Spitz and Fisher's

MEDICOLEGAL INVESTIGATION OF DEATH

Guidelines for the Application of Pathology to Crime Investigation

FIFTH EDITION

Edited by

WERNER U. SPITZ

and

FRANCISCO J. DIAZ

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"The search for truth is the essence of forensic pathology. This truth forms an essential link between the enforcement of law and the protection of the public in administration of justice." This illustration shows a sculpture by Una Hanbury, located in the lobby of Maryland's Medical Examiner's Building in Baltimore. The guardian figure on the left represents law. Next to it the doctor holds up the lamp of knowledge towards the symbolic figure of justice. Justice is interpreted in its aspect of love. The general public is suggested by the group of figures on the right. An inscription underneath the sculpture reads, "Wherever the art of medicine is practiced is there is also a love of humanity." (Hippocrates)

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With a Foreword by

RAMSEY CLARK
Former Attorney General of the United States

CHARLES C THOMAS • PUBLISHER • LTD.
Springfield • Illinois • U.S.A.

Published and Distributed Throughout the World by

CHARLES C THOMAS • PUBLISHER, LTD.
2600 South First Street
Springfield, Illinois 62704

ISBN 978-0-398-09312-9 (cloth)
ISBN 978-0-398-09313-6 (ebook)

First Edition, 1973
Second Edition, 1980
Third Edition, 1993
Fourth Edition, 2006
Fifth Edition, 2020

Library of Congress Catalog Card Number: 2019038286

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Printed in the United States of America
UBC-S-*2*

Library of Congress Cataloging-in-Publication Data

Names: Spitz, Werner U., 1926- editor. | Diaz, Francisco J. (Medical examiner), editor. | Fisher, Russell S., 1916-1984 past editor.
Title: Spitz and Fisher's medicolegal investigation of death: guidelines for the application of pathology to crime investigation/ edited by Werner U. Spitz, M.D., Consultant, Forensic Pathology and Toxicology, St. Clair Shores, Michigan, Chief Medical Examiner, Wayne and Macomb Counties, Michigan (Retired), Professor of Pathology, Wayne State University School of Medicine, Detroit, Michigan, Adjunct Professor of Chemistry (Former), University of Windsor, Windsor, Ontario, Canada (Former), co-edited by Francisco J. Diaz, M.D., Deputy Chief and Medical Director, Office of the Chief Medical Examiner, Washington, DC, Clinical Assistant Professor, George Washington School of Medicine, Former Assistant Medical Examiner of Wayne County, Michigan, Faculty at University of Michigan School of Medicine; with a foreword by Ramsey Clark, Former Attorney General of the United States.
Other titles: Medicolegal investigation of death
Description: Fifth edition. | Springfield, Illinois : Charles C Thomas, Publisher, Ltd., 2020. | Revised edition of: Spitz and Fisher's medicolegal investigation of death/ edited by Werner U. Spitz, co-edited by Fisher, Russell S., 4th ed. c2006. | Includes bibliographical references and index.
Identifiers: LCCN 2019038286 (print) | LCCN 2019038287 (ebook) | ISBN 9780398093129 (cloth) | ISBN 9780398093136 (ebook)
Subjects: LCSH: Forensic pathology. | Death--Causes.
Classification: LCC RA1063.4 .S63 2020 (print) | LCC RA1063.4 (ebook) | DDC 614/.1--dc23
LC record available at https://lccn.loc.gov/2019038286
LC ebook record available at https://lccn.loc.gov/2019038287

To my father
Siegfried Spitz, M.D.
my first and foremost teacher
and to
my mother
Anna Spitz, M.D.
who relentlessly showed me the way.

W.U.S.

To my parents
Luz Domingo de Diaz and Francisco Diaz-Morales
for their sacrifice and for showing me and my siblings
that education is our most valuable asset.
To
Javier
in hopes that this work inspires him in his life's journey
and to
Angalena
for making a reality of what seemed impossible

F.D.

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FOREWORD

"Mordre Wol Out," Chaucer's Prioress tells us. But those who work in homicide investigation, forensic pathology, and criminal law know better. The true manner of death which may have been murder is not determined in tens of thousands of cases annually in our violent land. The cost to the nation in truth, justice, health, and safety is enormous.

Had Hamlet put aside indecision, sentimentality, emotion, the wan grief spent on the skull of the jester of his youth—"Alas, poor Yorick! I knew him, Horatio"—and obtained an autopsy on his dead father, the King of Denmark, Shakespeare's play might have turned from tragical to historical. Surely, we now see how our failures can affect history itself. The violent death of a President will always cause the deepest fears and suspicions. There will always be the allegation of gunfire from a grassy knoll.

We can determine the truth, and medical science must play a major role. The coeditor of this important volume was one of four professionals I called on as Attorney General to review the autopsy photos and x-rays of our beloved President who looked "forward to the day when America would no longer be afraid of grace and beauty." In a time of profound doubt and international concern, with the highest integrity, self-discipline, and professional skill, Dr. Fisher contributed to those most reassuring phenomena, facts linked together pointing to truth.

