uwe Lewandrowski
President
Gun Choi
Executive Director

World Federation of Spine Endoscopy (WFSE)

It is a privilege, in my capacity as President of World Federation of Spine Endoscopy (WFSE), to endorse *Real World Evidence in Spine Surgery: 2026 Update*. The editors have assembled a work that moves beyond promotional narratives and instead examines how endoscopic techniques perform, evolve, and are adopted in the real world.

Its chapter architecture is particularly effective: focused PICO questions and updated literature reviews are paired with surgeon survey data analyzed through Rasch methodology, allowing the reader to see not only what the literature reports, but also how spine surgeons actually navigate decompression choices, endoscopic indications, and evolving cervical and lumbar techniques.

The text is especially persuasive in showing that endoscopic surgery should be assessed through longitudinal practice patterns, not only through isolated trial snapshots.

This volume deserves wide circulation among surgeons, educators, researchers, and decision-makers involved in the future of endoscopic spine surgery. I congratulate the editors on a book that is methodologically serious, clinically grounded, and internationally relevant.

The editors, Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, and Benedikt W. Burkhardt, are to be congratulated for producing a volume that will support informed surgical judgment, critical appraisal of new technologies, and higher-quality patient care across the spine community.

Sincerely,

Malcolm Darayes Pestonji, MD
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CHAPTER 1

Objectives, Methodology, and Book Layout

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Abstract: The field of spine surgery is shaped by the interplay between evidence-based medicine and real-world clinical practice. While randomized controlled trials (RCTs) and meta-analyses provide high-quality evidence, they often fail to address the complexities encountered in everyday patient care. This introductory chapter outlines the objectives and design of *Real World Evidence in Spine Surgery*, a pioneering work

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Kai-Uwe Lewandrowski, Alexander Richard Vaccaro, Morgan P. Lorio, Paul Park, Rossano Kepler Alvim Fiorelli, & Benedikt W. Burkhardt (Eds.)

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that systematically compares published clinical data with real-world insights derived from the experiences of practicing spine surgeons.

This introductory chapter establishes the rationale for the book, highlighting the need to bridge the gap between controlled research settings and practical clinical environments. Each chapter applies the PICO framework (Population, Intervention, Comparison, Outcome) to ask the most meaningful clinical questions in the conduct of systematic reviews of the literature, complemented by psychometric data collected from surgeon surveys. These surveys will be analyzed using Rasch methodology, a robust statistical approach that enables the evaluation of clinical decision-making and reduces bias through internal anchoring.

Each chapter was assembled in four phases: 1) formulating research questions and survey design, 2) conducting scoping literature reviews, 3) gathering real-world data *via* webinars and surveys, and 4) synthesizing the findings into a side-by-side comparison of evidence-based guidelines and consensus findings rooted in clinical practice. By exploring areas of alignment and divergence, this work aims to enhance surgical decision-making, optimize patient outcomes, and inform healthcare policy.

This chapter provides a comprehensive foundation for the book, inviting spine care providers—including neurosurgeons, orthopedic surgeons, pain management specialists, primary care physicians, and allied health professionals such as physical and occupational therapists—to engage with its findings. The goal is to foster a deeper understanding of spine care practices while promoting a more integrated, multidisciplinary approach that enhances patient outcomes and supports more efficient resource utilization to reduce healthcare costs without compromising quality.

Keywords: Spine surgery, evidence-based medicine, clinical decision-making, systematic review, psychometric analysis, Rasch methodology, PICO framework, healthcare policy, patient outcomes, value-based care.

INTRODUCTION

The practice of spine surgery stands at the intersection of two dynamic forces: evidence-based medicine and real-world clinical practice. On one hand, systematic reviews, meta-analyses, and randomized controlled trials (RCTs) provide robust, high-grade evidence that shapes guidelines and informs clinical decision-making [1]. On the other hand, the practical realities of patient care—shaped by individual patient characteristics, surgeon expertise, and healthcare system constraints—often diverge from the controlled environments of clinical trials [2]. This divergence raises important questions: How well do published standards of care align with the lived experiences of spine surgeons? What insights can be gained by systematically comparing these two perspectives?

Real World Evidence in Spine Surgery seeks to answer these questions by providing a comprehensive comparison of state-of-the-art clinical evidence and real-world data from practicing spine surgeons. The book highlights the importance of understanding not only what the evidence says but also how it is applied—or sometimes adapted—in daily clinical practice. By doing so, it aims to bridge the gap between the theoretical and the practical, offering valuable insights for spine surgeons, researchers, and healthcare decision-makers.

This work is unique in its dual approach. First, each chapter includes a systematic review of the literature on a specific topic in spine surgery, guided by the PICO framework (Population, Intervention, Comparison, Outcome) [3]. Second, it incorporates real-world data collected from surgeons through carefully designed surveys and webinars. These surveys are analyzed using Rasch methodology, a psychometric tool that allows for a detailed examination of clinical decision-making while minimizing bias [4, 5]. This combination of methodologies provides a balanced, comprehensive view of current practices in spine surgery (Fig. 1).

The ultimate goal of this book is to identify areas where clinical evidence and real-world practice converge and diverge, offering explanations for these discrepancies. By doing so, it aims to enhance patient outcomes, improve the efficiency of spine care, and support healthcare decision-makers in identifying high-value procedures. Furthermore, the insights gained from this work have the potential to influence future research and policy, ensuring that spine surgery remains a dynamic and adaptive field.

This introductory chapter outlines the rationale, objectives, and methodology of the book. It serves as a guide for the chapters that follow, inviting the global spine care community—including neurosurgeons, orthopedic surgeons, pain management specialists, primary care physicians, and allied health professionals—to engage with its findings. Together, we aim to foster a deeper understanding of spine care practices and promote a more integrated, multidisciplinary approach that improves patient outcomes while optimizing resource utilization (Fig. 2).

THE RATIONALE FOR THE BOOK

Spine surgery is a field that thrives on innovation, driven by advances in technology, surgical techniques, and clinical research. However, despite the wealth of evidence generated from high-grade studies such as randomized controlled trials (RCTs) and meta-analyses, the application of these findings in real-world clinical practice often presents unique challenges [6]. This book, *Real World Evidence in Spine Surgery*, was conceived to address a critical need: to

CHAPTER 2

Do Wound Drains Improve Surgical Outcomes in Routine ACDF Procedures?

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Abstract: Background: The routine use of wound drains in anterior cervical discectomy and fusion (ACDF) surgery remains a subject of ongoing debate. Proponents argue that drains mitigate postoperative complications, such as hematomas, which can lead to severe outcomes like airway or spinal cord compression. However, supporting evidence for their efficacy is limited. This chapter investigates the clinical impact of wound drains in routine ACDF procedures, focusing on whether drains reduce postoperative hematomas. Do they lower the incidence of dysphagia or other complications? How do surgical factors like prevertebral plating, fusion materials, and multilevel surgeries influence outcomes?

