TINTINALLI'S

Emergency Medicine

A COMPREHENSIVE STUDY GUIDE

NINTH EDITION

Judith E. Tintinalli, *Editor-in-Chief*

O. John Ma | Donald M. Yealy | Garth D. Meckler
J. Stephan Stapczynski | David M. Cline
Stephen H. Thomas

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Tintinalli's Emergency Medicine

A Comprehensive Study Guide

NOTICE

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Ninth Edition

Editor-in-Chief

Judith E. Tintinalli, MD, MS
Professor
Department of Emergency Medicine
Adjunct Professor, Department of Health Policy and Administration
Adjunct Professor, Medical Journalism, School of Journalism and Mass Communications
University of North Carolina
Chapel Hill, North Carolina

Clinical Professor
Department of Osteopathic Medical Specialties
Michigan State University
College of Osteopathic Emergency Medicine
East Lansing, Michigan

Co-Editors

O. John Ma, MD
Professor
Department of Emergency Medicine
Oregon Health & Science University
Portland, Oregon

Donald M. Yealy, MD
Chair, Department of Emergency Medicine
University of Pittsburgh/University of Pittsburgh Physicians
Senior Medical Director, Health Services Division, UPMC
Professor of Emergency Medicine, Medicine, and Clinical and Translational Sciences
University of Pittsburgh School of Medicine
Pittsburgh, Pennsylvania

Garth D. Meckler, MD, MSHS
Associate Professor and Division Head
Pediatric Emergency Medicine
University of British Columbia/BC Children's Hospital
Vancouver, British Columbia

Joseph Stephan Stapczynski, MD
Professor, Department of Emergency Medicine
Scholarly Projects Advisor
University of Arizona College of Medicine – Phoenix
Professor, Affiliate Faculty
Department of Emergency Medicine
Creighton University School of Medicine
Phoenix, Arizona

David M. Cline, MD
Professor and Director of Departmental Research
Department of Emergency Medicine
Wake Forest School of Medicine
Winston-Salem, North Carolina

Stephen H. Thomas, MD, MPH
Senior Lecturer in Emergency Medicine
Barts and The London School of Medicine and Dentistry
Queen Mary University of London
London, United Kingdom
Professor and Chairman of Emergency Medicine
Hamad General Hospital and Weill Cornell Medical College in Qatar
Doha, Qatar

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To my keenest supporters, my husband, Burton Fox, and my emergency medicine physician daughter, Anne Tintinalli, MD.

Judith E. Tintinalli, MD, MS

For Elizabeth, the love of my life.

O. John Ma, MD

I thank the people who trusted me with their care needs; the people who taught me how to think and to be a physician and scientist; the partners over the years who made me better; and to my family, who always supported and cared for me.

Donald M. Yealy, MD

To the patients, nurses, students, and mentors who teach me every day and to my partner, Steve, for his support and patience.

Garth D. Meckler, MD, MSHS

I dedicate this edition to my grandson, Charlie. In his eyes, I am just "Grandpa." And that means the world to me.

Joseph Stephan Stapczynski, MD

To my family, mentors, fellow clinicians, residents, students, and patients who give meaning to this work.

David M. Cline, MD

To Cathrine, Sarah Alice, and Caroline, who make it all worthwhile.

Stephen H. Thomas, MD, MPH

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Contents

PROCEDURAL AND ULTRASOUND VIDEOS

To access the collection of more than 100 emergency medicine videos, please scan the QR code below or visit www.tintinalliem.com. The password to access videos is **tem9**

SECTION 14 Neurology 1101

SECTION 15 Toxicology 1187

SECTION 16 Environmental Injuries 1333

Contributors

Benjamin S. Abella, MD, MPhil, FAHA, FACEP [26]
Professor and Vice Chair for Research
Director, Center for Resuscitation Science
Department of Emergency Medicine
Perelman School of Medicine
University of Pennsylvania
Philadelphia, Pennsylvania

Thomas Abramo, MD, FAAP, FACEP [148]
Professor of Pediatrics and Emergency Medicine
University of Arkansas School of Medical Sciences
Little Rock, Arkansas

Tiffany M. Abramson, MD [173]
Assistant Professor
Department of Emergency Medicine
Keck School of Medicine of the University of Southern California
LAC+USC Medical Center
Los Angeles, California

Srikar Adhikari, MD, MS [241]
Professor of Emergency Medicine
Chief, Section of Emergency Ultrasound
Department of Emergency Medicine
University of Arizona
Tucson, Arizona

Dewesh Agrawal, MD [123]
Professor of Pediatrics and Emergency Medicine
George Washington University School of Medicine
Director, Pediatric Residency Program
Children's National Medical Center
Washington, DC

Erik Akopian, MD [118]
Clinical Professor
LAC+USC Medical Center
Los Angeles, California
Clinical Educator
Arrowhead Regional Medical Center
Colton, California

Sylvia Gonzalez Alden, MD [294]
Assistant Professor
Associate Program Director, Emergency Medicine Residency Program
University of New Mexico
Albuquerque, New Mexico

Samina Ali, MD, FRCPC(PEM) [115]
Professor, Pediatrics and Emergency Medicine
Faculty of Medicine & Dentistry
University of Alberta
Edmonton, Alberta

William D. Alley, MD, FACEP, RDMS [54]
Assistant Professor
Wake Forest School of Medicine
Winston-Salem, North Carolina

Dhara P. Amin, FACEP [259]
Associate Program Director
Cook County Emergency Medicine
Assistant Professor of Emergency Medicine
Rush Medical College
Chicago, Illinois

Venkataraman Anantharaman, MBBS, FRCP (Edin), FRCS Ed (A&E), FAMS [24, 33]
Senior Consultant, Department of Emergency Medicine
Singapore General Hospital
Clinical Professor, National University of Singapore
Adjunct Professor, Duke-NUS Graduate Medical School
Singapore

Eric Anderson, MD, MBA, FACEP, FAAEM [65, 66]
Assistant Professor of Emergency Medicine
Cleveland Clinic Lerner College of Medicine
Case Western Reserve University
Cleveland, Ohio

Phillip Andrus, MD [172]
Associate Professor of Emergency Medicine
Icahn School of Medicine at Mount Sinai
New York, New York

Kim L. Askew, MD [91]
Associate Professor
Department of Emergency Medicine
Wake Forest School of Medicine
Winston-Salem, North Carolina

Patricia Ruth Atchinson, DO [29B]
Assistant Professor of Medicine
Sections of Emergency and Critical Care Medicine
Dartmouth-Hitchcock Medical Center
Lebanon, New Hampshire

Benjamin Azan, MD [95]
Attending Physician
Ochsner Health System
New Orleans, Louisiana

Franz Babl, MD, MPH [111]
Professor of Paediatric Emergency Medicine, University of Melbourne
Paediatric Emergency Physician, Royal Children's Hospital
Head, Emergency Research, Murdoch Children's Research Institute
The Royal Children's Hospital
Melbourne, Australia

Caitlin Bailey, MD [219]
Clinical Assistant Professor
University of California, San Francisco
Clerkship Director, Assistant Program Director
Emergency Medicine Residency Program
Highland Hospital
Alameda Health System
Oakland, California

Jessica A. Bailey, MD, FAAP [144, 145]
Assistant Professor
Oregon Health & Science University
Associate Program Director
Pediatric Emergency Medicine Fellowship
Oregon Health & Science University
Portland, Oregon

D. Aaron Baker, MD [302]
Command Surgeon
1st Special Forces Command (Airborne)
Fort Bragg, North Carolina

Brian Bales, MD, DTM&H [53]
Assistant Professor
Department of Emergency Medicine
Vanderbilt University Medical Center
Nashville, Tennessee

Kamna S. Balhara, MD, MA [155]
Assistant Professor
Department of Emergency Medicine
Assistant Residency Program Director
Johns Hopkins University School of Medicine
Baltimore, Maryland

Ciara J. Barclay-Buchanan, MD, FACEP [102, 256, 272]
Associate Professor (CHS)
Associate Vice Chair of Operations
BerbeeWalsh Department of Emergency Medicine
University of Wisconsin School of Medicine & Public Health
Madison, Wisconsin

Melissa A. Barton, MD [102, 256, 272]
Clinical Assistant Professor
Department of Emergency Medicine
Sparrow Hospital
Michigan State University College of Human Medicine
East Lansing, Michigan

Bryan E. Baskin, DO, FACEP [303]
Assistant Professor of Medicine
Cleveland Clinic Lerner College of Medicine
Case Western Reserve University
Associate Quality Improvement Officer
Emergency Services Institute
Cleveland Clinic
Cleveland, Ohio

Craig G. Bates, MD, MS [70]
Clinical Assistant Professor of Emergency Medicine
Case Western Reserve University
Attending Physician, MetroHealth Medical Center
Medical Director, Metro Life Flight
Cleveland, Ohio

Brigitte M. Baumann, MD, MSCE [57]
Professor of Emergency Medicine
Cooper Medical School of Rowan University
Camden, New Jersey

Ashley S. Bean, MD, MA, FACEP, FAAEM, FAWM, FIFEM [260]
Professor of Emergency Medicine
Director, Global Health and International EM Tract
Associate Director, Global Health and Service Honors Tract for Medical Students
Assistant Director, Ultrasound Fellowship
Member, Division of Emergency Ultrasound
University of Arkansas for Medical Sciences
Little Rock, Arkansas

Ronald W. Beaudreau, DMD, MD [245]
Chief of Emergency Services
Jiahui International Hospital
Shanghai, People's Republic of China
Emergency Physician
University Hospital Summerville
Augusta, Georgia

Maxwell A. Beck, MD [278]
Resident Physician
Regions Hospital/HealthPartners Institute Emergency Medicine Residency
Saint Paul, Minnesota

Michael A. Bellamy, DO [302]
Staff Physician
Womack Army Medical Center
Fort Bragg, North Carolina

Rachel Bengtzen, MD [274]
Assistant Professor
Department of Emergency Medicine
Assistant Professor
Department of Family Medicine
Oregon Health & Science University
Portland, Oregon

Jeremy G. Berberian, MD [85]
Assistant Professor of Emergency Medicine
Sidney Kimmel Medical College at Thomas Jefferson University
Associate Director of Emergency Medicine Residency Education
Christiana Care Health System
Newark, Delaware

Edward Bernstein, MD, FACEP [292]
Professor of Emergency Medicine
Boston University School of Medicine
Professor of Community Health Science
Boston University School of Public Health
Director of Faster Paths to Treatment
Boston Medical Center
Boston, Massachusetts

Bart Besinger, MD [79]
Associate Professor of Clinical Emergency Medicine
Department of Emergency Medicine
Indiana University School of Medicine
Indianapolis, Indiana

Rana Biary, MD [191]
Assistant Professor
NYU University
Program Director, Medical Toxicology Fellowship
Ronald O. Perelman Department of Emergency Medicine, NYU School of Medicine
New York City, New York

Michael Billet, MD [231]
Assistant Professor
University of Maryland Emergency Medicine
University of Maryland School of Medicine
Mercy Medical Center
Baltimore, Maryland

Nikki M. Binz, MD [105]
Clinical Associate Professor
University of North Carolina School of Medicine
Program Director, Emergency Medicine Residency Program
Chapel Hill, North Carolina

Lars Bjoernsen, MD, PhD, FACEP, FEBEEM [271]
Associate Professor
Program Director, Emergency Department
Clinic of Emergency Medicine and Prehospital Care
St. Olav's University Hospital
Trondheim, Norway
Adjunct Clinical Assistant Professor
BerbeeWalsh Department of Emergency Medicine
School of Medicine and Public Health
University of Wisconsin
Madison, Wisconsin

Tyler R. Black, MD, FRCPC [149]
Clinical Assistant Professor
University of British Columbia
Medical Director, CAPE Unit
BC Children's Hospital
Provincial Health Services Authority
Vancouver, British Columbia

Bentley J. Bobrow, MD, FACEP [26]
Professor and Chairman
John P. and Katherine G. McGovern Distinguished Chair
Department of Emergency Medicine
McGovern Medical School @UTHealth
Chief of Emergency Services
Memorial Hermann Hospital—TMC
Houston, Texas

Andy Boggust, MD [2]
Assistant Professor of Emergency Medicine
Mayo Clinic College of Medicine and Science
Mayo Clinic
Rochester, Minnesota

Brett Boggust, BSEMS [2]
Department of Emergency Medical Services
Creighton University
Omaha, Nebraska

Angela M. Bogle, MD [78]
Assistant Professor
Emergency Medicine
University of Missouri-Kansas City School of Medicine
Truman Medical Center Emergency Department
Kansas City, Missouri

Michael J. Bono, MD [7, 77]
Professor
Eastern Virginia Medical School
Vice Chair
Medical Student Clerkship Director
Emergency Medicine Residency Program
Eastern Virginia Medical School
Norfolk, Virginia

Gemma C. L. Bornick, MD, FACEP [291]
Clinical Adjunct Assistant Professor
University of Wisconsin School of Medicine and Public Health
Emergency Department Chair & Medical Director
Aurora BayCare Medical Center
Green Bay, Wisconsin

Kathy Boutis, MD, FRCPC, MSc [141]
Emergency Physician, Division of Emergency Medicine
Senior Associate Scientist, Research Institute
ImageSim, Academic Director
The Hospital for Sick Children
Professor of Pediatrics, University of Toronto
Toronto, Ontario

William J. Brady, MD, FACEP [18, 248, 249]
Professor of Emergency Medicine, Medicine, and Nursing
Vice Chair for Faculty Affairs
Department of Emergency Medicine
The David A. Harrison Distinguished Educator
Chair, Resuscitation Committee
University of Virginia Health System
Operational Medical Director
Albemarle County Fire Rescue
Charlottesville, Virginia

Anne F. Brayer, MD [220]
Professor of Emergency Medicine and Pediatrics
University of Rochester School of Medicine and Dentistry
University of Rochester Medical Center
Rochester, New York

Daniel Saul Brenner, MD, PhD [156]
Department of Emergency Medicine
Johns Hopkins Hospital
Baltimore, Maryland

Patricia Brock, MD [240]
Associate Professor
Deputy Chair
Department of Emergency Medicine
Medical Director of the Emergency Center
University of Texas MD Anderson Cancer Center
Houston, Texas

Daniel E. Brooks, MD [192]
Clinical Professor of Emergency and Internal Medicine
University of Arizona College of Medicine—Phoenix
Department of Medical Toxicology
Banner-University Medical Center Phoenix
Phoenix, Arizona

Justin K. Brooten, MD [300]
Assistant Professor
Emergency and Palliative Medicine
Wake Forest School of Medicine
Department of Emergency Medicine
Department of Internal Medicine
Section of Gerontology and Geriatric Medicine
Wake Forest Baptist Medical Center
Wake Forest Baptist Health
Winston-Salem, North Carolina

Douglas J.A. Brown, MD, FRCPC [209]
Clinical Assistant Professor
University of British Columbia, Department of Emergency Medicine
Emergency Physician, Royal Columbian Hospital
New Westminster, British Columbia

Eric J. Brown, MD, MS, FACEP [34]
Attending Staff Physician
US Acute Care Solutions
St. Francis Health System
Trauma Emergency Center
Tulsa, Oklahoma

Casey D. Bryant, MD [247]
Assistant Professor
Wake Forest School of Medicine
Department of Anesthesiology
Section on Critical Care Department of Emergency Medicine
Community Faculty
Wake Forest Baptist Health
Winston-Salem, North Carolina

Brian E. Burgess, MD, PT, FACEP, FAAEM [85]
Clinical Associate Professor of Emergency Medicine
Christiana Care Health System
Sidney Kimmel Medical College
Thomas Jefferson University School of Medicine
Philadelphia, Pennsylvania
Assistant Professor of Emergency Medicine
Philadelphia College of Osteopathic Medicine
Voluntary Faculty Appointment
Philadelphia, Pennsylvania
Assistant Professor of Emergency Medicine
School of Nursing
Drexel College of Medicine
Philadelphia, Pennsylvania

Boyd D. Burns, DO, FACEP [25]
George Kaiser Family Foundation Chair in Emergency Medicine
Associate Professor, Department of Emergency Medicine
University of Oklahoma School of Community Medicine
Tulsa, Oklahoma

John H. Burton, MD [284]
Professor and Chair
Virginia Tech Carilion School of Medicine
Chair, Department of Emergency Medicine
Carilion Clinic
Roanoke, Virginia

Don Byars, MD, RDMS, RDCS [84]
Associate Professor
Associate Program Director
Emergency Ultrasound Fellowship Director
Department of Emergency Medicine
Eastern Virginia Medical School
Norfolk, Virginia

Richard Byrne, MD [225]
Assistant Professor of Emergency Medicine
Cooper Medical School of Rowan University
Associate Program Director
Emergency Medicine Residency Program
Cooper University Hospital
Camden, New Jersey

Derya Caglar, MD [124]
Associate Professor, Pediatrics
University of Washington
Program Director
Pediatric Emergency Medicine Fellowship
Seattle Children's Hospital
Seattle, Washington

J. Hayes Calvert, DO [90]
Chief Medical Officer
Emergency Department Associate Medical Director
Emergency Medicine/Internal Medicine
Department of Emergency Medicine
Wake Forest Baptist Health Wilkes Medical Center
Winston-Salem, North Carolina

Peter A. Cameron, MBBS, MD, FACEM [254]
Academic Director
The Alfred Emergency and Trauma Centre
Monash University
Melbourne, Australia

Donna L. Carden, MD, MPH, FACEP [157]
Professor and Chief, Faculty Development
Department of Emergency Medicine
University of Florida
Gainesville, Florida

Jestin N. Carlson, MD, MS [28, 29A]
Director of Resident Research Emergency Medicine Residency Program
Saint Vincent Hospital
Erie, Pennsylvania

David Carr, MD, FCFP, CCFP, EM, CAC [61]
Associate Professor
Assistant Director of Risk Management and Faculty Development
University Health Network
Medical Director of Stadium Medicine
Toronto Blue Jays, Rogers Centre
Toronto, Ontario

Wallace A. Carter, MD [200, 206]
Associate Professor of Clinical Emergency Medicine
Weill Cornell Medicine
Director of Clinical and Faculty Affairs
Department of Emergency Medicine
New York Presbyterian Hospital
New York City, New York

Melissa Chan, MD [132]
Division of Pediatric Emergency Medicine
Department of Pediatrics
University of British Columbia
Vancouver, British Columbia

Michael E. Chansky, MD, FACEP, FAAEM [225]
Professor of Emergency Medicine
Cooper Medical School of Rowan University
Chairman, Department of Emergency Medicine
Cooper University Hospital
Camden, New Jersey

Betty Chen, MD [221]
Assistant Professor
Department of Emergency Medicine
University of Washington
Seattle, Washington

Benetta Chin, MD, FRCPC [135]
Clinical Instructor
University of British Columbia
Pediatric Emergency Medicine Physician
BC Children's Hospital
Vancouver, British Columbia

Yvonne C. Chow, MD, MSMS, CAQSM, FACEP [270]
Associate Professor
Albany Medical College
Associate Program Director
Emergency Medicine Residency Program
Albany Medical Center
Albany, New York

Stephen John Cico, MD, Med, FAAEM, FAAP [215, 232]
Assistant Dean for Graduate Medical Education Statewide Expansion & Faculty Development
Dean's Office of Graduate Medical Education (GME)
Indiana University School of Medicine
Associate Professor of Clinical Emergency Medicine & Pediatrics
Program Director, Pediatric Emergency Medicine Fellowship
Division of Emergency Pediatrics
Department of Emergency Medicine
Department of Pediatrics
Indiana University School of Medicine
Attending Physician, Pediatric Emergency Medicine
James Whitcomb Riley Hospital for Children
Indiana University Health
Indianapolis, Indiana

Richard F. Clark, MD [211]
Professor of Emergency Medicine
Director, Division of Medical Toxicology
UCSD Medical Center
University of California
San Diego, California

Michelle Clarke, MD, FRCPC [150]
Clinical Instructor
Department of Pediatrics
University of British Columbia
Pediatrician
Child Protection Service Unit
Pediatric Emergency Physician
BC Children's Hospital
Vancouver, British Columbia

Ilene Claudius, MD [117, 118]
Associate Professor
David Geffen School of Medicine at UCLA
Department of Emergency Medicine
Harbor-UCLA
Torrance, California

David M. Cline, MD [15, 38, 90]
Professor and Director of Departmental Research
Department of Emergency Medicine
Wake Forest School of Medicine
Winston-Salem, North Carolina

Wendy C. Coates, MD [42]
Emeritus Professor of Emergency Medicine
David Geffen School of Medicine
University of California
Los Angeles, California

Joanna S. Cohen, MD [123]
Associate Professor of Pediatrics and Emergency Medicine
George Washington University School of Medicine
Children's National Medical Center
Washington, DC

Jennifer P. Cohen, MD [185]
Attending Emergency Physician
Kaiser Permanente San Diego
San Diego, California
Attending Emergency Physician
Mt. Graham Regional Medical Center
Safford, Arizona
Attending Toxicologist
Arizona Poison and Drug Information Center
Tucson, Arizona

Clinton J. Coil, MD, MPH [238]
Health Sciences Associate Clinical Professor
David Geffen School of Medicine at UCLA
Associate Medical Director for Quality and Safety
Harbor-UCLA Medical Center
Torrance, California

Margaret Colbourne, MD, FRCP(C) [150]
Clinical Associate Professor
Department of Pediatrics
University of British Columbia
Division of Pediatric Emergency Medicine
B.C. Children's Hospital
Vancouver, British Columbia

Marc F. Collin, MD [108]
Associate Professor of Pediatrics
Medical Director, Neonatal Intensive Care Unit
MetroHealth Medical Center
Case Western Reserve University
Cleveland, Ohio

Sean P. Collins, MD, MSc [53]
Professor and Executive Vice Chair
Department of Emergency Medicine
Director
Center for Emergency Care Research and Innovation
Vanderbilt University Medical Center
Nashville, Tennessee

Nicholas J. Connors, MD [200, 206]
Associate Professor
Department of Emergency Medicine
Medical University of South Carolina
Charleston, South Carolina
Medical Toxicology Consultant
Palmetto Poison Center
Columbia, South Carolina

Carmen M. Coombs, MD, MPH [121]
Clinical Assistant Professor
Children's Hospital of Pittsburgh of UPMC
Division of Emergency Medicine
Division of Child Advocacy
Pittsburgh, Pennsylvania

Francis L. Counselman, MD, FACEP [89]
Chidester Endowed Chair of Emergency Medicine
Professor and Chairman
Department of Emergency Medicine
Eastern Virginia Medical School
Emergency Physicians of Tidewater
Norfolk, Virginia

Chris Courtney, MD, FACEP [273]
President, Scottsdale Emergency Associates
Envision Regional Director, Honor Health
Scottsdale, Arizona

Cameron Crandall, MD [294]
Professor and Vice Chair for Research
Department of Emergency Medicine
University of New Mexico
Director, LGBTQ Diversity, Equity, and Inclusion
Health Sciences Center Office for Diversity
University of New Mexico
Albuquerque, New Mexico

Maria T. Cruz-Carreras, MD [240]
Associate Professor of Emergency Medicine
MD Anderson Cancer Center
University of Texas
Houston, Texas

Shawn M. D'Andrea, MD, MPH, FACEP [162]
Attending Physician
Tsehootsooi Medical Center
Clinical Assistant Professor
Department of Emergency Medicine
University of Arizona-Phoenix College of Medicine
Phoenix, Arizona

Richard C. Dart, MD, PhD [212]
Director, Rocky Mountain Poison and Drug Center
Denver Health
Denver, Colorado
Professor of Emergency Medicine
University of Colorado Health Sciences Center
Aurora, Colorado

Moira Davenport, MD [43, 44]
Clinical Associate Professor
Temple University School of Medicine
Associate Residency Director, Emergency Medicine Residency
Allegheny General Hospital
Pittsburgh, Pennsylvania

Chris Davis, MD [216]
Associate Professor
University of Colorado Denver School of Medicine
UCHealth
Aurora, Colorado

Jonathan E. Davis, MD [93]
Professor and Academic Chair
Department of Emergency Medicine
Georgetown University
System Physician Chair, Graduate Medical Education
MedStar Health
Washington, DC

E. Paul DeKoning, MD, MS [81, 217]
Assistant Professor of Emergency Medicine
Geisel School of Medicine at Dartmouth
Program Director, Emergency Medicine Residency Program
Dartmouth-Hitchcock Medical Center
Lebanon, New Hampshire

David Della-Giustina, MD, FACEP, FAWM [279, 280]
Professor of Emergency Medicine
Yale School of Medicine
Chief of Education Section
Program Director of Emergency Medicine Residency
Yale New Haven Hospital
New Haven, Connecticut

Jonathan de Olano [191]
Assistant Professor of Medical Toxicology and Emergency Medicine
Emory University
Atlanta, Georgia

Tracy M. DeSelm, MD [289]
Assistant Professor
Department of Emergency Medicine
University of North Carolina
Chapel Hill, North Carolina

John J. Devlin, MD [213]
Commander, Medical Corps, United States Navy
Assistant Professor, Uniformed Services University
Program Director of Emergency Medicine Residency
Naval Medical Center Portsmouth
Portsmouth, Virginia

Annelies De Wulf, MD, MPH [162]
Clinical Assistant Professor
Louisiana State University
Director, Division of International Medicine
Associate Program Director, Emergency Medicine Residency
University Medical Center of New Orleans
New Orleans, Louisiana

Deborah B. Diercks, MD, MSc [49]
Professor and Chair
Department of Emergency Medicine
University of Texas Southwestern Medical Center
Dallas, Texas

Jeffrey S. Ditkoff, MD [72]
Clinical Assistant Professor
Oakland University William Beaumont School of Medicine
Patient Safety Officer
Director of Operations
Department of Emergency Medicine
Beaumont Health-Royal Oak
Royal Oak, Michigan

Andrew Dixon, MD, FRCPC [122, 130, 137]
Associate Professor
Program Director—Pediatric Emergency Medicine
Division of Pediatric Emergency Medicine Department of Pediatrics
University of Alberta Edmonton
Edmonton, Alberta

Laurie Ann Dixon, MD, MPH [237]
Adjunct Physician Instructor
Department of Emergency Medicine
University of Michigan Medical School
Howell, Michigan

Quynh H. Doan, MDCM, MHSc, PhD [116, 149]
Associate Professor, Department of Pediatric
Division of Emergency Medicine
University of British Columbia
Vancouver, British Columbia

Gail D'Onofrio, MD, MS [292]
Professor and Chair
Department of Emergency Medicine
Yale School of Medicine
Chief of Emergency Services
Yale New Haven Hospital
New Haven, Connecticut

Nicholas D. Drakos, MD [302]
Major, Medical Corps, US Army
Staff Emergency Physician
Womack Army Medical Center
Fort Bragg, North Carolina

Jonathan A. "Drew" Clare, MD [235]
Instructor of Emergency Medicine
Johns Hopkins Emergency Medicine
Baltimore, Maryland

Jeffrey Dubin, MD, MBA [279]
Chief Medical Officer
MedStar Washington Hospital Center
Professor of Clinical Emergency Medicine
Georgetown University School of Medicine
Washington, DC

James Ducharme, MD, CM, FRCP [35]
Clinical Professor of Medicine
McMaster University
Hamilton, Ontario
Adjunct Professor of Family Medicine
Queen's University
Kingston, Ontario
Humber River Hospital
Toronto, Ontario
President, International Federation for Emergency Medicine

Amy L. Dunn, DO, MPH [142]
Attending Physician
Division of Pediatric Emergency Medicine
Lehigh Valley Health Network
Allentown, Pennsylvania

Alexander Ebinger, MD, CAQ-SM [271]
Assistant Professor
Department of Emergency Medicine
University of Colorado
Aurora, Colorado

Kurt Power Eifling, MD [216]
Clinical Instructor
The University of Vermont Health Network
Burlington, Vermont

Paul Enarson, MD, PhD [132]
Clinical Assistant Professor
BC Children's Hospital
University of British Columbia
Vancouver, British Columbia

Carl Eriksson, MD, MPH [113]
Associate Professor
Oregon Health & Science University
Medical Capacity Officer
Doernbecher Children's Hospital
Portland, Oregon

Genevieve Ernst, MD, FRCPC [110]
Trauma Medical Director
BC Children's Hospital
Vancouver, British Columbia

Brenna M. Farmer, MD, MBA, MS, FAAEM, FACEP, FACMT [207]
Associate Professor of Clinical Emergency Medicine
Weill Cornell Medicine
Site Director
Department of Emergency
New York-Presbyterian Lower Manhattan Hospital
New York, New York

Anthony A. Ferroggiaro, MD, MHA [263]
Assistant Professor of Emergency Medicine
Oregon Health Sciences University
Vice Chair and Medical Director
OHSU Adventist Medical Center
Portland, Oregon

Emily C. S. Fisher, MD, FACEP [25]
Program Director and Assistant Professor
Department of Emergency Medicine
University of Oklahoma School of Community Medicine
Tulsa, Oklahoma

Ross J. Fleischman, MD, MCR [133, 255]
Department of Emergency Medicine
Harbor-UCLA Medical Center
Torrance, California
Assistant Clinical Professor
UCLA David Geffen School of Medicine
Los Angeles, California

Heather R. B. Fleming, MD [97]
Clinical Assistant Professor
Marion University College of Medicine
St. Vincent Hospital
Ascension Health
Indianapolis, Indiana

Todd A. Florin, MD, MSCE [128]
Associate Professor of Pediatrics
Department of Pediatrics
Northwestern University Feinberg School of Medicine
Director of Research
Division of Emergency Medicine
Ann & Robert H. Lurie Children's Hospital of Chicago
Head, Grainger Initiative in Pediatric Emergency Medicine Research
Chicago, Illinois

Timothy J. Fortuna, DO [284]
Assistant Professor
Virginia Tech Carilion School of Medicine
Carilion Clinic
Roanoke, Virginia

Sarah Elisabeth Frasure, MD, FACEP [101]
Assistant Professor of Emergency Medicine
Department of Emergency Medicine
George Washington University Hospital
Washington, DC

Stephen B. Freedman, MDCM, MSc, FAAP, FRCPC [131]
Professor of Pediatrics
Sections of Pediatric Emergency Medicine and Gastroenterology
Department of Pediatrics
University of Calgary
Professor in Child Health and Wellness
Alberta Children's Hospital Foundation
Calgary, Alberta

Gabrielle Freire, MDCM, FRCPC, MHSc [127]
Faculty of Medicine
Division of Paediatric Emergency Medicine
Department of Paediatrics
The Hospital for Sick Children
University of Toronto
Toronto, Ontario

Simone French, M.B.,B.S. (UWI), MSc/DM Emergency Medicine (UWI) [65]
Associate Lecturer
University of the West Indies
Medical Director, Emergency Medicine Division
University Hospital of the West Indies
Kingston, Jamaica

Phillip Friesen, DO [75]
Clinical Assistant Professor
Dell Medical School
The University of Texas at Austin
Austin, Texas

Monica L. Gaddis, PhD [299]
Associate Professor
Graduate Faculty, Department of Biomedical and Health Informatics, UMKC-SOM
Research Director, Department of Emergency Medicine, UMKC-SOM and TMC
University of Missouri Kansas City—School of Medicine (UMKC-SOM) and Truman Medical Center (TMC)
Kansas City, Missouri

John P. Gaillard, MD [12]
Assistant Professor
Department of Anesthesiology, Section on Critical Care
Department of Emergency Medicine
Department of Internal Medicine
Section of Pulmonary, Critical Care, Allergy, and Immunologic Diseases
Wake Forest Baptist Health
Winston-Salem, North Carolina

Eddie Charles Michael Garcia, MD [203]
Department of Emergency Medicine
University of California
San Francisco, California

Carl A. Germann, MD, MHPE, FACEP [283]
Associate Professor
Department of Emergency Medicine
Maine Medical Center
Tufts University School of Medicine
Portland, Maine

Michael A. Gibbs, MD, FACEP, FAAEM [36]
Professor and Chairman
Department of Emergency Medicine
Carolinas Medical Center and Levine Children's Hospital
Interim Vice President of Research
Atrium Health
Charlotte, North Carolina

Casey M. Glass, MD [16]
Assistant Professor
Department of Emergency Medicine
Wake Forest School of Medicine and Wake Forest Baptist Health
Winston-Salem, North Carolina

George F. Glass III, MD [18]
Assistant Professor
Department of Emergency Medicine
University of Virginia School of Medicine
Charlottesville, Virginia

Jonathan Glauser, MD, MBA, FACEP [295]
Professor
Emergency Medicine
Case Western Reserve University
Faculty
Emergency Medicine Residency Training Program
MetroHealth Medical Center/Cleveland Clinic
Cleveland, Ohio

Steven Go, MD [167, 258]
Professor of Emergency Medicine
Kansas City School of Medicine
University of Missouri
Department of Emergency Medicine
Truman Medical Center—Hospital Hill
Kansas City, Missouri

Brian Goldman, MD, FACEP, FCFP [170]
Emergency Physician
Schwartz Reisman Emergency Centre
Sinai Health System
Assistant Professor
Department of Family and Community Medicine
University of Toronto
Toronto, Ontario

