TOTAL BURN CARE

David N. Herndon

ELSEVIER

FIFTH EDITION

Total Burn Care

Total Burn Care

FIFTH EDITION

David N. Herndon, MD, FACS
Chief of Staff and Director of Research, Shriners Hospitals for Children–Galveston,
Director of Burn Services, University of Texas Medical Branch
Jesse H. Jones Distinguished Chair in Surgery
Professor, Department of Surgery and Pediatrics
University of Texas Medical Branch
Galveston, TX, USA

For additional online content visit ExpertConsult.com

ELSEVIER

Edinburgh London New York Oxford Philadelphia St Louis Sydney 2018

ELSEVIER

First edition 1996
Second edition 2002
Third edition 2007
Fourth edition 2012
Fifth edition 2018

Notices
Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds or experiments described herein. Because of rapid advances in the medical sciences, in particular, independent verification of diagnoses and drug dosages should be made. To the fullest extent of the law, no responsibility is assumed by Elsevier, authors, editors or contributors for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

ISBN: 978-0-323-47661-4
eISBN: 978-0-323-49742-8
Printed in China
Last digit is the print number: 9 8 7 6 5 4 3 2 1

Content Strategist: Belinda Kuhn
Content Development Specialist: Nani Clansey
Content Coordinator: Joshua Mearns
Project Manager: SriVidhya Shankar
Design: Amy Buxton
Illustration Manager: Amy Heyden-Naylor
Marketing Manager: Kristin Koehler

Preface

Over the past three decades, vast improvements in survival from severe burns have been accompanied by a progressively greater understanding of the complex processes underlying this type of trauma. Basic science, and translational and clinical discoveries have provided new opportunities to advance burn care along its entire spectrum from management of burn shock, inhalation injury, sepsis, and hypermetabolism to scar reconstruction and rehabilitation. These and other key aspects of care, which are the focus of this book, share the goal of providing burn survivors more complete recovery from burns so that they can return to their communities as fully functioning members. All aspects of the physiological, psychological, and emotional care of acutely burned patients evolving through recovery, rehabilitation, and reintegration back into society and daily life are reexamined in this new, fifth edition.

The objective of the fifth edition of this book remains the same—to serve as a sophisticated instruction manual for a variety of health care professionals less experienced in burns. It is intended to be a resource not only for surgeons, anesthesiologists, and residents, but also for nurses and allied health professionals. Although this edition of the book covers many of the same fundamental concepts and techniques as the previous edition, the chapters have been extensively updated with new data and references to reflect advances in care and knowledge that have arisen over the past 5 years. In some cases, the chapters have been completely rewritten. The new edition also contains new chapters dealing with the care of unique populations, as well as newer topics in reconstruction and scarring. As before, demonstrative color illustrations are provided throughout the book. Moreover, many chapters are accompanied by online PowerPoint presentations to aid group discussion, as well as video clips to enhance understanding of complex concepts and techniques.

This new edition would not be possible without the many respected colleagues and friends who have volunteered their time and worked tirelessly to produce the various chapters. Grateful acknowledgment is also given to Elsevier publishing staff, who have maintained a high standard in the development and preparation of this fifth edition. Special thanks are offered to Dr. Derek Culnan, who graciously assisted in reviewing and updating material throughout the book, as well as to Genevieve Bitz and Dr. Kasie Cole for editorial assistance. Finally, I wish to thank my wife, Rose, for her invaluable support.

In Memorium of Ted Huang, MD

Derek Culnan, MD, Genevieve Bitz, Karel D. Capek, MD, David Herndon, MD

Last year, returning with his wife from a medical mission trip to Taiwan, Dr. Ted Huang died. On that day, we lost a colleague; a friend; and a surgeon of unquestioned skill, passion, and knowledge as well as a teacher unstinting in his advice and zeal to help others. Following a career as a leader in the fields of gender reassignment and cosmetic surgery, Dr. Huang retired to spend the next 20 years working to revolutionize the practice of surgical reconstruction of pediatric burns. He left behind a legacy in research and surgery in the papers he authored and the surgeons he mentored that few can achieve. He was the principal author of the previous four editions of the reconstructive section of this book. Stepping into the OR filled him with joy, for he was a man who truly loved and lived his career. When a surgical fellow once asked if he could assist, Dr. Huang responded, "I've been operating on burn scars since before you were born. If I need your help, then the patient and I both have a big problem. But, if you want, you can come have fun with me." We are better for having known him, and our principal regret is that we never figured out the recipe for his legendary bread, which, as with everything, he doled out generously to family, friends, patients, and colleagues. As he would undoubtedly have said, that's how the cookie crumbles. This book is a testimonial to his humanity and skill, from those he collaborated with and those he mentored. Thank you, Dr. Huang, for everything.

With greatest honor and humility we dedicate this book to you.

List of Contributors

Rajeev B Ahuja MS MCh DNB FICS FACS FAMS
Senior Consultant in Plastic Surgery
Department of Plastic Surgery
Sir Ganga Ram Hospital Marg;
Ex-Head, Department of Burns and Plastic Surgery
Lok Nayak Hospital and Associated Maulana Azad Medical College
New Delhi, India

J F Aili Low MD PhD
Specialist in Plastic Surgery and Surgery
Associate Professor in Plastic Surgery
Art Clinic Uppsala
Uppsala, Sweden

Brett D. Arnoldo MD, FACS
Professor of Surgery
Medical Director Parkland Burn Center
UT Southwestern Medical Center
Dallas, TX, USA

Amina El Ayadi PhD
Department of Surgery
University of Texas Medical Branch
Shriners Hospitals for Children
Galveston, TX, USA

Sarah E Bache MBChB PhD MRCS Ed
Speciality Registrar in Burns and Plastic Surgery
St Andrew's Centre for Burns and Plastic Surgery
Broomfield Hospital Chelmsford
Essex, UK

Juan P Barret MD PhD
Head of Department
Professor of Surgery
Department of Plastic Surgery and Burns
University Hospital Vall d'Hebron
Universitat Autònoma de Barcelona
Barcelona, Spain

Robert E Barrow PhD
Retired Professor of Surgery, Coordinator of Research
University of Texas Medical Branch
Shriners Hospitals for Children–Galveston
Galveston, TX, USA

Debra A Benjamin RN MSN
Nursing Program Manager
University of Texas Medical Branch
Galveston, TX, USA

Mette M Berger MD PhD
Associate Professor, Burn Center Director, Intensive Care Service
University Hospital of Lausanne
Lausanne, Switzerland

Eileen Bernal MD
Resident
University of Texas Southwestern
Dallas, TX, USA

Genevieve H Bitz
Adjunct Researcher
JMS Burn and Reconstructive Center
Jackson, MS, USA

Fredrick J Bohanon MD
General Surgery Resident
Department of Surgery
University of Texas Medical Branch
Galveston, TX, USA

Branko Bojovic MD FACS
Chief of Plastic Surgery
Shriners Hospitals for Children–Boston
Member of the Faculty of Surgery
Harvard Medical School
Assistant Surgeon
Massachusetts General Hospital
Boston, MA, USA

Ludwik Branski MD
Assistant Professor
Department of Surgery, Division of Plastic Surgery
University of Texas Medical Branch
Staff Surgeon
Shriners Hospital for Children
Galveston, TX, USA

Elisha G Brownson MD
Burn Critical Care Fellow
Department of Surgery
Harborview Medical Center
Seattle, WA, USA

Michael C Buffalo DNP RN CCRN (A/P) CEN CPN CPEN ACNP ACPNP
Nurse Practitioner
Department of Surgery
University of Texas Medical Branch Blocker Burn Unit
Shriners Hospitals for Children–Galveston
Galveston, TX, USA

Janos Cambiaso-Daniel MD
Resident
Division of Plastic, Aesthetic and Reconstructive Surgery
Department of Surgery
Medical University of Graz
Graz, Austria

Stephanie A Campbell BSN RN CCRN
Burn Program Manager
Parkland Regional Burn Center
Parkland Health & Hospital System
Dallas, TX, USA

Leopoldo C Cancio MD FACS FCCM
Colonel, MC, US Army
Brooke Army Medical Center
Fort Sam Houston, TX, USA

Karel D Capek MD
Clinical and Research Fellow,
Surgical Critical Care, Burns, and Reconstruction Shriners Hospitals for Children
University of Texas Medical Branch
Galveston, TX, USA

Kelly D Carmichael MD
Associate Professor
Department of Orthopaedic Surgery and Rehabilitation
University of Texas Medical Branch
Galveston, TX, USA

Joshua S Carson MD
Assistant Professor
Division of Burns, Trauma & Acute *CARE* Surgery
Department of Surgery
University of Florida
Gainesville, FL, USA

Michele Carter PhD
Professor, Institute for the Medical Humanities
Frances C. and Courtney M. Townsend, Sr., MD Professor in Medical Ethics
University of Texas Medical Branch
Galveston, TX USA

Mario M Celis MS PA-C
Department of Surgery, University of Texas Medical Branch
Shriners Hospitals for Children
Galveston, TX, USA

Jiake Chai MD PhD
Professor of Burn Surgery
Department of Burn and Plastic Surgery, Burns Institute of PLA
The First Affiliated Hospital of PLA General Hospital
Beijing, China

Gp Capt Pallab Chatterjee MS DNB (Gen Surg) DNB (Plastic Surgery)
Sr Advisor (Surgery) & Plastic Surgeon
Associate Professor (Surgery)
Command Hospital Air Force
Bangalore, India

Linda Chilton
Registered Nurse, Surgical Nurse Practitioner
Senior SCP (Plastics)
St Andrew's Centre for Plastic Surgery and Burns
Broomfield Hospital
Chelmsford
Essex, UK

Dai H Chung MD FACS FAAP
Professor of Surgery
Chairman, Department of Pediatric Surgery
Vanderbilt University Medical Center
Nashville, TN, USA

Kevin K Chung MD FCCM FACP
Medical Director, Burn ICU
US Army Institute of Surgical Research
Fort Sam Houston
San Antonio, TX, USA

Audra T Clark MD
Clinical Research Fellow
Department of Surgery
University of Texas Southwestern Medical Ceneter
Dallas, TX, USA

Amalia Cochran MD
Associate Professor
Vice Chair of Education and Professionalism
Department of Surgery
University of Utah School of Medicine
Salt Lake City, UT, USA

April Cowan OTR OTD CHT
Assistant Professor
School of Health Professions
University of Texas Medical Branch
Galveston, TX, USA

Robert A Cox PhD
Professor
Department of Pathology
University of Texas Medical Branch
Galveston, TX, USA

Beretta Craft-Coffman PA-C
Vice President of Non-Physician Providers
Burn and Reconstructive Centers of America
Augusta, GA, USA

Derek M Culnan MD
Burn, Plastic, and Critical Care Surgeon
JMS Burn and Reconstruction Center
Merit Health Central Hospital
Jackson, MS, USA

Moayad Dannoun MD
Burn Reconstruction Fellow
University of Texas Medical Branch
Shriners Hospitals for Children–Galveston
Galveston, TX, USA

Alexis Desmoulière PhD
Professor of Physiology, Faculty of Pharmacy
University of Limoges
Limoges, France

Matthias B Donelan MD
Chief of Staff
Shriners Hospitals for Children–Boston
Associate Clinical Professor of Surgery
Harvard Medical School
Visiting Surgeon
Massachusetts General Hospital
Boston, MA, USA

Peter Dziewulski FFICM FRCS (Plast)
Clinical Director, Burn Service, Consultant Plastic and Reconstructive Surgeon
St Andrews Centre for Plastic Surgery and Burns
Chelmsford, Essex, UK

Naguib El-Muttardi FRCS
Consultant Plastic and Burns Surgeon
Department of Plastic Surgery
St. Andrew's Centre for Burns and Plastic Surgery
Chelmsford, UK

Perenlei Enkhbaatar MD PhD
Professor, Department of Anesthesiology and Charles Robert Allen Professor in Anesthesiology,
The University of Texas Medical Branch
Galveston, TX, USA

Shawn P Fagan MD
Chief Medical Officer
Burn & Reconstructive Centers of America
Augusta, GA, USA

James A Fauerbach PhD
Associate Professor
Department of Psychiatry and Behavioral Sciences
Johns Hopkins University School of Medicine
Baltimore, MD, USA

Celeste C Finnerty PhD
Associate Professor
Department of Surgery
University of Texas Medical Branch
Shriners Burns Hospital for Children
Galveston, TX, USA

Christian Gabriel MD
The Ludwig Boltzmann Institute for Experimental and Clinical Traumatology
Austrian Cluster for Tissue Regeneration
Altenberg, Austria

James J Gallagher MD
Associate Professor
Department of Surgery
Weill Cornell Medical College
New York, NY, USA

Nicole S Gibran
Director, UW Medicine Regional Burn Center
Professor, Department of Surgery
Harborview Medical Center
Seattle, WA, USA

Cleon W Goodwin MD
Director, Burn Services
Western States Burn Center
North Colorado Medical Center
Greeley, CO, USA

Jeremy Goverman MD FACS
Assistant Professor of Surgery
Division of Burns
Massachusetts General Hospital
Shriners Hospitals for Children
Boston, MA, USA

Ashley N Guillory PhD
Assistant Professor
Physician Assistant Studies
University of Texas Medical Branch
Galveston, TX, USA

Herbert L Haller MD
Senior Surgeon
UKH Linz der AUVA
Trauma and Burns
Linz, Austria

Houman K Hassanpour BA
Medical Student
School of Medicine
University of Texas Medical Branch
Galveston, TX, USA

Hal K Hawkins PhD MD
Professor, Department of Pathology
University of Texas Medical Branch
Galveston, TX, USA

David N Herndon MD FACS
Chief of Staff and Director of Research, Shriners Hospitals for Children–Galveston
Director of Burn Services, University of Texas Medical Branch
Jesse H. Jones Distinguished Chair in Surgery
Professor, Department of Surgery and Pediatrics
University of Texas Medical Branch;
Professor
Department of Surgery
University of Texas Medical Branch
Shriners Hospitals for Children
Galveston, TX, USA

Maureen Hollyoak MBBS MMedSc FRACS
General Surgeon
Brisbane, Australia

Ted T Huang MD FACS (deceased)
Professor
University of Texas Medical Branch
Shriners Hospitals for Children;
Clinical Professor of Surgery
Shriners Burns Hospital
University of Texas Medical Branch
Galveston, TX, USA

Byron D Hughes MD
Resident, General Surgery
University of Texas Medical Branch
Galveston, TX, USA

Gabriel Hundeshagen MD
Research Fellow, Department of Surgery
University of Texas Medical Branch
Galveston, TX, USA;
Resident, Department of Hand, Plastic and Reconstructive Surgery
BG Trauma and Burn Center Ludwigshafen
University of Heidelberg, Germany

Mohamed E. Ismail Aly MSc MRCS(Ed) MD FRCSEd(Plast)
Consultant Plastic and Burns Surgeon
Royal Manchester Children's Hospital and Wythenshawe Hospital
Manchester, UK

Mary Jaco RN MSN
Hospital Administrator
Shriners Hospitals for Children
Galveston, TX, USA

Marc G Jeschke MD PhD FACS FRCSC
Professor
Department of Surgery, Division of Plastic Surgery and Department of Immunology
University of Toronto
Sunnybrook Health Sciences Centre
Toronto, ON, Canada

Carlos Jimenez MD
Associate Professor
Department General Surgery
Shriners Burn Institute
Galveston, TX, USA

Andreas Jokuszies MD
Consultant Surgeon for Plastic, Hand and Reconstructive Surgery
Department of Plastic, Hand and Reconstructive Surgery
Burn Center
Hanover Medical School
Hanover, Germany

Lars-Peter Kamolz MD MSc
Professor and Head: Division of Plastic, Aesthetic and Reconstructive Surgery,
Department of Surgery
Medical University of Graz
Head of the Research Unit for Safety in Health
Medical University of Graz;
Deputy Chief Medical Officer
LKH- University Hospital Graz
Graz, Austria

Jennifer Kemp-Offenberg OTR
Rehabilitation Services Manager
Shriners Hospitals for Children
Galveston, TX, USA

Michael P Kinsky MD
Professor
Department of Anesthesiology
University of Texas Medical Branch
Galveston, TX, USA

Gordon L. Klein MD
Professor, Department of Orthopedics
University of Texas Medical Branch
Galveston, TX, USA

Makiko Kobayashi PhD
Professor
Department of Internal Medicine/Infectious Diseases
University of Texas Medical Branch
Galveston, TX, USA

George C Kramer PhD
Director
Department of Anesthesiology
University of Texas Medical Branch
Galveston, TX, USA

Maggie J Kuhlmann-Capek MD
Fellow, Division of Maternal Fetal Medicine
Department of Obstetrics and Gynecology
University of Texas Medical Branch
Galveston, TX, USA

Peter Kwan MD PhD
Assistant Professor, Department of Surgery
University of Alberta
Edmonton, Alberta, Canada

Jong O Lee MD FACS
Professor
Department of Surgery
University of Texas Medical Branch
Shriners Hospital for Children
Galveston, TX, USA

Kwang Chear Lee MD MSc
Clinical Research Fellow,
University of Birmingham
Birmingham, UK

Jorge Leon-Villapalos MD FRCS (Plast)
Consultant Plastic and Reconstructive Surgeon, Paediatric Clinical Lead
Department of Plastic Surgery and Burns, Chelsea and Westminster Hospital
London, UK

Benjamin Levi MD
Director, Burn/Wound and Regenerative Medicine Laboratory
Associate Burn Director
Assistant professor in Surgery
University of Michigan
Ann Arbor, MI, USA

William C Lineaweaver MD FACS
Medical Director
JMS Burn and Reconstructive Center
Chief of Surgery
Merit Health Central Hospital
Jackson, MS, USA

Kimberly M Linticum ACNP-BC
Acute Care Nurse Practitioner
Burn and Reconstructive Centers of America
Augusta, GA, USA

Jeffrey Lisiecki MD
Resident, Plastic Surgery
University of Michigan
Ann Arbor, MI, USA

Omar Nunez Lopez MD
General Surgery Resident
Department of Surgery
University of Texas Medical Branch
Galveston, TX, USA

Caroline Martinello MD
Assistant Professor
Department of Anesthesiology
University of Arkansas for Medical Sciences
Little Rock, AR, USA

J A Jeevendra Martyn MD FCCM
Professor of Anesthesia, Harvard Medical School
Anesthesiologist, Massachusetts General Hospital
Chief of Anesthesiology, Shriners Hospitals for Children
Boston, MA, USA

Arthur D Mason Jr MD (Deceased)
Emeritus Chief
Laboratory Division
US Army Institute of Surgical Research
Brooke Army Medical Center
San Antonio, TX, USA

Jillian M McLaughlin MD
Clinical Research Fellow
Division of Plastic Surgery, Department of Surgery
University of Texas Medical Branch
Staff Surgeon, Shriners Hospital for Children
Galveston, TX, USA

Kevin H Merkley MD MBA
Interim Chair, Department of Ophthalmology
University of Texas Medical Branch
Galveston, TX, USA

Walter J Meyer III MD
Gladys Kempner and R. Lee Kempner Professor in Child Psychiatry, Department of Psychiatry and Behavioral Sciences
Professor, Departments of Pediatrics and Human Biological Chemistry and Genetics
The University of Texas Medical Branch, Galveston, TX, USA
Head, Department of Psychological & Psychiatric Services for Children & Families, Shriners Hospitals for Children, Shriners Burns Hospital, Galveston, TX, USA

Esther Middelkoop PhD
Professor Skin Regeneration and Wound Healing
Director Association of Dutch Burn Centers
Plastic, Reconstructive and Hand Surgery Department, Red Cross Hospital, Beverwijk, the Netherlands
Amsterdam Movement Sciences, VU University Medical Center
Amsterdam, the Netherlands

Stephen M Milner MBBS MD
Professor of Plastic and Reconstructive Surgery
Director of the Johns Hopkins Burn Center
Director of the Michael D. Hendrix Burn Research Center
Johns Hopkins Bayview Medical Center
Baltimore, MD, USA

Ronald P Mlcak MBA PhD RRT FAARC
Administrative Director, Shriners Hospitals for Children–Galveston
Associate Professor, School of Health Professions, Department of Respiratory Care
University of Texas Medical Branch
Galveston, TX, USA

Naiem S. Moiemen MSc, FRCS(Plast)
Director, the Scar Free Burns Research Centre.
Honorary Professor, University of Birmingham;
Consultant, Burns and Plastic Surgeon, University Hospital Birmingham
Birmingham Children Hospital
Birmingham, UK

Stephen E Morris
Professor
Medical Director, Burn Center
Department of Surgery
University of Utah School of Medicine
Salt Lake City, UT, USA

David W Mozingo MD FACS
Professor
Department of Surgery
University of Florida College of Medicine
Gainesville, FL, USA

Michael Muller MBBS MMedSci FRACS
Associate Professor in Surgery, University of Queensland
Professor in Surgery, Bond University
Pre-Eminent Staff Specialist: General, Trauma and Burns Surgeon
Royal Brisbane and Women's Hospital
Division of Surgery
Brisbane, Queensland, Australia

Robert F Mullins MD
President and Medical Director
Burn and Reconstructive Centers of America
Augusta, GA, USA

Kuzhali Muthumalaiappan PhD
Assistant Professor, Department of Surgery,
Burn and Shock Trauma Research Institute
Loyola University Chicago, Stritch School of Medicine
Maywood, IL, USA

Andreas D Niederbichler MD
Assistant Professor of Plastic Surgery, Burn Center
Hanover Medical School
Hanover, Germany

William B Norbury MD
Assistant Professor
Division of Plastic Surgery, Department of Surgery
University of Texas Medical Branch
Staff Surgeon, Shriners Hospital for Children
Galveston, TX, USA

Sheila Ott OTR
Occupational Therapist
Department of Occupational Therapy
University of Texas Medical Branch
Galveston, TX, USA

Christian Peterlik MD
Anesthesiologist
UKH Linz der AUVA
Department of Anesthesiology and Intensive Care
Linz, Austria

Bruce Philp MA (Cantab) BMBCh (Oxon) FRCS(I) FRCS(Plast)
Consultant
Burns, Laser and Reconstructive Plastic Surgeon
St.Andrew's Centre
Broomfield Hospital
Chelmsford, UK