Study Design: This study employs a dual-method approach, combining a systematic review of PICO-derived questions and a Rasch analysis of real-world evidence from spine surgeon surveys.

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PICO Framework: Key clinical questions were developed through a structured consensus process, focusing on:

1. Whether sub-fascial or prevertebral drains reduce postoperative hematoma rates. 2. Whether drains decrease the incidence of complications such as dysphagia and emergency reoperations. 3. The influence of factors like prevertebral plating, multilevel surgeries, and fusion materials on postoperative outcomes.

Methods: A scoping literature review was conducted following PRISMA guidelines, including retrospective cohort studies, randomized controlled trials, and observational studies from 2000 to 2023. Outcomes such as postoperative hematomas, dysphagia, and reoperations were assessed. Concurrently, a survey of spine surgeons gathered real-world insights on drain usage. Rasch analysis evaluated the consistency and rationale behind their clinical decisions.

Results: A retrospective case series of 388 ACDF surgeries showed no significant benefit of wound drains in reducing hematomas or reoperations. Dysphagia occurred more frequently with prevertebral plating, and autologous bone grafting correlated with higher non-hematoma-related reoperation rates. Survey data highlighted variability in drain usage, with many surgeons favoring drains despite limited evidence. Rasch analysis indicated inconsistencies in decision-making influenced by individual experience and perceived medicolegal risks.

Conclusion: The findings suggest that routine use of wound drains in ACDF does not significantly improve outcomes for hematomas, dysphagia, or reoperation rates. Prevertebral plating and interbody fusion cages are associated with increased dysphagia risk, while autologous bone grafting without plating raises the likelihood of non-hematoma reoperations. These insights emphasize the need for a selective, evidence-based approach to drain usage in ACDF to optimize patient outcomes.

Keywords: Anterior Cervical Discectomy and Fusion (ACDF), wound drains, postoperative complications, dysphagia, hematoma prevention, surgical outcomes.

INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) is a widely performed decompressive procedure in the cervical spine, commonly used to treat cervical spondylosis (Fig. 1). However, navigating the complex anatomy of the anterior cervical region carries a risk of complications. Dysphagia occurs in 1.7–9.5% of cases, while the incidence of postoperative hematoma (POH) ranges from 0.4% to 5.6% [1]. POH is particularly concerning as it can compress critical structures such as the airway, esophagus, and neurological tissues and hinder proper wound closure, increasing the risk of surgical site infections (SSIs) postoperatively to remove excess blood and debris, aiming to reduce POH and prevent SSIs [2 - 4].

However, drains themselves are not without drawbacks [5]. They can cause insertion site pain, prolong hospital stays, and potentially serve as a pathway for infection [6]. Moreover, their removal can heighten anxiety, and hematoma

formation has been reported even after their use [7]. Given these risks and benefits, the use of postoperative drains remains a contentious issue among spine surgeons. While many believe drains mitigate complications, evidence on their efficacy remains inconclusive. This chapter seeks to evaluate the role of drains in ACDF, specifically examining their impact on POH, dysphagia, and SSI rates.

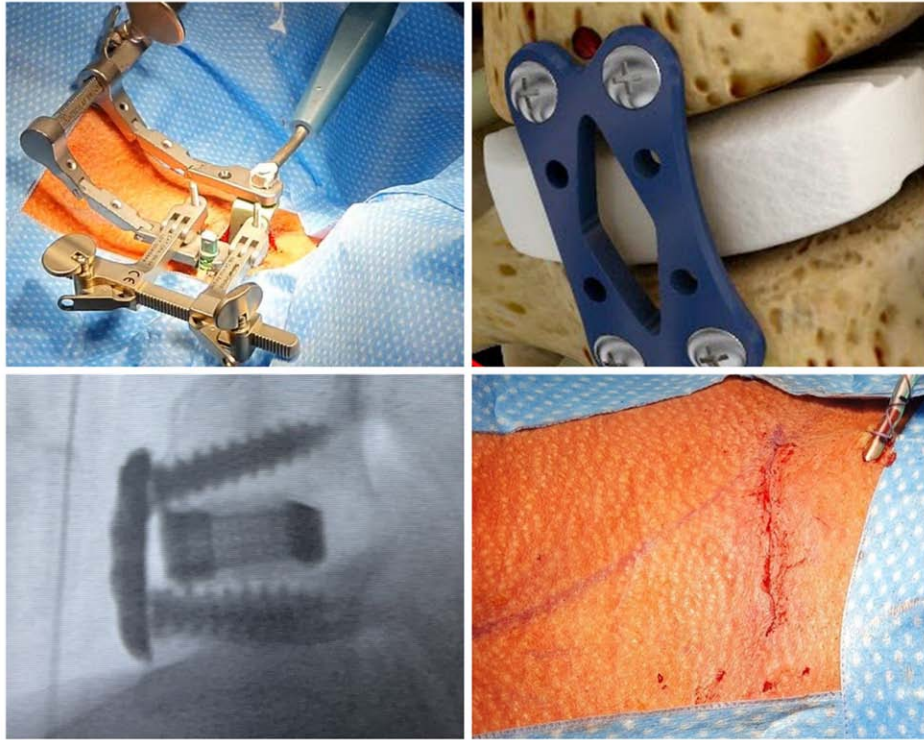


Fig. (1). Anterior Cervical Discectomy and Fusion (ACDF) Procedure. Top Left: Intraoperative view showing the surgical field with a retractor system in place, providing access to the anterior cervical spine. This setup allows optimal exposure for the discectomy and fusion process. Top Right: Close-up view of an illustrative ACDF construct demonstrating the placement of an interbody fusion cage and a prevertebral buttress plate secured with screws. The cage restores disc height and maintains spinal alignment, while the plate ensures stability and prevents implant migration. Bottom Left: Postoperative lateral X-ray of the cervical spine, highlighting the interbody cage and anterior cervical buttress plate. Proper positioning of the instrumentation ensures structural support and facilitates fusion. Bottom Right: Subfascial drain placement at the conclusion of the ACDF procedure. The drain aims to prevent postoperative hematoma formation and reduce potential compression of adjacent structures.

