The Comprehensive Textbook of Healthcare Simulation

Adam I. Levine
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Andrew D. Schwartz
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Editors
Adam I. Levine, MD
Departments of Anesthesiology
Otolaryngology, and Structural & Chemical Biology
Icahn School of Medicine at Mount Sinai
New York, NY
USA

Samuel DeMaria Jr., MD
Department of Anesthesiology
Icahn School of Medicine at Mount Sinai
New York, NY
USA

Andrew D. Schwartz, MD
Department of Anesthesiology
Icahn School of Medicine at Mount Sinai
New York, NY
USA

Alan J. Sim, MD
Department of Anesthesiology
Icahn School of Medicine at Mount Sinai
New York, NY
USA

Corrected at 2nd printing 2014

ISBN 978-1-4614-5992-7 ISBN 978-1-4614-5993-4 (eBook)
DOI 10.1007/978-1-4614-5993-4
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2013940777

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

I dedicate this book to my remarkable wife, Robin, and my beautiful daughter, Sam, whose love, support, and devotion have been unwavering.

–Adam I. Levine, MD

For the love of my life, Tara.

–Samuel DeMaria Jr., MD

To my wife, Pam, and our three beautiful children, Sammy, Kai, and Kona.

–Andrew Schwartz, MD

For my parents, Maria and Al, and my brother, Andrew.

–Alam J. Sim, MD

Foreword

While simulation in general is probably prehistoric and a recent review traces crude elements of simulation for healthcare purposes back thousands of years, in many respects the modern era of simulation in healthcare is only about 25–30 years old. Much has happened in those years. There are no definitive metrics for growth of this endeavor. In fact, experts still debate aspects of terminology, and even what qualifies as a "simulation" differs greatly among those in the field. Looking just at the last decade's growth of the Society for Simulation in Healthcare (SSH) is instructive of what has happened in this period. Whereas in 2004 the SSH had just under 200 members, in 2012 it has over 3,000 members. Similar growth has occurred in the attendance at the International Meeting on Simulation in Healthcare (IMSH) and other simulation meetings (nearly 3,000 attendees at the 2012 IMSH conference). There has been rapid expansion of industries connected to healthcare simulation: the primary industries of those who manufacture simulators or part-task/procedural trainers and the secondary and tertiary industries of those providing services to the primary manufacturers or to the educators and clinicians who utilize simulators to do their work. Similarly, simulation has spawned a variety of new jobs and job types from new gigs for working actors (as standardized "patients," "family members," or other) to "simulationists" or "simulation technicians" to "simulation educators."

Just, say, 15 years ago (let alone 25 years ago), there was only a smattering of publications about simulation in healthcare as we now think of it. Knowledge and experience about the topic were largely in the heads of a few pioneers, and both the published and unpublished knowledge dealt only with a handful of clinical domains. Things are very different today. Information about simulation is exploding. There are thousands of papers, thousands of simulation groups and facilities, and thousands of experts. Besides the flagship peer-reviewed, indexed, multidisciplinary journal *Simulation in Healthcare* (of which I am the founding and current Editor-in-Chief), papers on simulation in healthcare are published in other peer-reviewed journals in specific disciplines or about specific clinical domains. No one can keep track of all the literature any more. It is thus of great importance to have textbooks on the topic. Some textbooks are aimed at the novice. Other textbooks aim to be what I would call a "reference textbook"; they are intended to serve as a benchmark for the field, providing a comprehensive and in-depth view for all, rather than a cursory look for the beginner. Using a reference textbook, a serious individual new to the field can get up to speed, while those already experienced can find material about subfields not their own as well as new or different views and opinions about things they thought they knew. Drs. Levine, DeMaria Jr., Schwartz, and Sim should be commended; *The Comprehensive Textbook of Healthcare Simulation* is a reference textbook. The book aims to be comprehensive, and clearly it addresses just about every arena of simulation and every adjunctive technique and issue. It is indeed a place where anyone can find detailed information on any aspect of the full spectrum of the field. The authors represent many of the best-known simulation groups in the world. I am proud to say that many authors are on the editorial board of *Simulation in Healthcare*; some are Associate Editors. A number of authors are current or former members of the SSH Board of Directors. I should disclose that I myself am an author or coauthor of two contributions to this textbook.

The field of simulation in healthcare is very broad, and while it has matured somewhat in the last quarter century, it is still a very young field. As with every textbook—especially a multiauthored one—anyone with experience in the field will find much herein to agree with and some things about which they disagree. Agreement may lead to wider adoption of good ideas. The disagreements should lead to further innovation and research exploring the nuances and the limits of this powerful set of techniques. Whenever any of those outcomes transpires, it will be a testament to the power of the book to inspire others.

Stanford, CA, USA David M. Gaba, MD

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Contributors

Kathryn E. Adams, BS Department of Continuing Education, Society for Simulation in Healthcare, Minneapolis, MN, USA

Rajesh Aggarwal, PhD, MA, MRCS Division of Surgery, Department of Surgery and Cancer, Imperial College London, London, UK

Department of Surgery, Perelman School of Medicine, University of Pennsylvania, Philadelphia

St. Mary's Hospital, Imperial College NHS Trust, London, UK

Ali Alaraj, MD Department of Neurosurgery, University of Illinois at Chicago and University of Illinois Hospital and Health Science Systems, Chicago, IL, USA

Pamela Andreatta, PhD Department of Obstetrics and Gynecology, University of Michigan, Ann Arbor, MI, USA

Kivanc Atesok, MD, MSc Faculty of Medicine, Institute of Medical Science, University of Toronto, Toronto, ON, Canada

Tamika C. Auguste, MD Department of Obstetrics and Gynecology, Georgetown University School of Medicine, Washington, DC, USA

Department of OB/GYN Simulation, Women's and Infants' Services, Washington Hospital Center, Washington, DC, USA

Najib T. Ayas, MD, MPH Department of Medicine, University of British Columbia, Vancouver, BC, Canada

Thomas J. Benedetti, MD, MHA Department of Obstetrics and Gynecology, University of Washington, Seattle, WA, USA

Haim Berkenstadt, MD Department of Anesthesiology and Intensive Care, Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel

Department of Anesthesiology, Sheba Medical Center, Ramat Gam, Israel

Farhan Bhanji, MD, MSc Department of Pediatrics, Richard and Sylvia Cruess Faculty Scholar in Medical Education, McGill University, Montreal, QC, Canada

Divisions of Pediatric Emergency Medicine and Pediatric Critical Care, Montreal Children's Hospital, Montreal, QC, Canada

Daniel M. Birk, MD Department of Neurosurgery, University of Illinois at Chicago and University of Illinois Hospital and Health Science Systems, Chicago, IL, USA

Victoria Brazil, MBBS, FACEM, MBA School of Medicine, Bond University, Gold Coast, QLD, Australia

Department of Emergency Medicine, Royal Brisbane and Women's Hospital, Brisbane, QLD, Australia

Judith A. Buchanan, MS, PhD, DMD School of Dentistry, University of Minnesota, Minneapolis, MN, USA

Fady T. Charbel, MD Department of Neurosurgery, University of Illinois at Chicago and University of Illinois Hospital and Health Science Systems, Chicago, IL, USA

Adam Cheng, MD, FRCPC, FAAP Department of Research and Development, KIDSIM-ASPIRE Simulation, Alberta Children's Hospital and Pediatrics, University of Calgary, Calgary, AB, Canada

Sam Clarke, MD Department of Emergency Medicine, Harbor-UCLA Medical Center, Torrance, CA, USA

Paul D. Colavita, MD Department of Gastrointestinal and Minimally Invasive Surgery, Carolinas Medical Center, Charlotte, NC, USA