Craig Porter PhD
Assistant Professor
Department of Surgery, University of Texas Medical Branch
Shriners Hospitals for Children–Galveston
Galveston, TX, USA

Basil A Pruitt Jr MD FACS FCCM MCCM
Clinical Professor
Dr. Ferdinand P. Herff Chair in Surgery
UT Health San Antonio
San Antonio, TX, USA

Ravi S Radhakrishnan MD MBA FACS
Associate Professor
Chief, Division of Pediatric Surgery
Departments of Surgery and Pediatrics
University of Texas Medical Branch
Galveston, TX, USA

Ruth B Rimmer PhD
Chief Executive Officer
Care Plans for Life, LLC
Phoenix, AZ, USA

Laura Rosenberg PhD
Chief Clinical Psychologist
Shriners Hospitals for Children
Clinical Assistant Professor
Department of Psychiatry & Behavioral Sciences
University of Texas Medical Branch
Galveston, TX, USA

Marta Rosenberg PhD
Clinical Psychologist
Shriners Hospitals for Children
Clinical Assistant Professor
Department of Psychiatry & Behavioral Sciences
University of Texas Medical Branch
Galveston, TX, USA

Arthur P Sanford MD FACS
Associate Professor of Surgery
Department of Surgery
Loyola University Medical Center
Maywood, IL, USA

Kwabena O Sarpong MD MPH
Child Abuse and General Pediatrics
Associate Professor Of Pediatrics
Department of Pediatrics
University of Texas Medical Branch
Consultant Physician
Shriners Children's Hospital
Galveston, TX, USA

Michael A Serghiou OTR MBA
Clinical Care Specialist
Bio Med Sciences Inc.
Allentown, PA, USA

Robert L Sheridan MD
Medical Director of the Burn Service
Shriners Hospitals for Children
Boston, MA, USA

William C Sherman MD
Burn Fellow
Shriner's Hospital for Children
Galveston, TX, USA

Edward R. Sherwood MD PhD
Cornelius Vanderbilt Professor
Vice Chair for Research
Department of Anesthesiology
Department of Pathology, Microbiology and Immunology
Vanderbilt University Medical Center
Nashville, TN, USA

Lisa W Smith RPH BCPS
Lead Burn Clinical Pharmacist
Doctors Hospital of Augusta
Augusta, GA, USA

Linda E. Sousse, PhD MBA
Assistant Professor
Department of Surgery, University of Texas Medical Branch
Shriners Hospitals for Children–Galveston
Galveston, TX, USA

Marcus Spies MD PhD
Head
Department of Plastic, Hand, and Reconstructive Surgery
Hand Trauma Center (FESSH)
Pediatric Trauma Center
Breast Cancer Center
Krankenhaus Barmherzige Brueder
Regensburg, Germany

Oscar E Suman PhD MS
Professor, Associate Director of Research
Department of Surgery, University of Texas Medical Branch
Shriners Hospitals for Children–Galveston;
Professor
Associate Director of Research, Director of the Children's Wellness and Exercise Center
Shriners Hospitals for Children
University of Texas Medical Branch
Galveston, TX, USA

Fujio Suzuki PhD
Professor
Department of Internal Medicine/Infectious Diseases
University of Texas Medical Branch
Galveston, TX, USA

Mark Talon, CRNA, MSN, DNP
Chief Nurse Anesthetist
Shriners Hospital for Children
Galveston, TX, USA

Christopher R. Thomas MD
Robert L. Stubblefield Professor of Child Psychiatry
University of Texas Medical Branch
Galveston, TX, USA

Tracy Toliver-Kinsky PhD
Professor
Department of Anesthesiology
University of Texas Medical Branch
Scientific Staff
Shriners Hospitals for Children
Galveston, TX, USA

Edward E Tredget MD MSc FRCS(C)
Professor of Surgery
Director of Surgical Research
University of Alberta
Edmonton, Alberta, Canada

Stefan D Trocmé MD
Cornea Consultant, Professor of Ophthalmology (Ret.)
Shriners Hospitals for Children
MD Anderson Cancer Center
Case Western Reserve University
Galveston and Houston, TX, USA

Lisa L Tropez-Arceneaux PsyD MSCP
Pediatric Psychologist
New Orleans, LA, USA
APROQUEN Pediatric Burn Center
Department of Administration
International Consultant
Managua, Nicaragua

Peter M Vogt MD PhD
Professor and Head
Department of Plastic, Hand and Reconstructive Surgery
Burn Center
Hanover Medical School
Hanover, Germany

Charles D Voigt MD
Burn Research Fellow,
University of Texas Medical Branch
Shriners Hospitals for Children–Galveston
Galveston, TX, USA

David W Voigt MD
Co-Medical Director Saint Elizabeth's Regional Burn and Wound Care Center
Chief of Surgery, CHI Saint Elizabeth's Regional Medical Center
Lincoln, NE, USA

Glen Warden MD MBA FACS
Emeritus Chief of Staff
Shriners Hospitals for Children–Cincinnati
Cincinatti, OH, USA

Shelley Wiechman PhD ABPP
Associate Professor, Harborview Medical Center
University of Washington
Seattle, WA, USA

Mimmie Willebrand MD
Associate Professor
Licensed Psychologist
Department of Neuroscience, Psychiatry
Uppsala University
Uppsala, Sweden

Felicia N Williams MD
Assistant Professor
Department of Surgery
North Carolina Jaycee Burn Center
University of North Carolina, Chapel Hill
Chapel Hill, NC, USA

Stephen Williamson MBA CTBS
Tissue Bank Manager
Shriners Hospitals for Children
Galveston, TX, USA

Steven E Wolf MD FACS
Golden Charity Guild Charles R. Baxter, MD Chair
Professor and Vice-Chairman for Research
Chief, Burn Section, Department of Surgery
University of Texas Southwestern Medical Center
Editor-in Chief, Burns
Dallas, TX, USA

Lee C. Woodson MD PhD
Professor of Anesthesiology, University of Texas Medical Branch
Chief of Anesthesia, Shriners Hospitals for Children
Galveston, TX, USA

Sue M. Woodson PHD MLIS
Associate Director for User Services and Collections
William H Welch Medical Library
Johns Hopkins University
Baltimore, MD, USA

Paul Wurzer MD
Resident
Division of Plastic, Aesthetic and Reconstructive Surgery
Department of Surgery
Medical University of Graz
Graz, Austria

David Yngve MD
Professor Orthopaedic Surgery
Department General Surgery
Shriners Burn Institute
Galveston, TX, USA

Ramón L. Zapata-Sirvent MD FACS
Burn Reconstruction Clinical and Research Fellow
Department of Surgery
University of Texas Medical Branch
Shriners Hospital for Children
Galveston, TX, USA

Video Table of Contents

List of Video Contributors

Branko Bojovic MD FACS
Chief of Plastic Surgery
Shriners Hospitals for Children–Boston
Member of the Faculty of Surgery
Harvard Medical School
Assistant in Surgery
Massachusetts General Hospital
Boston, MA, USA

Ludwik K Branski MD
Assistant Professor
Department of Plastic Surgery
University of Texas Medical Branch
Shriners Hospitals for Children–Galveston
Galveston, TX, USA

April Cowan OTR OTD CHT
Assistant Professor
School of Health Professions
University of Texas Medical Branch
Galveston, TX, USA

Matthias B Donelan MD
Chief of Staff
Shriners Hospitals for Children–Boston
Associate Clinical Professor of Surgery
Harvard Medical School
Visiting Surgeon
Massachusetts General Hospital
Boston, MA, USA

Perenlei Enkhbaatar MD PhD
Charles Robert Allen Professor in Anesthesiology
Department of Anesthesiology,
University of Texas Medical Branch
Galveston, TX, USA

Serina McEntire PhD
Associate Professor
Valdosta State University
Valdosta, GA, USA

Sheila Ott OTR
Occupational Therapist
Department of Occupational Therapy
University of Texas Medical Branch
Galveston, TX, USA

Michael A Serghiou OTR MBA
Clinical Care Specialist
Bio Med Sciences Inc.
Allentown, PA, USA

Oscar E Suman PhD MS
Professor, Associate Director of Research
Department of Surgery, University of Texas Medical Branch
Shriners Hospitals for Children–Galveston
Galveston, TX, USA
Professor
Associate Director of Research, Director of the Children's Wellness and Exercise Center
Shriners Hospitals for Children
University of Texas Medical Branch
Galveston, TX, USA

Mark Talon CRNA
University of Texas Medical Branch
Galveston, TX, USA

Christopher Whitehead PT
Rehabilitation Services Department,
Shriner's Hospital for Children – Galveston
Galveston, TX, USA

Lee C Woodson MD
Chief of Anesthesia
Shriners Hospitals for Children
Galveston, TX, USA

1 A Brief History of Acute Burn Care Management

LUDWIK K. BRANSKI, DAVID N. HERNDON, and ROBERT E. BARROW

The recognition of burns and their treatment is evident in cave paintings that are more than 3500 years old. Documentation in the Egyptian Smith papyrus of 1500 BC advocated the use of a salve of resin and honey for treating burns.[1] In 600 BC, the Chinese used tinctures and extracts from tea leaves. Nearly 200 years later, Hippocrates described the use of rendered pig fat and resin-impregnated bulky dressings, which was alternated with warm vinegar soaks augmented with tanning solutions made from oak bark. Celsus, in the 1st century AD, mentioned the use of wine and myrrh as a lotion for burns, most probably for their bacteriostatic properties.[1] Vinegar and exposure of the open wound to air was used by Galen (130–210 AD) as a means of treating burns, while the Arabian physician Rhases recommended cold water for alleviating the pain associated with burns. Ambroise Paré (1510–1590 AD), who effectively treated burns with onions, was probably the first to describe a procedure for early burn wound excision. In 1607, Guilhelmus Fabricius Hildanus, a German surgeon, published *De Combustionibus*, in which he discussed the pathophysiology of burns and made unique contributions to the treatment of contractures. In 1797, Edward Kentish published an essay describing pressure dressings as a means to relieve burn pain and blisters. Around this same time, Marjolin identified squamous cell carcinomas that developed in chronic open burn wounds. In the early 19th century, Guillaume Dupuytren (Fig. 1.1) reviewed the care of 50 burn patients treated with occlusive dressings and developed a classification of burn depth that remains in use today.[2] He was perhaps the first to recognize gastric and duodenal ulceration as a complication of severe burns, a problem that was discussed in more detail by Curling of London in 1842.[3] In 1843, the first hospital for the treatment of large burns used a cottage on the grounds of the Edinburgh Royal Infirmary.

Truman G. Blocker Jr. (Fig. 1.2) may have been the first to demonstrate the value of the multidisciplinary team approach to disaster burns when, on April 16, 1947, two freighters loaded with ammonium nitrate fertilizer exploded at a dock in Texas City, killing 560 people and injuring more than 3000. At that time, Blocker mobilized the University of Texas Medical Branch in Galveston, Texas, to treat the arriving truckloads of casualties. This "Texas City Disaster" is still known as the deadliest industrial accident in American history. Over the next 9 years, Truman and Virginia Blocker followed more than 800 of these burn patients and published a number of papers and government reports on their findings.[4–6] The Blockers became renowned for their work in advancing burn care, with both receiving the Harvey Allen Distinguished Service Award from the American Burn Association (ABA). Truman Blocker Jr. was also recognized for his pioneering research in treating burns "by cleansing, exposing the burn wounds to air, and feeding them as much as they could tolerate."[7] In 1962, his dedication to treating burned children convinced the Shriners of North America to build their first Burn Institute for Children in Galveston, Texas.[7]

Between 1942 and 1952, shock, sepsis, and multiorgan failure caused a 50% mortality rate in children with burns covering 50% of their total body surface area (TBSA).[8] Recently burn care in children has improved survival such that a burn covering more than 95% TBSA can be survived in more than 50% of cases.[9] In the 1970s, Andrew M. Munster (Fig. 1.3) became interested in measuring quality of life after excisional surgery and other improvements led to a dramatic decrease in mortality. First published in 1982, his Burn Specific Health Scale became the foundation for most modern studies in burns outcome.[10] The scale has since been updated and extended to children.[11]

Further improvements in burn care presented in this brief historical review include excision and coverage of the burn wound, control of infection, fluid resuscitation, nutritional support, treatment of major inhalation injuries, and support of the hypermetabolic response.

Early Excision

In the early 1940s, it was recognized that one of the most effective therapies for reducing mortality from a major thermal injury was the removal of burn eschar and immediate wound closure.[12] This approach had previously not been practical in large burns owing to the associated high rate of infection and blood loss. Between 1954 and 1959, Douglas Jackson and colleagues at the Birmingham Accident Hospital advanced this technique in a series of pilot and controlled trials starting with immediate fascial excision and grafting of small burn areas and eventually covering up to 65% of the TBSA with autograft and homograft skin.[13] In this breakthrough publication, Jackson concluded that "with adequate safeguards, excision and grafting of 20% to 30% body surface area can be carried out on the day of injury without increased risk to the patient." This technique, however, was far from being accepted by the majority of burn surgeons, and delayed serial excision remained the prevalent approach to large burns. It was Zora Janzekovic (Fig. 1.4), working alone in Yugoslavia in the 1960s, who developed the concept of removing deep second-degree burns by tangential excision with a simple uncalibrated knife. She treated 2615 patients with deep second-degree burns by tangential excision of eschar between the third and fifth days after burn and covered the

Fig. 1.1 Guillaume Dupuytren.

Fig. 1.2 Truman G. Blocker Jr.

Fig. 1.3 Andrew M. Munster.

Fig. 1.4 Zora Janzekovic.

excised wound with skin autograft.[14] Using this technique, burned patients were able to return to work within 2 weeks or so from the time of injury. For her achievements, in 1974, she received the ABA Everett Idris Evans Memorial Medal and, in 2011, the ABA lifetime achievement award.

In the early 1970s, William Monafo (Fig. 1.5) was one of the first Americans to advocate the use of tangential excision and grafting of larger burns.[15] John Burke (Fig. 1.6), while at Massachusetts General Hospital in Boston, reported unprecedented survival in children with burns of more than 80% TBSA.[16] His use of a combination of tangential excision for the smaller burns (Janzekovic's technique) and excision to the level of fascia for the larger burns resulted in a decrease in both hospital time and mortality. Lauren Engrav et al.,[17] in a randomized prospective study, compared tangential excision to nonoperative treatment of burns. This study showed that, compared to nonoperative treatment, early excision and grafting of deep second-degree burns reduced hospitalization time and hypertrophic scarring. In 1988, Ron G. Tompkins et al.,[18] in a statistical review of the Boston Shriners Hospital patient population from 1968 to 1986, reported a dramatic decrease in mortality in severely burned children that he attributed mainly to the advent of early excision and grafting of massive burns in use since the 1970s. In a randomized prospective trial of 85 patients with third-degree burns covering 30% or more of their TBSA, Herndon et al.[19] reported a decrease in mortality in those treated with early excision of the entire wound compared to conservative treatment. Other studies have reported that prompt excision

Fig. 1.5 William Monafo.

Fig. 1.6 John Burke.

of the burn eschar improves long-term outcome and cosmesis, thereby reducing the amount of reconstructive procedures required.

Skin Grafting

Progress in skin grafting techniques has paralleled the developments in wound excision. In 1869, J. P. Reverdin, a Swiss medical student, successfully reproduced skin grafts.[20] In the 1870s, George David Pollock popularized the method in England.[21] The method gained widespread attention throughout Europe, but because the results were extremely variable it quickly fell into disrepute. J. S. Davis resurrected this technique in 1914 and reported the use of "small deep skin grafts," which were later known as "pinch grafts."[22] Split-thickness skin grafts became more popular during the 1930s, due in part to improved and reliable instrumentation. The "Humby knife," developed in 1936, was the first reliable dermatome, but its use was cumbersome. E. C. Padgett developed an adjustable dermatome that had cosmetic advantages and allowed the procurement of a consistent split-thickness skin graft.[23,24] Padgett also developed a system for categorizing skin grafts into four types based on thickness.[25] In1964 J. C. Tanner Jr. and colleagues revolutionized wound grafting with the development of the meshed skin graft;[26] however for prompt excision and immediate wound closure to be practical in burns covering more than 50% of the TBSA, alternative materials and approaches to wound closure were necessary. To meet these demands, a system of cryopreservation and long-term storage of human skin for periods extending up to several months was developed.[27] Although controversy surrounds the degree of viability of the cells within the preserved skin, this method has allowed greater flexibility in the clinical use of autologous skin and allogenic skin harvested from cadavers. J. Wesley Alexander (Fig. 1.7) developed a simple method for widely expanding autograft skin and then covering it with cadaver skin.[28] This so-called "sandwich technique" has been the mainstay of treatment of massively burned individuals.

Fig. 1.7 J. Wesley Alexander.

In 1981, John Burke and Ioannis Yannas developed an artificial skin that consists of a silastic epidermis and a porous collagen–chondroitin dermis and is marketed today as Integra. Burke was also the first to use this artificial skin on very large burns that covered more than 80% of the TBSA.[29] David Heimbach led one of the early multicenter randomized clinical trials using Integra.[30] Its use in the coverage of extensive burns has remained limited partly due to the persistently high cost of the material and the need for a two-stage approach. Integra has since become popular for smaller immediate burn coverage and burn reconstruction. In 1989, J. F. Hansbrough and S. T. Boyce first reported the use of cultured autologous keratinocytes and fibroblasts on top of a collagen membrane (composite skin graft; CSS).[31] A larger trial by Boyce[32] revealed that the use of CSS in extensive burns reduces the requirement for harvesting of donor skin compared to conventional skin autografts and that the quality of grafted skin did not differ between CSS and skin autograft after 1 year. The search for an engineered skin substitute to replace all of the functions of intact human skin is ongoing; composite cultured skin analogs, perhaps combined with mesenchymal stem cells, may offer the best opportunity for better outcomes.[33,34]

Topical Control of Infection

Infection control is an important major advancement in burn care that has reduced mortality. One of the first topical antimicrobials, sodium hypochlorite (NaClO), discovered in the 18th century, was widely used as a disinfectant throughout the 19th century, but its use was frequently associated with irritation and topical reactions.[35] In 1915, Henry D. Dakin standardized hypochlorite solutions and described the concentration of 0.5% NaClO as most effective.[36] His discovery came at a time when scores of severely wounded soldiers were dying of wound infections on the battlefields of World War I. With the help of a Rockefeller Institute grant, Dakin teamed up with the then already famous French surgeon and Nobel Prize winner Alexis Carrel to create a system of mechanical cleansing, surgical débridement, and topical application of hypochlorite solution, which was meticulously protocolized and used successfully in wounds and burns.[37] Subsequently concentrations of sodium hypochlorite were investigated for antibacterial activity and tissue toxicity in vitro and in vivo, and it was found that a concentration of 0.025% NaClO was most efficacious because it had sufficient bactericidal properties but fewer detrimental effects on wound healing.[38]

Mafenide acetate (Sulfamylon), a drug used by the Germans for treatment of open wounds in World War II, was adapted for treating burns at the Institute of Surgical Research in San Antonio, Texas, by microbiologist Robert Lindberg and surgeon John Moncrief.[39] This antibiotic would penetrate third-degree eschar and was extremely effective against a wide spectrum of pathogens. Simultaneously, in New York, Charles Fox developed silver sulfadiazine cream (Silvadene), which was almost as efficacious as mafenide acetate.[40] Although mafenide acetate penetrates the burn eschar quickly, it is a carbonic anhydrase inhibitor that can cause systemic acidosis and compensatory hyperventilation and may lead to pulmonary edema. Because of its success in controlling infection in burns combined with minimal side effects, silver sulfadiazine has become the mainstay of topical antimicrobial therapy.

Carl Moyer and William Monafo initially used 0.5% silver nitrate soaks as a potent topical antibacterial agent for burns, a treatment that was described in their landmark publication[41] and remains the treatment of choice in many burn centers today. With the introduction of efficacious silver-containing topical antimicrobials, burn wound sepsis rapidly decreased. Early excision and coverage further reduced the morbidity and mortality from burn wound sepsis. Nystatin in combination with silver sulfadiazine has been used to control *Candida* at Shriners Burns Hospital for Children in Galveston, Texas.[42] Mafenide acetate, however, remains useful in treating invasive wound infections.[43]

Nutritional Support

P. A. Shaffer and W. Coleman advocated high caloric feeding for burn patients as early as 1909,[44] and D. W. Wilmore supported supranormal feeding with a caloric intake as high as 8000 kcal/day.[45] P. William Curreri (Fig. 1.8) retrospectively looked at a number of burned patients to quantify the amount of calories required to maintain body weight over a period of time. In a study of nine adults with 40% TBSA burns, he found that maintenance feeding at 25 kcal/kg plus an additional 40 kcal/% TBSA burned per day would maintain their body weight during acute hospitalization.[46] A. B. Sutherland proposed that children should receive 60 kcal/kg body weight plus 35 kcal/% TBSA burned per day to maintain their body weight.[47] D. N. Herndon et al. subsequently showed that supplemental parenteral nutrition increased both immune deficiency and mortality and recommended continuous enteral feeding, when tolerated, as a standard treatment for burns.[48]

The composition of nutritional sources for burned patients has been debated in the past. In 1959, F. D. Moore advocated that the negative nitrogen balance and weight loss in burns and trauma should be met with an adequate intake of nitrogen and calories.[49] This was supported by many others, including T. Blocker Jr.,[50] C. Artz, [51] and later by Sutherland.[47]

Fig. 1.8 P. William Curreri.