Following the outline of “Real World Evidence in Spine Surgery”, a comprehensive process was undertaken by the authors to evaluate the efficacy of wound drains in Anterior Cervical Discectomy and Fusion (ACDF) procedures, encompassing several key phases that collectively address discrepancies between clinical practice and evidence-based guidelines (Fig. 2). The authors began by

CHAPTER 3

Obesity and Spine Surgery

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Abstract: Chapter 3, Obesity and Spine Surgery, explores the challenges, considerations, and strategies in managing spine surgery for obese patients. Obesity (BMI ≥ 30 kg/m²) impacts surgical outcomes due to associated comorbidities like diabetes and hypertension. This chapter reviews evidence from systematic reviews,

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meta-analyses, and real-world data, highlighting risks such as wound infections, thromboembolic events, and prolonged recovery. Minimally invasive techniques, particularly endoscopic approaches, are emphasized for reducing complications and improving outcomes. The chapter underscores the importance of multidisciplinary care and tailored surgical planning, including preoperative optimization and individualized protocols. Survey data from spine surgeons reveal variability in practices and highlight the need for standardized, evidence-based guidelines. Future priorities include refining techniques, improving access to care, and evaluating long-term outcomes to optimize spine surgery for this population.

Keywords: Obesity, spine surgery, BMI thresholds, minimally invasive surgery (MIS), endoscopic spine surgery, postoperative complications, preoperative optimization, multidisciplinary care, comorbidities, real-world evidence.

INTRODUCTION

Obesity has emerged as a critical challenge in modern healthcare, affecting nearly every specialty, including spine surgery. According to the World Health Organization (WHO), obesity is defined as a Body Mass Index (BMI) of 30 kg/m² or higher. This condition is further categorized into three distinct classes: Class I obesity, defined by a BMI ranging from 30 to 34.9 kg/m²; Class II obesity, with a BMI between 35 and 39.9 kg/m²; and Class III obesity, often referred to as morbid obesity, which applies to individuals with a BMI of 40 kg/m² or higher [1]. With obesity rates rising globally, spine surgeons are increasingly encountering patients whose weight and associated comorbidities significantly influence surgical planning, execution, and outcomes. These challenges have sparked ongoing debates about the best practices for managing obese patients in spine surgery, particularly in the absence of standardized guidelines or consensus protocols.

The implications of obesity on spine surgery are multifaceted. From technical difficulties in the operating room to elevated risks of complications such as infection and wound healing issues, obesity presents unique hurdles for both surgeons and patients [2]. Moreover, obesity often coexists with other medical conditions, including diabetes, hypertension, and cardiopulmonary diseases, further complicating surgical decision-making. Despite these complexities, spine surgery plays a pivotal role in improving mobility, alleviating pain, and enabling weight loss, which can contribute to broader health benefits and recovery.

This chapter aims to provide a comprehensive exploration of obesity in the context of spine surgery, with a focus on developing real-world protocols that address the unique needs of this patient population. We will examine the current state of evidence, including clinical challenges, surgical outcomes, and the role of decompression in rehabilitation. Additionally, we will incorporate insights from a

survey of spine surgeons, highlighting their experiences and perspectives on managing obese patients.

By synthesizing the literature, real-world data, and surgeon insights, this chapter seeks to bridge the gap between current practices and evidence-based guidelines. Our goal is to inform clinical decision-making, improve patient outcomes, and pave the way for standardized protocols that align with the evolving needs of patients and payers in modern spine surgery.

THE IMPACT OF OBESITY ON SPINE SURGERY

Obesity is associated with a range of challenges that significantly impact the outcomes of spine surgery. The increased body mass index (BMI) in obese patients presents both physiological and logistical complexities that influence perioperative planning, intraoperative execution, and postoperative recovery. Understanding these impacts is essential for tailoring surgical approaches and optimizing outcomes in this patient population.

Physiological Considerations

Obesity is often accompanied by comorbid conditions such as diabetes, hypertension, obstructive sleep apnea, and cardiopulmonary diseases, all of which increase the risks associated with spine surgery [3, 4]. These conditions can impair wound healing, increase susceptibility to infections [5], and complicate anesthesia management [6]. Furthermore, excess adipose tissue can alter spinal biomechanics, exacerbate degenerative processes, and increase mechanical stress on implants, raising the likelihood of surgical complications [7].

Technical Challenges

Performing spine surgery on obese patients often demands advanced surgical expertise and modified techniques to navigate technical hurdles [8]. Excess tissue may obscure anatomical landmarks, increasing operative time and the risk of inadvertent errors. Limited access to the surgical site can complicate decompression, instrumentation, and fusion procedures. Additionally, imaging challenges, such as reduced quality of intraoperative fluoroscopy or navigation, can hinder precision in these patients.

Obese patients frequently exceed the weight and size limitations of standard operating room (OR) tables and surgical positioning devices, such as the Wilson frame, which typically has a weight limit of approximately 350 pounds [9]. This necessitates the use of specialized bariatric equipment to ensure patient safety and stability during surgery. However, such equipment is not universally available,

CHAPTER 4

The Role of Intraoperative Neuromonitoring (IONM) in Spinal Surgery

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Abstract: Intraoperative neurophysiological monitoring (IONM) is a critical tool in spine surgery, designed to enhance surgical safety by providing real-time feedback on spinal cord and nerve function. This chapter explores the historical evolution, modalities, and clinical applications of IONM, focusing on its utility in complex spine surgeries, including deformity corrections and tumor resections, compared with its use in straightforward scenarios for the treatment of degenerative conditions of the spine. A narrative of systematic reviews and meta-analyses highlights the diagnostic accuracy of multimodal IONM approaches, which outperform unimodal techniques in sensitivity

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and specificity. Real-world surgeon survey data reveal variability in practice patterns, emphasizing challenges such as cost, administrative barriers, and reliance on skilled personnel. The survey also underscores discrepancies between theoretical benefits and practical outcomes, particularly in low-risk surgeries. Through Rasch analysis and qualitative insights, the chapter identifies areas for improvement, including standardizing protocols, refining alert thresholds, and tailoring IONM use to patient-specific risks. The findings advocate for evidence-based guidelines and equitable access to IONM to optimize its clinical utility and cost-effectiveness in spine care.

Keywords: Intraoperative neurophysiological monitoring, spine surgery, multimodal IONM, surgical safety, spinal deformities, tumor resections, real-world practice, cost-effectiveness, surgeon survey, guidelines development.

INTRODUCTION

Intraoperative neurophysiological monitoring (IONM) is a widely used tool among spine surgeons to minimize the risk of spinal cord and nerve root injury during surgery. Its primary purpose is to detect potential neural damage in real-time, enabling surgeons to intervene promptly and proceed with the procedure safely [1]. IONM has demonstrated high reliability, with sensitivity and specificity rates of 89% and 99%, respectively [2]. In developed countries, including the United States, multimodal IONM is a standard of care, particularly in spinal deformity surgeries, where its use is considered essential [3].

