Cardiac Arrest
The Science and Practice of Resuscitation Medicine

Second edition

Cardiac Arrest is the definitive and most comprehensive reference in advanced life support and resuscitation medicine.

This new edition brings the reader completely up-to-date with developments in the field, focusing on practical issues of decision making, clinical management and prevention, as well as providing clear explanations of the science informing the practice. The coverage includes information on the latest pharmacotherapeutic options, the latest chest compression techniques and airway management protocols, all backed by clearly explained, evidence-based scientific research. The content is consistent with the latest guidelines for practice in this area, as detailed by the major international governing organizations.

This volume is essential reading for all those working in the hospital environments of emergency medicine, critical care, cardiology and anesthesia, as well as those providing care in the pre-hospital setting, including paramedics and other staff from the emergency services.

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From reviews of the first edition:

... It is a tribute to the editors of this book, and the contributors they have selected, that they have managed to produce a book of enormous quality on the science of resuscitation medicine. \textit{The Lancet}

The excellent book, the first of its kind in the field of cardiac arrest, provides a balance of theoretical and clinical information. It achieves a level of authority and sophistication well beyond that of the advanced cardiac life support guidelines and will be of considerable use to all those practicing or teaching clinical resuscitation. \textit{The New England Journal of Medicine}

The book has virtually everything one would ever want to know about the causes of cardiac arrest, the applied physiology, and its treatment. Physicians and nurses involved in the management of critically ill or injured patients should have Cardiac Arrest in their personal libraries for ready reference. \textit{Resuscitation}
In memory of Harold Paradis, M.D., without whose inspiration this effort would never have been undertaken, and for Christine, without whose patience it would never have been completed. **N.A.P.**

To my wife, Sharon Tusa Halperin, and children, Victoria and Eric Halperin, whose patience and support inspired me to complete my contributions to this work. In memory of Victor Halperin, D.D.S., who inspired me to undertake a career in academic medicine and complete this work. **H.R.H.**

To Martha, my wife, who always understood that the most worthwhile books are written with friends, and that true friendship develops best while fly fishing, and to Matt, my youngest son, who has helped me keep my perspective that each day is wonderful and full of promise. **K.B.K.**

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To my wife Jennifer, who continues to be incredibly tolerant of a husband who is forever ensconced in his study and who offers no help with the washing up. **D.A.C.**
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Foreword

Myron L. Weisfeldt, M.D.

This monograph on cardiac resuscitation medicine is the standard reference in the field. This Second Edition a decade later presents an entirely changed and dynamic field. Advances in resuscitative medicine encompass the basic science understanding of physiology and pathophysiology as well as advances in understanding of the causal mechanisms involved in successful or non-successful resuscitation. There are new programs and approaches at a practical and real-world level that improve survival and the quality of survival from cardiac arrest. I would maintain that these prerequisites relate to the need for this updated monograph. It is important that this text be acquired and used by providers of emergency cardiac care in both the out-of-hospital and in-hospital settings. It will be of value universally in the emergency departments. Clinical investigators will find this text of tremendous value when pursuing the improvement of survival from cardiac arrest, as well as laboratory-based clinical investigators attempting to identify and justify approaches to improving the outcome of cardiac arrest. As the underlying science of resuscitation deepens, basic scientists will value these state-of-the-art discussions. Resuscitation Science has broadened the focus from mechanics to reperfusion injury, post-resuscitation inflammation and programmed cell death.

To substantiate my statements about this update and its value to the medical and resuscitative community, I have identified what I consider to be the eight major advances in resuscitative medicine over the last decade.

1. The advent of inexpensive, easy-to-use Automatic External Defibrillators (AEDs) for use by the lay public. Ten years ago, industry was just beginning to produce these revolutionary devices. The FDA considered use of these AEDs by other than physicians, nurses and trained Emergency Medical Technicians (EMTs) as "illegal," off label, over-the-counter use of an approved
device. Ten years ago, only one or two states referred to defibrillation as being covered by the Good Samaritan law. Now all states consider such resuscitative efforts by members of the lay public to be encompassed by the Good Samaritan statutes. Ten years ago there were no convincing data that AEDs are effective in improving the outcome of resuscitation. Perhaps the most remarkable result was in the casinos of Las Vegas where Terry Valenzuela and his colleagues measured time from collapse to defibrillation precisely (on video cameras). Security guards could defibrillate with an average time of 4.4 minutes and survival of 59% in 90 subjects. If defibrillation was performed within 3 minutes \((n = 20)\), survival was over 70%. As well, in the Public Access Defibrillation study (PAD), we now have data to support the value of the AEDs in the public arenas when added to CPR instruction. Ten years ago we had no conscientious programs to implement AEDs in full public view in airports and other transportation facilities, on-board airlines, in exercise facilities, or recently by government mandate in large public buildings. Although these programs clearly have had little impact on the overall public health survival rate from cardiac arrest, they have produced some of the most rewarding survivals because of the promptness of resuscitation and the clear ability of those resuscitated very quickly to recover fully and rapidly.