Department of General Surgery, Carolinas Medical Center, Charlotte, NC, USA

Colleen Y. Colbert, PhD Office of Medical Education, Evaluation & Research Development, Department of Internal Medicine, Texas A&M HSC College of Medicine/ Scott & White Healthcare, Temple, TX, USA

Office of Medical Education, Evaluation & Research Development, Department of Internal Medicine, Scott & White Healthcare, Temple, TX, USA

James M. Cooke, MD Department of Family Medicine, University of Michigan, Ann Arbor, MI, USA

Thomas Corrado, MD Department of Anesthesiology, Stony Brook University, Stony Brook, NY, USA

Paula Craigo, MD Department of Anesthesiology, College of Medicine, Mayo Clinic, Rochester, MN, USA

Shad Deering, MD, LTC MIL, USA, MEDCOM, MAMC Department of Obstetrics/ Gynecology, Uniformed Services University of the Health Sciences, Bethesda, MD, USA

Department of Obstetrics/Gynecology, Madigan Army Medical Center, Tacoma, WA, USA

Samuel DeMaria Jr., MD Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Ellen S. Deutsch, MD, FACS, FAAP Department of Anesthesia and Critical Care, Center for Simulation, Advanced Education, and Innovation, The Children's Hospital of Philadelphia, Philadelphia, PA, USA

Yue Dong, MD Departments of Pulmonary and Critical Care Medicine, Multidisciplinary Simulation Center, Mayo Clinic, Rochester, MN, USA

Bonnie Driggers, RN, MS, MPA Department of Nursing, Oregon Health and Science University, Portland, OR, USA

Jonathan P. Duff, MD, FRCPC Division of Critical Care, Department of Pediatrics, University of Alberta, Edmonton, AB, Canada

Edmonton Clinic Health Academy (ECHA), Edmonton, AB, Canada

William F. Dunn, MD, FCCP, FCCM Division of Pulmonary and Critical Care Medicine, Mayo Clinic Multidisciplinary Simulation Center, Mayo Clinic, Rochester, MN, USA

Kenneth A. Egol, MD Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York, NY, USA

Orit Eisenberg, PhD MAROM Unit, Assessment and Admissions Centers, National Institute for Testing and Evaluation, Jerusalem, Israel

Assessment and Measurement Unit, Israel Center for Medical Simulation, Jerusalem, Israel

Chad Epps, MD Departments of Clinical and Diagnostic Services and Anesthesiology, University of Alabama at Birmingham, Birmingham, AL, USA

Jason H. Epstein, MD Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

James I. Fann, MD Department of Cardiothoracic Surgery, Stanford University, Palo Alto, CA, USA

Stanford University Medical Center, Palo Alto, CA, USA

VA Palo Alto Health Care System, Palo Alto, CA, USA

Department of Cardiothoracic Surgery, CVRB, Stanford, CA, USA

Ruth M. Fanning, MB, MRCPI, FFARCSI Department of Anesthesia, Stanford University School of Medicine, Stanford, CA, USA

Richard H. Feins, MD Department of Thoracic Surgery, University of North Carolina, Chapel Hill, NC, USA

Rosemarie Fernandez, MD Division of Emergency Medicine, Department of Medicine, University of Washington School of Medicine, Seattle, WA, USA

David M. Gaba, MD Department of Immersive and Simulation-Based Learning, Stanford University, Stanford, CA, USA

Department of Anesthesia, Simulation Center, VA Palo Alto Health Care System, Anesthesia Service, Palo Alto, CA, USA

Maria F. Galati, MBA Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Christopher J. Gallagher, MD Department of Anesthesiology, Stony Brook University, Stony Brook, NY, USA

Kathleen Gallo, PhD, MBA, RN, FAAN Center for Learning and Innovation/Patient Safety Institute, Hofstra North Shore-LIJ School of Medicine, North Shore-LIJ Health System, Lake Success, NY, USA

Jesika S. Gavilanes, Masters in Teaching Statewide Simulation, Simulation and Clinical Learning Center School of Nursing, Oregon Health and Science University, Portland, OR, USA

Matthew T. Gettman, MD Department of Urology, Mayo Clinic, Rochester, MN, USA

Kenneth Gilpin, MD, ChB, FRCA Department of Anaesthesia, Cambridge University, Cambridge, UK

Anaesthetic Department, Cambridge University Hospital, Little Eversden, Cambridge, UK

Andrew Goldberg, MD Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Elizabeth Goldfarb, BA Department of Psychology, New York University, New York, NY, USA

Sara N. Goldhaber-Fiebert, MD Department of Anesthesia, Stanford University School of Medicine, Stanford, CA, USA

Michael Good, MD Administrative Offices, College of Medicine, University of Florida, Gainesville, FL, USA

Wanda S. Goranson, MSN, RN-BC Department of Clinical Professional Development, Iowa Health – Des Moines, Des Moines, IA, USA

James A. Gordon, MD, MPA MGH Learning Laboratory, Division of Medical Simulation, Department of Emergency Medicine, Massachusetts General Hospital, Boston, MA, USA

Gilbert Program in Medical Simulation, Harvard Medical School, Boston, MA, USA

Tristan Gorrindo, MD Division of Postgraduate Medical Education, Massachusetts General Hospital, Boston, MA, USA

Department of Psychiatry, Massachusetts General Hospital, Boston, MA, USA

Riki N. Gottlieb, DMD, FAGD Virtual Reality Simulation Laboratory, International Dentist Program, Virginia Commonwealth University School of Dentistry, Richmond, VA, USA

Department of General Practice, Admissions, Virginia Commonwealth University School of Dentistry, Richmond, VA, USA

Derek A. Gould, MB, ChB, FRCP, FRCR Department of Medical Imaging, Royal Liverpool University Hospital, Liverpool, UK

Department of Radiology, Royal Liverpool University NHS Trust, Liverpool, UK

Faculty of Medicine, University of Liverpool, Liverpool, UK

Lori Graham, PhD Office of Medical Education, Internal Medicine, Texas A&M HSC College of Medicine, Bryan, TX, USA

Vincent J. Grant, MD, FRCPC Department of Paediatrics, University of Calgary, Calgary, AB, Canada

KidSIM Human Patient Simulation Program, Alberta Children's Hospital, Calgary, AB, Canada

Gregory Hall, BA Department of Orthopaedic Surgery, NYU Langone Medical Center Hospital for Joint Diseases, New York, NY, USA

Basil Hanss, PhD Department of Medicine, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Rose Hatala, MD, MSc Department of Medicine, University of British Columbia, Vancouver, BC, Canada

Department of Medicine, St. Paul's Hospital, Vancouver, BC, Canada

Emily M. Hayden, MD, MHPE MGH Learning Laboratory, Division of Medical Simulation, Department of Emergency Medicine, Massachusetts General Hospital, Boston, MA, USA

Gilbert Program in Medical Simulation, Harvard Medical School, Boston, MA, USA

Bonnie An Henderson, MD Department of Ophthalmology, Harvard Medical School, Boston, MA, USA

Ophthalmic Consultants of Boston, Waltham, MA, USA

George L. Hicks Jr., MD Division of Cardiothoracic Surgery, University of Rochester Medical Center, Rochester, NY, USA

Lisa D. Howley, MEd, PhD Department of Medical Education, Carolinas HealthCare System, Charlotte, NC, USA

Luv R. Javia, MD Department of Otorhinolaryngology/Head and Neck Surgery, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA, USA

Department of Pediatric Otolaryngology, Children's Hospital of Philadelphia, Philadelphia, PA, USA

