SKELETAL TRAUMA

IDENTIFICATION OF INJURIES RESULTING FROM HUMAN RIGHTS ABUSE AND ARMED CONFLICT

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I dedicate this book to my family, Mike, and Sean.

E.H.K.

I dedicate this book to Maite and Sofia

J.P.B.

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A Foreword by Andrew T. Cayley, Esq.

SENIOR PROSECUTING COUNSEL AT THE INTERNATIONAL CRIMINAL COURT AND FORMER SENIOR TRIAL ATTORNEY OF THE INTERNATIONAL CRIMINAL TRIBUNAL FOR THE FORMER YUGOSLAVIA

On a warm September evening in 1999, in northeast Bosnia-Herzegovina, we were visiting the most recently discovered mass grave linked to the events in Srebrenica of July 1995. We were at Glogovac. José Pablo Baraybar was stripped to the waist and working in the excavated site. We watched him as he gently recovered the mortal remains of one of the thousands of victims of the genocide that had taken place in and around Srebrenica 4 years before. From these human remains and the other items found in the mass graves evidence would be recovered that became incontrovertible at the subsequent trial.

We led a substantial part of the forensic evidence at the trial of General Krstic, who was charged with crimes in and around Srebrenica in July 1995. The revelations of the human remains from Srebrenica left us all with a profound sense of shock and horror but also the satisfaction that nobody could deny that these catastrophic events had really taken place. Victims had been shot in the back of the head, victims had disabling injuries at the time of death, and bodies had been robbed from the primary sites and reburied in much more remote secondary locations in order to prevent discovery. Truth and condemnation poured forth from the Bosnian soil and into the trial chamber.

As the Krstic trial judgment made clear, "The extensive forensic evidence presented by the Prosecution strongly corroborates important aspects of the testimony of survivors from the various execution sites …. Overall, the Trial Chamber finds that the forensic evidence presented by the Prosecution provides corroboration of survivor testimony that, following the take-over of Srebrenica in July 1995, thousands of Bosnian Muslim men from Srebrenica were killed in careful and methodical mass executions."

As this timely book demonstrates, skeletal remains reveal not just the causes of death but also much about human suffering prior to death. The book is based on forensic analysis carried out in the former Yugoslavia, South America, and Cambodia. It is written by two experts in the field. Its future use by forensic practitioners, and prosecution and defense lawyers, will ensure the maximum exploitation of human remains for the purposes of proof in both domestic and international criminal prosecutions.

> We owe respect to the living, to the dead we owe only the truth.
>
> **Francois Marie Arouet Voltaire**

A Foreword by Morris Tidball-Binz, M.D.

FORENSIC COORDINATOR

INTERNATIONAL COMMITTEE OF THE RED CROSS,
GENEVA, SWITZERLAND

Just three decades ago, the suggestion of a causal link between the forensic identification of skeletal trauma and human rights advocacy and humanitarian action would have triggered a compassionate sneer from most forensic practitioners, human rights activists, and humanitarian workers alike. Not any longer: the need for proper interpretation of skeletal trauma in investigations into atrocities and disappearances is nowadays an obvious fact for all those concerned. Since the mid-eighties, a bulk of experience and knowledge has been acquired and a series of innovative human rights and forensic standards have been developed by practitioners worldwide to assist and guide investigations of extra-judicial killings, mass graves, and torture. These include, for example, the *UN Manual on the Effective Prevention and Investigation of Extra-legal, Arbitrary and Summary Executions* ("Minnesota Protocol") and the *UN Manual on the Effective Investigation and Documentation of Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment* ("Istanbul Protocol"). The United Nations has also adopted resolutions on human rights and forensic sciences and has prepared a standing list of forensic practitioners from around the world available for human rights investigations. Scientific literature increasingly includes articles on the forensic documentation of human rights violations. As a result of such remarkable developments—which the second author and some of the contributors of this book helped pioneer—forensic scientists are increasingly called on the world over to help investigations into war crimes, crimes against humanity, and genocide. Additionally, the use of forensic sciences in helping clarify the fate of the missing, including the identification of the living and of the dead, has also evolved remarkably over the past twenty years.

Nevertheless, in parallel to these developments, a false dichotomy has emerged regarding the purpose of using forensic sciences, including the analysis of trauma, for human rights and humanitarian investigations: On one hand, the need to document trauma, including torture, and establish the cause, manner and circumstances of death of victims, for ensuring the accountability of perpetrators (human rights' purpose); and on the other, the forensic identification of victims of abuse, to fulfill the needs of bereaved families (humanitarian purpose). In effect, some large-scale forensic investigations into mass graves carried out during the nineties to prosecute the perpetrators of massacres overlooked the need to identify the remains of victims, something which compounded the suffering of bereaved families and led to understandable criticism from concerned stakeholders. Much debate

followed about the role and duties of forensic practitioners involved in human rights and humanitarian investigations, to help ensure that the identification of victims also be part of their investigations into massacres, genocide, and other crimes against humanity. In 2003, the International Committee of the Red Cross (ICRC) organized an international conference on The Missing, which stressed the need and importance of proper recovery and identification of human remains to help fulfill the right to know for bereaved families. Recommendations from that conference on the use of forensic sciences focus on the proper recovery, management and identification of human remains, with the understanding that this is as important as establishing the cause, manner, and circumstances of death of the deceased.

The analysis of trauma is essential for both purposes. In effect, the diagnosis of pre-mortem, peri-mortem and, on occasions, even post-mortem trauma in human remains is often central to their identification. The debate and dichotomy on the purpose of forensic investigations into violations of human rights and Humanitarian Law is now over. But forensic scientists involved in human rights and humanitarian investigations still face the difficult challenge of identifying complex patterns of trauma, often in human skeletal remains and on a scale rarely encountered in domestic criminal investigations, to help establish their identity and how they died.

Forensic practitioners and other concerned investigators of gross violations of human rights and Humanitarian Law are therefore in greater need than ever of sound guidance for interpreting evidence from skeletal trauma suffered by the victims of such violations. The publication of this book, which is borne from solid research and extensive practice in the field, is as timely as it is necessary. It is set to become a guiding tool for forensic scientists, human rights activists, and humanitarian workers committed to giving a truthful voice to the dead.

Preface

The creation of the International Tribunal for the Prosecution of Persons Responsible for Serious Violations of International Humanitarian Law Committed in the Territory of the Former Yugoslavia since 1991 (ICTY) resulted in multinational, multidisciplinary forensic investigations that recovered, analyzed, and presented a range of physical evidence on cases involving thousands of individual victims. In the course of these investigations, search and recovery methods evolved to meet the particular circumstances of each new case. Likewise, mortuary analysis of physical evidence and the postmortem examinations of human remains grew into a sophisticated system capable of processing thousands of individual cases in a single field season. The forensic protocols and case law that have resulted from the ICTY have set a precedence for future investigations into international humanitarian and human rights law.

Crucial evidence for the successful prosecution of alleged war criminals includes the determination of the cause and manner of death among victims. Interpreting the circumstances surrounding a death begins with a reconstruction the person's injuries, as this evidence provides information as to crimes committed and establishes a record of what events occurred. Recovering skeletal remains and other evidence, such as bullet fragments or shrapnel from a grave, correctly and efficiently using clothing and radiography to aid in the recovery process, and analysis of complex skeletal injuries all lead to the correct identification of skeletal trauma.

Many victims of human rights atrocities and armed conflicts suffer multiple injuries, including high velocity gunfire and blasting injuries. It is not uncommon for victims to have suffered multiple gunfire injuries throughout the body from a variety of trajectories resulting from multiple attackers or complex fatal environments. In addition, extreme efforts have been made by the perpetrators of violence in some cases to hide evidence. Deceased bodies are blown up, burned, thrown off bridges or cliffs, altered in cursory attempts to hide the truth, buried in clandestine graves and sometimes re-interred multiple times to hide their locations. Each of these processes leaves its mark on the skeleton. Sorting through injuries, taphonomic alterations, and postmortem fractures for each victim is a routine part of the postmortem examination and paramount for accurately diagnosing the mechanism of injury.

Increasingly, the use of emerging judicial systems such as international tribunals and domestic truth commissions sets the stage for future forensic investigation in the pursuit of documenting, analyzing, and prosecuting these cases. This book is written to aid in the process of skeletal trauma identification in the context of large-scale human rights violations or armed conflict. It is our objective that this book will facilitate an understanding of mechanisms of injuries interpreted from skeletal remains, provide a synthesis of the variation in wounding patterns, and construct an epidemiological framework for interpreting physical evidence for use at trial.

The examples used throughout this text are taken from human rights violations, ethnic and armed conflict, extrajudicial executions, and acts of terrorism from numerous regions throughout the Americas, Europe, and Asia. Evidence is interpreted through an epidemiological model and set in a legal framework. Methods of differential diagnosis are used to describe and analyze wound characteristics to classify skeletal trauma and interpret the mechanisms of injury. It should be noted that the cases presented here were immediately fatal or without medical intervention. Therefore, the similarities or differences as compared to the large body of clinical literature and medical research, particularly related to war surgery may vary. The examples from the Balkans and many of the other examples discussed in this book have already been presented as evidence in criminal trials, such as those held by ICTY. In numerous examples, physical evidence of injuries and maltreatment, the mechanisms of trauma, and the manners of death are corroborated by witness testimony or other physical evidence and are discussed. Twenty-six leading scholars and practitioners from anthropology, pathology, and forensics have contributed their research, cases, and photographs comprising 16 contributed case studies throughout the book. There is a wide international spectrum of contributors, many of whom have extensive fieldwork investigating human rights cases internationally such as the armed conflicts in Guatemala, Peru, Sri Lanka, Panama, Cambodia, Rwanda, Haiti, and the Balkans.

Chapter 1 discusses contextual information about international forensic investigations and criminal proceedings into violations of international humanitarian law through international tribunals and other emerging judicial systems, and outlines an epidemiological framework for collecting and analyzing physical evidence. Chapter 2 discusses methodology for differential diagnosis of wounds during postmortem analysis and protocols for systematic data collection. The specific mechanisms of injuries, associated weaponry, and legal framework are discussed in the following chapters 3–8, organized topically: Blasting Injuries, Blunt Force Trauma, Skeletal Evidence of Torture, Sharp Force Trauma, and Gunfire Injuries. Within each chapter, there is a discussion of the wounding mechanisms, the pathophysiology of wounds, relevant legal examples for the type of evidence presented, and contributed case studies from leading experts in medicine, anthropology, and ballistics.