How many men in America can qualify for such a task? That this is the first volume in twenty-five years dealing directly and effectively with the subject of medicolegal investigation of death tells us that our neglect here is enormous. The deaths of John F. Kennedy, Medgar Evers, Malcolm X, Martin Luther King, Jr., Robert Kennedy, and Whitney Young, Jr., show how our inadequacy can alter our destiny.

About 4:45 a.m., on December 4, 1969, two young Black Panthers, Fred Hampton and Mark Clark, were killed by gunfire in the city of Chicago. The shooting occurred during the course of a police raid on Panther headquarters. There followed an official inquest, a protest inquest, three autopsies, and three grand jury investigations. Each of the autopsies was performed under conditions in a manner or reported in a way that added to speculation over the real cause of death.

A community has been left in profound doubt as to the identity of the guns from which the bullets causing death were fired, even the direction of entry and number of shots. Were the deaths accidental? Were police justified in this use of deadly force? Were the dead murdered by the police? Was Fred Hampton drugged at the time of death? That over five thousand people attended his funeral indicates the impact of our failure to establish the truth. The resulting division in the community will affect the quality of life there and, through those who live there, elsewhere, for a generation or more.

Perhaps many pathologists avoid medicolegal investigation of death because its contribution to life is not clear and the happy side of the docket is with the life savers. A study of such chapters as "Investigation of Deaths from Drug Abuse," "Forensic Aspects of Alcohol," and "Aircraft Crash Investigation" immediately demonstrates the great importance of this field in life saving and social problem solving. Indeed, few in the medical profession will be more involved in the action and passion of our times than those who seek to find and demonstrate these medical facts. We can foresee the risks of willful destruction of crowded airplanes and the meaning to mass urban technological society.

With a hundred new dangerous drugs to be created by chemical science in the next five years, with a youth culture in an age of anxiety approaching incoherence, with grossly inadequate preventive research, it often will be the autopsy that tells us of the new synthetic chemicals threatening life. With this knowledge, society can endeavor to cope with one of its most difficult problems.

There are few crueler injustices directly inflicted on an individual by government than conviction of a crime one did not commit. Important chapters such as "Sudden and Unexpected Death from Natural Causes in Adults," "Trauma and Disease," and "Injury by Gunfire" show us how easy it is to misjudge the cause of death where circumstances are suspicious. It is of the utmost importance to the individual, to society, to truth, justice, and safety that we find the facts concerning death.

Because of its pathos, we too often ignore the truths disclosed in Chapter XVIII, "Investigations of Death in Childhood—The Battered Child." How many of our most violent criminals were the subject of physical abuse as children? Forensic pathology can give us some indication. It is important that we know. The national attitude toward violent crime could be dramatically changed by this truth.

Few professions create greater despondency about the goodness of man and the worth of life than the practice of criminal law. Not many human documents are more pessimistic than Clarence Darrow's autobiography. Few activities tend to diminish an appreciation of life more than forensic pathology as generally practiced. Neither should be. The criminal lawyer seeks justice—the forensic pathologist, truth. Noble causes. If both will abandon rhetoric, ancient dogma and fictive contentions in favor of finding and presenting fact, which is the teaching of this text, their proper purposes will be justified. Practitioners will then enjoy the satisfaction of helping people.

We must have the courage, indeed the ardent desire, to know the causes of death. We cannot let the *corpus delicti* diminish our capacity for joy. We should not faint at the photos here. They are true, and while all truth may not seem beauty, all truth can strengthen our humanity. Then, however irresolute, we will find the compassion like Hamlet to hold in our hands the skull of a beloved friend, look on it and say, "Here hung those lips that I have kissed I know not how oft." The great and constant need of those who investigate

homicide and practice forensic pathology or criminal law is a warm humanism. A people who will not face death cannot revere life.

But these are mere musings. Study this work.

RAMSEY CLARK
Former Attorney General
of the United States
Washington, D.C.
14 July 1972

PREFACE TO THE FIFTH EDITION

This is not just a new edition but a different book emphasizing trauma and wound analysis. We have eliminated a number of chapters that are no longer applicable or that are adequately covered in other publications. The addition of a new co-editor, Dr. Francisco J. Diaz, has brought new ideas to this fifth edition. We are proud to include a chapter by Doctor Jan Leetsma, world-renowned neuropathologist. Doctor Leetsma's vast experience in forensic neuropathology will certainly enhance this book.

Over time, in the past 48 years since this book was first published, *Medicolegal Investigation of Death* has been dubbed the "Bible of Forensic Pathology." We hope that it will continue to be known as such.