Fluid Resuscitation

The foundation of current fluid and electrolyte management began with the studies of Frank P. Underhill, who, as Professor of Pharmacology and Toxicology at Yale, studied 20 individuals burned in a 1921 fire at the Rialto Theatre.[52] Underhill found that the composition of blister fluid was similar to that of plasma and could be replicated by a salt solution containing protein. He suggested that burn patient mortality was due to loss of fluid and not, as previously thought, from toxins. In 1944, C. C. Lund and N. C. Browder estimated burn surface areas and developed diagrams by which physicians could easily draw the burned areas and derive a quantifiable percent describing the surface area burned.[53] This led to fluid replacement strategies based on surface area burned. G. A. Knaysi et al. proposed a simple "rule-of-nines" for evaluating the percentage of body surface area burned.[54] In the late 1940s, O. Cope and F. D. Moore (Figs. 1.9 and 1.10) were able to quantify the amount of fluid required per area burned for adequate resuscitation from the amount needed in young adults who were trapped inside the burning Coconut Grove Nightclub in Boston in 1942. They postulated that the space between cells was a major recipient of plasma loss, causing swelling in both injured and uninjured tissues in proportion to the burn size.[55] Moore concluded that additional fluid, over that collected from the bed sheets and measured as evaporative water loss, was needed in the first 8 hours after burn to replace "third space" losses. He then developed a formula for replacement of fluid based on the percent of the body surface area burned.[56] M. G. Kyle and A. B. Wallace showed that the heads of children were relatively larger and the legs relatively shorter than in adults, and they modified the fluid replacement formulas for use in children.[57] I. E. Evans and his colleagues made recommendations relating fluid requirements to body weight and surface area burned.[58] From their recommendations, intravenous infusion of normal saline plus colloid (1.0 mL per kg/% burn) along with 2000 mL dextrose 5% solution to cover insensible water losses was administered over the first 24 hours after burn. One year later, E. Reiss presented the Brooke formula, which modified the Evans formula by substituting lactated Ringer's for normal saline and reducing the amount of colloid given.[59] Charles R. Baxter (Fig. 1.11) and G. Tom Shires (Fig. 1.12) developed a formula without colloid, which is now referred to as the Parkland formula.[60] This is perhaps the most widely used formula today and recommends 4 mL of lactated Ringer's solution per kg/% TBSA burned during the first 24 hours after burn. All these formulas advocate giving half of the fluid in the first 8 hours

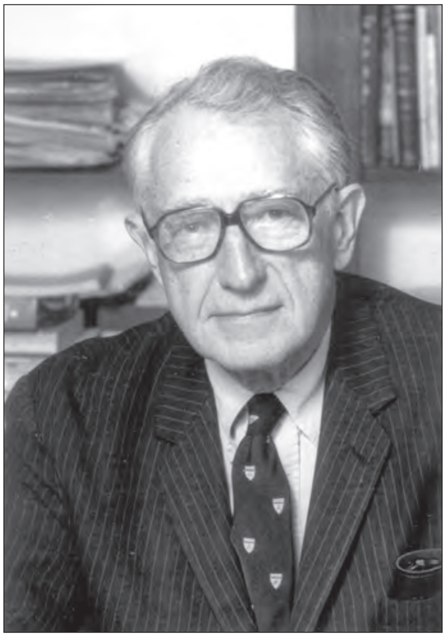

Fig. 1.10 Francis D. Moore.

Fig. 1.9 Oliver Cope.

Fig. 1.11 Charles R. Baxter.

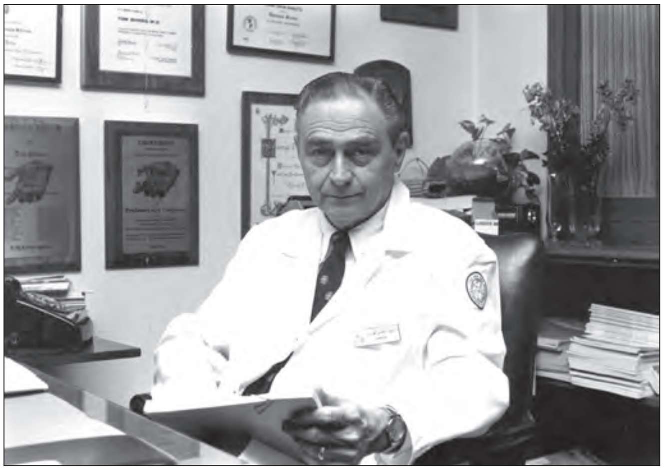

Fig. 1.12 G. Tom Shires.

Fig. 1.13 Basil A. Pruitt.

after burn and the other half in the subsequent 16 hours. Baxter and Shires discovered that after a cutaneous burn, not only is fluid deposited in the interstitial space, but marked intracellular edema also develops. The excessive disruption of the sodium–potassium pump activity results in the inability of cells to remove excess fluid. They also showed that protein, given in the first 24 hours after injury, was not necessary and postulated that, if used, it would leak out of the vessels and exacerbate edema. This was later substantiated in studies of burn patients with toxic inhalation injuries.[61] After a severe thermal injury fluid accumulates in the wound, and, unless there is adequate and early fluid replacement, hypovolemic shock will develop. A prolonged systemic inflammatory response to severe burns can lead to multiorgan dysfunction, sepsis, and even mortality. It has been suggested that, for maximum benefit, fluid resuscitation should begin as early as 2 hours after burn.[9,62] Fluid requirements in children are greater with a concomitant inhalation injury, delayed fluid resuscitation, and larger burns.

Inhalation Injury

During the 1950s and 1960s, burn wound sepsis, nutrition, kidney dysfunction, wound coverage, and shock were the main foci of burn care specialists. Over the past 50 years, these problems have been clinically treated with increasing success; hence a greater interest in a concomitant inhalation injury evolved. A simple classification of inhalation injury separates problems occurring in the first 24 hours after injury, which include upper airway obstruction and edema, from those that manifest after 24 hours. These include pulmonary edema and tracheobronchitis, which can progress to pneumonia, mucosal edema, and airway occlusion due to the formation of airway plugs from mucosal sloughing.[63,64] The extent of damage from the larynx to tracheobronchial tree depends on the solubility of the toxic substance and the duration of exposure. Nearly 45% of inhalation injuries are limited to the upper passages above the vocal cords, and 50% have an injury to the major airways. Less than 5% have a direct parenchymal injury that results in early acute respiratory death.[64]

With the development of objective diagnostic methods, the incidence of an inhalation injury in burned patients can now be identified and its complications identified. Xenon-133 scanning was first used in 1972 in the diagnosis of inhalation injury.[65,66] When this radioisotope method is used in conjunction with a medical history, the identification of an inhalation injury is quite reliable. The fiberoptic bronchoscope is another diagnostic tool that, under topical anesthesia, can be used for the early diagnosis of an inhalation injury.[67] It is also capable of pulmonary lavage to remove airway plugs and deposited particulate matter.

K. Z. Shirani, Basil A. Pruitt (Fig. 1.13), and A. D. Mason reported that smoke inhalation injury and pneumonia, in addition to age and burn size, greatly increased burn mortality.[68] The realization that the physician should not under-resuscitate burn patients with an inhalation injury was emphasized by P. D. Navar et al.[69] and D. N. Herndon et al.[70] A major inhalation injury requires 2 mL per kg/% TBSA burn more fluid in the first 24 hours after burn to maintain adequate urine output and organ perfusion. Multicenter studies looking at patients with acute respiratory distress syndrome (ARDS) have advocated respiratory support at low peak pressures to reduce the incidence of barotrauma. The high-frequency oscillating ventilator, advocated by C. J. Fitzpatrick[71] and J. Cortiella et al.,[72] has added the benefit of pressure ventilation at low tidal volumes plus rapid inspiratory minute volume, which provides a vibration to encourage inspissated sputum to travel up the airways. The use of heparin, *N*-acetylcysteine, nitric oxide inhalation, and bronchodilator aerosols have also been used with some apparent benefit, at least in pediatric populations.[73] Inhalation injury remains one of the most prominent causes of death in thermally injured patients. In children, the lethal burn area for a 10% mortality without a concomitant inhalation injury is 73% TBSA; however with an inhalation injury, the lethal burn size for a 10% mortality rate is 50% TBSA.[74]

Hypermetabolic Response to Trauma

Major decreases in mortality have also resulted from a better understanding of how to support the hypermetabolic response to severe burns. This response is characterized by an increase in the metabolic rate and peripheral catabolism. The catabolic response was described by H. Sneve as exhaustion and emaciation, and he recommended a nourishing diet and exercise.[75] O. Cope et al.[76] quantified the metabolic rate in patients with moderate burns, and Francis D. Moore advocated the maintenance of cell mass by continuous feeding to prevent catabolism after trauma and injury.[77] Over the past 30 years, the hypermetabolic response to burn has been shown to increase metabolism, negative nitrogen balance, glucose intolerance, and insulin resistance. In 1974, Douglas Wilmore and colleagues defined catecholamines as the primary mediator of this hypermetabolic response and suggested that catecholamines were five- to sixfold elevated after major burns, thereby causing an increase in peripheral lipolysis and catabolism of peripheral protein.[78] In 1984, P. Q. Bessey demonstrated that the stress response required not only catecholamines but also cortisol and glucagon.[79] Wilmore et al. examined the effect of ambient temperature on the hypermetabolic response to burns and reported that burn patients desired an environmental temperature of 33°C and were striving for a core temperature of 38.5°C.[80] Warming the environment from 28°C to 33°C substantially decreased the hypermetabolic response, but did not abolish it. He suggested that the wound itself served as the afferent arm of the hypermetabolic response, and its consuming greed for glucose and other nutrients was at the expense of the rest of the body.[81] Wilmore also believed that heat was produced by biochemical inefficiency, which was later defined by Robert Wolfe as futile substrate cycling.[82] Wolfe et al. also demonstrated that burned patients were glucose intolerant and insulin resistant, with an increase in glucose transport to the periphery but a decrease in glucose uptake into the cells.[83] D. W. Hart et al. further showed that the metabolic response rose with increasing burn size, reaching a plateau at a 40% TBSA burn.[84]

In the past three decades, pharmacologic modulators, such as the β-receptor antagonist propranolol, the anabolic agent human recombinant growth hormone, the synthetic anabolic testosterone analog oxandrolone, insulin, and the glucose uptake modulator metformin, have all shown some beneficial effects in reducing the hypermetabolic response in burn patients.

Conclusion

The evolution of burn treatments has been extremely productive over the past 50 years. The mortality of severely burned patients has decreased significantly thanks to improvements in early resuscitation, infection control, nutrition, attenuation of the hypermetabolic response, and new and improved surgical approaches. In burned children, a 98% TBSA burn now has a 50% survival rate.[74] It is hoped that the next few years will witness the development of an artificial skin that combines the concepts of J. F. Burke[29] with the tissue culture technology described by E. Bell.[85] Inhalation injury, however, remains one of the major determinants of mortality in those with severe burns. Further improvements in the treatment of inhalation injuries are expected through the development of arterial venous carbon dioxide removal and extracorporeal membrane oxygenation devices.[86] Research continues to strive for a better understanding of the pathophysiology of burn scar contractures and hypertrophic scarring.[87] Although decreases in burn mortality can be expected, continued advances to rehabilitate patients and return them to productive life are an important step forward in burn care management.

Complete references available online at www.expertconsult.inkling.com

Further Reading

Baxter CR, Shires T. Physiological response to crystalloid resuscitation of severe burns. *Ann N Y Acad Sci*. 1968;150(3):874-894.

Burke JF, Yannas IV, Quinby WC Jr, et al. Successful use of a physiologically acceptable artificial skin in the treatment of extensive burn injury. *Ann Surg*. 1981;194(4):413-428.

Hansbrough JF, Boyce ST, Cooper ML, et al. Burn wound closure with cultured autologous keratinocytes and fibroblasts attached to a collagen-glycosaminoglycan substrate. *JAMA*. 1989;262(15):2125-2130.

Janzekovic Z. A new concept in the early excision and immediate grafting of burns. *J Trauma*. 1970;10(12):1103-1108.

Tompkins RG, Remensnyder JP, Burke JF, et al. Significant reductions in mortality for children with burn injuries through the use of prompt eschar excision. *Ann Surg*. 1988;208(5):577-585.

Wilmore DW, Long JM, Mason AD Jr, et al. Catecholamines: mediator of the hypermetabolic response to thermal injury. *Ann Surg*. 1974;180(4):653-669.

References

1. Majno G. *The Healing Hand: Man and Wound in the Ancient World*. Cambridge, MA: Harvard University Press; 1975.
2. Dupuytren G, Brierre de Boismont A-J-F, Paillard ALM. *Leçons Orales de Clinique Chirurgicale, Faites à l'Hôtel-Dieu de Paris*. Paris: Baillière; 1839.
3. Curling TB. On acute ulceration of the duodenum, in cases of burn. *Med Chir Trans*. 1842;25:260-281.
4. Blocker V, Blocker TG Jr. The Texas City disaster: a survey of 3,000 casualties. *Am J Surg*. 1949;78(5):756-771.
5. Hendrix JH Jr, Blocker TG Jr, Blocker V. Plastic surgery problems in the Texas City disaster. *Plast Reconstr Surg*. 1949;4(1):92-97.
6. Blocker TG Jr, Blocker V, Graham JE, et al. Follow-up medical survey of the Texas City disaster. *Am J Surg*. 1959;97(5):604-617.
7. Bremer J. Giant. The saga of the first man to be called president of UTMB: Truman Graves Blocker Jr., M.D. *UTMB Quarterly*. 2000;(Summer/Fall):6-13.
8. Bull JP, Fisher AJ. A study of mortality in a burns unit: a revised estimate. *Ann Surg*. 1954;139(3):269-274.
9. Wolf SE, Rose JK, Desai MH, et al. Mortality determinants in massive pediatric burns. An analysis of 103 children with > or = 80% TBSA burns (> or = 70% full-thickness). *Ann Surg*. 1997;225(5):554-565, discussion 565-559.
10. Blades B, Mellis N, Munster AM. A burn specific health scale. *J Trauma*. 1982;22(10):872-875.
11. Munster AM, Horowitz GL, Tudahl LA. The abbreviated Burn-Specific Health Scale. *J Trauma*. 1987;27(4):425-428.
12. Cope O, Langohr JL, et al. Expeditious care of full-thickness burn wounds by surgical excision and grafting. *Ann Surg*. 1947;125(1):1-22.
13. Jackson D, Topley E, Cason JS, et al. Primary excision and grafting of large burns. *Ann Surg*. 1960;152:167-189.
14. Janzekovic Z. A new concept in the early excision and immediate grafting of burns. *J Trauma*. 1970;10(12):1103-1108.
15. Monafo WW. Tangential excision. *Clin Plast Surg*. 1974;1(4):591-601.
16. Burke JF, Bondoc CC, Quinby WC. Primary burn excision and immediate grafting: a method shortening illness. *J Trauma*. 1974;14(5):389-395.
17. Engrav LH, Heimbach DM, Reus JL, et al. Early excision and grafting vs. nonoperative treatment of burns of indeterminant depth: a randomized prospective study. *J Trauma*. 1983;23(11):1001-1004.
18. Tompkins RG, Remensnyder JP, Burke JF, et al. Significant reductions in mortality for children with burn injuries through the use of prompt eschar excision. *Ann Surg*. 1988;208(5):577-585.
19. Herndon DN, Barrow RE, Rutan RL, et al. A comparison of conservative versus early excision. Therapies in severely burned patients. *Ann Surg*. 1989;209(5):547-553.
20. Reverdin JP. Greffe epidermique. *Bull Soc Chir Paris*. 1869;101.
21. Freshwater MF, Krizek TJ. Skin grafting of burns: a centennial. A tribute to George David Pollock. *J Trauma*. 1971;11(10):862-865.
22. Davis JP. The use of small deep skin grafts. *JAMA*. 1914;63:985-989.
23. Padgett EC. Calibrated intermediate skin grafts. *Surg Gynecol Obstet*. 1939;69:779-793.
24. Padgett EC. Skin grafting and the 'three-quarter'-thickness skin graft for prevention and correction of cicatricial formation. *Ann Surg*. 1941;113(6):1034-1049.
25. Padgett EC. Indications for determination of the thickness of split skin grafts. *Am J Surg*. 1946;72(5):683-693.
26. Tanner JC Jr, Vandeput J, Olley JF. The mesh skin graft. *Plast Reconstr Surg*. 1964;34:287-292.
27. Bondoc CC, Burke JF. Clinical experience with viable frozen human skin and a frozen skin bank. *Ann Surg*. 1971;174(3):371-382.
28. Alexander JW, MacMillan BG, Law E, et al. Treatment of severe burns with widely meshed skin autograft and meshed skin allograft overlay. *J Trauma*. 1981;21(6):433-438.
29. Burke JF, Yannas IV, Quinby WC Jr, et al. Successful use of a physiologically acceptable artificial skin in the treatment of extensive burn injury. *Ann Surg*. 1981;194(4):413-428.
30. Heimbach D, Luterman A, Burke J, et al. Artificial dermis for major burns. A multi-center randomized clinical trial. *Ann Surg*. 1988;208(3):313-320.
31. Hansbrough JF, Boyce ST, Cooper ML, et al. Burn wound closure with cultured autologous keratinocytes and fibroblasts attached to a collagen-glycosaminoglycan substrate. *JAMA*. 1989;262(15):2125-2130.
32. Boyce ST. Cultured skin substitutes: a review. *Tissue Eng*. 1996;2(4):255-266.
33. Supp DM, Boyce ST. Engineered skin substitutes: practices and potentials. *Clin Dermatol*. 2005;23(4):403-412.
34. Butler KL, Goverman J, Ma H, et al. Stem cells and burns: review and therapeutic implications. *J Burn Care Res*. 2010;31(6):874-881.
35. Barillo DJ. Topical antimicrobials in burn wound care: a recent history. *Wounds*. 2008;20(7):192-198.
36. Dakin HD. On the use of certain antiseptic substances in the treatment of infected wounds. *Br Med J*. 1915;2(2852):318-320.
37. Haller JS Jr. Treatment of infected wounds during the Great War, 1914 to 1918. *South Med J*. 1992;85(3):303-315.
38. Heggers JP, Sazy JA, Stenberg BD, et al. Bactericidal and wound-healing properties of sodium hypochlorite solutions: the 1991 Lindberg Award. *J Burn Care Rehabil*. 1991;12(5):420-424.
39. Lindberg RB, Moncrief JA, Switzer WE, et al. The successful control of burn wound sepsis. *J Trauma*. 1965;5(5):601-616.
40. Fox CL Jr, Rappole BW, Stanford W. Control of pseudomonas infection in burns by silver sulfadiazine. *Surg Gynecol Obstet*. 1969;128(5):1021-1026.
41. Moyer CA, Brentano L, Gravens DL, et al. Treatment of large human burns with 0.5 per cent silver nitrate solution. *Arch Surg*. 1965;90:812-867.
42. Heggers JP, Robson MC, Herndon DN, et al. The efficacy of nystatin combined with topical microbial agents in the treatment of burn wound sepsis. *J Burn Care Rehabil*. 1989;10(6):508-511.
43. Monafo WW, West MA. Current treatment recommendations for topical burn therapy. *Drugs*. 1990;40(3):364-373.
44. Shaffer PA, Coleman W. Protein metabolism in typhoid fever. *Arch Intern Med*. 1909;IV(6):538-600.
45. Wilmore DW, Curreri PW, Spitzer KW, et al. Supranormal dietary intake in thermally injured hypermetabolic patients. *Surg Gynecol Obstet*. 1971;132(5):881-886.
46. Curreri PW, Richmond D, Marvin J, et al. Dietary requirements of patients with major burns. *J Am Diet Assoc*. 1974;65(4):415-417.
47. Sutherland AB. Nitrogen balance and nutritional requirement in the burn patient: a reappraisal. *Burns*. 1976;2(4):238-244.
48. Herndon DN, Barrow RE, Stein M, et al. Increased mortality with intravenous supplemental feeding in severely burned patients. *J Burn Care Rehabil*. 1989;10(4):309-313.
49. Moore FD. *Metabolic Care of Surgical Patients*. Philadelphia: Saunders; 1959.
50. Blocker TG Jr, Levin WC, Nowinski WW, et al. Nutrition studies in the severely burned. *Ann Surg*. 1955;141(5):589-597.
51. Artz CP, Reiss E. *The Treatment of Burns*. Philadelphia: Saunders; 1957. Available at: http://books.google.com/books?id=OM9rAAAAMAAJ.
52. Underhill FP. The significance of anhydremia in extensive surface burns. *JAMA*. 1930;95:852.
53. Lund CC, Browder NC. The estimation of areas of burns. *Surg Gynecol Obstet*. 1944;79:352-358.
54. Knaysi GA, Crikelair GF, Cosman B. The role of nines: its history and accuracy. *Plast Reconstr Surg*. 1968;41(6):560-563.
55. Cope O, Moore FD. The redistribution of body water and the fluid therapy of the burned patient. *Ann Surg*. 1947;126(6):1010-1045.
56. Moore FD. The body-weight burn budget. Basic fluid therapy for the early burn. *Surg Clin North Am*. 1970;50(6):1249-1265.
57. Kyle MJ, Wallace AB. Fluid replacement in burnt children. *Br J Plast Surg*. 1950;3(3):194-204.
58. Evans EI, Purnell OJ, Robinett PW, et al. Fluid and electrolyte requirements in severe burns. *Ann Surg*. 1952;135(6):804-817.
59. Reiss E, Stirmann JA, Artz CP, et al. Fluid and electrolyte balance in burns. *JAMA*. 1953;152(14):1309-1313.
60. Baxter CR, Shires T. Physiological response to crystalloid resuscitation of severe burns. *Ann N Y Acad Sci*. 1968;150(3):874-894.
61. Tasaki O, Goodwin CW, Saitoh D, et al. Effects of burns on inhalation injury. *J Trauma*. 1997;43(4):603-607.
62. Barrow RE, Jeschke MG, Herndon DN. Early fluid resuscitation improves outcomes in severely burned children. *Resuscitation*. 2000;45(2):91-96.
63. Foley FD, Moncrief JA, Mason AD Jr. Pathology of the lung in fatally burned patients. *Ann Surg*. 1968;167(2):251-264.
64. Moylan JA, Chan CK. Inhalation injury—an increasing problem. *Ann Surg*. 1978;188(1):34-37.
65. Agee RN, Long JM 3rd, Hunt JL, et al. Use of 133xenon in early diagnosis of inhalation injury. *J Trauma*. 1976;16(3):218-224.
66. Moylan JA Jr, Wilmore DW, Mouton DE, et al. Early diagnosis of inhalation injury using 133 xenon lung scan. *Ann Surg*. 1972;176(4):477-484.