Readers will benefit from this book by using it in the course of postmortem analysis as well as for teaching the next generation of investigators. The practical applications of this resource extend beyond international forensic investigations and are relevant for general forensic casework, medicolegal death investigations, mass disaster incidents, skeletal biology, bioarchaeology, and emergency war surgery. This book is intended to share our research, cases, and experience working with the skeletal remains of victims of war and terror, of extrajudicial execution, and enforced disappearances. *In these cases, the most basic human right was denied—life!*

Erin H. Kimmerle and José Pablo Baraybar

Acknowledgments

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We are sincerely thankful to our colleagues who shared their cases, research, photographs, and experience through contributed case studies—these contributions are invaluable to this project. We thank team members of the Peruvian Forensic Anthropology Team (EPAF), the Guatemalan Forensic Anthropology Foundation (FAFG), Fredy Armando Peccerelli, Claudia Rivera, and countless former International ICTY Forensic Team Members, anthropologists, pathologists, radiographers, autopsy technicians, scene of crime officers—all of the enthusiastic people that applied their skills and knowledge to a noble cause. We thank Dr. Lisa Leppo for her service and contributions to the cases. We thank Elayne Pope for sharing her research and photographs on burned bone. We also thank Carlos Jacinto, Juan Carlos Tello, Jorge M. Pachón, Max Popenker, Dr. Matthias Okoye, Dr. David Kiple and Jane Beck for contributing photographs. Special thanks to Alain Wittmann who contributed so many of the photographs.

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Finally, José Pablo Baraybar would like to thank his former staff at the Office on Missing Persons and Forensics (OMPF), in particular all forensic doctors, anthropologists, archaeologists, forensic scientists, laboratory technicians and assistants with whom he carried out so many autopsies including those too many to name here: Dr. Marek Gasior, Dr. Ananda Samaresekera, Dr. Maria Dolores Morcillo, Dr. Arsim Gerxhaliu, Dr. Asoka Seneviratne, Dr. Prijanith Perera, Dr. John Clark, Dr. Duarte Nuno Vieira, Dr. Maria Cristina de Mendonca, Dr. Joao Pinheiro, Dr. Annie Geraut, Dr. Maryelle Kolopp,

Dr. Carlo Campobasso, Dr. Bernhard Olbert, Peter Hoff-Olsen, Hans Petter Hougen, Thierry Marin, George Szilagyi, Patrick Reynolds, Rosmarie Hardmeier, Tom Grange, Hroar Frydenlund, Tania Delabarde, Oran Finegan, Ximena Novoa, Israel Hershkovitz, Edixon Quinones, Jennifer Randolph, Shuala Drawdy (Martin), Dr. Steve Symes, Carmen Rosa Cardoza, Juan Carlos Tello, Claudia Rivera, Catherine Cannet, Luc Tetrault, Susan Salazar, Klaire Kasibayo, Driton Spahiu ("Tony"), Izedin Durguti ("Dino"), Armend Haxhimustafa, Driton Shabani.

We believe that first and foremost this book belongs to the victims, their families and all survivors—from whom we learn the truth in the pursuit of justice.

Authors

Erin H. Kimmerle is an Assistant Professor in the Department of Anthropology at the University of South Florida (Tampa, Florida USA). She received her degrees in Anthropology from The University of Tennessee (Ph.D.), the University of Nebraska (M.A.), and Hamline University (B.A.). She served as Chief Forensic Anthropologist for the United Nations, International Criminal Tribunal for the Former Yugoslavia in 2001 and has worked on numerous missions in Kosova, Bosnia and Herzegovina, Bermuda, and Croatia. Dr. Kimmerle also worked as an osteologist for the National Museum of Natural History, Smithsonian Institution, in Washington, D.C., and the Osteology Laboratory at Hamline University in St. Paul, Minnesota. She continues to serve as a consultant for casework and law enforcement training in the United States and Internationally. Dr. Kimmerle has conducted extensive research in the areas of trauma, pathology, growth and development, and aging. She has published numerous scientific journal articles and book chapters and serves on the Advisory Board of the Nebraska Institute of Forensic Science, Inc.; the Executive Board of the Human Development Center, Tampa, FL; Adjunct Senior Lecturer, College of Medicine, Lagos State University, Nigeria; and is a member of the Florida Emergency Mortuary Operations Response System (FEMORS).

José Pablo Baraybar is President of the Peruvian Forensic Anthropology Team (EPAF). He obtained a M.Sc. at the University of London; a B.A. in archaeology at the University of San Marcos in Lima, Peru; and is currently a doctoral candidate at the University of Strasbourg, France. From the beginning of his career Mr. Baraybar worked on the recovery and analysis of human remains in archaeological contexts. He later applied his professional background to the forensic investigation of human rights abuses working as a consultant in forensic anthropology in various countries including: Peru, Guatemala, Ethiopia, Congo and Sierra Leone. He joined the United Nations in 1995 working for the International Civilian Mission to Haiti (MICIVIH), after which he joined the International Criminal Tribunal in Rwanda and later that for the former Yugoslavia. He has worked as resident forensic expert for the Office of the Prosecutor of the International Criminal Tribunal for Rwanda and Chief forensic anthropologist/archaeologist for the Office of the Prosecutor of the International Criminal Tribunal for the former Yugoslavia in Bosnia-Herzegovina, Croatia and Kosovo testifying and submitting expert reports in multiple cases. In June 2002 he was appointed Head of the Office on Missing Persons and Forensics (OMPF) in the Department of Justice of the United Nations Interim Administration in Kosovo, post he held until April 2007; in November 2006 OMPF was awarded the UN-21 Award.

Contributor Biographies

Gregory E. Berg earned his B.A. in anthropology from the University of Arizona in 1993 and his M.A. from the bioarchaeology program from Arizona State University in 1999. He is completing a Ph.D. at the University of Tennessee. He is currently a forensic anthropologist at the JPAC-Central Identification Laboratory in Hawaii where he works on the recovery and identification of missing U.S. service personnel. He has over fifteen years of field experience in archaeology and physical anthropology and has presented or published numerous articles and papers in the Journal of Forensic Sciences, Journal of Archaeological Science, and at various annual meetings. His recent research has concentrated on trauma analysis, aging techniques, human identification and eyewear, and intra- and inter-observer error studies, which have been particularly focused on aging and population determination methods used in human identification.

Shirley Chacón, studied Archaeology in Universidad San Carlos de Guatemala, she joined the Guatemalan Forensic Anthropology Foundation in 1997. She has led many Forensic Anthropology Investigations. She has also worked as an expert in Bosnia & Herzegovina and Honduras. Currently holds the position of Coordinator of the FAFG Osteology Laboratory.

Tania Delabarde, Ph.D., is a physical anthropologist with a subspecialty in bioarchaeology. She graduated from the University of Talence and Paris I La Sorbonne, France. Dr. Delabarde worked as consultant forensic anthropologist for the International Criminal Tribunal for the former Yugoslavia (ICTY) in Bosnia in 2001 and for the Office of Missing Persons and Forensic in Kosovo between 2002 and 2006. Dr. Delabarde collaborates with the Institute of Legal Medicine of Nancy and is a consultant for the French Police International Cooperation. Her actual research focus is on experimental studies of sharp force trauma linked to dismemberment activities. She is currently affiliated with the French Institute of Andean Studies (IFEA) where she also assists the Office of The Prosecutor of Ecuador in forensic cases where she now resides.

Oran Finegan M.Sc., M.A., is currently working for the United Nations Committee on Missing Persons in Cyprus under contract with the Argentine Forensic Anthropology Team (EAAF). Mr. Finegan earned his B.Sc. in Anatomy at Queen's University Belfast (1994–1997), a M.Sc. in Forensic Anthropology in the University of Bradford, England (1997–1998) and an M.A. in Theory and Practice of Human Rights in the University of Essex (2003–2004). Mr. Finegan has worked as a consultant forensic anthropologist for the International Criminal Tribunal for the former Yugoslavia in Bosnia, Croatia and Kosovo (1998, 2000, 2001) and for the Office on Missing Persons and Forensics (OMPF) in Kosovo (2002–2003, 2004–2006).

Kathryn Haden-Pinneri earned her M.D. degree from the University of Texas Southwestern Medical School at Dallas in 1997. She completed a residency in Anatomic and Clinical Pathology at the University of Tennessee Medical Center at Knoxville in 2002 and a fellowship in Forensic Pathology at the Dallas County Medical Examiner's Office in 2003. She is currently an Assistant Medical Examiner at the Harris County Medical Examiner's Office in Houston, Texas where she performs autopsies and medicolegal death investigations. She is also a member of the Disaster Mortuary Operational Response Team (DMORT). She is board certified in Anatomic and Forensic Pathology and is a member of the American Academy of Forensic Sciences and the National Association of Medical Examiners.

Professor Hans Petter Hougen earned his M.D. and Ph.D. from the University of Copenhagen as well as an MPA from the Copenhagen Business School. Dr. Hougen carried out post-Doctoral training in Forensic Pathology in the United States. Dr. Hougen is currently Professor of Forensic Medicine at the University of Copenhagen and Chief Forensic Pathologist for East Denmark. Dr. Hougen's areas of expertise and interest are sudden cardiac death, the epidemiology of suicides and homicides, the forensic aspects of Human Rights violations and the Pathology of gunshot and explosion injuries.

Mellisa Lund is a member of the Peruvian Forensic Anthropology Team (EPAF). She earned her B.A. in Archaeology at the University of San Marcos in Lima and is currently working on a Masters degree in Forensic Anthropology and Bioarchaeology at the Catholic University in Lima (PUCP). Ms. Lund has a long experience in the analysis of human remains both from archaeological and forensic contexts and has worked as forensic anthropology consultant for the International Criminal Tribunal for the former Yugoslavia (ICTY) in Bosnia, Croatia and Kosovo in 2001 and 2003.

Professor Bertrand Ludes, **M.D., Ph.D.,** teaches legal medicine at the Louis Pasteur University of Strasbourg (France) medical school. Professor Ludes holds a specialization in forensic pathology and DNA identification namely in disaster victim identifications. He is the director of the Institute of Legal Medicine of Strasbourg (France). Professor Ludes participated as consultant pathologist for the International Criminal Tribunal for the former Yugoslavia in Bosnia.

Professor George Maat earned his M.D. and Ph.D. at the University of Leiden, Holland in 1973 and 1974 respectively. Dr. Maat taught at Surinam University (1974–1976), Leiden University (1977–1986), Kuwait University (1986–1990), Utrecht University (1991–1993) and again at Leiden University Medical Center since 1993. In addition to teaching human anatomy, embryology and histology he teaches physical anthropology since 1977 and forensic anthropology since 2004 at the Forensic Human Identification Course at the University College London. Dr. Maat's fields of research are paleopathology and forensic anthropology. He currently is co-editor of the International Journal of Osteoarchaeology. He is affiliated with the Netherlands Forensic Institute at The Hague and is Honorary Professor at the University of Pretoria. As permanent member of the Dutch Disaster Identification Team and as a temporary member of the British Forensic Team, he has been deployed in Kosovo (ICTY; 1999, 2000, 2003), Enschede (fireworks disaster; 2000), Thailand (tsunami; 2004–2005) and in Afghanistan (military helicopter crash; 2006).