2. Change in the characteristics of the population suffering cardiac arrest. Ten years ago, broad population studies showing that 70% or so of people suffering cardiac arrest have ventricular fibrillation (or ventricular tachycardia) as the first documented electrocardiographic rhythm. Now, multiple large population studies note that 20% to 30% of those suffering a cardiac arrest have ventricular tachycardia (VT) or ventricular fibrillation (VF) as their initial rhythm. The majority now have an absence of electrical activity, or occasionally will have electromechanical dissociation. The reason for this major change, one can only speculate. One possibility is that, in fact, modern drug treatment of coronary disease and heart failure combined with implantation of automatic defibrillators in their target population has led to this change. For survivors of cardiac arrest caused by ventricular tachycardia or fibrillation, implantation of defibrillators has provided an increasing standard of care. This is also true for patients with congenitally inherited causes of sudden death, and many individuals with reduced left ventricular function due to previous myocardial infarction or cardiomyopathy. It is possible that we are implanting defibrillators currently at sufficient rate to have an impact in the United States on the overall public health’s incidence of cardiac arrest from these arrhythmias. Drug and procedural treatment strategies for chronic coronary disease and heart failure may also be impacting on the incidence of sudden death from VT/VF. It is very clear that, in these broad populations, beta-blocking agents as well as angiotensin II receptor blockers, and anti-platelet drugs (for coronary disease), and aldosterone antagonist improve survival from these chronic cardiac states. It is less clear that they reduce the incidence of sudden death particularly sudden death from VF or VT. That is a likely possibility. A final speculation is that cardiac arrest in advanced age is more likely not VT/VF. With the striking decline in age-adjusted mortality from cardiovascular disease, we have less incidence of death and perhaps less sudden death from VT/VF in younger individuals on a population basis.

This change in the initial arrhythmia has a number of significant impacts. First, survival of this group of patients who do not have VT/VF is much lower and we know little about what are effective ways of resuscitating this population. We also know less about the long-term management and care of these patients that may result in their survival since it is likely that placing automatic implantable defibrillators in these patients will not improve their long-term outcome even if they survive their initial arrest. These, and a whole host of other theoretical and practical problems, emanate from this change in population suffering cardiac arrest.

3. In recent years there has been recognition of the need to extend animal data on CPR performance and effectiveness from the laboratory into the clinical arena. It is very clear from animal studies that all interruptions of chest compressions are detrimental to the hemodynamics of CPR, particularly coronary blood flow. It has long been recognized that indices of coronary blood flow are very closely related to human survival. Interruptions from repeated looks at the electrocardiogram, multiple defibrillation attempts, or procedures such as inefficient intubation, have been minimized on the basis of these data. In addition, it has been demonstrated in animal models very convincingly that hyperventilation or even “usual” ventilation during resuscitation is too much ventilation and is detrimental. Related to these issues, performance of cardiopulmonary resuscitation in the real-world situation, both in the hospital by healthcare professionals and out-of-the hospital by EMTs, is characterized by multiple, prolonged and repeated interrupts of chest compression and hyperventilation. Monitoring systems, feedback systems, and other systems for controlling or at least documenting the way resuscitation is
We are beginning to see devices that may improve perfu-

4. In VT/VF-Arrest, Dr. Lance Becker and I proposed a three-

5. We are beginning to see devices that may improve perfu-

6. Moderate hypothermia may be useful in patients who

after out-of-hospital cardiac arrest have not awakened when they reach the emergency department. Two studies

appear to show benefit of 12 to 24 hours of 32 ° to 33 °C, hypothermia in terms of improving survival and brain function following such episodes of out-of-hospital cardiac arrest. This benefit has been accepted in AHA guidelines, but is not accepted by the FDA. Much is happen-

7. Registry-based information on in-hospital and out-of-

hospital CPR. Detailed performance data with results are now available for thousands of in-hospital resuscitations. There are also increasing numbers of epidemi-

8. There is a new horizon of technology that will certainly impact on resuscitation This technology revolution I predict will include patient sensors that identify futility of cardiac resuscitation. Diagnosis of death is inadequa-

ly made in many individuals with current clinical criteria. Perhaps more importantly, we will use sensors that will identify patient status from the point of view of metabolism blood flow and oxygen delivery. They will provide an assessment of the current status of the patient and/or what the resuscitative maneuvers have accomplished. This type of information will dictate care patterns and strategies to improve survival from the point of view of drug administration as well as device and hemodynamic strategies. The strategies are likely to be complex and therefore it is highly likely that devices will integrate the clinical status of the patient with the information obtained with sensors into a care and management. These will emerge particularly as metabolic phase markers lead to specific therapeutic strategies. Information will likely be used at the scene and in the emergency department that is ultimately going to receive the patient. Similar devices and approaches will almost certainly change in-hospital and ED manage-

ment of the arrest occurring in that circumstance.