Sarah Goss, MD [302]
Staff Physician
Fellow, Austere and Wilderness Medicine
Madigan Army Medical Center
Tacoma, Washington

Tadahiro Goto, MD, MPH [69]
Research Fellow, Department of Emergency Medicine
Massachusetts General Hospital, Massachusetts
Researcher, Graduate School of Medical Sciences
University of Fukui
Fukui, Japan

Nikhil Goyal, MD [223]
Clinical Professor of Internal Medicine and Emergency Medicine
Wayne State University
Director of Medical Education
Henry Ford Wyandotte Hospital
Director of Emergency Medicine Informatics
Henry Ford Health System
Detroit, Michigan

Charles S. Graffeo, MD, ABEM-UHM [227]
Professor and Assistant Residency Director
Department of Emergency Medicine
Eastern Virginia Medical School
Norfolk, Virginia

Autumn Graham, MD [82]
Emergency Physicians of Tidewater
Emergency Medicine Physician with Sentara Health System
Norfolk, Virginia

Matthew C. Gratton, MD [78]
Professor and Chair
Truman Medical Center
UMKC School of Medicine
Kansas City, Missouri

Sarah M. Greenberger, MD [73]
Associate Professor
Associate Residency Director
Department of Emergency Medicine
University of Arkansas for Medical Sciences
Little Rock, Arkansas

Shaun Greene, MBChB, MSc, FACEM, FACMT [176, 201]
Medical Director
Victorian Poisons Information Centre
Director
Austin Toxicology Service
Melbourne, Australia

John C. Greenwood, MD [58]
Assistant Professor
Department of Emergency Medicine, Division of Critical Care
Department of Anesthesiology and Critical Care
Perelman School of Medicine at the University of Pennsylvania
Philadelphia, Pennsylvania

Chip Gresham, MD [182, 192, 204]
Emergency Medicine Physician
Middlermore Hospital
Medical Toxicologist
The National Poisons Centre
Auckland, New Zealand

Sim Grewal, MD, FRCPC [135]
Clinical Associate Professor
University of British Columbia
Medical Director, Division of Pediatric Emergency
BC Children's Hospital
Vancouver, British Columbia

Frances W. Grimstad, MD, MS [299]
Assistant Faculty
Division of Pediatric and Adolescent Gynecology
Department of Surgery
Boston Children's Hospital
Instructor, Harvard Medical School
Boston, Massachusetts

Brian Grunau, MD, MHSc [14]
Emergency Physician
St. Paul's Hospital
Clinical Assistant Professor
Department of Emergency Medicine
University of British Columbia
Scientist
Centre for Health Evaluation & Outcome Sciences
Vancouver, British Columbia

Nachi Gupta, MD, PhD [172]
Resident Physician
Department of Emergency Medicine
Icahn School of Medicine
Mount Sinai Hospital
New York, New York

Paul Haller, MD [275, 278]
Emergency Medicine Department
Regions Hospital
Saint Paul, Minnesota

Pinchas (Pinny) Halpern, MD [7]
Chair, Division of Emergency Medicine
Tel Aviv Medical Center
Tel Aviv Clinical Associate Professor of Emergency Medicine
Anesthesiology and Intensive Care
Chair, Division of Emergency Medicine
Tel Aviv University
Tel Aviv, Israel

Bachar Hamade, MD, MSc [32]
Emergency Medicine Critical Care Medicine Fellow
Departments of Critical Care Medicine and Emergency Medicine
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Bophal Sarha Hang, MD [72, 96, 104]
Clinical Assistant Professor
Oakland University William Beaumont
Rochester, Michigan
Director of Medical Simulation
Department of Emergency Medicine
Beaumont Health System
Royal Oak, Michigan

Matthew L. Hansen, MD, MCR [113, 114]
Associate Professor of Emergency Medicine and Pediatrics
Oregon Health & Science University
Portland, Oregon

Nicholas D. Hartman, MD, MPH [246]
Assistant Professor of Emergency Medicine
Wake Forest School of Medicine
Assistant Program Director
Emergency Medicine Residency Program
Wake Forest Baptist Medical Center
Winston-Salem, North Carolina

Kohei Hasegawa, MD, MPH [69]
Associate Professor, Harvard Medical School
Department of Emergency Medicine
Massachusetts General Hospital
Boston, Massachusetts

William E. Hauda II, MD, FACEP, FAAP [109]
Associate Professor of Emergency Medicine
Virginia Commonwealth University School of Medicine
Assistant Professor of Pediatrics
University of Virginia School of Medicine
Charlottesville, Virginia

Kathryn Hawk, MD, MHS [292]
Assistant Professor
Yale University School of Medicine
Drug Use, Addiction and HIV Scholar
Department of Emergency Medicine
Yale New Haven Hospital
New Haven, Connecticut

Heather A. Heaton, MD [98]
Attending Physician
Department of Emergency Medicine
Assistant Professor of Emergency Medicine
Mayo Clinic College of Medicine, Mayo Clinic
Rochester, Minnesota

Tarlan Hedayati, MD, FACEP [259]
Assistant Professor
Chair, Education Division
Department of Emergency Medicine
Cook County Hospital
Chicago, Illinois

James Heilman, MD, CCFP(EM) [266]
Clinical Assistant Professor
Department of Emergency Medicine
Faculty of Medicine
University of British Columbia
Vancouver, British Columbia

C. William Heise, MD [199]
Assistant Professor
Division of Medical Toxicology and Precision Medicine
Department of Medicine
University of Arizona College of Medicine—Phoenix
Department of Medical Toxicology
Banner-University Medical Center Phoenix
Phoenix, Arizona

Corey R. Heitz, MD [243]
Emergency Physician
Lewis Gale Medical Center
Salem, Virginia

Robin R. Hemphill, MD, MPH [231, 235, 237]
Chief Quality and Safety Officer
Clinical Professor of Emergency Medicine
Virginia Commonwealth University Health System
Richmond, Virginia

Robert G. Hendrickson, MD [5, 8]
Professor, Department of Emergency Medicine
Program Director, Medical Toxicology Fellowship
Medical Director, Oregon Poison Center
Oregon Health & Science University
Portland, Oregon

Melanie Heniff, MD, FACEP, FAAEM, FAAP [97]
Assistant Professor of Clinical Emergency Medicine
Indiana University School of Medicine
Indianapolis, Indiana

Stephanie H. Hernandez, MD, MSCR [198]
Assistant Professor
Department of Emergency Medicine
Icahn School of Medicine at Mount Sinai
Mount Sinai Hospital
New York City, New York

David Hile, MD [280]
Emergency Physician
Valley View Hospital
Glenwood Springs, Colorado

Jon Mark Hirshon, MD, PhD, MPH [22]
Professor, Department of Emergency Medicine
Professor, Department of Epidemiology and Public Health
University of Maryland School of Medicine
Baltimore, Maryland

Cherri D. Hobgood, MD, FACEP [301]
Chair, Department of Emergency Medicine
Rolly McGrath Professor
Indiana University School of Medicine
IU Health Methodist Hospital
Sidney & Lois Eskenazi Hospital
IU Health Physicians
Indianapolis, Indiana

Heather Holahan, MD [253]
Assistant Professor
Department of Dermatology
University of North Carolina
Chapel Hill, North Carolina

Rachel M. Holland, PharmD, BCPS [19, 20]
Pharmacy Clinical Specialist III
Emergency Department
Henrico Doctors Hospital
HCA Healthcare
Richmond, Virginia

Judd E. Hollander, MD [39, 40, 41, 47, 49]
Senior Vice President for Healthcare Delivery Innovation, TJU
Associate Dean for Strategic Health Initiatives
Sidney Kimmel Medical College
Vice Chair for Finance and Healthcare Enterprises
Professor, Department of Emergency Medicine
Thomas Jefferson University
Philadelphia, Pennsylvania

Maija Holsti, MH, MPH [138]
Professor, University of Utah
Department of Pediatrics
Division of Pediatric Emergency Medicine
Salt Lake City, Utah

Edmond A. Hooker, MD, DrPH [87]
Assistant Professor
Residency Research Director
Department of Emergency Medicine
University of Cincinnati
Cincinnati, Ohio

B. Zane Horowitz, MD, FACMT [5, 8]
Professor, Emergency Medicine
Oregon Health Science University
Medical Director, Oregon Poison Center
Portland, Oregon

Kathleen Hosmer, MD [51, 242]
Assistant Professor
Department of Emergency Medicine
Wake Forest University School of Medicine
Winston-Salem, North Carolina

Craig J. Huang, MD [126]
Associate Professor
Medical Director, Trauma Services Children's Health Plano
Trauma Director, Division of Emergency Medicine
Department of Pediatrics, Division of Emergency Medicine
University of Texas Southwestern Medical Center
Dallas, Texas

David T. Huang, MD, MPH [32]
Associate Professor
Critical Care Medicine, Emergency Medicine, Clinical and Translational Science
Director, MACRO (Multidisciplinary Acute Care Research Organization)
Director, CRISMA Administrative Core (Clinical Research, Investigation, and Systems Modeling of Acute illness)
University of Pittsburgh
Pittsburgh, Pennsylvania

J. Stephen Huff, MD [164, 168, 169]
Professor of Emergency Medicine and Neurology
University of Virginia Health System
Charlottesville, Virginia

Maite Anna Huis in't Veld, MD [22]
Assistant Professor of Emergency Medicine
University of Maryland School of Medicine
Baltimore, Maryland

Fredric M. Hustey, MD [295]
Associate Professor
Cleveland Clinic Lerner College of Medicine
Case Western Reserve University
Emergency Services Institute
Cleveland Clinic
Cleveland, Ohio

Alzamani Mohammad Idrose, MBBS, BoJ MMed (Emergency), MITM, EDMM [228, 229, 230]
Consultant Emergency Physician
Hospital Kuala Lumpur
Kuala Lumpur, Malaysia

Mohammad Jalili, MD [224]
Professor, Emergency Medicine Department
Tehran University of Medical Sciences
Tehran, Iran

David H. Jang, MD, MSc, FACMT [181, 188]
Assistant Professor
Perelman School of Medicine at the University of Pennsylvania
Department of Emergency Medicine
Division of Medical Toxicology and Critical Care Medicine (ResCCU)
Anesthesia and Critical Care Mitochondrial Unit (ACMU)
Philadelphia, Pennsylvania

Peter Johns, MD [170]
Assistant Professor
Department of Emergency Medicine
University of Ottawa
The Ottawa Hospital
Ottawa, Ontario

Gary A. Johnson, MD [59, 60]
Associate Professor and Chair
Department of Emergency Medicine
Upstate Medical University
Syracuse, New York

Alan E. Jones, MD [151]
Professor and Chairman
Department of Emergency Medicine
Chief Operations Physician
University of Mississippi Medical Center
Jackson, Mississippi

David Jones, MD, MCR [261]
Assistant Professor of Emergency Medicine
Oregon Health & Science University
Associate Program Director, Emergency Medicine Residency Program
Co-Director, Emergency Medicine Education Fellowship
Portland, Oregon

Elaine B. Josephson, MD [95]
Assistant Professor of Clinical Emergency Medicine
Weill Cornell Medical College of Cornell University
Program Director, Emergency Medicine Residency
Department of Emergency Medicine
Lincoln Medical and Mental Health Center
Bronx, New York

Tarina L. Kang, MD, MHA, FACEP [173]
Clinical Associate Professor
University of Southern California
Medical Director, Evaluation and Treatment Clinic
Keck Hospital of USC
Los Angeles, California

Turan Kayagil, MD [84]
Novant Health University of Virginia System
Prince William Medical Center
Manassas, Virginia

Gabor D. Kelen, MD, FRCP(C), FACEP, FAAEM [15]
Professor and Chair
Department of Emergency Medicine
Johns Hopkins Medicine
Baltimore, Maryland

Alex P. Keller IV, MD, DiMM [302]
Lt Col, USAF, MC, SFS
Command Surgeon, Special Operations Command Korea
Diplomate American Board of Emergency Medicine
Assistant Professor of Military and Emergency Medicine
Uniformed Services University of the Health Sciences (USUHS)
Bethesda, Maryland

Elizabeth W. Kelly, MD [152]
Assistant Professor
Department of Emergency Medicine
Wake Forest School of Medicine
Winston-Salem, North Carolina

Jennifer Kelly, PharmD [37]
Clinical Pharmacist Specialist-Emergency Medicine
University of North Carolina Healthcare
Chapel Hill, North Carolina

Tan Boon Kiat Kenneth, MBBS, MMed (EM), FAMS [24]
Consultant, Head of Department
Department of Emergency Medicine
Singapore General Hospital
Adjunct Assistant Professor Duke NUS
Core Faculty Singhealth Emergency Medicine Residency
Singapore

Katharine Kenyon, MD [251]
Department of Dermatology
UNC Health Care
University of North Carolina at Chapel Hill School of Medicine
Chapel Hill, North Carolina

Kathleen Kerrigan, MD [101]
Assistant Professor
University of Massachusetts Medical School-Baystate
Director of Simulation
Emergency Medicine Residency Program
Baystate Medical Center
Springfield, Massachusetts

Utsha Khatri, MD [188]
Penn National Clinician Scholars Fellow
Hospital of the University of Pennsylvania
Department of Emergency Medicine
Philadelphia, Pensylvania

Janeva Kircher, MD, FRCPC (EM, PEM) [122]
Clinical Lecturer
University of Alberta
Departments of Emergency Medicine and Pediatrics
Edmonton, Alberta

Bryan B. Kitch, MD, FAEMS, FACEP [161]
Assistant Professor
Department of Emergency Medicine
Brody School of Medicine
East Carolina University
Greenville, North Carolina

Andrew D. Kitlowski, MD [75]
Clinical Assistant Professor
Simulation Director, EM Residency Program
Dell Seton Medical Center
University of Texas
Austin, Texas

Jeffrey A. Kline, MD [56]
Eskenazi Foundation Professor
Vice Chair of Research
Department of Emergency Medicine
Indiana University School of Medicine
Indianapolis, Indiana

Nicholas E. Kman, MD, FACEP [73]
Clinical Professor of Emergency Medicine
Department of Emergency Medicine
Ohio State University College of Medicine
Columbus, Ohio

Barry J. Knapp, MD [254]
Distinguished Professor in Emergency Medicine
Eastern Virginia Medical School
Program Director
Emergency Medicine Residency Program
Norfolk, Virginia

Ryan M. Knight, MD, MAJ USSOCOM USASOC 75RR [302]
Major
75th Ranger Regiment
United States Army

Kevin J. Knoop, MD, MS [213]
Program Director
Emergency Medicine Residency
Riverside Regional Medical Center
Newport News, Virginia
Clinical Professor of Emergency Medicine
Virginia Commonwealth University
Richmond, Virginia
Clinical Professor of Military and Emergency Medicine
Uniformed Services University of the Health Sciences
Bethesda, Maryland
American Red Cross Volunteer Clinical Faculty
Emergency Medicine Residency
Naval Medical Center
Portsmouth, Virginia

Paul M. A. Korn, MD [111]
Clinical Associate Professor
Department of Pediatrics
University of British Columbia
Vancouver, British Columbia

Josh Kornegay, MD [171]
Assistant Professor
Department of Emergency Medicine
Associate Residency Program Director
Department of Emergency Medicine
Simulation Education Director
Department of Emergency Medicine
Medical Director
Center for the Advancement of Resuscitation Education (CARE)
Oregon Health & Science University (OHSU)
Portland, Oregon

Alex Koyfman, MD, FACEP, FAAEM [24, 67, 72, 165, 236, 262, 268, 269, 297]
Assistant Professor and Assistant Program Director
UT Southwestern Department of Emergency Medicine
Editor-in-Chief, http://www.emdocs.net
Dallas, Texas

Richard Kwun, MD [124]
Attending Physician
Department of Emergency Medicine
Swedish Medical Center
Issaquah, Washington

Jay G. Ladde, MD, FACEP, FAAEM [175]
Professor of Emergency Medicine
University of Central Florida College of Medicine
Senior Associate Program Director
Orlando Health Emergency Medicine Residency
Orlando, Florida

Richard Lammers, MD [45]
Assistant Dean for Simulation
Professor of Emergency Medicine
Department of Emergency Medicine
Western Michigan University Homer Stryker M.D. School of Medicine
Kalamazoo, Michigan

Stephanie A. Lareau, MD, FACEP, FAWM [243]
Associate Professor of Emergency Medicine
Fellowship Director, Wilderness Medicine
Virginia Tech Carilion School of Medicine
Carilion Clinic
Roanoke, Virginia

Stewart W. Lee, MD, FAWM [270]
Sports Medicine Fellow
Department of Emergency Medicine
University of Mississippi Medical Center
Jackson, Mississippi

Cedric W. Lefebvre [64]
Associate Professor
Wake Forest School of Medicine
Program Director
Emergency Medicine Residency Program
Winston-Salem, North Carolina

Tracy Leigh LeGros, MD, PhD, FACEP, FAAEM, FUHM [21]
University Medical Center
Clinical Professor, Emergency Medicine
Program Director LSU Undersea and Hyperbaric Medicine Fellowship
LCMC Health System
New Orleans, Louisiana

Skyler Lentz, MD [29B]
Assistant Professor of Surgery and Medicine
Divisions of Emergency Medicine and Pulmonary Diseases and Critical Care Medicine
The Robert Larner, M.D. College of Medicine at The University of Vermont
Burlington, Vermont

Julie C. Leonard, MD, MPH [112]
Associate Professor
Division of Emergency Medicine
Department of Pediatrics
The Ohio State College of Medicine
Nationwide Children's Hospital
Columbus, Ohio

Benjamin S.H. Leong, MBBS, MRCS, MMED [23]
Senior Consultant
Emergency Medicine Department
National University Hospital
National University Health System
Assistant Professor
Department of Surgery
Yong Loo Lin School of Medicine
National University of Singapore
Singapore

Amy Levine, MD [120]
Professor of Pediatric Emergency Medicine
University of North Carolina at Chapel Hill
Chapel Hill, North Carolina

Michael Levine, MD [180, 193, 205]
Associate Professor
Department of Emergency Medicine
Chief, Division of Medical Toxicology
University of Southern California
Los Angeles, California

Rachel Levitan, MD [189]
Chair, Department of Emergency Medicine
Flagstaff Medical Center
Flagstaff, Arizona

Swee Han Lim, MBBS, FRCS Edin (A&E), FRCP Edin [24, 33]
Senior Consultant
Department of Emergency Medicine and Education Director
Singapore General Hospital
Associate Designated Institutional Officer
SingHealth Residency, SingHealth
Adjunct Professor, Duke-NUS School of Medicine
Adjunct Associate Professor, Yong Loo Ling School of Medicine
National University of Singapore
Republic of Singapore

Deborah R. Liu, MD [136]
Associate Division Head
Division of Emergency Medicine
Children's Hospital Los Angeles
Associate Professor of Pediatrics
USC Keck School of Medicine
Los Angeles, California

Bruce Lo, MD, MBA [76]
Professor
Eastern Virginia Medical School
Chief, Department of Emergency Medicine
Sentara Norfolk General Hospital
Norfolk, Virginia

Brit Long, MD [24, 67, 72, 165, 236, 262, 268, 269, 297]
Assistant Professor of Emergency Medicine
Department of Emergency Medicine
San Antonio Uniformed Services Health Education Consortium
Fort Sam Houston, Texas

Annette M. Lopez, MD [10]
Adjunct Assistant Professor
Emergency Medicine
Oregon Health & Science University
Assistant Chief Emergency Medicine
Portland VA Health Care System
Staff Toxicologist, Oregon & Alaska Poison Center
Portland, Oregon

Jennifer S. Love, MD [186]
Toxicology Fellow, Department of Emergency Medicine
Oregon Health & Science University
Portland, Oregon

Frank LoVecchio, DO, MPH, ABMT, FACEP
[177, 178, 179, 180, 182, 184, 189, 196, 197, 199, 202, 204, 210]
Maricopa Medical Center
Professor of Emergency Medicine, Pharmacology, and Medicine
University of Arizona College of Medicine
Banner Poison and Drug Information Center
Phoenix, Arizona

Cary L. Lubkin, MD [225]
Associate Professor of Emergency Medicine and Internal Medicine
Cooper Medical School of Rowan University
Cooper University Hospital
Camden, New Jersey

Michael Lynch, MD [218]
Medical Director, Pittsburgh Poison Center
Assistant Professor, Division of Medical Toxicology
Department of Emergency Medicine
Divisions of Adolescent and Pediatric Emergency Medicine
Department of Pediatrics
University of Pittsburgh School of Medicine
Pittsburgh, Pennsylvania

O. John Ma, MD [166, 174, 255, 263]
Professor
Department of Emergency Medicine
Oregon Health & Science University
Portland, Oregon

Sharon E. Mace, MD, FACEP, FAAP [66]
Professor of Medicine
Cleveland Clinic Lerner College of Medicine
Case Western Reserve University
Director, Research, Emergency Services Institute (ESI)
Assistant Director of EMS, Cleveland Clinic Health Systems
Former Director, Observation Unit, ESI
Former Director of Pediatric Education and Quality Improvement, ESI
Faculty, MetroHealth Medical Center/Cleveland Clinic Emergency Medicine Residency
Cleveland Clinic
Emergency Services Institute
Cleveland, Ohio

Simon A. Mahler, MD, MS, FACEP [48, 160]
Associate Professor
Wake Forest School of Medicine
Director of Clinical Research
Department of Emergency Medicine
Department of Implementation Science
Department of Epidemiology and Prevention
Wake Forest Baptist Health
Winston-Salem, North Carolina

Gerald E. Maloney, DO, FACOEP, FACEP [65, 222]
Associate Chief
Department of Emergency
Louis Stokes Cleveland VA Medical Center
Associate Professor of Medicine and Emergency Medicine
Case Western Reserve University
Cleveland, Ohio

Deepak S. Manhas, MD [116]
Clinical Assistant Professor
University of British Columbia
Program Director
Neonatal-Perinatal Medicine Subspecialty Residency Program
British Columbia Children's & Women's Hospitals
Vancouver, British Columbia

James E. Manning, MD [24]
Adjunct Professor
Department of Emergency Medicine
Resuscitation Research Laboratory
University of North Carolina School of Medicine
Chapel Hill, North Carolina
Adjunct Research Professor
Division of Trauma Surgery
Oregon Health & Science University
Co-Founder, Resusitech, Inc.
Redwood City, California

David E. Manthey, MD, FAAEM [50, 68, 92, 94]
Professor of Emergency Medicine
Wake Forest School of Medicine
Winston-Salem, North Carolina

Catherine A. Marco, MD [27, 155, 156]
Professor of Emergency Medicine
Department of Emergency Medicine
Wright State University Boonshoft School of Medicine
Dayton, Ohio

Asa M. Margolis, DO, MPH, MS, FACEP [4]
Assistant Professor
Department of Emergency Medicine
Johns Hopkins University School of Medicine
Medical Director
Johns Hopkins Lifeline Critical Care Transportation Program
Program Director
Emergency Medical Services Fellowship
Baltimore, Maryland

Roberta Marino, MD, MSc [17]
Emergency Medicine Unit Director
SS.Pietro e Paolo Hospital
Borgosesia, Italy

John P. Marshall, MD, MBA [143]
Chair, Department of Emergency Medicine
Maimonides Medical Center
Brooklyn, New York

Caitlin A. Mase, MD [166]
Doctors Emergency Service, PA
Anne Arundel Medical Center
Annapolis, Maryland

David A. Masneri, DO, FACEP, FAAEM [71]
Assistant Professor of Emergency Medicine
Wake Forest University School of Medicine
Assistant Residency Program Director
Wake Forest University School of Medicine
Winston-Salem, North Carolina

Clifford P. Masom, MD [195]
Toxicology Fellow
University of California
San Diego, California

Joshua Mastenbrook, MD [45]
Assistant Professor of Emergency Medicine
Department of Emergency Medicine
Western Michigan University Homer Stryker M.D. School of Medicine
Kalamazoo, Michigan

Erik G. Mattison, MD [178]
Attending Physician
Chandler Regional Medical Center
Chandler, Arizona

Ryanne J. Mayersak, MD, MS [267]
Assistant Professor
Associate Residency Program Director
Interim Medical Student Clerkship Director
Department of Emergency Medicine
Oregon Health & Science University
Portland, Oregon

Henderson D. McGinnis, MD, FACEP [244]
Associate Professor
Department of Emergency Medicine
Wake Forest School of Medicine
Winston-Salem, North Carolina

Diana B. McShane, MD [250, 251, 252, 253]
Clinical Assistant Professor
University of North Carolina
Pediatric Dermatologist
UNC Department of Dermatology
University of North Carolina Hospitals
UNC Health Care
Chapel Hill, North Carolina

C. Crawford Mechem, MD [1]
Professor, Department of Emergency Medicine
Perelman School of Medicine at the University of Pennsylvania
Hospital of the University of Pennsylvania
Philadelphia, Pennsylvania

Garth D. Meckler, MD, MSHS [106, 129, 139]
Associate Professor of Pediatrics and Emergency Medicine
University of British Columbia
Division Head, Pediatric Emergency Medicine
BC Children's Hospital
Vancouver, British Columbia

Sarah A. Mellion, MD [140]
Clinical Instructor
University of Colorado Denver
Children's Hospital Colorado
Aurora, Colorado

Lisa H. Merck, MD, MPH, FACEP [257]
Vice Chair, Emergency Medicine Research
Associate Professor, Department of Emergency Medicine
University of Florida College of Medicine
Gainesville, Florida

John T. Meredith, MD [161]
Clinical Assistant Professor
Director, Global Health Program
Department of Emergency Medicine
Brody School of Medicine
Greenville, North Carolina

Megan Mickley, MD, FAAP, FACEP [144, 145]
Co-Director, Emergency Medicine Ultrasound
Children's Hospital of Colorado
Assistant Professor of Pediatrics & Emergency Medicine
University of Colorado
Denver, Colorado

Chadwick D. Miller, MD, MS [51]
Professor and Chair
Department of Emergency Medicine
Wake Forest School of Medicine
Winston-Salem, North Carolina

Michael G. Millin, MD, MPH, FACEP, FAEMS [4]
Associate Professor
Department of Emergency Medicine
Johns Hopkins University School of Medicine
Baltimore, Maryland
Medical Director, Prince George's County Fire/EMS Department
Baltimore, Maryland

Lisa D. Mills, MD [6]
Professor, Department of Emergency Medicine
UC Davis School of Medicine
Director, Division of EM Ultrasound
Medical Director, UC Davis Fire Department
Sacramento, California

Trevor J. Mills, MD, MPH [6]
Professor
Department of Emergency Medicine
University of California Davis Health
Chief of Emergency Medicine
Northern California Veterans Affairs Health Care System
Sacramento, California

Joel Moll, MD [157]
Associate Professor
Residency Program Director
Department of Emergency Medicine
Virginia Commonwealth University School of Medicine
Richmond, Virginia

Malcolm E. Molyneux, MD, FRCP, FMedSci, OBE [159]
Emeritus Professor
Liverpool School of Tropical Medicine
Liverpool, United Kingdom

Greg Moran, MD [154]
Professor of Clinical Emergency Medicine
David Geffen School of Medicine at UCLA
Chief, Department of Emergency Medicine
Faculty, Division of Infectious Diseases
Olive View-UCLA Medical Center
Los Angeles, California

Lisa A. Moreno-Walton, MD, MS, MSCR, FAAEM, FACEP, FIFEM [293]
Clinical Professor
Louisiana State University Health Sciences Center—New Orleans
Director of Research, Diversity, Viral Testing, and Latino Health Scholars Programs
University Medical Center
New Orleans, Louisiana

Dean S. Morrell, MD [250, 251, 252, 253]
Clinical Professor
University of North Carolina at Chapel Hill School of Medicine
Program Director
Dermatology Residency and Pediatric Dermatology Fellowship Programs
UNC Healthcare
Chapel Hill, North Carolina

Nidal Moukaddam, MD, PhD [286]
Associate Professor
Menninger Department of Psychiatry & Behavioral Sciences
Baylor College of Medicine
Director, Ben Taub Adult Outpatient Services
Medical Director
Stabilization, Treatment and Rehabilitation (STAR) Program for Psychosis
Houston, Texas

Anita Mudan, MD [181]
Toxicology Fellow
Department of Emergency Medicine
California Poison Control Center
University of California San Francisco
San Francisco, California

Heather Murphy-Lavoie, MD, FAAEM, FACEP, FUHM [21]
Director of Faculty Development
Clinical Professor
Emergency Medicine Residency
UHM Fellowship
LSU School of Medicine
University Medical Center
New Orleans, Louisiana

Keith Murray, MD, FAWM, FACEP [30]
Clinical Assistant Professor of Emergency Medicine
University of Pittsburgh Medical Center—Mercy Campus
Medical Director Pittsburgh SWAT
Medical Director University of Pittsburgh SERT
Pittsburgh, Pennsylvania

M. Kathryn Mutter, MD, MPH [168]
Assistant Professor
Department of Emergency Medicine
University of Virginia
Charlottesville, Virginia

Justin G. Myers, DO, MPH [37]
Clinical Assistant Professor
Department of Emergency Medicine
University of North Carolina at Chapel Hill
Chapel Hill, North Carolina

Regina C. Mysliwiec, MD, MS [265]
Assistant Professor
Vice Chair, Department of Emergency Medicine
Oregon Health & Science University
Medical Director, Department of Emergency Medicine
Columbia Memorial Hospital

Anna M. Nelson, MD [166]
Emergency Physician
Emanuel Hospital
Portland, Oregon

Jessie G. Nelson, MD, FACEP, FAAEM [234]
Senior Staff Physician, Emergency Medicine
Regions Hospital
Director of Emergency Medicine Education Research
Associate Professor of Emergency Medicine
University of Minnesota
St. Paul, Minnesota

Lewis S. Nelson, MD [190, 198, 203, 207, 221]
Professor
Rutgers New Jersey Medical School
Chair, Department of Emergency Medicine
Chief, University Hospital
Newark, New Jersey

R. Darrell Nelson, MD, FACEP, FAEMS [282]
Associate Professor of Emergency Medicine
Wake Forest University Health Sciences
Program Director, EMS and Disaster Fellowship Program
Winston-Salem, North Carolina

Jo-Ann O. Nesiama, MD, MS [119]
Associate Professor
Associate Program Director
Pediatric Emergency Medicine Fellowship Program
Department of Pediatrics—Emergency Medicine
Children's Health/UT Southwestern Medical Center
Dallas, Texas

Yih Yng Ng, MBBS, FAMS, MRCS A&E, MPH, MBA [23]
Consultant in Emergency Medicine
Tan Tock Seng Hospital, Singapore
HomeTeam Chief Medical Officer
Ministry of Home Affairs, Singapore
Consultant, Hospital Services Division
Ministry of Health, Singapore

Michael Nguyen, MD, FACEP [142]
Department of Emergency and Hospital Medicine
Lehigh Valley Health Network
Bethlehem, Pennsylvania
Assistant Professor of Medicine
Morsani College of Medicine
University of South Florida
Tampa, Florida

Bret A. Nicks, MD, MHA [12, 50, 68, 94]
Professor, Emergency Medicine
Wake Forest School of Medicine
CMO, WFBH Davie Medical Center
Wake Forest Baptist Health
Winston-Salem, North Carolina

James T. Niemann, MD, FACEP [55]
Emeritus Professor of Medicine
David Geffen School of Medicine at UCLA
Senior Physician Specialist
Harbor-UCLA Medical Center
Torrance, California

Mahtab Niroomand, MD [224]
Assistant Professor
Internal Medicine Department, Endocrinology Division
Research Deputy, Internal Medicine Department
Shahid Beheshti University of Medical Sciences
Tehran, Iran

Anna K. Nowacki, MD, FRCPC [61]
Assistant Professor
University of Toronto
UHN Emergency Medicine Postgraduate Program Coordinator
University Health Network
Toronto, Ontario

Andrew Nyce, MD [225]
Associate Professor
Cooper Medical School of Rowan University
Vice Chairman
Department of Emergency Medicine
Cooper University Hospital
Camden, New Jersey

Mary Claire O'Brien, MD [71]
Professor
Department of Emergency Medicine
Senior Associate Dean for Healthcare Education
Wake Forest School of Medicine
Winston-Salem, North Carolina

Elizabeth C. Oehler, MD [74]
Clinical Assistant Professor
Director of Emergency Department Administration Education
Dell Medical School
The University of Texas at Austin
Austin, Texas

Kelly P. O'Keefe, MD, FACEP [281]
Founding Program Director
Emergency Medicine Residency
Professor of Clinical Sciences
Florida State University College of Medicine
Sarasota Memorial Hospital
Sarasota, Florida

Susan R. O'Mara, MD [80]
Assistant Clinical Professor of Emergency Medicine
Georgetown University
Chair, Emergency Department
MedStar Washington Hospital Center
Washington, DC

Talib Omer, MD, PhD [276, 277]
Assistant Professor of Clinical Emergency Medicine
Keck School of Medicine of USC
Director of Undergraduate Ultrasound Education
LAC+USC Medical Center
Los Angeles, California