Jorge M. Pachón, B.A., is a Criminalist (Administrative Department of Security (Departamento Administrativo de Seguridad-DAS) and Professional Technician in Forensic Ballistics (Judicial School of Technical Police) in Colombia. Mr. Pachón has 17 years experience working at the National Institute of Legal Medicine and Forensic Sciences in Bogota. His area of expertise during the last ten years is the examination of projectile injuries and blunt force trauma in cadavers as well as skeletal remains. Mr. Pachón has been trained in Administration and Operations of the Integrated Ballistic Identification System (IBIS) for the DAS and DAS stations in Colombia. He also worked as a Scene of Crime Officer in Kosovo for the International Criminal Tribunal for the former Yugoslavia and in 2003 for the Office on Missing Persons and Forensics.

Leonel Paiz Diez, B.A., has worked in mass grave investigations since 1997, as an Archeologist, Forensic Anthropologist, and Coordinator of the Laboratory. Currently he is the Director of Forensic Archaeology Direction of the Guatemalan Forensic Anthropology Foundation (FAFG). He has performed as an advisor for the Guatemalan Truth Commission, instructor for the Chief Examiner's Office in Honduras and Prosecutors in Perú, as an expert consultant in forensic investigations in Bosnia & Herzegovina, Croatia and Kosovo for ICTY. He has participated in lectures for the American Association of Forensic Sciences. He is also a founder and member of the Latin American Association of Forensic Anthropology.

Vanessa Parodi, B.Sc., joined the Peruvian Forensic Anthropology Team (EPAF) in 2005. She earned her B.Sc. in Psychology and Physical Anthropology at the University of Toronto, Canada, and has worked for almost 10 years in the analysis of human remains of different archaeological and historical sites. She worked as consultant forensic anthropologist in Kosovo for the Office on Missing Persons and Forensics in 2005.

Carmen Rosa Cardoza, B.A., is a founding member of the Peruvian Forensic Anthropology Team (EPAF). She earned her B.A. in Archaeology at the University of San Marcos in Lima, Peru and is currently working on a Master in Forensic Anthropology and Forensic Genetics at the University of Granada, Spain. For the last 10 years Ms. Cardoza has participated as consultant forensic anthropologist for the International Criminal Tribunal for the former Yugoslavia (ICTY) in Bosnia, Croatia and Kosovo between 1997 and 2000 and for the Office on Missing Persons and Forensics (OMPF) in Kosovo between 2004 and 2005. Ms. Cardoza has also participated as expert in a number of cases or the Office of the Prosecutor, the Judiciary or the Defense in Peru.

Fredy Armando Peccerelli, B.A., began his career in forensics when he joined the Guatemalan Forensic Anthropology Team in 1995; later in 1997 he became a founding member of the Guatemalan Forensic Anthropology Foundation. He studied Physical Anthropology and Osteology in Brooklyn College, New York City University and from 2003 to 2004 he studied an MSc in Forensic & Biological Anthropology in Bournemouth University, England. During 1997, 1998 and 2001 he participated in forensic investigations conducted by the United Nations International Tribunal for the Prosecution of Persons Responsible for Serious Violations of the International Humanitarian Law Committed in the territory of the former Yugoslavia, since 1991. On May 1999, he was selected by Time Magazine and

CNN as one of the 50 Latin American Leaders for the New Millennium and on September 1999, he was selected by the Guatemalan National Youth Council as an icon for the youth of Guatemala. On May 2006 he received the Washington Office of Latin America's (WOLA) Human Rights Award. Currently Mr. Peccerelli is the Executive Director of the Guatemalan Forensic Anthropology Foundation.

Jean-Sébastien Raul, M.D., Ph.D., is an Associate Professor of Legal Medicine in Strasbourg University. He is a neurosurgeon, forensic scientist, and medical expert in legal medicine and toxicology. His research includes developing the use of finite element models in forensic sciences with a special focus on adult and child head injury with Remy Willinger's team working on Impact Biomechanics at University Louis Pasteur in Strasbourg, France.

Claudia Rivera, B.A., is an Archeologist graduated from Universidad San Carlos de Guatemala. She worked in Mayan traditional archaeology, and in 1997 she started working for the Guatemalan Forensic Anthropology Foundation (FAFG) finding human remains from Guatemalan citizens that were killed during the Internal Armed Conflict. Since then she has participated in international missions in Bosnia & Herzegovina and Kosovo. Currently she holds the position of Director of Operations at the FAFG.

Ann H. Ross, Ph.D., is an Associate Professor of Anthropology at NC State University. She is a physical anthropologist with a subspecialty in forensic anthropology and bioarchaeology. She received her education from the University of Tennessee. Her research focus includes developing population specific identification standards using traditional measurement techniques and modern three-dimensional methods. Dr. Ross has participated in Human Rights missions in Bosnia, the Republic of Panama and Chile. She also consults on a regular basis for the Republic of Panama Institute of Legal Medicine and occasionally consults on local cases in North Carolina.

Ananda Samarasekera, M.D., M.B.B.S., D.L.M., D.M.J. (London), Dip. F. M. (Glasgow). Dr. Samarasekera is Chief Forensic Medical Examiner in the Office on Missing Persons and Forensics (OMPF), Department of Justice, United Nations Mission in Kosovo (UNMIK) since 2004. Dr. Samarasekera received his Medical Degrees as well as a Diploma in Legal Medicine in Sri Lanka and a Diploma in Medical Jurisprudence and one in Forensic Medicine in the United Kingdom (London and Glasgow respectively). Dr. Samarasekera was Chief Judicial Medical Officer in Colombo North, Sri Lanka (1991–2004). Dr. Samarasekera worked as consultant pathologist for the International Criminal Tribunal for the former Yugoslavia between 1999 and 2001 and is currently President of the College of Forensic Pathologists of Sri Lanka and treasurer of the Indo Pacific Association of Law, Medicine and Sciences. During his tenure in Sri Lanka Dr. Samarasekera has been involved with many forensic investigations of many bomb explosions.

Asoka B. Seneviratne, **M.D., M.B.B.S. and D.L.M. (Sri Lanka), D.M.J. (Pathology, London)** is Consultant Judicial Medical Officer in the General (Teaching) Hospital in Kandy, Sri Lanka. Dr. Seneviratne received his Medical Degrees as well as a Diploma in Legal Medicine in Sri Lanka and a Diploma in Medical Jurisprudence in Pathology in London, UK. Dr. Seneviratne worked as a consultant pathologist for the International Criminal Tribunal for the former Yugoslavia (ICTY) in Bosnia and for the Office on Missing Persons and Forensics

(OMPF) in Kosovo. Dr. Seneviratne is member of the Board of Studies in Forensic Medicine and examiner, Post-graduate Institute of Medicine, University of Colombo, Founder member of College of Forensic Pathologists of Sri Lanka and Life member, Medico-Legal Society of Sri Lanka and of the Kandy Society of Forensic Medicine.

Clyde Collins Snow, Ph.D., D.A.B.F.A., is a board certified forensic anthropology consultant. His notable cases include the John Wayne Gacy serial murders, the 273-victim DC10 accident (Chicago 1979), the identification of the notorious Nazi war criminal Dr. Josef Mengele and the 1995 Oklahoma City bombing. Beginning in 1984, he extended his investigative efforts to the identification of victims of human rights violations and war crimes. Since then, he has participated in investigative missions in over twenty countries, ranging from Argentina to Zimbabwe. He has testified as an expert witness in many U.S. states, foreign countries and international tribunals. In 2006, he gave expert testimony in Baghdad at the trial of Saddam Hussein and his co-defendents for their genocidal campaign against the Kurds. His testimony was based on evidence of mass executions and chemical warfare from mass graves he and his team exhumed in Iraqi Kurdistan in 1992. However, his proudest achievement has been in helping recruit and train the forensic anthropology teams of Argentina (EAAF), Guatemala (FAFG) and Peru (EPAF) who are recognized throughout the world as the pioneers in the application of the forensic sciences to the investigation of human rights violations.

Herbert F. Spirer, Ph.D., is Adjunct Professor of International Affairs, Columbia University, New York, a Professor Emeritus of Information Management at the University of Connecticut at Stamford, as well as a consultant on statistical science for numerous corporations and organizations. He received his Ph.D. from the University of Columbia in 1970. He has been a statistical science consultant for the UN's International Tribunals on the Former Yugoslavia and Rwanda (1994–1997), and Chair of the American Statistical Association Committee on Scientific Freedom and Human Rights (1990–1993). He is further a Fellow of the American Statistical Association (1996), and elected member of the International Statistical Association (2000) in recognition of achievements in applying statistics to human rights.

Loreto Suarez S., B.A., received her training in archaeology at the Universidad de Chile and served as Director of Anthropology for the Panamanian Truth Commission.

Sabrina C. Ta'ala, B.A., earned her B.A. in Anthropology from the University of Colorado at Boulder, and M.A. in Anthropology from East Carolina University. She is currently a forensic anthropologist working to recover and identify missing U.S. service members with the Joint POW/MIA Accounting Command, Central Identification Laboratory (JPAC-CIL) in Hawaii. Ms. Ta'ala has excavated a variety of historic and prehistoric archaeological sites throughout the world. Recent research has focused on geophysical techniques for detection of clandestine graves, trauma analysis, determination of ancestry from skeletal remains, and the use of eye wear to predict identity. Her work has been published in the *Journal of Forensic Sciences* and presented at regional and national archaeological and forensic meetings.

Elsa Tomasto Cagigao, Lic., is Lecturer of Physical Anthropology at the Pontificia Universidad Catolica del Peru (PUCP) and former Curator of Human Remains at the National Museum

of Archaeology, Anthropology and History of Perú. She earned her B.A. in archaeology at the PUCP where she is currently working on a Masters degree in Forensic Anthropology and Bioarchaeology. Ms. Tomasto has a long experience in the analysis of human remains from archaeological contexts and has worked in multiple projects on the subject. Ms. Tomasto also worked with the Truth and Reconciliation Commission in Peru.

Sgt. C. J. Waters is a retired police sergeant who is currently the Forensic Investigation Unit Supervisor in the Criminal Investigation Division, Tampa Police Department. Sgt. Waters has more than 40 years of experience in law enforcement with special emphasis on crime scene investigation and ballistics. He obtained his B.A. at the University of Tampa where he studied History, Criminology, and Political Science. He formerly worked for the United States Army Security Agency and holds a teaching license in Police Science. He is also on the Board of Directors for the Human Development Center and is active in other community NGOs.

