

AI IN CLINICAL MEDICINE

A PRACTICAL GUIDE FOR
HEALTHCARE PROFESSIONALS

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WILEY Blackwell

AI in Clinical Medicine

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A Practical Guide for Healthcare Professionals

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Dedication

I dedicate this book to my beloved parents, Tom and Philomena, who truly nurtured and encouraged me, and genuinely made countless sacrifices to give me the wonderful opportunities in life that I have; to my brother and best friend, Sean, always there for support and laughs; and, of course, to my truly wonderful, patient, supportive, loving, and beautiful wife, Vivian. I hope this book goes some small way to show my gratitude to all of them.

—Michael F. Byrne, Lead Editor

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He is also CEO of Satisfai Health (and founder of ai4gi), a company aiming to deliver precision endoscopy to gastroenterology using artificial intelligence and allied technologies.

Dr Byrne is a graduate of both Cambridge and Liverpool Universities, and trained in advanced endoscopy at Duke University. He holds a doctorate degree from Cambridge University for his molecular science bench research work on *Helicobacter pylori* and Cyclooxygenase.

He is widely regarded as one of the leading physician experts in artificial intelligence as applied to gastroenterology. He is in huge demand as a medical AI reviewer for all the top medical journals, and is frequently described as one of *the* pioneers in bringing AI to gastroenterology and endoscopy.

He has presented at many international conferences, particularly in relation to artificial intelligence and gastroenterology.

He has published over 150 papers in peer-reviewed journals, and over 200 abstracts.

Dr Byrne is a clinical innovator and physician entrepreneur with more than 25 years' experience as a practising physician.

Editorial Team



Dr Nasim Parsa

Dr Nasim Parsa is a board-certified gastroenterologist and clinical researcher. She attended Tehran University of Medical Sciences, completed her gastroenterology fellowships at the University of Missouri, and pursued an additional year of training in advanced oesophageal disorders at the Mayo Clinic. She is also the Vice President of Medical Affairs at Satisfai Health Inc., a leading medical solution provider specializing in AI applications in gastroenterology.

Through her work as a clinician and researcher, she has published extensively, with over 30 peer-reviewed publications and over 40 abstract presentations at national and international meetings. She has been an invited reviewer for several prestigious journals, including *Gastroenterology* and

Gastrointestinal Endoscopy. She is committed to serving her profession, and is currently serving on several GI Society committees, including the Educational Affairs Committee for the American College of Gastroenterology (ACG), the Education Committee of the International Society for the Disease of the Esophagus, and the Quality Leadership Council of the American Gastroenterological Association (AGA).

Dr Parsa is passionate about improving patient outcomes through cutting-edge technology and the meaningful implementation of AI in clinical practice. She is the youngest member of the *AI in Clinical Medicine* editorial team, and has made significant editorial contributions to this book.



Dr Alexandra T. Greenhill

Dr Alexandra T. Greenhill is one of the leading physicians in health innovation, and the CEO/Chief Medical Officer of Careteam Technologies. After a more than 15-year career in director and C-level leadership roles, she has spent the last few years leading and advising some of the most innovative healthtech companies. She is a TEDx and keynote speaker, has been recognized as one of the Top 40 under 40, Most Influential Women in STEM, and WXN Most Powerful Woman, and has received the Queen Elizabeth II Medal of Service.



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Dr Daljeet Chahal completed his bachelor's degree at the University of Northern British Columbia, followed by his master's and medical degrees through the University of British Columbia. He completed his internal medicine and gastroenterology training in Vancouver. Dr Chahal is currently completing advanced hepatology training at the Mount Sinai Hospital in New York. He has an interest in applying machine learning technologies to various aspects of clinical medicine, and hopes to incorporate such technologies into his future clinical practice and research endeavors.



Dr Omer Ahmad

Dr Omer Ahmad is a gastroenterologist and senior clinical research scientist at University College London, with a specialist interest in interventional endoscopy, advanced imaging techniques, and computer vision.