Marcus E.H. Ong, MBBS, MPH, FAMS, PBM [23, 24]
Professor
Senior Consultant and Clinician Scientist
Department of Emergency Medicine
Singapore General Hospital
Director Health Services and Systems Research (HSSR)
Duke-NUS Medical School
Head, Health Services Research Center (HSRC)
SingHealth Services
Director, Health Services Research Institute
Medical Director, Unit for Prehospital Emergency Care (UPEC)
Senior Consultant, Ministry of Health, Hospital Services Division
Singapore

Irene A. Oriaifo, MB,BS, FAAP [146]
Assistant Professor of Pediatrics
Division of Pediatric Emergency Medicine
SSM Health Cardinal Glennon Children's Hospital
Saint Louis University School of Medicine
Saint Louis, Missouri

Joseph P. Ornato, MD [11]
Professor
Virginia Commonwealth University
Chairman, Department of Emergency Medicine
Virginia Commonwealth University Health System
Richmond, Virginia

Daniel G. Ostermayer, MD [107]
Department of Emergency Medicine
McGovern Medical School
University of Texas Health Science Center at Houston
Houston, Texas

Kevin M. Overmann, MD, MS [128]
Assistant Professor of Pediatrics
Division of Emergency Medicine
Cincinnati Children's Hospital Medical Center
University of Cincinnati College of Medicine
Cincinnati, Ohio

Charissa B. Pacella, MD [163]
Associate Professor and Vice Chair of Academic Operations
University of Pittsburgh
Chief of Emergency Services
UPMC Presbyterian Hospital
Pittsburgh, Pennsylvania

Michael T. Paddock, DO, MS [208]
Assistant Professor, Emergency Medicine
University of Minnesota
Regions Hospital
HealthPartners Institute
Saint Paul, Minnesota

Amit Anil Kumar Pandit, MD [249]
Assistant Professor
Department of Emergency Medicine
University of Mississippi Medical Center
Jackson, Mississippi

Rushi R. Parikh, DO [126]
Associate Faculty
Department of Pediatrics
Division of Pediatric Emergency Medicine
University of Texas Southwestern Medical Center
Dallas, Texas

Peter R. Peacock, Jr., MD [88]
Assistant Professor
Department of Emergency Medicine
SUNY Downstate
Chief Medical Informatics Officer
Kings County Hospital
Brooklyn, New York

Debra Perina, MD [226]
Professor
Department of Emergency Medicine
University of Virginia
Charlottesville, Virginia

Andrew D. Perron, MD, FACEP, FACSM [164]
Professor and Residency Program Director
Department of Emergency Medicine
Maine Medical Center
Portland, Maine

Jeanmarie Perrone, MD, FACMT [186, 187]
Professor, Emergency Medicine
Director, Medical Toxicology
Department of Emergency Medicine
Perelman School of Medicine
University of Pennsylvania
Philadelphia, Pennsylvania

Alanna C. Peterson, MD [30]
Assistant Professor of Emergency Medicine
University of Pittsburgh
ED Trauma Liaison, UPMC Presbyterian-Shadyside
Curriculum Co-Director, Emergency Medicine Residency
University of Pittsburgh Medical Center
Pittsburgh, Pennsylvania

Roberta Petrino, MD [17]
Director Emergency Medicine Department
S. Andrea Hospital
EUSEM Immediate Past President
Vercelli, Italy

Anthony F. Pizon, MD [218]
Chief, Division of Medical Toxicology
Department of Emergency Medicine
University of Pittsburgh Medical Center
Associate Professor
University of Pittsburgh School of Medicine
Pittsburgh, Pennsylvania

Charles V. Pollack, Jr, MA, MD [239]
Professor of Emergency Medicine
Sidney Kimmel Medical College of Thomas Jefferson University
Associate Provost
Thomas Jefferson University
Philadelphia, Pennsylvania

Naveen Poonai, MSc, MD, FRCPC [115]
Associate Professor Paediatrics & Internal Medicine
Schulich School of Medicine & Dentistry
Scientist, Child Health Research Institute
Research Director, Division of Paediatric Emergency Medicine
London, Ontario

Nicholas W. Porter, DO [148]
Assistant Professor of Pediatrics
Program Director, Pediatric Emergency Medicine Fellowship
Section of Emergency Medicine
Arkansas Children's Hospital
University of Arkansas for Medical Sciences
Little Rock, Arkansas

Timothy G. Price, MD [83]
Associate Professor
Chief, Division of EMS
Department of Emergency Medicine
University of Louisville
Louisville, Kentucky

Louise A. Prince, MD, FACEP [59, 60]
Associate Professor
Department of Emergency Medicine
SUNY Upstate Medical University
Syracuse, New York

Michael A. Puskarich, MD, MS [151]
Associate Professor
University of Minnesota
Research Director, Department of Emergency Medicine
Hennepin County Medical Center and the University of Minnesota
Minneapolis, Minnesota

Dan Quan, DO, FAAEM, FACEP, FACMT [183, 185, 196]
Director, Toxicology Consultation Service
Department of Emergency Medicine
Maricopa Integrated Health System
Clinical Associate Professor, Department of Emergency Medicine
University of Arizona College of Medicine—Phoenix
Associate Professor, Department of Emergency Medicine
Creighton University Arizona Health Education Alliance
Phoenix, Arizona

Linda Quan, MD [215]
Professor of Pediatrics
University of Washington School of Medicine
Pediatric Emergency Medicine
Seattle Children's Hospital
Seattle, Washington

James Quinn, MD, MS [46, 52]
Professor of Emergency Medicine
By Courtesy, Health Research and Policy
Stanford University School of Medicine
Stanford, California

Nadeem Qureshi, MD, FAAP, FCCM [146]
Professor of Pediatrics
School of Medicine, St Louis University
Director Quality Management
Attending Pediatric Emergency Medicine
Cardinal Glennon Children's Hospital
St. Louis, Missouri

Sarah M. Reid, MD, FRCPC [134]
Assistant Professor
Departments of Pediatrics and Emergency Medicine
University of Ottawa
Pediatric Emergency Physician
Children's Hospital of Eastern Ontario
Ottawa, Ontario

Matthew K. Riddle, MD [194]
Associate Physician
Department of Emergency Medicine
University of California San Diego School of Medicine
San Diego, California

David M. Rodriguez, MD [119]
Assistant Professor
UT Southwestern Medical Center
Children's Health
Dallas, Texas

Matthew A. Roginski, MD, MPH [29B]
Assistant Professor of Medicine
Assistant Medical Director, Dartmouth-Hitchcock Advanced Response Team
Medical Director, Associate Provider Critical Care Residency
Sections of Emergency and Critical Care Medicine
Dartmouth-Hitchcock Medical Center
Geisel School of Medicine at Dartmouth
Lebanon, New Hampshire

Richard E. Rothman, MD, PhD [155, 156]
Professor, Executive Vice Chair and Vice-Chair Research
Department of Emergency Medicine
The Johns Hopkins University
Baltimore, Maryland

Brian H. Rowe, MD, MSc, CCFP(EM), FCFP, FCCP, FCAHS [14]
Scientific Director
Institute of Circulatory and Respiratory Health (ICRH)
Canadian Institutes of Health Research
Professor, Department of Emergency Medicine
Adjunct Professor, School of Public Health
Adjunct Professor, Departments of Medicine and Psychiatry
University of Alberta
Edmonton, Alberta

William Rushton, MD, FACEP, FACMT [248]
Assistant Professor
Department of Emergency Medicine
Office of Medical Toxicology, UAB Medicine
The University of Alabama at Birmingham
Birmingham, Alabama

Vikram Sabhaney, MD, FRCPC [125]
Clinical Assistant Professor
Departments of Pediatrics and Emergency Medicine
University of British Columbia
Pediatric Emergency Medicine Fellowship Director
BC Children's Hospital
Vancouver, British Columbia

Charlotte A. Sadler, MD [214]
Assistant Professor
University of California, San Diego
Program Director, Undersea and Hyperbaric Medicine Fellowship
Department of Emergency Medicine
San Diego, California

Elizabeth A. Samuels, MD, MPH, MHS [292]
Assistant Professor
Brown Emergency Medicine
Alpert Medical School of Brown University
Rhode Island and Miriam Hospitals
Providence, Rhode Island

Sally A. Santen, MD, PhD [233, 238]
Senior Associate Dean and Professor of Emergency Medicine
Virginia Commonwealth University School of Medicine
Richmond, Virginia

Margarita Santiago-Martinez, MD [276, 277]
Clinical Physician
Little Company of Mary
Torrance, California

Adam Schlichting, MD, MPH [223]
Aurora Health Care
Aurora Critical Care Services
Aurora Emergency Services
Milwaukee, Wisconsin

Aaron Schneir, MD [211]
Clinical Professor of Medicine
Division of Medical Toxicology
Department of Emergency Medicine
University of California, San Diego Health System
San Diego, California

Samuel T. Selby, DO [148]
Pediatric Emergency Medicine Physician
Cook Children's Medical Center
Fort Worth, Texas

Karen D. Serrano, MD [153]
Clinical Assistant Professor of Emergency Medicine
University of North Carolina
Chapel Hill, North Carolina

Andrew C. Seymore, MD [282]
Clinical Adjunct Faculty
Department of Emergency Medicine
Wake Forest School of Medicine
Winston-Salem, North Carolina

Robert W. Shaffer, MD [233]
Assistant Professor
Department of Emergency Medicine
Michigan Medicine
University of Michigan Medical School
University Hospital
Ann Arbor, Michigan

Allan Evan Shefrin, MD, FRCPC [127]
Assistant Professor
Department of Pediatrics and Division of Pediatric Emergency Medicine
Children's Hospital of Eastern Ontario
University of Ottawa
Ottawa, Ontario

Christina L. Shenvi, MD, PhD, FACEP [288]
Assistant Professor
University of North Carolina School of Medicine
Associate Program Director
Emergency Medicine Residency Program
Chapel Hill, North Carolina

Suzanne M. Shepherd, MD, DTM&H [103, 296]
Professor Emeritus
Department of Emergency Medicine
University of Pennsylvania Healthcare System
Philadelphia, Pennsylvania

David Sheridan, MD, MCR [139]
Assistant Professor, Pediatric Emergency Medicine
Co-Director Emergency Medicine Clinical Innovation
OHSU Doernbecher Children's Hospital
Portland, Oregon

Sara Haney Shields, PharmD, BCPS [19, 20]
Director of Pharmacy
Wake Forest Baptist Health—Davie Medical Center
Department of Pharmacy
Bermuda Run, North Carolina

Jonathan E. Siff, MD, MBA, FACEP, FAMIA [303]
Associate Chief Medical Informatics Officer
The MetroHealth System
Associate Professor
Department of Emergency Medicine
Case Western Reserve University School of Medicine
Cleveland, Ohio

Troy Christian Sims, DO [63]
Clinical Assistant Professor
University of Pittsburgh
Pittsburgh, Pennsylvania

Richard Sinert, DO [88]
Professor of Emergency Medicine
Vice-Chair In-Charge of Research
State University of New York—Downstate Medical Center
Chair, Facility Research Review Committee
Kings County Hospital
New York Health and Hospitals
Brooklyn, New York

Adam J. Singer, MD [39, 40, 41, 47]
Professor and Vice Chairman for Research
Department of Emergency Medicine
Stony Brook University
Stony Brook, New York

Manpreet Singh, MD [55]
Faculty, Department of Emergency Medicine
Harbor-UCLA Medical Center
Torrance, California
Assistant Professor of Emergency Medicine
David Geffen School of Medicine at UCLA
Los Angeles, California

Aaron Skolnik, MD [193]
Senior Associate Consultant
Department of Critical Care Medicine
Mayo Clinic Hospital
Phoenix, Arizona
Assistant Professor
Department of Emergency Medicine
Mayo Clinic Alix School of Medicine
Scottsdale, Arizona

David E. Slattery, MD, FACEP, FAEMS [239]
Professor and Research Director
Department of Emergency Medicine
UNLV School of Medicine
University Medical Center of Southern Nevada
US Acute Care Solutions
EMS Medical Director
Las Vegas Fire & Rescue
Las Vegas, Nevada

Benjamin Small, PharmD, BCPS [19]
Clinical Pharmacist
Wake Forest Baptist Medical Center
Winston-Salem, North Carolina

Lane M. Smith, MD, PhD [48, 160]
Assistant Professor of Emergency Medicine
Wake Forest School of Medicine
Winston-Salem, North Carolina

Brian K. Snyder, MD [214]
Clinical Professor
Department of Emergency Medicine
University of California San Diego
San Diego, California

Mark R. Sochor, MD, MS, FACEP [249]
Associate Professor and Vice Chair of Research
Department of Emergency Medicine
Medical Director Center for Applied Biomechanics
School of Engineering and Applied Science
University of Virginia
Charlottesville, Virginia

Mitchell C. Sokolosky, MD [285]
Associate Professor
Wake Forest School of Medicine
ACGME Designated Institutional Official
Associate Dean
Graduate Medical Education Wake Forest Baptist Health
Winston-Salem, North Carolina

David M. Somand, MD, FACEP [13]
Assistant Professor
Medical Director, Adult Emergency Services
Department of Emergency Medicine
University of Michigan
Ann Arbor, Michigan

Joseph Stephan Stapczynski, MD [47, 62]
Professor
Department of Emergency Medicine
Scholarly Projects Advisor
University of Arizona College of Medicine—Phoenix
Professor, Affiliate Faculty
Department of Emergency Medicine
Creighton University School of Medicine
Phoenix, Arizona

Brandy Stauffer, MD, MEd (HSE), FRCPC (ER, PEM) [137]
Clinical Lecturer
Department of Emergency Medicine
University of Alberta
Edmonton, Alberta

Christine R. Stehman, MD [79]
Clinical Assistant Professor
Department of Emergency Medicine
Indiana University School of Medicine
Indianapolis, Indiana

Jennifer A. Stephani, MD [10]
Peace Southwest Medical Center
Vancouver, Washington
Adjunct Assistant Professor
Oregon Health and Science University
Portland, Oregon

Keith C. Stone, MD [3]
Professor
Texas A&M Health Science Center College of Medicine
Chairman
Department of Emergency Medicine
Baylor Scott & White Health—CTX Division
Temple, Texas

Alan B. Storrow, MD [53]
Associate Professor
Department of Emergency Medicine
Associate Director
Center for Emergency Care Research and Innovation
Vanderbilt University Medical Center
Center for Medicine, Health, and Society
Vanderbilt University
Nashville, Tennessee

David J. Story, MD [92]
Assistant Professor
Wake Forest University School of Medicine Clerkship Director
Emergency Medicine Acting Internship
Wake Forest Baptist Medical Center
Winston-Salem, North Carolina

Charles E. A. Stringer, MD, MSc [125]
Clinical Instructor
University of British Columbia
Emergency Physician
Lions Gate Hospital/Surrey Memorial Hospital
Vancouver, British Columbia

Amy M. Stubbs, MD [264]
Assistant Professor
University of Missouri—Kansas City School of Medicine
Program Director, Emergency Medicine Residency
Truman Medical Center-Health Sciences District
Kansas City, Missouri

Jared A. Sutton, MD [302]
Critical Care Emergency Medicine
Hennepin County Medical Center
Minneapolis, Minnesota

Joe Suyama, MD, FACEP [9]
Associate Professor
Department of Emergency Medicine
University of Pittsburgh School of Medicine
Chief of Emergency Services
UPMC Magee-Womens Hospital
Pittsburgh, Pennsylvania

Carolyn K. Synovitz, MD, MPH, FACEP [34]
Adjunct Clinical Associate Professor
Department of Emergency Medicines
University of Oklahoma School of Community Medicine
Tulsa, Oklahoma
Winn Army Community Hospital
Fort Stewart, Georgia

Sukhjit S. Takhar, MD [154]
Mills-Peninsula Emergency Medical Associates
Burlingame, California

Mary E. Tanski, MD, MBA [174]
Medical Director
Oregon Health & Science University
Portland, Oregon

Melisa S. Tanverdi, MD [140]
Pediatric Emergency Medicine Fellow
Children's Hospital Colorado
University of Colorado School of Medicine
Aurora, Colorado

William A. Teeter, MD [254]
Clinical Assistant Professor
University of North Carolina at Chapel Hill
Department of Emergency Medicine
Chapel Hill, North Carolina

Wee Siong Teo, MBBS, FRCP, FHRS [33]
Senior Advisor, Electrophysiology and Pacing
National Heart Centre
Singapore

Stephen H. Thomas, MD, MPH [3]
Senior Lecturer in Emergency Medicine
Barts and The London School of Medicine and Dentistry
Queen Mary University of London
London, United Kingdom
Professor and Chairman of Emergency Medicine
Hamad General Hospital and Weill Cornell Medical College in Qatar
Doha, Qatar

Jennifer Thull-Freedman, MD, MSc [131]
Medical Director of Quality and Safety
Alberta Children's Hospital Physician Lead for Quality
ACH Emergency Department Clinical Associate Professor
Departments of Pediatrics and Emergency Medicine
University of Calgary
Calgary, Alberta

Joel Tieder, MD, MPH [117, 118]
Associate Professor of Pediatrics
Division of Hospital Medicine
Program Director Pediatric Hospital Medicine Fellowship
Director, Maintenance of Certification Portfolio Program
Seattle Children's Hospital and the University of Washington School of Medicine
Seattle, Washington

Adam Z. Tobias, MD, MPH, FACEP [290]
Associate Professor of Emergency Medicine
University of Pittsburgh School of Medicine
Associate Program Director
University of Pittsburgh Emergency Medicine Residency
Pittsburgh, Pennsylvania

Christian Tomaszewski, MD, MS, MBA, FACEP, FACMT [194, 195]
Professor of Clinical Emergency Medicine
University of California San Diego Health
San Diego, California

Veronica Tucci, MD, JD, FAAEM, FACEP [286]
Professor of Emergency Medicine and Research
William Carey University School of Osteopathic Medicine
Director of Research and Scholarly Activity
Emergency Medicine Residency
HCA West Florida GME Consortium
Brooksville, Florida

Adam E. Vella, MD [147]
Associate Professor of Clinical Pediatrics
Director of Pediatric Emergency Medicine Quality Assurance
Division of Pediatric Emergency Medicine
Weill Cornell Medicine
New York Presbyterian Hospital
Phyllis and David Komansky Children's Hospital
New York, New York

Richard A. Walker, MD [241]
Professor
Attending Physician
Nebraska Medicine
University of Nebraska Medical Center
Omaha, Nebraska

Henry E. Wang, MD, MS [28, 29A]
Professor and Vice Chair for Research
Department of Emergency Medicine
The University of Texas Health Science Center at Houston
Houston, Texas

Vincent J. Wang, MD, MHA [119]
Seay Distinguished Chair in Pediatric Medicine
Professor of Pediatrics and Emergency Medicine
Division Chief—Pediatric Emergency Medicine
UT Southwestern Medical Center
Director of Emergency Services
Children's Health
Dallas, Texas

Yvonne L. Wang, MD [261]
Assistant Professor
Oregon Health & Science University
Portland, Oregon

Kevin R. Ward, MD [13]
Professor
Departments of Emergency Medicine and Biomedical Engineering
Executive Director
Michigan Center for Integrative Research in Critical Care (MCIRCC)
University of Michigan
Ann Arbor, Michigan

Shawn R. Wassmuth, MD, FACEP [74]
Clinic Assistant Professor
Dell Medical School
Assistant Program Director
Emergency Medicine Residency Program
University of Texas at Austin
Austin, Texas

Lindsay M. Weaver, MD [301]
Assistant Professor of Clinical Medicine
Indiana University
Assistant Medical Director of Quality and Patient Safety
Department of Emergency Medicine
Methodist Hospital
Indiana University Health System
Indianapolis, Indiana

David J. Weber, MD, MPH, FSHEA, FIDSA, FRCM [158]
Professor of Medicine, Pediatrics, and Epidemiology
UNC School of Medicine and UNC Gillings School of Global Public Health
Medicine Director, Hospital Epidemiology (Infection Prevention)
UNC Hospitals
University of North Carolina
Chapel Hill, North Carolina

Andrea K. Weiers, MD [275]
Emergency Medicine Resident
HealthPartners Institute/Regions Hospital
Saint Paul, Minnesota

Scott G. Weiner, MD, MPH [292]
Associate Professor
Harvard Medical School
Medical Director
Brigham Comprehensive Opioid Response and Education (B-CORE) Program
Chief, Emergency Medicine Division of Health Policy and Public Health
Brigham and Women's Hospital
Boston, Massachusetts

Brian Weiss, MD [103]
Penn Medicine Clinician
Sections of Emergency Medicine and Anesthesiology
Department of Emergency Medicine
Hospital of the University of Pennsylvania
Philadelphia, Pennsylvania

Janna Welch, MD [75]
Assistant Clinical Professor
Dell Medical School at The University of Texas
Austin, Texas

Howard A. Werman, MD, FACEP [73]
Professor of Clinical Emergency Medicine
The Ohio State University
Columbus, Ohio

Lori J. Whelan, MD [99]
GKFF Chair in Emergency Medicine #2
Vice Chair of Education
Department of Emergency Medicine
Associate Professor & Director of Ultrasound
Associate Program Director
OU-TU School of Community Medicine
Tulsa, Oklahoma

Julian White, MB, BS, MD, FACTM [212]
Associate Professor and Unit Head
Toxinology Department
Women's and Children's Hospital
North Adelaide, South Australia

Lauren Wiesner, MD [80]
Assistant Professor of Clinical Emergency Medicine
Georgetown University School of Medicine
Associate Chair, Department of Emergency Medicine
MedStar Washington Hospital Center
MedStar Health
Washington, DC

Rachel S. Wightman, MD [187, 190]
Assistant Professor of Emergency Medicine
Warren Alpert Medical School of Brown University
Division of Medical Toxicology
Brown Emergency Medicine
Providence, Rhode Island

Joanne Williams, MD, MAAEM, FAAEM [298]
Associate Professor of Clinical Emergency Medicine
Charles R. Drew University of Medicine and Science
Adjunct Professor of Clinical Emergency Medicine
Keck School of Medicine of USC
Los Angeles, California

Zachary I. Willis, MD, MPH [158]
Clinical Assistant Professor of Pediatrics
Division of Pediatric Infectious Diseases
University of North Carolina School of Medicine
UNC Children's Hospital
Chapel Hill, North Carolina

Michael Wilson, MD, PhD, FAAEM, FACEP [287]
Assistant Professor, Division of Research and Evidence-Based Medicine
UAMS Department of Emergency Medicine
Assistant Professor, Department of Psychiatry
Director, Department of Emergency Medicine Behavioral Emergencies Research (DEMBER) Lab
Director, UAMS Department of Emergency Medicine Research Associates Program
University of Arkansas for Medical Sciences
Little Rock, Arkansas

Michael Winters, MD, MBA, FACEP, FAAEM [58]
Professor of Emergency Medicine and Medicine
Vice Chair for Clinical and Administrative Affairs
Department of Emergency Medicine
University of Maryland School of Medicine
Baltimore, Maryland

Michael D. Witting, MD, MS [86]
Professor
Department of Emergency Medicine
Baltimore Veterans Administration Medical Center
University of Maryland School of Medicine
Baltimore, Maryland

Rachel M. Wolfe, MD [282]
Assistant Professor
Section on Rheumatology and Immunology
Department of Internal Medicine
Wake Forest School of Medicine
Winston-Salem, North Carolina

William A. Woods, MD [226]
Associate Professor of Emergency Medicine and Pediatrics
University of Virginia Health System
Charlottesville, Virginia

David W. Wright, MD, FACEP [257]
Professor and Interim Chair
Department of Emergency Medicine
Adjunct Faculty
Wallace H. Coulter Department of Biomedical Engineering
Adjunct Faculty
Nell Hodgson Woodruff School of Nursing
Emory University School of Medicine
Atlanta, Georgia

Sam Wu, MD [250]
Resident Physician
Department of Dermatology
University of North Carolina School of Medicine at Chapel Hill
UNC Healthcare
Chapel Hill, North Carolina

Teresa Wu, MD, FACEP [36]
Director, Simulation Curriculum
Director, Simulation Educators Program
Associate Professor, Emergency Medicine
University of Arizona College of Medicine—Phoenix
Director, Point of Care Ultrasound Program and Fellowships
Banner-University Medical Center Phoenix
Phoenix, Arizona

Chris Wyatt, MD [31]
Assistant Professor
Department of Emergency Medicine
MetroHealth Medical Center
Case Western Reserve University
Cleveland, Ohio

Donald M. Yealy, MD [30]
Chair, Department of Emergency Medicine
University of Pittsburgh/University of Pittsburgh Physicians
Senior Medical Director, Health Services Division, UPMC
Professor of Emergency Medicine, Medicine, and Clinical and Translational Sciences
University of Pittsburgh School of Medicine
Pittsburgh, Pennsylvania

Alan X. You, MD [157]
Resident Physician
VCU Health System
Richmond, Virginia

Janet S. Young, MD [100]
Associate professor
Virginia Tech Carilion Department of Emergency Medicine
Director of Ultrasound
Carilion Medical Center
Roanoke, Virginia

Esther L. Yue, MD, MCR [129]
Adjunct Assistant Professor
Division of Pediatric Emergency Medicine
Oregon Health & Science University
Randall Children's Hospital at Legacy Emanuel
Portland, Oregon

Alexandra E. Zeitany, MD [252]
Resident Physician
University of North Carolina at Chapel Hill
Chapel Hill, North Carolina

Roger Zemek, MD, FRCPC [127]
Associate Professor
Department of Pediatrics and Emergency Medicine
Director, Clinical Research Unit
Children's Hospital of Eastern Ontario
University of Ottawa
Ottawa, Ontario

Christopher M. Ziebell, MD, FACEP [75]
Clinical Assistant Professor
Division Chief—Emergency Medicine
Department of Surgery and Peri-operative Care
Dell Medical School
Emergency Department Medical Director
Dell SETON Medical Center
University of Texas
Texas, Austin

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Pharmacy Reviewers

Chapter 19, Pharmacology of Antiarrhythmics and Antihypertensives

Andrea J. Miura, PharmD, BCPS
Clinical Pharmacist, Cardiology and Critical Care
University of Washington Medical Center
Seattle, Washington

Chapter 20, Pharmacology of Vasopressors and Inotropes

Cassie A. Barton, PharmD, BCPS, BCCCP
Clinical Pharmacy Specialist
Trauma Critical Care and Emergency Medicine
Oregon Health & Science University
Portland, Oregon

Chapter 25, Resuscitation in Pregnancy

Cierra N. Treu, PharmD, BCCCP
Pharmacy Clinical Coordinator, Emergency Medicine
NewYork-Presbyterian Brooklyn Methodist Hospital
Brooklyn, New York

Chapter 35, Acute Pain Management

Kerry Kathleen Moore, PharmD
Critical Care Pharmacist
Oregon Health & Science University
Portland, Oregon

Nathan D. Mah, PharmD
Emergency Medicine Clinical Pharmacy Supervisor
Oregon Health & Science University
Portland, Oregon

Chapter 99, Comorbid Disorders in Pregnancy

Cierra N. Treu, PharmD, BCCCP
Pharmacy Clinical Coordinator, Emergency Medicine
NewYork-Presbyterian Brooklyn Methodist Hospital
Brooklyn, New York

Chapter 239, Thrombotics and Antithrombotics

Kerry Kathleen Moore, PharmD
Critical Care Pharmacist
Oregon Health & Science University
Portland, Oregon

Nathan D. Mah, PharmD
Emergency Medicine Clinical Pharmacy Supervisor
Oregon Health & Science University
Portland, Oregon

Chapter 289, Mood and Anxiety Disorders

Nadia I. Awad, PharmD, MS, BCPS
Emergency Medicine Pharmacist
Robert Wood Johnson University Hospital
New Brunswick, New Jersey

Chapter 290, Psychoses

Nadia I. Awad, PharmD, MS, BCPS
Emergency Medicine Pharmacist
Robert Wood Johnson University Hospital
New Brunswick, New Jersey

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Preface

This marks the 41st year of publication of our textbook, which began as a compendium of "answers" to a massive set of questions developed by members of the American College of Emergency Physicians (ACEP) and the American Board of Emergency Medicine (ABEM) for the Emergency Medicine Board Certification Examination. The first ACEP edition was developed in 1978 as "The Study Guide," and in 1985, it matured into the first of 34 years of McGraw-Hill editions. This ninth edition continues to expand in a scope and depth that we could not foretell 41 years ago. We continue to provide clinically focused information for all emergency medicine learners and practitioners, from students and residents, to emergency medicine physicians, advanced practice providers, emergency medical technicians, and paramedics. We believe each subsequent edition demonstrates the vital contemporary role of emergency medical care for individual patients as well as for the health of the public.

This is much more than a book of emergency medicine content. It is the result of contributions over the years by over 2000 authors committed to the education and practice of emergency medicine. I give special thanks to *Howard Werman, MD*, Professor of Emergency Medicine at Ohio State University, *James Niemann, MD,* Professor of Emergency Medicine at David Geffen School of Medicine, and *Joseph Stephen Stapczynski, MD,* Professor of Emergency Medicine at the University of Arizona – Phoenix, for being the only authors who have contributed to every single McGraw-Hill edition over its 41-year history!

The ninth edition is a component of a larger work, AccessEmergencyMedicine.com, which blends the advantages of the web version of the ninth edition of *Tintinalli's Emergency Medicine*, with the leading web-based clinical texts including *Ma & Mateer's Emergency Ultrasound*; Shah & Lucchesi's *Atlas of Pediatric Emergency Medicine*; *Goldfrank's Toxicologic Emergencies*; Iserson's *Improvised Medicine*; and Knoop, Stack, and Storrow's *Atlas of Emergency Medicine*. Audio posts of each chapter are available as TNT (Tintinalli's Necessary Takeaways, by E. Paul DeKoning, Christina Shenvi, Timothy Buff, and Collyn Murray), and monthly blogs are available as BoB (Best of the Blogs, by Alex Koyfman and Brit Long). Procedure videos using traditional and ultrasound techniques are available through Multimedia. Videos are hyperlinked in the web version of the ninth edition and are continually developed at emergency medicine academic sites. Our goal is to continue to develop a set of exemplary educational tools to meet the needs of today's and tomorrow's emergency physicians.

Judith E. Tintinalli, MD, MS
Editor-in-Chief
Chapel Hill, North Carolina

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SECTION 1

Prehospital Care

CHAPTER 1

Emergency Medical Services

C. Crawford Mechem

INTRODUCTION

EMS is the extension of emergency medical care into the prehospital setting. Today's EMS systems have their roots in legislative and clinical developments of the 1960s and 1970s. The 1966 report "Accidental Death and Disability—The Neglected Disease of Modern Society" highlighted the deficiencies of prehospital care of trauma victims, attributable to inadequate equipment and training. Until that time, more than half of ambulance services were run by funeral homes because hearses were among the few vehicles able to transport a stretcher. The National Highway Safety Act of 1966 established the Department of Transportation and made it the lead agency responsible for upgrading EMS systems nationwide.[1]

In 1967, J. F. Pantridge began using a physician-staffed mobile coronary care unit in Belfast, Northern Ireland, to provide prehospital cardiac care.[2] Physician staffing of ambulances never gained popularity in the United States. However, in the late 1960s and 1970s, nonphysician personnel began learning advanced skills, including IV administration of medications, cardiac rhythm interpretation, and defibrillation.[3]

The U.S. EMS Systems Act of 1973 made available federal grants to develop regional EMS systems. Approximately 300 EMS regions were established. To receive funding, the Act required that EMS systems address 15 key elements (**Table 1-1**). These elements form the foundation of many EMS systems today.[4]

The 1970s became a Golden Age for EMS. The U.S. Department of Transportation developed curricula for emergency medical technicians, paramedics, and first responders. EMS communications systems were formalized. In 1972, the Federal Communications Commission recommended 9-1-1 be adopted as the emergency telephone number nationwide. In addition, the concept of designated trauma centers was introduced, with the idea being that EMS personnel would transport injured patients preferentially to these facilities.

The Omnibus Budget Reconciliation Act of 1981 eliminated direct federal funding for EMS. Instead, federal funds were distributed as block grants. The result was a decrease in both EMS funding and coordination. EMS systems took on a decidedly local flavor, with great variation between systems. This trend has had long-term consequences for the field.[1]

In 2011, the American Board of Emergency Medicine recognized EMS as its seventh subspecialty. The certification examination is based on the Core Content of EMS Medicine with four major content areas: Clinical Aspects of EMS Medicine, Medical Oversight of EMS, Quality Management and Research, and Special Operations.[5]

EMS SYSTEM OVERVIEW

A review of the 15 elements of EMS systems identified by the EMS Systems Act of 1973 (Table 1-1) provides insight into the structure of EMS systems and the challenges they face.