Despite its widespread adoption, there is limited research definitively proving the benefit of IONM across all types of spinal procedures [4]. Existing studies have explored its role in tumor surgeries [5], discectomies [6], cervical spine operations [7], and deformity corrections [8]. While these studies highlight its potential value, they fall short of providing comprehensive evidence for its utility in broader degenerative contexts. To address this gap, our study aimed to evaluate the surgeons' perspectives on the effectiveness of IONM in various spinal surgeries in a real-world setting. Specifically, we sought to determine its impact on intraoperative decision-making and postoperative patient outcomes, offering new insights into its practical applications across multiple indications.

HISTORICAL PERSPECTIVES

The concept of neuromonitoring, which enables real-time assessment of spinal cord function during surgery, has its roots in the early 20th century [9]. In the 1930s, the idea of using electrical stimulation to collect data on the nervous system first emerged, laying the groundwork for later advancements [10]. By the 1970s, Japanese researchers had developed spinal cord evoked potential (SCEP) technology, enabling direct stimulation of the spinal cord to monitor sensory

pathways [11]. However, in the United States, surgeons initially had to improvise by modifying existing equipment, leading to inefficient and cumbersome setups.

The introduction of the first commercial intraoperative neuromonitoring (IONM) system in the 1980s marked a pivotal moment. This innovation, adopted in both the United Kingdom and the United States, streamlined the monitoring process and made it more accessible. During this period, sensory tract monitoring was the primary focus, while motor function was assessed using the “Wake-Up Test,” introduced by Vauzelle and Stagnara in 1973 [12]. A breakthrough occurred in 1980 when Merton and Morton demonstrated the feasibility of transcranial brain stimulation, revolutionizing motor tract monitoring [13].

By 1990, the American Society of Neurophysiological Monitoring was established to support the rapidly growing field. The society defined IONM as any method used to assess the functional integrity of the nervous system during surgery or in acute care settings [14]. Advances in hardware, software, and anesthesiology further refined and standardized neuromonitoring, transforming it into a routine component of modern surgical practice.

TYPES OF NEUROMONITORING

Somatosensory Evoked Potentials (SSEPs) are the most widely utilized [15]. SSEPs work by using peripheral electrodes to stimulate the nervous system, generating cortical responses that enable surgeons to track sensory pathway integrity and identify potential neurologic changes during surgery. This technique is valued for its reliability and ability to provide continuous feedback throughout the procedure. However, it has notable limitations. The need for temporal summation in signal interpretation can delay the detection of changes by up to 16 minutes [16], which can be critical in certain scenarios. Additionally, SSEPs are prone to false positives and negatives [16], reducing their effectiveness when used as a standalone method [17]. As a result, combining multiple neuromonitoring techniques is often necessary to achieve a comprehensive and timely assessment of spinal cord function.

Transcranial MEPs monitor corticospinal tract activity by recording signals from peripheral muscle groups following spinal cord or motor cortex stimulation. MEPs are reliable for tracking corticospinal activity and identifying postoperative deficits [18]. However, their sensitivity to volatile anesthetic gases necessitates the use of intravenous anesthetics [19], and their monitoring is dependent on triggered stimuli, preventing continuous observation [14]. Meanwhile, EMG, which has both spontaneous (sEMG) [20] and triggered (tEMG) forms [21], plays a crucial role in monitoring nerve roots and detecting cortical breaches during spinal instrumentation. Continuous sEMG provides real-time feedback, while

CHAPTER 5

3D-Printed Personalized vs. Off-The-Shelf Spinal Implants: Is it Worth it?

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Abstract: The adoption of 3D-printed titanium (3DT) spinal implants is redefining spinal surgery by integrating advanced material science with innovative manufacturing techniques. This chapter evaluates the trade-offs between personalized and off-the-shelf (OTS) 3DT spinal implants in terms of clinical efficacy, cost-effectiveness, and surgeon adoption. Enhanced osseointegration, modular elasticity, and customizability position 3DT implants as superior to traditional materials like PEEK. However, high

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initial costs, technical complexity, and limited long-term clinical data remain barriers to widespread use. Survey findings and unsolicited surgeon insights highlight variability in adoption, perceptions of cost-effectiveness, and the clinical advantages of 3DT cages, particularly in enhancing fusion rates and reducing infection risks. The chapter underscores the need for longitudinal studies, targeted education, and regulatory advancements to fully integrate 3DT technology into spinal care. While challenges persist, the potential of 3DT implants to improve surgical outcomes and patient care signifies a pivotal shift in spine surgery.

Keywords: 3D-printed spinal implants, titanium cages, personalized implants, off-the-shelf implants, osseointegration, spinal fusion, minimally invasive surgery, surgeon perspectives, cost-effectiveness, medical technology innovation.

INTRODUCTION

The emergence of 3D-printed titanium spine implants represents a groundbreaking advancement in spinal surgery, offering both custom personalized implants tailored to individual anatomy and off-the-shelf options designed for broader applications. By merging the distinctive material properties of medical-grade Ti6Al4V titanium [1] with the precision of 3D printing technology [2 - 4], this approach enables the production of durable interbody fusion implants custom-fitted to individual anatomy and engineered for enhanced bioactivity. These implants promise improved surgical precision, better anatomical fit, and enhanced patient outcomes by reliably maintaining vertebral spacing and facilitating fusion between adjacent vertebrae to reduce pain [5]. Additionally, the cutting-edge design and manufacturing processes have significantly elevated the functionality [6, 7], customization [8], and overall effectiveness of orthopaedic and spinal implants [9]. However, the added expense of 3D printing and its integration into standard clinical practice raise important questions about cost-effectiveness and tangible patient benefits. This chapter explores the cost-benefit analysis of these advanced implants, evaluating whether their adoption is justified by superior outcomes or if they remain a premium solution with limited practical advantages (Fig. 1).

MATERIAL PROPERTIES OF TITANIUM

Titanium's unique properties have established it as a preferred material for medical implants [10 - 13]. Its exceptional strength-to-weight ratio closely mirrors that of human bone, offering robust structural support without undue weight [14]. Furthermore, its remarkable biocompatibility minimizes adverse immune reactions, and its superior resistance to corrosion ensures durability and long-term functionality within the human body [15]. Advances in 3D printing technology have expanded titanium's utility by enabling the creation of intricate and patient-

specific designs tailored to meet diverse clinical demands. However, achieving the optimal balance of implant porosity, structural architecture, and mechanical strength remains a critical challenge. These design elements must be carefully calibrated to enhance osteointegration and provide stable biomechanical performance [16 - 18].



