
Evidence-Based Imaging

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Aims of the Series

Evidence-Based Imaging: Improving the Quality of Imaging in Patient Care series presents the radiologist and clinician with a user-friendly guide to the evidence-based science and the merit behind the diagnostic imaging performed in medicine. This ideal reference gathers contributions by internationally renowned specialists in the field. The series provides a systematic framework for understanding the best imaging choices for patient care. Chapters highlight key points that support the clinical applications, allowing fast access to pertinent information. Topics include patient selection, imaging, strategies, test performance, cost-effectiveness, and applicability.

By offering a clear understanding of the science behind the evidence, the book fills a void for radiologists, clinicians, physician assistants, nurse practitioners, residents, fellows, students and others with an interest in medical imaging and a desire to implement an evidence-based approach.

More information about this series at <http://www.springer.com/series/8865>

Aine Kelly • Paul Cronin • Stefan Puig
Kimberly E. Applegate
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Evidence-Based Emergency Imaging

Optimizing Diagnostic Imaging of
Patients in the Emergency Care
Setting

 Springer

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To our patients, who are our best teachers

To our students, who are the healthcare providers of tomorrow

To the researchers, who made this book possible

To our families, friends, and mentors

AMK: To my loving family past, present, and future, Paddy, Anita, Paul, Alison, Anna, and Eva

PC: To my parents, Brendan and Claire. To my loving and supportive wife, Aine, who makes it all possible and our two children who are truly our pride and joy. To my sister, Alison

SP: To my wife, Rosi; my sons, Julian, Simon, and Sebastian; and my grandson, Liam

Foreword

The practice of emergency radiology encompasses the diagnostic imaging management of acutely ill and injured patients in the emergency setting. It is one of the newest subspecialties of diagnostic radiology and one of the fastest growing. Its growth parallels the escalation in emergency medical practice as emergency departments experience an ever-increasing patient volume each year. Many institutions have experienced an annual growth rate of emergency department volume greater than 5%. The sophistication of emergency imaging has also been increasing as trauma surgeons and emergency physicians expect and require the availability of all imaging modalities including radiography, ultrasound, computed tomography, and magnetic resonance imaging at all hours, every day of the week. Emergency physicians are also requesting rapid turnaround times with final image interpretations available days, evenings, and nights. Recent investigations have shown that the timely performance and interpretation of emergency imaging examinations cannot only increase emergency department throughput, decompressing busy centers, but also contribute to improved patient outcomes and decreased healthcare costs.

Emergency radiology as a radiology subspecialty has been experiencing increasing recognition for its advances in patient care. Both the Radiological Society of North America and the American Roentgen Ray Society include educational and scientific programs devoted to emergency imaging at their annual meetings. The American Society of Emergency Radiology (ASER) was established 28 years ago and currently has over 1000 members, a vibrant annual meeting with postgraduate course, and an official journal, *Emergency Radiology*, established in 1994. The journal has showcased original research relevant to emergency and trauma imaging. Emergency radiology fellowships have been established at many academic radiology departments, and an increasing number of radiology trainees are entering the practice of emergency radiology.

It would appear that the time is most appropriate for a compilation of scholarly communications on evidence-based emergency radiology available in textbook format to assist those in emergency practice. The editors have skillfully accomplished this goal. The text is organized into two main sections beginning with an introductory segment on the principles of evidence-based imaging, appraising the literature critically, emergency imaging information systems, and consequences of inappropriate imaging. The second segment is comprised of 36 chapters (in 5 subsections) covering common emergency conditions requiring high-quality, state-of-the-art imaging man-

agement. This unique text is not only intended to educate emergency physicians and emergency radiologists but all healthcare workers providing care in the emergency setting.

I have no doubt that this task will be successfully accomplished with *evidence-based emergency radiology*.