MANPOWER

In most urban areas, paid public safety and ambulance personnel provide prehospital care. In contrast, suburban, rural, or wilderness EMS systems commonly use volunteers. Personnel fall into one of four licensure levels in accordance with the National EMS Scope of Practice Model, set forth by the National Highway Traffic Safety Administration. These are emergency medical responder, emergency medical technician, advanced emergency medical technician, and paramedic. Each type of provider must master a minimum set of skills. Emergency medical responders are often first on the scene of an emergency. They are trained to perform CPR, spine immobilization, and hemorrhage control and to use auto-injectors, automated external defibrillators, and other basic interventions while awaiting an ambulance. Emergency medical technicians function as part of an ambulance crew. Their training includes oxygen administration, CPR, hemorrhage control, and patient extrication, immobilization, and transportation. They assist patients in using some of their own medications and can administer certain over-the-counter medications. Advanced emergency medical technician training includes additional assessment skills plus placement of IVs and supraglottic airway devices and administration of some medications. Paramedics have the highest skill level. Because of their advanced level of training, paramedics function under a designated physician's supervision.[6]

TRAINING

Training includes initial provider training and continuing education. As EMS call volume increases, providers often care for a disproportionate number of patients with minor medical issues. Maintaining proficiency in skills to manage critically ill patients may be difficult. Innovative training methods to ensure skills retention must be sought. Use of computerized human patient simulators is one option, both for reviewing skills and learning new ones.

COMMUNICATIONS

The adoption of 9-1-1 as a nationwide emergency number has greatly facilitated public access to emergency care. In many systems, the local public safety answering point has software that provides the number and location of a caller (enhanced 9-1-1). Widespread use of cellular telephones has prompted the development of technology to identify and locate these callers as well, in accordance with Federal Communications Commission regulations. Emergency call takers are trained to collect necessary information, dispatch appropriate resources, and offer first aid or prearrival instructions while the ambulance is en route. Ambulance personnel should also be able to communicate with the destination hospital. Most EMS personnel operate under standing orders and protocols. However, there are times when providers may require online medical control, talking directly with a physician for direction.[7] Historically, communications represent the weakest link in disasters. It is important that EMS communication systems have built-in redundancy to ensure uninterrupted service.

TRANSPORTATION

Ambulance design must enable EMS personnel to provide care such as airway and ventilatory support while transporting the patient safely. Basic life support ambulances carry equipment appropriate for personnel trained at the emergency medical technician level, such as automated external defibrillators, oxygen, bag-mask ventilation devices, immobilization and splinting devices, and wound dressings. They carry few medications and cannot transport patients requiring IVs or cardiac monitoring. Advanced life support ambulances are equipped for advanced emergency medical technicians or paramedics, including IV

TABLE 1-1 Fifteen Key Elements of EMS Systems Defined by U.S. EMS Systems Act of 1973

- Manpower
- Training
- Communications
- Transportation
- Facilities
- Critical care units
- Public safety agencies
- Consumer participation
- Access to care
- Patient transfer
- Coordinated patient record keeping
- Public information and education
- Review and evaluation
- Disaster plan
- Mutual aid

fluids and medications, intubation equipment, cardiac monitors, and pulse oximeters. Ground transportation is appropriate for the majority of patients, especially in urban and suburban areas. However, air transport, generally by helicopter, should be considered for critically ill patients when ground transport time would be long or if the terrain is difficult to navigate.[4]

FACILITIES AND CRITICAL CARE UNITS

Patients are often transported to the closest appropriate hospital. In recent years, the number of specialty hospitals has increased, including pediatric hospitals, trauma centers, burn centers, stroke centers, and centers with advanced cardiac or resuscitation capabilities.[8] Tertiary care centers provide many of these services and may also have a large number of critical care unit beds. The decision to bypass hospitals to go directly to a specialty center, often at a greater distance, is not a simple one. Although specialty hospitals often have more resources, transporting an unstable patient past an ED to get to the specialty hospital is not without risks. Furthermore, bypassing hospitals may have negative financial consequences for bypassed facilities.[1] It is wise to solicit input from the local medical community before developing destination policies involving specialty centers.

Due to ED overcrowding, even the largest hospitals may not always have adequate resources to care for EMS patients. This may result in prolonged offload times of ambulance patients, long wait times for patients to be seen, and ED boarding of admitted patients. Furthermore, some EDs may request EMS divert elsewhere.[9] Because of these issues, regional EMS systems should develop methods to monitor available resources of their receiving hospitals. A secure, Internet-based website of hospital resources, including ED and inpatient bed availability, is one option.

PUBLIC SAFETY AGENCIES

EMS systems should have strong ties with police and fire departments. Many large EMS systems are run by fire departments. In addition to providing scene security, public safety agencies can provide first responder services because they are often first on the scene. Fire and police automated external defibrillator programs are common.[10,11] Police administration of naloxone to opioid overdose victims is also a growing trend.[12] Such practices have been shown to improve patient outcomes. Finally, EMS personnel often provide medical support to police and fire departments in hazardous circumstances.

CONSUMER PARTICIPATION

Public support, both political and financial, is necessary for a good EMS system. It is important that laypersons contribute to policymaking. One way to accomplish this is to encourage representation of the public on regional EMS councils. The public can also participate by volunteering for local EMS agencies.

ACCESS TO CARE

Successful EMS systems ensure all individuals have access to care regardless of ability to pay. The EMS system is often a patient's primary entry point into the healthcare system. There should be no barriers preventing access. A more difficult problem exists when terrain or low population densities result in longer response times for some citizens, as in rural or wilderness areas. EMS telemedicine programs may be one way to bring high-level medical expertise to patients in remote areas.[13]

PATIENT TRANSFER

Patients are often transferred from one medical facility to another for a higher level of care. Safe and seamless transfer is an important concept and may be facilitated if transferring and receiving facilities develop transfer agreements in advance. The Emergency Medical Treatment and Active Labor Act of 1986 sets forth rules hospitals participating in the Medicare program must follow. Under the Emergency Medical Treatment and Active Labor Act, all patients must receive a medical screening exam and be stabilized before transfer. There must also be explicit acceptance of the transfer by the receiving hospital.[14]

COORDINATED PATIENT RECORD KEEPING

Maintaining good medical records is important to any patient encounter. Prehospital medical records must be legible and readily accessible to hospital providers. Standardization of EMS records among different agencies within a region helps streamline transfer of information between prehospital and hospital providers. The adoption of electronic charting and cloud-based electronic medical record keeping by EMS systems is a step toward this goal. Electronic charts can be printed out in the receiving ED or downloaded from a secure Internet website. Regardless of the system used, EMS agencies must comply with the Health Insurance Portability and Accountability Act of 1996, designed to protect the privacy of patient health information.[15]

PUBLIC INFORMATION AND EDUCATION

EMS systems have a responsibility to train the public on how to access EMS and use it appropriately. As EMS call volumes rise and available resources decline, educating the public to use 9-1-1 for true emergencies is an appropriate goal. However, given the obstacles that many patients encounter in accessing office- or hospital-based care, conveying this message is not simple. The public needs to know that EMS will always be there when needed.

Another important message EMS can convey to the public is the importance of learning CPR, first aid, and basic disaster preparedness. Recent disasters have illustrated that, at times, the emergency response infrastructure may be so seriously disrupted that it may take hours or longer for help to arrive. A public that is adequately prepared and trained will be in a better position to safely await help.[16]

REVIEW AND EVALUATION

To ensure proper functioning of an EMS system and high-quality care, there must be a process for ongoing review and evaluation. This requires input from EMS providers and active involvement of a physician medical director. A continuous quality improvement program should be established to assess system performance and formulate improvements.[17] Routine audits of communications, response and scene times, and patient care records should be performed. Focused audits of conditions such as cardiac arrest and trauma are valuable. However, obtaining patient outcomes may be problematic. An unforeseen consequence of the Health Insurance Portability and Accountability Act is that hospitals are often hesitant to release patient information, even to EMS services, for fear of liability.

EMS research is invaluable in advancing prehospital care. It should not be assumed that what works in the hospital will work in the prehospital setting. Issues such as limited funding, barriers to getting patient outcomes, and obtaining informed consent from critically ill patients, or waivers of consent, can make prehospital research daunting. However, these barriers must be overcome if patients are to receive quality care.[18]

DISASTER PLAN

The EMS system is an integral part of disaster preparedness and should be involved in planning with other agencies and the medical community. The Omnibus Budget Reconciliation Act legislation of 1981 ended direct federal block grants to EMS. Because EMS is often not considered to be a public safety entity, emergency preparedness funding for EMS has fallen behind that of police and fire services.[1] Despite this, EMS agencies must maintain a high level of disaster preparedness. This involves written policies and procedures, stockpiling supplies that may be depleted in multicasualty situations, and participating in regional disaster drills with other emergency response agencies and hospitals.[19]

MUTUAL AID

EMS services should develop mutual aid agreements with neighboring jurisdictions so care is available when local agencies are unable to respond.[20] Depending on the size and resources of the system, mutual aid may be required frequently or only under extreme circumstances. Addressing in advance details such as reimbursement, credentialing, liability, and chain of command at incident scenes will streamline the process.

CHALLENGES AND FUTURE TRENDS

The 2006 Institute of Medicine publication *Emergency Medical Services at the Crossroads*[1] detailed many of the challenges facing EMS. These include fragmentation and lack of interoperability between EMS systems, between EMS and other public safety agencies, and between EMS and the rest of the healthcare infrastructure. These limit the efficiency of EMS systems and may have serious consequences in disaster response. In addition, the fallout from the Omnibus Budget Reconciliation Act legislation of 1981 is still being felt. Funding for EMS continues to fall behind other public safety agencies. Restructuring of Medicare payment for advanced life support and basic life support services has impacted reimbursement. The effect of the Affordable Care Act on EMS is unclear. It has resulted in an increased number of individuals covered by Medicaid and a proliferation of high-deductible insurance plans, factors that may affect EMS revenues. In the face of these uncertainties, many EMS agencies may have to find other funding sources or cut services. This is occurring at a time when call volumes are rising in many areas, in part due to the aging of the population and limited access to health care.[1]

While demand for EMS steadily grows, in many parts of the country, EMS staffing is not keeping pace. Many EMS systems are currently experiencing paramedic shortages. Low pay, high stress, increased length of training, and limited advancement opportunities may make alternative careers in health care more appealing.[21]

As a consequence of funding and staffing constraints, many EMS systems routinely operate at full capacity. As a result, their surge capacity, or ability to accommodate a sudden, large increase in demand for services, is limited. To enhance surge capacity, EMS systems need additional funding for personnel, vehicles, and supplies. They must also participate in mutual aid programs and frequent training based on threats they are most likely to encounter.[22-25]

Despite the many challenges EMS faces, the quality of care continues to improve, driven in part by EMS research. Some of the advances involve regionalization of care, resuscitation of cardiac arrest victims, and management of ST-segment elevation myocardial infarction (STEMI) patients. The quality of cardiac arrest studies has been enhanced by adoption of the **Utstein template** for data reporting. The Utstein style presents a systematic and standardized format for reporting cardiac arrest data, facilitating comparison of results of studies from different EMS systems.[26] The importance of basic life support skills in cardiac arrest and other emergencies is being rediscovered. Basic interventions in some cases can have a greater impact on outcome than advanced life support skills. More widespread use of automated external defibrillators by first responders and the public has the potential to increase cardiac arrest resuscitation rates. The emphasis on high-quality, uninterrupted CPR, as set forth by the 2015 Guidelines for CPR and Emergency Cardiovascular Care,[27,28] is widely reflected in EMS protocols.[29,30] Devices that provide instant feedback on the quality of CPR are in use by many EMS services.[31] Prehospital use of 12-lead electrocardiograms on patients with chest pain is now common.[32-35] Some systems transmit electrocardiograms to receiving EDs. Others activate cardiac catheterization labs directly when a patient with STEMI is identified on electrocardiogram.

EMS is maturing as an important subspecialty of emergency medicine. Growing populations and increased urbanization are driving the development of EMS systems worldwide.[36,37] The aftermath of the 2004 Asian tsunami emphasized the need for organized and effective prehospital care in developing countries, as well as for international cooperation among EMS agencies.[38,39] Although EMS systems in some countries are similar to those in the United States, in other countries, differences in geography, healthcare system design, funding, and political structure present unique challenges and the potential for novel solutions. These developing systems have the advantage of not being encumbered by decades of tradition and thus can take advantage of lessons learned elsewhere. They also present the opportunity for collaboration on international research initiatives that can lead to improved patient outcomes.[40]

REFERENCES

The complete reference list is available online at www.TintinalliEM.com.

CHAPTER 2

Prehospital Equipment

Brett Boggust
Andy Boggust

INTRODUCTION

To a large extent, early EMS equipment began as hospital equipment that was extrapolated to the field; it was assumed that if something worked in the hospital, then it would work in the field. It soon became apparent that hospital equipment did not always perform under the more rigorous conditions of the prehospital environment. Over the past 30 years, equipment has evolved specifically for EMS that is better adapted to field use in terms of size, weight, and durability. This equipment is directed at resuscitating and sustaining the patient during emergency or interfacility transport. As the science of EMS continues to mature, more equipment will be scrutinized for effectiveness.[1] The four basic questions regarding efficacy of EMS equipment are:

1. Does it do the job?
2. Is it safe?
3. Can it be applied to the field environment?
4. Can it be used effectively by prehospital personnel?

The nature of EMS equipment is changing due to the expanded scope of practice by paramedics and the blurring of care levels between basic life support (BLS) and advanced life support (ALS) personnel. Equipment once considered only for ALS care is now being carried on some BLS ambulances (e.g., defibrillators, vascular access adjuncts, and airway adjuncts).

VEHICLES

The vehicles may be ground ambulances, helicopters, fixed-wing aircraft, or a variety of first-response vehicles (fire engines, police cruisers, or sport utility vehicles). The most common vehicle used is the ground ambulance, categorized into three common varieties:

Type I: A standard truck (e.g., pick-up) chassis with a separate modular box to carry personnel, patient, and equipment

Type II: An enlarged van-type vehicle

Type III: A van chassis with an integrated modular box on the back for medical care and equipment

In types II and III, there is physical access between the driver's and patient care compartments, as opposed to type I, in which these spaces are separate.

Ground vehicles typically have warning devices (lights and siren) as part of their equipment. Unwarranted use of red lights and sirens is dangerous for the EMS crew, the patient onboard (if present), and the general public on the streets.[2,3] Protocols or guidelines to limit the use of these devices only to times when they are medically indicated are important.

COMMUNICATIONS

The two-way radio is an important piece of equipment carried by prehospital providers. As the arena of wireless communication changes, EMS systems will need to adapt their communications system to best fit their needs. The spectrum of frequencies available for emergency services is limited and shared with other industries that require wireless communications. In the United States, EMS services may use specific frequencies (*channels*) in the very-high-frequency (around 170 MHz), ultra-high-frequency (around 460 MHz), and public safety (around 800 MHz) bands. In an attempt to create more channels for users, the Federal Communications Commission (FCC) has decreased channel spacing from 25 to 12.5 kHz, and there is an FCC mandate to continue spacing down to 6.25 kHz. Although newer radio equipment can be reprogrammed to allow for the change in channel spacing, older equipment may not function correctly with this spacing.

Historically, EMS systems in rural or suburban settings have had broad control over their communications systems; however, as they transport patients into urban settings and attempt to communicate with urban providers, the problems of compatible frequencies and channel congestion may develop. Trunked systems (typically used by urban EMS systems) may be analog, very-high-frequency/ultra-high-frequency digital radio, or 800-MHz digital radio. An 800-MHz digital trunked system is popular because of the advantages of shared equipment between different providers (EMS, police, and fire), enhanced radio coverage, shared or lowered cost, and wide-area communications. The main disadvantage with all trunked systems is the cost necessary to upgrade the current system.[4]

The First Responder Network Authority (FirstNet) was created under the Middle Class Tax Relief and Job Creation Act of 2012 as an independent authority within the United States. FirstNet is charged with establishing, operating, and maintaining an interoperable public safety broadband network. To do this, Congress allotted $7 billion and 20 MHz of radio spectrum to build the network. FirstNet requires each state to have a Radio Access Network connecting to FirstNet's network core. FirstNet is responsible for consulting with states, local communities, and tribal governments to develop the requirements for its Radio Access Network deployment plan.[5] FirstNet is creating the first nationwide high-speed broadband network providing a single interoperable platform for law enforcement, firefighters, paramedics, and other public safety officials in every state, county, locality, and tribal area.[6]

ELECTRONIC MEDICAL RECORD

Use of the prehospital electronic medical record has increased substantially over the past 10 years. As usage of these electronic systems increases, bio-surveillance, research, and system quality assurance analysis have become easier because of better data access.[7-11]

Large systems with enough resources often have their own software specifically written for that system. Smaller EMS systems often use off-the-shelf alternatives. Using one of the latter products may require either modification of a vendor's product or modification of the EMS system workflow to make the software fully functional. Many states are in the process of generating or have already generated a common data set and are collecting statewide data, which are submitted to the state EMS agency.

One common difficulty with the prehospital electronic medical record is incompatibility with the hospital electronic medical record. This means that the ambulance record cannot be expeditiously transferred to the hospital database. Long-term solutions need to be devised to ensure that all of these record systems are compatible.[12]

PERSONAL PROTECTIVE EQUIPMENT

Every EMS provider must be educated about the risks of occupational exposure and protected against exposure to blood and other body fluids from patients. Equipment such as masks, goggles, and gloves for routine use should be carried on every EMS vehicle. On occasion, gowns or sturdy gloves may be needed.[13]

Exposure to hazardous material or biologic or chemical weapons of mass destruction requires more protective equipment. **Minimum personal protective equipment for such exposure should include a high-efficiency particulate air filter mask that filters 99.97% of airborne particles 0.3 μm in diameter (or an acceptable alternative for the purpose, such as an M95 military gas mask), goggles, gloves, and protective clothing.** Protective clothing should be nonabsorbent and puncture resistant (**Figure 2-1**).[14]

Some urban EMS providers wear soft body armor as a standard part of the uniform. Suburban and rural providers can be placed in situations that necessitate similar protection. With advances in soft-armor technology, there are now a variety of styles and levels of protection from which to choose. Although each service must consider such variables as comfort, heat, weight, and cost, for EMS providers, a combination of ballistic/stab protection is optimal.[15]

EQUIPMENT FOR STABILIZATION, RESUSCITATION, AND TREATMENT

This section reviews defibrillators, ECGs, airway and ventilation adjuncts, vascular access devices, spinal immobilization, and extremity immobilization.

DEFIBRILLATORS

Defibrillators have been an essential part of prehospital care since Pantridge showed that defibrillation could be done in the field on the streets of Belfast in 1965. **Because early defibrillation is the most important factor in surviving a cardiac arrest,**[16] defibrillators have become smaller, less costly devices that are more appropriate for the prehospital setting.

FIGURE 2-1. Personal protective equipment: filtered (high-efficiency particulate air, M95, N95, or chemical-specific) mask, goggles, gloves, and protective clothing. [From Professional Paramedic Association of Ottawa, http://www.ottawaparamedics.ca/special-ops/]

An increasing percentage of BLS services carry automated external defibrillators. These devices are shock advisory defibrillators. Automated external defibrillators analyze the patient's rhythm by computer algorithm, determine if the rhythm meets defibrillation criteria, inform the operator that a shock is advised, charge the capacitor, and deliver a defibrillation when the operator pushes the appropriate button. Automated external defibrillators are designed only to shock ventricular fibrillation and very fast ventricular or supraventricular tachycardias (usually >180 beats/min). Automated external defibrillators have become so easy to use and are so effective that many health and medical organizations are promoting these devices for first responder public safety personnel and for public access defibrillation by laypersons.[17-19]

Automated external defibrillators are basic and relatively inexpensive. They often do not have monitor screens that display the patient's rhythm. This actually may be better because a rhythm on the screen may serve only to distract a non-ALS operator.[20] The device should have recording capabilities so that the cardiac arrest can later be reviewed for medical oversight and quality assurance reasons.[21] The medical director should be involved in choosing such devices, training in their use, establishing protocols for their use, and reviewing their use afterward for quality assurance.[17]

Defibrillators used by ALS personnel are typically more sophisticated devices, usually with additional functions. Defibrillation is facilitated using hands-off combination monitoring/defibrillation adhesive pads rather than with handheld paddles. Pads give better contact with the skin and decrease skin resistance to allow for a higher success rate of rhythm conversion. It is also safer for the operator who does not have direct contact with the patient when the shock is delivered. The ALS defibrillator has a screen for interpreting rhythms and so is also used for ongoing monitoring of patients' rhythms. It may be used for cardioversion of nonlethal rhythms or pacing bradyasystolic rhythms. Additional critical care patient monitoring can be incorporated into an ALS defibrillator, including noninvasive blood pressure, pulse oximetry, end-tidal partial pressure of carbon dioxide in intubated patients, and other physiologic parameters. ALS personnel can use these machines for closely monitoring very ill patients during emergent calls or interfacility transfers.

Modern defibrillators use biphasic waveforms for shock delivery (as opposed to the traditional monophasic waveform). Biphasic defibrillators defibrillate and cardiovert at lower energy levels and thus decrease myocardial injury.[22]

Prehospital 12-lead ECGs have become increasingly important in the management of ST-segment elevation myocardial infarctions. Both BLS and ALS ambulance services can perform ECGs in the prehospital setting.[23,24] Analysis of ECGs provided immediately by the electrocardiograph has demonstrated limited sensitivity for detecting ST-segment elevation myocardial infarction.[25] However, sensitivity can be increased using serial prehospital ECGs, training paramedics to interpret ECGs, and providing computer-assisted interpretation or remote physician overread of the ECG.[26-29] Irrespective of the method of interpretation, patients with a prehospital 12-lead ECG showing ST-segment elevation myocardial infarction arriving at a hospital with a dedicated percutaneous coronary intervention team in place have reduced door-to-balloon time and reduced mortality when compared with similar patients arriving without a prehospital 12-lead ECG.[30-33]

AIRWAY AND VENTILATION ADJUNCTS

In a patient with acute respiratory failure or arrest, these devices maintain a patent airway that otherwise would have to be maintained by the paramedic. In addition, some airway adjuncts aid in preventing complications of airway management, such as gastric distention or aspiration. See Chapter 28, "Noninvasive Airway Management and Supraglottic Airways," and Chapter 29A, "Tracheal Intubation" and Chapter 29B, "Mechanical Ventilation," for detailed discussions of these topics.

Oral and Nasal Airways The simplest devices for airway management after manual airway maneuvers are the oropharyngeal and nasopharyngeal airways. These basic airway adjuncts usually are paired in the field with a simple bag-valve mask device for ventilation and will work quite well together.[34] Ventilation with the bag-valve mask can be difficult for a single person to both attain a good seal with the mask and compress the bag to produce an adequate tidal volume for the patient. It is probably more effective (especially for first responder and ambulance personnel who do not perform the skill often) to make this a two-person task (one person to maintain the seal and one person to compress the bag to maintain tidal volume). Along with these adjuncts, effective portable suction devices are available to be carried to the patient's side to help clear the airway.

TABLE 2-1 Comparison of Combitube®, LMA®, and King LTS-D®

Device	Use	Comments
Combitube®	Adults Adolescents >48 in. tall or age >14 y	Prevents/minimizes aspiration If inadvertently placed in trachea, will still ventilate Cannot use if gag reflex present Sturdy balloon
LMA®	Sizes for adults and children	May not prevent aspiration Can cause respiratory obstruction if incorrectly placed Cannot use if gag reflex present
King LTS-D®	Sizes for adults and children	Prevents/minimizes aspiration If inadvertently placed in trachea, will still ventilate Cannot use if gag reflex present Sturdy balloon Port for gastric decompression tube

Abbreviation: LMA® = laryngeal mask airway.

Supraglottic Airways More advanced airway devices are used if the patient appears to need more prolonged airway management or is at greater risk for aspiration.[35,36] At the BLS level, these airways include, most commonly, the **esophagotracheal Combitube®** or **King LTS-D® airway** or the **laryngeal mask airway (LMA®) (Table 2-1).** Each of these is used in conjunction with a bag-valve mask for ventilation. Supraglottic devices improve the airway seal to promote better ventilation than the bag-valve mask with the oral airway and seal the airway off with a balloon to reduce the risk of aspiration. Supraglottic airways may decrease hands-off time during resuscitation, but there is limited prehospital evidence to suggest that any advanced airway offers a neurologic survival benefit compared to simple bag-valve mask use.[37] Previous in-hospital evaluations of supraglottic devices have reported safety and efficacy. Future prehospital evaluations of supraglottic devices will need to address benefit, harm, and neurologic outcomes.

Although supraglottic devices are available for the pediatric population, a review of pediatric alternative airway devices used in prehospital care demonstrates the problems encountered in the field with airway management of children.[38] No clear benefit exists for endotracheal intubation over simple bag-valve mask, and evidence of benefit for prehospital supraglottic device use is very limited.[39,40]

Endotracheal Intubation Endotracheal intubation is the "gold standard" for airway management in all patients and is especially useful in patients in whom the other airway adjuncts are not satisfactory.[28] The majority of ALS systems use endotracheal intubation as the airway of choice for patients in respiratory failure or with an unprotected airway. Numerous adjuncts to assist with endotracheal intubation can be found in the ED as well as the prehospital setting. However, provider procedural experience is a primary determinant for successful placement. For further discussion, see Chapter 29A, "Tracheal Intubation" and Chapter 29B, "Mechanical Ventilation."

The basic emergency medical technician curriculum has an optional module for endotracheal intubation training. Therefore, intubation equipment may be found on some BLS ambulances. Increasing the number of ambulance personnel in need of endotracheal intubation training in an EMS system may cause logistic problems for the medical director. It is sometimes difficult to obtain adequate live intubation opportunities for the personnel in an EMS system to maintain skills. Some studies have shown that basic emergency medical technicians do not maintain endotracheal intubation skills and have low rates of successful completion.[41,42] This might suggest that intubation should remain an ALS skill.[43,44]

Rapid-Sequence Intubation Another intubation-related modality that has bearing on the equipment carried on an ambulance is **rapid-sequence intubation**. Critical care transport services have been performing rapid-sequence intubation for more than a decade, and now this same level of care is provided in ALS systems as well. Rapid-sequence intubation raises the level of training, judgment, and psychomotor skills needed by the paramedic, but has the advantage of being able to secure more difficult airways. In addition to the usual equipment required for intubation, rapid-sequence intubation requires ALS services to carry the medications needed for sedation and paralysis.[39] The technique increases the need for oversight and vigilance by the medical director. Numerous large EMS systems have all indicated difficulties with ALS prehospital intubation, with or without the assistance of neuromuscular junction blockade or sedation.[45-47] Intubation, especially rapid-sequence intubation, is a training-intensive modality. Large systems with many paramedics may have difficulties with training type and intensity.[44] Smaller services, such as air medical services, which have a smaller group to train, a smaller span of medical control, and more intubation experience per provider, may be able to attain and maintain the complex skills needed for rapid-sequence intubation.[48]

CONTINUOUS POSITIVE AIRWAY PRESSURE AND BILEVEL POSITIVE AIRWAY PRESSURE

Continuous positive airway pressure maintains a continuous level of positive airway pressure throughout the respiratory cycle. Similarly, bilevel positive airway pressure delivers continuous positive airway pressure in a preset or measured inspiratory positive airway pressure phase and expiratory positive airway pressure phase. BLS and ALS services become competent in the use of this adjunct with additional training and a broadened understanding of respiratory physiology.[49-51] Use of either modality in the ED and prehospital setting is lifesaving and cost-effective in the treatment of the severely dyspneic patient.[52,53]

VASCULAR ACCESS EQUIPMENT

The equipment used to establish IV access is the same as at hospital: tourniquets, cleaning agent, IV catheters, IV fluid bags, and IV tubing. ALS ambulances need IV access for fluid resuscitation and for administration of medications. In general, vascular access for medication administration is completed as soon as possible after the patient is assessed and it is determined that pharmacologic intervention is needed. For fluid resuscitation, usually in trauma patients, vascular access usually is started en route to the hospital after the patient is immobilized, unless there is prolonged scene time due to extrication. This is to avoid prolonged scene times that may be detrimental to a trauma patient who may need intervention in the operating room. In any event, the amount of fluid that can be administered during transport is modest and may not be physiologically significant. Some data show that aggressive fluid resuscitation of hypovolemic trauma patients is detrimental, in that it may increase morbidity and mortality by enhancing exsanguination from vascular or organ injury requiring operative intervention.[54,55] The difference between hospital and EMS usage of IV equipment is that the medical director must provide guidelines for when and how to institute vascular access to allow appropriate interventions at the appropriate time. Use of vascular access should be examined in the quality assurance process in an ongoing manner.

IO access devices are important adjuncts for rapid vascular access in the critically ill patient.[56] Multiple recent works document the ability of ALS providers to quickly establish functional IO access.[57,58] Guidance is provided in a position paper from the National Association of EMS Physicians (http://www.naemsp.org).[59,60]

PREHOSPITAL ULTRASOUND

US is an important diagnostic tool in the practice of emergency medicine. New diagnostic applications for bedside US in the ED are reported in emergency medicine literature almost monthly. Moving US into the prehospital setting would seem like a logical next step. Multiple investigations demonstrate the feasibility of prehospital US in the United States and Europe. Some prospective observational data on prehospital US in EMS systems is available.[61-64]

TABLE 2-2 Guidelines for Cervical Spine Clearance in the Field

- Absence of neck pain, tenderness, or discomfort
- Age between 11 and 65 y
- No altered sensorium
- No intoxication
- No distracting injuries

Source: Data from Tatum JM, et al. Validation of a field spinal motion restriction protocol in a level I trauma center. *J Surg Res*, 2017. 211: p. 223-227.

SPINAL IMMOBILIZATION

Preservation of the integrity of the spinal column and spinal cord is of paramount importance in the prehospital setting. The first person to assess the patient should immobilize the cervical spine immediately and, if necessary, simultaneously perform a modified jaw thrust to open the airway. Manual stabilization of the neck is not released until the patient has been transferred and securely strapped to a board. Short or long boards, either alone or in combination, are used to immobilize the spine depending on the initial position in which the patient is found by the emergency medical technician or first responder.

Carrying boarded patients takes a physical toll on emergency medical technicians and paramedics. Evaluation of the boarded patient is more expensive and time consuming in the ED because of the need to clear the cervical spine.[65] A reasonable approach is for the medical director to develop protocols and guidelines for clearance of the spine in the field.[66] A patient with no neck pain, tenderness, or discomfort (neck pain must be defined liberally and include stiffness or "feels funny"); not in the extremes of age (<10 years or >65 years); with no altered sensorium (no drugs or alcohol present, no head injury); and with no distracting injuries (long-bone fracture, abdominal or chest injury) may be cleared in the field because there is an extraordinarily low probability of neck injury (**Table 2-2**).[67]

SPINAL BOARDS AND CERVICAL COLLARS

Long or short spinal boards are made from plastic or wood and provide a rigid surface to minimize movement of the cervical, thoracic, or lumbar spine. Straps secure the patient to the board for transport. Some boards are provided with firm rubber blocks on either side of the head with straps to go across the blocks to keep the head steady. Blanket rolls or sandbags secured to the board with tape are also effective head blocks. A popular and effective variation of the short board is the Kendrick Extrication Device® (KED®) (**Figure 2-2**), which consists of slats of rigid material bound together by heavy cloth.

This board immobilizes the cervical spine, wraps partly around the patient, and is then strapped the rest of the way around the thorax and around the thighs for secure immobilization. If necessary, the patient can be lifted by the straps, allowing for easier and safer upward extrication from the vehicle.[68]

Rigid cervical collars are more accurately called cervical extrication devices. Multiple types are used in the field, such as the Philadelphia® collar, the Miami J® collar (**Figure 2-3**), the Stifneck® (Laerdal Medical, Wappingers Falls, NY), and the Nec Loc® (Junkin Safety Appliance Co., Louisville, KY).

The collars come in two asymmetric pieces, which are used and marked for back and front, or as a single piece that is folded into the correct shape. By themselves, collars are not adequate for cervical immobilization but require additional lateral support to avoid movement in that direction. For adequate immobilization, the patient needs to be strapped on the backboard and secured with head blocks and head straps. Once the patient is well secured to the board, the collar does not add a significant amount of stabilization and actually can

FIGURE 2-2. Kendrick Extrication Device® (KED®) (Armstrong Medical Industries, Lincolnshire, IL). [Reproduced with permission from Armstrong Medical Industries, Inc.]

be removed without compromise of the spine; however, it is often left in place for added protection. Patients with mandible or soft tissue neck injuries probably should not have a collar applied because of the potential for airway compromise, which could be masked by the collar. Newer collars have openings in the front to allow observation of the trachea and jugular veins, but this may not be adequate for observing other neck areas. Soft cervical collars are not adequate or appropriate for prehospital care.

FIGURE 2-3. Miami J® collar. [Reproduced with permission from Ossur Americas, Foot Hill Ranch, CO.]