Fig. (1). Assortment of 3D-printed titanium spinal fusion cages featuring various designs and configurations tailored for different anatomical and surgical requirements. The collection includes cages designed for Posterior Lumbar Interbody Fusion (PLIF), Transforaminal Lumbar Interbody Fusion (TLIF), and Anterior Cervical Discectomy and Fusion (ACDF) procedures. The porous lattice structure is intended to enhance bone ingrowth, promote fusion, and provide improved stability, while the titanium material ensures biocompatibility and durability. The variety of shapes and sizes reflects the versatility of additive manufacturing in addressing the specific needs of spinal fusion surgery across different regions of the spine.

Porosity

The porosity of titanium implants plays a crucial role in facilitating osseointegration [19], a process in which bone cells adhere to and integrate with the implant surface, improving both its stability and durability [20]. Porous designs also help align the implant's mechanical properties with those of natural bone by reducing stiffness, which promotes better load distribution and minimizes stress shielding effects [21]. However, while increased porosity supports bone ingrowth, it can also weaken the implant's mechanical strength, making it more vulnerable to fatigue and failure under the repetitive loading conditions typical of spinal applications [22]. Achieving an optimal balance between porosity for biological integration and sufficient structural integrity remains a significant challenge in the development of 3D-printed titanium implants.

CHAPTER 6

Precision Redefined: Robotics and Navigation in Spine Surgery – A Leap Forward or a Technology in Search of Purpose?

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Abstract: Robotics and navigation technologies have emerged as transformative tools in spine surgery, offering enhanced precision, safety, and efficiency. This review explores their clinical, economic, and operational implications through a comprehensive analysis of literature, meta-analyses, systematic reviews, and real-world data. Robotics and navigation systems demonstrate superior accuracy in pedicle screw

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placement, reduced complications, and support for minimally invasive techniques, yet challenges remain. Cost-effectiveness, operational efficiency, and equitable access are significant barriers to broader adoption, particularly in resource-limited settings. Real-world surgeon surveys highlight concerns about prolonged setup times, steep learning curves, and an over-reliance on technology that may be diminishing manual skills. Addressing these challenges requires scalable financial models, comprehensive training, and expanded clinical applications beyond pedicle screw placement. The future of robotics and navigation in spine surgery lies in advancing automation, developing standardized guidelines, and fostering collaborations to ensure ethical, evidence-based integration. These technologies, when balanced with traditional surgical expertise, hold the potential to redefine standards in spine care while improving patient outcomes.

Keywords: Robotics, navigation, spine surgery, pedicle screw placement, minimally invasive surgery, surgical precision, cost-effectiveness, surgeon training, healthcare technology, clinical outcomes.

INTRODUCTION

Spinal surgery has experienced transformative advancements in recent years, driven by innovations in surgical techniques, equipment, implants, and biological interventions. Among these breakthroughs, the integration of computer-assisted navigation and robotic systems has revolutionized the field, offering enhanced precision, safety, and efficiency. These technologies represent a pivotal shift in surgical practices, leveraging real-time imaging and automated guidance to improve outcomes and reduce complications.

The evolution of image-guided surgery began with early radiographic imaging systems and stereotactic techniques designed to enhance accuracy. The foundations of modern navigation can be traced back to 1908, when Horsley and Clarke [1] introduced stereotactic frames for lesion targeting in the brain. This early innovation laid the groundwork for frameless stereotaxy with real-time imaging in cranial surgery by the 1990s [2, 3]. Building on these advances, navigation systems in spinal surgery now utilize 3D mapping to generate real-time visualizations of the surgical field, enabling precise intraoperative guidance. These systems have been particularly impactful in procedures requiring accurate pedicle screw placement, deformity correction, and tumor resections.

Robotics, another game-changing development, has further redefined the landscape of spinal surgery. Robotic systems, particularly shared-control models, integrate seamlessly with navigation platforms to provide unparalleled accuracy during procedures. Unlike early supervisory-controlled or telesurgical systems, modern shared-control systems allow surgeons to maintain manual control while benefiting from robotic precision. These systems use preoperative and

intraoperative imaging to determine optimal trajectories, guiding surgical instruments with unmatched consistency. Such technology has found widespread application in pedicle screw placement, where it reduces error rates and minimizes radiation exposure compared to traditional fluoroscopic techniques [4 - 6].

The growing adoption of navigation and robotic systems in spinal surgery is supported by robust evidence of their clinical benefits. Studies have demonstrated higher accuracy rates in pedicle screw placement, reduced complications, and decreased radiation exposure compared to traditional techniques. Furthermore, these systems facilitate minimally invasive approaches, which can lead to faster recovery times and improved patient outcomes. Despite these advantages, critics argue that steep learning curves, high costs, limited access to the technology in some regions, and, most importantly, marginal improvements in clinical outcomes.

This chapter examines the current state of navigation and robotic systems in spinal surgery, offering a comprehensive analysis of their advantages, limitations, and practical applications. By exploring clinical outcomes and their integration into surgical practice, it addresses a critical question: Do these technologies represent a transformative breakthrough or an expensive innovation without a clear purpose? As part of the new book **Real World Evidence in Spine Surgery**, this chapter highlights their impact on clinical workflows and potential for future advancements. To provide a well-rounded perspective, the authors conducted a survey of practicing spine surgeons, focusing on the intraoperative use of navigation and robotics to evaluate their true value and role in modern spine surgery.

CURRENT NAVIGATION AND ROBOTIC SYSTEMS IN SPINAL SURGERY

The **Telesurgical Robotic System** (da Vinci Surgical System) was FDA-approved in 2000 for laparoscopic surgeries and is widely used in cardiac, thoracic, and urological procedures. Offering 10x magnification and 3D vision with tremor control, it is utilized for laparoscopic anterior lumbar interbody fusion. Despite its potential for intracavitary procedures, its role in spinal surgeries, like pedicle screw placement, remains under-researched [7, 8].

The **Computer-Assisted Navigation** (CAN) systems are increasingly used in spine surgery for accuracy and safety. Popular 3D CAN platforms include:

- **Airo Mobile Intraoperative CT Navigation** (Brainlab, Germany)
- **Stryker Spinal Navigation** (USA)

CHAPTER 7

The Better Bet for Lumbar Stenosis: Real World Evidence on Tubular vs. Endoscopic Decompression

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Abstract: Lumbar spinal stenosis is a common degenerative condition requiring surgical intervention for patients unresponsive to conservative management. This chapter compares tubular-based microscopic decompression and full-endoscopic decompression techniques, focusing on real-world evidence and surgeon perspectives.

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A comprehensive review of literature and survey data highlights the advantages and limitations of each approach, including clinical outcomes, surgical metrics, patient satisfaction, and technical challenges. While endoscopic techniques offer benefits such as reduced blood loss, faster recovery, and smaller incisions, tubular methods are favored for their familiarity, cost-effectiveness, and reliability in complex cases like multilevel stenosis. Challenges like steep learning curves, high costs, and fluid management in endoscopic methods remain significant barriers to widespread adoption. Insights into practice patterns and surgeon preferences provide a deeper understanding of the contemporary clinical application of these techniques, guiding evidence-based decision-making and future advancements in lumbar stenosis treatment.