Laith M. Jazrawi, MD Division of Sports Medicine, Department of Orthopaedic Surgery, NYU Langone Medical Center Hospital for Joint Diseases, New York, NY, USA

Kanav Kahol, PhD Affordable Health Technologies, Public Health Foundation of India, New Delhi, India

Joel A. Kaplan, MD Department of Anesthesiology, University of California San Diego, San Diego, CA, USA

Daniel Katz, MD Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Yury Khelemsky, MD Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Amrita Kumar, MD, BSc, MBBS, MSc, FRCR Department of Medical Imaging, Royal Liverpool University Hospital, Liverpool, UK

Department of Imaging, University College Hospital London, London, UK

Kim Leighton, PhD, RN, CNE Department of Educational Technology, Center for Excellence in Clinical Simulation, Bryan College of Health Sciences, Lincoln, NE, USA

Staci Leisman, MD Department of Medicine, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Adam I. Levine, MD Departments of Anesthesiology, Otolaryngology, and Structural and Chemical Biology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Ronald S. Levy, MD, DABA Patient Simulation Center, Departments of Anesthesiology/Neuroscience and Cell Biology, University of Texas Medical Branch at Galveston, Galveston, TX, USA

Jenifer R. Lightdale, MD, MPH Department of Pediatrics, Harvard Medical School, Boston, MA, USA

Department of Gastroenterology and Nutrition, Children's Hospital Boston, Boston, MA, USA

Jay D. Mabrey, MD, MBA Department of Orthopaedics, Baylor University Medical Center, Dallas, TX, USA

Brian P. Mahoney, MD Department of Anesthesiology, Ohio State Wexarn Medical Center, Boston, MA, USA

Jennifer Manos, RN, BSN Center for Simulation and Research, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA

Juli C. Maxworthy, DNP, MSN, MBA, RN, CNL, CPHQ, CPPS School of Nursing and Health Professions, University of San Francisco, San Francisco, CA, USA

WithMax Consulting, Orinda, CA, USA

James McKinney, MD, MSC Department of Cardiology, University of British Columbia, Vancouver, BC, Canada

Steven A. McLaughlin, MD Department of CME and Simulation, University of New Mexico, Albuquerque, NM, USA

Department of Emergency Medicine, University of New Mexico, Albuquerque, NM, USA

Shekhar Menon, MD Division of Emergency Medicine, Northshore University Healthsystem, Evanston, IL, USA

Curtis Mirkes, DO Department of Internal Medicine, Scott & White Healthcare/Texas A&M HSC College of Medicine, Temple, TX, USA

Deborah D. Navedo, PhD, CPNP, CNE Center for Interprofessional Studies and Innovation, MGH Institute of Health Professions, Boston, MA, USA

MGH Learning Laboratory, Massachusetts General Hospital, Boston, MA, USA

Thomas P. Noeller, MD, FAAEM, FACEP Department of Emergency Medicine, Case Western Reserve University School of Medicine, Cleveland, OH, USA

Department of Emergency Medicine, MetroHealth Stimulation Center, MetroHealth Health Medical Center, Cleveland, OH, USA

Lou Oberndorf, MBA/MS METI, Sarasota, FL, USA

Oberndorf Family Foundation, Sarasota, FL, USA

Oberndorf Holdings LLC, Sarasota, FL, USA

John M. O'Donnell, RN, CRNA, MSN, DrPH Nurse Anesthesia Program, University of Pittsburgh School of Nursing, Pittsburgh, PA, USA

Department of Anesthesiology, Peter M. Winter Institute for Simulation, Education and Research (WISER), Pittsburgh, PA, USA

Department of Acute/Tertiary Care, University of Pittsburgh School of Nursing, Pittsburgh, PA, USA

Thomas A. Oetting, MS, MD Department of Ophthalmology and Visual Sciences, University of Iowa Hospitals and Clinics, Iowa City, IA, USA

Surgical Service Line, Department of Ophthalmology, Veterans Medical Center, UIHC-Ophthalmology, Iowa City, IA, USA

Paul Edward Ogden, MD Department of Internal Medicine, Academic Affairs, Texas A&M University System – HSC College of Medicine, Bryan, TX, USA

Yasuharu Okuda, MD Department of Emergency Medicine, SimLEARN, Simulation Learning Education & Research Network, Veterans Health Administration, Orlando, FL, USA

Timothy Ryan Owens, MD Department of Neurological Surgery, Duke University Medical Center, Durham, NC, USA

Susan J. Pasquale, PhD Department of Administration, Johnson and Wales University, Providence, RI, USA

Adam D. Peets, MD, MSc (Med Ed) Department of Critical Care Medicine, University of British Columbia, Vancouver, BC, Canada

Tiffany Pendergrass, BSN, RN, CPN Center for Simulation and Research, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA

Marjolein C. Persoon, MD Department of Urology, Catharina Hospital Eindhoven, Eindhoven, The Netherlands

Department of Surgery, Jeroen Bosch Ziekenhuis, 's-Hertogenbosch, Noord-Brabant, The Netherlands

Paul E. Phrampus, MD Department of Anesthesiology, Peter M. Winter Institute for Simulation, Education and Research (WISER), Pittsburgh, PA, USA

Department of Emergency Medicine, UPMC Center for Quality Improvement and Innovation, University of Pittsburgh, Pittsburgh, PA, USA

Rajesh Reddy, MD Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Gina M. Rogers, MD Department of Ophthalmology and Visual Sciences, University of Iowa Hospitals and Clinics, Iowa City, IA, USA

Kathleen Rosen, MD Department of Anesthesiology, Cleveland Clinic Lerner College of Medicine, Case Western Reserve University, Cleveland, OH, USA

Department of Anesthesiology, Cleveland Clinic, Cleveland, OH, USA

Jenny W. Rudolph, PhD Center for Medical Simulation, Boston, MA, USA

Department of Anesthesia, Critical Care and Pain Medicine, Massachusetts General Hospital, Boston, MA, USA

Robert M. Rush Jr., MD, FACS Department of Surgery and the Andersen Simulation Center, Madigan Army medical Center, Tacoma, WA, USA

Central Simulation Committee, US Army Medical Department, Andersen Simulation Center, Madigan Army Medical Center, Tacoma, WA, USA

Department of Surgery, University of Washington, Seattle, WA, USA

Department of Surgery, USUHS, Bethesda, MD, USA

Ross J. Scalese, MD, FACP Division of Research and Technology, Gordon Center for Research in Medical Education, University of Miami Miller School of Medicine, Miami, FL, USA

Barbara M.A. Schout, MD, PhD Urology Department, VU University Medical Center, Amsterdam, Noord Holland, The Netherlands

Andrew D. Schwartz, MD Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Howard A. Schwid, MD Department of Anesthesiology and Pain Medicine, University of Washington School of Medicine, Seattle, WA, USA

Michael Seropian, MD Department of Anesthesiology, Oregon Health and Science University, Portland, OR, USA

Megan R. Sherman, BA Department of Surgery, Institute for Simulation and Interprofessional Studies (ISIS), University of Washington, Seattle, WA, USA

Jeffrey H. Silverstein, MD Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Alan J. Sim, MD Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Robert Simon, EdD Department of Anesthesia, Harvard Medical School, Boston, MA, USA

Center for Medical Simulation, Cambridge, MA, USA

Pramudith V. Sirimanna, MBBS, BSc (Hons) Division of Surgery, Department of Surgery and Cancer, Imperial College London, London, UK

St. Mary's Hospital, Imperial College NHS Trust, London, UK

Michael D. Smith, MD, FACEP Department of Emergency Medicine, Case Western Reserve University, MetroHealth Medical Center, Cleveland, OH, USA