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Robert A. Novelline

Foreword

Emergency physicians often depend on sophisticated imaging for many of the patients evaluated in emergency departments (EDs). In fact, nearly 50% of the 130,000 million annual ED visits in the USA are accompanied by radiological imaging of some type, making the field of emergency radiology one that impacts a large percentage of the US population. While emergency imaging has become more sophisticated over the past decades, allowing clinicians access to immediate diagnostic tools, this has also come with costs, both financial and otherwise. As with all tests, sensitivity and specificity are not perfect, leading to under- and overdiagnosis. Although the risks to patients of underdiagnosis are more apparent to clinicians and patients alike, overdiagnosis has its own insidious and potentially harmful consequences. Incidental findings on radiological images can lead to unnecessary and potentially harmful testing and treatment, as well as undue patient anxiety. Concerns regarding radiation exposure from radiography, particularly computer tomography (CT), have also come to the forefront in the past decade, with many studies raising concerns over radiation-induced malignancies. Since 1980, the use of CT has increased approximately eightfold. This is of particular concern in children, given their greater sensitivity to radiation than adults, their longer life expectancies during which malignancies can be expressed, and the higher dose of radiation they frequently receive unless the CT scan radiation doses are appropriately adjusted to meet their body sizes.

Fortunately, CT use has decreased in recent years for a number of reasons, including the increasing use of ultrasound and other imaging modalities, quality improvement initiatives (which include monitoring and feedback of physician radiology use), and shared decision-making between clinicians and their patients regarding the tradeoffs of performing or avoiding specific imaging. Finally, the past decade has seen a sharp increase in the use of clinical decision rules and computer-based clinical decision support tools for the use of emergency imaging. This has led to more rational, evidence-based, and cost-effective use of diagnostic imaging. In addition, the Choosing Wisely Campaign of the ABIM (American Board of Internal Medicine) has been championing evidence-based and cost-effective use of diagnostic testing, including the use of imaging in the ED.

One specific example of research and efforts dedicated toward evidence-based imaging comes from the Pediatric Emergency Care Applied Research Network (PECARN), which has made emergency imaging decision rules one of its foci in the last decade given the previous lack of evidence around imag-

ing of injured children. Studies from several countries examining the implementation of the PECARN cranial CT decision rules for children with minor head trauma have demonstrated safe decreased use of CT in these children.

In 2015, the Society for Academic Emergency Medicine hosted the Academic Emergency Medicine consensus conference entitled “Diagnostic Imaging in the Emergency Department: A Research Agenda to Optimize Utilization.” Leaders in emergency medicine, radiology, and health services research and other experts came together to discuss and debate the issues described previously and to develop a consensus research agenda. After much preparation and discussion, six content areas emerged as those of greatest importance and in need of future study. These included the development and validation of clinical decision rules for emergency diagnostic imaging; the use of administrative data for emergency imaging research; patient-centered outcomes research; training, education, and competency; knowledge translation and barriers to imaging optimization; and comparative effectiveness research in alternatives to traditional CT use. Many of the issues considered at that conference are intertwined with the contents of this novel and timely textbook.

Evidence-Based Emergency Imaging will undoubtedly serve as an outstanding resource for all clinicians who care for acutely ill and injured adults and children. Within the pages of this text, the reader will find the principles of evidence-based imaging and the specific imaging needed for a variety of emergent conditions. This melding of the principles of radiology, clinical epidemiology, and health services research will help clinicians identify who to image in the emergency setting, what piece of technology to use, and what issues to consider and anticipate. I greatly welcome and applaud the arrival of this new textbook.

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Preface

Demand for emergency healthcare is rising consistently across the developed world, with the number of presentations to emergency departments (EDs) increasing by 3–6% per year over the last decade. The role of EDs within the US healthcare system is also changing with more than half of patients admitted to the hospital in the USA now starting their hospital stay in the ED. The ED is a location where subspecialty consultation and advanced diagnostic imaging technology are available at all hours. In the USA, EDs are unique sources for healthcare because services are provided to all persons regardless of insurance coverage or ability to pay. In addition, the proportion of elderly people in developed world populations is growing. This age shift has important implications for EDs, with a resultant increase in medical complexity of patients attending the emergency room.

Medical imaging has grown exponentially in the last three decades with the development of many promising and often noninvasive diagnostic studies. Several studies from the developed world have shown a steady increase in the use of imaging especially cross-sectional imaging such as computed tomography (CT) in the ED with the need for rapid and accurate diagnosis. These studies have also shown a trend toward less invasive diagnostic testing. Over the last decade, there have been profound changes in the diagnostic testing and work-up of patients presenting to their physician/healthcare provider with emergent symptoms or to the ED. The most profound change has been the increased availability, speed, and accuracy of imaging. This is in part due to technical improvements such as the development of multi-detector CT. This reflects a decade or more of increased utilization of imaging especially advanced imaging such as CT, magnetic resonance imaging (MRI), and positron emission tomography (PET) imaging. Although in the last few years high-end imaging use has plateaued in general, this is not the case in the ED. The dramatic increase in advanced imaging modalities such as MRI and PET, previously not commonly employed in the ED setting, continues. This increase in imaging is understandable since ED patients are more acutely ill, and there is constant pressure to make an accurate diagnosis as quickly as possible to facilitate prompt disposition or treatment and to ensure fast throughput and efficiency in ED services. There is also strong evidence for the beneficial use of imaging in the emergency setting which correlates with improved patient outcomes.