67. Moylan JA, Adib K, Birnbaum M. Fiberoptic bronchoscopy following thermal injury. *Surg Gynecol Obstet*. 1975;140(4):541-543.
68. Shirani KZ, Pruitt BA Jr, Mason AD Jr. The influence of inhalation injury and pneumonia on burn mortality. *Ann Surg*. 1987;205(1):82-87.
69. Navar PD, Saffle JR, Warden GD. Effect of inhalation injury on fluid resuscitation requirements after thermal injury. *Am J Surg*. 1985;150(6):716-720.
70. Herndon DN, Barrow RE, Traber DL, et al. Extravascular lung water changes following smoke inhalation and massive burn injury. *Surgery*. 1987;102(2):341-349.
71. Fitzpatrick JC, Cioffi WG Jr. Ventilatory support following burns and smoke-inhalation injury. *Respir Care Clin N Am*. 1997;3(1):21-49.
72. Cortiella J, Mlcak R, Herndon D. High frequency percussive ventilation in pediatric patients with inhalation injury. *J Burn Care Rehabil*. 1999;20(3):232-235.
73. Desai MH, Mlcak R, Richardson J, et al. Reduction in mortality in pediatric patients with inhalation injury with aerosolized heparin/N-acetylcystine [correction of acetylcystine] therapy. *J Burn Care Rehabil*. 1998;19(3):210-212.
74. Barrow RE, Spies M, Barrow LN, et al. Influence of demographics and inhalation injury on burn mortality in children. *Burns*. 2004;30(1):72-77.
75. Sneve H. The treatment of burns and skin grafting. *JAMA*. 1905;45(1):1-8.
76. Cope O, Nardi GL, Quijano M, et al. Metabolic rate and thyroid function following acute thermal trauma in man. *Ann Surg*. 1953;137(2):165-174.
77. Moore FD. Metabolism in trauma: the reaction of survival. *Metabolism*. 1959;8:783-786.
78. Wilmore DW, Long JM, Mason AD Jr, et al. Catecholamines: mediator of the hypermetabolic response to thermal injury. *Ann Surg*. 1974;180(4):653-669.
79. Bessey PQ, Watters JM, Aoki TT, et al. Combined hormonal infusion simulates the metabolic response to injury. *Ann Surg*. 1984;200(3):264-281.
80. Wilmore DW, Mason AD Jr, Johnson DW, et al. Effect of ambient temperature on heat production and heat loss in burn patients. *J Appl Physiol*. 1975;38(4):593-597.
81. Wilmore DW, Aulick LH, Mason AD, et al. Influence of the burn wound on local and systemic responses to injury. *Ann Surg*. 1977;186(4):444-458.
82. Wolfe RR, Durkot MJ, Wolfe MH. Effect of thermal injury on energy metabolism, substrate kinetics, and hormonal concentrations. *Circ Shock*. 1982;9(4):383-394.
83. Wolfe RR, Durkot MJ, Allsop JR, et al. Glucose metabolism in severely burned patients. *Metabolism*. 1979;28(10):1031-1039.
84. Hart DW, Wolf SE, Chinkes DL, et al. Determinants of skeletal muscle catabolism after severe burn. *Ann Surg*. 2000;232(4):455-465.
85. Bell E, Ehrlich HP, Buttle DJ, et al. Living tissue formed in vitro and accepted as skin-equivalent tissue of full thickness. *Science*. 1981;211(4486):1052-1054.
86. Zwischenberger JB, Cardenas VJ Jr, Tao W, et al. Intravascular membrane oxygenation and carbon dioxide removal with IVOX: can improved design and permissive hypercapnia achieve adequate respiratory support during severe respiratory failure? *Artif Organs*. 1994;18(11):833-839.
87. Gurtner GC, Werner S, Barrandon Y, et al. Wound repair and regeneration. *Nature*. 2008;453(7193):314-321.

2 Teamwork for Total Burn Care: Burn Centers and Multidisciplinary Burn Teams

JANOS CAMBIASO-DANIEL, OSCAR E. SUMAN, MARY JACO, DEBRA A. BENJAMIN, and DAVID N. HERNDON

Introduction

Severe burn injuries evoke strong emotional responses in most people including health professionals who are confronted by the specter of pain, deformity, and potential death. Intense pain and repeated episodes of sepsis, followed by either death or survival encumbered by pronounced disfigurement and disability, have been the expected sequelae to serious burns for most of mankind's history.[1] However, these dire consequences have been ameliorated so that, although burn injury is still intensely painful and tragic, the probability of death has been significantly diminished. During the decade prior to 1951, young adults (15–43 years of age) with total body surface area (TBSA) burns of 45% or greater had a 49% mortality rate (Table 2.1).[2] Forty years later, statistics from the pediatric and adult burn units in Galveston, Texas, show that a 49% mortality rate is associated with TBSA burns of 70% or greater in the same age group. Over the past decade, these mortality figures have improved even more dramatically, so that almost all infants and children can be expected to survive when resuscitated adequately and quickly.[3] Although improved survival has been the primary focus of burn treatment advancement for many decades, today the major goal—since survival rates have highly increased—is rehabilitation of burn survivors to maximize quality of life and reduce morbidity.

Such improvement in forestalling death is a direct result of the maturation of burn care science. Scientifically sound analyses of patient data have led to the development of formulas for fluid resuscitation[4–6] and nutritional support.[7,8] Clinical research has demonstrated the utility of topical antimicrobials in delaying onset of sepsis, thereby contributing to decreased mortality of burn patients. Prospective randomized clinical trials have shown that early surgical therapy is efficacious in improving survival for many burned patients by decreasing blood loss and diminishing the occurrence of sepsis.[9–14] Basic science and clinical research have helped decrease mortality by characterizing the pathophysiological changes related to inhalation injury and suggesting treatment methods that have decreased the incidence of pulmonary edema and pneumonia.[15–18] Scientific investigations of the hypermetabolic response to major burn injury have led to improved management of this life-threatening phenomenon, not only enhancing survival, but also promising an improved quality of life.[19–32]

Optimal treatment of severely burned patients requires significant healthcare resources and has led to the development of highly specialized burn centers over the past decades. Centralizing services to regional burn centers has made implementation of multidisciplinary acute critical care and long-term rehabilitation possible. It has also enhanced opportunities for study and research over the past several decades. This has led to great advances both in our knowledge and in clinical outcomes, with further advancements being expected.

Implementation of a wide range of medical discoveries and innovations has improved patient outcomes following severe burns over the past half century. Key areas of advancements in recent decades include fluid resuscitation protocols; early burn wound excision and closure with grafts or skin substitutes, nutritional support regimens, topical antimicrobials and treatment of sepsis, thermally neutral ambient temperatures, and pharmacological modulation of hypermetabolic and catabolic responses. These factors have helped to decrease morbidity and mortality following severe burns by improving wound healing, reducing inflammation and energy demands, and attenuating hypermetabolism and muscle catabolism.

Melding scientific research with clinical care has been promoted in recent burn care history largely because of the aggregation of burn patients into single-purpose units staffed by dedicated healthcare personnel. Dedicated burn units were first established in Great Britain to facilitate nursing care. The first U.S. burn center was established at the Medical College of Virginia in 1946. The same year, the U.S. Army Surgical Research Unit (later renamed the U.S. Army Institute of Surgical Research) was established. Directors of both centers and later, the founders of the burn centers at University of Texas Medical Branch in 1947 and Shriners Hospitals for Children–Galveston in 1963 emphasized the importance of collaboration between clinical care and basic scientific disciplines to improve the patient's outcome.[1]

The organizational design of these centers engendered a self-perpetuating feedback loop of clinical and basic scientific inquiry. In this system, scientists receive first-hand information about clinical problems, while clinicians receive provocative ideas about patient responses to injury from experts in other disciplines. Advances in burn care attest to the value of a dedicated burn unit organized around a collegial group of basic scientists, clinical researchers, and

Table 2.1 Percent total body surface area (TBSA) burn producing an expected mortality of 50% in 1952, 1993, and 2006

Age (years)	1953[†] (% TBSA)	1993* (% TBSA)	2006° (% TBSA)
0–14	49	98	99
15–44	46	72	88
45–65	27	51	75
65	10	25	33

[†]Bull, JP, Fisher, AJ. *Annals of Surgery* 1954;139.
*Shriners Hospital for Children and University of Texas Medical Branch, Galveston, Texas.
°Pereira CT et al. *J Am Coll Surg* 2006; 202(3): 536–548 and unpublished data. PP. 1138–1140 (PC65).

clinical caregivers, all asking questions of each other, sharing observations and information, and seeking solutions to improve patient welfare.

Findings from the group at the Army Surgical Research Institute point to the necessity of involving many disciplines in the treatment of patients with major burn injuries and emphasize the utility of a team concept.[1] For this reason the International Society of Burn Injuries and its journal, *Burns*, as well as the American Burn Association and its publication, *Journal of Burn Care and Research*, have publicized the notion of successful multidisciplinary work by burn teams to widespread audiences.

Members of a Burn Team

The management of severe burn injuries benefits from concentrated integration of health services and professionals, with care being significantly enhanced by a true multidisciplinary approach. The complex nature of burn injuries necessitates a diverse range of skills for optimal care. A single specialist cannot be expected to possess all skills, knowledge, and energy required for the comprehensive care of severely injured patients. For this reason, reliance is placed on a group of specialists to provide integrated care through innovative organization and collaboration.

In addition to including burn-specific providers, the burn team consists of epidemiologists, molecular biologists, microbiologists, physiologists, biochemists, pharmacists, pathologists, endocrinologists, and numerous other scientific as well as medical specialists. Because burn injury is a complex systemic injury, the search for improved treatments leads to inquiry from many approaches. Each scientific finding stimulates new questions and the potential involvement of additional specialists.

At times, the burn team can be thought of as including the environmental service workers responsible for cleaning the unit, the volunteers who may assist in a variety of ways to provide comfort for patients and families, the hospital administrator, and many others who support the day-to-day operations of a burn center and significantly impact the well-being of patients and staff. However, the traditional burn team consists of a multidisciplinary group of direct-care providers. Although burn surgeons, plastic surgeons, nurses, nutritionists, and physical and occupational therapists form the skeletal core; most burn units also include anesthesiologists, respiratory therapists, pharmacists, spiritual therapists, and music therapists. The increasing number of survivors has consequently also added psychologists, psychiatrists, and, more recently, exercise physiologists to the burn team. In pediatric units, child life specialists and school teachers are also significant members of the team of caregivers.

Patient satisfaction can be formally measured through questionnaires to provide positive feedback to caregivers and highlight potential areas of improvement. Allowing patients to feel as if they are part of decisions about their care, listening and responding to concerns, providing encouragement, and displaying empathy are all important for maintaining satisfaction in patients and their families. These approaches also reduce fear, apprehension, and misunderstandings.

Healing relies on a complex array of factors. These include individual factors such as motivation, pre-existing health status, obesity, malnutrition, comorbidities, family support, and social support. They also include wider societal factors such as reintegration, individual perception, and coping strategies as well as factors specific to the mechanism of injury such as trauma, bereavement, grief, and loss.

Patients and their families are infrequently mentioned as members of the team but are obviously important in influencing the outcome of treatment. Persons with major burn injuries contribute actively to their own recovery, and each brings individual needs and agendas into the hospital setting that may influence the way treatment is provided by the professional care team.[33] The patient's family members often become active participants. This is even more important in the case of children, but is also true in the case of adult patients. Family members become conduits of information from the professional staff to the patient. At times, they act as spokespersons for the patient, and, at other times, they become advocates for the staff in encouraging the patient to cooperate with dreaded procedures.

With so many diverse personalities and specialists potentially involved, purporting to know what or who constitutes a burn team may seem absurd. Nevertheless, references to "burn teams" are plentiful, and there is agreement on the specialists and care providers whose expertise is required for the optimal care of patients with significant burn injuries (Fig. 2.1).

BURN SURGEONS

Ultimate responsibility and overall control for the care of a patient lies with the admitting burn surgeon, the key figure of the burn team. The burn surgeon is either a general surgeon or plastic surgeon with expertise in providing emergency and critical care, as well as in performing skin grafting and amputations. The burn surgeon provides leadership and guidance for the rest of the team, which may include several surgeons. The surgeon's leadership is particularly important during the early phase of patient care when moment-to-moment decisions must be made based on the surgeon's knowledge of physiologic responses to injury, current scientific evidence, and appropriate medical/surgical treatments. The surgeon must not only possess

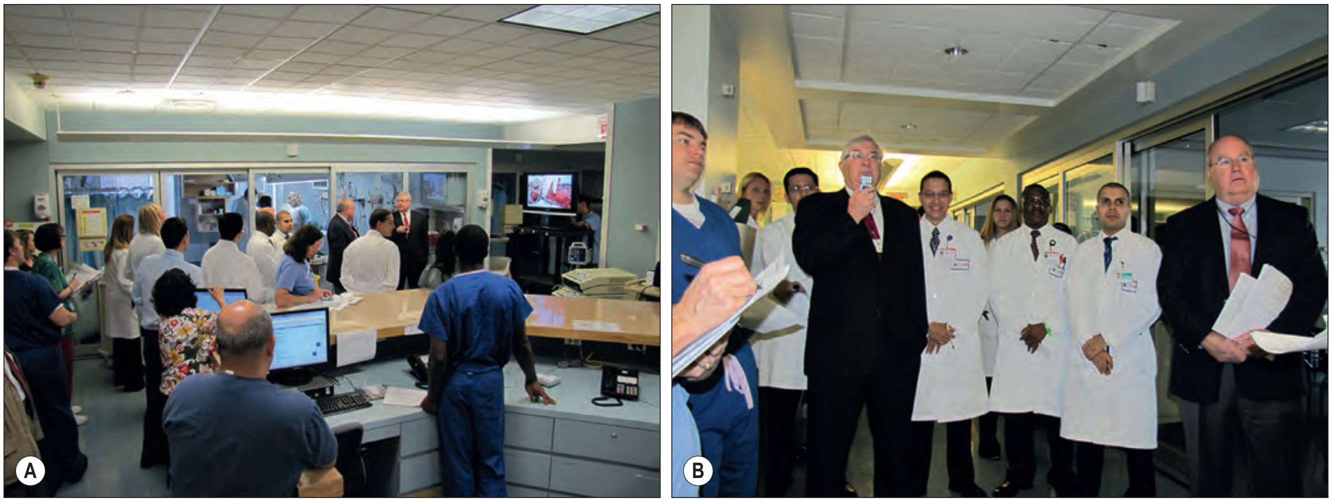

Fig. 2.1 (**A, B**) Experts from diverse disciplines gather together with common goals and tasks and overlapping values to achieve their objectives.

knowledge and skills in medicine, but also be able to clearly exchange information with a diverse staff of experts in other disciplines and lead the team. The surgeon alone cannot provide comprehensive care but must be wise enough to know when and how to seek counsel as well as how to clearly and firmly give directions to direct activities surrounding patient care. The senior surgeon of the team is accorded the most authority and control of any member of the team and thus bears the responsibility and receives accolades for the success of the team as a whole.[33]

PLASTIC SURGEONS

Next to burn surgeons, who are particularly involved in the immediate and acute phase of surgical treatment, are the plastic surgeons, who are typically involved instead in long-term surgical treatment. The plastic surgeons aim to deliver care that yields the best functional and aesthetic results for the burn survivor. The burn surgeon should always work in close collaboration with the plastic surgeon. Most burn surgeons are plastic surgeons, but in instances where this is not the case, the presence of plastic surgeons in the team is essential. Ideally, this collaboration should start during the initial phase of surgical treatment. The plastic surgeon's duty is primarily to care for the patient in terms of functional improvement through surgeries that aim to lessen scarring and decrease the functional limitations created by scarring. This surgical treatment often requires numerous operations that may take place for years after the burn injury.

ANESTHESIOLOGISTS

An anesthesiologist who is an expert in the altered physiologic parameters of burned patients is critical to the survival of the patient who usually undergoes multiple acute surgical procedures. Anesthesiologists on the burn team must be familiar with the phases of burn recovery and the physiologic changes to be anticipated as burn wounds heal.[1] Anesthesiologists play significant roles in facilitating comfort for burned patients, not only in the operating room, but also during the painful ordeals of dressing changes, staple removal, and physical exercise.

NURSES

Nurses represent the largest single disciplinary segment of the burn team, providing continuous coordinated care to the patient. The nursing staff is responsible for technical management of the 24-hour physical treatment of the patient. They control the therapeutic milieu that allows the patient to recover. They also provide emotional support to the patient and patient's family.[34] Nursing staff are often the first to identify changes in a patient's condition and initiate therapeutic interventions. Because recovery from a major burn is rather slow, burn nurses must merge the qualities of sophisticated intensive care nursing with the challenging aspects of psychiatric nursing. Nursing case management can play an important role in burn treatment, extending the coordination of care beyond hospitalization through the lengthy period of outpatient rehabilitation.

PHYSICAL AND OCCUPATIONAL THERAPISTS

Occupational and physical therapists begin planning therapeutic interventions at the patient's admission to maximize functional recovery. Burned patients require special positioning and splinting, early mobilization, strengthening exercises, endurance activities, and pressure garments to promote healing while controlling scar formation. These therapists must be very creative in designing and applying the appropriate appliances. Knowledge of the timing of application is necessary. In addition, rehabilitation therapists must become expert behavioral managers since their necessary treatments are usually painful to the recovering patient who will resist in a variety of ways. While the patient is angry, protesting loudly, or pleading for mercy, the rehabilitation therapist must persist with aggressive treatment to combat quickly forming and very strong scar contractures. The same therapist, however, is typically rewarded with adoration and gratitude from an enabled burn survivor.

RESPIRATORY THERAPISTS

Inhalation injury, prolonged bed rest, fluid shifts, and the threat of pneumonia, all concomitant with burn injury, render respiratory therapists essential to the patient's welfare. Respiratory therapists evaluate pulmonary mechanics, perform therapy to facilitate breathing, and closely monitor the status of the patient's respiratory functioning and improvements during the recovery.

EXERCISE PHYSIOLOGIST

The exercise physiologist has recently been recognized as a key member of the comprehensive burn rehabilitation team. Traditionally, exercise physiologists study acute and chronic adaptations to a wide range of exercise conditions. At our institution, the exercise physiologist performs clinical duties and conducts clinical research.

Clinical duties include monitoring and assessing cardiovascular and pulmonary exercise function, as well as muscle function. Additional clinical duties include writing exercise prescriptions for cardiopulmonary and musculoskeletal rehabilitation. Clinical research conducted by the exercise physiologist mainly focuses on the effect of exercise on burn sequelae and the mechanisms by which exercise can reduce or reverse burn-induced catabolic and hypermetabolic conditions and improve a patient's quality of life.

There is no licensing body or requirements for exercise physiologists to practice their profession. However, many organizations, such as the American College of Sports Medicine and the Clinical Exercise Physiology Association, offer national certifications. These certifications include the exercise test technologist, exercise specialist, health/fitness director, and clinical exercise specialist. We recommend that if the exercise physiologist is primarily involved in clinical duties, he or she should have a minimum of a master's degree and be nationally certified by a well-known and respected organization. If clinical or basic research will be part of his or her duties, then we recommend a doctorate degree as well as a national certification.

NUTRITIONISTS

A nutritionist or dietitian monitors daily caloric intake and weight maintenance. These specialists also recommend dietary interventions to provide optimal nutritional support to combat the hypermetabolic and catabolic responses to burn injury. Caloric intake as well as intake of appropriate vitamins, minerals, and trace elements must be managed to promote wound healing and facilitate recovery. Nutritionists and exercise physiologists may work together in implementing methods to increase daily physical activity (caloric expenditure) to counteract any sequelae due to a sedentary lifestyle.

PSYCHOSOCIAL EXPERTS

Psychiatrists, psychologists, and social workers with expertise in human behavior and psychotherapeutic interventions provide continuous sensitivity in caring for the emotional and mental well-being of patients and their families. These professionals must be knowledgeable about the process of burn recovery as well as human behavior to make optimal interventions. They serve as confidants and supports for patients, families of patients, and, on occasion, other burn team members.[35] They often assist colleagues from other disciplines in developing behavioral interventions for problematic patients, allowing the colleague and patient to achieve therapeutic success.[36] During initial hospitalization, these experts manage the patient's mental status, pain tolerance, and anxiety level to provide comfort to the patient and facilitate physical recovery. As the patient progresses toward rehabilitation, the role of the mental health team becomes more prominent in supporting optimal psychological, social, and physical rehabilitation.

SPIRITUAL THERAPISTS

Not all patients and relatives are religious, but for those who are religious, the presence of a spiritual therapist can be extremely important and can help to overcome or deal with the difficult times the burn survivors are experiencing. The power and efficacy of prayer and religious-spiritual involvement during illness and recovery have been often discussed and have been demonstrated to be very important for many patients.[37] For these reasons, hospitals and especially burn centers should have a spiritual therapist in the team to assist not only the burn survivors but also their relatives.[38]

MUSIC THERAPISTS

Music therapy is the use of music interventions to accomplish individualized goals within a therapeutic relationship between the patient and the figure of the music therapist. The principal goals and interventions can be designed to promote wellness, manage stress, alleviate pain, express feelings, enhance memory, improve communication, and promote physical rehabilitation.[39] As reported, music therapy can improve a patient's range of motion and help during the hospitalization and rehabilitation periods.[40] The music therapist has an important role to play for burn patients and should be considered an essential member of the burn team.

STUDENTS, RESIDENTS, AND FELLOWS

Medical students, graduate students, postdoctoral fellows, and residents are vital members of the burn care team. Burn care professionals often do not have the time or energy to perform activities outside of work hours or set responsibilities. However, these young students, fellows, and residents frequently have the time, energy, and desire to take on additional work, whether in the form of clinical work or research. The close working relationship between these individuals and the rest of the burn care team yields numerous benefits, including the conception of new clinical and translational questions that, when answered, directly improve patient care.