Dimitrios Stefanidis, MD, PhD, FACS, FASMBS Department of General Surgery, University of North Carolina–Charlotte, Charlotte, NC, USA

Department of General Surgery, Carolinas HealthCare System, Charlotte, NC, USA

Christopher G. Strother, MD Departments of Emergency Medicine and Pediatrics, Mount Sinai Hospital, New York, NY, USA

Demian Szyld, MD, EdM Department of Emergency Medicine, The New York Simulation Center for the Health Sciences, New York, NY, USA

Department of Emergency Medicine, New York University School of Medicine, New York, NY, USA

Jeffrey M. Taekman, MD Department of Anesthesiology, Duke University School of Medicine, Durham, NC, USA

Department of Anesthesiology, Human Simulation and Patient Safety Center, Duke University Medical Center, Durham, NC, USA

David D. Thiel, MD Department of Urology, Mayo Clinic Florida, Jacksonville, FL, USA

Matthew K. Tobin, BS College of Medicine, University of Illinois at Chicago, Chicago, IL, USA

Nancy Tofil, MD, MEd Department of Pediatrics, Division of Critical Care, Pediatric Simulation Center, University of Alabama at Birmingham, Birmingham, AL, USA

Laurence C. Torsher, MD Department of Anesthesiology, College of Medicine, Mayo Clinic, Rochester, MN, USA

Alexander J. Towbin, MD Department of Radiology, Radiology Informatics, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA

Ankeet D. Udani, MD Department of Anesthesia, Stanford University School of Medicine, Stanford, CA, USA

Kathleen M. Ventre, MD Department of Pediatrics/Critical Care Medicine, Children's Hospital Colorado/University of Colorado, Aurora, Denver, CO, USA

J. Marjoke Vervoorn, PhD, DDS Educational Institute, Academic Centre for Dentistry Amsterdam (ACTA), Amsterdam, The Netherlands

Courtney West, PhD Office of Medical Education, Internal Medicine, Texas A&M HSC College of Medicine, Bryan, TX, USA

Marjorie Lee White, MD, MPPM, MEd Department of Pediatrics and Emergency Medicine, Pediatric Simulation Center, University of Alabama at Birmingham, Birmingham, AL, USA

Robert I. Williams, MBA Department of Anesthesiology, The Mount Sinai Hospital, New York, NY, USA

Leslie A. Wimsatt, PhD Department of Family Medicine, University of Michigan, Ann Arbor, MI, USA

Amitai Ziv, MD, MHA Medical Education, Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel

Patient Safety and Risk Management, Israel Center for Medical Simulation (MSR), Chaim Sheba Medical Center, Tel Hashomer, Israel

Part I

Introduction to Simulation

Healthcare Simulation: From "Best Secret" to "Best Practice"

1

Adam I. Levine, Samuel DeMaria Jr., Andrew D. Schwartz, and Alan J. Sim

Introduction

Throughout history healthcare educators have used patient surrogates to teach, assess, and even conduct research in a safe and predictable environment. Therefore, the use of healthcare simulation is historically rooted and as old as the concept of healthcare itself. In the last two decades, there has been an exponential rise in the development, application, and general awareness of simulation use in the healthcare industry. What was once essentially a novelty has given rise to entire new fields, industries, and dedicated professional societies. Within a very short time, healthcare simulation has gone from "best secret" to "best practice."

Ambiguity, Resistance, and the Role of Simulation: Organization of this Book

So why do we need a comprehensive textbook of healthcare simulation? Although growth has been relatively rapid, in reality, the ambiguity of the field's vision, resistance of adoption by practitioners, and an ill-defined role for simulation in many healthcare arenas have characterized the recent history of simulation. Despite this fact, we are now at a place where clarity, acceptance, and more focused roles for simulation have begun to predominate. This transformation has spawned a rapidly evolving list of new terminologies, technologies, and teaching and assessment modalities. Therefore, many educators, researchers, and administrators are seeking a definitive, up-to-date resource that addresses solutions to their needs in terms of training, assessment, and patient safety applications.
Hence, we present this book *The Comprehensive Textbook of Healthcare Simulation*.

Most medical disciplines now have a collective vision for how and why simulation fits into trainee education, and some have extended this role to advanced practitioner training, maintenance of competency, and even as a vehicle for therapeutic intervention and procedural rehearsal. Regardless of the reader's background and discipline, this book will serve those developing their own simulation centers or programs and those considering incorporation of this technology into their credentialing processes. It will also serve as a state-of-the-art reference for those already knowledgeable or involved with simulation, but looking to expand their knowledge base or their simulation program's capability and target audience. We are proud to present to the reader an international author list that brings together experts in healthcare simulation in its various forms. Here you will find many of the field's most notable experts offering opinion and best evidence with regard to their own discipline's best practices in simulation.

Organization

The book is divided into five parts: Part 1: Introduction to Simulation, Part 2: Simulation Modalities and Technologies, Part 3: The Healthcare Disciplines, and Parts 4 and 5: on the practical considerations of Healthcare Simulation for Professional and Program Development.

In Part 1 the reader is provided with a historic perspective and up-to-date look at the general concepts of healthcare simulation applications. The book opens with a comprehensive review of the history of healthcare simulation (Chap. 2). The embedded memoir section ("Pioneers and Profiles") offers the reader a unique insight into the history of simulation through the eyes and words of those responsible for making it. These fascinating personal memoirs are written by people who were present from the beginning and who were

A.I. Levine, MD (✉)
Departments of Anesthesiology, Otolaryngology, and Structural and Chemical Biology, Icahn School of Medicine at Mount Sinai, New York, NY, USA
e-mail: adam.levine@mountsinai.org

S. DeMaria Jr., MD • A.D. Schwartz, MD • A.J. Sim, MD
Department of Anesthesiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

A.I. Levine et al. (eds.), *The Comprehensive Textbook of Healthcare Simulation*,
DOI 10.1007/978-1-4614-5993-4_1, © Springer Science+Business Media New York 2013

responsible for simulation's widespread adoption, design, and application. Here we are honored to present, for the first time, "the stories" of David Gaba, Mike Good, Howard Schwid, and several others. Drs. Gaba and Good describe their early work creating the Stanford and Gainesville mannequin-based simulators, respectively, while Dr. Schwid describes his early days creating the first computer-based simulators. Industry pioneer Lou Obendorf shares his experience with simulation commercialization including starting, expanding, and establishing one of the largest healthcare simulation companies in the world. Other authors' stories frame the early days of this exciting field as it was coming together including our own involvement (The Mount Sinai Story) with simulation having acquired the first simulator built on the Gainesville simulator platform, which would ultimately become the CAE METI HPS simulator.

The rest of this section will prove invaluable to healthcare providers and is devoted to the application of simulation at the broadest levels: for education (Chaps. 3, 4, and 5), assessment (Chaps. 11 and 12), and patient safety (Chap. 9). The specific cornerstones of simulation-based activities are also elucidated through dedicated chapters emphasizing the incorporation of human factors' training (Chap. 8), systems factors (Chap. 10), feedback, and debriefing (Chaps. 6 and 7). Special sections are included to assist educators interested in enriching their simulation-based activities with the introduction of humor, stress, and other novel concepts.

The earlier opposition to the use of simulation by many healthcare providers has to a large degree softened due to the extensive work done to demonstrate and make simulation a rigorous tool for training and assessment. As the science of simulation, based in adult learning theory (Chap. 3), has improved, it has become more and more difficult for healthcare workers to deny its role in healthcare education, assessment, and maintenance of competence. Further, this scientific basis has helped clarify ambiguity and better define the role of simulation never before conceived or appreciated. Crisis resource management (Chap. 8), presented by the team who pioneered the concept, is a perfect example of evidence driving best practice for simulation. Two decades ago, one might have thought that simulation was best used for teaching finite psychomotor skills. We know now that teamwork, communication, and nontechnical human factors necessary to best manage a crisis are critical to assure error reduction and patient safety and can be a major attribute of simulation-based training. This scientific rigor has helped redefine and guide the role for simulation in healthcare.