SEQUENCE OF SPINAL IMMOBILIZATION

Prehospital personnel are taught to have a high index of suspicion for spine trauma. **If the patient is sitting in a car after an accident and is stable from respiratory and circulatory standpoints, a short spine board and rigid cervical collar or Kendrick Extrication Device® are first used to get the patient out of the vehicle safely and onto a long spine board.** If the situation at hand is a critical one because of the patient's condition or the threat of hazards, such as chemicals, fire, or water, the patient can be extricated more rapidly using only the cervical collar. After applying the cervical collar, the patient is carefully rotated out and slid onto the waiting long board.

At a noncritical scene, when the patient is still sitting in the vehicle, one emergency medical technician secures the neck with his or her hands and applies the necessary airway maneuvers, while the second emergency medical technician applies the rigid cervical collar. The short board is then slid in behind the patient, and the patient is strapped to the short spine board. (Short boards are not used if the patient is not seated in a vehicle.) The first emergency medical technician maintains manual stabilization of the neck until the patient is secured to the short board. The patient's head and trunk can then be rotated around as one unit and slid directly onto the long board positioned on the car seat or on the ambulance cot. The patient is then strapped to the long board and then to the cot. A properly boarded patient can be turned on the board or even stood on end if necessary to move the patient to the ambulance. If the patient vomits, for instance, the board can be partly log-rolled up to prevent aspiration.

Because of the difference in relative size and positions of head and body, adults and children need slightly different positioning on a backboard. **An adult needs more padding under the head, whereas a child needs more padding under the body to maintain neutral neck position.**

If a patient is walking at the scene when the paramedical personnel arrive but complains of neck pain, the patient can be boarded from a standing position. If the patient is lying on the ground when the emergency medical technicians arrive, the patient can be carefully log-rolled by several attendants onto a long backboard.

Immobilization on a rigid board produces midline cervical pain and tenderness, so examination and radiographs should be performed promptly on arrival. Radiographs can be done without difficulty through short and long boards. In general, patients should not be removed from immobilization until the spine has been cleared clinically and radiographically. Transfer from the hard prehospital board to a padded board at the hospital is desirable if the patient may spend prolonged time immobilized.[69,70]

FOOTBALL HELMET REMOVAL

The National Athletic Trainers' Association and the Inter-Association Task Force for the Appropriate Care of the Spine-Injured Athlete developed guidelines for the prehospital care of athletes with potential spine injury. **These guidelines had recommended that the face mask of a football helmet be removed at the earliest opportunity, before transportation and regardless of respiratory status.**[71] However, because a properly fitted football helmet with shoulder pads holds the head in a position of neutral spinal alignment, field removal of these devices is no longer recommended by these guidelines, a tenet held in many EMS systems. It is recommended that the helmet and shoulder pads remain on as the athlete is immobilized and transported on a rigid backboard.[72-74] Simultaneous removal of the helmet and shoulder pads should be done after clinical assessment and radiographs at the hospital, although radiographs may have to be repeated after equipment removal.

Removal of football shoulder pads and helmet requires several individuals to maintain spinal alignment (**Figure 2-4**). One individual stands at the head of the bed to stabilize the patient's head, neck, and helmet, while others stabilize the spine and body. All straps and laces that secure the pads to the torso and arms are cut, not unbuckled or unsnapped. The laces or straps over the sternum are cut, allowing the right and left anterior portions to be spread open, exposing the chest. The posterior portion of the shoulder pads is kept in place to maintain spinal alignment with the helmet. Another individual cuts the chin

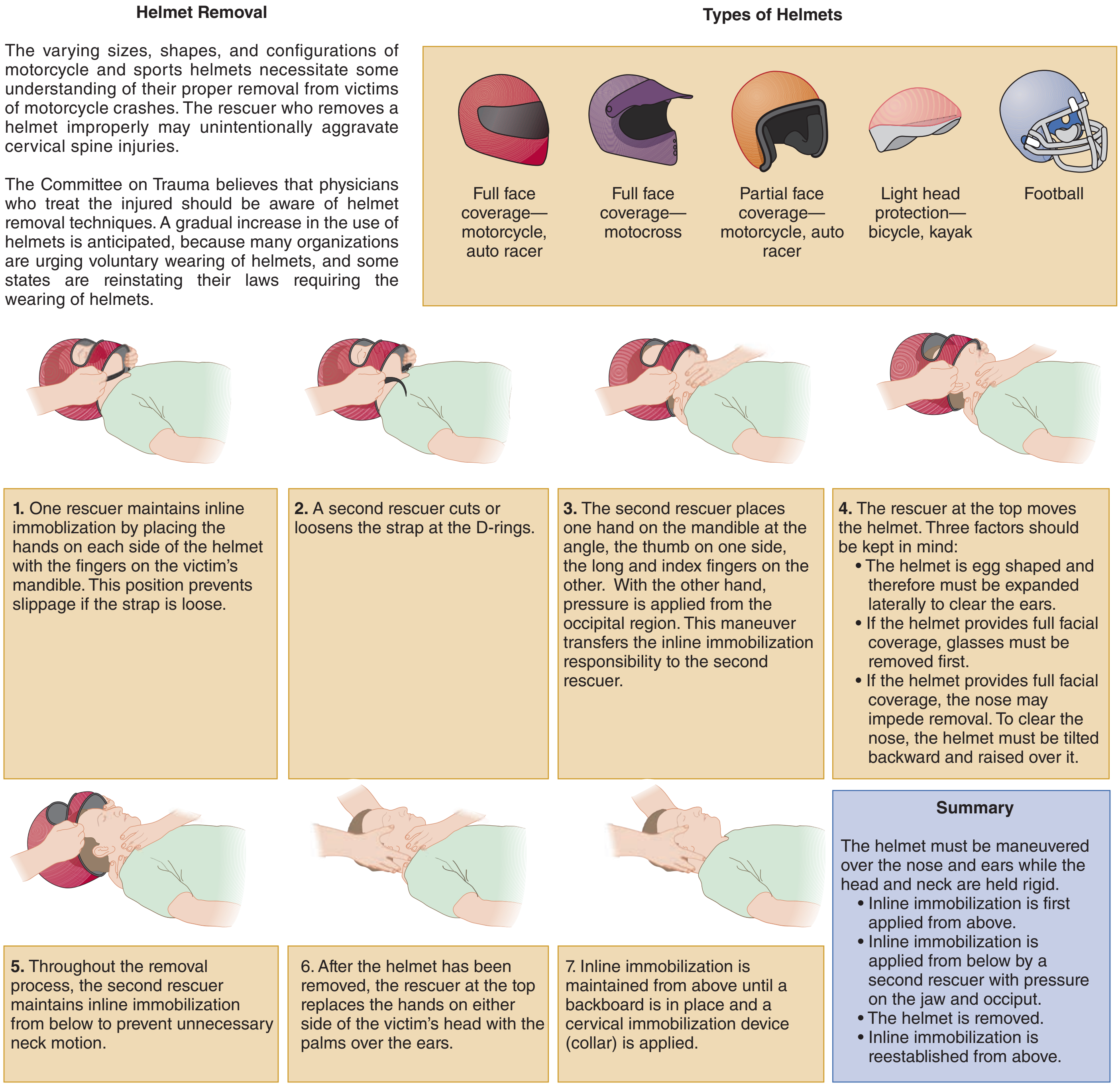


FIGURE 2-4. Helmet removal technique. [Reproduced with permission from American College of Surgeons, Committee on Trauma Brochure, April 1997.]

strap from below while standing beside the patient's chest. Accessible internal padding should be removed from inside the helmet and any air bladders deflated. The individual standing alongside the patient's chest then reaches up into the helmet to stabilize the head by placing a hand with fingers and thumbs spread alongside the jaw, mastoid region, and occiput. (See Video: Football Helmet Removal.)

Two additional individuals stand alongside the patient's chest and place their hands directly on the skin in the thoracic region. On command, the patient is lifted slightly, with all four individuals maintaining spinal alignment. The individual standing at the head of the bed can remove the helmet by a slight forward rotation to slide it off the occiput. Slight traction or anteroposterior motion may be necessary, but care should be taken not to move the head and neck unit. Attempting to assist removal by pulling on the ear holes tightens the helmet in the forehead and occipital regions and does not help. The posterior portion of the shoulder pads is removed, and the patient is lowered. A rigid cervical collar can then be placed.

TRACTION SPLINTS

Pelvic fractures and lower extremity fractures are potentially life and limb threatening. Fractures of the femur can damage vessels and nerves when bony fragments move. Stabilization in the field is important to minimize blood loss and soft tissue damage. The femoral traction splint is the preferred device for femur fractures.

Several leg traction splint variations are available for use. The two most commonly used types are the Hare® splint (Dynamed, Westbury, Tasmania) and the Sager® splint (Minto Research and Development, Inc., Redding, CA). The underlying technique is the application of traction by a hitch on the ankle against resistance when the splint impinges

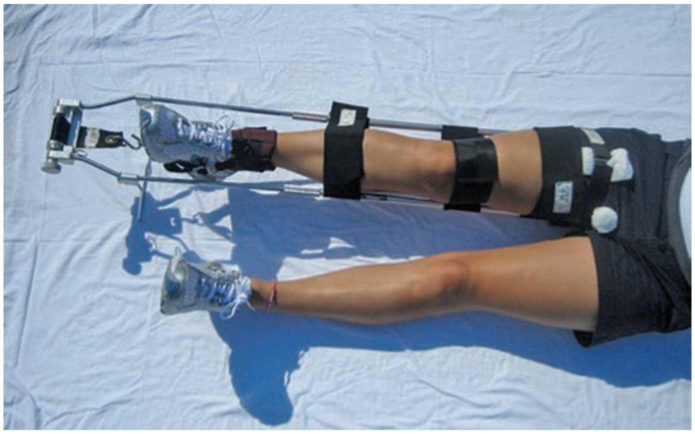


FIGURE 2-5. Hare® traction splint. (Courtesy of Jan Smith, RN, MPH, NREMT-P; acknowledgments to Kara Smith and Lucky Bruton, EMT-P.)

proximally on the pelvis. The padded proximal end of the Hare® splint abuts the ischial tuberosity (**Figure 2-5**). The proximal end of the Sager® splint rests against the pubic symphysis (**Figure 2-6**). **These splints cannot be used if a pelvic fracture is suspected because the pressure on the pelvis may further displace a fracture and cause more bleeding. Also, do not apply a traction splint if there is open fracture, hip dislocation, suspicion for neurovascular injury to the extremity, or injury about the knee, because a traction splint may exacerbate neurovascular or knee injury.** (See Video: Hare Traction Splint.)

Leg traction splints also may be used for tibial shaft fractures. Traction splints should not be used for fractures near the knee because longitudinal traction may damage neurovascular structures in the popliteal region. Traction splints for the tibia should be reserved for angulated or displaced fractures; otherwise, an air splint or a pillow splint would suffice.

At the scene, clothing should be removed and the extremity assessed for injury and distal neurovascular function. If the Hare® splint is used, the proximal half ring is placed in the crease of the buttocks against the ischial tuberosity. Traction is placed on the ankle with the padded ankle strap by one rescuer while the splint is strapped to the leg. The ankle strap is then attached to a ratcheting mechanism, and traction is tightened. If a Sager® splint is used, the splint is placed on the medial side of the limb up against the groin. The padded ankle hitch is applied, and traction is applied until malalignment is reduced and pain is relieved. Elastic straps are then applied to hold the splint to the leg.

The Hare® splint can be longer than an ambulance cot when fully extended, and care needs to be taken when closing the rear door of the ambulance. The Sager® splint is shorter than the Hare® splint, and one Sager® splint can be used to splint both legs simultaneously. The Sager®

FIGURE 2-6. Sager Emergency Traction Splint; Model S304, Form III Bilateral, Application step 3 "Secure." [Used with permission from: Minto Research & Development, Inc., Redding, CA.]

splint is less bulky and therefore takes up less room in an ambulance or a helicopter.

PELVIC STABILIZERS

Unstable pelvic fractures can be immobilized to minimize the risk of bleeding from patient movement and during transport.[75] A sheet wrap, applied around the patient at the level of the trochanter and fastened with a clamp or hemostat, is the simplest stabilization method. Commercial devices, such as the SAM Pelvic Sling®, are also available.

PHARMACEUTICAL SUPPLIES

The basic emergency medical technician curriculum has modules that teach emergency medical technicians to administer a patient's personal medication in specific circumstances. For example, modules are provided for administering nitroglycerin for chest pain, inhaled β-agonists for bronchospasm, glucagon for hypoglycemia, and epinephrine-preloaded injections for anaphylaxis. Some states have gone beyond this and allow BLS services to stock and provide the medications covered in these modules.

The medications carried by ALS services are more extensive, but prehospital pharmaceutical interventions are limited to the few that make a real difference before or during transport.[76,77] These include oxygen, glucose, nitroglycerin, inhaled β-agonists, naloxone, parenteral narcotic and nonsteroidal analgesics, benzodiazepines, furosemide, epinephrine, lidocaine, magnesium, amiodarone, adenosine, diltiazem, calcium, and sodium bicarbonate. In the system that provides rapid-sequence intubation, neuromuscular junction–blocking agents (succinylcholine, vecuronium) are also provided.

REFERENCES

The complete reference list is available online at www.TintinalliEM.com.

CHAPTER 3

Air Medical Transport

Keith C. Stone
Stephen H. Thomas

INTRODUCTION

Air medical transport consists of helicopter (or rotor-wing) and airplane (or fixed-wing) transport and is an important component of EMS systems for prehospital care and interfacility transport. These specialized vehicles offer fast speeds, ranging from 100 to 200 miles per hour for helicopters to >500 miles per hour for airplanes. Although many ill and injured patients can be transported safely by ground, air medical transport provides added medical assessment and care capabilities beyond those of the paramedic-staffed ground ambulance. Guidelines for the use of air medical transport exist, but field EMS personnel and physicians involved in transfer decision making should be able to consider situational circumstances to determine the appropriate transportation mode.

Weather can be an operational limitation, particularly for helicopters. The radius of service differs between helicopters and fixed-wing craft, but, as a general rule, fixed-wing transport is considered when weather conditions are poor or when transport distances exceed 150 to 200 miles.

The complexity of air transport far exceeds the simple act of loading a patient on an airborne vehicle. National organizations such as the Air Medical Physician Association, the Committee on Accreditation of Medical Transport Systems, and the National Association of EMS Physicians have published texts, position statements, and guidelines covering aspects of air medical transport. The Air Medical Physician Association (http://www.ampa.org) *Air Medical Physician Handbook* is a particularly helpful resource for medical issues. The Committee on Accreditation of Medical Transport Systems (http://www.camts.org) accreditation standards address medical, aviation, organizational, and operational issues. The National Association of EMS Physicians (http://www.naemsp.org) has created detailed position statements and guidelines addressing helicopter EMS trauma and nontrauma triage criteria, as well as training of physicians involved as air medical crew or medical directors.

Rigorous training programs, covering both cognitive and procedural skills, enable flight crews to provide a high level of intratransport care. In-flight communications capabilities should include the ability of the air medical crew to speak with medical control physicians, as well as arrange for any change of plan (e.g., direct transport to the operating suite) necessitated by patient condition.

HELICOPTER TRANSPORT

AVIATION ISSUES

Individual hospitals, hospital systems, or private for-profit enterprises run most U.S. civilian air transport programs. Because helicopters are expensive (ranging from $750,000 to more than $5 million each) and other aviation needs (e.g., maintenance, pilot training) are also resource intensive, most hospital-based programs lease their helicopters from vendors. The air medical program typically provides and equips communications and medical personnel, whereas the aircraft vendor supplies the helicopters, pilots, and maintenance personnel. Although costs vary depending on geographic region, patient case mix, equipment and aircraft used, and even the methods used for their calculation, annual operating costs for a rotor-wing service typically exceed $2 million.

Safety is an overriding consideration for air transport. Optimization of safety begins well before an actual air transport, with training of the flight crew and of those who interact with them at scenes and hospitals. Training is especially important for scene responses, in which the helicopter may be landing in an unknown area with more nearby obstacles (e.g., wires, trees) than the hospital helipad. In addition to providing training for referring agencies, helicopter EMS pilots and medical crew should undergo both initial and recurrent safety training. For added protection, most helicopter EMS programs have followed the lessons of the military experience and adopted injury-prevention maneuvers such as the use of helmets and fire-resistant clothing. As another safety issue, the pilot should be "blinded" to the nature of the call during mission planning; this eliminates the introduction of acuity-related subjectivity as the pilot considers whether the mission should be accepted.

Safety is partially behind the transition of helicopter EMS programs from single-engine helicopters with visual flight rules capability to twin-engine helicopters that can fly under instrument flight rules conditions. The latter aircraft have greater lifting capacity, range, and speed and usually can execute controlled landings in the event of failure of one engine. A visual flight rules aircraft can fly only during good visibility, whereas instrument flight rules aircraft operate safely in poorer conditions; both comply with visibility limitations imposed by the Federal Aviation Administration, but the instrument flight rules helicopter has fewer restrictions. If the pilot unexpectedly encounters bad weather during a flight, an instrument flight rules helicopter (as compared with a visual flight rules aircraft) has a better chance of completing the mission successfully and safely. Due to the complexity of instrument flight rules operations, some programs (especially those with frequent bad weather periods) have elected to use two-pilot instrument flight rules.

Air medical programs operate under rules established by the national aviation authority—in the United States, the Federal Aviation Administration. Additionally, the industry itself has set forth stringent standards under the auspices of the Committee on Accreditation of Medical Transport Systems. On request, the Committee on Accreditation of Medical Transport Systems performs site visits of air medical programs to certify that they comply with strict safety and operational (as well as clinical) standards. As of September 2016, 183 U.S. transport programs were accredited by the Committee on Accreditation of Medical Transport Systems.

AIR MEDICAL CREW

The primary considerations regarding medical members of the flight crew are crew configuration and training. Although there are few absolutes with regard to optimal configuration, initial and recurrent training is at least as important as the credentials of the flight team members.

The air medical team can have multiple compositions: nurse–paramedic, nurse–nurse, nurse–physician, or nurse–respiratory therapist. These differences may be one reason that the literature has failed to answer definitively the seemingly simple question of whether a physician should be on board the helicopter. Most U.S. programs agree that physicians are not a necessary component of helicopter EMS crews, and a recent survey showed that 92% of programs use nurse–paramedic crews.[1]

The capabilities of most U.S. nonphysician crews represent an *extended scope of practice.* For instance, flight paramedics and/or nurses frequently are credentialed to perform such procedures as neuromuscular blockade–assisted endotracheal intubation and cricothyrotomy. This example of extended practice scope is important, given the importance of prehospital airway considerations and the fact that flight crews represent a highly trained group with particular expertise in this area. Reported success rates for nonphysicians are as high as 94.6% for drug-assisted and 97.7% for rapid sequence intubation–assisted endotracheal intubation and 90.9% for surgical cricothyrotomy.[2]

At this time, the best recommendation with regard to crew configuration is for programs to continue to do what works for them, as the literature does not report the superiority of a particular model. Most U.S. programs perform a variety of scene and interfacility missions for trauma and nontrauma indications, so the nurse–paramedic configuration, combining the complementary skills of prehospital and hospital-based practitioners, meets their needs. Some transport population heterogeneity can be addressed by the accommodation of extra crew members (e.g., neonatal nurses, intra-aortic balloon pump technicians) when logistics allow. Regardless of the background of the air medical crew, initial and recurrent training in both cognitive and procedural skills is necessary to ensure an optimal level of care.

ENVIRONMENTAL FACTORS OF AIR TRANSPORT

Patient care in any transport vehicle differs from that provided while the patient is on a hospital stretcher. Vehicle vibrations, bumpy rides, noise, physiologic stress, ergonomic constraints (**Figure 3-1**), and motion sickness are among the factors that can affect monitoring and interventions.

The impact of most vehicle-related issues in helicopter EMS can be eliminated, or at least reduced. Some solutions are easy (e.g., visual rather than aural alarms on ventilators), but flight crews must learn to "work around" other limitations (e.g., perform preflight intubation

FIGURE 3-1. The patient care compartment in a Dauphin II helicopter.

on patients who appear likely to deteriorate). Some problems will be specific to a service's particular aircraft, mission profile, or crew background. Individual program patient care protocols should take into account the service's equipment and personnel-related capabilities and limitations.

One transport-related issue that cannot be avoided is the question of **altitude and its potential effects on the patient and the crew**. In fact, altitude considerations vary with location—a Denver-based program has concerns that are different from those of a Miami service. Environmental conditions also have an impact on altitude considerations, because aircraft operating under instrument flight rules frequently fly at higher altitudes than those operating under visual flight rules. Of course, fixed-wing transports have more pronounced altitude considerations.

Helicopter (or fixed-wing) altitude and environment have potential effects on patient pathology as well as the crew's ability to monitor and care for the patient. Helicopters generally transport patients at about 1000 to 3500 ft above ground level (not necessarily sea level), although sometimes these altitudes are increased for instrument flight rules flights or for clearing of obstacles or terrain. Therefore, altitude-related problems such as hypoxemia, dehydration, and low temperature tend to be mild or relatively easily to overcome. However, geographic differences are important. Some western U.S. programs fly with supplemental oxygen for the medical crews.

Pressure-related problems related to Boyle's law (the volume of a gas increases when the pressure decreases at a constant temperature) may represent the most important consideration for helicopter-transported patients. For example, even the relatively low transport altitude range for helicopter EMS may affect patients with certain diagnoses (e.g., decompression sickness, cerebral arterial gas embolism) or instrumentation (e.g., tamponading devices for esophageal variceal hemorrhage). Endotracheal intracuff pressures increase an average of 33.9 cm of water at a mean altitude of 2260 ft.[3] This could raise the cuff pressure above the perfusion pressure of the tracheal mucosa, leading to injury. Hand-held commercially available devices can be used to keep cuff pressure within the target range of 20 to 30 cm of water. The devices are held in one hand and connected to the cuff inflation port. An inflation bulb can be used to further inflate the cuff, or an air-release button can be used to remove air while the cuff pressure is simultaneously measured by the device.

In some cases, an understanding of altitude issues is important in preventing complications. To minimize aspiration risk, gastric intubation should be performed for unconscious patients transported by air. Alternatively, understanding of the relevant science can be used to prevent overreaction to potential barometric risks. For example, not all patients with small pneumothoraces who do not otherwise require tube thoracostomy require pretransport chest decompression simply because they are to be transported by air.

CLINICAL USE OF HELICOPTERS

While trauma still constitutes the majority of helicopter transports for most programs, as more time-critical treatments develop, **more transports will be arranged for noninjured patients**. There are many schemes (age group, scene/interfacility mission type) for categorization of helicopter EMS transports, but the simplest categorization is into trauma and nontrauma. Logistical issues are important to both categories. Therefore, these are considered first.

LOGISTICS AND HELICOPTER EMS USE

Some logistic prompts for helicopter consideration include **(1) lengthy transport time for ground ambulances to reach the tertiary center, (2) ground vehicle transport time to the local hospital exceeds the time required for helicopter transport to the tertiary center, and (3) for entrapped trauma patients, extrication time is expected to exceed 20 minutes**. In some cases, helicopter EMS is used because local ground EMS personnel lack the expertise to provide the indicated level of intratransport care. Another important consideration is whether a region's ground EMS system can provide transport to the receiving tertiary center while maintaining the ability to cover its base area with appropriate advanced life support care. Questions that can assist healthcare providers in determining the appropriate transport modality for an individual patient are listed in **Table 3-1**.

TABLE 3-1 Questions to Aid in Determining Need for Helicopter Transport

- Is minimization of time spent out of hospital important?
- Is time-sensitive evaluation and treatment involved, and is it available at the referring facility?
- Is the patient inaccessible to ground transport?
- What are the transport route weather conditions?
- Does the weight of the patient preclude air medical transport?
- Are aircraft landing facilities available at or near the referring hospital?
- Is critical-care life support required that is not available with ground transport?
- Would ground transport leave the local area without adequate EMS coverage?
- If local ground transport is not an option, are regional ground critical-care transport services available?

HELICOPTER EMS FOR TRAUMA PATIENTS

There is one group of trauma patients—those in **traumatic cardiac arrest**—for whom air medical scene response has shown a very low rate of resuscitation and essentially zero survival.[4] Most helicopter EMS programs have their crews accompany traumatic arrest patients by ground to the nearest facility.

After the initial triage response decision, **the larger issue is whether helicopter EMS actually improves outcome for *any* injured patients**. There is disagreement over this question, but multiple studies have shown improved outcomes.[5-8]

The recent largest study to demonstrate improved outcomes after traumatic injury related to helicopter transport analyzed 223,475 patients from the National Trauma Data Bank transported by helicopter (28%) or ground EMS (72%). For trauma patients who were admitted to level I or level II centers, patients transported by helicopter had a significantly improved survival to hospital discharge compared with patients transported by ground transport.[5] Another recent study of 14,440 trauma patients taken to a level I trauma center demonstrated that patients transported by helicopter had a reduced overall mortality and that patients transported by all other means were more likely to die in the ED.[8]

The outcomes of rural trauma patients are thought to be worse than those of urban trauma victims. After controlling for age, gender, and Injury Severity Score, a Utah study[9] of helicopter transports from rural and urban trauma scenes found no difference in mortality. This study demonstrated that the helicopter scene transport of rural trauma victims appears to be a mortality equalizer.

A shortcoming of the literature is that studies generally address only the hard end point of mortality, with little emphasis on either mechanisms for survival improvement or nonmortality end points. Regardless of these shortcomings, the primary issue for trauma helicopter EMS is not whether some patients benefit, but rather how well those patients most likely to benefit from helicopter use can be identified by improved triage criteria. Although definitive criteria are lacking, the National Association of EMS Physicians has published guidelines for clinical situations that are appropriate for air transport (**Table 3-2**).

HELICOPTER EMS FOR NONTRAUMA PATIENTS

The reason that helicopter EMS trauma literature is (relatively) abundant is that there are ready means for controlling for the differing acuities of air- and ground-transported patients. Unfortunately, there is no such easy methodology for patients with nontrauma diagnoses, and acuity scales for nontrauma patients generally have not been accepted for use in assessing the association between transport mode and outcome.

Some general guidelines are available (**Table 3-3**), and the logistic considerations noted previously apply to nontrauma flights. **In most helicopter EMS programs, the largest single nontrauma diagnostic category is cardiac**. Patients in cardiac arrest should be transported to the nearest hospital rather than loaded on an aircraft. Transport for

TABLE 3-2 Air Transport Indications for Scene Trauma

General and mechanism of injury
- Trauma score <12
- Unstable vital signs
- Significant trauma in patients age <12 or >55 y and pregnant patients
- Multisystem injuries
- Ejection from vehicle
- Pedestrian or cyclist struck
- Death in same passenger compartment
- Penetrating trauma of the head, neck, chest, abdomen, or pelvis
- Crush injury of the head, chest, or abdomen
- Fall from height
- Near drowning

Neurologic injuries
- Glasgow Coma Scale score <10
- Mental status deterioration
- Obvious skull fracture
- Spinal cord injury

Thoracic injury
- Major chest wall injury (e.g., flail chest)
- Pneumothorax
- Hemothorax
- Suspected cardiac injury

Abdominal/pelvic injuries
- Significant abdominal pain after injury
- Seatbelt sign or abdominal contusion
- Rib fractures below the nipple line
- Unstable pelvis
- Open pelvic fracture
- Pelvic fracture with hypotension

Orthopedic injuries
- Amputation of limb (partial or complete)
- Finger or thumb amputation when replantation is available
- Fracture/dislocation with associated vascular compromise
- Limb ischemia
- Open long-bone fractures
- Two or more long-bone fractures

Thermal injury
- Burns of >20% body surface area
- Burns of face, head, hands, feet, or genitalia
- Inhalation injury
- Chemical or electrical burns
- Burns associated with other traumatic injuries

TABLE 3-3 Air Transport Indications for Nontrauma Conditions

Cardiac
- Acute coronary syndromes
- Cardiogenic shock
- Cardiac tamponade
- Mechanical cardiac disease (cardiac rupture)

Critically ill medical or surgical patients
- Pretransport cardiac arrest
- Pretransport respiratory arrest
- Mechanical ventricular assist
- Continuous vasoactive medications
- Risk of airway deterioration
- Severe poisoning
- Need for hyperbaric oxygen treatment
- Emergent dialysis
- Unstable GI bleeding
- Surgical emergencies (e.g., aortic dissection)

Obstetric
- Delivery will require obstetric or neonatal care beyond the capabilities of the referring facility
- Active premature labor <34 wk or estimated fetal weight <2000 grams
- Acute abdominal emergencies <34 wk or estimated fetal weight <2000 grams
- Preeclampsia or eclampsia
- Third-trimester hemorrhage
- Fetal hydrops
- Complicated maternal medical conditions
- Predicted severe fetal heart disease

Neurologic
- CNS hemorrhage
- Spinal cord compression
- Status epilepticus

Neonatal
- Gestational age <30 wk or fetal weight <2000 grams
- Supplemental oxygen exceeding 60%, continuous positive airway pressure, or mechanical ventilation
- Extrapulmonary air leak, interstitial emphysema, or pneumothorax
- Medical emergencies (e.g., congestive heart failure, disseminated intravascular coagulation)
- Surgical emergencies (e.g., diaphragmatic hernia, necrotizing enterocolitis)

primary or rescue coronary intervention for ST-segment elevation myocardial infarction is a frequent indication for helicopter use and can be done rapidly and safely.[10,11] Cardiac patients with pacemakers or those who have received thrombolytic therapy can be transported safely and effectively by helicopter EMS.

Another growing indication is the provision of lytic therapy or vascular intervention for ischemic stroke.[12] The American Stroke Association (http://www.strokeassociation.org) Task Force on Development of Stroke Systems[13] identified helicopter EMS as an important part of stroke systems. However, a study of 122 patients transported to a stroke center after receiving recombinant tissue plasminogen activator at the referring hospital demonstrated no benefit in patient outcomes in air-transported patients.[14]

Obstetric transports are a special consideration for air transport because many high-risk patients are best delivered at tertiary care centers. The question for this population is primarily one of safety during transport. In-flight deliveries are a major resuscitation problem for both mother and infant. Experience has provided some reassurance that the use of helicopter EMS to transport high-risk obstetric patients did not result in deliveries in the back of the helicopter, and **neonatal outcomes are not adversely impacted by transport**.

FIXED-WING AIR MEDICAL TRANSPORT

Fixed-wing aircraft can serve a wide variety of missions, from urgent to routine, over great distances. Because airplanes land only at airports, they cannot respond to the scene, and fixed-wing transports need ground ambulance connections at both ends of the flight to transport the patient between the hospital and airport. Because of these factors, fixed-wing flights generally take longer to arrange and are uncommonly used for truly emergent patients.

Helicopters are virtually always dedicated as air medical transport vehicles when used by U.S. EMS services, but fixed-wing airplanes used for medical transport may have other roles. When fixed-wing aircraft are used for air medical transport, cabins must be reconfigured. Vendors have developed removable medical equipment modules that can be placed relatively quickly in the aircraft cabin.

On a per-mile basis, fixed-wing transports are less expensive than helicopter EMS transports. However, the optimal transport radius for fixed-wing triage varies with regional and patient-specific considerations. The appropriate aircraft to use for any one mission depends on many factors: distance, the nature of the airport at the patient's pickup point, the condition of the patient, the amount of equipment, and the crew required in transport. A larger plane that can be pressurized can fly above 3000 m (10,000 ft), which means that the aircraft can travel faster, farther, and more comfortably. At these higher altitudes, flight crews must have a deeper understanding of altitude physiology issues. Cabin pressure (i.e., indicated altitude above sea level) should be recorded on medical records because of the importance of pressure issues to physiology, and crew safety training should include measures to take in case of inadvertent cabin depressurization.

All fixed-wing services must comply with civil aviation authority rules for airplanes. The Commission on Accreditation of Medical Transport Systems has developed standards for air medical fixed-wing transport. These standards, which are also a useful primer for more detailed information about fixed-wing air medical transport, deal with aircraft configuration, medical equipment requirements, medical crew configuration and training, and medical director qualifications.

MEDICAL DIRECTION OF AIR MEDICAL SERVICES

Medical direction may be even more important with rotor- and fixed-wing services than with ground services; it is certainly more complicated because it involves most aspects of ground EMS in addition to vehicle-specific and altitude- and acuity-related issues. The medical director should be familiar with the physiology and stress of flight on patients and should oversee the teaching of these and other applicable principles to the air medical crew. Overall, **a flight crew requires more initial and ongoing training than do most ground EMS personnel due to the higher patient acuity and extended practice scope**. Because flight crews are often far from their base of operations and may be out of voice contact, they must be sufficiently trained so that they can act independently when necessary. For nonphysician crew, standing orders or protocols (especially for advanced procedures such as cricothyrotomy) are needed. Periodic review and updating of these protocols, as well as close inspection of every transport record, are among the many responsibilities of the medical director. The Air Medical Physician Association and the National Association of EMS Physicians have published information on the responsibilities and function of the air medical program physician director.

REFERENCES

The complete reference list is available online at www.TintinalliEM.com.