Dynamics and Functioning of the Burn Team

Gathering a group of experts from diverse disciplines does not form a team.[41] In fact, the diversity of the disciplines, along with individual differences in gender, ethnicity, values, professional experience, and professional status, render such teamwork a process fraught with opportunities for disagreements, jealousies, and confusion.[42] The process of working together to accomplish the primary goal (i.e., returning burn survivors to a normal, functional life) is further complicated by the fact that the patient and the patient's family must collaborate with these professionals. It is not unusual for the patient to attempt to diminish his or her immediate discomfort by pitting one team member against another or "splitting" the team. Much as young children will try to manipulate parents by first going to one and then the other, patients will complain about one staff member to another or assert to one staff member that another staff member allows less demanding rehabilitation exercises or some special privilege.[43] Time must be devoted to a process of trust building among the team members. It is also imperative that the team communicate openly and frequently or the group will lose effectiveness.

Communicating and discussing a daily, weekly, and long-term management plan among team members allows for clarification and organization of early plans to flag issues early on with regard to further surgery, rehabilitation, discharge planning, nutritional goals, patient understanding, and patient compliance. Such issues are all simultaneously addressed in a holistic approach.

The group becomes a team when they share common goals and tasks as well as when they have overlapping values that will be served by accomplishing their goals.[44,45] The team becomes an efficient work group through a process of establishing mechanisms of collaboration and cooperation that facilitate focusing on explicit tasks rather than on covert distractions of personal need and interpersonal conflict.[44,46] Work groups develop best under conditions that allow each individual to feel acknowledged as valuable to the team.[47]

Multidisciplinary burn care involves taking into account all aspects of patient care when treatment decisions are made as well as considering subsequent effects and consequences of decisions. With good communication and coordination among all team members, the team can optimize outcome for a patient in every aspect of their care (Fig. 2.1).

Research into the area of multidisciplinary teams has highlighted the wide application of such teams in healthcare settings as well as some of the shortcomings affecting their efficacy.[41] Clearly defining the various components of these teams will allow improved analysis. Some of the factors that are useful for assessing how well a team is functioning are listed in Box 2.1.

A burn team has defined and shared goals with clear tasks. For a group of burn experts to become an efficient team, skillful leadership that facilitates the development of shared values among team members and ensures the validation of team members as they accomplish tasks is necessary. The burn team consists of many experts from diverse professional backgrounds; each profession has its own culture, problem-solving approach, and language.[48] For the team to benefit fully from the expertise of its members, every expert voice must be heard and acknowledged. Team members must be willing to learn from each other, eventually developing their own culture and language that all can understand. Attitudes of superiority and prejudice are most disruptive to the performance of the team.

Box 2.1 Factors for analyzing multidisciplinary team effectiveness and function

- Size of team
- Composition (professions represented)
- Specific responsibilities
- Leadership style (individual or co-leadership/voluntary or assigned/stable or rotating/authoritarian or nonauthoritarian)
- Scope of work (consultation or intervention or both/idea generating/decision-making)
- Organizational support
- Communication and interactional patterns within the team (e.g., frequency/intensity/type)
- Contact with the patient, family, or care system (e.g., frequency/intensity/type)
- Point in treatment process when team is involved (e.g., intake through to discharge, one phase only, only if case not progressing)

(From Al-Mousawi et al., Burn Teams and Burn Centers,[52] adapted from Schofield & Amodeo[41])

Disagreement and conflict will be present, but these can be expressed and resolved in a respectful manner. Research suggests that intelligent management of emotions is linked with successful team performance in problem-solving and conflict resolution.[49] When handled well, conflicts and disagreements can increase understanding and provide new perspectives, in turn enhancing working relationships and leading to improved patient care.[50]

The acknowledged formal leader of the team is the senior surgeon, who may find the arduous job of medical and social leadership difficult and perplexing (Fig. 2.1). Empirical studies indicate, with remarkable consistency, that the functions required for successful leadership can be grouped into two somewhat incompatible clusters: (1) directing the group toward tasks and goal attainment and (2) facilitating interactions among group members and enhancing their feelings of worth.[44,47,50]

At times, task-oriented behavior by the leader may clash with the needs of the group for emotional support. During those times, the group may inadvertently impede the successful performance of both the leader and the team by seeking alternate means of establishing feelings of self-worth. When the social/emotional needs of the group are not met, the group begins to spend more time attempting to satisfy individual needs and less time pursuing task-related activities.

Studies of group behavior demonstrate that high-performance teams are characterized by synergy between task accomplishment and individual need fulfillment.[44,51] Since one formal leader cannot always attend to task and interpersonal nuances, groups informally or formally allocate leadership activities to multiple persons.[44,46,47] According to the literature in organizational behavior, the most effective leader is one who engages the talents of others and empowers them to utilize their abilities to further the work of the group.[44,46] Failure to empower the informal leaders limits their ability to contribute fully.

For the identified leader of the burn team (i.e., the senior surgeon) to create a successful, efficient burn team, the leader must be prepared to share leadership with one or more "informal" leaders in such a way that all leadership functions are fulfilled.[44,46,47] The prominence and identity of any one of the informal leaders will change according to the situation. The successful formal leader will encourage and support the leadership roles of other members of the team, developing a climate in which the team members are more likely to cooperate and collaborate toward achievement beyond individual capacity.

For many physicians, the concept of sharing leadership and power initially appears threatening, for it is the physician, after all, who must ultimately write the orders and be responsible for the patient's medical needs. However, sharing power does not mean giving up control. The physician shares leadership by seeking information and advice from other team members and empowers them by validating the importance of their expertise in the decision-making process. However, the physician maintains control and responsibility over the patient's care and medical treatment.

Summary

Centralized care provided in designated burn units has promoted a team approach to both scientific investigation and clinical care that has demonstrably improved the welfare of burn patients. Multidisciplinary efforts are imperative to continue improving and understanding the rehabilitation and emotional, psychological, and physiologic recovery of burn patients. Tremendous scientific and technological advances have led to dramatic increases in the survival of burn victims.

Wider issues to be considered by leaders in the field include burn prevention, access to care in rural regions and developing countries, and promotion of investment and funding for burn care. Centralization of care at burn centers as well as enhanced care have provided tremendous opportunities for research and education.

We hope that, in the future, scientists and clinicians will follow the same model of collaboration to pursue solutions to the perplexing problems that burn survivors must encounter. Physical discomforts such as itching still interfere with patient rehabilitation. New techniques for controlling hypertrophic scars and surgical reconstruction could do much to diminish disfigurement.[52] The use of treatments to attenuate hypermetabolism, use of anabolic agents,[19,27] and supervised strength and endurance training[22,23] are all currently being investigated as means of enhancing the well-being of survivors of massive burn injuries. Further development of psychological expertise within burn care and increased public awareness of the competence of burn survivors may ease the survivor's transition from an incapacitated patient to a functional member of society. We hope that, in the future, burn care will continue to devote the same energy and resources that have produced such tremendous advances in saving lives and optimizing the quality of life for survivors.

Complete references available online at
www.expertconsult.inkling.com

References

1. Artz CP, Moncrief JA. The burn problem. In: *The Treatment of Burns*. 2nd ed. Philadelphia, PA: W B Saunders; 1969:1-21.
2. Bull JP, Fisher AJ. A study of mortality in a burns unit: a revised estimate. *Ann Surg*. 1954;139(3):269-274.
3. Pereira CT, Barrow RE, Sterns AM, et al. Age-dependent differences in survival after severe burns: a unicentric review of 1,674 patients and 179 autopsies over 15 years. *J Am Coll Surg*. 2006;202(3):536-548.
4. Baxter CR, Marvin J, Curreri PW. Fluid and electrolyte therapy of burn shock. *Heart Lung*. 1973;2(5):707-713.
5. Carvajal HF. Fluid therapy for the acutely burned child. *Compr Ther*. 1977;3(3):17-24.
6. Evans EI, Purnell OJ, Robinett PW, Batchelor A, Martin M. Fluid and electrolyte requirements in severe burns. *Ann Surg*. 1952;135(6):804-817.
7. Curreri PW, Richmond D, Marvin J, Baxter CR. Dietary requirements of patients with major burns. *J Am Diet Assoc*. 1974;65(4):415-417.
8. Hildreth MA, Herndon DN, Desai MH, Duke MA. Reassessing caloric requirements in pediatric burn patients. *J Burn Care Rehabil*. 1988;9(6):616-618.
9. Burke JF, Bondoc CC, Quinby WC. Primary burn excision and immediate grafting: a method shortening illness. *J Trauma*. 1974;14(5):389-395.
10. Desai MH, Herndon DN, Broemeling L, et al. Early burn wound excision significantly reduces blood loss. *Ann Surg*. 1990;211(6):753-759, discussion 759-762.
11. Desai MH, Rutan RL, Herndon DN. Conservative treatment of scald burns is superior to early excision. *J Burn Care Rehabil*. 1991;12(5):482-484.
12. Engrav LH, Heimbach DM, Reus JL, Harnar TJ, Marvin JA. Early excision and grafting vs. nonoperative treatment of burns of indeterminant depth: a randomized prospective study. *J Trauma*. 1983;23(11):1001-1004.
13. Herndon DN, Barrow RE, Rutan RL, et al. A comparison of conservative versus early excision. Therapies in severely burned patients. *Ann Surg*. 1989;209(5):547-552, discussion 552-543.
14. Janzekovic Z. A new concept in the early excision and immediate grafting of burns. *J Trauma*. 1970;10(12):1103-1108.
15. Cioffi WG Jr, Rue LW 3rd, Graves TA, et al. Prophylactic use of high-frequency percussive ventilation in patients with inhalation injury. *Ann Surg*. 1991;213(6):575-580, discussion 580-572.
16. Herndon DN, Barrow RE, Linares HA, et al. Inhalation injury in burned patients: effects and treatment. *Burns Incl Therm Inj*. 1988;14(5):349-356.
17. Herndon DN, Barrow RE, Traber DL, et al. Extravascular lung water changes following smoke inhalation and massive burn injury. *Surgery*. 1987;102(2):341-349.
18. Shirani KZ, Pruitt BA Jr, Mason AD Jr. The influence of inhalation injury and pneumonia on burn mortality. *Ann Surg*. 1987;205(1):82-87.
19. Hart DW, Wolf SE, Ramzy PI, et al. Anabolic effects of oxandrolone after severe burn. *Ann Surg*. 2001;233(4):556-564.
20. Wilmore DW, Long JM, Mason AD Jr, Skreen RW, Pruitt BA Jr. Catecholamines: mediator of the hypermetabolic response to thermal injury. *Ann Surg*. 1974;180(4):653-669.
21. Hart DW, Wolf SE, Chinkes DL, et al. Determinants of skeletal muscle catabolism after severe burn. *Ann Surg*. 2000;232(4):455-465.
22. Celis MM, Suman OE, Huang TT, Yen P, Herndon DN. Effect of a supervised exercise and physiotherapy program on surgical interventions in children with thermal injury. *J Burn Care Rehabil*. 2003;24(1):57-61, discussion 56.
23. Suman OE, Thomas SJ, Wilkins JP, Mlcak RP, Herndon DN. Effect of exogenous growth hormone and exercise on lean mass and muscle function in children with burns. *J Appl Physiol*. 2003;94(6):2273-2281.
24. Low JF, Herndon DN, Barrow RE. Effect of growth hormone on growth delay in burned children: a 3-year follow-up study. *Lancet*. 1999;354(9192):1789.
25. Cucuzzo NA, Ferrando A, Herndon DN. The effects of exercise programming vs traditional outpatient therapy in the rehabilitation of severely burned children. *J Burn Care Rehabil*. 2001;22(3):214-220.
26. Suman OE, Mlcak RP, Herndon DN. Effects of exogenous growth hormone on resting pulmonary function in children with thermal injury. *J Burn Care Rehabil*. 2004;25(3):287-293.
27. Murphy KD, Thomas S, Mlcak RP, et al. Effects of long-term oxandrolone administration in severely burned children. *Surgery*. 2004;136(2):219-224.
28. Herndon DN, Stein MD, Rutan TC, Abston S, Linares H. Failure of TPN supplementation to improve liver function, immunity, and mortality in thermally injured patients. *J Trauma*. 1987;27(2):195-204.
29. Herndon DN, Barrow RE, Stein M, et al. Increased mortality with intravenous supplemental feeding in severely burned patients. *J Burn Care Rehabil*. 1989;10(4):309-313.
30. Thomas S, Wolf SE, Murphy KD, Chinkes DL, Herndon DN. The long-term effect of oxandrolone on hepatic acute phase proteins in severely burned children. *J Trauma*. 2004;56(1):37-44.
31. Demling RH, DeSanti L. Oxandrolone induced lean mass gain during recovery from severe burns is maintained after discontinuation of the anabolic steroid. *Burns*. 2003;29(8):793-797.
32. Hart DW, Wolf SE, Mlcak R, et al. Persistence of muscle catabolism after severe burn. *Surgery*. 2000;128(2):312-319.
33. Shakespeare PG. Who should lead the burn care team? *Burns*. 1993;19(6):490-494.
34. Callejas Herrero A, Cuadrado Rodriguez C, Pena Lorenzo A, Diez Sanz MJ. [Psychosocial nursing care patient with major burns]. *Rev Enferm*. 2014;37(2):59-64.
35. Morris J, McFadd A. The mental health team on a burn unit: a multidisciplinary approach. *J Trauma*. 1978;18(9):658-663.
36. Hughes TL, Medina-Walpole AM. Implementation of an interdisciplinary behavior management program. *J Am Geriatr Soc*. 2000;48(5):581-587.
37. Ameling A. Prayer: an ancient healing practice becomes new again. *Holist Nurs Pract*. 2000;14(3):40-48.
38. Saad M, de Medeiros R. Programs of religious/spiritual support in hospitals: five "whies" and five "hows". *Philo Ethics Humanit Med*. 2016;11(1):5.
39. Koelsch S. Music-evoked emotions: principles, brain correlates, and implications for therapy. *Ann NY Acad Sci*. 2015;1337:193-201.
40. Neugebauer CT, Serghiou M, Herndon DN, Suman OE. Effects of a 12-week rehabilitation program with music & exercise groups on range of motion in young children with severe burns. *J Burn Care Res*. 2008;29(6):939-948.
41. Schofield RF, Amodeo M. Interdisciplinary teams in health care and human services settings: are they effective? *Health Soc Work*. 1999;24(3):210-219.
42. Fallowfield L, Jenkins V. Effective communication skills are the key to good cancer care. *Eur J Cancer*. 1999;35(11):1592-1597.
43. Perl E. Treatment team in conflict: the wishes for and risks of consensus. *Psychiatry*. Summer 1997;60(2):182-195.
44. Harris P, Harris DL. High performance team management. *Leadership Org Dev J*. 1989;10(4):28-32.
45. Miller E, Rice A. Systems of organization. In: Coleman A, Bexton W, eds. *Group Relations Reader*. Sausalito, CA: Grex; 1975:43-68.
46. Yank GR, Barber JW, Hargrove DS, Whitt PD. The mental health treatment team as a work group: team dynamics and the role of the leader. *Psychiatry*. 1992;55(3):250-264.
47. Litterer J. *The Analysis of Organizations*. 2nd ed. John Wiley & Sons; 1973.
48. Hall P. Interprofessional teamwork: professional cultures as barriers. *J Interprof Care*. 2005;19(suppl 1):188-196.
49. Jordan PJ, Troth AC. Managing emotions during team problem solving: emotional intelligence and conflict resolution. *Hum Perform*. 2004;17(2):195-218.
50. Van Norman G. Interdisciplinary team issues – online publication. 1998. Available from: https://depts.washington.edu/bioethx/topics/team.html.
51. Al-Mousawi AM, Mecott-Rivera GA, Jeschke MG, Herndon DN. Burn teams and burn centers: the importance of a comprehensive team approach to burn care. *Clin Plast Surg*. 2009;36(4):547-554.
52. Constable JD. The state of burn care: past, present and future. *Burns*. 1994;20(4):316-324.

3 Epidemiological, Demographic and Outcome Characteristics of Burns

STEVEN E. WOLF, LEOPOLDO C. CANCIO, and BASIL A. PRUITT

Introduction

In 2014, approximately 200,000 deaths occurred in the United States from all injuries, and 31 million sustained nonfatal injuries. In a population of 318,857,056 persons, this represents a per capita death rate from injury of 0.063% (or approximately 6 per 10,000), and a nonfatal injury rate of 9.73% (or approximately 1 in 10). Therefore injury is common but related death is uncommon. For injuries from fire and burns specifically, 3,194 deaths occurred (1/100,000 population), which represented 1.6% of all injury fatalities but only 1.3% of injuries. In all, 408,945 nonfatal burns occurred in the United States in 2014, giving a rate of 0.129% of persons in the United States sustaining a burn, or about 1 per 1000.

We constructed trend lines in addition to the preceding data in the rate of reported injuries and death since 2005. These data were found on the WISQAR database produced by the U.S. Centers for Disease Control and Prevention (CDC).[1] We found that total injuries were relatively unchanged in this period from 2005 to 2009, then saw a large spike (a 10% increase) from 2010 to 2012. This spike has since receded (Fig. 3.1). When seen on a per capita basis, a 7.5% increase in the rate of reported injury occurred in the 2010–2012 period; therefore the spike in reported injuries was not from an increase in population; this is an interesting societal trend. Of further interest is the increase in injury fatalities which began at the same time and is mostly associated with an increased injury mortality rate (a 12.3% increase from 0.57% to 0.64%). This continues to rise despite a subsequent decline in total and per capita injuries. Whether this is from an increase in injury severity or age distribution cannot be answered in these data. A potential reason is a perceived increase in the use of palliative withdrawal of care, suggesting that those who might live with known treatments are unnecessarily adding to the mortality rate.

The incidence of total burns saw a similar spike in the 2010–2012 period, but this was not reflected in the per capita statistics, likely because of blunting by the relatively low incidence of burns (Fig. 3.2). Interestingly burn fatalities continue to decrease overall with a flattening trajectory in 2013–2014. The per capita numbers also showed a decline that has leveled at 0.001% (1 in 100,000). What is not seen is an increase in burn fatality rate that is evident in the all-injury fatality rate.

Burns occur unequally among the age groups in the WISQAR data, and the interim changes from 2005 to 2014 are interesting. The total number of burns have generally decreased in those aged 0–45, whereas the total number of burns in those older than 45 have increased dramatically, 31% from 2005 to 2014 in those aged 46–65, and 12% in those aged over 65 (Table 3.1).

The spike seen in total injuries between 2010 and 2012 is parallel with burns in those aged 0–4 but has settled back to a 6% decline in this age group from that in 2005. For those aged 5–18, we see a similar steady decline in the number of burns, and also in those aged 19–45. However the numbers of burns in those aged 46–65 and in those older than 65 years have seen a steady and dramatic increase. When indexed to population, this is almost completely accounted for by the increase in population in these age groups. Therefore no increase in per capita rate has occurred, and the increased numbers are from an increase in the population of those aged over 45 years.

When considering plans in health care utilization to respond to changes in the incidence of burns, strategies should be for the *total* number of burns likely to be encountered. For regional plans, per capita estimations should be used as specific regions grow and contract. In this light, the past 10 years have seen a significant decrease in the total number of burns in those aged 45 years and younger. Populations in the United States are generally stable for these age groups in the past 10 years, thus the decline in total numbers of burns must be attributed to cultural changes and prevention efforts, both legislative and educational. Therefore future resource utilization for the care of burns in this age group in the United States will likely continue to diminish unless some change occurs in the population. However those older than 45 years continue to increase in many areas, and thus considerations might be made to plan for further growth in burns in older persons.

We then analyzed the epidemiologic data from the National Burn Repository (NBR) available from the American Burn Association for the years 2006–2015.[2] In this, we examined recent trends in burn incidence and qualities in the United States. The NBR contains data from 96 of the128 self-designated burn centers in the United States as well as 7 burn centers in Canada, Sweden, and Switzerland. Of these 96 centers, 65 were verified as a burn center using American Burn Association criteria. The data we include here come only from the reporting US centers.