In Part 2, we present the four major areas of modalities and technologies used for simulation-based activities. These can be found in dedicated chapters (Chap. 13 on standardized patient, Chap. 14 on computer- and internet-based simulators, Chap. 15 on mannequin-based simulators, and Chap. 16 on virtual reality and haptic simulators). Again, this group of fundamental chapters provides the reader with targeted and timely resources on the available technology including general technical issues, applications, strengths, and limitations. The authors of these chapters help to demonstrate how the technological revolution has further expanded and defined the role of simulation in healthcare. Each chapter in this section is written by experts and in many cases is presented by the pioneers in that particular technological genre.

Throughout this textbook, the reader will find examples to determine which way the "wind is blowing" in various medical disciplines (Part 3). Here we include a comprehensive listing of healthcare disciplines that have embraced simulation and have expanded the role in their own field. We have chosen each of these disciplines deliberately because they were ones with well-established adoption, use, and best practice for simulation (e.g., anesthesiology and emergency medicine) or because they are experiencing rapid growth in simulation implementation and innovation (e.g., psychiatry and the surgical disciplines). While many readers will of course choose to read the chapter(s) specific to their own medical discipline, we hope they will be encouraged to venture beyond their own practice and read some of the other discipline-specific chapters that may seem to have little to do with their own specialty. What the reader will find in doing so will most certainly interest them, since learning what others do, in seemingly unrelated domains, will intrigue, inspire, and motivate readers to approach simulation in different ways.

The book closes with Parts 4 and 5, wherein the authors present several facets of professional and program development in simulation (i.e., how to become better at simulation at the individual, institutional, and societal levels). We have organized the available programs in simulation training "up the chain" from medical students, resident and fellow, to practicing physicians and nurses as well as for administrators looking to start centers, get funding, and obtain endorsement or accreditation by the available bodies in simulation.

Welcome

This textbook has been a labor of love for us (the editors), but also for each one of the authors involved in this comprehensive, multinational, multi-institutional, and multidisciplinary project. We are honored to have assembled the world's authorities on these subjects, many of whom were responsible for developing the technology, the innovative applications, and the supportive research upon which this book is based. We hope the reader will find what he or she is looking for at the logistical and informational level; however, we have greater hope that what they find is a field still young but with a clear vision for the future and great things on the horizon. We as healthcare workers, educators, or administrators, in the end, have patients relying upon us for safe and intelligent care. This young but bustling technique for training and assessment, which we call simulation, has moved beyond "best secret" to "best practice" and is now poised for a great future.

The History of Simulation

2

Kathleen Rosen

Pioneers and Profiles

Personal Memoirs by Howard A. Schwid, David Gaba, Michael Good, Joel A. Kaplan, Jeffrey H. Silverstein, Adam I. Levine, and Lou Oberndorf

Introduction

Simulation is not an accident but the result of major advancements in both technology and educational theory. Medical simulation in primitive forms has been practiced for centuries. Physical models of anatomy and disease were constructed long before plastic or computers were even conceived. While modern simulation was truly borne out in the twentieth century and is a direct descendent of aviation simulation, current healthcare simulation is possible because of the evolution of interrelated fields of knowledge and the global application of systems-based practice and practice-based learning to healthcare.

Technology and the technological revolutions are fundamental to these advancements (Fig. 2.1). Technology can take two forms: enhanced technology and replacement technology. As the names imply, enhanced technology serves to improve existing technologies, while replacement technology is potentially more disruptive since the new technology serves to displace that which is preexisting. However, according to Professor Maury Klein, an expert on technology:

> Technology is value neutral. It is neither good nor evil. It does whatever somebody wants it to do. The value that is attached to any given piece of technology depends on who is using it and evaluating it, and what they do with it. The same technology can do vast good or vast harm [1].

The first technological revolution (i.e., the industrial revolution) had three sequential phases, each having two components. The power revolution provided the foundation for later revolutions in communications and transportation. It was these revolutions that resulted in the global organizational revolution and forever changed the way people relate to each other and to the world. The communications revolution was in the middle of this technology sandwich, and today simulation educators recognize their technology is powerless without effective communication (see Fig. 2.1).

Overview

This overview of the history of healthcare simulation will begin with a review of the history of computers and flight simulation. These two innovations provide a context for and demonstrate many parallels to medical simulation development. The current technology revolution (information age) began in the 1970s as computer technology, networking, and information systems burst upon us. Computing power moved from large expensive government applications to affordable personal models. Instantaneous communication with or without visual images has replaced slower communication streams. During this same time period, aviation safety principles were identified as relevant to healthcare systems.

Previous "history of simulation narratives" exerted significant effort toward the historic justification of simulation modalities for healthcare education. The history and success of simulation in education and training for a variety of other disciplines was evidence for the pursuit of healthcare simulation. However, no other field questioned the ability of deliberate practice to improve performance. At long last, most healthcare professionals cannot imagine a world without simulation. It is time to thank simulation education innovators for their perseverance. An editorial in Scientific American in the 1870s declared erroneously that the telephone was destined to fail [1]. Similarly, simulation educators didn't stop when they were dismissed by skeptics, asked to prove the efficacy of simulation, or ridiculed for "playing with dolls."

K. Rosen, MD
Department of Anesthesiology, Cleveland Clinic Lerner College of Medicine, Case Western Reserve University, Cleveland, OH, USA

Department of Anesthesiology, Cleveland Clinic, Cleveland, OH, USA
e-mail: krr622@gmail.com

A.I. Levine et al. (eds.), *The Comprehensive Textbook of Healthcare Simulation*,
DOI 10.1007/978-1-4614-5993-4_2, © Springer Science+Business Media New York 2013