His academic work focused on the clinical translation of artificial intelligence in endoscopy, providing experience across the entire translational pipeline for AI software as a medical device. His pioneering interdisciplinary research at UCL led to the development of AI software for real-time use during colonoscopy, which is currently being used in clinical practice. He was awarded the young clinical and translational scientist of the year by the British Society of Gastroenterology. His specific research interests include identifying barriers to the implementation of artificial intelligence

in healthcare. He has published numerous international initiatives related to the effective validation and implementation of AI solutions. He also serves as an expert member on AI working groups for international endoscopy societies and is developing educational programmes to improve foundational knowledge of AI for clinicians.



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AIR (artificial intelligence resource) at the NIH. He has also served as an area chair for MICCAI for several years, and is an Associate Editor of top-tier journals in his fields such as *IEEE Transactions on Medical Imaging*, *Medical Physics*, and *Medical Image Analysis*. Dr Bagci teaches machine learning, advanced deep learning methods, computer and robot vision, and medical imaging courses. He has several international and national recognitions, including best paper and reviewer awards.

Dr Ulas Bagci is an Associate Professor at Northwestern University's Radiology, ECE, and Biomedical Engineering Departments in Chicago, and Courtesy Professor at the Center for Research in Computer Vision, Department of Computer Science, at the University of Central Florida. His research interests include artificial intelligence, machine learning, and their applications in biomedical and clinical imaging. Dr Bagci has more than 250 peer-reviewed articles in these areas. Previously, he was a staff scientist and lab co-manager at the National Institutes of Health's Radiology and Imaging Sciences Department, and Center for Infectious Diseases Imaging. Dr Bagci holds two NIH R01 grants (as Principal Investigator), and serves as a Steering Committee member of



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AI in Clinical Medicine: A Practical Guide for Healthcare Professionals was her most challenging project to date and also one of the most rewarding. She especially enjoyed working with all the editors and authors.

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Foreword

Ten years ago, the technology world was fascinated with *SMAC*. The perfect storm of social networks, mobile computing, analytics, and cloud computing seemed to be happening all at once. Facebook would soon go public. The iPad and iPhone had captured the world's imagination, a wonderful, keyboard-free device with more power than the supercomputers of the 1990s. Cloud computing had just begun, scoffed at by many, but growing fast. Companies everywhere were beginning to apply analytics at scale, reimagining themselves as digital natives. *SMAC*. Social, Mobile, Analytics, and Cloud. What could *possibly* be next?

That summer two papers were released, in seemingly different domains.

- Geoffrey Hinton et al. published 'ImageNet classification with deep convolutional neural networks', a breakthrough in AI that demonstrated how computers could actually *see*. His software combined the power of video game consoles (graphics processing units or GPUs) with recent advances in analytics and cloud computing, creating the first AI that could correctly identify over 1000 different items from millions of images. Hinton and his peers ignited a Cambrian explosion of computer systems that could perceive.
- Jennifer Doudna et al. published 'A programmable dual-RNA-guided DNA endonuclease in adaptive bacterial immunity', which to me demonstrated the human ability to modify the programming of biological cells. Jennifer and her team could not only read the source code of life, their biological apparatus could now *change* it. A universe of possibilities opened up, forever changing genomics, medicine, and biology.

As I write this Foreword today, kids in elementary school are dancing to TikTok videos, where video 'filters' change their appearance in hilarious ways. These filters implement a far more sophisticated version of Hinton's algorithm, now running on mobile phones. The Pinocchio of my youth now appears as realistic long noses in videos of their parents at a family dining table, with kids giggling in delight.

Biology students are regularly reading the DNA of strawberries, using hand-held sequencers with the same power of the larger machines Doudna had in her lab. Astronauts are sequencing their blood on the space station, a prelude to precision medicine and the world's best care for adventurers that take an eight-month trip to Mars on SpaceX rockets.

These powerful technologies amplify who we are as humans, and portend a truly exciting future. We can now build computers that see, hear, taste, and feel, then describe what they perceive in human terms. We're beginning to understand the source code of life, and from that detect cancers and wellness transitions, far earlier and in less invasive ways than today's biopsies and mammograms.

That's both exciting – but also unnerving. Humans must make assumptions about the world to function properly. Our *reticular focus* subconsciously filters signals that

bombard our everyday senses, allowing us to focus on what *we think* matters. That inherent and often hidden bias is crucial for proper use of our neocortex.