The fifth edition includes over 600 case reports and hundreds of color photographs. The cases are from files we have handled. Many times we have found that analysis of small wounds will lead to understanding of a giant case—like the case in Hawaii, where a body was found under a full-size van with a thread mark on the cheek consistent with the victim's having been hit with a black pipe used for gas lines that were found in a bucket in the rear of the van. As it turned out, this was a murder, not an accident. The book is full of such cases.

Medicolegal Investigation of Death now embraces not just basic forensic pathology, but also includes death during restraint, including conscious pain and suffering, and new concepts related to the interpretation of injuries by detailed wound analysis.

I remember spending hours into the night with Doctor Karplus teaching me the details of injuries, to understand how a person was injured and how he or she died. Injuries that you would never believe significant would suddenly shed a new light on the case—like the small rectangular (dice) imprint on the back of a bald head which indicated that the shot that killed the driver was fired from outside the vehicle through the rear window of the car, and was not fired by the passenger sitting next to him.

We have again included the foreword by Ramsey Clark, former Attorney General of the United States. His words could not have been more appropriate when he said, "Study this work."

We wish to thank Michael Thomas of Charles C Thomas, the publisher of this tome, for all the help, advice, and patience that he and his staff have given us in the preparation and printing of the fifth edition.

Last but not least, we acknowledge with gratitude the contributions of Diane Lucke for preparing this manuscript.

W.U.S.
F.J.D.

PREFACE TO THE FOURTH EDITION

It is with great pleasure that I present this fourth edition of *Medicolegal Investigation of Death* and introduce my son Daniel as Coeditor. I am thrilled that he decided to follow in my footsteps. After working several years in Florida at the Dade and Hillsborough Counties Medical Examiner's Offices, Dan has now joined me in Michigan. His relocation enables us to exchange ideas, discuss cases, and work together.

This book was first published in 1972 with Russell Fisher, then Chief Medical Examiner of Maryland. Russ was a pioneer who early on recognized the importance of teaching, research, and publication in forensic pathology, if this discipline was to withstand the challenges of time. Russ died in 1987, but left an indelible mark in these pages. This is the reason why his name is and will be on the cover.

Medicolegal Investigation of Death has been applauded since its inception, primarily because of its simple style, avoidance of technical terminology, and the numerous illustrations it contains. The book was meant for pathologists, pathology residents, coroners, and all those who have an interest in the recognition and interpretation of wound patterns, and mechanisms of injury, including prosecuting and criminal defense attorneys, attorneys engaged in civil litigation, detectives, investigators, forensic nurses, and others.

Medicolegal Investigation of Death is a textbook in forensic pathology. It has become a tradition that this book is rewritten, updated, and expanded every 10 years or so. The present version has been completely redone. Eleven new chapters and sections, an overall updated and expanded text, hundreds of new illustrations, and many new contributors make this a totally new book. I want to acknowledge my profound gratitude to all contributors and welcome the new authors.

The illustrations are still in black and white and not only to reduce cost. Color evokes emotions. Black and white is more neutral. For an astute observer, the lack of color will not be significant.

The popularity of shows depicting medical legal death investigation, such as *Quincy* in the 1980s, and recently *CSI*, *Crossing Jordan*, and *Court TV*, to name but a few, has brought the world of forensic science into everyone's living room. These shows have caused the general public to become aware and intrigued, while raising expectations of what may be derived from a postmortem examination.

Every piece of the puzzle plays a role, from the observations recorded by the police officer at the scene, EMS workers, nurses, and physicians in the ER, to the forensic pathologist in the autopsy room. It is therefore important that each understand their role and the significance of their notes when reconstructing an event.

Such manpower must realize that their notes in patients records may well become evidence in later legal proceedings. Thus, what were once mere words

lost in reams of paper are now subject to scrutiny and cross-examination. Diagnoses are no longer buried with the patient's demise, and clinical forensic medicine where physicians are called upon as experts to testify in courts of law has grown and prospered far beyond training in the field.

This book hopes to fill the void and its text has been adapted to a broader readership.

W.U.S.

PREFACE TO THE THIRD EDITION

Medicolegal Investigation of Death has recently celebrated its twentieth year of publication. When Russ Fisher and I were compiling the first edition back in 1970, we were aware of a need for such a book. Ten years later, widespread demand required a second, expanded edition. Since that time, frequent queries and concerns of attorneys, investigators, pathologists, and others interested in medicolegal investigation, coupled with recent developments, prompted a third edition, not only to keep abreast of the present state of the art, but perhaps, more importantly, to deal with areas not addressed in previous editions. Some of these areas are not new, but their absence in the text was obviously significant.

To those who have stimulated me by their inquiries and prompted this third, expanded edition of this book, I wish to extend my heartfelt gratitude for keeping the fire alive.

The present text is profusely illustrated, with many new photographs and added diagrams and sketches to show mechanisms of injury. Most of the old pictures have been retained because it was considered senseless to replace classic illustrations only for the purpose of novelty.

The book has largely kept its simplistic and practical approach, avoiding technical terminology where possible, in compliance with its aim of addressing not only physicians but all those who are engaged in the study of injury patterns and the practice of pathology as it relates to the law.