Professor Rémy Willinger, **Ph.D.**, has managed a research team since 1972 working on Impact Biomechanics at University Louis Pasteur, Strasbourg, France. His background is mechanical engineering applied to biomechanics. The activity ranges from biological tissues identification and modelling to human body characterization followed by lumped and distributed mathematical modelling. Once validated the numerical and physical models are used for theoretical and experimental accident reconstruction in order to derive tolerance limits relative to specific injury mechanisms. Human models are also coupled to protective systems in order to optimise them in respect to biomechanical criteria. Most of his work addressed the cranio-cerebral and cervical complex. Main result of this research is the development of an improved head finite element model and the proposal of new tolerance limits to specific head injury mechanisms.

Abbreviations

AAAS	American Association for the Advancement of Science
AIS	Abbreviated injury scale
BFT	Blunt force trauma
BiH	Bosnia-Herzegovina
CCIU	Central Investigation Unit
CEH	Guatemalan Historical Clarification Commission
CSF	Cerebro-spinal fluid
CTS	Cracked tooth syndrome
CWF	Conventional warfare
EAAF	Argentine Forensic Anthropology Team
EOD	Explosive ordinance device
EQUITAS	Colombian Interdisciplinary Team on Forensic Work and Psychosocial Services
EPAF	Peruvian Forensic Anthropology Team
FAFG	Guatemalan Forensic Anthropology Foundation
FEM	Finite element modeling
FMJ	Full metal jacket
FRY	Federal Republic of Yugoslavia
FW	Fatal wounds
GAMBIT	General acceleration model for brain injury threshold
GSW	Gunshot wounds
HE	High order
HHRR	Human rights
HIC	Head injury criterion
ICC	International Criminal Court
ICTJ	International Center for Transitional Justice
ICTR	International Criminal Tribunal for Rwanda

ICTY	International Tribunal for the Prosecution of Persons Responsible for Serious Violations of International Humanitarian Law Committed in the Territory of the Former Yugoslavia since 1991 (also referred to the International Criminal Tribunal for the Former Yugoslavia)
ICRC	International Committee of the Red Cross
ID	Identification
IED	Impoverished ordinance device
IHL	International Humanitarian Law
IHRL	International Human Rights Law
ITF	Incomplete tooth fracture
JNA	Yugoslav National Army
KLA	Kosovo Liberation Army (UÇK, Oslobodilacka Vojska Kosova)
LE	Low order
LTTE	Liberation Tigers of Tamil Eelam
MRTA	Movimiento Revolucionario Tupac Amaru
NHTSA	National Highway Traffic Safety Administration
NRW	Non-fatal wounds
OMPF	Office of Missing Persons and Forensics
PHR	Physicians for Human Rights
PDW	Personal defense weapon
RPG	Rocket propelled grenade
RTA	Road traffic Accident
SFT	Sharp force trauma
SDH	Subdural haematoma
SIMON	Simulated injury monitor
WSU	Wayne State University
W/K	Wounded to killed ratio
ULP	Universitė Louis Pasteur
UNCHR	United Nations Committee of the Red Cross
UNMIK	United Nations Mission in Kosovo
UN	United Nations
USF	University of South Florida

An Epidemiological Approach to Forensic Investigations of Violations to International Humanitarian and Human Rights Law

1

> It was never the people who complained of the universality of human rights, nor did the people consider human rights as a Western or Northern imposition. It was often their leaders who did so.
>
> **Kofi Annan**[*]

Contents

The identification of skeletal trauma is based on the recovery of remains and physical evidence such as bullet fragments or shrapnel from a grave, correctly and efficiently using clothing and radiography to aid in the recovery process, and analysis of complex skeletal wounds. Many victims of human rights (HHRR) atrocities and armed conflict suffer multiple injuries, including high velocity gunfire and blasting trauma. Further, these cases are typically investigated years later, once bodies have decomposed and been exposed to natural elements that may also alter the physical remains. Sorting through injuries, taphonomic alterations, and postmortem fractures for each victim is a routine part of the postmortem examination and is essential to accurately diagnose the mechanism of injury that may have contributed to the death.

This book was written to aid in the process of skeletal trauma identification in the context of large-scale human rights violations, extrajudicial executions, terrorism, and armed conflict. The purpose of this book is to offer a point of reference that synthesizes the variation of wounding patterns through the use of photographs and illustrations, and an

[*] Kofi Annan was the seventh UN Secretary-General. Quote cited in Singh 2001.

analytical discussion of the pathophysiology of wounds and the biomechanics of skeletal trauma. The primary objectives are to facilitate an understanding of the mechanisms of injuries interpreted from skeletal remains, provide an overview of variation in wounding patterns, and construct an epidemiological framework for the interpretation of physical evidence for use at trial. This chapter outlines background information about international forensic investigations and criminal proceedings in violation of international humanitarian and human rights (IHL and IHRL) laws through international tribunals and provides an epidemiological framework for collecting and analyzing trauma evidence.

International Law and Forensics

Anthropological and medicolegal investigations can uncover potential violations to international humanitarian (IHL), human rights (IHRL) and domestic laws, such as genocide and crimes against humanity or peace (i.e., Gray 1986; Benomar 1993; Geiger and Cook-Deegan 1993; Best 1994; Edelenbosch 1994; Binford 1996; Grodin and Annas 1996; Stover and Shigekane 2002; Coupland 1997; Leaning 2003; Bosnar et al. 2005; Blau et al. 2006; Tidball-Binz 2006; Warren 2007). Conventions promote enforcement of human rights through judicial accountability, for those who commit "grave breaches" against them and are aimed at distinguishing between civilians and combatants, protecting civilians or unarmed persons, the wounded, and captured soldiers (refer to the Geneva Conventions 1949 and 1977). IHRL differs from IHL in that this body is designed to protect people both in times of armed conflict and in peace. The sources for these laws are also diverse, but they have generally developed on a common theme—to protect individuals or groups from government actions—and are applicable to cases in which armed insurgents or militia groups are fighting each other or the state (Tidball-Binz 2006).

Increasingly, the application of forensic sciences to HHRR investigations falls within a variety of legal contexts, subject to variation within legal rules of evidence, admissibility, and scientific witness testimony (Goldstone 1997; Wilson 2005). Anthropologists, pathologists, and other forensic investigators working within the IHL or IHRL framework may function under a number of different judicial or investigative contexts based on culture and are guided by the various international bodies involved. During the course of operation, these frameworks may even change as cases are transferred from international tribunals to domestic courts. To understand this variation, one only needs to look at the range of emerging court systems and the transformation of existing systems (Hayner 1994; Hinton 2002). For example, during the 1990s genocides occurring in Europe and Africa caught the world's attention with the disappearance, torture, murder, and forced evacuations of millions of people; the need of judicial accountability for serious war crimes led to the formation of two international ad hoc tribunals. The United Nations Security Council established the International Criminal Tribunal for Rwanda (ICTR)* and the International

* ICTR was established by the Security Council, acting under Chapter VII of the Charter of the United Nations, titled, *The International Criminal Tribunal for the Prosecution of Persons Responsible for Genocide and Other Serious Violations of International Humanitarian Law Committed in the Territory of Rwanda and Rwandan Citizens Responsible for Genocide and Other Such Violations Committed in the Territory of Neighboring States, between January 1, 1994, and December 31, 1994*. The resolution states, "hereinafter [the Tribunal is] referred to as the International Tribunal for Rwanda." UN Security Council *Resolution 1994/995* provides a mandate to investigate crimes committed in Rwanda in 1994.

Tribunal for the Prosecution of Persons Responsible for Serious Violations of International Humanitarian Law Committed in the Territory of the Former Yugoslavia since 1991[*] (ICTY). These courts have been referred to as the "second-generation" of criminal courts (Romano et al. 2004)[†]. More recently, the International Criminal Court (ICC)[‡] has also begun to investigate cases in various regions of Africa and South Asia. A growing body of jurisprudence and international "hybrid" legal systems have also emerged in recent years in the form of "third-generation" courts, such as regional human rights courts and truth commissions, i.e., the War and Ethnic Crimes Court in Kosovo, the Special Court for Sierra Leone, the Serious Crimes Panels in the District Court of Dili in East Timor, and the Extraordinary Chambers in the Courts of Cambodia (Romano et al. 2004). These ad hoc judicial bodies seek justice for war crimes or other violations of human rights and humanitarian laws. In contrast, many of the well-known examples of international forensic and anthropological investigations are examples of domestic truth commissions that in some cases have relied on international investigative teams (e.g., Argentina) but occur in domestic courts who have jurisdiction over domestic or customary law (e.g., Guatemala, Peru, or South Africa) (Romano et al. 2004).

The relevance of these courts and medicolegal investigations is noteworthy. They offer more than legal accountability; they provide a platform for education, law enforcement, and a foundation for emerging democratic and judicial reform (www.ictj.org) (UN, *ICTR Tribunal at a Glance*). For example, in prosecuting cases the ICTY has taken the testimony of more than 4500 witnesses who were able to give their name, document their story, and in most cases testify in court (UN, *ICTY Tribunal at a Glance*). Increasingly, forensic investigations into HHRR violations and war crimes pursue accountability and reconciliation through a framework of *transitional justice*. The emerging concept of transitional justice is supported by many organizations who seek to rebuild postconflict societies. In their mission statement, the ICTJ (International Center for Transitional Justice) wrote that their organization was " … founded on the concept of a new direction in human rights advocacy: helping societies to heal by accounting for and addressing past crimes after a period of repressive rule or armed conflict." Increasingly, forensic science under the purview of transitional justice has much to offer in the areas of missing persons, human identification (for both victims and perpetrators of offenses), the documentation of historical events and crimes committed, and is playing a significant role in the enforcement of IHL through judicial process (e.g., Skinner 1987; Snow et al. 1984; Lollar 1992; Skolnick 1991; Kirschner 1984; Tedeschi 1984; Kirschner and Hannibal 1994; Koff 1996; Scott and Conner 1997; Burns 1998; Ferllini 1999; Campobasso et al. 2003; Haglund et al. 2000; Haglund 2001; Hunter et al. 2001; Schmitt 2001; Skinner et al. 2001; Arnold 2002; Cordner and McKelvie 2002; Fondebrider 2002; Komar 2003; Koff 2004; Juhl 2005; Wilson 2005; Okoye et al. 2006; Brinkley et al. 2007).

[*] The ICTY mission was "to prosecute persons responsible for serious violations of international humanitarian law committed in the territory of Yugoslavia since 1991" (UN Security Council *Resolution 1993/827*).

[†] *First-generation* courts refer to the Tokyo and Nuremberg Trials, whereas *second-generation* refers to the ICTY, ICTR, and ICC (Romano et al. 2004).