Keywords: Lumbar spinal stenosis, endoscopic decompression, tubular decompression, minimally invasive spine surgery, surgical outcomes, learning curve, surgeon preferences, patient recovery, spine surgery techniques.

INTRODUCTION

Lumbar spinal stenosis is a degenerative condition characterized by narrowing of the spinal canal and compression of the nerve roots, often caused by disc degeneration, hypertrophy of the ligamentum flavum, facet joint overgrowth, and osteophyte formation [1, 2]. Patients commonly experience symptoms such as neurogenic claudication, low back pain, radicular pain, and, in advanced cases, neurological deficits [3]. As the disease progresses, it may result in significant functional limitations and reduced quality of life [4]. For individuals with severe symptoms unresponsive to conservative treatments, surgical intervention becomes a viable option, particularly for those with debilitating pain, progressive neurological impairments, or bowel and bladder dysfunction [5].

Historically, conventional laminectomy has been the primary surgical approach for lumbar spinal stenosis. However, its extensive disruption of posterior spinal structures, including the paraspinal muscles, ligaments, and bones, has been associated with postoperative issues such as low back pain, iatrogenic instability, and spondylolisthesis. To address these complications, minimally invasive spinal surgery (MISS) techniques, including those utilizing tubular retractors and endoscopes, were developed to minimize soft tissue damage, reduce blood loss, and shorten recovery times [6 - 15]. These innovations have demonstrated benefits such as reduced incision size, lower postoperative pain, decreased analgesic requirements, and shorter hospital stays, promoting faster recovery [13, 16 - 21].

Microscopic techniques, particularly those employing tubular retractors, are widely recognized as standard procedures for lumbar decompression and have shown reliable outcomes [22, 23]. The tubular system further minimizes paraspinal muscle disruption during microsurgery, enhancing recovery and

reducing morbidity [24, 25]. Meanwhile, the advent of full-endoscopic techniques, particularly the interlaminar approach, has introduced new possibilities for lumbar discectomy, foraminotomy, and decompression. This approach offers exceptional visualization through enhanced magnification and illumination, contributing to its growing popularity among spine surgeons [26]. Favorable results have been reported for full-endoscopic decompression in lumbar spinal stenosis, suggesting its viability as an alternative to tubular-based microsurgery [9, 27 - 42].

Both tubular and endoscopic decompression techniques have passionate proponents, with practitioners in each camp expressing strong confidence in their respective methods. The current body of evidence supports the success of both approaches in achieving positive clinical outcomes for patients. However, direct comparisons between the two techniques remain limited, and the relative benefits of one approach over the other are not yet well-established. While some studies highlight the advantages of one technique, others emphasize different strengths, leaving room for further exploration.

In this chapter, the authors aim to broadly assess practice patterns and surgeon preferences for tubular *versus* endoscopic decompression, rather than delve deeply into the technical specifics of each procedure. By focusing on real-world applications and perceptions, we hope to provide insights into which technique is more widely adopted, perceived as superior, or presents unique advantages and limitations. This broader perspective may help guide future research and facilitate informed decision-making in the surgical treatment of lumbar spinal stenosis.

BRIEF DESCRIPTION OF ENDOSCOPIC VS. TUBULAR LUMBAR DECOMPRESSION TECHNIQUES

In this chapter, we intentionally chose not to distinguish among the myriad endoscopic techniques and approaches, acknowledging the vast variation in surgeon preferences and skill levels across techniques. Instead, we focused on differentiating two broad categories of minimally invasive approaches: tubular unirrigated retractors, which typically have a working channel diameter of no less than 16 mm (and most commonly 18 to 22 mm), and endoscopic techniques, most of which are irrigated but include unirrigated methods such as the Destandau technique and its variation. This deliberate framework allows the research presented here to concentrate on the two principal camps of minimally invasive surgeons—those who employ tubular retractors and those who use endoscopes—and to explore how each group views the application of their preferred technique in the treatment of central stenosis of the lumbar spinal canal (Fig. 1).

CHAPTER 8

Transforaminal Endoscopic Lumbar Decompression: Defining its Scope and Limitations

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Abstract: This chapter examines the expanding application of transforaminal endoscopic lumbar decompression (TELD) in spinal surgery, focusing on its effectiveness in managing foraminal and extraforaminal herniations and in alleviating

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painful conditions within the lateral lumbar spinal canal. TELD is distinguished by its superior visualization and minimally invasive access, leading to fewer complications and quicker patient recovery compared to traditional open techniques. Nonetheless, complex cases such as central stenosis pose ongoing challenges, requiring advanced surgical proficiency. Practitioner surveys show varying perceptions, highlighting the necessity for standardized training to align real-world practices with published outcomes. Ultimately, this discussion underscores TELD's potential to broaden the scope of endoscopic spinal decompression surgery, advocating for enhanced education and protocol development to maximize its effectiveness, particularly in treating central canal stenosis, a procedure best performed by highly experienced endoscopic spine surgeons.

Keywords: Transforaminal endoscopic lumbar decompression, minimally invasive surgery, spinal stenosis, lumbar herniation, foraminal stenosis, lateral canal stenosis, central canal stenosis, surgical visualization, patient recovery, TELD efficacy.

INTRODUCTION

Transforaminal endoscopic lumbar decompression has become the workhorse procedure for addressing foraminal and extraforaminal herniations, as well as painful compressive pathology in the lateral lumbar spinal canal [1 - 9]. Its reliability and efficiency are rooted in its minimally invasive nature, leveraging the naturally existing foraminal opening to access affected areas without significant disruption to surrounding structures. Advancements in instrumentation, including motorized drills, and refinements in surgical technique have further expanded its indications, allowing for effective decompression of bony stenosis in the foramen, lateral canal, and, in skilled hands, even the central canal [10].

A key advantage of the transforaminal approach is its superior visualization of the surgical field [11], achieved without retracting the dural sac—a common requirement in interlaminar techniques [12]. Unlike translaminar decompression, which often necessitates the removal of a significant portion of the lumbar facet joint [13], especially in cases with severe degenerative changes or narrow interlaminar windows, the transforaminal approach preserves spinal integrity. Its ability to minimize surgical trauma reduces the risks of bleeding, durotomy, and epidural hematoma [14]. Additionally, it avoids complications associated with irrigation fluid flow, which, during interlaminar [15] or unilateral biportal endoscopy (UBE) procedures [16 - 18], can lead to postoperative spinal headaches, seizures, cardiac arrest, or meningitis in cases of wound infection [15]. The transforaminal approach also allows direct intradiscal exploration [3, 11, 19 - 21], enabling visualization of painful pathology within the intervertebral disc itself. It is a relatively quick procedure, characterized by a low complication rate and minimal postoperative burden on the patient. While some dysesthesia may

occur postoperatively – 1 to 4.7% as reported by Cho *et al.* and up to 21.5% in a multi-center study by Lewandrowski *et al.* [22 - 25], the procedure's efficiency and safety make it well-suited for ambulatory surgery centers [26].