Unfortunately, since the last edition of this book, three prominent contributors, leaders in the field of forensic pathology and friends, are no longer with us, Doctor James T. Weston, Doctor Russell S. Fisher, and Doctor Richard Lindenberg. Their spirits live on in these pages.

A number of new contributors bring fresh ideas and expertise to this volume, and I wish to extend my sincere thanks to them for their indispensable effort.

Lastly, I wish to indicate my debt of gratitude to Diane Lucke for her tireless efforts in compiling and coordinating this entire manuscript. Without such help this book could not have been completed.

W.U.S.

PREFACE TO THE SECOND EDITION

When the first edition of this text was published in 1973, we intended that it would fill an existing void for an up-to-date account of the current state of knowledge of death investigation. The need for a second printing three years later supported our original belief that such a publication did indeed meet a demand. Rather than continue with a third printing, we felt that it would be appropriate at this time to undertake a complete revision of the text and to include new developments, including primarily a considerable volume of material that had been previously omitted.

Consequently, many additions and alterations were made to nearly all of the chapters. New sections on sudden infant death syndrome and chemical considerations associated with postmortem changes were included. A new chapter dealing with methodology and interpretation of toxicological procedures was added. Furthermore, a shortcoming of the previous edition was corrected by devoting space to preparation of a medicolegal autopsy report and formulation of a medicolegal opinion, as have been found to be advantageous in the author's own experience.

Significantly more space was allotted to illustrations. We were almost tempted to include color, but in the interest of lower cost, photographs were again limited to black and white, although the emphasis on quality was continued.

In conformity with the first edition, an attempt was made to maintain the practical character of the book, and where possible, technical terminology was avoided in the interest of easier understanding for a wider spectrum of readers.

It is the editors' pleasure to acknowledge the assistance received from so many colleagues, pathologists, police officers, and attorneys, who contributed by their questions and suggestions. As previously, a great debt of gratitude is owed to Mrs. Hannelore Russell-Wood (Schmidt-Orndorff) for assistance with the editorial work, preparation of the index, and collating of the entire manuscript. Elaine Sacra, research assistant at the Wayne County Medical Examiner's Office, helped transform a raw manuscript into a coordinated text, and Nancy Whayne prepared additional drawings. Special thanks are due to our photographers, Lester Walter and Anna Faulkner, for hours of expert labor spent in providing illustrations for the new material in this edition.

W.U.S.
R.S.F.

PREFACE TO THE FIRST EDITION

Whenever a new textbook is to be written three basic questions should be answered by the authors: Why, who needs it? Is it needed now? Why should the authors in question, rather than others, undertake the work?

In the last thirty years there has been increasing sophistication in the training of police officers assigned to homicide investigation. To a significant degree this has been due to the philosophy developed at the Harvard Medical School in the late 1940s of teaching homicide investigators the nature of the medical aspects of injuries. This has led to the development of a sizeable corps of highly expert individuals in this field. The need for this type of information has also been greatly emphasized by the fact that throughout a large part of the United States the medical investigation of death at the scene is woefully inadequate, conducted by untrained and unskilled coroners who are frequently nonphysicians. No new textbook oriented to the homicide investigator or the novice forensic pathologist has appeared in the last two and one-half decades. It is our aim to meet the need by presenting, in readable style, an authoritative text embracing all aspects of the pathology of trauma as it is witnessed daily by law enforcement officers, interpreted by pathologists of varying experience in forensic pathology, and finally used by attorneys involved in the prosecution and defense in criminal cases, as well as by those engaged in civil litigation.

Since the text is addressed to a wide range of professional disciplines, some of the chapters are inevitably directed more towards readers with medical backgrounds, whereas others are suited for general understanding. Nevertheless, the large number of illustrations and diagrams will, we hope, render the text comprehensible to all who are interested in the interpretation of forensic pathologic findings.

As it has been noted above, no up-to-date textbook covering the material contained herein is currently available. While working in the Maryland Medical Examiner's Office and its partner in teaching and research, the Maryland Medical-Legal Foundation, we have accumulated a large volume of material upon which to base the text. This material and experience also serve to answer the question: Why us? We have been concerned not only with the day-to-day investigation of sudden and violent deaths in a statewide medical examiner's system but also with teaching in medical and law schools in Baltimore and elsewhere throughout the country as well as with training of young pathologists who wish to become expert in the field. Furthermore, we have been conducting the *Frances G. Lee Seminars in Homicide Investigation* for state and other police officers for many years. It is our hope that our experience and those of our coauthors will make a significant contribution to the improvement of the investigation of sudden and violent death, the

prosecution and defense of those related to such events, and the protection of the public welfare.

W.U.S.
R.S.F.