[‡] The ICC was established (1998) by United Nations members participating in the "United Nations Diplomatic Conference of Plenipotentiaries on the Establishment of an International Criminal Court." Members established the treaty and currently 104 states have become party to the statute (UN, *ICC Tribunal at a Glance*).

Over the past 20 years, a variety of organizations* have employed forensic anthropologists, pathologists, or other forensic experts and scientists to monitor, collect, document, and analyze evidence of HHRR violations (e.g., Gibbons 1992, Stover and Eisner 1982, Joyce and Stover 1991, Snow and Bihurriet 1992, Welsh and Van Es 2003). Physical evidence provides tangible proof that is more challenging to refute than testimony alone; ICTY Deputy Prosecutor Graham Blewitt writes: "[physical evidence] provides unequivocal corroboration of what could otherwise be suspect or dubious evidence" (Blewitt in Cordner and McKelvie 2002, 284). For example, recent international proceedings have relied on large-scale forensic evidence, specifically forensic anthropological evidence of violations of IHL in Rwanda and the former Yugoslavia, including such cases as *The Prosecutor v. Kayishema and Ruxindana* (ICTR-95-1), *The Prosecutor v. Rutaganda* (ICTR-96-3), *The Prosecutor v. Mrksic, Radic, Sljivancanin, Dokmanovic* (IT-95-13a), *The Prosecutor v. Jelisic* (IT-95-10), *The Prosecutor v. Cesic* (IT-95-10-1/a), *The Prosecutor v. Krstić* (IT-98-33), *The Prosecutor v. Brdjanin and Zupljanin* (IT-99-36), *The Prosecutor v. Blagojevic and Jokic* (IT-02-60), *The Prosecutor v. Nikolic* (IT-02-60/1), *The Prosecutor v. Obrenovic* (IT-02-60/2), *The Prosecutor v. Mejakic* et al. (IT-02-65), and *The Prosecutor v. Banovic* (IT-02-65), *The Prosecutor v. Limaj* et al. (IT-03-66), *The Prosecutor v. Milutinovic* et al. (IT-05-87), and *The Prosecutor v. Popovic* et al. (IT-05-88).

Forensic investigations play a crucial role in the successful prosecution of high-ranking officials as listed in the criminal cases prosecuted by the ICTR and ICTY. Moreover, such investigations provide public education and discourse about HHRR and contribute to the corpus of IHL and IHRL jurisprudence. In addition to witness and survivor testimony about human rights abuses, forensic science provides essential physical proof of crimes committed though new sources of information (Kirschner and Hannibal 1994). Eriksson and Wallensteen (2004) report:

> A total of 229 armed conflicts in 148 countries have been recorded for the period after World War II (1946–2003). Of these, 116 conflicts in 78 countries were active in the period after the end of the Cold War (1989–2003). Most conflicts are internal: only seven interstate armed conflicts were recorded in the period 1989–2003, of which two were still active in 2003. The measurement of armed conflict is mainly based on news reporting, and it suffers from national and cultural biases. But the scrutiny of armed conflict is becoming more intense, and new sources of information are emerging.

The investigation and excavation of graves for victim identification has itself been viewed as an act of justice and is well articulated in a report by the Commission for Historical Clarification in Guatemala (in Cordner and McKelvie 2002, 870): "The Commission believes that exhumation of the remains of the victims … is in itself an act of justice and reparation and an important step of the path to reconciliation … because it constitutes part of the right to know the truth and it contributes to the knowledge of the whereabouts of the disappeared … ." The effect of

* For example, some of the most active organizations include the United Nations, the American Association for the Advancement of Science (AAAS), Physicians for Human Rights (PHR), Amnesty International, and various regional forensic teams (the Argentine Forensic Anthropology Team EAAF, the Guatemalan Forensic Anthropology Foundation FAFG, the Peruvian Forensic Anthropology Team EPAF, and the Colombian Interdisciplinary Team on Forensic Work and Psychosocial Services EQUITAS). Additionally, many forensic scientists from various fields have directly worked for governments, human rights organizations, and other nongovernmental organizations.

international criminal investigations on influencing the behavior of some perpetrators in their attempts to conceal crimes or avoid prosecution is well documented (*The Prosecutor v. Krstić,* IT-98-33). However, the range of effects from these criminal proceedings have yet to be fully realized.

An Epidemiological Framework for Trauma Analysis

Medicolegal death investigations provide critical evidence as to the manner and cause of death, the demography of victims, and the nature of crimes committed. The main objective of postmortem analysis is to diagnose skeletal wounds and accurately interpret the mechanism of injury, from which the diagnosis of the cause of death may be derived, as this evidence demonstrates whether a crime was committed. An epidemiological framework provides an accurate and meaningful approach to the differential diagnosis of wounds and their mechanism of injuries in the context of IHL and IHRL (Coupland 1994; Coupland 2001; Reza et al. 2001; Taback and Coupland 2005). Coupland (2001, 35) wrote, "An epidemiological approach to armed violence is an essential component in promoting and strengthening all laws, including international laws, pertaining to weapons and armed violence." Constructing an epidemiological paradigm for analysis of scientific evidence involves answering a number of questions. Building from Coupland's model (2001), we add components of differential diagnosis for skeletal wounds, evidence from the grave or fatal environment, weaponry, and ballistic science, as presented in Table 1.1. Epidemiological methods have been applied to paleopathology (e.g., refer to Cook and Powell [2006] for a general overview, or to Barrett et al. [1998] and Walker [2001] for specific examples). For various examples of demographic and other epidemiological variables' influence on wounding and skeletal trauma, refer to Ormstad et al. (1986), Missliwerz and Wieser (1989), and Leibovici et al. (1996). Applying this framework for forensic evidence provides context and new lines of data for a robust interpretation.

Demography

Demography is such an important topic for armed conflict and forensic science that it is an "emerging new field" within the auspice of IHL (Brunborg 2000; Brunborg and Tabeau 2005).

Table 1.1 Epidemiological Framework for Trauma Analysis

- Demography of victims
- Vulnerability of victims
- Wound to killed ratio
- Context
- Fatal environment
- Intention of perpetrators
- Scientific protocols
- Methods for differential diagnosis
- Weaponry and ballistics science
- Estimation of cause of death
- Manner of death

Coupland (2001, 33) wrote, "… weapons differ considerably both in the way they are used to execute violence and in their potential to do so; and the type and number of weapons available influence not only how, when, and why the violent act is committed, but also who the victims are and how they are affected." For example, gunfire and landmine injuries are more common among military fatalities in combat, whereas fragmenting explosive ordinance devices (EOD) are more common among civilians caught in an armed conflict (Meddings and O'Connor 1999). The age and sex distribution of victims, the ratio of wounded to killed, patterns among civilians versus soldiers, and the risk to victims provides evidence of the type of crime committed (Missliwerz and Wieser 1989; Leibovici et al. 1996; Salama et al. 1999). Former Under-Secretary-General for Humanitarian Affairs of the United Nations Jan Egeland* wrote:

> In Iraq, Sudan, Uganda, Somalia, Afghanistan and the Democratic Republic of the Congo … civilians continued to bear the full brunt of armed conflict and terror. Despite all efforts, women were still raped and violated as a matter of course; children were still forcibly recruited; and defenseless civilians continued to be killed—in violation of the most basic principles enshrined in centuries of international lawmaking.

For example, the El Mozote Massacre in El Salvador (1981) resulted in the recovery and analysis of 143 skeletons, 136 of whom where children, whose mean age at death was 6 years (Amnesty International 1990). The children and adults were put into a church where they were murdered, and the church burned (Kirschner and Hannibal 1994). In another example, 420 patients in the Vukovar Hospital, Croatia (1992), were taken out of the hospital, bused to a nearby farm, and executed (Kirschner and Hannibal 1994). The remains of more than 200 individuals were recovered in a mass grave. The intentional targeting of a hospital in this example is not an isolated incident. The OSCE Verification Mission HHRR reports (1999a, 1999b) on violations in Kosovo in 1998–1999 discuss numerous incidents where children, the elderly, and the wounded were held for ransom, murdered in front of others to instill fear, raped, burned alive, or beaten. These examples illustrate the demographic trends of victims of mass atrocities, namely society's most vulnerable, noncombatants, small children, and the wounded who were specifically targeted (refer also to Dean [1992]). Refer to Case Study 6.1 in Chapter 6, "Disappearance, Torture and Murder of Nine Individuals in a Community of Nebaj, Guatemala," by Chacón and coworkers, for a further example of differential violence targeted at a 14-year-old boy.

Demography also has implications for wounding patterns and the identification of skeletal trauma based on differential morphological or physiological responses (Lee et al. 2006). For example, the immature skeletal remains of a child or the osteoporotic skeleton of an elderly female can substantially affect the morphology of skeletal wounds and influence fracture patterns or wound severity. A comprehensive study of 1155 injuries due to gunfire and blast injuries resulting from terrorist activity reports that gunfire victims were on average older than blast victims because of the specific public areas targeted for attack, such as buses and cafes (Peleg et al. 2004).

The unique contribution of anthropologists to medicolegal death investigations is their biocultural framework built on an understanding and study of human variation.

* UN, Security Council SC/8763, 5476th Meeting, 28 June 2006 http://www.un.org/News/Press/docs/2006/sc8763.doc.htm.

How does who you are or how healthy you are affect bone injuries? In other words, what does human variation have to do with biological differences in wounding? Bone composition depends on genetics, growth, health, age, the type of applied stress, and the underlying bony architecture (Gorman 1981). Therefore, individual characteristics such as who is injured or targeted, who survives, and what are the wounding features, i.e., differential fracture patterns may be significant in interpreting skeletal evidence in HHRR investigations (Gorman 1981a, 1981b, 1981c; Salama et al. 1999; Coupland 2001; Reza et al. 2001; Peleg et al. 2004; Taback and Coupland 2005; Stawicki et al. 2002; Ryan et al. 2006).

Context

Taback and Coupland (2005) report the most significant factors of mortality among civilian victims in armed conflicts are not only the number and type of weaponry but also the victim's vulnerability and the context. Context accounts for the intention of those perpetrating crimes and the fatal environment (i.e., where the incident took place). Were the victims fighting, detained, bound, crowded into a small concrete room, or lying in a field at the time of their deaths? Coupland (2001, 33–34) wrote:

> The extent of tissue damage is determined by the mass, velocity, construction, and stability in flight of the bullet as well as by the rapidity with which the weapon can fire multiple bullets. These are the "design-determined" effects of the weapon. The potential to use a weapon, however, is influenced by the weapon itself, the user's perception of the design-determined effect, and the number of other people armed. The users perception of the vulnerability of the intended victim or victims also comes into play.