CHAPTER 4 Mass Gatherings

Asa M. Margolis
Michael G. Millin

INTRODUCTION

Mass gathering medical care refers to the provision of medical services to organized events or venues with relatively large numbers of people in a defined geographic area. Typically, mass gatherings are considered to be events that have at least 1000 people; however, this does not have to be the case.[1,2] In fact, large organizations including the World Health Organization and the U.S. Federal Emergency Management Administration do not focus on the number of attendees when defining mass gatherings; rather, they recognize the impact on the surrounding resources.

There are several variables in event and crowd characteristics that may affect patient presentation rates, thus resulting in demands on the event medical staff and larger surrounding system that bear little direct relationship to the number in attendance. Some of these variables include weather conditions, presence of alcohol and/or illicit substances, type of event, violent spectator behavior, and presence of potable water. Further, events that are considered "bounded/focused" (stadium sporting events) are associated with higher patient presentation rates than those considered "unbounded/extended" (parades), likely due to the leakage of patients in the unbounded events into the surrounding healthcare system.[3] Event medical directors should also consider the transport to hospital rate from the same or similar previous events when planning their event. In conjunction with the patient presentation rate, the transport to hospital rate can assist in estimating resources needed.[4]

TABLE 4-1 Factors Affecting Planning for a Mass Gathering Event

- Venue entry and exit
- Communication
- Environment
- Potential public health threats

Table 4-1 lists some of the major factors affecting planning for a mass gathering event. Physical barriers may inhibit easy entry and exit from the site. These barriers can make it difficult to get medical resources into, and to get patients out of, the event location. **Reliable communication between medical personnel, event organizers, and outside medical resources is key to a successful medical response.** Finally, event planners should consider possible public health threats of widespread communicable disease and the potential for a terrorist attack with explosive or other devices.

EPIDEMIOLOGY AND TYPES OF MASS GATHERINGS

The need for mass gathering medical care was first described after two spectators collapsed and died during a University of Nebraska football game in 1965.[5] The event organizers were not prepared to manage medical emergencies in the midst of the event, and consequently, when these two patients needed medical care, the organizers were not able to meet the need. Medical directors have become experienced in mass gathering medicine, and case reports are described for sporting events, concerts, expositions, and other large congregations of people.[2]

One of the largest global gatherings, the Islamic Hajj pilgrimage to Mecca, Saudi Arabia, has required officials to manage threats to public safety from outbreaks of infectious disease to major traumatic injuries from stampedes. Other notable global mass gatherings include the 2010 World Expo in Shanghai, China, which attracted approximately 70 million visitors,[6] and the Olympic and Paralympic Games in Rio de Janeiro, Brazil, in 2016. More recently, music festivals, including electronic dance events, are increasingly common. These events have predictable risks and patient presentations. Studies suggest that appropriate on-site healthcare resources may reduce significantly the impact on the prehospital and emergency health resources in the surrounding community.[7] As mass gathering events become more common, there is a need to develop the science of mass gathering medicine. The growing field of mass gathering medicine continues to be instrumental in exploring the health risks of mass gatherings and providing strategies that contribute positively to delivering care during these events.

Interestingly, despite the fact that mass gatherings are generally attended by individuals in good health, these events tend to have a higher incidence of illness and injury than that which would be found in the general population.[8] The incidence of usage of medical care at mass gatherings has been reported to range from 4 to 440 patients per 10,000.[2] The wide variance in medical usage rate is a function of the variables previously discussed.

COMPONENTS OF A MEDICAL ACTION PLAN

In preparing for a mass gathering event, medical directors should develop an organized approach through the development of a medical action plan.[9]

PHYSICIAN MEDICAL OVERSIGHT

All mass gathering events should have an identified physician medical director who is responsible for developing the medical action plan. The objective of this plan, which should be a component of the overall incident action plan, is to describe the details about the organization and delivery of medical care. The medical director is also responsible for providing medical oversight before and during the event. This person should be board certified in emergency medicine and have a current medical license from the state(s) where the event will be located. The medical director should also have experience in the medical direction of EMS and the provision of medical care at mass gathering events. It is becoming more common for the event medical director to be board certified in EMS. Experience and training in EMS provide an event medical director with skills in field medicine, including creative thinking, the ability to make diagnostic and treatment decisions purely on clinical grounds, and an awareness of operational environments that are very different from a typical ED.

The medical director is responsible for developing plans for indirect medical oversight and ensuring a coordinated system of direct medical oversight. Indirect oversight describes a system of written protocols that provide the medical personnel with a standardized set of directions for the care of a variety of traumatic and medical conditions that may be encountered during the event. **These protocols should always be at least commensurate with local EMS protocols unless the medical director has prior approval from the local jurisdictional EMS medical director to deviate from them.** Direct medical oversight describes a method of direct communication with medical providers during the event to answer questions and provide medical direction in real time during the event. Although direct oversight can be delegated to a team of physicians for an event of long duration, ideally, the medical director should plan to be on site during the event as much as possible.

COMMAND AND CONTROL

In addition to an event medical director, mass gathering plans should have an organized system of command and control. Although many systems exist for the command and control of resources at emergency incidents or mass gatherings, one of the most well-tested and efficient methods is the Incident Command System. The system can be used for any type or size of emergency, disaster, or mass gathering, with the purpose of allowing either a single agency or multiple agencies to communicate using common terminology and operating procedures.[10]

The purpose of establishing a command and control system like the Incident Command System is to define clear lines of reporting and communication among all major functioning components that may coexist during an incident. The organizational structure develops in a modular fashion from the top down. While the Command function is always established, the other divisions, which include Operations, Logistics, Planning, and Finance, form as needed (**Figure 4-1**).[11] As will be discussed later, the physician's role within the Incident Command System structure should be focused on direct oversight of patient care and not involve the global issues that are the concern of the incident commander.

Within a typical Incident Command System, the provision of medical care to the public occurs within the Operations Section. Often referred to as the "doers," it is the function of the Operations Section to complete the primary tasks of the mission. Members of the medical branch in Operations include, but are not limited to, emergency medical technicians, paramedics, nurses, physician assistants, and physicians. It is not required that the physician take the lead role of each medical team. In fact, it may be more beneficial to have the individual with EMS or fire service experience in the role of team lead, which ideally may be an EMS physician. An agency's medical director should be available for direct medical oversight as needed and should ideally be on site as much as possible. The medical director(s) should function as a commander within the Operations Section and report back to the section head of Operations who ultimately reports to the incident commander. Key to the success of the Incident Command System is that every individual abides by the established hierarchical ranks of command.

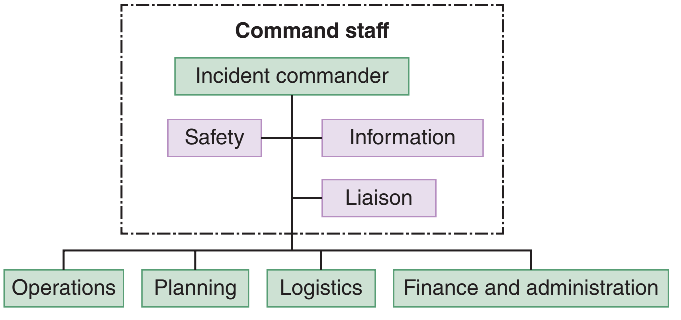


FIGURE 4-1. Incident Command System organizational chart.[11]

FORCE PROTECTION MEDICAL SUPPORT

It is well known that if a medical provider becomes sick or injured, the provider will use resources intended for the public and distract other providers from the ability to perform their duties. As such, a sick or injured medical provider has the potential to dramatically disrupt the overall medical mission for the event. While medical personnel are always responsible for assessing and ensuring their own safety and those with whom they work, it is imperative to have a well-designed plan for the overall medical care and protection of the medical providers at the event. The provision of dedicated force protection medical support can be a critical factor toward enhancing individual law enforcement and EMS/fire personnel health sufficient to maintaining effectiveness for the duration of the event.[12]

One of the duties of the event medical director is to be prepared to provide care to the other medical and law enforcement providers should the need arise. In addition, communication with law enforcement personnel will help to ensure the overall protection of the medical providers. Their support should be readily available and have the means to immediately respond to any location should the situation become unsafe. Depending on the type of event, threats could range from those that are readily seen (e.g., crowds at a concert) to those that are hidden (e.g., explosives and other weapons carried by an individual with the goal of using mass gathering events to kill and injure).

EVENT RECONNAISSANCE

In the beginning stages of preparation, the medical director and assistants need to assess the site to identify potential risks for morbidity during the event. This should ideally be done with the dates and duration of the event in mind and should also account for the geographic variants that will affect their ability to provide medical care to the public. Adequacy of exits should be addressed, routes of ingress and egress should be reviewed, and the geographic area the medical care sector is responsible for should be identified. Backup plans should also be developed. Planners should determine ideal locations for setting up a base of operations, fixed medical care sites, and staging areas for mobile units. Decisions should take into account the effects of predicted traffic flow, predicted sites of high-volume medical need, natural geographic barriers, and location of receiving medical facilities. Ideally, the event medical director should meet with the jurisdictional 9-1-1 EMS medical director(s) to discuss planning and response should a mass casualty response be required.

EVENT NEGOTIATIONS

The process of developing a medical plan for a mass gathering event requires a cohesive teamwork approach with multiple interest groups. First and foremost, the medical planners should develop a plan that meets the needs of the public and the event planners. This first step may require some negotiations with event planners in determining locations for fixed and mobile medical units, level of care to be provided, and resources provided to the medical units. Negotiations will determine if the medical units will be paid under contractual terms by the event planners or if they will volunteer their services to the event. This negotiation stage should also resolve who will finance the purchase of needed supplies and pay for other needed resources, such as costs of transportation and liability coverage.

Regardless of who pays for supplies, it is important that the medical teams coordinate to ensure that equipment and supplies are readily available when needed. Similarly, regardless of who is responsible for acquiring supplies, there is value to the event medical director having ultimate control over the acquisition and maintenance of critical medical supplies, as this will ensure that the medical needs of the public are met.

Medical planners should also establish communication and agreements with other outside agencies that have a potential need to interact with the medical response team for the event. Medical teams that are formed outside the local jurisdictional EMS system should have an agreement with local EMS that addresses transportation of patients out of the event to local resource hospitals. Transfer and acceptance agreements should be developed with the hospitals. Local law enforcement should be contacted for assistance with traffic flow and security. Events that have the potential to be affected by security issues on a national scale may also require agreements with the U.S. Department of Homeland Security for disaster and security response.

HUMAN RESOURCES, LEVEL OF CARE, AND TRAINING

The event medical director should determine the desired level of care for the event based on the predicted medical need and available resources. While there is no universally acceptable formula that can accurately predict staffing requirement, the number of medical providers should be a balance between the number determined to be optimal based on reconnaissance, statistical estimates, and review of previous similar events. Emergency medical technician should be the minimum acceptable level of care. However, depending on the event type and size and the number of medical providers available to staff the event, there may also be a role for the emergency medical responder to provide operational medical support. Once the desired level of care and the predicted patient volume are determined, the medical director will be able to develop a plan for human resource needs. These resources may be acquired through the local EMS system, area hospitals, medical training programs, or other sources such as ski patrols and medical reserve corps.

Medical personnel should be licensed to practice at their level of training in the local jurisdiction. Although the medical personnel should be trained for their established level of care, the medical director may want to have additional training sessions to address specific injuries and medical conditions that are predicted to be encountered by the medical personnel during the event. Using new or modified protocols should be preceded by pre-event education of all relevant personnel and close medical oversight. Regardless, it is important that the providers work within a defined scope of practice as determined by level of training and any operational-specific protocols that may be authorized by local authorities for mass gathering events.

EQUIPMENT

When considering equipment for a mass gathering event, planners and medical directors should take into account the type of event, the weather, and the skill level of the medical staff. Units with physicians may elect to have on hand supplies to do simple suturing and advanced resuscitation. However, thought should be given to the available time needed to suture a wound in balance to the patient volume and the availability of the fixed standing acute care centers. If available, it may be more advantageous to refer patients needing procedures to acute care hospitals. The appropriate way to manage the need for procedures is dependent on the available resources and the overall mission of the medical care at the event.

Often, a large proportion of time spent planning out supplies is focused on generating a broad list and subsequently obtaining supplies that would be necessary to provide medical care for a critical patient. As discussed earlier, it is important to consider that rapid transport of this patient away from the incident to the controlled environment of an acute care hospital may be more beneficial for the patient and free up the provider to care for other patients who would likely not receive evaluation given the time-consuming nature of the critical patient. In addition, proportionally fewer critical patients are seen at a given event compared with the vast majority who seek aid for minor complaints such as scrapes, blisters, headaches, and sprains. Therefore, more effort should be placed on obtaining supplies in highest demand. As suggested by the number and type of complaints seen, those supplies in highest demand typically include bandages, foam padding for blisters, ice for sprains, fluids for oral rehydration, acetaminophen, and ibuprofen.

Data have demonstrated the incidence of cardiopulmonary arrest and the need for major resuscitation at mass gathering events is low.[13] However, **medical units should, at the very least, have access to an automated external defibrillator**.

Event-specific protocols should address the use of advanced airway equipment, including the possible use of medications for rapid-sequence intubation. Plans for other resuscitation needs should also be addressed prior to the event so that all providers manage these small numbers of cases in a standard format (e.g., fluids for sepsis, postresuscitation care, management of cardiac arrhythmia, status asthmaticus). Although it is rare that there is a need for major resuscitation, there may be value to having supraglottic airways and intraosseous needles.

In addition to the level of training of the medical staff, equipment needs will be determined by the mobility of the unit. Some events may need mobile medical units that are able to reach patients in difficult locations or easily move through large crowds. Units on foot and other nonmotorized means of travel will be able to carry fewer supplies than those using motorized vehicles such as golf carts. For events using nonmotorized mobile units, it will be important to design a means to bring heavier supplies to a patient should the need arise. Units in fixed locations will be able to stock a greater quantity of materials, possibly including cots, shelter, and additional medical supplies.

Although the equipment needs are unique for each event, there are some things that are universal. **Tables 4-2** and **4-3** show suggested items for both mobile and fixed units as well as suggested equipment based on the skill level of medical personnel.

TREATMENT FACILITIES

Medical directors will need to determine if the scope of the event will require fixed treatment facilities or if mobile units will be sufficient. Factors that contribute to this decision include, but are not limited to, the predicted number of patients expected to seek medical care, length of the event, distance to off-site medical care, and environmental factors. Fixed treatment facilities can be set up in mobile tents or within a permanent structure. Regardless, fixed treatment facilities should be set up in such a way as to be able to withstand the predictable weather conditions that may be encountered during the duration of the event. The location of the facility should also be easily accessible and have a secure path for ingress and egress. From a patient care perspective, it is important to have a facility that has environmental control to manage heat-related illness in warm weather and cold-related illness in cold/wet weather. Off-site treatment facilities should be arranged with local hospitals.

Staffing of both fixed treatment facilities and mobile units contributes to the success of the overall event's medical response plan. Appropriately placed physicians can expand on-site definitive treatment, including the use of chemical sedation, advanced wound care, and disposition of high-risk cases who wish to sign out against medical advice. Further, physicians on site have been able to affect ambulance transport rates, thereby helping to preserve EMS and resources for the surrounding community.[14]

TRANSPORTATION

Nonmedical and medical transportation is necessary, taking into account the number, capacity, and staging location for transport units. Nonmedical transportation units move personnel and resources throughout the site. Medical transportation moves patients within the event location and out to area hospitals. Ambulances are the mainstay of ground transport from the venue to outlying medical facilities. They should be dedicated to the event and prepositioned in an easily accessible and known location. If the supply of event-dedicated ambulances becomes depleted, there should be a plan in place to support emergency medical transportation.

TABLE 4-2 Equipment List for Mobile Units

	Item
Basic (BLS-level EMS provider and above)	Automatic external defibrillator
	(*May alternatively place in a strategic location in the site venue*)
	Cervical collar
	(*May strategically place in the site venue a method for transport of a patient requiring in-line spinal immobilization*)
	Airway adjuncts
	Oxygen delivery devices (nasal cannula, nonrebreather mask, bag-valve mask)
	Oxygen and suction
	(*May be strategically placed in site venue*)
	Bandages (4×4, roller gauze)
	Triangular cravats
	Adhesive bandages
	Nonlatex gloves
	Splints
	Stethoscope
	Sphygmomanometer
	Tape
	Shears
	Flashlight
	Documentation forms
	Hazardous waste bags
	Compact foil space blankets
	Petroleum jelly (used to prevent chaffing by marathon runners)
	Oral fluids for hydration (water, sports drinks)
Advanced (ALS-level EMS provider and above)	Advanced airway equipment including laryngoscope with assorted blades, endotracheal tubes, and cricothyrotomy kit
	(*May alternatively use a supraglottic airway device*)
	IV access devices and tubing
	(*May choose to carry an adult intraosseous set*)
	Normal saline in 1-L bags
	Glucometer
	Dextrose for IV administration
	Advanced cardiovascular life support medications: epinephrine, atropine, amiodarone, adenosine
	Aspirin
	Nitroglycerin
	IV diphenhydramine
	Parenteral benzodiazepine
	Multidose inhaler albuterol
	Epinephrine in 1:1000 concentration
	Morphine
	Airway medications: induction agent, paralytic

Abbreviations: ALS = advanced life support; BLS = basic life support.

Planners may also need to address nontraditional modes of transportation, such as golf carts, all-terrain vehicles, boats, bicycles, horses, snowmobiles, and toboggans.[15] Operators must have experience in their handling, and these resources should be dedicated for use throughout the duration of the event. Protocols should also be developed that address the appropriate use of air medical transportation, including location and setup of a safe landing zone.

PUBLIC HEALTH

Public health concerns during a mass gathering event may be addressed by the event managers or delegated to the local public health authority or the medical director and EMS system. Even if these concerns are not delegated to the medical response team, public health concerns can affect patient care, and therefore, the medical director should be aware of these issues. **Table 4-4** lists some potential public health concerns.

TABLE 4-3 Equipment List for Fixed Units

	Item
Physician-level care (some of these skills and/or medications may be available for use by EMS providers with authorized operational-specific scope of practice for mass gathering events)	Suture kits with absorbable and nonabsorbable sutures
	Needles and syringes
	Forceps
	Scalpel
	Normal saline for irrigation
	Local anesthetics
	Otoscope
	Analgesics: acetaminophen, ibuprofen, morphine
	Antacids
	Antiemetics
	Prednisone
	Antibiotics: ointment, oral
	Activated charcoal
	Airway management: induction agent, paralytic
Nonmedical equipment	Cots
	Shelter
	Blankets
	Chairs
	Hazardous waste receptacle
	Sharps box

ACCESS TO CARE

The event managers and medical director should develop plans to ensure that the public will be able to access emergency care, if needed. These plans should ensure that the locations of fixed treatment facilities are well marked with signs and other visual aids and that there are limited barriers to access these facilities. Fixed treatment facilities should be accessible to all members of the public, regardless of their ability to actively seek care, and comply with guidelines that are in accordance with the Americans with Disabilities Act. Mobile medical personnel should also wear vests or other high-visibility clothing easily identified by the public. Pamphlets or signage can alert the public about methods for accessing emergency care.

COMMUNICATIONS

Successful management of any mass gathering event is contingent upon an effective communication system. To maintain coordination and control, the system must be tailored to the unique needs of the scenario. The design is dictated by a variety of factors, including geography and size of venue, number of participants, budget, and the systems of those with whom providers will be interfacing. Consideration should also be given to environmental factors including temperature extremes, water,

TABLE 4-4 Public Health Concerns to Be Considered for a Mass Gathering Event

- Access to potable water
- Proper waste management for human waste
- Waste management for nonhuman waste
- Proper management of food service to prevent spread of foodborne illness
- Proper road/traffic management to prevent traffic-related injuries
- Other considerations for injury prevention
- Large-scale natural or man-made disaster

and noise. Venues at music concerts and motor sports may require special communication devices to allow for providers to communicate with each other while in the presence of loud background noise.

Modalities can range from simple flag signals to sophisticated radio networks and may include consumer Family Radio Service devices (walkie-talkies), cellular systems, and landline phones. Each has their strengths and weaknesses. Walkie-talkies have a multitude of channel options but are typically limited to a 1- to 2-mile range. Cellular and other phone systems may provide an inexpensive option but are easily overwhelmed by large numbers of users during a crisis. Two-way radios with more power and range than Family Radio Service systems may be analog or digital, using very high frequency, ultra-high frequency, or 800-MHz frequencies. Systems using a repeater antenna allow for communication over greater distances and across rugged terrain. Large-scale, trunked radio systems provide central control of end-user access to selected channels, allowing a greater number of people to function within a limited spectrum. These systems also allow for discrete groups of responders to communicate among themselves without disturbing other groups.

The communication center should be located in an area that affords the greatest coverage for the event and is fully accessible to the medical director. If situationally appropriate, it may be advantageous to have it co-located in the event command center. This communications network should be separate from the surrounding EMS jurisdiction and should be solely dedicated to the event. Ideally, the communications center should be linked by cell phone, landline, or radio to surrounding jurisdictional services, which include, but are not limited to, public safety answering point (PSAP), local emergency management, EDs, and public health departments.

If the communications network is not linked to surrounding resources, a protocol must be in place for making contact and for relaying information as needed. In an urban environment, this may be in the form of an on-site representative from the local EMS system or an identified phone number or frequency designated for the activation of additional resources. In a remote area, one or more people may be tasked with relaying messages via radio or traveling to the nearest telephone or area of cellular service to contact local authorities, or a specific "communications tent" may be organized.

DOCUMENTATION

The medical director should develop a system for documentation of patient encounters during the event. This system need not be as extensive as that which would be found in the typical ED setting and, instead, should be focused on the event to address specific components of the patient encounter as outlined in **Table 4-5**. Medical documentation should be easy to complete and not exhaustive, such that it can be quickly completed if large numbers of patients seek medical care at the same time. Medical directors may want to consider a method of electronic documentation. Paper documentation should ideally be on a single sheet that can be used by all providers involved in the patient's care (**Figure 4-2**).

TABLE 4-5 Documentation
Purposes of medical documentation for a mass gathering event
• Assist in transfer of care from the event site to off-site medical facilities
• Record medical interactions for the purposes of liability control
• Establish a means of data capture for continuous quality oversight and research
Essential components of medical documentation for a mass gathering event
• Patient's name, contact information, sex, and age
• Vital signs
• Chief complaint
• Focused physical examination
• Suspected diagnosis
• Medical care rendered
• Disposition

LIABILITY

All members of the medical response team for a mass gathering event should have medical liability coverage. Depending on the restrictions of the carrier, liability coverage may be provided by the policy of one's primary employment or may need to be purchased as additional coverage. The medical director may want to arrange coverage for all members of the medical response team as a group. This should be factored into the cost of providing medical care for the event and should be discussed with planners during the negotiation stage before the event. It is important to note that, if the medical personnel will be reimbursed for services in the form of legal tender or payment in kind (even in the form of a free meal at the event), they may not be protected from liability through Good Samaritan laws, depending on the state. In addition, if the medical providers are advertising their medical services to the public at an event even by setting up an established medical tent, the providers have established a duty to act and are liable to the public to provide care at an established standard. To mitigate untoward risk, the medical director should review the laws that pertain to the local area before the event.

CONTINUOUS QUALITY IMPROVEMENT

Unless an event is anticipated to be a one-time occurrence of a short duration, the medical director should establish a method of continuous quality improvement. The continuous quality improvement program should begin with a review of the documentation for patient encounters to identify elements of the system that are performing well and elements that need improvement. The results of continuous quality improvement review should then be used to improve upon the system of delivery of care. The medical director may also consider having regular case reviews with the medical personnel at the event to improve the care being delivered. In addition, an after-action report, which includes all aspects of the event from planning through execution, can identify areas of improvement for future events.

SPECIAL SITUATIONS

CARDIAC ARREST

In general, the incidence of cardiopulmonary arrest and the need for major resuscitation at mass gathering events is low. However, cardiac arrest has been shown to be particularly susceptible to successful intervention in this type of setting.[16] The foundational components of successful resuscitation, CPR and early defibrillation, should be delivered to a patient within 3 minutes of notification of collapse.[17] Thus, staging of medical personnel within an appropriate response radius and equipping medical units with an automated external defibrillator should be a priority. Planners should also consider the placement of ambulances within a location at the event for easy egress and the provision of advance life support care.

MASS CASUALTY INCIDENT

In preparing for a mass gathering event, the event medical director should contribute to and have full working knowledge of the action plan in response to a mass casualty incident. Plans should include methods of triage, coordination of the mass casualty with local EMS, and distribution of large numbers of patients as needed to area acute care facilities. There should be predesignated communication channels so incoming responders can communicate with the scene of the incident. The medical teams should function seamlessly in the Incident Command System structure. Success is partly predicated on predetermined roles of the personnel at the event, which allows for immediate implementation of the Incident Command System. History has demonstrated that mass gathering events can be targets for intentional acts of harm. Given this possibility, the medical director should be involved, along with the director of event security, in formulating an action plan should such an event occur. This plan should include a contingent causality collection area able to manage an influx of patients.

Patient Encounter Form

Event: ____________________

DATE & TIME (24hr) ____________________
Last Name: ____________________
First Name: ____________________
Phone #: ____________________
Age: __________ ☐Female ☐Male ☐Transgender
DOB*: __________ PHN*: __________
Family Physician*: ____________________

PATIENT CATEGORY ____________________
(A=Athlete, E=Event Staff, P=Performer, S=Spectator, U=Unknown)
PARTICIPANT ID ____________________
(Race/Bib Number)
TRIAGE ACUITY SCALE**
☐Black ☐Red ☐Yellow ☐Green ☐White

PRESENTING COMPLAINT ____________________

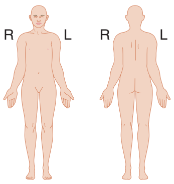
HISTORY ____________________

Past history ____________________

Medications ____________________

Allergies ____________________

Level of Consciousness (AVPU) ____________________



VITAL SIGNS

	#1	#2	#3
Time			
Temp.			
Pulse			
B.P.			
R.R.			
SaO2			
Glucose			
GCS			

PHYSICAL FINDINGS ____________________

***DOB, PHN, Family Physician** (Optional)
****Triage/Discharge Acuity Scale Level**
Black/Deceased – obvious non-survivable injury
Red/Emergent – critical, resuscitation, chest pain, collapse
Yellow/Urgent – overdose no ABC compromise, SOB
Green/Minor – assessment required, wound care, prescriptions
White/Dispensary – product requests, customer service
****Level of Training of Care Provider**
PCP, SFA, OFA #, EMR, LPN, RN, NP, MD, Chiro, Physio, etc. __________

MGM Pt. ID: __________
RA ID: __________

CLINICAL IMPRESSION OF CARE PROVIDER
☐Abrasion ☐Dental ☐Hypothermia
☐Blister ☐Dislocation ☐Intoxication
☐Chest Pain ☐Dizziness ☐Laceration
☐Concussion ☐Fracture ☐Sprain/Strain
☐Contusion ☐Hyperthermia
☐Other ____________________

MEDICATION or IV GIVEN

Time:	Medication/IV	Provider Name:

TREATMENT & SERVICES PROVIDED
☐Antacid ☐Splint/Taping/Tensor
☐Counselling ☐Stretching
☐Ibuprofen ☐Tylenol
☐Immobilization ☐Vaseline
☐R.I.C.E. ☐Wound Management
☐Sling ☐Other __________
☐Other __________ ☐Other __________

DISCHARGE ACUITY SCALE**
☐Black ☐Red ☐Yellow ☐Green ☐White

FOLLOW-UP
☐Event Medical Team
☐ER
☐Family Physician/Clinic
☐Other __________

DISPOSITION
☐Returned to Event/work
☐Left Event (private vehicle)
☐Left Event (taxi)
☐Left Event (event staff)
☐Ambulance Transport
☐Air Evacuation
☐AMA
☐Other __________

DISCHARGE INSTRUCTIONS ____________________

ADDITIONAL NOTES ____________________

Did the care provided on site prevent a visit to another medical facility (i.e. hospital, clinic, family doctor)? ☐Yes ☐No

LEVEL OF TRAINING OF CARE PROVIDER** __________
LOCATION CARE WAS PROVIDED __________
DISCHARGE TIME __________
Name of Attendant (please PRINT) __________
Signature of Attendant __________

2011

FIGURE 4-2. Patient encounter form. (Used with permission from the Mass Gathering Medicine On-Line Registry, accessed at http://ubcmgm.ca/registry/.)

REFERENCES

The complete reference list is available online at www.TintinalliEM.com.

SECTION 2

Disaster Management

CHAPTER 5

Disaster Preparedness

Robert G. Hendrickson
B. Zane Horowitz

INTRODUCTION

Disasters have claimed millions of lives and cost billions of dollars worldwide in the past few decades. Examples of large-scale disasters include the terrorist attacks of September 11, 2001; the 2004 Pacific Ocean tsunami; the 2010 earthquake in Haiti; the 2011 earthquake and tsunami in Japan; the 2015 earthquake in Nepal; Superstorm Sandy of 2012; and the refugee and civil war crises in Africa. Emergency physicians frequently have extensive responsibilities for community and hospital-level disaster preparedness and response. Planning for these may include smaller-scale disasters such as active shooters, explosions, building fires, or transportation accidents, and increased patient volume from predictable events (e.g., storms, blizzards, floods, large gatherings for major sporting events or music festivals, or protests of large scale with anticipated violence). This chapter discusses the definition of a disaster, disaster preparedness and planning, the hospital emergency operations plan, field disaster response, and the ED disaster response.

DISASTER DEFINITION

The World Health Organization defines a disaster as a sudden ecologic phenomenon of sufficient magnitude to require external assistance. A disaster is an event that overwhelms the resources of the region or location in which it occurs. Furthermore, a hospital disaster may similarly be defined as an event that overwhelms the resources of the receiving hospital. A hospital disaster may be of any size and is not limited to mass casualty incidents. A single patient who ingested an organic phosphorous pesticide may overwhelm the resources of a hospital if that hospital is not prepared to decontaminate external to the ED. A single patient with suspected smallpox or a single influential patient (e.g., world leader or a celebrity) may use so many ED resources that it affects the care of other patients.

Whether an event is a disaster further depends on the time of day, nature of the injuries, type of event, and the amount of preparation time before the arrival of patients. The ED "surge capacity" (ability of the ED to care for more patients than is typical) may be severely limited by hospital overcrowding.

When it appears that the normal procedures of an ED may be interrupted by an event, there must be policies and procedures in place to activate a disaster response, direct the mobilization of personnel and equipment, and permit the rapid triage, assessment, stabilization, and definitive care of victims.

TYPES OF DISASTERS

Disasters are subdivided into several categories (**Table 5-1**). **External disasters occur at locations that are physically separate from the hospital (e.g., transportation accident, industrial accident). An internal disaster is an event that occurs within the confines of the hospital (e.g., bomb scare, laboratory accident involving radiologic agents, power failure).** Disasters can be both internal and external (e.g., earthquake with mass casualties as well as damage to the internal hospital). Further discussions of disasters are provided in the following chapters: Chapter 6, "Natural Disasters"; Chapter 8, "Chemical Disasters"; and Chapter 9, "Bioterrorism."

DISASTER CHARACTERISTICS

Regardless of the cause, most disasters have common characteristics that are important for disaster preparedness and planning. In an acute disaster, or a disaster with an identifiable time of onset that produces casualties (e.g., explosion, chemical release, fire, earthquake), the event is followed by a large number of minimally injured patients presenting to the nearest hospitals, usually without prehospital triage or evaluation.[1,2] This is typically followed by prehospital transport of the most affected patients to the same hospitals.[3] Initial patients can be expected within minutes, and peak volumes can be expected at 2 to 3 hours after the event.[2,3] The vast majority (~80%) of patients are not transported by prehospital agencies, but instead self-transport by car, van, police vehicle, cabs, foot, or any means available to the nearest ED.[2-4] Even in acute events, ED volumes tend to remain elevated for days to weeks after events.[3] In nonacute events, such as a pandemic of an infectious disease, ED volumes have a slower onset of surge, but ED and hospital volumes remain elevated for extended periods.

Based on previous events, common factors that may hinder ED response are listed in **Table 5-2**.

DISASTER PREPAREDNESS AND PLANNING

Planning for any type of disaster consists of common elements. A hospital disaster planning group is responsible for generating the hospital's emergency operations plan. Include a diverse membership of hospital employees and decision makers. **Table 5-3** lists some potential members and their roles. The group should meet on a regular basis to assess hazards, develop and update short- and long-term disaster plans, plan exercises and training, and redesign the disaster plan based on evaluations of exercises and real events.

The general components of the disaster plan include hazard vulnerability analysis, hospital–community coordination, integration with national response assets, and training and disaster exercises. Develop specific plans (for radiation, explosions, mass casualties, decontamination) based on an assessment of the potential disasters in the area as well as study of the events that would cause the most disruption to the ED and hospital.