The distribution of burns among age groups in the NBR data has more granularity than does the WISQAR data. Burn distribution has a major grouping in those younger than 10 years of age. Those aged 11–20 have a smaller incidence, which then increases in those aged 21–60;

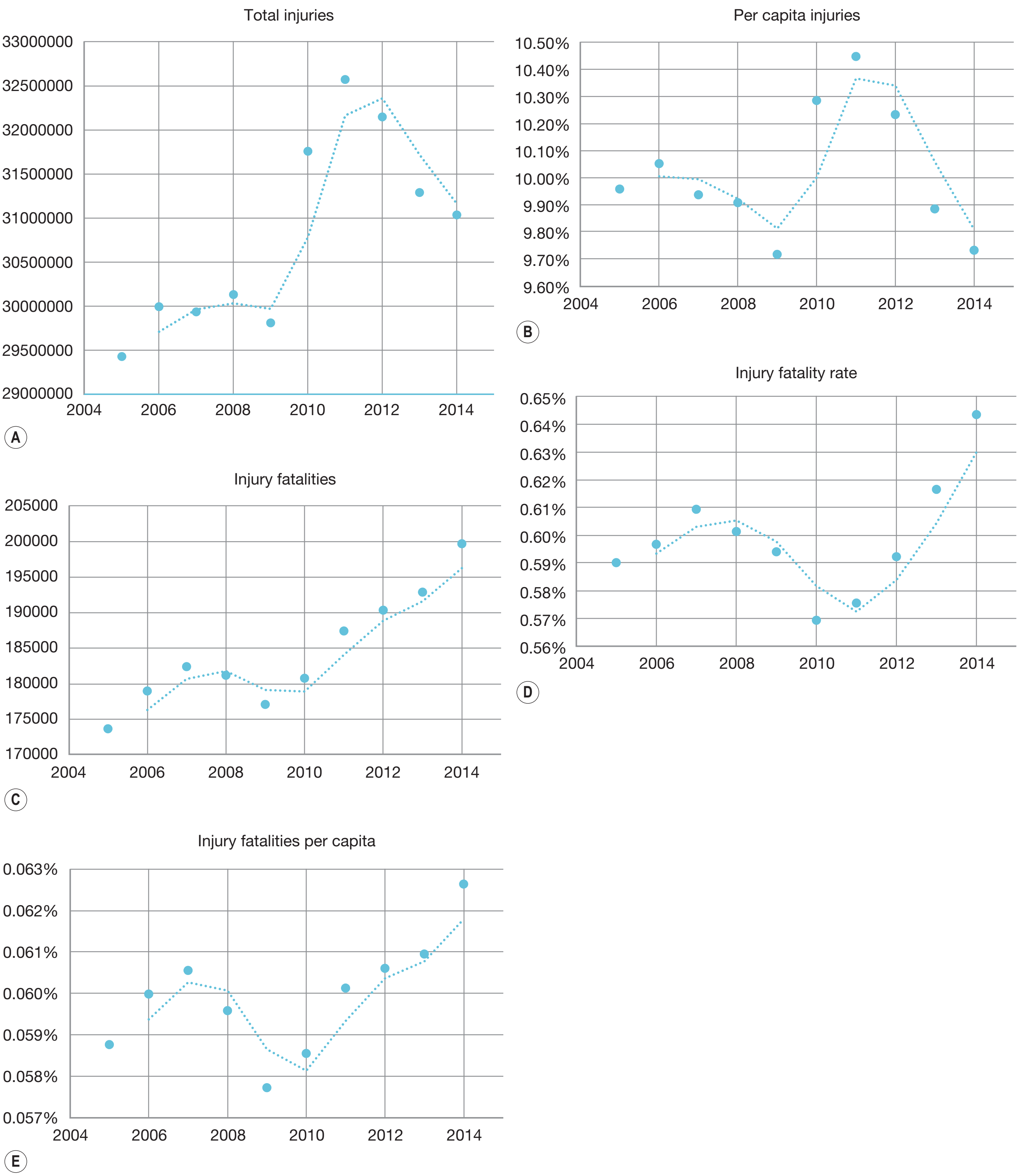

Fig. 3.1 Injury statistics taken from the WISQARS database maintained by the U.S. Centers for Disease Control and Prevention. Panel A describes the total number of reported injuries from the period 2005–2014. The y-axis is the total number of injuries. The trendline is the moving average of the adjoining two values. Panel B describes the per capita incidence of reported injuries in %, calculated by dividing the number of injuries by population for that year. Panel C describes the total number of fatalities ascribed to injury for the years 2005–2014. Panel D is the injury fatality rate by year calculated by dividing the number of fatalities by the number of reported injuries. Panel E is the injury fatalities per capita, calculated by dividing the number of fatalities by the population for that year.

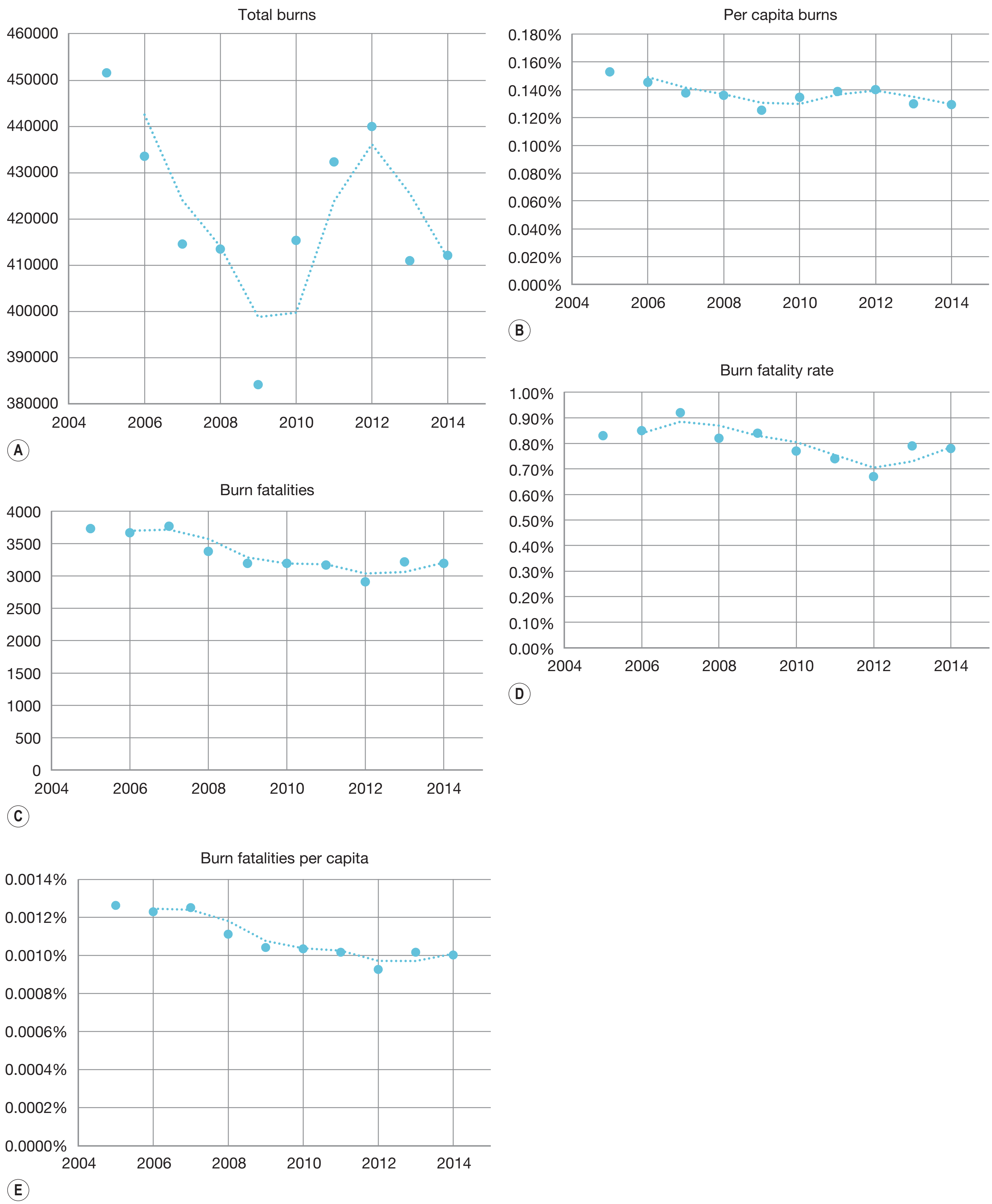

Fig. 3.2 Burn injury statistics taken from the WISQARS database maintained by the U.S. Centers for Disease Control and Prevention. Panel A describes the total number of injuries from the period 2005–2014. The y-axis is the number of injuries, with the included trendline the moving average of the two adjoining values. Panel B describes the per capita incidence with a trendline similarly calculated. Panel C is the number of fatalities with Panel D as the corresponding fatality rate. Finally, Panel E is the per capita burn fatalities.

Table 3.1 Burn Mortality Rates Over Time.

		BURNS					ALL	FATAL
Age	**Year**	**Nonfatal**	**Fatal**	**Total**	**Mortality (%)**	**Population**	**Per Capita Burn (%)**	**Per Capita Burn (%)**
0–4	2005	71935	279	72214	0.4	19917400	0.36	0.0014
	2006	64821	250	65071	0.4	19938883	0.33	0.0013
	2007	63207	266	63473	0.4	20125962	0.32	0.0013
	2008	60571	219	60790	0.4	20271127	0.30	0.0011
	2009	58400	208	58608	0.4	20244518	0.29	0.0010
5-yr Avg		63787	244	64031	0.4	20099578	0.32	0.0012
	2010	61091	212	61303	0.3	20201362	0.30	0.0010
	2011	67225	172	67397	0.3	20125958	0.33	0.0009
	2012	68130	141	68271	0.2	19980310	0.34	0.0007
	2013	63297	165	63462	0.3	19867849	0.32	0.0008
	2014	57117	151	57268	0.3	19876883	0.29	0.0008
5-yr Avg		63372	168	63540	0.3	20010472	0.32	0.0008
10-yr Avg		63579	206	63786	0.3	20055025	0.32	0.0010
5–18	2005	74159	312	74471	0.4	57831395	0.13	0.0005
	2006	66652	279	66931	0.4	58119881	0.12	0.0005
	2007	61400	300	61700	0.5	58288081	0.11	0.0005
	2008	63831	229	64060	0.4	58421598	0.11	0.0004
	2009	52910	208	53118	0.4	58424283	0.09	0.0004
5-yr Avg		63790	266	64056	0.4	58217048	0.11	0.0005
	2010	60711	198	60909	0.3	58480960	0.10	0.0003
	2011	61699	187	61886	0.3	58193935	0.11	0.0003
	2012	62847	154	63001	0.2	58091861	0.11	0.0003
	2013	58077	197	58274	0.3	58038492	0.10	0.0003
	2014	55991	170	56161	0.3	57932325	0.10	0.0003
5-yr Avg		59865	181	60046	0.3	58147515	0.10	0.0003
10-yr Avg		61828	223	62051	0.4	58182281	0.11	0.0004
19–45	2005	208907	929	209836	0.4	112647339	0.19	0.0008
	2006	203442	878	204320	0.4	112514315	0.18	0.0008
	2007	191442	874	192316	0.5	112442872	0.17	0.0008
	2008	182288	694	182982	0.4	112505361	0.16	0.0006
	2009	173432	717	174149	0.4	112716130	0.15	0.0006
5-yr Avg		191902	818	192721	0.4	112565203	0.17	0.0007
	2010	190820	632	191452	0.3	112814655	0.17	0.0006
	2011	194082	627	194709	0.3	113358991	0.17	0.0006
	2012	197541	549	198090	0.3	114032337	0.17	0.0005
	2013	181735	620	182355	0.3	114758868	0.16	0.0005
	2014	178110	628	178738	0.4	115429655	0.15	0.0005
5-yr Avg		188458	611	189069	0.3	114078901	0.17	0.0005
10-yr Avg		190180	715	190895	0.4	113322052	0.17	0.0006
46–65	2005	70827	1028	71855	1.4	70711525	0.10	0.0015
	2006	72704	1124	73828	1.5	72928734	0.10	0.0015
	2007	74386	1132	75518	1.5	74994337	0.10	0.0015
	2008	79990	1110	81100	1.4	76870172	0.11	0.0014
	2009	74215	1035	75250	1.4	78416768	0.10	0.0013
5-yr Avg		74424	1086	75510	1.4	74784307	0.10	0.0015
	2010	79685	1068	80753	1.3	79661338	0.10	0.0013
	2011	84717	1095	85812	1.3	81352090	0.11	0.0013
	2012	82370	1044	83414	1.3	82417467	0.10	0.0013
	2013	79213	1120	80333	1.4	82497447	0.10	0.0014
	2014	92813	1081	93894	1.2	82759431	0.11	0.0013
5-yr Avg		83760	1082	84841	1.3	81737555	0.10	0.0013
10-yr Avg		79092	1084	80176	1.4	78260931	0.10	0.0014
>65	2005	22054	1183	23237	5.1	34408940	0.07	0.0034
	2006	22277	1136	23413	4.9	34878099	0.07	0.0033
	2007	20393	1196	21589	5.5	35379955	0.06	0.0034
	2008	23449	1127	24576	4.6	36025708	0.07	0.0031
	2009	22034	1026	23060	4.4	36969830	0.06	0.0028

Continued

Table 3.1 Burn Mortality Rates Over Time.—cont'd

		BURNS					ALL	FATAL
Age	**Year**	**Nonfatal**	**Fatal**	**Total**	**Mortality (%)**	**Population**	**Per Capita Burn (%)**	**Per Capita Burn (%)**
5-yr Avg		22041	1134	23175	4.9	35532506	0.07	0.0032
	2010	19872	1083	20955	5.2	37587223	0.06	0.0029
	2011	21465	1087	22552	4.8	38690658	0.06	0.0028
	2012	26219	1021	27240	3.7	39590103	0.07	0.0026
	2013	25449	1114	26563	4.2	41334875	0.06	0.0027
	2014	24914	1164	26078	4.5	42858762	0.06	0.0027
5-yr Avg		23584	1094	24678	4.5	40012324	0.06	0.0027
10-yr Avg		22813	1114	23926	4.7	37772415	0.06	0.0030

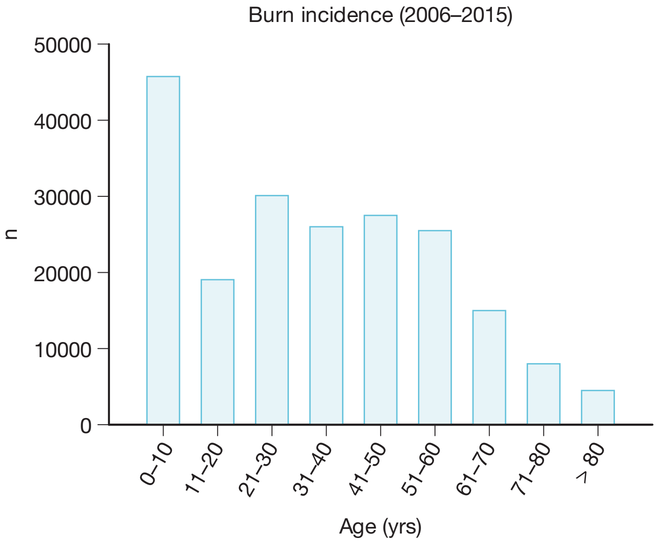

Fig. 3.3 Burn-specific injury statistics taken from the WISQARS database. These are the number of recorded injuries in each age group.

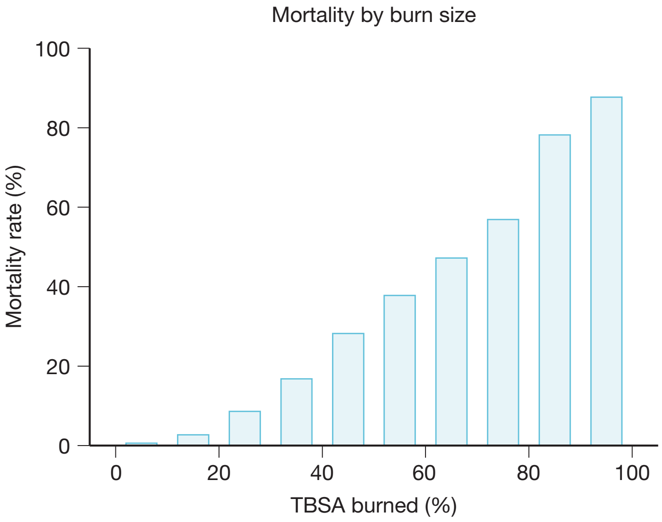

Fig. 3.4 Reported mortality by burn size.

thereafter the total numbers decline (Fig. 3.3) for a bimodal distribution when grouped in this way. Among these, 67% were in men, which is similar to previous reports of burns by gender. In terms of ethnicity, 58% of burns in the United States were in European-Americans, 21% in African-Americans, 13% in Hispanic-Americans, 5% in other ethnicities, and 3% in Asian-Americans.

Most burns were below 10% total body surface (TBSA), which included 78% of the burned population. Another 14% measured 11–20% TBSA, and the remaining 8% were greater than 20% TBSA. These numbers are all from designated burn centers, and it is likely that many additional burns below 10% TBSA were treated in nonburn centers. With this in mind, it is likely that almost all burns over 10% were treated at burn centers, thus the distribution in the NBR data is likely to be biased to larger burns from the true incidence in the United States.

Most burns were the result of injuries due to fire and flame at 41% of the total. Scalds accounted for another 33%, followed by contact with hot objects at 9%, and then chemical and electrical burns at 3% each. Overall mortality for those with burns was 3.1% during this period, which declined by almost 25% from 4.0% in 2006. Mortality was generally higher in women, except in 2015. Deaths did increase significantly with burn size (as expected), which was almost linear with increasing burned area (regression formula $y = x - 13.7$, $r^2 = 0.97$) (Fig. 3.4). This is a change from previous mortality rates, which was mostly a first-order distribution. According to this formula, probability of mortality for a burn (without considering age) can be estimated at %TBSA burned minus 14.

We did a probit analysis on the overall mortality data which revealed an LD50 for a 55% TBSA burn among all age groups. Thus a 55% TBSA burn would be expected to have a mortality rate of 50%; this is an improvement from previous reports.[3] When the Baux score (age plus TBSA burned) was examined for mortality, a 50% mortality was reported at about 105 and a 90% mortality was reported at 130.

Demography

Geographic and housing tract location significantly influences the rate of house fires and the subsequent death rates from associated burns. Age of the home, economic status, number of vacant houses, and immigration status affect the house fire rate.[4–5] House fire death rates are higher in

Table 3.2 Causes of Burn Injuries.

	Fires (%)	Injuries (%)	Deaths (%)	Odds Ratio of Death
Cooking Equipment	46	44	19	0.4
Heating Equipment	16	12	19	1.2
Electrical Equipment	9	9	16	1.8
Intentional	8	7	14	1.8
Smoking	5	10	22	4.4

the Eastern part of the United States, particularly the Southeast, compared to the West.[6] Cooking is the leading cause of house fires in the United States: 46% of house fires and 44% of fire-related injuries are by this cause.[7] Another leading cause of house fires is from heating equipment at 16% of instances. Other causes include electrical system fires (9%), intentional fires (8%), and fires from cigarette smoking (5%). Interestingly the cause of fire with the highest mortality is that from cigarette smoking, comprising 22% of residential fire-related deaths (Table 3.2). The ratio of deaths compared to other causes is also much higher in this group, at 4.4.

Gratifyingly the number of residential fires has dramatically decreased since 2004, falling 22%; similarly related fire death rates have fallen by the same amount. Injuries, however, have only gone down by 7%, suggesting that in those fires that do occur, more injuries are occurring.[8] Interestingly fire death rates are reduced by 50% with working fire alarms.[9] When the rate of fire deaths is considered by state, we find these are highest in Alabama, Alaska, Arkansas, District of Columbia, Mississippi, Oklahoma, Tennessee, and West Virginia. The lowest rates are Arizona, California, Colorado, Florida, Massachusetts, Nevada, New Jersey, Texas, and Utah.

The economic consequences of residential fires are also great. The highest fire-related losses in recent history were in 2008, with $16.7 billion in property damage and other direct costs. This has significantly fallen since then, with a reported $11.5 billion in losses in 2013.[8] The healthcare costs of burns are also prodigious. Each year in the United States, 40,000–60,000 people undergo in-hospital care for burns. The average charges for hospital care of a burned patient range from $47,557.00 to $1,203,410.00 (average $92,377), with much higher costs incurred by patients with extensive burns. The length of hospital stay ranges from one day to hundreds of days (mean 9.7), and, for patients 80 years and older is more than twice as long as that for children under 5.[2]

High-Risk Populations

CHILDREN

The number of pediatric burn patients admitted to hospitals is influenced by cultural differences, resource availability, and medical practice. Consequently the number of pediatric burn patients admitted to a hospital for treatment varies by geographic area from a low rate of 1.4/100,000 population in North America to a high of 10.8/100,000 population in Africa.[1,10] It has been estimated that 113,108 children aged 18 and younger were treated for burns in the United States in 2014. Of those injuries, approximately 60% were scald burns in those under 5 years of age; contact burns, 20%; fire/flame, 15%; and 5%, other.[2] For those aged 5–18, scalds accounted for approximately 33% of injuries; fire/flame, 45%; contact, 10%; and other, 12%, demonstrating a shift from scalds to fire and flame with increasing age. In 2013, 334 children died from fires or burns, and 44% of these were 4 years of age and younger.[9]

Scald burns are the most common cause of burns in the particularly young. The occurrence of tap water scalds can be prevented by adjusting the temperature settings on hot water heaters or by installing special faucet valves so that water does not leave the tap at temperatures above 120°F (48.8°C).[9,11] All code-making bodies at the national and regional levels have established standards for new or reconstructed dwellings requiring antiscald technology and a maximum water temperature of 120°F.

Home exercise treadmills represent a recently identified source of burns in pediatric patients. The injuries are a consequence of contact with a moving treadmill and almost always involve the upper extremity (97%), often the volar surface of the hand.[12] Approximately 50% undergo surgical intervention in the form of skin grafting, and some develop hypertrophic scars.[13]

ELDERLY

The elderly represent an increasing population segment, as previously described, and they have an increased prevalence in the burned population due to increased numbers as well as increased risk of being burned. Furthermore mortality from burns increases with age. The WISQAR data demonstrate that about 6% of all burns occur in those older than 65 years, although other reports from single centers approach 16% of all admissions for burns,[14] and mortality in this age group is significantly higher than that of all other ages, at 4.7% of all over 65 years of age who are burned compared to between 0.4% and 1.4% in all other age groups.

Interestingly the rates of burn by gender are almost even in the elderly who are burned, 51% in men and 49% in women. In an older paper, it was noted that 67% of injuries in the elderly are caused by flame or explosion, 20% by scalds, 6% by electricity, 2% by chemicals, and 6% by other causes. Forty-one percent of the injuries occurred in the bedroom and/or living room, 28% out of doors or in the workplace, 18% in the kitchen, 8% in the bathroom, and 5% in the garage or basement. Seventy-seven percent of the patients had one or more preexisting medical conditions.[15] Examination of predictors of mortality revealed that the usual signals such as increasing age, burn size, and inhalation injury continue to remain the most useful in this age group, but each of these had much more impact on mortality than in other age groups, as reflected by the much higher mortality rate.[14] Several authors reported lower mortality rates in the elderly than expected from standard prediction models, such as those from Bull, ASBI, and Ryan,[16] indicating that we are improving in this age group as well.