The transforaminal approach, while highly effective, presents challenges in certain cases, such as central stenosis, far-migrated disc herniations, and painful facet joint pathology. These indications may require additional experience and skill, potentially pushing novice endoscopic spine surgeons to the limits of their comfort zone [27 - 29]. This chapter explores the full scope of transforaminal endoscopic lumbar decompression, highlighting its clinical strengths while acknowledging the technical demands of more complex cases. Beyond its established success in treating foraminal and extraforaminal herniations and lateral lumbar spinal canal pathology, the authors provide insights into best practices for optimizing its use and delineating cases in which advanced expertise or alternative surgical approaches may be more advantageous, ensuring informed and effective surgical decision-making.

EVOLUTION OF TRANSFORAMINAL ENDOSCOPIC SPINE SURGERY

The origins of endoscopic spine surgery can be traced back to the 1930s when Burman employed arthroscopic tools for “myeloscopies,” enabling visualization of the spinal cord and nerve roots in cadaver specimens [30, 31]. Shortly thereafter, Pool and Ooi [32, 33] advanced the technique, performing myeloscopies on live patients and enhancing the visualization of neurologic structures. These early endeavors paved the way for technological advancements in optics and microscopy, propelling minimally invasive spine (MIS) surgery into a rapidly evolving field.

Efforts to access the disc space percutaneously began in the 1970s with Kambin and Sampson [34] and Hijikata [35], who pioneered a fluoroscopic-guided cannula approach for percutaneous discectomy [36]. Kambin's definition of the “safe zone” for transforaminal docking laid the foundation for addressing foraminal pathology [37]. By 1988, Kambin *et al.* [37] reported direct visualization using endoscopes, while Schreiber *et al.* [38] used arthroscopic instruments to remove disc material under direct visualization for patients with sciatica.

The 1990s saw significant breakthroughs, notably Yeung's development of a fully functional uniportal endoscopic system, which achieved successful outcomes in the management of disc herniation [39]. Water-based endoscopy introduced continuous irrigation for maintaining a clear surgical field. Around the same time, Caspar's innovation of the tubular approach and Foley's implementation of the first tubular-based microendoscopic discectomy demonstrated effective treatment

CHAPTER 9

Redefining Cervical Spinal Surgery: Endoscopic Techniques and Real-World Applications

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Abstract: Cervical endoscopy is rapidly advancing as a minimally invasive alternative to traditional surgical techniques for a wide range of cervical spine disorders. This chapter explores the general acceptance, clinical implementation, indications, and perceived outcomes of cervical endoscopic procedures, without focusing exclusively on anterior or posterior approaches, which are discussed in detail in separate chapters. By preserving spinal motion and minimizing surgical trauma, endoscopy offers potential benefits over traditional methods like anterior cervical discectomy and fusion (ACDF) and multilevel laminectomy with or without fusion, particularly for conditions like cervical radiculopathy and myelopathy. ACDF, while effective, is associated with problems, such as adjacent segment disease, subsidence, hardware failure, deformity,

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or kyphosis, some of which require reoperation. Similarly, multilevel laminectomy, though reliable in decompressing the spinal cord, carries risks such as postoperative instability and kyphosis, prompting fusion in certain cases. Endoscopy competes by enabling anterior and posterior decompression for radiculopathy and myelopathy while preserving spinal stability and avoiding fusion. A systematic review and real-world data analysis reveal that endoscopic procedures achieve high clinical effectiveness with lower morbidity, although steep learning curves, high equipment costs, and surgeon variability have limited widespread adoption. This chapter provides insights into current practice patterns, geographic differences, and surgeon perspectives, emphasizing the need for training standardization, cost reductions, and procedural refinements to establish cervical endoscopy as a viable alternative to traditional surgeries.

Keywords: Cervical endoscopy, anterior cervical discectomy and fusion (ACDF), minimally invasive spine surgery, cervical radiculopathy, endoscopic decompression, adjacent segment disease, subsidence, hardware failure, deformity, surgical outcomes.

INTRODUCTION

The focus of cervical spinal endoscopy is the preservation of surrounding soft tissues and structures, lowering the burden of the surgical approach and minimizing the risk of infection, atrophy, deformity, and iatrogenic instability. Advancements in endoscopic spinal surgery (ESS) have broadened its application to the cervical spine. The core aim of cervical endoscopy within ESS is the decompression of neural structures afflicted by various pathologies. This technique allows for the precise removal of pathologies like herniated intervertebral disc (HIVD), hypertrophic ligamentum flavum, facet joint cysts, overgrown facet joints, and uncovertebral osteophytes in the subaxial cervical spine [1 - 7].

The location and level of the target lesion greatly influence the surgical approach. Particularly in the cervical spine, endoscopic techniques must be adapted to address specific anatomical challenges [3]. The cervical foramen presents limitations due to its narrowness, hindering the passage of an endoscope [7]. Additionally, critical arteries located at the posterior aspect of the cervical intervertebral foramen pose risks during transforaminal approaches [5]. As a result, cervical endoscopy predominantly employs posterior or anterior approaches to navigate these challenges effectively [3].

Additional clinical applications have emerged. For example, ESS has proven advantageous in addressing infectious spinal diseases involving the cervical region, such as discitis, particularly when complicated by an epidural abscess [8]. Targeted and minimally invasive, cervical endoscopic approaches allow for

effective full-endoscopic discectomy, debridement, and drainage, thereby controlling infection and restoring neurological function with reduced surgical and anesthetic risks [9]. The technique facilitates the collection of causative organisms and direct nerve decompression, benefiting patients with significant comorbidities or surgical risks. Another example relates to the use of ESS in spinal tumors. Cervical endoscopy may offer opportunities for tumor biopsy or selected epidural tumor removals [10 - 12]; however, it remains challenging, particularly with epithelially complex, vascularized, or intradural tumors, where the tumor dissection endoscopically may be difficult, especially in highly vascularized tumors where hemostasis may be difficult [13].

These examples underscore the ongoing need for further investigation into the appropriate indications for cervical spinal endoscopy and for developing clinical evidence to support its surgical applications. This ultra-minimally invasive technology has the potential to offer significant benefits that may outweigh its risks. Consequently, this chapter aims to provide a current snapshot of clinical decision-making. It explores appropriate patient selection criteria, current practice patterns, including implementation challenges, and surgeons' perspectives on the value of cervical spinal endoscopy compared to traditional surgical techniques.