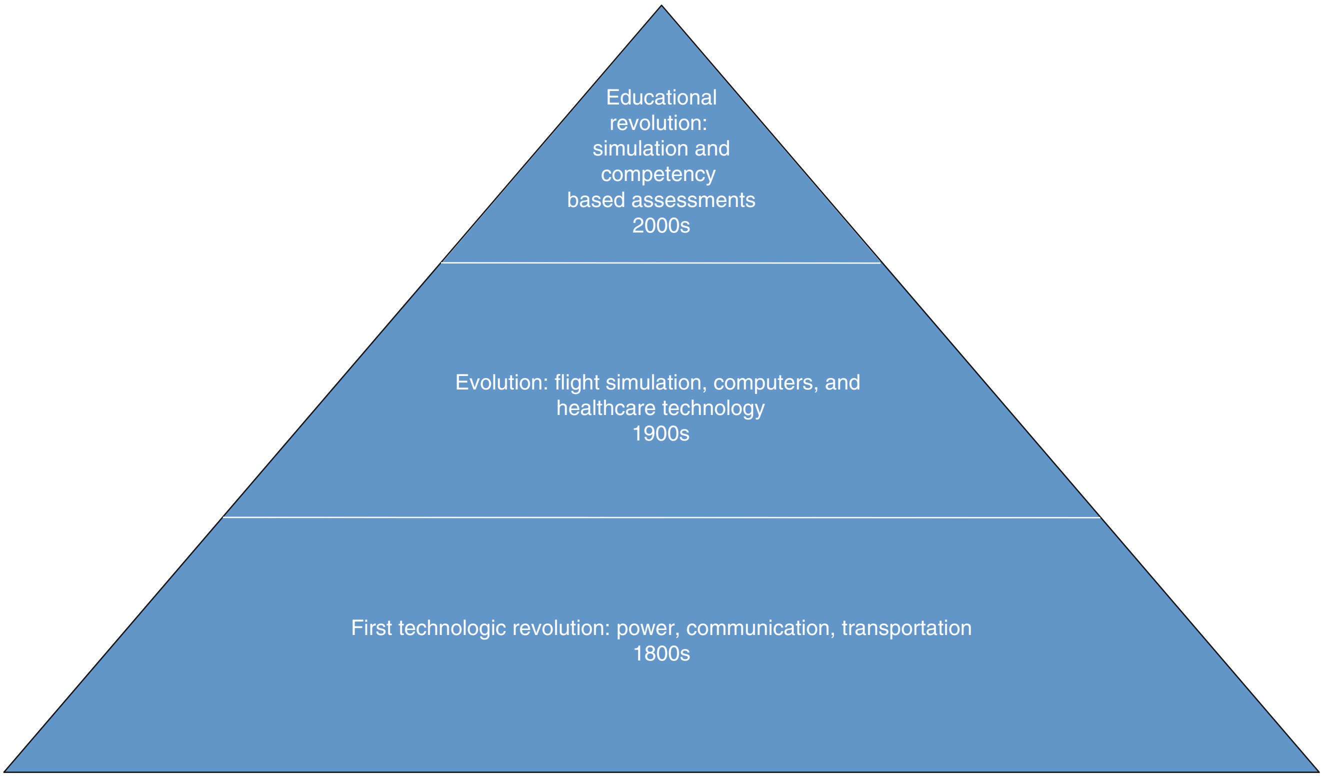

Fig. 2.1 Overview of the revolutions in technology, simulation, and medical education

The History of Computers

Man developed counting devices even in very primitive cultures. The earliest analog computers were designed to assist with calculations of astronomy (astrolabe, equatorium, planisphere), geometry (sector), and mathematics (tally stick, abacus, slide rule, Napier's bones). The Computer History Museum has many Internet-based exhibits including a detailed timeline of the history of computation [2–5]. One of the oldest surviving computing relics is the 2000-year-old Antikythera mechanism. It was discovered in a shipwreck in 1901. This device not only predicted astronomy but also catalogued the timing for the Olympic games [6].

During the nineteenth century, there was an accelerated growth of computing capabilities. During the 10-year period between 1885 and 1895, there were many significant computing inventions. The precursor of the keyboard, the comptometer, was designed and built from a macaroni box by Dorr E. Felt in 1886 and patented a year later [7]. Punch cards were introduced first by Joseph-Marie Jacquard in 1801 for use in a loom [8]. This technology was then applied to calculator design by Charles Babbage in his plans for the "Analytical Machine" [9].

Herman Hollerith's Electric Tabulating Machine was the first successful implementation of punch card technology on a grand scale and was used to tabulate the results of the 1890 census [10]. His innovative and successful counting solution earned him a cover story for Scientific American. He formed the Tabulating Machine Company in 1895. In 1885, Julius Pitrap invented the computing scale [11]. His patents were bought by the Computing Scale Company in 1891 [12]. In 1887, Alexander Dey invented the dial recorder and formed Dey Patents Company, also known as the Dey Time Register, in 1893 [13, 14]. Harlow Bundy invented the first time clock for workers in Binghamton, NY, in 1889 [15]. Binghamton turned out to be an important site in the history of flight and medical simulation during the next century. Ownership of all of these businesses would change over the next 25 years before they were consolidated as the Computing Tabulating Recording Corporation (CTR) in 1911 (see Fig. 2.2). CTR would change its name to the more familiar International Business Machines (IBM) in 1924 [16].

Interestingly, the word *computer* originally referred only to people who solved difficult mathematical problems. The term was first applied to the machines that could rapidly and accurately calculate and solve problems during World War II [17]. The military needs during the war spurred development of computation devices, and computers rapidly progressed from the mechanical-analog phase into the electronic digital era. Many of the advances can be traced to innovations by Konrad Zuse, a German code breaker, who is credited by many as the inventor of the first programmable computer [18]. His innovations included the introduction of binary processing with the Z1 (1936–1938). Ultimately, he would separate memory and processing and replace relays with vacuum tubes. He also developed the first programming language.

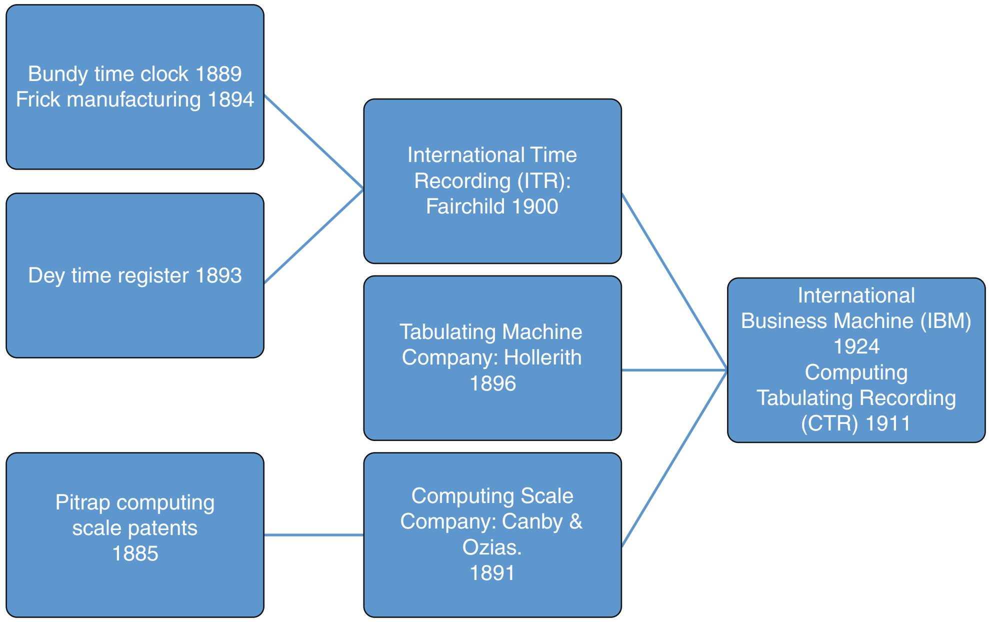

Fig. 2.2 Development of IBM

During the same time period (1938–1944) in the USA, the Harvard Mark 1, also known as the Automatic Sequence Controlled Calculator, was designed and built by Howard Aiken with support from IBM. It was the first commercial, electrical-mechanical computer. Years later, Aiken, as a member of the National Bureau of Standards Research Council, would recommend against J. Presper Eckert and John Mauchly and their vision for mass production of their computers [17].

In the 1950s, Remington Rand purchased the Eckert-Mauchly Computer Company and began production of the UNIVAC computer. This universal computer could serve both business and scientific needs with its unique alphanumeric processing capability [19]. Computers were no longer just for computing but became managers of information as well as numbers. The UNIVAC's vacuum tube and metallic tape design was the first to challenge traditional punch card models in the USA. Many of its basic design features remain in present-day computers. IBM responded to this challenge with the launch of a technologically similar unit, simply labeled 701. It introduced plastic tape and faster data retrieval. The key inventions of the latter part of the decade were solid-state transistor technology, computer disc storage systems, and magnetic core memory.

The foundation for modern computers was completed in the 1960s when they became entirely digital. Further developments and refinements were aimed at increasing computer speed and capacity while decreasing size and cost. The 1980s heralded the personal computer and software revolution, and the 1990s saw progressive increases in magnetic data storage, networking, portability, and speed. The computer revolution of the twenty-first century has focused on the client/server revolution and the proliferation of small multipurpose mobile-computing devices.