Therefore, the purpose of this book is to educate radiologists, physicians, and all healthcare providers who utilize diagnostic imaging in the ED or other

acute care settings regarding the best and most up-to-date evidence-based imaging. This book is also relevant to internal medicine (adult and pediatric) and family medicine physicians and healthcare providers who care for patients with emergent symptoms. The scope includes practicing radiologists, radiologists in training, clinicians in practice or in training, medical students, and allied personnel such as physician assistants and nurses who may practice in the acute care setting.

The book is organized into two sections, the first being an introductory section with chapters on the principles of evidence-based imaging, critical appraisal of the literature, information systems in emergency imaging, and consequences of inappropriate emergency imaging in adults and children. The second section, divided into five parts, includes chapters written by authors who practice in the fields of emergency care imaging and covers all aspects, including neuroimaging, head and neck imaging, musculoskeletal imaging, chest and cardiac imaging, abdominal and pelvic imaging, pediatric imaging, and women's imaging. Although other books in the evidence-based series cover the organ systems listed above, this book specifically deals with the emergent and acute presentations. The 40 chapters cover the most prevalent emergent conditions and diseases that affect those in developed countries. Additionally, this book contains the most accurate and up-to-date information with the latest evidence and protocols. Recommendations and society guidelines are also discussed. Emergency imaging in adults is covered with a special focus on emergent imaging in specific patient groups including women of childbearing age, pregnant women, and also adolescent and pediatric populations. Unique and defining features of this book include that it is the first book of its kind to focus on emergency imaging in adults, children, and special populations with chapters by a multidisciplinary team of experts, all contained in one volume. It also represents the most up-to-date evidence-based approach to acquiring the most appropriate and comparative effective imaging in patients who present to the emergency department or in the acute setting.

To make the book user-friendly and to enable fast access to pertinent information, we have organized all of the chapters in the same format. The chapters are framed around important emergent clinical questions relevant to the physician's daily practice. A short table of contents at the beginning of each chapter helps three different tiers of users: (1) the busy physician searching for quick guidance, (2) the physician seeking deeper understanding, and (3) the medical-imaging researcher requiring a comprehensive resource. The format for each chapter starts with the important clinical issues to be discussed. This is followed with a box of key points in bullet form with the strength of the supporting evidence in parenthesis. After this, there are sections covering definitions, etiology, pathophysiology and risk factors, relevant epidemiology, and costs to society in economic terms, followed by a section discussing the goals of imaging and a section detailing the methodology used to obtain the most up-to-date literature.

Next, the issue being discussed is framed with a summary of evidence including existing literature and guidelines if any. This is further elaborated by the supporting evidence with paragraphs discussing the diagnostic modali-

ties available, the imaging findings/criteria for diagnosis, the impact of imaging on treatment decision-making, and the treatment options if applicable. Given that all research and evidences are not created equal, we use a four-level classification detailing the strength of the evidence based on the Oxford Centre for Evidence-Based Medicine Criteria: Level I (strong evidence), Level II (moderate evidence), Level III (limited evidence), and Level IV (insufficient evidence). The strength of the evidence is presented in parenthesis throughout the chapters so the reader gets immediate feedback on the weight of the evidence behind each topic. If a cost-effectiveness analysis has been performed, these data are also presented. In addition, some chapters contain special cases (e.g., pregnant patients or children), and important issues which require a separate or additional discussion (such as radiation concerns) are also presented.

Each chapter text includes tables and figures, imaging case studies, and protocols. The tables summarize diagnostic test accuracy and summary statistics such as the sensitivity and specificity of different imaging studies. The figures show decision trees summarizing the evidence, e.g., risk factors, diagnostic performance, and algorithms/flowcharts with suggested protocols/guidelines. Imaging case studies are cases that highlight the diagnostic performance of the different imaging studies. Examples include important true-positive, false-positive, true-negative, and false-negative cases and imaging pitfalls if applicable. Suggested imaging protocols are a brief summary of imaging steps supported by the evidence. Future research discusses in bullet points the critical gaps in the evidence. All chapters are extensively referenced with the most up-to-date literature.