A recently identified factor in burns in the elderly are those in relation to dementia. Harvey and others identified a 1.6 odds ratio of burns between the aged with and without dementia. In addition, the burns were more likely to be larger, were more likely associated with ignition of clothing or scalds, and hospital length of stay was twice as long.[17]

DISABLED

The disabled are a group of patients considered to be burn-prone and are often injured in the home in incidents associated with scalds. From a report in 1993, the effects of disability and preexisting disease in those patients are evident in the duration of hospital stay (27.6 days on average) and the death rate (22.2%) associated with the modest average extent of burn (10% TBSA).[18] Another report on burns in generally elderly patients with dementia (who were also disabled) emphasized prevention measures to reduce the incidence of burns when such patients are performing the activities of daily living.[19]

MILITARY PERSONNEL

In wartime, military personnel are at high risk for burns both related to combat and nonintentional causes. The incidence of burns is associated with the types of weapons employed and combat units engaged and has ranged from 2.3% to as high as 85% in a number of conflicts over the past 8 decades. The detonation of a nuclear weapon at Hiroshima in 1945 instantaneously generated an estimated 57,700 burned patients and destroyed many treatment facilities, which thereby compromised their care.[20] In the Vietnam conflict, as a consequence of the total air superiority achieved by the U.S. Air Force and the lack of armored fighting vehicle activity, those with burns constituted only 4.6% of all patients admitted to Army medical treatment facilities from 1963 to 1975.[21] Approximately 60% of the 13,047 burned patients were nonbattle injuries. Furthermore in the Panama police action in late 1989, the low incidence of burns (only 6 or 2.3% of the total 259 casualties had burns) has been attributed to the fact that the action involved only infantry and airborne forces using small-arms weaponry.

Burns during conflicts have not always been this low, as exemplified by the Israeli conflicts of 1973 and 1982, and the British Army of the Rhine experience in World War II. Both of these conflicts were dense, with personnel in armored fighting vehicles who had a relatively high incidence of burns.[22,23] Burns have also been common injuries in war at sea, such as in the Falkland Islands campaign of 1982: 34% of all casualties from the British Navy ships were burns.[24,25] The increased incidence of burns, 10.5% and 8.6% in the Israeli conflicts of 1973 and 1982, respectively, as compared to the 4.6% incidence in the 1967 Israeli conflict, was considered to reflect what has been termed “battlefield saturation” with tanks and antitank weaponry.[22,26] Decreasing incidence of burns in armored vehicle combat has been attributed to enforced use of flame-retardant garments and the effectiveness of an automatic fire extinguishing system within tanks.[26] Those factors have also been credited with reducing the extent of the burns that did occur. For example, in the 1973 Israeli conflict 29% of burned patients had injuries of more than 40% TBSA, and only 21% had burns of less than 10% TBSA. After institution of garment and fire-extinguisher policies, in the 1982 Israeli conflict those same categories of burns represented 18% and 51%, respectively, of all burn injuries.

Modern weaponry may have eliminated the differential incidence of burns between armored fighting vehicle personnel and those in other combat elements. One of every seven casualties had burns in the British and Argentinean forces in the 1982 Falkland Islands conflict in which there was little if any involvement of armored fighting vehicles.[24,25] Conversely only 36 (7.8%) burns were sustained in the total 458 casualties in the U.S. Forces during Operation Desert Shield/Desert Storm in 1990–1991, in which there was extensive involvement of armored fighting vehicles.

In the most recent armed conflicts, Operations Iraqi Freedom and Enduring Freedom, the U.S. Army Burn Center (U.S. Army Institute of Surgical Research [ISR]) in San Antonio, Texas, provided care for all military patients who sustained burns. Trained burn surgeons from the ISR provided care at the Burn Center in San Antonio; at a general hospital in Landstuhl, Germany, while in transit from the theater of operations to the continental United States; as well as at the Level III hospital in-theater (Balad, Iraq). During this conflict, approximately 900 combat casualties were admitted to the burn center, among whom 34 expired (3.9%).[27] Interestingly another 11 expired within 10 years of injury from either a drug overdose (5), another combat injury (3), or a motor vehicle crash (3).[28] Therefore about 10% of deaths occurred from self-induced overdose, which should be investigated further and mitigated. On average, definitive care was administered in the United States within 96 hours of injury, which was accomplished through active use of the Global Patient Movement Regulating Center and the Burn Flight Team. This team consists of Army personnel who work with existing Air Force crews to support and rapidly transport severely burned patients from theater. In this conflict, more than 250 critically ill patients were transported successfully, with only one mortality during the flight.[29]

The U.S. Army Burn Center maintains readiness by caring for civilians in south Texas, and this activity continued during the conflict. When examined, these two populations who were cared for by the same personnel with the same equipment showed no differences in outcomes when those of the same ages were compared. Interestingly the burn size distributions of both groups were the same and were similar to that reported from the general databases at the beginning of this chapter.[30]

Burn Etiologies

FIRE/FLAME

Flame is the predominant cause of burns (43%) in patients admitted to burn centers, particularly in the adult age group.[2] Misuse of fuels and flammable liquids is a common cause of burns, constituting 66% of flame injuries.[31] The predominant affected population is young men, and the distribution of burn sizes is similar to that of all burns.[32] However mortality rates are higher than in the general burn population (50% increase), and length of hospital stay is up to twice as long as for other causes of burns. This might be related to a higher incidence of full-thickness burns due to the higher temperatures associated with gasoline, which results in more excision and grafting procedures, ICU care, and the like.[33] Because of these findings, the use of gasoline for purposes other than as a motor fuel, and any indoor use of a volatile petroleum product, should be discouraged as part of any prevention program.

Another commonly encountered cause of flame burns is that associated with automobile crashes. A comprehensive study done in Germany demonstrated that about 1% of car crashes had associated burns; these injuries were more common in frontal and high-energy collisions.[34] In a review of 178 patients who had been burned in an automobile crash, it was noted that slightly more than one-third had other injuries, most commonly involving the musculoskeletal system, and that approximately 1 in 6 had inhalation injury (1 in 3 of those who died).[35] A review of patients admitted to a referral burn center revealed that burns sustained while operating a vehicle involved an average of more than 30% TBSA and were associated with mechanical injuries (predominantly fractures) much more frequently than those burns incurred in the course of vehicle maintenance activities, which involved an average of less than 30% TBSA.[36]

Automotive-related flame burns can also be caused by fires and explosions resulting from "carburetor-priming" with liquid gasoline, although this is much less common now that almost all automobile engines are equipped with fuel injectors. The burns sustained in boating accidents are also most often flash burns due to an explosion of gasoline or butane and typically affect the face and hands.[37]

The ignition of clothing is the second leading cause of burn admissions for most ages. The fatality rate of patients with burns due to the ignition of clothing is second only to that of patients with burns incurred in house fires.[9] More than three-quarters of deaths due to the ignition of clothing occur in patients older than 64.[6] Clothing ignition deaths, which were a frequent cause of death in young girls, have decreased as clothing styles have changed and are now rare among children, with little overall gender difference at the present time.

SCALD

Burns due to hot liquids cause approximately 33% of all burns in any age group, but this incidence in much higher in children, particularly those under 4 years of age, at up to 60% of admissions.[38–40] These injuries are generally partial-thickness; however full-thickness injury can occur. In particular, full-thickness burns have a much higher incidence with hot oil burns. Young children are most commonly injured by pulling a container of hot liquid onto themselves,[40] while older children and adults are most commonly injured by improper handling of hot oil appliances.[41–43]

Burns from scalds and contacts with hot materials cause approximately 100 deaths per year.[6] The case fatality rate of scald injury is low (presumably due to the usually modest extent and limited depth of the burn), but scalds are major causes of morbidity and associated healthcare costs, particularly in children younger than 5 years of age and in the elderly.

CONTACT

Contact burns are the third most encountered cause of injury and are most common in children and young adults. For children, the incidence is higher due to lack of safety awareness and grasping hot objects. Another cause recently identified was contact burns due to glass-fronted fireplaces.[44] In this study, 402 children were identified with this injury in the United States in a 5-year period. This rate was 20 times higher than that estimated by the U.S. Consumer Product Safety Commission.

For younger adults, motorcycle exhaust pipes are another common cause of injury related to the use of vehicles. In Greece, the incidence of burns from motorcycle exhaust pipes has been reported to be 17/100,000 person-years, or 208/100,000 motorcycle-years. The highest occurrence was in children. In adults, the incidence is 60% higher in women than in men. As anticipated, the most frequent location of the burns was on the right leg below the knee, where contact with the exhaust pipe occurs. The authors concluded that a significant reduction of incidence could be achieved by wearing long pants and by the use of an external exhaust pipe shield.[45]

WORK-RELATED BURNS

Work-related burns account for 20–25% of all serious burns and also account for about 2% of all workplace injuries.[46] Interestingly, in a recent study from Michigan, accommodation and food services as well as the healthcare and social assistance industries accounted for more than 50% of the injuries.[47] Restaurant-related burns, particularly those due to deep fryers, represent a major and preventable source of occupational burn morbidity and, in restaurants, account for 12% of work-related injuries.[6] Other significant causes of work-related injuries are associated with electrical injuries, chemical injuries, and contact burns. Also as anticipated, the risk of burns due to hot tar is greatest for roofers and paving workers. Of all incidents involving roofers and sheet metal workers, 16% are burns caused by hot bitumen, and 17% of those injuries are of sufficient severity to prevent work for a variable period of time.

CHEMICAL BURNS

Chemicals are a well-known cause of burns, and these burns are generally caused by either acidic or alkali chemicals, although chemical burns can also occur with organic solvents. In a recent review of the literature for chemical burns, the reported percentage of burns related to chemical agents is between 2% and 10% of injuries. Most of those affected are men who were injured either in the workplace or domestic setting. Acids caused about 25% of the injuries and bases 55%.[48] The limited extent of burns reported from chemicals may be affected by many being treated as outpatients.

The greatest risk of injury due to strong acids occurs in patients who are involved in plating processes and fertilizer manufacture, whereas the greatest risk from alkalis is associated with soap manufacturing and in the home with the use of oven cleaners. The greatest risk of organic solvent injuries is associated with the manufacture of dyes, fertilizers, plastics, and explosives, and that for hydrofluoric acid injury is associated with etching processes, petroleum refining, and air conditioner cleaning. Anhydrous ammonia injury is most common in agricultural workers and cement injury (an alkali injury with associated thermal injury) is most common in construction workers.

ELECTRICAL CURRENT INJURY

Electrical current is another cause of injury seen in burn centers. Approximately one-third of electrical current injuries occur in the home, with another one-quarter occurring on farms or industrial sites and the rest occurring in the occupational setting.[6] A once common cause of electrical injury by household current occurred in children who inserted uninsulated objects into electrical receptacles or bit or sucked on electrical cords in sockets, resulting in oral commissure burns;[49] this has significantly diminished with the universal adoption of alternating electrical current for household use. Low-voltage direct current injury can be caused by contact with automobile battery terminals or by defective or inappropriately used medical equipment such as electrical surgical or external pacing devices,[50] or defibrillators.[51] Although such injuries may involve the full thickness of the skin, they are characteristically of limited extent.

Employees of utility companies, electricians, construction workers (particularly those working with cranes), farm workers moving irrigation pipes, oil field workers, truck drivers, and individuals installing antennae are at greatest risk of work-related high-voltage electric injury.[52] The greatest incidence of electrical current injury occurs during the summer as a reflection of farm irrigation activity, construction work, and work on outdoor electrical systems and equipment.[53]

During the period 1994 to 2008, 26 patients with high-voltage injury and 30 with low-voltage injury were treated at a regional burn center. Mortality was only 3.6%, which is likely biased in that those who died at the scene of injury were not included.[54] In another study, about one-half of patients with high-voltage injury underwent fasciotomy, and, even so, amputation was necessary in almost all of these. Of note, about 15% developed some long-term neurologic deficit, and 3% developed cataracts.[55] Another study reported the outcome of 195 patients with high-voltage electrical injury treated at a single burn center during a 19-year period. A total of 187 (95.9%) of the 195 patients survived and were discharged. Fasciotomy was undertaken in the first 24 h following injury in 56 patients, and 80 patients underwent an amputation because of extensive tissue necrosis. The presence of hemochromogens in the urine predicted amputation with an overall accuracy of 73.3%.[56]

LIGHTNING BURNS

Death due to lightning strikes has now fallen to the third most common cause of death during storms[57] and is now down to less than 30 deaths per year in the United States. Most lightning strikes (70%) occur between clouds; however approximately 30% hit the ground or other site. In the United States, these are most common in Florida and the Southeast coast and occur most often in the warmer months. Only about 3–5% of injuries result from a direct lightning strike; instead most of the energy is mediated by other objects, such as the ground or a tree.[58] Most injuries in survivors are superficial, and deep injuries are rare.

Lightning injuries and deaths occur most often in individuals who work outside or participate in outdoor recreational activities. Thus men are five times more likely to be struck by lightning than are women.[59] In some older studies, the annual death rate from lightning was greatest among those aged 15–19 years (6 deaths per 10 million population; crude rate: 3 per 10 million) and is seven times greater in men than in women. Approximately 30% of those struck by lightning die, with the greatest risk of death being in those patients with cranial or leg burns. Fifty-two percent of patients who died from lightning injury were engaged in outdoor recreational activity, such as playing golf or fishing, and 25% were engaged in work activities when struck.[60]

FIREWORKS

Fireworks are another seasonal cause of burns. Approximately 8% of patients with fireworks injuries undergo hospitalization for care, and approximately 60% of those injuries are for burns of specific areas, mostly those of the hands, head, and eyes.[61] Other data estimate that 1.86–5.82 fireworks-related burns per 100,000 persons occurred in the United States during the Fourth of July holiday.[62] Sparklers, firecrackers, and bottle rockets caused the greatest number of burns.[63] Of note, the incidence of injuries has decreased by 30% over the past 25 years. Boys, especially those aged 10–14, are at the highest risk for fireworks-related injuries. Children aged 4 and under are at highest risk for sparkler-related injuries.[9] Proposed prevention measures include reducing the explosive units per package, package warnings, and limiting the sale of the devices to children.[64]

INTENTIONAL BURNS

Burns can be intentional, either self-inflicted or done purposefully by another. It is estimated that 4% of burns (published range 0.37–10%) are self-inflicted. The region of the world has great import in determining the rates of intentional burns, with a particularly high rate in young women in India and middle-aged men in Europe. The average burn size in intentional burns is larger than other causes, at approximately 20% TBSA. The reasons for intentional burns, specifically assaults, are reported to be due to conflict between persons including spouses, elderly abuse, and economic transactions. For self-inflicted injuries, these are related to domestic discord, difficulty between family members, and social distress from unemployment. Mortality rates worldwide for intentional burns are reported at 65%.[65] Rates for Europe and the United States are also higher, with a twofold increase in the risk of mortality compared to nonintentional injuries.[66] Data from the NBR in 2007 indicated that 3% of admitted burns were intentional, with about 50% self-inflicted and the other 50% from assault. Similar to the prior report, burn size was on average 22% TBSA compared to 11% for nonintentional and exhibited a fourfold higher mortality rate.[67]

In some other studies, interesting findings were noted. In those with self-inflicted injuries, 43% occurred at home and another 33% occurred while in a psychiatric institution. Importantly 73% had a history of psychiatric disease; these were predominantly affective disorders or schizophrenia in the suicide attempts and personality disorders in self-mutilation. Also, 55% of suicide attempts had previously attempted suicide; 66% of the self-mutilators had made at least one previous attempt at self-mutilation. The authors concluded that the very fact of self-burning warranted psychiatric assessment.[68]

Assault by burning is most often caused by throwing liquid chemicals at the face of the intended victim or by the ignition of a flammable liquid with which the victim has been doused. These types of injuries are generally rare in the developed world but are quite common in low- and middle-income countries.[65] In those injuries that do occur in such places as the United States, most are African-American women who were unemployed and are associated with premorbid substance abuse.[69] Occasionally injuries will be induced by spouses characteristically dousing the face or genitalia.[70] In India, a common form of spouse abuse is burning by intentional ignition of clothing. When such burns are fatal, they have been called “dowry deaths” because they have been used to establish the widower’s eligibility for a new bride and her dowry.

Child abuse represents a special form of burns perpetrated by parents, siblings, caregivers, or child care personnel. Child abuse has been associated with teenage parents, mental deficits in either the child or the abuser, illegitimacy, a single-parent household, and low socioeconomic status, although child abuse can occur in all economic groups. Abuse is usually inflicted on children younger than 2 years of age who, in addition to burns, may exhibit signs of poor hygiene, psychological deprivation, and nutritional impairment.[71] The most common form of child abuse involving burns is caused by hot water in bathing. In a recent report, it was noted that about 5% of pediatric burn admissions were associated with abuse, and most were due to scalds (90%). Mortality was double that of patients with nonintentional injuries (5.4% vs. 2.3%).[72]

A distribution typical of child abuse immersion scald burns (i.e., feet, posterior legs, buttocks, and hands) should heighten the suspicion of child abuse. The presence of such burns mandates a complete evaluation of the circumstances surrounding the injury and the home situation. The importance of identifying child abuse in the case of a burn injury resides in the fact that if such abuse goes undetected and the child is returned to the abusive environment, there is a high risk of fatality due to repeated abuse.

Elder abuse can also take the form of severe burn. A congressional report published in 1991 indicated that 2 million older Americans are abused each year, and some estimates claim a 4–10% incidence of neglect or abuse of the elderly.[73] A recent retrospective review of 28 patients 60 years and older admitted to a single burn center during a calendar year identified self-neglect in seven, neglect by others in three, and abuse by others in one.[74] Adult protective services were required in two cases. The authors of that study concluded that abuse was likely to be underreported because of poor understanding of risk factors and a low index of suspicion on the part of the entire spectrum of healthcare personnel.

HOSPITAL BURNS

Patients may also sustain burns while in the hospital for diagnosis and treatment of other disease. Approximately 2% of surgical anesthesia malpractice claims involve fire incidents, and 85% of these were in head and neck surgery. These were most commonly associated with the use of electrocautery around oxygen sources.[75,76] Application of excessively hot soaks or towels or inappropriate use of heat lamps or a heating blanket are other causes of burn injury to patients.[77] Localized high-energy ultrasound may also produce coagulative necrosis, as exemplified by full-thickness cutaneous injury and localized subcutaneous fat necrosis of the abdominal wall in a patient who had received focused-beam high-intensity ultrasound treatment for uterine fibroids.[78] A common cause of burn injury, particularly in disoriented hospital or nursing home patients, is the ignition of bed clothes and clothing by a burning cigarette. Smoking should be banned in healthcare facilities or at least restricted to adequately monitored situations.

Burn Patient Transport and Transfer

As noted earlier, distance between viable burn centers and variable population density implies that many burned patients undergo transfer to burn centers from other locations. For transfer across short distances and in congested urban areas, ground transportation is frequently the most expeditious. For longer distances, aeromedical transfer for major burns is often indicated when ground transportation takes more than 2 hours.[79] In the United States, helicopters are most frequently employed for distances of less than 200 miles. The instance of vibration, poor lightning, restricted space, and high noise make in-flight monitoring and therapeutic interventions difficult, a fact that emphasizes the importance of carefully evaluating the patient and modifying treatment prior to the transfer. If distances of more than 200 miles are considered, fixed-wing aircraft are often a better option. The patient compartment of such an aircraft should be well lighted, permit movement of attending personnel, and have some measure of temperature control. In general, burned patients travel best in the immediate period after the burn injury has occurred, as soon as hemodynamic and pulmonary stability has been attained. This is particularly true in those with inhalation injury, whereby an increased mortality rate was shown in those taking more than 16 hours to arrive at definitive care.[80]

Physician-to-physician case review to assess the patient’s need for and ability to tolerate aeromedical transfer, prompt initiation of the aeromedical transfer mission, examination of the patient in the hospital of origin by a burn surgeon from the receiving hospital and correction of organ dysfunction prior to undertaking aeromedical transfer, and in-flight monitoring by burn-experienced personnel ensure both continuity and quality of care during the transport procedure. During the first half of the Iraq/Afghanistan conflicts (2003–2007), the U.S. Army ISR Burn Care Flight Teams using such a regimen completed 380 patient transfers from theater to the burn center in San Antonio using dedicated burn transport teams including physicians, nurses, respiratory therapists, and support personnel. One-third of the patients (33.6%) received ventilatory support throughout the transport, but no in-flight deaths occurred.[81] This demonstrates that burned patients can be transported safely throughout the world if indicated.

Mass Casualties

Mass casualty incidents may be caused by forces of nature or by accidental or intentional explosions and conflagrations. Interest in man-made mass casualties has been heightened by recent terrorist activities and the threat of future incidents. The incidence of severe burns in a mass casualty incident varies with the cause of the incident, the magnitude of the inciting agent, and the site of occurrence (indoors vs. outdoors). The terrorist attacks in which airplanes laden with aviation fuel crashed into the Pentagon and the World Trade Center on September 11, 2001, produced 10 and 39 patients with burns, respectively, for treatment at burn centers.[82,83] Since then, many events have occurred throughout the world, with the most recent taking place at a festival in Taiwan in 2015, where 499 persons were burned who were between the ages of 12 and 38: 281 sustained burns over 40% TBSA. These patients were distributed between many hospitals, and the eventual mortality rate was 3%, akin to that normally seen in burn centers. The assembled response was massive, including thousands of providers, and was effectively coordinated at the federal level.[84] Another prominent burn event occurred in Bali, in 2002, caused by an explosion and fire that killed more than 200 people and generated 60 burn patients who, after triage and emergency care, were transported by aircraft to Australia and treated at various hospitals.[85] The casualties produced in terrorist attacks often have associated blast injury and mechanical trauma in addition to burns.

Recent nonterrorist mass casualty incidents have been of greater magnitude in terms of numbers of burn casualties. In the Station nightclub fire in Warwick, Rhode Island, in February 2003, 96 people died at the scene and 215 people were injured. Forty-seven of the 64 burned patients were evaluated at one burn center and admitted for definitive care.[86] Additionally an explosion at a pharmaceutical plant in North Carolina in January 2003 killed 3 and injured more than 30 to an extent that necessitated admission to a hospital. Ten of the injured patients, all with inhalation injury and 6 with associated mechanical trauma, required admission to the regional burn center.[87]

To deal effectively and efficiently with a mass casualty situation burn treatment facilities must have an operational and tested mass casualty disaster plan and be prepared to provide burn care to a highly variable number of patients injured in either natural or man-made disasters.[88] In reality, mass casualty events are likely to involve some form of burns, particularly in those with explosions. All regions should be prepared for such an event with established plans that are reviewed regularly and drilled.