ACKNOWLEDGMENTS TO THE FIFTH EDITION

Let it be Known

Now that we have completed the fifth edition, we miss Bill Loechel more than ever. Bill made all the drawings, sketches, and diagrams that appeared in all five editions of *Medicolegal Investigation of Death* since 1972, when the first book appeared in print. He prepared the drawings while I talked to him and told him what I needed. He was amazing; he was a perfectionist, a master at his job. I wish he was still here.

William Edgar Loechel was born and raised in Baltimore, where I first met Bill. He was the first medical illustrator for the NIH. Bill died on September 7, 2011, at the age of 88. As amazing as he was, he was humble, always patient, meticulous and perfect.

We wish to acknowledge and thank Javier Diaz for spending hours on end to help locate pictures, which was not an easy task, and help in preparation of the manuscript. Javier just started college and intends to continue a career in orthopedic medicine. We wish him good luck.

Our sincere gratitude to Diane Lucke for her devotion and dedication to preparing this manuscript for print and compiling the index. Only her perseverance and tireless effort made it possible to accomplish this task. Without Diane's meticulous efforts in the third, fourth, and present fifth editions, this book would have never been published.

Lastly, we wish to acknowledge our gratitude to Philip Pokorski, Ph.D., for the days he spent doing library research in connection with the publication of this book.

W.U.S.

ACKNOWLEDGMENTS TO THE FOURTH EDITION

My sincere gratitude, as editor of this book, goes to Diane Lucke, my assistant and office manager, who has been with me 32 years. Her tireless perseverance in preparing the manuscript, often providing valuable advice, sorting the illustrations, compiling the index, proofreading, and much of the work usually done by the editor, deserve special recognition. Without Diane's help, this book would not have seen the light of day.

David Woodford, Forensic Manager of the Michigan State Police Crime Laboratory in Sterling Heights merits more than just thanks for his expertise, availability to consult at all times and obtaining and confirming information on so many different topics. Indeed, Dave is not only a colleague but a dear friend. Unfortunately on March 9, 2005, while this book was in print, we lost him.

Many of the drawings and sketches were prepared by William Loechel, retired director of Medical Illustrations at Wayne State University, School of Medicine. Bill made work fun. His keen knowledge of anatomy resulted in renditions with a perfection that only Bill could have achieved. For this, my utmost gratitude to Bill.

A special thanks also to one of the leading Evidence Photographers in the Detroit area, Edward Gostomski of the Robert J. Anderson Company, for preparing a large number of the photographs in this book and his expert advice in regards to the photography chapters.

Cameron L. Marshall, Charleston, South Carolina, formerly Solicitor of the Ninth Judicial Circuit, now in private practice, provided case information and numerous hours of stimulating and delightful discussion.

Last, but not least, I am deeply moved by all those unnamed individuals who provided case material, advice, and encouragement in the course of preparation of the manuscript. Many thanks to them as well.

W.U.S.

ACKNOWLEDGMENTS TO THE FIRST EDITION

The idea of compiling a book such as this was not new to us. We had been toying with this thought many times in the past. However, by insisting on the need for such a book and by impulsively establishing contact with the publishers, Col. James T. McGuire, Superintendent of the Illinois State Police, gave us the necessary impetus to go ahead with our plan. To him goes our appreciation for his insight and understanding of the need for dissemination of experience in the pathology of trauma among law enforcement personnel to help ensure a better administration of justice.

Our thanks to all those who have contributed to this book with their knowledge and experience, and who have thereby helped us make this endeavor possible.

Finally, our sincere gratitude to Hannelore Schmidt-Orndorff for her able assistance with the editorial work. Her continuous drive and suggestions have helped immensely in the task of preparing the manuscript from its inception.

The editors also wish to acknowledge the cooperation of the photographers of the Medical Examiner's Office in Baltimore—Walter C. Carden and M. Gibson Porter—for the preparation of the illustrations of the chapters contributed by the editors as well as Chapters IV, XVII, and XXI.

W.U.S.
R.S.F.

CONTENTS

"In fine, nothing is said now
That has not been said before."

TERENCE (185–159 B.C.)

Spitz and Fisher's
MEDICOLEGAL INVESTIGATION OF DEATH

Open your mind to the wonders of forensic science.

Chapter I

TIME OF DEATH AND POSTMORTEM CHANGES

When did he/she die? That is probably the most common question that the forensic pathologist is asked by family members, law enforcement, and attorneys; and nowadays, it is a question that is expected to be answered. Despite scientific advances, the determination of time of death remains elusive because of the multiple and varied factors that are involved in the postmortem process.

We are going discuss those factors that are needed to estimate the time of death.

DEFINITION OF DEATH

A consensus in the definition of death is as elusive as trying to determine the time of death. In 2014, the Uniform Law Commission (ULC) published a summary on determination of death.[1] In that summary it is postulated that "advances in medical techniques and equipment have made it necessary to re-evaluate traditional legal standards for declaring a human being dead."

Until the 1960s, the *cessation of circulation and respiration* was the unchallenged definition of death. Even today in most deaths, particularly in those which occur outside hospitals, or are unwitnessed, the criteria used are still the cessation of circulation and respiration.