HAZARD VULNERABILITY ANALYSIS

The hospital planning group should address those disasters that are most likely to occur in their community and geographic area. For example, planners on the West Coast of the United States may make earthquake planning a priority and those on the Gulf and Atlantic coasts may prioritize hurricane planning. Give consideration to the proximity of population centers to chemical release threats (military chemical weapons depots, large industrial sites, or transportation hubs).[5] Industrial sites that store large volumes of potentially harmful chemicals are required by Title III of the Superfund Amendments and Reauthorization Act to participate in local emergency planning committees. Industries are required to report spills of potentially harmful chemicals, and the approximate location of these sites may be found at http://toxmap.nlm.nih.gov. Terrorist-related disasters may be prioritized in hospitals that are in proximity to sites that may be significant terrorist targets. Include factors such as proximity to transportation facilities (e.g., ports, airports) as well as locations where large numbers of people collect (e.g., festivals, stadiums, arenas) with the risk assessment.

TABLE 5-1 Types of Disasters

Disaster Type	Definition	Examples
Natural disaster	Disaster caused by a naturally occurring event	Earthquakes, tsunamis, tornadoes, hurricanes/typhoons, volcanic eruption, pandemic influenza
Man-made disaster	Nonnatural events that are not purposefully produced	Vehicle crashes (e.g., car, plane, bus), mass casualty events, explosions, fires, industrial accident/chemical release
Terrorist-related disaster	Events that are purposefully produced in an effort to cause terror	Events of September 11, 2001, as well as intentional chemical, biological, radiologic, or toxin releases
Internal disaster	An event that occurs within the hospital	Hazardous materials spill in hospital laboratory, fire or explosion within hospital, power failure
External disaster	An event that occurs external to the hospital	Transportation accident, industrial accident
Acute disaster	Disaster that occurs in a narrow and well-defined time frame	Explosion, industrial release, earthquake
Nonacute disaster	Disaster with no well-defined start point or continuous production of casualties over a broad time frame	Pandemic infectious disease, incremental release of a biological or toxin (e.g., anthrax sent through mail)

The hazard vulnerability analysis can prioritize planning efforts because different disasters are characterized by different morbidity and mortality patterns and different challenges to the ED and hospital. For example, earthquakes may cause severe traumatic injuries requiring a concentration on surge capacity of the critically ill patient. Rescue operations may last several days. Unique needs, such as dialysis for renal failure for multiple crush injury victims, may need to be considered. Natural disasters often cause large numbers of homeless or displaced persons whose everyday medical needs are exacerbated by limited access to usual health care, as occurred after Hurricane Katrina. Chemical releases may require mass decontamination as well as large numbers of ventilators, oxygen, and specific antidotes that are not typically available in large quantities.

HOSPITAL–COMMUNITY COORDINATION

Every hospital should integrate its emergency operations plan with those of community disaster management agencies. This is especially important regarding disaster notification and communications, transportation of casualties, and provisions for dispatch of hospital medical teams to a disaster site. Strong relationships with community agencies (e.g., fire department, regional EMS system, local emergency management, or public health agency) are important to ensure a coordinated disaster response. There are a large number of community agencies that have some responsibility for disaster planning and response (**Table 5-4**).

Other organizations that a hospital may interact with during the disaster planning process include the military, local chapters of the American Red Cross, local emergency planning committees, Citizen Corps Councils, and other volunteer agencies, along with state and federal agencies (e.g., National Disaster Medical System, Metropolitan Medical Response System, Centers for Disease Control and Prevention). Medical planning in a community is usually the responsibility of local and state health departments and EMS councils.

TABLE 5-2 Factors That May Hinder ED Response to Disasters

- Poor communication between ED and disaster scene
- Poor communication within the hospital (e.g., ED to emergency operations center, emergency operations center to patient care areas)
- Inability to control volunteer healthcare personnel who are unfamiliar with the ED function and their roles in disaster response
- Inability to engage and control convergence of media to the ED
- Inability to engage, control, and direct visitors who are searching for loved ones
- Inability to control large numbers of patients (i.e., crowd control)
- Difficulty maintaining high staffing needs for extended periods

TABLE 5-3 Hospital Planning Group

Hospital Planner	Role in Disaster Planning and Response
Public safety	Crowd control, hospital lockdown, and hospital access control
Facilities/engineering	Evaluate structural damage and advise on stability of facilities
Logistics/equipment supply	Provide supplies/equipment; arrange for rapid ordering of additional supplies
Pharmacy	Provide pharmaceuticals, antidotes, and antibiotics; arrange for rapid ordering of additional pharmaceuticals
Transportation	Assist with patient transport
Clinical fields	A wide array of clinical fields should be represented, including representatives from the ED, primary specialties (internal medicine, family medicine, pediatrics), and surgical specialties
Media/public relations	Act as single point of contact for media; liaise between media and clinical areas, emergency operations center, and other hospital resources
Communications officer	Coordinate communication to employees during a disaster through e-mail, website, paging groups, phone, or social media
Nonclinical patient care	Housekeeping and food services
Safety officer	Determine and ensure safe practices for employees (e.g., appropriate personal protective equipment for decontamination)
Radiation safety officer	Prepare plan for and respond to radiologic emergencies
Infection control officer	Prepare for and respond to infectious disease emergencies

INTEGRATION WITH NATIONAL RESPONSE ASSETS

Some of the important federal response resources are listed in **Table 5-5**. During a response, these agencies may play pivotal roles and may interface and coordinate with hospitals and emergency physicians.

TABLE 5-4 Community Agencies Involved in Disaster Planning

Community Agency	Responsibilities
Federal Bureau of Investigation	Incident command if a federal crime may be involved
FEMA	Incident command in public health disaster
State governor	Authority to declare health emergency; requests federal assistance (e.g., FEMA); responsible for public safety
State health department	Authorized by governor to coordinate disaster response
State emergency management association	State-level equivalent of FEMA
City/county health department	May have jurisdiction for local disasters (variable); may be initial incident command for local health disasters
EMS	Patient triage in field; decontamination in field (if necessary); stabilization and transfer to definitive care facility
Fire service	Overall scene command in an acute disaster; victim rescue and hazard control
Police service	Traffic management and scene security in an acute disaster
Public works	Support equipment and personnel; structural safety expertise
Hazardous materials (HAZMAT) teams	Initial incident command at scene of hazardous materials spill/exposure

Abbreviation: FEMA = Federal Emergency Management Agency.

TABLE 5-5 Federal Response Resources

Agency	Role
U.S. Public Health Service/Office of Emergency Response; http://www.phe.gov/preparedness/pages/default.aspx	Office within DHHS. Management and coordination of federal health and medical activities related to preparation, response, and recovery from major emergencies or presidentially declared disasters.
Metropolitan Medical Response System For more information: www.ncbi.nlm.nih.gov/books/NBK220762/	Enhance local emergency preparedness systems by promoting coordination between local responders (e.g., police, fire, hazardous materials agencies, EMS, hospitals).
National Disaster Medical System; https://www.phe.gov/Preparedness/responders/ndms/Pages/default.aspx	Asset-sharing program between DHHS, Federal Emergency Management Agency, U.S. Department of Defense, U.S. Department of Veterans Affairs, and public/private organizations—developed to provide surge capacity for natural disasters, wartime military casualties, and large-scale bioterrorism events.
DMAT; https://www.phe.gov/preparedness/responders/pages/default.aspx	Multidisciplinary teams that deploy in response to federally declared disasters and emergencies to support a local jurisdiction's response. Teams include physicians, nurses, medics, pharmacists, and logisticians.
National Disaster Medical System Response Teams; https://www.phe.gov/preparedness/responders/pages/default.aspx	Specialty teams, based on the DMAT concept, developed to respond to chemical, biological, and radiologic events.
Disaster Mortuary Operational Response Teams; https://www.phe.gov/preparedness/responders/pages/default.aspx	Teams that respond to federally declared disasters and emergencies to support a local jurisdiction's ability to process large volumes of deceased patients.
Centers for Disease Control and Prevention; http://www.cdc.gov	Centers within DHHS. Lead federal agency in developing and applying disease prevention and control. Advisory agency in bioterrorism response.
CDC Outbreak Response Teams	Teams of CDC epidemiologists to assist with local efforts in investigating potential outbreaks, confirmation of cases and exposures, and environmental clean-up.
Laboratory Response Network; https://emergency.cdc.gov/lrn/index.asp	Network that links local and state public health laboratories to advanced-capacity laboratories, including military, chemical, veterinarian, agricultural, water, and food testing labs.
National Notifiable Diseases Surveillance System; http://wwwn.cdc.gov/nndss/script/nedss.aspx	National public health surveillance system.
Health Alert Network; http://emergency.cdc.gov/han/	System that allows for rapid early warning broadcast alerts to health departments for potential emerging infectious diseases or outbreaks.
Strategic National Stockpile; http://www.cdc.gov/phpr/stockpile/stockpile.htm	Two-part system designed to provide local jurisdictions with medications, vaccines, and equipment during a disaster. Prepackaged cache—delivered within 12 h in the U.S. Situation-specific cache—delivered within 36 h in the U.S.
Federal Bureau of Investigation	Lead federal agency for crisis management. Has authority to conduct law enforcement investigations into acts of terrorism.

Abbreviations: CDC = Centers for Disease Control and Prevention; DHHS = Department of Health and Human Services; DMAT = Disaster Medical Assistance Teams.

TRAINING AND DISASTER EXERCISES

Regular training and exercises familiarize staff with their disaster roles and responsibilities and identify weaknesses or omissions in the plans that require additions or revisions. Exercises can range from full-scale, community-wide simulations, with moulage (use of makeup or theater techniques to represent injuries) victims, to tabletop triage scenarios, mini-exercises that test only certain components of the disaster plan (such as call-up of personnel), and tests of communications. The Joint Commission requires two annual exercises at least one of which involves the movement of patients. The scenarios should reflect incidents that are likely to occur in the community as determined by the hazard vulnerability analysis.

HOSPITAL EMERGENCY OPERATIONS PLAN

The hospital emergency operations plan provides for an organized response of the hospital from the time of notification of a disaster until the situation normalizes (**Table 5-6**).

Functions include activation of the emergency operations plan, establishment of an emergency operations center, assessment of hospital capacity, surge capacity planning, communications, supply and resupply, triage and treatment of casualties, establishment of support areas, and termination of the disaster state to allow for recovery and the return to normal activities.

ACTIVATE THE EMERGENCY OPERATIONS PLAN

Clearly delineate the roles and responsibilities of all employees in the ED and any employees who may respond to the ED in the planning process; those roles must be clearly listed and easily accessed in the event of a disaster. Clarify the reasons for activation of the emergency operations plan. Activation of the emergency operations plan should provide for the immediate mobilization of supplies, equipment, and personnel.

ESTABLISH EMERGENCY OPERATIONS CENTER

The Incident Command System is a standard emergency management system used throughout the United States to provide a flexible command and control structure upon which to organize a response.[6] The Incident Command System is generally used when there is an identifiable single scene for a disaster event, such as the site of a plane crash. By standardizing an organizational structure and using common terminology, the Incident Command System provides a management system that

TABLE 5-6 Components of the Hospital Emergency Operations Plan

Component	Function
Activate emergency operations plan	Notify and mobilize personnel and equipment
Set up emergency operations center	Nerve center for hospital response and communication with outside agencies
Assess hospital capacity	Determine safety of hospital itself; determine capabilities of hospital in all units
Create surge capacity	Determine ways to handle the maximum number of patients
Establish communication systems	Develop multiple and redundant systems, including cellular phones, satellite phones, two-way radios, runners
Provide supplies and equipment	Deliver available supplies to proper areas and plan for resupplying or obtaining other needed materials
Establish support areas	Volunteer, media, and family information centers
Establish decontamination, triage, and treatment areas	Decontamination, triage, resuscitation, acute care, and minor care areas; surgical triage and holding; psychiatric area; morgue
Terminate disaster response and provide for remediation	Return personnel and supplies to normal activity; provide emotional support for caregivers; improve emergency operations plan for future incidents

is adaptable to incidents involving a multiagency or multijurisdictional response. At the most basic level, there are five main components to the organizational structure: (1) incident command, (2) operations, (3) planning, (4) logistics, and (5) finance. With this type of organizational infrastructure and the flexibility to expand and collapse as needed, an orderly and efficient response to any incident can theoretically be implemented.

The Hospital Emergency Incident Command System is modeled after the Incident Command System. Upon declaration of a disaster, an emergency operations center within the hospital should be established in a predesignated area. This center should be able to communicate with the ED and triage area and with external authorities (regional EMS, police, fire, and public health agencies). There should be a primary emergency operations center as well as a secondary site to be used in the event that the primary site is damaged or inaccessible. Provisions for multiple redundant modes of communication should be made. Other responsibilities of the emergency operations center include opening up additional hospital wards or clinics, obtaining outside assistance, evacuating endangered patients, assigning staff to treatment areas, and terminating the disaster mode of operation.

ASSESS HOSPITAL CAPACITY

Before the hospital can receive casualties, it must be determined if the hospital itself has sustained any structural damage or loss of use as a result of a disaster. These include blocked passageways or inoperable elevators; potential for fire, explosion, or building collapse; failure of utilities; loss of equipment or supplies; contamination of water; and outside access problems. This damage assessment is usually the responsibility of the hospital safety officer or engineer. If the hospital's structural integrity has been compromised, it may be necessary to initiate the evacuation plan to evacuate staff and patients.

Once it is determined that the hospital itself is safe, the hospital should determine how many casualties from the disaster site it can safely manage. This may be limited by available personnel, beds, operating room and intensive care unit capacity, and supplies, as well as by the type of disaster and the availability of other community resources. At the time of disaster notification, it is necessary to know the status of many of the hospital's capabilities: how many beds are available, how much critical supplies and medications are available, how many personnel are on duty, what structural damage has occurred, how many operating rooms are in use, which clinicians are present in the hospital, and so forth.

CREATE SURGE CAPACITY

Surge capacity is the ability to increase hospital bed capacity over normal limits. Intrahospital surge may include doubling patients in rooms, converting an acute care ward to an intensive care level unit, opening previously closed wards, or caring for patients in typically nonclinical locations, such as the hallway or cafeteria. Interhospital or regional surge may include discharging hospitalized patients to an external low acuity unit, either mobile or fixed, and altering standards of care (typically a role of the state governor and legislature and only during governor-declared disasters).[7,8] The standards of care should be altered only in the most extreme circumstances, as patient surge has been linked to somewhat worse outcomes for individual patients.[9]

ESTABLISH COMMUNICATIONS SYSTEMS

Establishment of good communications is critical in any disaster or mass casualty situation. Even the best disaster plans fail without well-established communications systems. Unfortunately, experience shows that this essential function is difficult to achieve for a variety of reasons. Many communication modes become inoperative during a disaster. Cellular telephones, in particular, are often overwhelmed in disasters. Disaster planning must include a multitiered plan for intrahospital (blackboard, two-way radios, messengers/couriers) and interhospital (citizen band groups, cellular telephones, satellite telephones, two-way radios) communication.

SUPPLIES

During a disaster, necessary supplies and equipment must be ready for immediate distribution to appropriate locations in the hospital. Each hospital will need to estimate the amount of supplies that will be needed in stock over and above their regular hospital supply. Unfortunately, due to "just in time" stocking, most U.S. hospitals do not have a surge of supplies that may be used in a disaster. The Centers for Disease Control and Prevention has arranged a series of medication push-packs throughout the United States that can be delivered to any area of disaster within 12 hours (https://www.cdc.gov/phpr/stockpile/index.htm). Once delivered, additional time is necessary to unpack the supplies and deliver the supplies to individual hospitals. The regional/local disaster plan must include a mechanism to unpack the push-packs, determine the hospitals in greatest need of individual items, divide the push-pack contents, and deliver the supplies to the hospital. This logistical issue makes it necessary for most hospitals to rely on their own supplies for a period of at least 96 hours.

ESTABLISH SUPPORT AREAS

Family Information Center During a disaster, families and friends will arrive at the hospital seeking information about victims. This convergence can seriously interfere with efforts of the hospital to respond effectively to the situation. For this reason, predesignate a separate area for family members seeking information. This area may also be used to discharge in-hospital patients and treated disaster victims.

Volunteer Coordination Center In major disasters, anticipate the potential for large numbers of volunteers, including those wishing to donate blood. Although some of these people may have appropriate clinical skills, they are unlikely to be familiar with the hospital functions and could be more hindrance than help. A separate place should be identified to handle these volunteers and, if appropriate, credential and decide how they may best be used. This area should include all equipment and personnel that are required to perform emergency credentialing (if appropriate and necessary).

Media Center Identify a single hospital spokesperson to relay information to the media. This public information officer ideally should have some training in handling media questions and making clear statements to the press and public. Similar to the family information center, the media briefing room should be set up away from clinical care areas so that the press does not negatively impact on medical care while seeking a story. Direct members of the media to this area, and closely supervise their access to any treatment area by utilizing security personnel and either the hospital administrator or public information officer.

DECONTAMINATION, TRIAGE, AND TREATMENT

Certain areas of the hospital must be designated for specific functions, including decontamination, triage, care of major and minor casualties, presurgical holding and surgical triage, psychiatric care, and morgue facilities. The plan should be quite specific as to the function of these areas, staffing requirements, and basic supplies to be used.

Decontamination **Perform decontamination in an area that is outside of the clinical care area of the ED.**[4] Typically, this area is located external to the ED, but may be in internal locations. Use the decontamination facility to remove clothing and cleanse the skin and hair of patients exposed to a chemical or radioisotope (**Table 5-7**).[10] Provide patient coverage and protection from the environment. Make sufficient personal protective equipment available for hospital staff assisting with decontamination.

Triage **Restrict patient entry to only one location—the triage area.** The primary functions of a disaster triage area are rapid assessment of all incoming casualties or ill patients, patient registration and identification, the assignment of priorities for management, and distribution of patients to appropriate treatment areas in the ED and hospital.

Treatment Patient care in disasters requires alteration of scale and sometimes location of clinical care, but staff should perform the clinical roles that are familiar to them. Several exceptions to this rule may

TABLE 5-7 Decontamination Guidelines

- **Decontaminate patients exposed to solids, liquids, vapors, or mists.**
- **Patients exposed only to a fully dispersed gas need to be assessed for pulmonary symptoms and systemic toxicity and do not require decontamination.** When uncertain if a substance is a gas or actually a vapor or mist, decontamination should occur.
- Hospital personnel should have the **initial ability to decontaminate one patient at a time with a shower or hose system** while setting up a larger tent or a multiple-person decontamination system.
- **Perform decontamination outside of the ED** in a way that prevents patients from entering the ED before decontamination.
- Hospital personnel require level C personal protective equipment while performing decontamination. Higher levels of protection are not necessary and should only be used by hospitals that follow stringent training protocols and criteria, and use only personnel who have been specifically trained to use the equipment. **Sufficient equipment for multiple personnel and rotations of personnel in and out of the decontamination zone every 30 min are suggested.**
- **The first and a very effective method for decontamination is to disrobe, brush off solid dusts or powders, and wash and dry the face.** Patient clothing and belongings should be individually bagged and labeled. Watches, earrings, body piercings, jewelry, and contact lenses should be removed. Hearing aids should be wiped with a moistened cloth and may be returned to patients after the decontamination procedure because the need to hear instructions outweighs any risk of wearing the hearing aid.
- Warm water is the universal decontamination fluid. Hosing a patient from head to toe (or showering) for 5 min will decontaminate most ambulatory patients.
- Patients with adherent materials will need additional scrubbing of hair and affected body parts with soap to remove these; medical assistance will be necessary in some circumstances. An additional check to ensure the removal of all earrings and body piercings should be done.
- Young children need assistance and reassurance and should be decontaminated with the aid of a parent or guardian who can hold and reassure the child while medical personnel perform the decontamination.
- After the decontamination procedure, provide hospital clothing (cloth or paper gowns) and triage patients to an area to await further assessment. Retriage patients with eye pain after whole-body decontamination for individual irrigation of their eyes with sterile normal saline. Patients with contaminated wounds will likely need additional irrigation of debris in wounds.
- Contain runoff water from the decontamination to prevent environmental contamination.
- Critical medical devices (infusion pumps, hearing aids, ostomy bags, etc.) may remain with the patient unless a high-risk chemical has been identified. Wash canes and walkers with soap and water or diluted household bleach and return to patients to ensure their mobility.
- At least one radiation survey meter (e.g., Geiger-Müller counter) and staff that are trained in its use are necessary for events that potentially involve radioisotopes. Patients may need a radiation survey sweep before and after decontamination, and further decontamination may be needed until levels reach background radiation levels.
- Staff involved in the decontamination process and systems need annual training and practice drills. Share an assessment of strengths and weakness learned from each drill with hospital personnel to improve preparedness and performance.

exist (decontamination); however, in general, staff are more efficient at performing typical tasks quickly than learning new tasks in real time.

Organize patient care stations so that clinicians who are familiar with the assessment and treatment of the clinical problems may staff them. One suggested method of organizing patient care stations includes "resuscitation" and "minor treatment" areas.

RESUSCITATION

From the triage location, most, if not all, of the **seriously injured patients will be sent to the resuscitation area** (trauma and cardiac resuscitation, treatment of hypovolemic or septic shock, severe respiratory distress). This is usually physically located in the ED and staffed by emergency physicians. Other areas that may be used include direct to operating room or postoperative recovery room triage.

PRESURGICAL HOLDING AREA AND SURGICAL TRIAGE

Send trauma patients who are initially stabilized in the ED to the presurgical holding area for preoperative preparation and observation. **The number of operating rooms that can be staffed is the main limiting factor in the provision of definitive care for a large number of severely injured casualties.** The most experienced surgeon available should take the responsibility to prioritize cases and to rapidly assign surgeons to individual cases.

MINOR TREATMENT AREA

In most disaster situations, the majority of patients are not very seriously injured. **These low-acuity patients can be sent to an "urgent care" area for definitive care**, including splinting of fractures, primary closure of lacerations, tetanus prophylaxis, and observation for delayed symptoms. This minor treatment area can be established in the hospital's outpatient clinics and staffed by the clinic physicians.

MENTAL HEALTH

In the event of a disaster involving mass casualties, and even property damage with loss of possessions, it is common for patients to present with episodes of anxiety and depression, or exacerbations of their psychiatric disorders.[11] Agitated patients, visitors, or staff can be extremely disruptive to hospital disaster operations. Consider a separate isolated area to receive individuals in need of psychological intervention. Include consideration for assessing patients and hospital staff who are psychologically affected by the disaster. Consider providing a critical stress response team, including social workers and psychiatrists, to provide support and critical stress debriefing.

MORGUE FACILITIES

Disasters can result in a large number of fatalities. Morgue capacities may need to be expanded to other areas of the hospital (medical school anatomy area, auditorium), enhanced by mobilization of local freezer trucks (this must be prearranged during the planning stage), or enhanced by federal assets (Disaster Mortuary Operational Response Teams). Viewing of deceased patients should take place here, not in treatment areas.

TERMINATING DISASTER RESPONSE (RECOVERY)

As soon as appropriate, direct efforts toward returning the hospital to normal operations. Besides restocking and cleaning, give consideration to the emotional stress experienced by both the EMS and hospital staff. *Critical incident stress debriefing* can reduce the psychological impact of these events on medical responders and offer immediate emotional support to healthcare workers. Data from previous experiences suggest that such intervention can assist providers in maintaining job performance and satisfaction, resulting in improved patient care.[12] Provide all members who participated in the disaster, not just medical personnel, the opportunity to participate in critical incident stress debriefing.

Carefully record and review deficiencies in a hospital's disaster plan that are revealed during a disaster, and write an after-action report. Take immediate steps to correct these flaws in the plan.

FIELD DISASTER RESPONSE

Elements of field disaster response are field triage and medical care, communications, distribution of casualties, and management of on-site disaster medical teams.

FIELD TRIAGE AND MEDICAL CARE

In the field, rescue personnel often use a simple triage and rapid treatment technique that depends on a rapid assessment of respiratory status, perfusion, hemorrhage control, and mental status. Patients are then triaged to immediate care, delayed care, or dead/dying.[13,14] Subsequently, determining how much and what type of care to administer at the disaster site depends on several factors. If the number of patients is small and there are sufficient prehospital personnel and transportation resources available, on-site medical care can proceed in a fairly normal manner, with rapid stabilization and transportation to nearby hospitals. When extrication will be prolonged, interventions such as fluid resuscitation and pain control should be instituted in the field. On the other hand, early, rapid transportation with a minimum of treatment should be practiced when there is danger to rescuers and casualties from fire, explosion, falling buildings, hazardous materials, and extreme weather conditions.

When patients are likely to have significantly delayed transport from a scene (e.g., number of casualties exceeds transportation capacity or damage to hospital infrastructure), the "Secondary Assessment of Victim Endpoint" triage system may be helpful to identify patients who are most likely to benefit from the care available under austere field conditions.[15] The Secondary Assessment of Victim Endpoint triage system is intended to triage patients into categories that reflect a balance between resource use and probability of survival. Category 1 includes patients who will die regardless of how much care they receive. Category 2 includes patients who will survive whether or not they receive care. Category 3 includes patients who will benefit significantly from austere field interventions.[15]

COMMUNICATION—DISASTER SITE TO HOSPITALS

The local emergency communications or emergency operations center should alert hospitals in the affected area of possible mass/multiple casualty situations or disasters. This report should include the total number of injured, the number of seriously injured (who may need intensive care unit capability), and the number for whom ambulatory treatment is sufficient. Hospitals should report to the local emergency communications center the following information: bed availability, number of casualties received thus far, number of additional casualties that the hospital is prepared to accept, and specific items in short supply.

DISTRIBUTION OF CASUALTIES TO RECEIVING HOSPITALS

Maintain good communication between hospitals and on-site EMS command in order to minimize unequal distribution of victims. **Alert the on-scene incident commander immediately of a potentially overloaded hospital.** In this situation, the less injured and more stable can be sent a farther distance to outlying hospitals.

Casualties with special problems, such as major burns, carbon monoxide poisoning, spinal cord injuries, or victims of chemical or biological terrorism, may need to be transferred directly to specialized units, although it may not be possible for these units to accept a large number of ill or injured. For that reason, develop regional plans to allow for the care of specialty patients in nonspecialty hospitals.

MANAGEMENT OF ON-SITE DISASTER MEDICAL TEAMS FROM HOSPITALS

On-site disaster medical teams dispatched from local hospitals may be of value in situations in which victims require prolonged extrication; transportation routes are blocked, preventing easy evacuation to hospitals; or the number of casualties is of such magnitude that they exceed transportation capacities. Dispatch such a team with great caution. Physicians and nurses function optimally in an in-hospital setting. Few, however, are prepared to work under austere field conditions. Such hospital-based teams should probably not come from the ED staff until back-up staff has arrived to care for patients arriving from the disaster site or who are already present. Explicitly describe how such personnel are placed in action in the hospital emergency operations plan and coordinate with state and local agencies through memoranda of understanding.

Carefully map out the resources for such field response teams on a regional basis. At least one institution from each region should maintain an on-site triage team of physicians and nurses. The designated hospital should store disaster triage kits containing essential resuscitation and stabilization equipment for field use.

ED DISASTER RESPONSE

INITIAL RESPONSE

When a call is made to the hospital indicating the occurrence of a disaster or potential mass casualty–producing event, the incident must be verified by the appropriate predesignated official, who then puts the emergency operations plan into effect. In some events, the first sign of a disaster may be patients arriving at the hospital. In this case, contact the regional emergency communications center to notify the regional hospitals of the impending disaster and initiate the emergency operations plan.

This sets a series of activities into motion. The information obtained from the call is given to the charge nurse; the nursing and medical personnel in the ED are notified of the impending arrival of casualties; and the ED's plan for calling additional staff is activated. If hospital telephone communications have been completely disrupted, ED personnel may have to be reached by radio, cellular phone, e-mail, or television announcement. In many disasters, cellular phone and text messaging systems are quickly overwhelmed. Alternatively, a calling station remote from the hospital, such as at the residence of an administrator, physician, or nurse, may be able to handle this extensive calling job without taxing the hospital's phone system.

An initial needs assessment is conducted by the nurse and/or physician in charge, given the information available. They should evaluate the current status of the patients in the ED and make the appropriate disposition decisions. The ED physician or charge nurse becomes the on-site incident commander until the plan-designated incident commander arrives. **Among the decisions to be made are those related to the admission, discharge, or transfer of patients, and decisions about the priority of patient care.** Discharge all nonemergency patients from the ED with responsible individuals.

Based on the initial assessment, the number of patients that the department can receive is determined and communicated to the prehospital disaster communications center. The nurse and the physician in charge then assign staff to those areas in the department to be used during the disaster.

Take all available litters and wheelchairs to the ambulance entrance immediately on announcement of the disaster status. Patients from the disaster site are met at the receiving area by hospital escorts who assist the emergency medical technicians in transferring patients to wheelchairs or stretchers.

Place essential equipment, such as endotracheal tubes, IV fluids, cervical collars, splints, and bandages, near the ambulance entrance to permit convenient restocking of the ambulance (when plans call for ambulance restocking from hospitals) and rapid return to the disaster site.

SECURITY

Hospital security diverts nonessential vehicles and ensures a smooth, one-way flow of traffic to the ambulance entrance. Once patients, family, and media arrive, security is also responsible for protecting the treatment areas and inhibiting unplanned entry into the hospital.[4]

TRIAGE

Triage establishes priorities for care and determines the clinical area of treatment. Many seeking help will arrive independent of the EMS system.[3,4] **Triage will need to be performed at the ED entrance even if it was done at the scene.**

Triage category is identified by use of a colored band or trauma/disaster tag that is placed on the patient to document that triage has been done.

The approach to patient evaluation and treatment is quite different when dealing with disaster situations that result in high casualties.[16] To accomplish the most good for the most number of patients, the triage team should evaluate all patients arriving at the ED and classify their condition with regard to severity of injury and need for treatment. Some principles of medical care must be altered to achieve the best overall result. Patient care at triage should be limited to manually opening airways and controlling external hemorrhage.

TABLE 5-8 Triage Categories

Red

- First priority
- Most urgent
- Life-threatening shock or hypoxia is present or imminent, but the patient can likely be stabilized and, if given immediate care, will probably survive.

Yellow

- Second priority
- Urgent
- The injuries have systemic implications or effects, but patients are not yet in life-threatening shock or hypoxia; although systemic decline may ensue, given appropriate care, patients can likely withstand a 45- to 60-min wait without immediate risk.

Green

- Third priority
- Nonurgent
- Injuries are localized without immediate systemic implications; with a minimum of care, these patients generally are unlikely to deteriorate for several hours, if at all.

Black

- Dead
- No distinction can be made between clinical and biological death in a mass casualty incident, and any unresponsive patient who has no spontaneous ventilation or circulation is classified as dead. Some place catastrophically injured patients who have a slim chance for survival regardless of care in this triage category.

The most common triage classification in the United States still involves assigning patients to one of four color-coded categories (red, yellow, green, or black), depending on injury severity and prognosis (Table 5-8). In addition to the nature and urgency of the patient's systemic condition, triage decisions should be sensitive to factors affecting prognosis, such as age, general health, and prior physical condition of the patient, as well as the qualifications of the responders and the availability of key supplies and equipment.

Catastrophically injured patients who have a minimal chance for survival despite optimal medical care should be classified as "expectant" ("black": to include patients with burns involving 95% body surface area, and patients in full cardiac arrest or septic shock). Devoting time and resources to patients who are not likely to live jeopardizes other patients who are truly salvageable. The goal with these "expectant" patients should be adequate pain control and the opportunity to be with friends and family.

TRIAGE TEAM

A team consisting of an emergency physician, an ED nurse, and medical records or admitting clerks should receive every patient. In extraordinary situations, several triage teams may be required to handle the casualty load. Acknowledge the physician performing hospital triage as being in command of the triage area (clearly identified by a specially colored vest or other garment) and understanding all triage options.

Assign one member of the triage team (admitting or medical records clerk) the job of recording the victim's name on the disaster tag along with the triage destination within the hospital. If identification of the patient is not available, ethnicity, gender, and approximate age should be noted on the tag. An initial diagnostic impression should also be registered on the tag. This information is entered into a department log or into the electronic medical record, if possible. In some patient tracking systems, a scan of the bar code on the disaster tag may allow for immediate registration by disaster tag number and open an electronic medical record. Additional care can be recorded in the electronic medical record or in a paper disaster chart and kept with the patient at all times and later scanned into the electronic medical record.

ED DISASTER PATIENT CARE

Disaster care concepts often vary from the typical ED routine. Care that is not immediately time sensitive can be provided the next day. For example, wounds may benefit from delayed closure after copious irrigation due to delayed presentations or gross contamination. In the event of prolonged extrication from rubble, assess for delayed signs and symptoms, including cardiac dysrhythmias, hyperkalemia from crush injury, renal failure, and pulmonary blast injury.