9. In summary, this new volume on the science and prac-

tice of resuscitative medicine is extraordinarily timely. The depth and breadth of new material and chapters are remarkable and valuable. The new authors include...
the current generation of the most contributory and thoughtful leaders of the field. The text should be embraced by a broad and deep audience of those interested in this exciting and forward-moving field and branch of medicine. The worldwide authorship reflects the fact that sudden death is a worldwide problem that is increasingly gaining true worldwide attention!

July 12, 2006
Preface to the first edition

O, that I could but call these dead to life!

King Henry VI
William Shakespeare

There is a no more frightening experience for a clinician than a patient’s sudden and complete loss of vital signs. The need to initiate multiple complex therapies, all the while knowing that each minute that passes dramatically decreases the chances for a good outcome, makes sudden death the penultimate medical emergency.

Premature death is the adversary of physicians. For millennia, the loss of life signs was considered the victory of death. Students were taught that once patients had succumbed they were beyond the healing arts. Only relatively recently have physicians regularly attempted to wrest such patients back from death.

Accurate numbers are difficult to obtain. It is said that more than 300,000 persons die each year from sudden cardiac death in the United States alone. Worldwide the figure is in the millions. Sudden death is not, however, caused by coronary artery disease alone. Hemorrhage and asphyxiation, among others, can kill physiologically competent patients without warning. Sudden death is not defined by etiology; it is the circumstance of cardiopulmonary arrest in a person with functional vital organ systems. It is death in the midst of life, and it is always tragic.

We are just beginning to appreciate the magnitude of this problem and the potential for therapy. Just a 5% improvement in outcome – something that could be achieved in many communities by better application of standard care – would save more lives than therapies that have received far more attention. The potential for good is astounding; the relationship of cost to benefit compelling.

Sudden cardiopulmonary arrest is the most difficult disease state to treat. Remarkable improvement in the
quality of care has been achieved in a relatively short time by the American Heart Association’s and the European Resuscitation Council’s guidelines to therapy. Their efforts define the standard; this text is an attempt to delineate state-of-the-art. Our efforts are complementary. One cannot hope to individualize therapy to the patient’s benefit without excellent basic care, and international consensus provides this basis.

Our difficulty in treating cardiopulmonary arrest reflects a limited understanding of the pathophysiology of global ischemia and reperfusion. Physicians are naturally uncomfortable in using therapies that are poorly understood and that have not been clearly demonstrated effective. However, these patients do not allow us the luxury of waiting for more definite knowledge. We must apply all our skill and limited knowledge immediately if persons with “hearts and brains too good to die” are not to be lost forever.

This text is for clinicians who wish to practice both the science and the art of resuscitation. Every physician will at some time attempt to resuscitate a patient from sudden death, but few will have had the opportunity to learn from teachers dedicated to this skill. That is the purpose of this book. In each chapter, a recognized authority has been asked not only to review present knowledge, but also to describe the state of their art. Cardiac arrest patients do not have the luxury of seeking out experts. You must bring that expertise to the bed or curb side.

This is intended to be a comprehensive text incorporating critical analysis of material not readily available elsewhere. The text begins with chapters that place our current knowledge into context, describing the magnitude of the problem. The next two sections describe the basic science of ischemia and reperfusion at the cellular, organ system, and organismal levels and the pathophysiology of cardiopulmonary arrest and resuscitation. The fourth and fifth sections focus on state-of-the-art therapy for cardiopulmonary arrest, first without respect to etiology and then under specific circumstances. Contributors were asked to provide insights that complement widely disseminated guidelines. The sixth section focuses on the pathophysiology and therapy of postresuscitation syndrome, a complex disease state that is increasingly believed to underlie the morbidity and death following resuscitation. The therapy sections conclude with summaries intended to bring together concepts discussed throughout the chapters on cardiopulmonary resuscitation and postreperfusion syndrome.

We are at the beginning of what will be a rapid expansion in our knowledge of the pathophysiology and therapy of sudden death, global ischemia, and reperfusion injury. This text is intended not only to reflect the field, but also to affect it. We hope to convince the reader that there is art even in the management of this, the most dire medical emergency. “Life is short and the art is long.” Considering the millions of lives that are cut short and the limits of our knowledge, the art must be very long indeed.

The Editors