However, the classical definition of death has been challenged in recent times by medical advances, such as resuscitation techniques and advanced life sustaining equipment capable of maintaining blood pressure, circulation and respiration in individuals with severe brain injury.

These developments necessitated, in many cases, the obvious revision of the definition of death from just *cessation* to *irreversible cessation* of respiratory and heart activity following modern resuscitation attempts. The reversibility of the death process is dependent on the capability of tissues to recover from the effects of ischemia/anoxia occurring between the advent of clinical death to the initiation of effective resuscitation. The resistance of various organs to ischemia/anoxia is variable, with the central nervous system displaying a particularly high sensitivity. The classic literature indicates that a four- to six-minute period of cerebral anoxia from a delay in effective resuscitation will commonly result in irreversible and extensive brain damage. Exceptions have been reported where the reversible interval was longer.[2]

Young children and hypothermic individuals are known to resist cerebral hypoxia for thirty minutes or longer with no ill effects. In the well-known case reported by Kvittingen and Naess,[3] a five-year-old boy fell into a partly frozen river and recovered fully, following a presumed submersion time of twenty-two minutes.

The development of life-sustaining equipment has also changed the definition of death by permitting dissociation between a severely hypoxic or dead brain (incapable of sustaining spontaneous respiration and circulation) and the peripheral organs, which can be kept alive artificially. Therefore, the definition of death in a person with severe and irreversible brain injury, incapable of sustaining spontaneous respiration and/or circulation, had to be revised to include what is now defined as *brain death.*[4–5]

According to Bernat,[6] physicians now may lawfully determine death using brain criteria in every state of the United States, all Canadian provinces, and 80 countries around the world.

POSTMORTEM CHANGES AND ESTIMATION OF THE TIME OF DEATH

Following death, numerous physicochemical changes occur, which ultimately lead to the liquefaction of all soft tissues. The medicolegal importance of these postmortem changes is related primarily to their sequential nature which can be utilized in the determination of the time of death and the related destructive and/or artefactual changes which may simulate premortem injuries or modify toxicological findings.

The determination of the time of death is generally based on the principle of using sequential changes as a *postmortem clock*. Physicochemical changes are evident upon direct examination of the body, such as changes in body temperature, livor, rigor, and decomposition. These changes are routinely reported in protocols and are most commonly used in postmortem timing.

Injuries to the decedent are also often useful in determining the time of death. The survival time after injuries, particularly when the time of infliction is known, can be estimated. Qualities to look for include the nature, extent, and severity of injuries, the quantitation of associated complications, amount of bleeding, and early tissue reaction to injuries. In addition, any adequate autopsy will record the amount, composition, and appearance of gastric contents.

The major problem encountered in the estimation of the time of death is the variation in the environmental and individual factors that impact the magnitude and kinetics of postmortem phenomena. The physicochemical changes following death are greatly dependent on environmental conditions and the metabolic status of the individual prior to death. Therefore, the deceased must be considered in view of environmental factors (temperature, ventilation, humidity) and his or her characteristics (body build, premortem exercise, state of health). Due to the significant variation in the kinetics of postmortem phenomena, the time of death cannot be pinpointed exactly; the time of death is rather estimated within a range of time. The time range is wider when the interval since the actual death is longer. As the actual time of death is longer, the estimate of time of death becomes more inaccurate.

A young, thin, adult female was found on her bed, uncovered, nude, with over 100 stab wounds on the limbs and torso. Due to a ceiling fan operating over the body, she was not decomposed, despite the room temperature being in the mid-80s (°F), with high humidity and time of death estimate of 12-15 hours.

Because of inherent inaccuracies in the timing of individual postmortem changes, the following approach is usually effective. An initial determination of a wide *window of death* is made, which is then subsequently narrowed and refined by using variable parameters. The *window of death* is defined as the time interval prior to which one may assert with confidence, that the individual was alive. The window of death should be established according to the most reliable testimony or evidence as to when the individual was last known to be alive (witnesses, verified signed documents, last time newspapers were brought into the house, last time of withdrawal on bank accounts, use of credit cards, use of phone and social media, etc.).

Postmortem Cooling (Algor Mortis)

Postmortem body temperature declines progressively until it reaches ambient temperature. Under average conditions, the body cools at a rate of 2.0°F to 2.5°F per hour during the first few hours and slower thereafter, with an average loss of 1.5°F to 2°F during the first twelve hours and 1°F for the next twelve to eighteen hours. The final slowing of the rate of cooling is attributed to the reduced gradient between body temperature and ambient temperature. Careful studies under controlled conditions have shown that the decrease in the postmortem body temperature is not rectilinear but sigmoid in shape with a *plateau* at the beginning and at the end of the cooling process.[7]

The initial plateau, which rarely lasts more than three to four hours, is generally explained on the basis of heat generated by the residual metabolic process of dying tissues and by the metabolic

activity of intestinal bacteria. A study by Hutchins[8] reports elevations of the temperature, rather than a plateau, within the first hours following death, with a return to base line within four hours. Whereas the average postmortem temperature increment in Hutchins' series is minimal, it is significant that during the first few hours following death, the temperature did not decline, as would have been expected under the above rule of thumb. It is also significant that all of Hutchins' cases were patients in a hospital setting who had died from natural causes with a possibility of an acute occult infection in progress. (*Comment:* Also to be considered is the temperature regulation stops with death and the patient is then exposed and takes on the temperature of the environment in the bed.)