Finally, we had the privilege of working with a group of outstanding contributors from major medical centers and universities in North America and Europe. We believe that the authors' expertise, breadth of knowledge, and thoroughness in writing the chapters provide a valuable source of information and can guide decision-making for physicians and patients. In addition to guiding practice, the evidence summarized in the chapters may have policy-making and public health implications. We hope that this book highlights key points and generates discussion, promoting new ideas for future research. We value your suggestions and comments on how to improve this book. Please email them to us and the authors so that we can bring you the best of the evidence over the years.

Ann Arbor, MI, USA

Aine Marie Kelly
Paul Cronin

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Editors' Biographies and List of Contributors

Editors

Aine Kelly is a professor of cardiothoracic radiology at the Michigan Medicine, Ann Arbor, Michigan, USA.

She is board certified in internal medicine by the Royal College of Physicians in Ireland and in diagnostic radiology by the Royal College of Radiologists in the UK and the American Board of Radiology. Dr. Kelly graduated from the School of Medicine, Trinity College Dublin, Ireland. She completed an internship at St. James's Hospital, Dublin, and an internal medicine residency at the Dublin Federated Hospitals Scheme, followed by an endocrinology fellowship at the Meath Hospital, Dublin, Ireland. After this, Dr. Kelly pursued a radiology residency at the Leeds/Bradford/Huddersfield Radiology Training Scheme, before joining the University of Michigan. She completed two fellowships in thoracic imaging and body MRI imaging at the University of Michigan.

Dr. Kelly obtained a master's degree in clinical research design and statistical analysis from the University of Michigan School of Public Health. She also completed a master's degree in higher education from the School of Education at Michigan. Dr. Kelly has been principal investigator on multiple grants, including the General Electric-Association of University Radiologists Radiology Research Academic Fellowship (GERRAF), the Educational Scholar Award from the Radiological Society of North America (RSNA), and the American Roentgen Ray Society (ARRS) Leonard Berlin Scholarship in professionalism and ethics. She has been co-investigator on multiple other grants, including National Institutes of Health (NIH)-funded studies and the National Lung Screening Trial (NLST). Her research focused on evidence-based imaging, noninvasive cardiothoracic imaging, patient preferences, comparative effectiveness, efficiency, value-based insurance design, quality, and safety.

Dr. Kelly served on the executive board for the Association of University Radiologists (AUR) and is currently president elect of the Alliance of Medical Student Educators in Radiology (AMSER), past president of the Alliance of Clinician Educators in Radiology (ACER), past president of the Radiology Alliance for Health Services Research (RAHSR). She is past chairperson of the health services research committee of the RSNA and has served as grant

reviewer for the Radiological Society of North America (RSNA). She has been an international and national invited speaker and author on the topic of evidence-based imaging. Dr. Kelly currently serves as deputy editor for education at *Academic Radiology*. Dr. Kelly has authored or coauthored more than 70 peer-reviewed scientific manuscripts and 5 book chapters.

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Paul Cronin is an associate professor of radiology at the Michigan Medicine. He also serves as the cardiothoracic radiology fellowship director.

Dr. Cronin was born in Dublin, Ireland. After graduating from medical school at Trinity College Dublin, he completed an internal medicine residency and received his membership to the Royal College of Physicians of Ireland (MRCPI). He completed a radiology residency in Leeds, UK, and also received his fellowship to the Royal College of Radiologists (FRCR). Following that, he then went to the University of Michigan and completed two fellowships (in cardiothoracic and magnetic resonance imaging) and has stayed there as faculty. He received a master's degree in clinical research design and statistical analysis from the University of Michigan School of Public Health.