HISTORY

Over the past decade, endoscopic techniques for cervical disc diseases have developed significantly since the initial description of cervical percutaneous discectomy by Tajima *et al.* In 1981, Tajima introduced the first working channel for cervical discectomy, featuring a 2mm diameter and 8 cm length [14]. This setup included dilators, a guide needle for discography, and forceps of varying sizes, which were prone to breakage during use [15]. These minimally invasive methods, including chemoneucleolysis, offer early recovery and maintain the stability of intervertebral segments [16]. The simplified percutaneous endoscopic cervical discectomy (PECD) surgery initially targeted the center of the disc but has evolved to access the posterior subannular and epidural spaces to effectively remove extruded herniated disc fragments [17]. Furthermore, advances in endoscopic and instrument technology have supported this evolution, reducing the risk of instrument breakage during procedures. Enhanced videoendoscopic visualization has also expanded the modern indications as outlined below. Today's advanced cervical endoscopic systems, like the Karl Storz WSH set [18], surpass their predecessors by offering a central working channel of 4.2mm and ports for integrated high-resolution optics, illumination, and irrigation [19]. These modern tools enable precise disc removal using microforceps and a Ho:YAG laser under direct visualization (Fig. 1), significantly reducing prior risks and enhancing exploration of cervical anatomy [20].

CHAPTER 10

Anterior and Endoscopic Cervical Spine Surgery: A Comprehensive Survey-Based Review of Current Indications and Practice Patterns

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Abstract: This chapter presents a comprehensive, survey-based review of current indications, practice patterns, and surgeon perceptions regarding anterior cervical endoscopic spine surgery. By examining three key techniques—anterior transcorporeal cervical discectomy (ATCD), anterior cervical endoscopic discectomy (ACED), and full-endoscopic anterior cervical decompression and fusion (eACDF)—the study com-

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pares real-world surgical perspectives with published literature using survey data and Rasch analysis. The findings reveal significant discrepancies in surgeon confidence, risk perception, and adoption of these techniques. While literature highlights the benefits of anterior cervical endoscopy, including reduced complication rates and motion preservation, surveyed surgeons express concerns about procedural safety, patient selection criteria, and long-term outcomes. ATCD is perceived as a promising alternative to ACDF but lacks consensus on its indications and risks, particularly regarding vertebral collapse and kyphosis. Similarly, ACED, though supported by literature for symptomatic relief, faces skepticism regarding its effectiveness in cervical spondylotic radiculopathy. eACDF, despite advancements in instrumentation and technique, is met with low confidence among surgeons, with concerns about safety and procedural complexity hindering widespread adoption. The Rasch analysis further underscores variability in risk perception and learning curve concerns, particularly among surgeons with limited exposure to endoscopic techniques. These findings highlight the need for standardized patient selection criteria, enhanced surgeon training, and multicenter long-term outcome studies to bridge the gap between evidence-based recommendations and real-world surgical adoption. Establishing consensus guidelines and expanding educational initiatives will be crucial for integrating anterior cervical endoscopy into mainstream spine surgery practice.

Keywords: Anterior cervical endoscopy, anterior transcorporeal cervical discectomy (ATCD), anterior cervical endoscopic discectomy (ACED), full-endoscopic anterior cervical decompression and fusion (eACDF), spine surgery, minimally invasive surgery, cervical disc herniation, motion preservation, surgical indications.

INTRODUCTION

This chapter builds upon the previously established foundation detailing patient selection criteria and indications for cervical endoscopy in general. Here, the authors focus specifically on anterior cervical endoscopic procedures, examining three key techniques: anterior transcorporeal cervical discectomy (ATCD), anterior cervical endoscopic discectomy (ACED), and full endoscopic anterior cervical decompression and fusion (eACDF).

By leveraging surgeon survey data and advanced statistical modeling, this chapter aims to provide an objective assessment of contemporary approaches to anterior cervical endoscopy. The integration of Rasch analysis enables a deeper examination of consensus and variability in surgical decision-making, highlighting areas where further standardization and education may be beneficial. Ultimately, this chapter seeks to bridge the gap between established guidelines and real-world practice, offering insights that can inform future research, training, and clinical decision-making in minimally invasive cervical spine surgery.

ANTERIOR CERVICAL ENDOSCOPIC TECHNIQUES

Anterior Percutaneous Endoscopic Cervical Discectomy (PECD) has emerged as a minimally invasive alternative to traditional open anterior cervical discectomy and fusion (ACDF) for treating symptomatic cervical disc herniations [1 - 5]. While conventional anterior PECD approaches—such as the transdiscal anterior cervical endoscopic discectomy (ACED) method—offer motion preservation benefits, they have been associated with progressive cervical disc collapse due to anterior annular disruption [6 - 13]. To mitigate these concerns, the anterior transcorporeal approach was introduced as a modified technique (ATCD), enabling direct decompression of herniated cervical discs through a small transosseous tunnel in the vertebral body. This technique aims to preserve disc integrity, limit access-related damage, and reduce the risk of adjacent segment degeneration (ASD) [1 - 12]. Some patients may still require fusion. Full endoscopic anterior cervical decompression and fusion (ACDF) techniques are emerging for these applications [14].

Anterior Transcorporeal Cervical Discectomy (ATCD)

Percutaneous Endoscopic Cervical Discectomy (PECD) has emerged as a minimally invasive alternative to traditional open anterior cervical discectomy and fusion (ACDF) for treating symptomatic cervical disc herniations [1 - 5]. While conventional anterior PECD approaches—such as the transdiscal method—offer motion preservation benefits, they have been associated with progressive cervical disc collapse due to anterior annular disruption [6 - 13]. To mitigate these concerns, the anterior transcorporeal approach was introduced as a modified technique, enabling direct decompression of herniated cervical discs through a small transosseous tunnel in the vertebral body. This technique aims to preserve disc integrity, limit access-related damage, and reduce the risk of adjacent segment degeneration (ASD) [1 - 12].

The anterior transcorporeal cervical discectomy (ATCD) technique [5, 15] provides enhanced visualization of herniated disc material and allows for a targeted surgical trajectory, avoiding excessive disruption of surrounding structures (Fig. 1). The method has demonstrated promising clinical outcomes with the microforaminotomy and the transuncal technique [16 - 25], with reduced postoperative complications such as dysphagia, recurrent laryngeal nerve palsy, and anterior cervical hematoma. By minimizing iatrogenic injury to the intervertebral disc, the technique helps maintain cervical spinal stability while achieving effective decompression [26].

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