We've all experienced this phenomenon. Having a baby? Suddenly, you see babies, baby carriages, and pregnant women seemingly everywhere. Looking to buy a new car? Your favourite car seems to appear at all your favorite spots.

These activities, of course, were always there. We just weren't paying attention.

That brings me to this wonderful book, either a heavy, thick tome in your hands at home, or perhaps on a mobile phone that you're reading at 30,000 feet on a flight.

Michael F. Byrne, lead editor of this book, has an incredible skill for finding humans from all walks of life, brilliant and accomplished in their own way, and inspiring them to contribute for the collective good. He found me speaking at a conference on AI and gastroenterology in San Diego, one foggy afternoon in May of 2022. I've been in AI for over 30 years – starting when it 'didn't work' back at MIT to today, where I've been leading a team at Google of Applied AI in precision medicine and science. If you've met Michael, you'll know he's hard to turn down!

In this book you'll dive into such fun topics as the history of AI, the use of machine vision to detect polyps, or machines that can interpret and process clinical notes. My brother hopes all this work can lead to the elimination of keyboards in medical offices, 'zero clicks', using technology to give everyone more valuable time with patients.

Hold on to this book. Meet the authors, reach out to them on LinkedIn, seek them at conferences or in your daily work. You all form a community collective. Realize that we all have a reticular focus. Only together can we perceive the proverbial elephant in the room. AI is truly a team sport, where diversity of thought, perception, and background is *required* by human biology and science.

Michael's collection of brilliant, accomplished authors are the seed of a broader community that will redefine clinical practice in medicine, powered by AI and the source code of life. As a reader, you too can contribute, and I strongly encourage you to reach out.

How do we ensure that AI is treated in an ethical way? What sort of projects are meaningful and worthy of our time, and which should we avoid? How do humans and AI effectively collaborate for better patient outcomes? Working together, we all see what's truly out there, the bigger picture, the classic three blind humans perceiving the elephant. We need to. By overlapping our assumptions and rooting out unfair bias, we can build truly wonderful systems and science.

To the authors of this book, the editors, and especially to Michael, thank you for diving in, taking the time to think carefully about AI and how it can change the field of medicine. I'm excited to see what this community will achieve together in the next decade. Your diversity of thought is paramount to advancing the state of the art, protecting and ensuring healthy lives for millions of patients, now and for centuries to come.

Read on. Your journey has just begun.

Scott Penberthy
Director of Applied AI, Google

Preface

Michael F. Byrne

Why This Book, Why Now?

When I was approached by the publisher, Wiley, at a large gastroenterology conference in San Diego over two years ago, it was not immediately clear to me that this would quickly morph from a commitment to lead a book on AI in my field of gastroenterology to a significantly bigger undertaking – namely, leading a book for AI in the entire field of clinical medicine! After the initial consternation about this decision, my excitement grew week by week as my support team came together and the writing started in earnest.

With the book beginning to take some initial shape, my enthusiasm sky-rocketed as it was abundantly clear to me that now, more than at any time in the history of AI in medicine, we truly needed a practical guide in this field. The speed of development and adoption of AI in clinical medicine has increased so much since I took on this project that I became totally convinced that we were doing something very necessary and timely. I sincerely hope that this book does not disappoint.

The Promise of AI in Clinical Medicine

Artificial intelligence is an overarching term used to describe the use of machine learning algorithms and software. In healthcare applications, AI mimics human cognition in the analysis, presentation, and comprehension of complex data, such as in medical imaging.

AI is a rapidly growing technology, involving much of what we do day to day, from the smart devices on our wrists to the virtual library we access online. We are, rightly, seeing AI applications and advancement in clinical medicine. In the last few years, deep learning techniques and data availability have resulted in an explosion of applications/potential applications of AI to the whole of clinical medicine. We are moving ahead in our applications for radiology, pathology, dermatology, endoscopy, surgery, robotics, drug discovery, and more. It's not a matter of when anymore: we are already living in the AI age, and we can expect and celebrate that AI is increasingly being applied for medical purposes to address some of our biggest clinical challenges.