Terrorist-related or industrial explosive events may lead to medical conditions or exposure to chemicals that are not familiar to clinicians.[4] Patients may require prolonged observation (e.g., exposure to phosgene or ricin) or unique testing. For infectious exposures, the Centers for Disease Control and Prevention and local/state public health agencies can guide testing, observation time, and treatment. Immediately contact the local public health agency if a biological terrorist agent or a rare and potentially fatal infectious disease is seen or suspected in the ED. In the event of a chemical agent, the regional Poison Center (1-800-222-1222) can provide information and guidance on whether decontamination is necessary, as well as testing, observation time, and antidotal or supportive treatment. Fact sheets on biological, chemical, and radiologic agents are available at http://www.cdc.gov.[4,17]

Use radiographic and laboratory studies sparingly, if at all, in a mass casualty situation, and only if the results of such tests will change treatment. For example, possible closed, nonangulated fractures can be splinted, and radiographs can be safely delayed for 24 to 48 hours. A chest radiograph may be appropriate in patients complaining of chest pain, dyspnea, or abnormal chest wall motion, or who were potentially exposed to blast waves secondary to bombs. CT imaging may be quicker than plain radiographs in some injuries, and prioritization to CT may be required. Ultrasonography to detect free intraperitoneal fluid, pericardial fluid, and pneumothorax is time- and cost-effective and has been used in earthquakes to triage operative care.[18]

With the exception of identification of biological and chemical agents, there are few indications for laboratory testing in disaster medicine. If testing will change management, use point-of-care testing to expedite care. For example, obtain a baseline hematocrit and type and cross-matching for blood in cases of hemorrhagic shock. Pulse oximetry monitors may need to be used as spot assessments, rather than continuous bedside monitoring of a single patient. Consider laboratory studies to be accessory and ordered only in specific circumstances (carboxyhemoglobin in cases of smoke inhalation).

In a disaster situation involving many casualties, the blood bank should have up to 50 units of blood available and should have access to volunteer donors who can be rapidly mobilized. Potential donors include friends and family members of patients, as well as mildly injured patients.

REFERENCES

The complete reference list is available online at www.TintinalliEM.com.

CHAPTER 6 Natural Disasters

Lisa D. Mills
Trevor J. Mills

INTRODUCTION AND EPIDEMIOLOGY

Natural disasters continue to be an unpredictable source of worldwide morbidity and mortality and present unique challenges for practitioners of emergency care. The 2005 to 2014 annual average worldwide mortality rate was 76,416 deaths per year from natural disasters, with an average of 199.2 million worldwide victims per year during the same time period and an economic cost of $70.3 billion in 2015.[1] With the increase in rapidly mobilized recovery teams, emergency physicians are at the forefront of patient care after a natural disaster. It is here that we can have the greatest impact in treating survivors and minimizing secondary

TABLE 6-1 Timing of Disease Presentation

Timing of Onset	Presentation						
Acute phase	Trauma	Stress reactions	Drowning	Inhalational injury	Burns		
Immediate postevent phase	Infectious complications of trauma	Exacerbation of chronic disease	Acute stress disorder	Burns	Inhalational injury		
Recovery phase	Trauma	Communicable disease	Infectious complications of trauma	Soft tissue infections	Exacerbation of chronic disease	Vectorborne disease	Posttraumatic stress disorder

morbidity and mortality, often in the setting of a significantly impaired healthcare system. Research suggests that the burden of natural disasters is likely to rise in the coming years, due to increasing population density in high-risk areas and risks associated with expanding technology (e.g., fires or earthquakes in larger and taller buildings or critical infrastructure).[2]

Although the mechanics, warning period, and impact vary widely between types of natural disasters, there is a predictable pattern of events that occur and may be used to maximize the subsequent response. Natural disasters result in a combined loss of resources—infrastructure, economic, social, and health. Although this may be tempered by pre-event preparedness and infrastructure strength, this combination of resource loss has a synergistic impact on the health of and the delivery of health care to the affected population. Another commonality is the predictable pattern of pathology, seen in the progression from the impact of the event itself, through the acute aftermath, to the immediate postdisaster phase, and into the recovery phase (**Table 6-1**). Perhaps most salient for emergency practitioners, relief efforts can be implemented based on data from previous disaster experience, while simultaneously being tailored to the type of disaster (e.g., hurricane, earthquake, tornado, flood, tsunami, or snow) and region affected. Finally, disaster responders should be prepared to face the duty of management of dead bodies, on a scale otherwise seen only in the setting of combat.

LOSS OF RESOURCES

Most natural disasters—whether by water, wind, fire, or snow—cause some disruption of power, communication, and transportation systems. In developed and developing nations, entire cities can be destroyed instantly, overwhelming nearby healthcare facilities and personnel. In such cases, the traditional triage system may not be effective.[3] A Centers for Disease Control and Prevention posthurricane assessment in 2012 determined that most of the resulting public health emergencies were directly due to loss of public health infrastructure and related to clean-up and repair activities.[4] Because standard amenities, such as power, running water, and sanitation methods, may be unavailable for extended periods of time, all medical disaster planning must include practical, simple alternatives to technologies that are likely to fail during a disaster.

Lack of communication is a common feature of both the impact and delayed phases of a disaster. Even the most sophisticated equipment may fail due to regionwide outages or loss of electricity for charging devices. In our experience during the active phase of Hurricane Katrina, the only working means of communication within Charity Hospital was a single landline telephone. Difficulty in communication has led to recent innovation with proposals for disaster-specific electronic medical records.[5]

Evidence suggests that the predisaster level of preparedness and resources in a community has a significant impact on its response to a catastrophic event. Analysis of four earthquakes in different regions (developed and developing countries) found that regions with the least preparedness and weakest preexisting medical infrastructure had the highest number of deaths per patients injured.[6] Investment in targeted disaster preparedness efforts before an event occurs, particularly for the most vulnerable populations, is crucial in mitigating the effects of an inevitable disruption in resources during a disaster.[7]

DISEASE BURDEN

Understanding of the likely health emergencies to be encountered in the acute and postdisaster phases is crucial to any emergency response. Although it is widely thought that outbreaks of rare and/or severe disease inevitably follow many types of natural catastrophe, evidence does not support this belief.[8,9] Common medical problems after natural disasters include traumatic injury, infectious disease, exacerbations of chronic medical conditions, and a surge in mental health issues (**Table 6-2**). In addition to the common medical problems previously listed, the handling of bodies has an additional unique impact on the health of the affected population.

TRAUMA

Traumatic injuries frequently occur in the acute phase of a natural disaster, commonly from direct trauma from collapsing structures or flying debris. A second spike in trauma is seen during the recovery/clean-up phase, mainly due to unsafe infrastructure. However, this secondary spike in trauma may also include violent injuries, depending on the level of civil unrest.[10] Although most trauma is minor, management of severe injuries by healthcare professionals can prove especially challenging when resources are lacking, as they often require coordinated surgical care. **This necessitates adequate resources of anesthesia, blood products, surgical equipment and the ability to sterilize it, intensive care capacity, and operating theaters.** When these resources are unavailable, limb amputation, nonunion, and missed injury rates are high, and lack of safe blood products hampers surgical capability.[11,12] Recommendations for adequate surgical capability include mobile blood banks with adequate supply and well-trained staff, at least two units of blood available per operation, adequate supplies of appropriate anesthesia, strict adherence to national or international quality and safety standards, and functioning critical care units.[3,12,13]

TABLE 6-2 Common Disease Patterns

Trauma	Communicable Disease	Chronic Medical Conditions	Infectious Disease	Mental Health
Strains and sprains	Respiratory infections	Hypertension	Soft tissue infections	Stress reactions
Falls	GI infections	Diabetes	Open fractures	Depression
Lacerations		Renal failure	Vectorborne disease	Exacerbation of chronic condition
Burns		Chronic obstructive pulmonary disease	Local diseases	
Fractures				

INFECTIOUS DISEASE

Infectious diseases are commonly feared and should be anticipated after natural disasters. Although popular media often focuses on the possibility of rare disease epidemics, most postdisaster infections are directly related to the usual pathogens of that region.[9,14] One exception to this was the outbreak of cholera after the 2010 earthquake in Haiti, which is believed to have been brought in by United Nations relief workers.[15] Evidence indicates that the combination of communicable disease and population malnutrition is the major cause of morbidity and mortality in most disasters. Infectious disease predominantly occurs in the extended postevent phase.[16] Infectious disease risks are heightened by certain characteristics common to natural disasters: mass population movement and resettlement; overcrowding; poverty; sanitation and waste issues, including water contamination; absence of shelter, food, and healthcare access; and disruption of public health programs. Respiratory, GI, skin/soft tissue, and vectorborne infectious diseases are most commonly analyzed in disasters.

Respiratory illnesses range from direct aspiration of contaminated water (floods and tsunamis) to airborne droplet transmission to inhalation injuries caused by excess dust, allergens, or debris. In both the acute and postdisaster phases, reactive airway disease may be exacerbated. After one thunderstorm in 2016, nine patients died and the EMS system was overwhelmed in Melbourne, Australia, due to acute asthma exacerbations.

While infectious respiratory infections are mild, respiratory illness may account for 20% of all natural disaster deaths in children <5 years old.[13] In the acute phase of a flood or tsunami, inhalation of water with polymicrobial contamination may cause aspiration pneumonia.[17] Most respiratory infections emerge several weeks after disaster as disease spreads through shelters and settlement camps. **Both disaster victims and rescue workers are at risk for respiratory illness due to crowded conditions and compromised sanitation.[18,19]** Some respiratory illnesses (pertussis and measles) are preventable with adequate vaccination; thus, knowledge of the predisaster vaccination status of a population and sufficient vaccine stores may prevent severe outbreaks. Tuberculosis presents a special challenge for public health officials. To prevent outbreaks, adequate stores of antimicrobials must be on hand, and strict adherence to surveillance of known infectious cases is essential.[9]

GI illness—primarily diarrheal—is another common feature of postdisaster health care. Approximately 40% of deaths in the acute postevent phase (with 80% of these being children) can be attributed to diarrhea. These diseases are mainly due to issues of water quality and availability, sanitation, and cleaning materials; in one study, the mere presence of soap decreased diarrhea by 27% in a refugee camp.[16] As with respiratory illness, the incidence of GI disease often peaks several weeks after the disaster, and the infections are generally mild. With good health surveillance and attention to typical endemic disease patterns, severe GI illness outbreaks requiring extraordinary public health resources are rare.

Skin and soft tissue infections are seen in a variety of natural disasters. Falling debris from wind, fire, or earthquake can cause traumatic abrasions or lacerations. With a disrupted healthcare system or contaminated water exposure to the wound, the incidence of infection is likely to increase. Although wounds are frequently seen in the acute phase of a disaster, they are also often encountered during the clean-up phase several weeks to months after an event.[20,21] Severe infections are not prevalent; however, organisms such as *Vibrio vulnificus* in water-based disasters and gram-negative bacteria due to soil contamination of wounds in tornadoes and earthquakes have the potential for severe threats to life and limb.[9,22]

Vectorborne illnesses, such as yellow fever, malaria, and dengue fever, generally have a higher incidence during water-based disasters but can occur after any event in a vulnerable population. Although rare, the outbreak can occur up to 8 weeks after disaster.[13] Regions without predisaster populations of vectors or disease are not likely to suddenly acquire such infections; thus, although there was intense media speculation of the perceived risk of malaria, yellow fever, and other vectorborne illnesses after Hurricane Katrina, these illnesses were not seen in the Gulf Coast.[9] In regions where these illnesses are endemic, vector control is key, and initial postdisaster public health efforts should direct resources toward appropriate programs.

CHRONIC MEDICAL CONDITIONS

Management of the chronic health conditions of a displaced population is a significant contributor to postdisaster morbidity. Separation from medications or health technology products, removal from the usual sources of care, and disruption of the healthcare infrastructure after a catastrophic event can all contribute to exacerbations of patients' chronic disease. In an analysis of patients presenting to one of the few healthcare facilities available in the 2 months after Hurricane Katrina, 51% of all native patients had at least one preexisting medical condition, and half took at least one regular medication.[20] Other studies have shown that >25% of patients presenting after a variety of natural disasters have chronic medical conditions, and "medication refill" or "chronic medical problem" is frequently among the top five diagnoses made in disaster relief health clinics.[21,23]

Inability to properly control chronic diseases, such as hypertension, diabetes, asthma, or coronary artery disease, may well be the biggest unanticipated health threat to a postdisaster population (Table 6-3).[7] Understanding of the common chronic diseases of a region is essential for health relief efforts. In our experience, well-meaning donations of medications for conditions not normally experienced by our population (e.g., outdated psychiatric medications, older generation antiarrhythmics) went unused. Conversely, we were unable to keep enough antihypertensives or diabetic medications to supply the vast demand.

MENTAL HEALTH

An often-overlooked consequence of natural disasters is the psychological burden inflicted on survivors. Destruction of communities and property, witnessing terrifying and often fatal events, and disruption of normal life for days to years after the disaster can cause severe mental health consequences in survivors. In one study of post–Hurricane Katrina survivors, rates of posttraumatic stress disorder were 10 times the expected population incidence and on par with rates in returning Vietnam War veterans.[24] Psychological disorders may be exacerbated by lack of housing and illness or death of a close family member due to the disaster.[25] Disaster-related physical injury or illness may also contribute to mental health comorbidity. The number of emergency amputations due to the 2004 tsunami in an Indonesian surgical clinic quickly overwhelmed the ability of the healthcare system to provide the necessary psychological counseling for patients.[26] Conversely, mental health conditions, such as major depression, may exacerbate acute or chronic physical ailments due to weakened immune systems, disconnection with the larger community and healthcare systems, or attempts to cope by using drugs or alcohol. Suicide rates may also be elevated years after a significant disaster. Any appropriate healthcare response to disasters must include sufficient resources to deal with the degree and severity of psychological disorders suffered by survivors, including children, first responders, and those who have endured severe trauma or loss.

HANDLING OF BODIES

Any natural disaster with a significant number of casualties requires efficient and sanitary removal and proper burial of dead bodies. Although the fear of disease outbreak from survivor or rescue worker exposure to corpses is prevalent, such exposures are rare. Most initial victims of

TABLE 6-3 Commonly Neglected Disaster Response Medications and Supplies
• Antihypertensives
• Tetanus prophylaxis
• Soap
• Analgesics—oral and parenteral
• Insulin
• Oral hypoglycemics and sulfonylureas
• Antibiotics, especially for soft tissue infections
• Albuterol and ipratropium inhalers

natural disasters die of traumatic injuries; few are likely to have acute, communicable diseases, although the standard transmission risks of chronic infectious diseases, such as human immunodeficiency virus, tuberculosis, or hepatitis, to body-handling rescue workers are present.[27] Universal precautions for protective coverings, hand washing, disposal bags, and vaccinations should be followed by anyone working with dead bodies; this includes having sufficient refrigerated trucks on standby should morgue capabilities be overwhelmed.

HURRICANES

Hurricanes are among the most destructive natural disasters, particularly in coastal areas. Morbidity in the acute phase may be due to wind forces (collapsing buildings or flying debris) or water (storm surge or rapid flooding). Hurricanes tend to cause more structural damage than floods and therefore can disrupt infrastructure and population resettlement more severely.[28] Hospitals themselves are frequently damaged, but even if structurally intact, they may be affected by loss of power.[29] With catastrophic destruction of a densely populated region, such as in Hurricanes Katrina, Sandy, and Maria, temporary medical facilities may be needed months after a disaster. **Indeed, hurricanes may be the only natural disaster where more injury and death occur during the recovery period than in the acute phase.[30]**

Most posthurricane illness and injury falls into predictable categories. Studies from eight different hurricanes over the past 15 years all list a handful of patient diagnoses that compose the vast majority (up to 75%) of visits to healthcare centers: infections (specifically respiratory, GI, and skin); treatment of chronic medical conditions; wounds and lacerations; musculoskeletal injury and trauma; and rashes.[19,20,28-34] In functioning healthcare facilities, ED visits peak several days to weeks after the hurricane as citizens are allowed reentry into the area; there may be an acute, brief influx of several times the normal patient volume or a steady rise in visits over time.[5,20,31]

Initial traumatic injury directly due to hurricanes is relatively uncommon, and simple supplies for minor sprain, strain, and fracture care are recommended. Although surgical units and personnel are an important adjunct, basic supplies and some radiographic capability may provide the best investment of limited resources.[28,30] Unintentional injuries predominate; a post–Hurricane Katrina evaluation of injuries found that only 2% were due to intentional trauma.[18] Causes of traumatic death in the acute period include falling objects, motor vehicle crashes, and electrocution. In the recovery period (weeks to months after the hurricane), clean-up–associated trauma predominates. One study after Hurricane Hugo found that one-third of all wounds evaluated in an ED were caused by chainsaw accidents.[32]

As with other disasters, infections are generally mild, are reflective of the typical local disease burden, and occur several weeks to months after the hurricane. Scattered outbreaks of mild respiratory and GI illness have been described, with overcrowding in shelters and sanitation issues the main predictors of disease. Unless hurricanes are associated with concomitant prolonged flooding in endemic areas, the risks of waterborne disease are minor. Post–Hurricane Katrina incidence of *V. vulnificus* skin infection was consistent with typical nondisaster rates.[9]

Individuals without transportation or with tenuous connection to community resources are potentially more likely to be negatively impacted by the effects of a severe hurricane. These individuals may not be able to evacuate in advance of a storm and thus suffer greater risks of direct trauma and water- or wind-related morbidity during the initial impact. Effects may persist beyond the acute phase. A study of Hurricane Mitch survivors noted that GI illness and emotional distress were more likely months after the storm in those without access to housing, food, or medical care.[25] Other population concerns often seen in hurricanes include the healthcare burden of relief workers (civilian and military). Recovery efforts often require massive numbers of workers whose living conditions are often on par with storm victims. In one study, relief workers were nearly six times more likely than natives to use nonhospital healthcare facilities, and a spike in respiratory illness was attributed to transmission through a military battalion.[18] Our experience found that although younger than the native population, nearly half of relief workers seeking care had significant comorbidities that further burdened the struggling medical system after Hurricane Katrina.[20] Disaster planning should account for the needs of disenfranchised citizens as well as the expected influx of relief workers, many of whom may have chronic medical conditions.

EARTHQUAKES

Earthquakes are a unique disaster phenomenon in that there is no technology to detect a pending earthquake and thus no opportunity to provide a warning. Due to the lack of warning, supplies and a response plan must be continuously available. As was evidenced by the Haiti experience in January 2010, earthquakes can destroy water, electric, communication, gas, and sewage lines and cause structural instability. With no opportunity to evacuate before an earthquake, there is increased potential for casualties. People are at increased risk for being trapped in rubble or stranded. The first 1 to 14 days of response to an earthquake are dedicated to recovery of the injured. After an earthquake, the majority of fatalities occur within the first 3 hours.[35]

Injuries after earthquakes are the result of falling structures and debris. The most common injuries are fractures and crush injuries.[36,37] One hospital that registered 2892 patients after an earthquake reported that 37% of patients had musculoskeletal injuries. This hospital also reported the frequent occurrence of scalp injuries with large tissue defects.[36] Another hospital that registered 1500 patients in the first 72 hours after an earthquake reported that 78.4% of patients had extremity injuries; 50.4% of injuries were fractures, primarily closed. This same study reported that 37% of injuries required extensive debridement.[12] After the Mansehra earthquake in Pakistan in 2005, the medical equipment that the response teams found most useful was "external fixators that are easily applied."[36]

As with all disaster areas, the most common "illnesses" are the "regular medical needs of the people living in the earthquake zone."[36] In undeveloped regions recovering from large earthquakes, "preventable diseases, such as measles, are on the rise."[37] With proper sanitary and sewage techniques and adequate supplies of potable water, GI disease remains uncommon.

People with compromised mobility, including some geriatric patients, people with paralysis, amputees, people on ventilators, and people in wheelchairs and walkers, will be less likely to evacuate before the disaster and will have increased difficulty extracting themselves from the ruins. These people are more likely to be stranded in debris and to sustain crush injuries (see also Chapter 7, "Bomb, Blast, and Crush Injuries") by collapsing buildings. These populations are especially at risk after earthquakes, because there will be no opportunity to evacuate before the disaster. Rescue and health services coordinators should make provisions for larger numbers of patients with increased needs after earthquakes. One study analyzed a metropolitan area in the United States and found that 31.6% of people >65 years old had a disability and 16.6% of people >65 years required assistance to evacuate. Planning for and responding to earthquakes requires an estimate of the number of citizens with special needs.[38]

TORNADOES

The continent of North America sustains more tornadoes than any other location in the world.[39] Nationally, 800 tornadoes are sighted annually. The annual human toll is estimated to be 80 deaths and 1500 injuries.[40] Tornadoes cause focal damage to buildings and lines above ground. It is unusual for entire regions to lose power and communications capacity. It is unusual for multiple hospitals to be disabled by a single tornado.[41,42] As a result, medical infrastructure in developed countries remains functional. Surge capacity may be tested in the immediate aftermath, but the provision of adequate chronic medical care is usually unhampered.

Most commonly, injuries from tornadoes result from being struck by flying debris or being thrown by the force of the tornado. Patients who were thrown or airborne as a result of the tornado sustain more severe injuries than patients who are struck by debris.[43,44] Additional risk factors for hospitalization or death include being struck by broken glass or falling objects, having one's home lifted off of its foundation, collapsed ceiling or floor, or loss of walls of the shelter structure.[44,45] Injuries are commonly multisystem. Fractures and soft tissue trauma are the most common injuries reported.[39,46-48] In one study, most patients (91%) sustained injuries to the extremities. Head, chest, and abdominal injuries were also common, occurring in 45%, 45%, and 27% of patients, respectively.[43] Head injuries are the more common cause of death.[39,47,48] Death from the impact after being thrown by the tornado is thought to most often occur at the scene, rather than en route to or at the hospital.[49-51]

Wound contamination is common among patients who are thrown by the tornado. Polymicrobial contamination is common.[39,46] Gram-negative organisms commonly infect the wounds of those injured by tornadoes.[43] Studies that report low infection rates attribute this to meticulous attention to open wounds.[52]

Where functioning tornado warning systems exist, injury and loss of life are dramatically reduced.[40,53] People in mobile homes or outdoors without cover are more likely to sustain severe and fatal injuries during a tornado.[45,53,54] Deaths are more common in patients who are in mobile homes or in rooms above ground with windows, who are "older," or who have less warning regarding the approaching tornado.[43,44,48,49,55] Use of a tornado shelter is associated with a significant reduction in tornado-associated injuries.[54]

FLOODS AND TSUNAMIS

Water-based natural disasters, such as floods and tsunamis, can be extremely destructive. Although floods can occur from a storm or flowing body of water, tsunamis are formed when a massive force (e.g., an underwater earthquake, volcanic eruption, meteorite impact, or landslide) displaces a large amount of water in a rapid period of time. A spring flood of the Yangtze River in China in 1931 caused >3 million deaths, and more recently, deaths from the Indian Ocean tsunami in 2004 approached 300,000. Factors that contribute to the catastrophic nature of these events include the short (if any) warning period to vulnerable populations and their association with other natural events, such as an oceanic earthquake resulting in a tsunami. Key challenges faced by healthcare providers include severe and prolonged incapacitation of physical buildings due to structural damage or persistent standing water; handling and identification of large numbers of dead bodies; and the chronic needs of a large, displaced population in temporary shelter.[26,56,57]

Acute injuries may be caused by sheer force of water, drowning, and trauma from falling objects. A review of flood deaths from 1989 to 2003 found that morbidity and mortality after flood were related not only to direct physical impact but also the socioeconomic conditions of the affected area. Two thirds of fatalities were from drowning, mostly associated with motor vehicles in the acute phase (e.g., when floodwaters are still high); low crossings and bridges were most dangerous. Only 12% of deaths were from trauma, and the vast majority of cases occurred in the initial impact phase of the disaster.[58]

Illnesses from water-based disasters generally occur after the acute phase and are dominated by infectious disease. True epidemics are rare, and respiratory illnesses predominate. These are generally minor and self-limited, although uncommonly, severe pulmonary infections or pneumonitis directly related to aspiration of floodwaters (e.g., "tsunami lung") may occur. As long as clean, safe, adequate supplies of potable water are available, acute gastroenteritis and diarrheal illnesses are relatively rare; a Sri Lankan refugee camp after the 2004 tsunami diagnosed GI complaints in <1% of patients.[23] Minor skin trauma is common and has the potential to progress to infected wounds if prolonged exposure to floodwaters and delayed access to care are present.

Certain population groups have been shown to have higher risks of morbidity and mortality after floods and tsunamis. Women had three times the risk of death compared with men after the 2004 tsunami due to heavier clothes impeding escape, risking lives to save their children, lack of swimming ability, and increased dangers in settlement camps.[26] In a comprehensive study of flood deaths, however, men had more than twice the mortality rate of women, which the authors surmised was due to increased risk-taking behavior during the storm (attempting to drive through flooded passages, traveling to unsafe areas in an attempt to retrieve belongings).[58] Public awareness of the rapidity and danger of water, simple swimming instruction, and clear warnings of the dangers of driving during floods may prevent at-risk populations in flood-prone areas from loss of life in future disasters.

BLIZZARDS AND SNOW DISASTERS

A blizzard is a winter storm with wind speeds of 35 miles per hour or higher accompanied by significant falling or blowing snow. The Mid-Atlantic, New England, Midwest, Plains, Rocky Mountain states, and Alaska are affected by blizzards and snow disasters. Above-ground power and communication lines are the primary resources lost during winter storms. Traditionally, these are restored relatively quickly as compared with the duration without resources after other natural disasters.[59]

Generally, ED volumes do not significantly increase after blizzards and snow disasters. However, there is a shift in the presenting complaints.[59-61] Injuries after winter weather disasters most commonly result from slipping on the ice, falling from trees while clearing branches, and injuries from clearing snow. The most common injuries are back injuries and fractures.[62,63] In one study, the incidence of fractures increased until the sixth day after the storm.[64]

Carbon monoxide poisoning increases dramatically during and following winter weather disasters.[60,62,65-68] Most people presenting with carbon monoxide poisoning report using a portable generator.[69] A smaller group reported burning charcoal in the house to generate heat.[65] In one study after a blizzard, the local hyperbarics services were overwhelmed and unable to respond to the sudden surge in carbon monoxide poisonings.[62]

One study documented an increase in the number of myocardial infarctions and angina after a blizzard. This was primarily in association with shoveling snow. The majority of these cases were in people who did not have previously diagnosed coronary artery disease. One fourth of these patients were women.[70]

RELIEF EFFORTS

Of particular importance to the emergency medical practitioner is the experience and effect of postdisaster volunteer relief efforts. Although well meaning, the literature is filled with examples of emergency personnel who ended up burdening rather than assisting a fractured community. Any emergency practitioner who truly wishes to provide meaningful health care to a displaced and disenfranchised patient population should be mindful of the lessons learned from a variety of natural disasters.

Medical relief volunteers are often the first outside help to arrive in the aftermath of a disaster, and although some are well coordinated, many are not. Volunteers are often exuberant, expecting dramatic rescues and emergency interventions. They may be unwilling to provide much-needed routine medical care, unfamiliar with the region or local disease patterns, and unable to fully comprehend the loss of resources.[71] Furthermore, the needs of rescue personnel often strain a fragile infrastructure, with demands on housing, food, health care, and essential resources; one analysis of relief efforts after the 2004 tsunami concluded that "personnel who do not bring essential skills are often a burden—much more should also be done to ensure that the right type of people are sent on relief missions."[26]

Embedding locals familiar with the language, culture, and healthcare patterns of the affected region can significantly enhance the effectiveness of relief efforts and promote cooperation between disparate volunteer groups. Furthermore, appropriate anticipation by relief groups of the true population needs can be crucial: reproductive hygiene kits were distributed to women in a postflood refugee camp after an initial spike in sexual assaults and were widely credited with improving patient morale and health.[26]

The National Disaster Medical System, a government agency responsible for sending highly organized and often experienced teams to disaster areas, recommends the following for disaster response: teams with well-trained and organized support staff; the ability to be self-sufficient for at least 72 hours; clear communication with area hospitals and medical resources; individuals dedicated to transportation issues; a designated coordinator of walk-in volunteers; and professional methods of record keeping, forms, and copy-making capability.[30] Our experience during Hurricane Katrina also suggests that strong, coordinated partnerships between local emergency personnel and formal military medical units have great promise for sophisticated, expanded acute and delayed postdisaster medical relief as well as continuance of medical education and resident training programs in a devastated community.[20]

REFERENCES

The complete reference list is available online at www.TintinalliEM.com.

CHAPTER 7

Bomb, Blast, and Crush Injuries

Michael J. Bono
Pinchas (Pinny) Halpern

BOMB AND BLAST INJURIES

EPIDEMIOLOGY

Blast injuries using conventional weapons have emerged as the terrorist weapon of choice. In 2016, the National Counterterrorism Center reported 11,072 terrorist attacks worldwide, with 33,800 people injured and more than 25,600 deaths.[1] Total terrorist attacks decreased by 9% and total deaths decreased by 13% compared to 2015. As a comparison, in 2007, there were 14,000 terrorist attacks, with 44,000 injuries and 22,000 deaths, which was a 20% to 30% increase over 2006.[1] Explosive devices in military conflicts killed or injured more than 25,000 U.S. and Coalition forces and more than 100,000 Iraqis.[2] Blast injuries are increasing in the civilian setting, particularly suicide bombings, and emergency personnel must be familiar with the management and treatment of blast injuries and potential mass casualty incidents.[3-10] The United States is not immune from intentional bombings, with about 36,000 bombing incidents reported from 1983 to 2002 including explosive, incendiary, premature, and attempted bombings.[7] There were 281 people injured in the 2013 Boston Marathon bombing, with most injuries involving the lower extremities and soft tissue.[9] Blast injury is not a modern phenomenon, and there are reports of flammable gases causing blast injuries from volcanic eruptions and mining accidents dating back to 1316.[11] Death, survival, and hospitalization rates vary greatly, depending on the type of explosive, distance from the explosion, and whether the explosion occurred in an open or closed space. Although some victims die immediately at the scene, the majority of injuries suffered by the immediate survivors of bombings are potentially survivable. Blast injuries commonly occur not as isolated incidents, but as part of multiple-casualty incidents of varying sizes. This pattern, combined with the fact that most emergency physicians have never encountered a blast injury victim or a true mass casualty incident, makes the care of often eminently salvageable victims contingent upon appropriate training and skill retention by the individual emergency physician, along with appropriate institutional leadership, planning, and preparation.

Terrorist bombings result in high injury scores for victims as well as higher hospital resource use by victims than by victims of other trauma. Blast victims have increased immediate scene mortality, greater hospital mortality, more frequent need for surgical intervention, longer hospital stays, and greater use of critical care.

PATHOPHYSIOLOGY

An explosion is the instantaneous transformation of a solid or liquid into a gas, releasing tremendous kinetic and heat energy. Detonation of a conventional high explosive generates a blast wave that spreads out from the detonation point and displaces air, water, or anything in its path. The blast wave consists of two parts: a shock wave of high pressure followed closely by a blast wind, which is air mass in motion. The blast wave loses its energy over distance and time.

FIGURE 7-1. Secondary blast injury to the chest and abdomen due to flying debris. It is difficult to assess the degree of underlying internal organ injury without imaging and careful clinical follow-up, especially if the patient is unconscious. [Image used with permission of Tel Aviv Medical Center.]

There are four main types of blast effects. A primary injury is caused by a direct effect of blast wave overpressure on tissue. Primary blast injury mostly (but not exclusively) affects air-filled structures such as the lungs, ears, and GI tract, by the following mechanisms: spalling, shearing, and implosion. **Spalling** is displacement and fragmentation of a dense medium into a less dense medium.[12] An example of spalling is a blast wave causing the lung parenchyma to explode into the alveolar space like a geyser. **Shearing**, sometimes called inertia, is a stress caused by the blast wave traveling through different tissue densities at different velocities. An example of shearing is the blast wave traveling through the pulmonary vessels and air spaces, resulting in ruptured vascular and bronchial pedicles. **Implosion** is the opposite of spalling, where the less dense material is displaced into denser material. An example of implosion is the blast wave causing the flexible air spaces to rebound to greater than original size, sometimes causing air embolism from the alveoli into the pulmonary vessels.[12] A secondary blast injury is due to collateral damage from flying objects and shrapnel (**Figures 7-1 and 7-2**). Tertiary blast injury results from the victim being propelled through the air and striking stationary objects. A quaternary blast injury is a result of burns, smoke inhalation, or chemical agent release.

FACTORS AFFECTING BLAST INJURY

The effects of a bomb blast are difficult to predict in the individual victim, as well as in the group. However, a number of important principles are known:

Distance of victim from explosion: The intensity of an explosion pressure wave declines with the cubed root of the distance from the explosion. A person 3 m (10 ft) from an explosion experiences eight times more overpressure than a person 6 m (20 ft) away. Proximity of the victim to the explosion is an important factor in a primary blast injury.

Enclosed versus open space: The effects of an explosion in a closed space, such as a room, bus, or train, are much greater than in an open space. Injuries are more severe, and mortality is greater.

Surrounding environment: Blast waves are reflected by solid surfaces; thus, a person standing next to a wall may suffer increased primary blast injury.

Quantity of explosive: A greater quantity of explosive produces greater potential for damage at any distance.

Type of explosive: Explosives are commonly classified as either low-order or high-order. Low-order explosives burn rapidly and produce