The examples throughout this book demonstrate that the specific context of the victim at the time of death is not only informative about the manner of death but also has important implications in wounding variation. This is discussed in greater detail in subsequent chapters. For example, when dealing with HHRR violations or armed conflict, it is important to understand that the use of high-velocity assault rifles against civilians or detained persons will generate patterns of injury and mortality different then what is expected in traditional warfare (Meddings 1997; Michael et al. 1999).

Patterns vary when victims are intentionally targeted or medical treatment is not available, or not allowed. What implication does the context have for the interpretation and presentation of injuries? Coupland and Meddings (1999) demonstrate the ratio of the number of people injured to killed ranges from 2:1 to 13:1, depending on context. In situations in which people killed had been "immobilized, in a confined space, or unable to defend themselves," the ratio of wounded to killed may be zero and indicative of war crimes (Coupland and Meddings 1999, 407). Further, Coupland and Meddings (1999, 409) discuss the psychology of perpetrators, who at closer range aim for the head or chest, which results in a higher fatality rate:

> The My Lai massacre has been examined in depth. In the mass shootings in which the wounded-to-killed ratio was less than 1, the civilians were unarmed or could not take cover. The implication of this is that when the victims are military, an equally low wounded-to-killed ratio could be a strong indicator of death by execution rather than in battle.

Finally, cases in which victims were intentionally targeted may include evidence multiple shooters, multiple injuries, multiple mechanisms of injuries or other evidence

of maltreatment. Refer to Case Study 1.1, by Snow and co-workers, presented at the end of this chapter, for a practical demographic example of possible war crimes.

Intent

Evidence of executions, such as blindfolds, ligatures, wounds to the back of the head, or those inflicted when the individual was in a kneeling or lying position and witness testimony or other investigative/documentary forms of evidence are all indicative of murder. The location, number, and severity of wounds also demonstrate this intention. For example, the frequency of injuries caused by firearms may provide an indication of intent because firearms require an "act of volition" (Meddings and O'Connor 1999). Moreover, the distribution of injuries in areas such as the head or trunk in civilian populations, devoid of body armor, provides additional evidence of the intention to kill (Baraybar 2006).

Moving human remains after *primary* interment results in commingled body parts and incomplete recovery of bodies. In the 2001 verdict against General Radislav Krstić (*The Prosecutor v. Krstić,* IT-98-33: 596, p. 212), evidence of s*econdary* burials was accepted by the trial judges:

> … a strong indication of the intent to destroy the group as such in the concealment of the bodies in mass graves, which were later dug up, the bodies mutilated and reburied in other mass graves located in even more remote areas, thereby preventing any decent burial in accord with religious and ethnic customs and causing terrible distress to the mourning survivors, many of whom have been unable to come to a closure until the death of their men is finally verified.

Consequently, the way in which bodies are disposed of and the specific burial environment may influence what data are present for analysis and show clear evidence of the intention to conceal crimes.

Scientific Protocol

The various exhumation, autopsy, anthropological, and investigative protocols for medicolegal death and missing persons investigations must be integrated in a way that provides a functional, consistent, and reliable model and at the same time remains flexible to adapt to varying contexts. International protocols for medicolegal death investigations, postmortem analysis, and forensic science are flexible and adaptable by design to fit the context and goals of each mission. International work in a multiplicity of cross-cultural settings requires protocols that can be adapted due to biological, cultural, and legal variation of each setting. At the same time, these protocols must be consistent in the collection, preservation, analysis, and presentation of data, built on scientific rigor and forensic standards such as chain of custody, to ensure the findings are reliable and admissible in court. Some examples of the guidelines commonly referenced for general standards of best practice include the Interpol's *Disaster Victim Identification Guide* (2005; first publication 1984), Protocol for Preventing Arbitrary Killings through Adequate Death Investigation and Autopsy ("Minnesota Protocol" 1988), *UN Manual on the Effective Prevention and Investigation of Extra-Legal, Arbitrary, and Summary Executions* (1991), *Guidelines for the Conduct of United Nations Inquiries into Allegations of Massacres* (1997), *Istanbul Protocol:*

Manual on the Effective Investigation and Documentation of Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment (2001), and the Human Remains and Forensic Sciences Electronic Workshop (2002).

Anthropologists and pathologists are scientists, and as such serve as expert witnesses. Each discipline has a set of standard protocols and methodology for the documentation and analysis of trauma (Moritz 1954; Ortner and Putschar 1981; Spitz 1993; Buikstra and Ubelaker 1994; Mason and Purdue 2000). These methods are scientifically verified and peer-accepted to be admissible in most courts. Refer to Chapter 2 for an in-depth discussion of the anthropological protocol for trauma analysis, as used throughout this text and also to Snow (1982), Orentlicher (1990), and Olmbe and Yakub (2002).

The indictment against Pavle Strugar, retired Lieutenant general of the JNA (*The Prosecutor v. Pavle Strugar,* IT-01-42-T), included six counts of violation of the laws or customs of war (Article 3 of the Statute of the Tribunal) for the murder and maltreatment of four civilians during an artillery attack against Dubrovnik, Croatia. In this case, the defense attorney questioned the prosecution's witness, a forensic pathologist, as to whether the forensic protocol was followed. The defense claimed that the pathology report presented by the prosecution:

> … was not compiled in conformity with the rules of forensic medicine. According to these forensic rules he contended, in a report, among other things, all wounds must be described, the exact amount of fluid must be measured, and consistency and colour of the blood must be recorded. [The pathologist] on the other hand did not use the required parameters [performed only an external examination, not a full autopsy, and] in his report and made liberal remarks, such as, "There is a lot of blood." (*The Prosecutor v. Pavle Strugar,* IT-01-42-T, Trial Judgment, 31 January 2005, para. 247: 116)

Although the defense attempted to demonstrate that the prosecution's witness (a pathologist) did not fulfill all of the legal requirements of an autopsy by following the protocol, the argument was not persuasive to the Trial Chamber:

> … [autopsies] conducted under remarkable circumstances which explain entirely, in the Chamber's view, his nonobservance of more normal procedures. He had to examine the bodies of 19 deceased people on 7 December 1991. There was no power for refrigeration or lighting and there was no running water. Despite these restraints, in the Chamber's finding, he was able to draw on his clear expertise to reach entirely satisfactory and persuasive findings which the Chamber accepts. (*The Prosecutor v. Pavle Strugar,* IT-01-42-T, Trial Judgment, 31 January 2005, para. 257: 119)

Importantly, the Chamber recognized that the extenuating circumstance surrounding the postmortem examinations of the victims in a war zone, as carried out by the forensic pathologist, does not preclude the use of such evidence collected outside the boundaries of postmortem protocols.

Weaponry

In today's conflicts, most civilian deaths are caused by *small arms* (Aboutanos and Baker 1997), which by definition are light-weight and designed to be used by a single person (i.e., revolvers, pistols, rifles, shotguns, submachine guns, assault rifles, grenades, landmines, or mortars).

In many regions, even farming or utilitarian tools have been used to systematically commit HHRR abuses or war crimes, such as the use of machetes in the Rwandan Genocide (refer to Chapter 6 of this volume for a thorough discussion of these types of weapons and the resultant injuries).

Small arms are generally classified based on the materials used to construct the weapon and the intended purpose of the weapon, i.e., antipersonnel, antiaircraft, antitank, or hunting weapons (refer to Bellamy [1992], Boutwell et al. [1995], Bowen and Bellamy [2002], Ben-Ya'acov et al. [2005], and Celiköz et al. [2005] for wounds and weapons related to modern war). *Antipersonnel weapons* are those designed to attack people. Firearms include handguns (pistols and revolvers), rifles, and shotguns for which a chemical charge launches a projectile down a riffled or smooth-bored barrel. The term *missile* is generally used to describe projectile weapons but also refer to rockets that are guided after launch (Bellamy 1992). Explosive weapons are designed to be destructive either through a blast or by spreading shrapnel, which act as small projectiles.

Aboutanos and Baker (1997) point out that civilians account for the greatest number of casualties in modern wars with an increasing number of deaths resulting from explosive devices such as artillery and mines. According to Coupland (2001, 36), "small arms were transferred following the Cold War to many untrained, undisciplined, or nonmilitary users." This point is further illustrated in the Human Security Report, which states (2005, 5):

> Today most wars are fought in poor countries with armies that lack heavy conventional weapons or superpowers patrons. In a typical low-intensity conflict weak government forces confront small, ill-trained rebel forces equipped with small arms and light weapons. Skirmishes and attacks on civilians are preferred to major engagements.

The Conventional Arms Branch of the UN Department for Disarmament* reports:

> There are over 600 million small arms and light weapons (SALW) in circulation worldwide. Of 49 major conflicts in the 1990s, 47 were waged with small arms as the weapons of choice. Small arms are responsible for over half a million deaths per year, including 300,000 in armed conflict and 200,000 more from homicides and suicides.

Consequently, the high lethality of small arms and a lack of medical treatment in many conflicts, contributes to the high number of civilian casualties (Champion et al. 2003).

Cause and Manner of Death

T.D. Stewart (1979, 76) wrote, "When a forensic anthropologist has finished his examination of a skeleton, he is likely to be asked: 'Did you learn the cause of death?'" For Judicial accountability, the number, case, and manner of death must be considered. Can the cause and manner of death be ascertained from skeletonized or even fragmented remains? Can the cause of death be determined for the majority of individuals from a given site, considering that many mass atrocities often result in mass burials or *commingled* remains? Further, can the systematic and widespread distribution of crimes be demonstrated over a given time range or wide geographic distribution?

* Peace and Security through Disarmament. Conventional Arms Branch of the UN Department for Disarmament Affairs. http://disarmament.un.org/cab/index.html.

The cases presented throughout this book demonstrate that the answer to these questions is most often yes, cause and manner of death can be determined from skeletal injuries.

Anthropologists play leading roles in medicolegal death investigations into war crimes and HHRR abuses, from interviewing witnesses or family members about antemortem (or missing person's) information, to locating and excavating clandestine burials to the laboratory analysis of skeletal remains, in which they document skeletal trauma and biological parameters useful for victim identification. Although ascertaining the cause and manner of death falls within the expertise and legal responsibility of forensic pathologists, investigations into cases of war crimes, human rights abuses, extrajudicial executions, or armed conflicts most often occur years after the deaths occurred. Therefore, postmortem examinations in the course of these investigations occur after remains have become skeletonized. Clues about who the victims were and the circumstances surrounding their deaths lie in the bones themselves. Anthropologists and pathologists are tasked with piecing together the fragments of remaining skeletal tissue and associated physical evidence to elicit a mechanism of trauma that is factually based, methodologically scripted, and scientifically interpreted.