The skin, as the closest organ to the environmental air, cools quite rapidly and is not useful for sequential temperature measurements. Temperature changes of the *core* are preferred, because the decline is slower and more regular.[9] Many sites have been tried for taking body temperatures. The most convenient and commonly used procedure involves hourly measurements of the deep rectal temperature (8" depth). Some prefer the liver as a more representative site of *core* temperature

The postmortem rate of cooling may be used for estimating the time interval since death. As a matter of fact, literature surveys indicate that more than 150 years ago, postmortem cooling was used for this purpose in medicolegal cases. Since then, numerous studies by forensic scientists have attempted to refine the use of the cooling rate as a reliable postmortem clock. A thorough historical review of various methods of estimating the time of death from body temperature by Bernard Knight[10] concluded that *in spite of the extensive application of physical theory and a great deal of direct experimentation, the level of accuracy remains low, even in the artificial venue of a controlled experiment.* This does not mean that measurements of postmortem temperatures are worthless in determining the postmortem interval, but that the data should be cautiously interpreted in view of variables affecting postmortem cooling (Table I-1).

TABLE I-1
BODY COOLING:
IMPORTANT FACTORS

Clothing
State of nutrition
Environmental temperature and wind
Relative humidity
Contact of body with hot and cold objects
Temperature of body at death

Postmortem cooling of the human body at the skin surface (loss of heat to the environment) takes place by three major mechanisms:

1. ***Conduction:*** transfer of heat by direct contact to another object.
2. ***Radiation:*** transfer of heat to the surrounding air by infrared rays.
3. ***Convection:*** transfer of heat through moving air currents adjacent to the body.

Internal organs cool primarily by conduction. It follows that factors which affect these mechanisms are bound to affect the rate of cooling as well.

For example, body insulators such as clothing and increased body fat will decrease the rate of heat loss, therefore decreasing the rate of cooling. Active air currents increase heat loss by convection, which accelerates the rate of cooling. Similarly, immersion in cold water will increase the heat loss by conduction and accelerate the rate of cooling.

The rate of body cooling in water, such as in a warm swimming pool at air temperature, may be double the temperature lost on dry land. Under these circumstances, it would be possible to estimate the time since death in a body recovered from a pool.

A larger body surface ratio to body mass, such as in children, will increase relative heat loss and therefore increase the rate of cooling. Furthermore, the rate of cooling is dependent on the temperature gradient between the body and the environment. Its calculation assumes that the environment is cooler than the body temperature; the higher the gradient, the faster the loss of heat.

However, if the environment is warmer than the body temperature, the postmortem body temperature will be increased. In calculating back to the time of death, one should not necessarily

assume that the body temperature at the time of death was normal (36.5°C to 37°C, or 98.6°F). People may die with hyperthermia at much higher than normal body temperature because of a variety of conditions, including sepsis, hyperthyroidism, physical exercise, heat stroke, seizures, or drugs (cocaine, amphetamines, anticholinergic drugs, phencyclidine, synthetic stimulants). Head injury, with damage of the hypothalamic area of the brain, may cause a terminal body temperature of 105°F or higher. Obviously, postmortem cooling would be significantly affected in such cases. On the other hand, individuals may die in a state of hypothermia caused by shock, environmental exposure or drugs (alcohol, sedative hypnotics, opiates, phenothiazine).

Early Postmortem Ocular Changes

The eyes often exhibit some of the earliest postmortem changes. An immediate sign of death in the fundi of the eyes is the arrest of capillary circulation, with settling of red blood cells in a *rouleaux* or *boxcar* pattern.

When the eyes remain open, a thin film may be observed within minutes on the corneal surface, and within two to three hours, corneal cloudiness sets in. If the eyes are closed, the appearance of the corneal film may be delayed by hours and that of corneal cloudiness by 24 hours or longer.

If the eyes are partly open in a dry environment, the exposed areas between the lids may develop a blackish brown discoloration known as *tache noire* (black spot) (Fig. I-1). This phenomenon has been mistakenly interpreted as bruising. Denting of the cornea and absence of intraocular fluid suggest a time of death of several days.

Postmortem changes of the pupils consist of dilatation of the pupils and central positioning, resulting from relaxation of the iris muscle. The iris muscle, like all muscles in the body, abides by the rules governing rigor mortis.