Dr. Cronin teaches medical students, residents, and fellows on a daily basis while maintaining a busy clinical practice. He has received an Excellence in Thoracic Radiology Award and multiple annual commendations for excellence in teaching at the University of Michigan. Dr. Cronin has received multiple honors and awards and has been invited to visiting professor programs in Australia, Europe, and North America. He has been on the "Best Doctors in America" list since 2011. He was awarded the GE-AUR Radiology Research Academic Fellowship (GERRAF). Dr. Cronin's research interests include evidence synthesis and outcomes research of multiple aspects of cardiothoracic radiology. He has been co-investigator on other grants, including the National Lung Screening Trial (NLST) and Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) III Trial. He has authored 142 scientific and educational papers, abstracts, posters, and book chapters; he has given over 190 local, national, and international lectures and is a member or chair of over 20 professional radiology society committees. He serves on the executive board for the Radiology Alliance for Health Services Research and is currently the immediate past president. He also serves on the research committee and as grant reviewer for the Radiological Society of North America (RSNA). Dr. Cronin is a reviewer for a dozen journals. He is the guest editor for the RAHSR edition of *Academic Radiology* and the deputy editor for health services research. He is an associate editor for the evidence-based practice subsection of *Radiology*. He has recently completed a 3-year term as the health services policy and research subcommittee chair of the scientific program committee at the RSNA. Dr. Cronin is also a fellow of the American College of Radiology.

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Associate Editors

Stefan Puig is an associate professor of radiology and holds a master's degree in healthcare management.

Dr. Puig was born in Vienna, Austria. After graduating from medical school at the University of Vienna, he completed his internal medicine residency at the University Clinic of Radiology, Vienna, and continued working there as a senior radiologist. In 2003, he became associate professor of radiology, and in 2006 he received a master's degree in healthcare management from the Danube University Krems, Austria.

In 2008, he left the country to gain some working experience abroad and worked in the radiology departments of the American Hospital in Dubai, the University Clinic of Ulm in Germany, and the University Clinic of Bern in Switzerland. In 2015, he moved to Zurich, Switzerland, where he has been working as a radiology consultant at the Hirslanden Clinic while still teaching at the University Clinic of Bern, Switzerland.

In addition to gaining broad practical experience in the various fields of radiology in Austria and abroad, Dr. Puig authored and coauthored a long list of publications for scientific medical journals. His scientific expertise is focused on emergency imaging, pediatric radiology, interventional radiology, and evidence-based radiology. He has been a reviewer for a number of scientific journals and authored systematic reviews and decision support tools for the Austrian Ministry of Health and the General Association of Austrian Social Insurance Institutions.

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Kimberly E. Applegate is a tenured professor of radiology and pediatrics, division chief of pediatric radiology at the University of Kentucky in Lexington, and radiology liaison for quality at the Kentucky Children's Hospital. Dr. Applegate is a leader in radiology—she currently serves on the American College of Radiology Board of Chancellors, after completing a 2-year term as the first woman to be elected ACR Council Speaker. She is also the President of the Association for University Radiologists (AUR) Research and Education Foundation and a member of the National Quality Forum Patient Safety Committee and both the National and the International Councils for Radiation Protection.

Dr. Applegate's policy and research work has resulted in an improved understanding of the structure, process, and outcomes of how pediatric imaging is practiced, including the volume of ionizing imaging in children, the variation in radiation dose in pediatric CT, and the standardization of practice for both children and adults. She has worked tirelessly around the world with collaborators in the IAEA, WHO, and IRPA to improve access to best practices. In 2017, Dr. Applegate became a member of the ICRP Main Commission as the chair of the committee 3 (medicine).

Kimberly has received a number of awards that include an ABR Lifetime Achievement Award, Academy of Radiology Research Distinguished Investigator, ARRS Scholar, RSNA Editorial Fellowship, SPR Presidential Recognition, the Indiana ACR Chapter Gold Medal, and AUR Gold Medal. She enjoys mentoring talented colleagues and trainees—who have received over 20 mentee awards to date. At the 2015 RSNA meeting, Kimberly received the American Association for Women in Radiology's Marie Sklodowska Curie Award for her unique roles in leadership and outstanding contributions to the advancement of women in the radiology professions.

Dr. Applegate has published over 200 peer-reviewed papers and book chapters and presented scientific papers and lectures at medical and scientific assemblies around the world. She has an interest in health services research in radiology, coediting the evidence-based imaging textbook series. In 2006, she began work on the Steering Committee for the *Image Gently Campaign* to improve safe and effective imaging care of children worldwide. The campaign has received a number of awards for its advocacy, education, and collaboration to change imaging practice. She is also on the Executive Committees of the World Federation of Paediatric Imaging and *Image Wisely*. She and her husband, Dr. George Parker, have three sons, David, and twins Andrew and Eric.

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