The *manner of death* explains how death occurred and assigns responsibility to nature, a random mishap, the decedent, or someone else. The classification system used in the medicolegal system includes five manners of death: natural, homicide, suicide, accidental, and indeterminate or unknown. The *cause of death* refers to the "medical condition which *initiates* the lethal chain of events culminating in death" (Adams and Hirsch 1993, 178). This is known as the proximate (or direct) cause and should not be confused with associated complications that may arise as a result. Numerous provisions of IHL and customary law provide guidelines for dealing with the deceased, including protocols for death investigations and diagnosing the cause of death (Tidball-Binz 2006). A few examples include guidelines on:

- How the dates and places of capture, death, and burial are to be recorded (Geneva Convention, Protocols I–IV)
- How the identity of victims, their personal effects, and the cause and manner of death are to be determined (Geneva Convention, Protocols I–IV)
- How the remains should be identified and repatriated to family members (Geneva Convention, Protocol I, Article 34[2][c])

How does the manner and cause of death contribute to the investigation and prosecution of violations of IHL? Stated simply, they establish whether a crime has been committed and, if so, what crime. In prosecuting violations of IHL, the individual and collective identities of victims and the circumstances surrounding the victim's death attests largely to whether a crime was committed. For example, during the trial of General Radislav Krstić (*The Prosecutor v. Krstić,* IT-98-33; para. 3769), the defense lawyer questioned the cause and nature of deaths as presented in court, which were largely attributed to gunfire. Specifically, the defense questioned whether the deaths resulted from combat or were in fact the result of suicides, to which the anthropological witness replied (*The Prosecutor v. Krstić,* IT-98-33; 3769): "Well, I just would like again to point out that I have investigated many suicides. I have never seen an individual with their hands bound behind their back shoot themselves multiple times."

The scientist as an expert witness provides a level or degree of certainty. Opinions and estimations of fact, drawn from physical evidence, are presented with varying levels of certainty such as a "reasonable degree of certainty," or a "preponderance of evidence" (Adams and Hirsch 1993, 191). Interpretations presented as "probable" are based on statistical levels

of probability based on quantifiable likelihood estimates but are not applicable to trauma analysis. The documentation and interpretation of injuries are based on experience and professional opinion. The scientist who is called as a witness to provide testimony on trauma in a criminal trial provides an expert opinion. Adams and Hirsch (1993, 192) wrote:

> Medical opinions are conclusions based on facts. Some facts, such as gross autopsy findings generally do not change. Other facts, especially those derived from witness accounts, do change. Opinions are based on the facts and findings as they are known at the time the opinion is formulated. If the facts which form the foundation of the opinion changes, the opinion can and often will change.

The military shelling of civilian populations as already discussed in the case of *The Prosecutor v. Pavle Strugar* (IT-01-42-T) highlights a number of important issues of which anthropologists and pathologists need to be aware in their analysis of skeletal injuries, their reporting, as well as testimony (refer also to Kravetz [2004]). In this case, the defense attorney questioned the prosecution's forensic pathologist and claimed that the time and cause of death could not be determined from postmortem examination because the standard forensic protocol was not followed when only an external examination was performed:

> The Chamber has received, and accepts, evidence of the physical circumstances in which [the victim] was suddenly injured at the time of the explosion of a shell during the bombardment of the Old Town by JNA forces. [The victim] died a relatively short time thereafter. A skilled and experienced pathologist … discovered that a fragment of shrapnel had torn his right lung from which death resulted. In the experienced opinion of [the pathologist] the injury bore all the characteristics of an injury caused by an explosive device … There was an explosion of a military shell in the vicinity of [the victim]. He was obviously wounded when this occurred. Not long after he died. Examination revealed a shrapnel wound characteristic of such an explosion which caused injuries which would normally cause death if intervention could not prevent death. Given these circumstances the Chamber is entirely satisfied that the fact of death and the cause of death are established. (*The Prosecutor v. Pavle Strugar,* IT-01-42-T, Trial Judgment, 31 January 2005, para. 248: 116)

Importantly, this case demonstrates that even when the specific cause of death cannot be ascertained, as in many instances in which only skeletal evidence is present, the *fact of death* may be established by the nature of the injuries and the lack of medical intervention.

In a prior case prosecuted by the ICTY, the same issue was addressed and shown to apply also to cases in which there may not be a body but death can be inferred from other evidence. According to the trial judgment in *The Prosecutor v. Krnojelac* (IT-97-25; Trial Chamber II Judgment, 15 March 2002, para. 326):

> The fact of a victim's death can be inferred circumstantially from all of the evidence presented to the Trial Chamber. All that is required to be established from that evidence is that the only reasonable inference from the evidence is that the victim is dead …

In this and similar cases,* the prosecution has been able to demonstrate that the nature of injuries, without medical intervention would have been inevitably fatal. A similar concept,

* Refer also to *The Prosecutor v. Kvocka* et al., IT-98-30/1, Appeals Judgment, para. 260, *The Prosecutor v. Tadic,* IT-94-1, Trial Judgment, para. 240, and *The Prosecutor v. Strugar,* IT-01-42, Trial Chamber, para. 236.

fatal if untreated, has been used as a category for the documentation of injuries and provides a framework for determing the *most likely cause of death* (Baraybar and Gasior 2006).

Summary Guidelines for Best Practice

Two decades after the application of forensic sciences to human rights reporting and enforcement, the potential of the field are just beginning to be realized. As anthropologists, pathologists, and forensic investigators work in postconflict societies within the framework of transitional justice, they are challenged as scientists to work within an epidemiological framework—cognizant of culture, context, and varying legal systems. Interpreting trauma to estimate the cause and manner of death helps families and communities. Work in this area over the past 20 years has raised the bar for standards of serving both families and the judicial system. New technology and innovations such as DNA analysis add promise for victim identification; at the same time, practical constraints to funding and access remind investigators that the process must move along a path toward justice, in keeping with the practical functional needs of the communities and judicial entities being served.

Technological advances are widening and strengthening the use of forensics in the pursuit of justice. Future applications will require interdisciplinary teams for investigative and analytical purposes, the creation of specialized teams to ascertain the fate of the missing after internal conflicts, a need for training local practitioners in conflict areas, and innovative solutions to bring new lines of evidence to light. There is also a need for creative solutions to make the results accessible and understandable to members of the communities being served, refinement of protocols and methods for increased reliability and broad applicability, and cooperation between States regarding the fate of missing persons after international conflicts. Above all, science and technology must become accessible and applicable in the countries where armed conflicts occur and where financial support is not always available. The need for multidisciplinary research in anthropology, medicine, forensics, and international law cannot be postponed. Building from the model and jurisprudence of international tribunals, future investigations will find an appropriate epidemiological model useful for enforcing human rights through forensics.

Case 1.1: Firefight in Lima: Wounded/Killed Ratio Analysis of MRTA Casualties in the 1997 Hostage Rescue Operation at the Japanese Embassy

Clyde Collins Snow
Norman, Oklahoma

José Pablo Baraybar
Peruvian Forensic Anthropology Team

Herbert Spirer
Columbia University, New York
Professor Emeritus of Information Management
University of Connecticut at Stamford

Investigators of alleged human rights violations resulting in many deaths are often confronted with conflicting stories. On one hand, the accused perpetrators—usually military or police—stoutly maintain the victims were killed in armed confrontations. On the other hand, survivors and their sympathizers adamantly claim the dead were victims of extrajudicial execution. Forensic scientists investigating such events must put aside the claims of both sides and, instead, objectively follow the evidence wherever it leads. Stated simply, they must let the dead tell their own stories.

In a 1999 review article, Coupland and Meddings (1999) compared the proportion of combatants wounded to those killed (W/K ratio) in ordinary combat with instances in which defenseless people are killed in mass murders. In conventional warfare, they found that, normally, the wounded outnumber fatalities by at least two to one ($W/K \geq 2$). In mass murders, on the other hand, the number killed is usually greater than the number wounded ($W/K \leq 1$). The authors conclude that the W/K ratio has implications for recognizing violations of the internationally accepted rules of warfare. Thus, in incidents in which the killed outnumber the wounded, the "threshold of suspicion" that such a violation may have occurred is lowered. They suggest the W/K ratio may be helpful in developing a preliminary evaluation of the nature of mass casualty incidents reported in the media or other sources and therefore might be a useful rule of thumb for journalists, human rights investigators, and others who monitor compliance with the laws of war.

To illustrate, suppose "Force Red" attacks a town defended by "Force Blue." After a battle lasting a couple of days, Force Red prevails and occupies the town and their commander announces that 500 Force Blue soldiers were killed but does not allow journalists to verify his claim by visiting the battlefield. However, an enterprising reporter visits the local hospital and finds that only 50 Force Blue wounded were brought there for treatment. If it is assumed that the Force Red commander was telling the truth, the W/K ratio would be 50/500 or 0.1, suspiciously low, suggesting that many of the Force Blue defenders were killed while trying to surrender or after being wounded. On the other hand, it is also possible that he was simply attempting to bolster his military reputation by exaggerating the extent of his victory. In either case, the low W/K ratio triggers doubts that would justify further investigation. If this led to the exhumation of the mass grave where the Force Blue fatalities were buried and only ten bodies were found (W/K ratio = 5.0), the Force Red commander would simply be exposed as a liar. However, if it indeed revealed 500 bodies, the low ratio of wounded to dead might suggest a war crime and justify further investigation.

As forensic scientists who frequently serve as expert witnesses are fully aware, testimony based on a "rule of thumb" is not likely to carry much weight with an aggressive cross-examiner or a skeptical judge. On the other hand, opinions that can be soundly defended with good science and statistics are usually well received in court. We feel that the data on which the authors based their findings are sufficient to lend some statistical rigor to their approach and, therefore, might prove a valuable evidentiary tool.

In the present study, we will explore this possibility by applying the Coupland–Meddings approach to the 1997 operation conducted by Peruvian special forces to rescue hostages held by 14 *Movimiento Revolucionario Tupac Amaru* (*MRTA)* terrorists in the Japanese embassy in Lima. Although exemplary in planning and execution in that 71 of 72* hostages were rescued, essentially unscathed, all 14 of the *MRTA* terrorists were killed. Soon after the attack, stories began to circulate that some of the guerillas had been extrajudicially executed. For example,

> One of the hostages said that he saw a member of the *Tupac Amaru* … shot to death despite the fact that he was holding up his hands in surrender …. Another said that he saw an *MRTA* rebel captured alive and taken out by soldiers, "I realized that the arrested rebel was killed when I heard a report that all 14 rebel members died in the raid," he said. *(Asahi Evening News*, April 24, 1997)

> A CNN report on April 25 cited a Lima newspaper (*La Republica*) as stating that the two female rebels were not killed in the initial assault and that listening devices picked up their pleas not to shoot as they huddled in a doorway but that the soldiers open fire. An unidentified intelligence officer was given as the source of this information.