Outcome Analysis in Burns

The importance of the extent of injury to burn outcomes was recognized by Holmes in 1860, and further evidence was produced to relate either measured area or the specific parts of the body to outcomes in the latter 19th and early 20th centuries.[89,90] Formal expression of burn size as a percentage of total body surface area, however, awaited the work of Berkow in 1924.[91] Although not well known, this single finding in accurately estimating severity of injury made burns the first form of trauma in which the injury was measured and easily communicated. This measurement, then, was the first "trauma score" and made assessing burn size the basis for the accurate prediction of mortality, direct comparison of populations of burned patients, and the measurement of the effects of treatment on outcomes.

The earliest comprehensive statistical technique used for such assessment was univariate probit analysis.[92,93] Before the age of desktop computing, this approach was quite laborious and thus uncommon. An early attempt at multivariate evaluation was made by Schwartz, who used probit plane analysis to estimate the relative contributions of partial- and full-thickness burns to mortality.[94] The advent of computers of suitable power and the further development of statistical techniques has reduced the difficulty of analyzing burn mortality, removed the necessity for arbitrary partitioning, and made these techniques much more accessible.

One of the first comprehensive analyses of this sort was done on a population of 8448 patients admitted for burn care to the U.S. Army ISR between January 1, 1950, and December 31, 1991. To ensure the validity of such studies, an important first step is to achieve uniformity among the population to be analyzed. Variables of interest include time from injury, burn size, and age; these patients were encountered between the day of injury and day 531 after burn (mean 5.86 days, median 1 day), with burns averaging 31% (range 1–100%, median 26%) TBSA. The ages were biphasic, with one peak at 1 year of age and another at age 20; the mean age of the entire population was 26.5 years (range 0–97 years, median 23 years). From this group, 7893 (93.4%) who had flame or scald burns were selected, excluding patients with electrical or chemical injuries. Some of these were from the Vietnam conflict and were first transferred to Japan and then selectively transferred to the Institute; arriving late at the Institute biased this cohort toward survival. To account for this, the analysis focused on the 4870 with flame or scald burns who reached the Institute on or before the second day after burn. Burn size in these patients averaged 34% TBSA (range 1–100%, median 29%), and age was again biphasic, with peaks at 1 and 21 years and a mean of 27.1 years (range 0–93 years, median 24 years).

Between 1950 and 1965, most of the admissions were young soldiers; mean age approximated 22.5 years and was relatively stable. During the succeeding decade, this value rose to an irregular plateau centering on 30 years of age, a

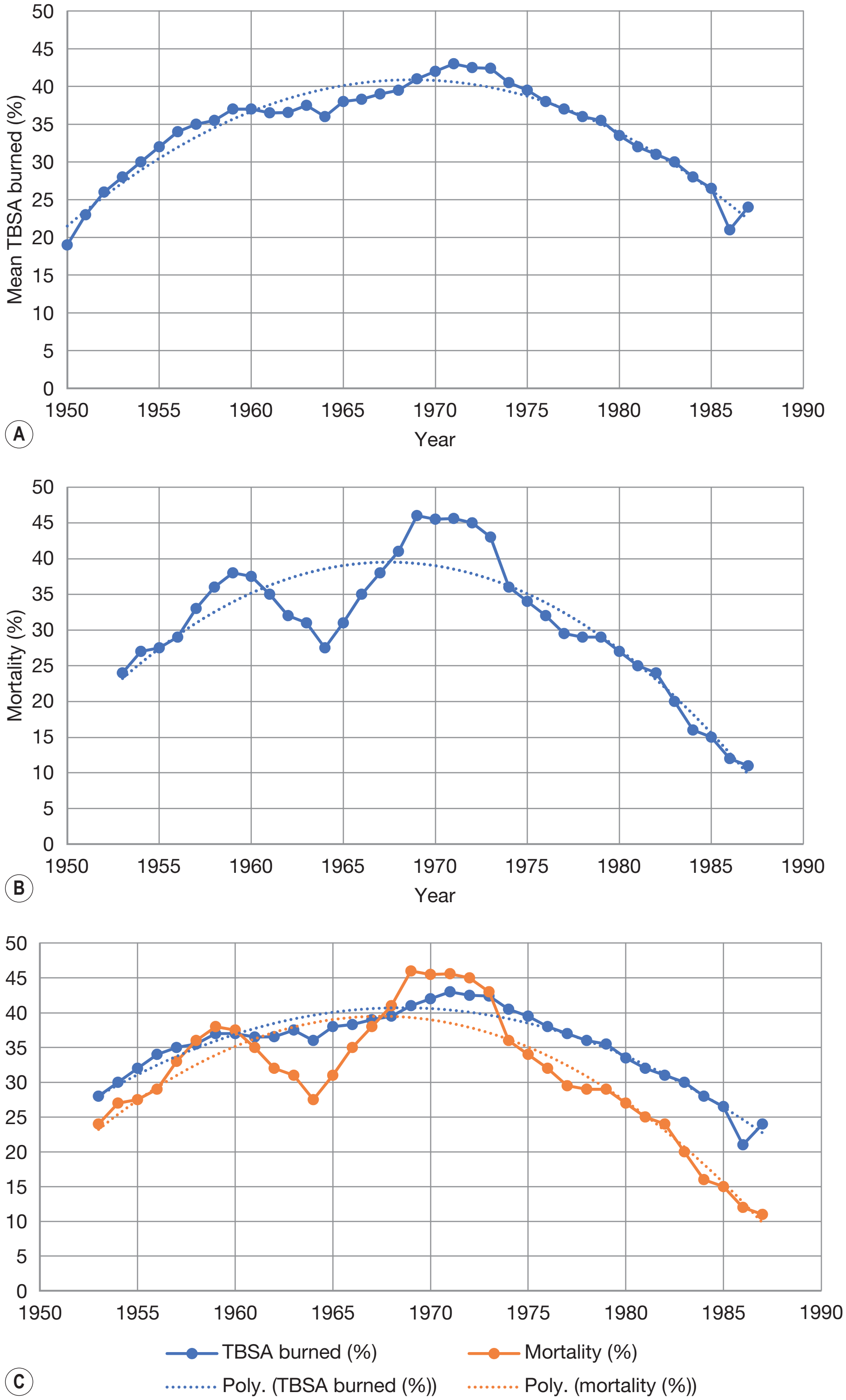

Fig. 3.5 U.S. Army Institute for Surgical Research Burn Incidence and Outcomes Data (1950–1988). Panel A describes the mean burn size encountered among admissions. The figure includes a polynomial trendline. Panel B shows the overall mortality rate and also includes a polynomial trendline. Panel C is a combination of these curves over time and shows both trendlines.

change reflecting a greater number of civilian admissions and increasing age in the military population.

Fig. 3.5A shows the variation in mean burn size during the study interval, and Fig. 3.5B shows the roughly parallel mortality. Mean burn size peaked in the two intervals spanning 1969 to 1974 and decreased steadily after that time. Mortality peaked at 46% during those years. The two datasets are shown together in Fig. 3.5C and suggest a crude index of the results of burn care in this population. When comparing the polynomial lines derived from the data, it appears that a separation favoring improved survival occurred in about 1970. This was about the time of the development of effective topical antimicrobial chemotherapy.

Raw percent mortality, even in conjunction with burn size, is never an adequate index of the effectiveness of treatment since the frequency of death after burn injury is also determined by prior patient condition, age, inhalation injury, and the occurrence of pneumonia and burn wound sepsis. Each of these elements, except for prior condition, can be addressed in analysis, but only burn size, age, and the presence or absence of inhalation injury are known at the time of admission. Furthermore the definition of significant comorbidities and development of complications are constantly being revised, making addition of these to prediction formulas difficult, and this must be kept in mind by the reader.

For a uniform population of specific age, a plot of the relationship between burn size and percent mortality is S-shaped, or sigmoid: small burns produce relatively few deaths, but, generally, as burn size increases mortality rises steeply and then plateaus as it approaches its maximum of 100%. Of note, in our recent analysis presented early in the chapter (Fig. 3.4), this appears to be more linear as burn size increases when age is not considered. When age is added, children and young adults will fit this more accurately, and older adults will have a more first-order distribution. When these are added, the curve flattens, yielding that is seen in Fig. 3.5. Although this experience conforms with that of most burn centers in the United States, it should be noted that there are still many areas of the world where the survival of patients with burns of more than 40% TBSA is rare.

The U.S. Army Burn Center (at the U.S. Army ISR, Fort Sam Houston, Texas) is the second oldest continuously operating burn center in the United States. Thus data from this burn center provide an invaluable opportunity to understand long-term changes in patient care and their effects on outcome. To further address the changes previously found up to 1991, we analyzed changes in mortality risk occurring over time from 1950 to 2013. In this analysis, only patients admitted to the burn center on the day of burn or 1 or 2 days after burn were included. Furthermore only patients with fire/flame and scald injuries were included; those with electrical, chemical, or other thermal processes and exfoliative dermatitides were excluded. Patients of all ages and burn sizes were included. Mortality was assessed as death at any time during the index hospitalization at the burn center, regardless of cause.

Data were analyzed using binomial logistic regression (backward likelihood-ratio method). In the analysis, age was represented as cubic age function, given by the equation

$$\text{Age Function} = (-5*\text{AGE}+14*\text{AGE}^2/100-7*\text{AGE}^3/10000)/100$$

This permits use of a single term that captures the observation that the relationship between age and outcome is not linear but rather "bathtub-shaped," with a nadir at about 20 years and a leveling off in advanced age.[95] Year of admission was entered into the analysis as a categorical variable, permitting calculation of odds ratios for mortality for each individual year from 1950–2013.

A total of 9755 patients met study inclusion criteria and were analyzed. The mortality rate was 18.1%. The mean age was 31.6 years (standard deviation [SD] 19.8 years). Mean total burn size was 24.4% (SD 23.5%). Odds ratios of mortality as a function of year of admission are shown in Fig. 3.6. The graph is remarkable for two peaks in mortality risk, marked "A" and "B." Peak A, in the late 1950s and early 1960s, represents increased mortality associated with invasive Gram-negative burn wound infections. This peak was followed by a striking decrease in mortality risk in 1964 with the introduction of topical mafenide acetate cream for antimicrobial chemoprophylaxis. Peak B, in 1969–72, reflects the emergence of other virulent Gram-negative organisms less sensitive to mafenide acetate (e.g., *Klebsiella* spp.). With the introduction of silver sulfadiazine cream, first as a single agent and then as an alternating

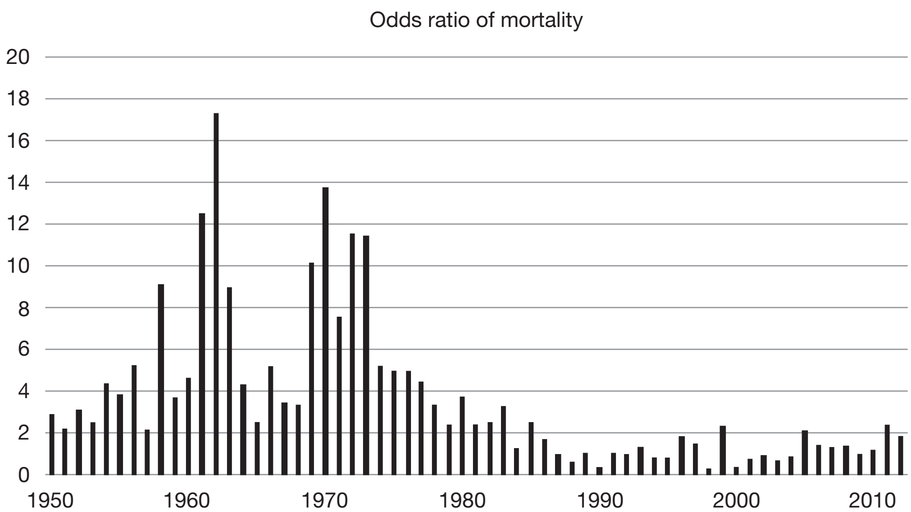

Fig. 3.6 Odds ratio of mortality distributed across a 63-year period from a single center (U.S. Army Institute of Surgical Research). These data show two spikes, in the 1960s and 1970s, that have subsequently significantly diminished in size to reach the current ratios.

agent along with mafenide acetate, a subsequent decline in mortality risk occurred. Further decreases in mortality risk were observed with the introduction and then essentially standardized use of burn wound excision in the late 1970s, enhanced infection control in the early 1980s, and improvements in mechanical ventilation in the early 1990s. The reduction in mortality risk has been maintained over the past two decades.

Conclusion

Much has been accomplished in acute burn care during the past half century, and further improvement in outcome will probably occur as inhalation injury and pneumonia come under better control and new wound coverage techniques are developed, but such improvement will be harder won and smaller in magnitude. Preservation of function, reconstruction, and rehabilitation, areas which have received less attention in the past, appear the more likely primary targets of future burn research and may be expected to materially enhance the quality of life for burn survivors.

Complete references available online at
www.expertconsult.inkling.com

References

1. WISQARS Data and Statistics, Centers for Disease Control and Prevention. Available at: www.ded.gov/injury/wisqars/index.html.
2. National Burn Repository, American Burn Association. Available at: www.ameriburn.org/2016/%20ABA%20Full.pdf.
3. Olser T, Glance LG, Hosmer DW. Simplified estimates of the probability of death after burn injuries: extending and updating the Baux score. *J Trauma*. 2010;68:690-697.
4. Shai D. Income, housing, and fire injuries: a census tract analysis. *Pub Health Rep*. 2006;121:149-154.
5. Schachterle SE, Bishai D, Shields W, et al. Proximity to vacant buildings is associated with increased fire risk in Baltimore Maryland homes. *Inj Prev*. 2012;18:98-102.
6. Baker SP, O'Neill B, Ginsberg NJ, et al. Fire, burns, and lightning. In: *The Injury Fact Book*. 2nd ed. New York: Oxford University Press; 1992:161-173.
7. National Fire Protection Association, News and Research Page. Available at: NFPA.org/news-and-research/fire-statistics-and-reports.
8. United States Fire Administration, US Fire Statistics. Available at: usfa.fema.gov/data/statistics.
9. Safe Kids Worldwide, Burn Injury Fact Sheet 2015. Available at: www.safekids.org/sites/default/files/documents/skw_burns_fact_sheet_feb_2015.pdf.
10. Albertyn R, Berg A, Numanoglu A, et al. Traditional burn care in sub-Saharan Africa: a long history with wide acceptance. *Burns*. 2015;41:203-211.
11. Baptiste MS, Feck G. Preventing tap water burns. *Am J Public Health*. 1980;70:727-729.
12. Lohana P, Hemington-Gorse S, Thomas C, et al. Pediatric injuries due to home treadmill use: an emerging problem. *Ann R Coll Surg Engl*. 2012;94:121-123.
13. Goltsman D, Li Z, Connolly S, et al. Pediatric treadmill burns: assessing the effectiveness of prevention strategies. *Burns*. 2016;42:1581-1587.
14. Lumenta DB, Hautier A, Desouches C, et al. Mortality and morbidity among elderly people with burns – evaluation of data on admission. *Burns*. 2008;34:965-974.
15. McGill V, Kowal-Vern A, Gamelli RH. Outcome for older burn patients. *Arch Surg*. 2000;135:320-325.
16. Khadim MF, Rashid A, Fogarty B, et al. Mortality estimates in the elderly burn patients: a Northern Ireland experience. *Burns*. 2009;35:107-113.
17. Masud D, Norton S, Smailes S, et al. The use of a frailty scoring system for burns in the elderly. *Burns*. 2013;39:30-36.
18. Harvey L, Mitchell R, Brodaty H, et al. Dementia: a risk factor for burns in the elderly. *Burns*. 2016;42:282-290.
19. Backstein R, Peters W, Neligan P. Burns in the disabled. *Burns*. 1993;19:192-197.
20. Glasstone S Effects on personnel. In: *The effects of nuclear weapons*. Department of the Army Pamphlet No. 39-3. United States Atomic Energy Commission; June 1957: 455–464.
21. Burns sustained in Vietnam, 1965–1973. Data tables supplied by Department of the Army, the Chief of Military History and the Center of Military History, Washington D.C. 20314;1980.
22. Shafir R Burn injury and care in the recent Lebanese conflict. Presentation on behalf of the Surgeon General, Israeli Defense Forces and staff. The Israeli Society of Plastic and Reconstructive Surgery; 1984.
23. Owen-Smith MS. Armoured fighting vehicle casualties. *J R Army Med Corps*. 1977;123:65-76.
24. Chapman CW. Burns and plastic surgery in the South Atlantic campaign 1982. *J R Navy Med Serv*. 1983;69:71-79.
25. Sereday C MAJ, Major, Argentine Navy Medical Corps. Personal communication; 1990.
26. Eldad A, Torem M. Burns in the Lebanon War 1982: "the blow and the cure". *Mil Med*. 1990;155:130-132.
27. Renz EM, King BT, Chung KK, et al. The US Army burn center: professional service during 10 years of war. *J Trauma*. 2012;73:S409-S416.
28. Escolas SM, Archuleta DJ, Orman JA, et al. Postdischarge cause of death analysis of combat related burned patients. *J Burns Care Res*. 2017;38:e158-e164.
29. Chan RK, Aden J, Wu J, et al. Operative utilisation following severe combat-related burns. *J Burns Care Res*. 2015;36:287-296.
30. Wolf SE, Kauvar DS, Wade CE, et al. Comparison between burns and combat burns from Operation Iraqi Freedom and Operation Enduring Freedom. *Ann Surg*. 2006;243:786-792.
31. Williams JB, Ahrenholz DH, Solem LD, et al. Gasoline burns: the preventable cause of thermal injury. *J Burn Care Rehabil*. 1990;11:446-450.
32. Gough J, Cheng ES, Pegg SP. Ten-year Brisbane experience in petrol burns: a preventable health burden. *Burns*. 2006;32:597-601.
33. Barillo DJ, Stetz CK, Zak AL, et al. Preventable burns associated with the misuse of gasoline. *Burns*. 1998;24:439-443.
34. Brand S, Otte D, Stubig T, et al. Mechanisms of motor vehicle crashes related to burns – an analysis of the German in depth accident study (GIDAS) database. *Burns*. 2013;39:1535-1540.
35. Purdue GF, Hunt JL, Layton TR, et al. Burns in motor vehicle accidents. *J Trauma*. 1985;25:216-219.
36. Barillo DJ, Cioffi WG, McManus WF, et al. Vehicle-related burn injuries. *Proc Assoc Adv Automot Med*. 1993;11:209-218.
37. Shergill G, Scerri GV, Regan PJ, et al. Burn injuries in boating accidents. *Burns*. 1993;19:229-231.
38. Battle CE, Evans V, James K, et al. Epidemiology of burns and scalds in children presenting to the emergency department of a regional burns unit: a 7-year retrospective study. *Burns Trauma*. 2016;4:19.
39. Rimmer RB, Weigand S, Foster KN, et al. Scald burns in young children – a review of Arizona burn center pediatric patients and a proposal for prevention in the Hispanic community. *J Burns Care Res*. 2008;29:595-605.
40. Sanyaolu L, Javed MU, Eales M, et al. A 10-year epidemiological study of pediatric burns at the Welsh Centre for burns and plastic surgery. *Burns*. 2017;43:632-637.
41. Hankins CL, Tang XQ, Phipps A. Hot beverage burns: an eleven-year experience of the Yorkshire Regional Burns Centre. *Burns*. 2006;32:87-91.
42. Hankins CL, Tang XQ, Phipps A. Hot oil burns-a study of predisposing factors, clinical course and prevention strategies. *Burns*. 2006;32:92-96.
43. Klein MB, Gibran NS, Emerson D, et al. Patterns of grease burn injury: development of a classification system. *Burns*. 2005;31:765-767.
44. Wibbenmeyer L, Gittelman MA, Kluesner K, et al. A multicenter study of preventable contact burns from glass fronted fireplaces. *J Burns Care Res*. 2015;36:240-245.
45. Matzavakis I, Frangakis ZE, Charalampopolulou A, et al. Burn injuries related to motorcycle exhaust pipes: a study in Greece. *Burns*. 2005;31:372-374.
46. Clouatre E, Gomez M, Banfield JM, et al. Work-related burn injuries in Ontario, Canada: a follow-up 10-year retrospective study. *Burns*. 2013;39:1091-1095.
47. Kica J, Rosenman KD. Multisource surveillance system for work-related burns. *J Occup Environ Med*. 2012;54:642-647.
48. Hardwicke J, Hunter T, Staruch R, et al. Chemical burns – an historical comparison and review of the literature. *Burns*. 2012;38:383-387.
49. Leeming MN, Ray C, Howland WS. Low-voltage direct current burns. *JAMA*. 1970;214:1681-1684.
50. Pride HB, McKinley DF. Third-degree burns from the use of an external cardiac pacing device. *Crit Care Med*. 1990;18:572-573.
51. Reisin L, Baruchin AM. Iatrogenic defibrillator burns. *Burns*. 1990;16:128.
52. Baker SP, O'Neill B, Ginsberg NJ, et al. Unintentional injury. In: Baker SP, O'Neill B, Ginsberg NJ, eds. *The Injury Fact Book*. 2nd ed. New York: Oxford University Press; 1992:39-64.
53. Vierhapper MF, Lumenta DB, Beck H, et al. Electrical injury: a long-term analysis with review of regional differences. *Ann Plast Surg*. 2011;66:43-46.
54. Arnoldo BD, Purdue GF, Kowalske K, et al. Electrical injuries: a 20-year review. *J Burn Care Rehabil*. 2004;25:479-484.
55. Cancio LC, Jimenez Reyna JF, Barillo DJ, et al. One hundred ninety five cases of high-voltage electric injury. *J Burn Care Rehabil*. 2005;26:331-340.
56. Jensenius JS. A detailed analysis of recent lightning deaths in the United States. 23rd International Lightning Detection Conference, 2014. Available at: www.vaisala.com/Vaisala%20Documens/Scientific%20papers.
57. Roeder WP. Lightning has fallen to third leading source of US storm deaths. National Weather Association annual meeting, 2012. Available at: www.nwas.org/meetings/nwa2012/extendedabstract/NWA2012_P2.29_Roeder.pdf.
58. Cooper MA, Holle RL. Mechanisms of lightning injury should affect lightning safety messages. 3rd International Lightning Meteorology Conference, Orlando, Florida, 2010.