For this reason, physicians across the entire healthcare spectrum and at all stages of their careers need to have at least a basic appreciation of the AI tools that are already in use in clinical medicine, and a knowledge base to grasp those that come down the pike. We wrote this book for inquisitive pre-med or medical students,

graduate-level students, practising physicians, academics, and nursing and allied health professionals – basically, everyone involved in healthcare. The content includes information that is understandable for the clinician who wants to integrate and apply this knowledge to improve patient care. This book is also valuable for those already in the medical AI space, including entrepreneurs and those who are developing clinical tools, as well as regulatory/policy/political personnel involved in digital health.

Our goal was that *AI in Clinical Medicine: A Practical Guide for Healthcare Professionals* would become the definitive reference book for the emerging and exciting use of AI throughout clinical medicine. This book:

- Describes where AI is currently being used to change practice in specific medical domains.
- Discusses the applicability of AI, and provides successful cases of AI approaches in the setting of specific specialties.
- Addresses some of the unique challenges associated with AI in clinical medicine.
- Includes bulleted lists of
 - Learning objectives.
 - Key insights.
 - Clinical vignettes (where appropriate).
 - Brief examples of where AI is successfully deployed.
 - Brief examples of potential problematic uses of AI, and possible risks or issues.

The background artwork on the front cover was created by Ai-da, the world's first ultra-realistic artist robot. I was keen to bring some art to this book, as the practice of medicine is an art as well as a science. In my opinion, this will not and should not change as we incorporate some of the AI solutions described in this book to our clinical practice. I will quote Aidan Meller, creative director and project manager for the Ai-da robot project, as his words say much better what I am trying to say!

Today, a dominant opinion is that art is created by the human, for other humans. This has not always been the case. The ancient Greeks felt art and creativity came from the Gods. Inspiration was divine inspiration. Today, a dominant mind-set is that of humanism, where art is an entirely human affair, stemming from human agency. However, current thinking suggests we are edging away from humanism, into a time where machines and algorithms influence our behaviour to a point where our 'agency' isn't just our own. It is starting to get outsourced to the decisions and suggestions of algorithms, and complete human autonomy starts to look less robust. Ai-Da creates art, because art no longer has to be restrained by the requirement of human agency alone. (Aidan Meller, www.aidanmeller.com)

We know that we have some readers who are fearful and apprehensive about the advent of AI in clinical medicine. Our hope is that this book reassures them about the future role of AI and the interplay with clinicians. Other readers are excitedly anticipating that, once implemented, AI will take over all aspects of their jobs. The messages in our book may disappoint them. This book, for the most part, presents a realistic vision of where AI is used now, and where it is most likely to go.

What We Didn't Cover in This Edition

This book will not present exhaustive detail of the history, development, or technical foundations of AI, nor delve into really niche areas of AI in clinical practice. As there are already many other general AI resources available, the book will not explore in great detail the different AI models, the different types and details of neural networks, AI in statistical learning, AI for general clinical data analysis, AI for genomics, or AI for drug discovery.

We were simply unable to cover every aspect of clinical medicine to which AI applies or can apply. We can only direct our readers to online publications in these areas, and we hope to include these topics in future editions of this book.

How This Book Is Organized

The book contains four sections. The idea is that you can dip in and out of each section as you need to.

- *Section 1.* This short section gives readers the basic vocabulary that they require and a framework for thinking about AI, and highlights the importance of robust AI training for physicians.
- *Section 2.* AI Foundations covers foundational ideas and concepts. This includes the history of AI, and chapters on the basics and a deeper dive into some of the definitions used in AI.
- *Section 3.* Applications to different clinical areas provide a discipline-specific deep dive into how AI is applied in that given area. Specialties overlap to a certain degree, so most readers will be interested in at least two or three of those chapters. Readers can select the chapters they want without having to read everything in this section. The chapters are not hyper-specialized, but do represent a 101 level that will equip readers with what they need to be able to explore further by reading more specialized books and published medical articles in that domain.
- *Section 4.* On emerging trends and applications of AI in medicine in the future, this section addresses some of the wider issues, challenges, and solutions with regard to AI. This includes issues related to the evolution of AI regulation, data privacy legislation, and AI-enabled consumer-facing health technology. The section discusses challenges with bias, consent, and ethical