In life, constricted pupils occur as a result of certain drugs, such as heroin and morphine, and differences in the size of the pupils may have neurological significance, such as stroke or brain tumor. However, postmortem differences in pupillary size are variable and unreliable for such determination.

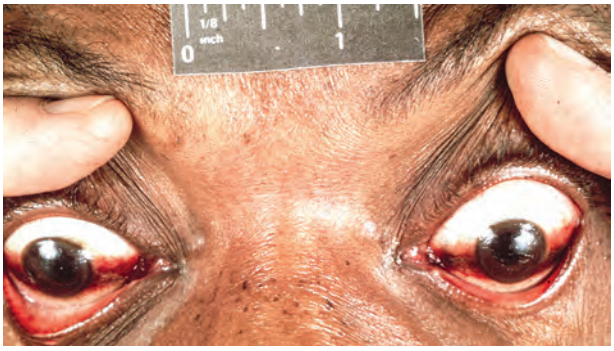

FIGURE I-1. Tâche noire is a black discoloration between the lids caused by drying. The portion of the eye covered by the lid retains moisture.

Myosis (constriction), often referred to as pinpoint pupils, may persist in some opiate deaths, while it may disappear in others. Similarly, differences in the shape of the pupil are equally variable and unreliable. Postmortem changes may affect the shape of the iris and create artefactual irregularities.

Postmortem Lividity (Livor Mortis)

Postmortem lividity (*livor mortis*), or postmortem hypostasis, is a purplish blue discoloration due to the settling of blood by gravitational forces within dilated, toneless capillaries of the body.

Accordingly, livor is seen in the dependent areas, such as on the back if the body was in a supine position and on the face and front if the body remained prone. A body which remained hanging for several hours in an upright position will have livor mortis from the elbows to the fingertips and from the mid-abdominal level down to the toes. Within the circumscribed sites of livor, one may see pale areas where the skin was pressed against a hard surface or object preventing postmortem sedimentation (Fig. I-2). Postmortem lividity may be evident as early as 20 minutes after death or may become apparent after several hours. The development of lividity is a gradual process which progressively becomes more pronounced. However, even after a number of hours, postmortem lividity may be difficult to discern in cases of severe anemia or following extensive blood loss. In a case of a ruptured aortic

FIGURE I-2. Livor mortis. The pale area is due to pressure of the head against the floor on which he was lying. Death was due to heart disease. The abrasions on the forehead, located in protuberant areas of the underlying skull, were sustained when he collapsed.

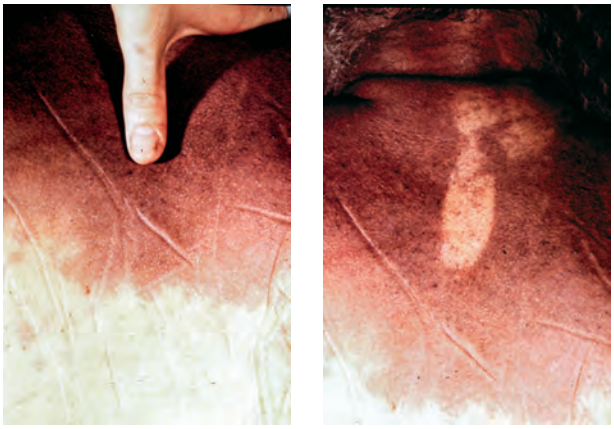

FIGURE I-3. Pressure in areas of livor causes blanching, in this case 7 hours after death.

aneurysm or aortic tear, postmortem lividity may be so faint as to be practically indiscernible. At all times, evaluation of the presence of livor mortis requires good lighting conditions; daylight is best. In individuals with dark skin pigmentation, lividity in the skin can go unnoticed. At autopsy, finding congestion of internal organs may assist in determining the presence of lividity.

In the early stages, livor can be blanched by compression (Fig. I-3) and may shift if the position of the body is changed. Livor mortis is also seen in the fingernail beds. The fingernail beds are a good location for evaluation of livor in individuals of dark complexion and for determination of whether livor is fixed or is still blanchable by application of pressure. Depending on temperature, but usually after eight to twelve hours, the blood congeals in the capillaries or diffuses into the extravascular tissues and does not usually permit blanching or displacement. In advanced stages of livor, skin capillaries in dependent areas often burst and cause pinpoint hemorrhages known as *Tardieu spots* (Figs. I-4 to I-6b).

Unusual discoloration of postmortem lividity may serve as a diagnostic clue regarding the cause of death. The pathological mechanism responsible for the abnormal discoloration is usually the presence of an abnormal hemoglobin compound (carboxyhemoglobin, methemoglobin). In some instances, cherry-red discoloration may be caused

FIGURE I-4. Multiple pinpoint hemorrhages (Tardieu spots) on the skin in a case of early decomposition.

FIGURE I-5. Tardieu spots in a case of early decomposition. Woman lying in bed her arm hanging over the side, blood settling in the skin out of the vessels, by gravity.