History of Flight Simulation

Early flight training used real aircraft, first on the ground and then progressing to in-flight dual-control training aircraft. The first simple mechanical trainers debuted in 1910 [20]. The Sanders trainer required wind to simulate motion. Instructors physically rocked the Antoinette Learning Barrel to simulate flight motions [21]. By 1912, pilot error was recognized as the source of 90% of all crashes [22]. Although World War I stimulated and funded significant developments in aviation training devices to reduce the number of noncombat casualties and improve aerial combat, new inventions stalled during peacetime until the innovations of Edwin A. Link.

Edwin Link was born July 26, 1904, less than a year after the first powered flight by the Wright brothers. His father started the Link Piano and Organ Company in 1910 in Binghamton, NY. He took his first flying lesson at the age of 16 and bought his first airplane in 1928. Determined to find a quicker and less expensive way to learn to fly, Link began working on his Blue Box trainer and formed the Link Aeronautical Corporation in 1929. He received patent # 1,825,462 for the Combination Training Device for Student Aviators and Entertainment on September 29, 1931 [23]. At first he was unable to convince people of its true value, and it became a popular amusement park attraction. National Inventor's Hall of Fame posthumously recognized Edwin Link for this invention in 2003 [24]. In the 1930s, the US Army Air

Corps became responsible for mail delivery. After experiencing several weather-related tragedies, the army requested a demonstration of the Link trainer. In 1934 Link successfully sold the concept by demonstrating a safe landing in a thick fog. World War II provided additional military funding for development, and 10,000 trainers were ordered by the USA and its allies.

Edwin Link was president of Link Aviation until 1953. He stayed involved through its 1954 merger with General Precision Equipment Corporation and finally retired in 1959. Link simulators progressed for decades in parallel with the evolution of aircraft and computers. Link began spaceflight simulation in 1962. The Singer Company acquired Link Aviation in 1968. Twenty years later, the flight simulation division was purchased by CAE Inc. [25]. This company would become involved with the commercial manufacture of high-fidelity mannequin simulators in the 1990s. By 2012, CAE expanded their healthcare simulation product line by acquiring Immersion Medical, a division of Immersion Inc. devoted to the development of virtual reality haptic-enabled simulators, and Medical Education Technologies Inc. (METI), a leading model-driven high-fidelity mannequin-based simulation company.

Pioneers of Modern Healthcare Education and Simulation

"The driving force of technology evolution is not mechanical, electrical, optical, or chemical. It's human: each new generation of simulationists standing on the shoulders - and the breakthroughs - of every previous generation" [26]. The current major paradigm shift in healthcare education to competency-based systems, mastery learning, and simulation took almost 50 years. This history of simulation will pay tribute to those pioneers in technical simulation, nontechnical simulation, and patient safety who dared to "boldly go where no man had gone before" [27, 28] and laid the foundation for medical simulation innovations of the 1980s and beyond.

The Legacy of Stephen J. Abrahamson, PhD

Stephen Abrahamson wrote a summary of the events in his professional life titled "Essays on Medical Education." It chronicles his 30-year path as an educator. Although chance meetings ("Abrahamson's formula for success: Dumb Luck") and coincidences play a role in his story, the accomplishments would not have occurred without his knowledge, persistence, and innovative spirit [29]. He was first a high school teacher and then an instructor for high school teachers before entering Temple University where he received his Master of Science degree in 1948 and his PhD in Education from New York University in 1951. His postdoctoral work at Yale focused on evaluation [30].

Abrahamson began his first faculty appointment at the University of Buffalo in 1952. His expertise was quickly recognized and he was appointed as head of the Education Research Center. His career in medical education began when he met George Miller from the School of Medicine who sought help to improve medical education with assistance from the education experts. This was indeed a novel concept for 1954. Dr. Abrahamson knew education, but not medical education, and adopted an ethnographic approach to gain understanding of the culture and process. After a period of observation, he received a grant for the "Project in Medical Education" to test his hypothesis that medical education would benefit from faculty development in educational principles. Two of his early students at Buffalo who assisted in this project achieved later significant acclaim in the field of medical education. Edwin F. Rosinski, MD, eventually became the Deputy Assistant Secretary for the Department of Health Education and Welfare and drafted legislation favoring research in medical education. Hillard Jason was a medical student who was also awarded a doctorate in education and would help to advance standardized patient evaluation.

This project held several seminars that were attended by medical school administrators. Three of the attendees from California would eventually figure prominently in Abrahamson's future. Dr. Abrahamson describes 1959 as the year his career in medical education began [30]. He accepted an invitation to serve as a visiting professor at Stanford in the capacity of medical consultant (1959–1960). His primary function was to provide expertise on student evaluation for their new curriculum.

The University of Southern California (USC) successfully recruited Dr. Abrahamson to become the founding leader of their Department of Medical Education in 1963. Howard Barrows, MD, attended a project seminar before he and Abrahamson would become colleagues at USC. In a 2003 interview, Abrahamson stated, "Howard is one of the most innovative persons I have ever met" [31]. He collaborated with Dr. Barrows on the development of "programmed patients" (see Barrows' tribute below) for medical education by writing a successful grant application to support the program and coauthored the first paper describing this technique [32].

The first computerized patient simulator, known as Sim One, was conceived during a "3-martini lunch" with medical colleagues in 1964 [33]. Dr. J. Samuel Denson, Chief of the Department of Anesthesiology, was a clinical collaborator. Denson and Dr. Abrahamson attempted to obtain funding from the National Institutes of Health (NIH) but received many rejections. Dr. Abrahamson's submitted a proposal to the United States Office of Education's Cooperative Research

Project and was awarded a $272,000 grant over 2 years to cover the cost of development. The group partnered with Aerojet General and unveiled Sim One on March 17, 1967. A pictorial overview of Sim One is available [34–36].

The team of researchers from USC (Stephen Abrahamson, Judson Denson, Alfred Paul Clark, Leonard Taback, Tullio Ronzoni) applied for a patent on January 29, 1968. The full name of the simulator on the patent was Anesthesiological Training Simulator. Patent # 3,520,071 was issued 2 years later on July 14, 1970 [37]. The patent is referenced in 26 future patents by the American Heart Association; the Universities of Florida, Miami, and Texas; and many companies including CAE-Link, MedSim-Eagle, Gaumard, Simbionix, Laerdal, Bausch & Lomb, Critikon, and Dragerwerk Aktiengesellschaft.

The opening argument for the patent may be the first documented discussion of using simulation to improve medical education and promote patient safety: "It has been considered possible to improve the efficacy of medical training and to reduce the potential hazards involved in the use of live patients during the teaching process by means of simulation techniques to teach medical skills."

The mannequin used for Sim One was an original construction and not a repurposed low-fidelity model. The mannequin was open at the back and bolted to the operating table to accommodate electric and pneumatic hardware. Interestingly the patent asserted that "mannequin portability is neither necessary nor desirable," a concept that was ultimately contradicted in the evolution of mannequin-based simulation.

There were a number of features in Sim One that are found in current high-fidelity mannequins. The mannequin could breathe "normally." The virtual left lung had a single lobe while the right had two. The lower right lobe contained two-thirds of the right lung volume. Temporal and carotid arteries pulses were palpable. Heart sounds were present. Blood pressure could be taken in the right arm, and drugs injected in the left via a coded needle that would extrapolate drug concentration. Ten drugs were programmed in the simulator including thiopental, succinylcholine, ephedrine, medical gases, and anesthetic vapors. Not only did the eyelids open and close but the closing tension was variable. Pupils were also reactive to light in a continuous fashion. The aryepiglottic folds could open and close to simulate laryngospasm. Similar to the early versions of Harvey®, The Cardiopulmonary Patient Simulator, Resusci Annie®, and PatSim, the mannequin did not extend below the hips.

Some of its capabilities have not yet been reproduced by modern mannequins. This mannequin could simulate vomiting, bucking, and fasciculations. In addition to eye opening, the eyebrows wrinkled. They moved downward with eye closing but upward with forehead wrinkling. Sophisticated sensors gauged endotracheal tube placement, proper mask fit (through magnets), and lip pinching. The jaw would open and close with slight extension of the tongue upon jaw opening. The jaw was spring loaded with a baseline force of 2–3 lb and capable of exerting a maximum biting force of 10–15 lb. A piano wire changed the position of the epiglottis when a laryngoscope was inserted. Sensors in the airway could also detect endobronchial intubation and proper endotracheal tube cuff inflation. Cyanosis was visible diffusely both on the face and torso and in the mouth. The color change was continuous from pink to blue to gray. Cyanosis was most rapidly visible on the earlobes and mucus membranes.

The project received a great deal of publicity. It was prominently featured by Time, Newsweek, and Life magazines. CBS news with Walter Cronkite interviewed Dr. Abrahamson. In 1969, the USC collaborators published two papers featuring Sim One. The first was a simple description of the technology [38]. The second paper described a prospective trial comparing acquisition of skill in endotracheal intubation by new anesthesia residents with and without simulation training. Mastery of this routine anesthesia procedure was achieved more rapidly by simulation trainees than controls [39]. Large interindividual variability and small sample size prevented portions of the results from achieving statistical significance. This article was rereleased in 2004 as a classic paper [40].

Considering the computing power of the day, it is impressive what this mannequin could do from a commercial computer model circa 1968. Sim One was lauded by some but was discounted by many despite this success, a theme common to most disruptive technology. Sim One was used to train more than 1,000 healthcare professionals before its "death" in 1975, as parts wore out and couldn't be replaced [31]. Abrahamson's forecast of mastery education and endorsement of standardized patients were equally visionary. His essays detail some of the obstacles, biases, and frustrations that the truly farsighted encounter. In the end, Sim One was likely too far ahead of its time.

The Legacy of Howard S. Barrows, MD

Howards Barrows is credited with two major innovations in medical education: standardized patients and the problem-based learning discussion (PBLD) [41, 42]. Both are now commonplace types of simulation. He completed his residency in neurology at Columbia and was influenced by Professor David Seegal, who observed each medical student on his service perform a complete patient examination [43]. This was considered rare in 1960. In that year, he joined the faculty at USC. Early in his career, he developed a passion for medical education that was influenced by attending one of the Project Medical Education Seminars hosted by Stephen Abrahamson.

Several unrelated events stimulated the birth of the first "programmed patient." Sam, a patient with syringomyelia for the National Board of Neurology and Psychiatry exam, related to Barrows that he was treated roughly by an examiner, so he falsified his Babinski reflex and sensory findings as repayment [44]. Stephen Abrahamson joined USC in 1962 and gave Barrows 8-mm single-concept film cartridges to document and teach the neurologic exam. Barrows hired Rose McWilliams, an artist's model, for the film lessons. He wanted an objective way to assess medical students' performance at the end of their neurology clerkship. As a result in 1963, he developed the first standardized patient case dubbed Patty Dugger. He taught Rose to portray a fictionalized version of a real patient with multiple sclerosis and paraplegia. He even constructed a checklist for Rose to complete. While Barrows was passionate about the technique, his critics far outnumbered the supporters, especially at USC. Standardized patients were discounted as "too Hollywood" and "detrimental to medical education by maligning its dignity with actors" [32, 44].

In spite of widespread criticism, Barrows persisted in using standardized patients (SPs) because he thought that it was valuable to grade students on actual performance with "patients" instead of the grooming or manners displayed to preceptors. He and coauthor Abrahamson published their experience in a landmark article [45]. Initially, they called the patient actors "programmed patients." Other terms used to describe early SPs are patient instructor, patient educator, professional patient, surrogate patient, and teaching associate. Barrows left to a more supportive environment, the brand new McMaster University, in 1971. He began working with nurse Robyn Tamblyn at McMaster. She transitioned from SP to writing her doctoral thesis about the SP education method and would later play a role in the development of the SP portion of the Canadian licensing exam.

In the 1970s Barrow's major project was to serve as founding faculty of McMaster University Medical School, the first school to employ an entirely PBLD based curriculum. During this time period, Barrows received support from the American Medical Association (AMA) to use SPs for continuing education seminars titled "Bedside Clinics in Neurology." The SPs not only portrayed neurology patients but also conference attendees to help challenge and prepare the faculty [46]. Another early supporter of the SP programs for medical schools was Dr. Hilliard Jason. He established the standardized patient program at Michigan State University after seeing a Patty Dugger demonstration at a conference. He developed four cases of difficult patients who presented social challenges in addition to medical problems. Jason advanced the concept with the addition of video recording of the interaction.

Barrows relocated once again to Southern Illinois University in 1981. There, his SP programs progressed from education and evaluation tools to motivations for curricular reform. The Josiah Macy Foundation provided critical support over the next two decades to complete the transition of SP methodology from Barrow's soapbox to the national standard for medical education and evaluation. Stephen Abrahamson was the recipient of a 1987 grant to develop education sessions for medical school deans and administrators and in the 1990s the Macy foundation supported the development of consortia exploring the use of SPs for high-stakes assessment.

Despite the early struggles, the goal to design and use national Clinical Performance Exams (CPX) was ultimately achieved. By 1993, 111 of 138 US medical schools were using standardized patients and 39 of them had incorporated a high-stakes exam [43]. The Medical Council of Canada launched the first national CPX in 1993. The Educational Commission for Foreign Medical Graduates (ECFMG) adopted their CPX in 1994 followed by the United Kingdom's Professional Linguistics Assessment Board in 1998. Finally in 2004, USMLE Step II Clinical Skills Exam became an official part of the US National Board of Medical Examiners licensing exam [47].

The Legacy of Ellison C. (Jeep) Pierce, MD

The Anesthesia Patient Safety Foundation (APSF) was the first organization to study and strive for safety in healthcare. The APSF recognizes Dr. Ellison (Jeep) Pierce as its founding leader and a true visionary whose work would profoundly affect the future of all healthcare disciplines. "Patients as well as providers perpetually owe Dr. Pierce a great debt of gratitude, for Jeep Pierce was the pioneering patient safety leader" [48]. Pierce's mission to eliminate anesthesia-related mortality was successful in large part because of his skills, vision, character, and passion, but a small part was related to Abrahamson's formula for success which John Eichhorn described in the APSF Newsletter as an original serendipitous coincidence [49]. His training in anesthesia began in 1954, the same year that the first and highly controversial paper describing anesthesia-related mortality was published [50]. This no doubt prompted much of his later actions. Would the same outcome have occurred if he remained in surgical training and not gone to the University of Pennsylvania to pursue anesthesia training? What if he didn't land in Boston working for Dr. Leroy Vandam at Peter Bent Brigham Hospital? Would another faculty member assigned the resident lecture topic of "Anesthesia Accidents" in 1962 have had the same global impact [50]?

Two Bostonian contemporary colleagues from the Massachusetts General Hospital, Arthur Keats and Jeffrey Cooper, challenged the 1954 conclusions of Beecher and Todd in the 1970s. Dr. Keats questioned the assignment of blame for anesthesia mortality to one individual of a group when three complex and interrelated variables (anesthesia,