> Shortly after the incident, Hidetaka Ogura, an embassy political officer, stated that he saw three of the guerillas—two men and one woman—alive and held as prisoners. The woman and one of the men, who was handcuffed, were standing on the second floor, surrounded by soldiers. On the first floor, he saw the third man, whom he recognized as "Tito" (Eduardo Nicolas Cruz Sanchez), lying on the floor, handcuffed with his feet trussed. Mr. Ogura's steadfastness in this claim apparently cost him his diplomatic career, and he has been accused of being a victim of the "Stockholm syndrome." He has since written a book recounting his hostage experience (Caretas 2001, 1661).

Peruvian authorities staunchly denied these claims:

> "All of them died in combat," Peruvian Interior Minister General Cesar Saucedo said … Peruvian President Alberto Fujimori … vehemently denies any executions took place (CNN, April 27, 1997).

Methods

This study is based on military casualty figures reported in the medical literature and other official sources. The casualties were incurred in conflicts in which the internationally accepted rules of war have generally been observed and in which both sides have employed conventional weapons. The latter, as defined by Coupland and Meddings (1999, 407), "legitimate weapons … that utilize projectiles or nonnuclear explosions." They thus include firearms as

* An elderly male hostage died of an apparent heart attack a few hours after being rescued.

Table 1.2 Nonfatal (NFW) and Fatal Wounds (FW) in Conventional Warfare (CWF) Conflicts

No.	Conflict	Nonfatal Wounds	Fatal Wounds	Total Casualties	FrqF	Reference
1	U.S. Army, New Georgia 1943	3873	1094	4967	0.220	Hopkins 1962
2	U.S. Army, Burma 1944	156	56	212	0.264	Hopkins 1962
3	U.S. Army, Bougainville 1944	1393	395	1788	0.221	Oughterson et al. 1962
4	U.S. Army, Italy 1944	52386	15642	68028	0.230	Snyder and Culbertson 1962
5	U.S. Army, Europe 1945	148816	42401	191217	0.222	Bzik and Bellamy 1984
6	U.S. Army, Korea 1950–53	77788	21310	99098	0.215	Bzik and Bellamy 1984
7	U.S. Marine Corps, Korea 1950–53	23744	4267	28011	0.152	Bellamy 2000
8	British Army, Malaya 1950–53	386	204	590	0.346	Clyne 1955
9	U.S. Army, Dominican Republic 1965–66	172	27	199	0.136	Pike 2005
10	U.S. Navy, *USS Liberty* attack 1967	170	33	203	0.163	Pike 2005
11	U.S. Army, Korean DMZ 1966–69	111	43	154	0.279	Pike 2005
12	U.S. Army, Vietnam 1964–73	96811	28862	125673	0.230	Bzik and Bellamy 1984
13	U.S. Marine Corps, Vietnam 1964–73	51399	12944	64343	0.201	Bzik and Bellamy 1984
14	Omani Forces, Oman 1972–73	71	9	80	0.113	Melsom et al. 1975
15	British Army, North Ireland 1970–80	1700	300	2000	0.150	Smith 1981
16	British Army North Ireland 1974–84 (bombs)	612	216	828	0.261	Mellor and Cooper 1989
17	U.S. Army, *Mayaguez* rescue 1975	50	18	68	0.265	Pike 2005
18	Israeli Army, Lebanon 1982	1599	351	1950	0.180	Gofrit et al. 1997
19	U.S. Army, Grenada 1983	119	19	138	0.138	Pike 2005
20	U.S. Army, Panama 1989	292	25	317	0.079	Dice 1991
21	U.S. Army, Persian Gulf War 1991	458	147	605	0.243	Pike 2005
22	Croatian Army 1991–92	78	15	93	0.161	Butkovic-Soldo et al. 1995
23	U.S. Army, Somalia 1993	125	18	143	0.126	Mabry et al. 2000
24	Israeli Army, Palestine 2001–2	73	23	96	0.240	Lakstein and Blumenfeld 2005
25	U.S. Marine Corps, Iraq 2003	337	56	393	0.142	Chambers et al. 2005

well as fragment-producing explosive devices ranging from hand grenades to artillery shells, missiles, and aerial bombs. It is also understood that they are nonchemical/biological.

Coupland and Meddings cited eleven studies dealing with casualties sustained in combat between ground forces. In reviewing the literature, we have found 14 additional reports, including one of a naval action, bringing the total series to 25. Chronologically, the conflicts range from World War II to U.S. marine casualties in Iraq in 2003. Eighteen (72.0%) are reports on casualties sustained by U.S. forces. The remaining seven treat casualties of other armed forces: British (n = 3), Israeli (n = 2), Omani (n = 1), Croatia (n = 1). Most of these reports were compiled by military physicians and statisticians whose objectives were to evaluate the effects of weapons, improve treatment of the wounded, and assess the protection offered by body armor. They are confined to the study of battlefield casualties caused by hostile action and do not include illness and death from disease or from injuries in "behind-the-lines" incidents such as vehicular or aircraft accidents. The studies from which we have drawn the data used in the analysis are shown in Table 1.2.

In the data tabulated in Table 1.2, the first category, *nonfatal wounds* (NFW), refers to hospitalized casualties; it does not include lightly wounded combatants returned to duty after treatment in the field. The second category, *fatal wounds* (FW), includes both those killed in action (KIA) and those who died of wounds (DOW) after hospitalization.

For statistical convenience, we use the *frequency* of fatal wounds among all casualties rather than the ratio of killed to wounded employed by Coupland and Meddings. Thus,

$$\textit{Frequency of fatal wounds (frqF)} = FW/(NFW + FW) \tag{1.1}$$

Results

The distribution of *frqF* values in the surveyed conventional warfare series is shown in Figure 1.1. Despite the wide variation in the type and size of conventional warfare (CWF) conflicts, the frequency of fatal wounds has remained close to about one in five over the six decades of this survey. Although the series is small, it meets the criterion of a Gaussian (normal) distribution (*Kolmogorov–Smirnov distance = 0.121, p > 0.10, ns*). The 95% *prediction interval* (P.I.) defines the limits beyond which values are statistically significant at the 0.05 probability level.

Thus, an incident in which fatally wounded combatants comprise more than a third of total casualties, (*frq*F > 0.33) falls above the limit expected in conflicts where legitimate weapons are used and the laws of conventional warfare observed. Such a statistically unusual incident might prove worthy of further investigation to determine, if possible, what factors were at work to produce such a high fatality rate.

An Example: The *MRTA* Incident

As noted previously, soon after the embassy hostages had been rescued, controversy arose over allegations that at least some of the *MRTA* combatants had been extrajudicially executed after being wounded, or having surrendered. This suspicion was fueled in part by allegations of witnesses among the hostages themselves. However, as many studies have shown, eyewitness statements often prove fallible, especially in tense and life-threatening situations. Forensic scientists investigating such incidents must confine their analysis to objectively observable facts. In the case of the embassy firefight, it begins with the stark mathematical

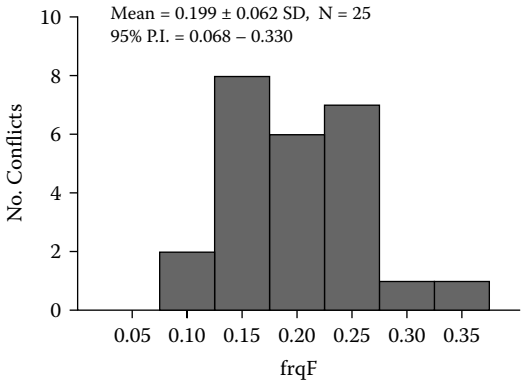

Figure 1.1 Distribution of frequencies of fatal wounds (*frqF*) in conventional warfare conflicts (1943–2003).

fact that there were no survivors among the 14 *MRTA* combatants. In this case, the *frqF* is 14/14 or 1.0, the highest possible value and one that far exceeds the CWF series mean of 0.199.

However, a further factor must be considered: the relatively small number of *MRTA* combatants. Even when the laws of war are observed, such a small force might all receive lethal wounds just by chance. In other words, sometimes the "fortunes of war" transmute into "bad luck." It is therefore fair to ask how often, through chance alone, might we expect to encounter a 100% mortality rate in a group of 14 wounded in a CWF situation? The binomial probability of such an outcome is calculated from the equation:*

$$P_{N:F} = \left(\frac{N!}{F!(N-F)!} \right) frqF^{F} (1 - frqF)^{N-F} \tag{1.2}$$

where
N = Number of seriously wounded (NWF + FW)
F = Number of fatally wounded (FW)
*frq*F = Mean frequency of fatal wounds in CWF combat
$P_{N:F}$ = Probability of F fatal wounds in N wounded

In the embassy case, $N = 14$, $F = 14$, and *frq*F = 0.199, so substituting the values in the preceding equation yields:

$$P_{14:14} = \left(\frac{14!}{14!(14-13)!} \right) (0.199)^{14} (1 - 0.199)^{14-1}$$

$$P_{14:14} = 0.00000000015 \tag{1.3}$$

* The tedious calculations involved can be avoided by using a spreadsheet function such as "BINOMDIST" in Microsoft Excel, which returns the binomial probability of observing a specified number of "successes" in a fixed number of independent "trials."

Discussion

From the preceding account, it is apparent that the chances of all 14 *MRTA* combatants being killed in an ordinary CWF are extremely remote. The finding allows the case to be pinpointed as one worth further investigation to determine, if possible, what factors were at work to produce the observed results. Ideally, such an effort would be multifaceted. The investigation would begin, of course, with a detailed examination of the scene itself, using accepted forensic methods such as blood-splatter and trajectory analysis in relation to body locations. It would also include detailed medicolegal autopsies of the victims to determine the number, location, and range of their wounds. A third investigatory component would consist of detailed and independent, after-action interviews of combat participants and other witnesses to see to what extent they corroborate or contradict the material evidence collected through the crime scene and autopsy investigations. Any available documentary evidence, such as orders specifying the roles of combatants and rules of engagement would also be collected and reviewed. Finally, meta-analysis of the scene, medicolegal testimonial, and documentary evidence would be conducted.

In the *MRTA* case, it might be found that certain factors of the combat environment contributed to the higher-than-expected mortality. For example, one factor might be *range*—the distance between the shooter and the targeted opponent. Shots fired at closer range result in larger wounds and increase the chance of multiple wounds—especially when automatic weapons are employed. Also, at closer ranges, shooters are more likely to direct their fire at the head or chest (Grossman 1995). Average ranges would have been shorter within the confined space in which the *MRTA* casualties occurred. Another environmental factor that may have influenced the outcome was *target density*—a function of the number of shooters to the number of targets. The 14 (n = 14) *MRTA* were outnumbered by a factor of about 10:1 (ten to one); therefore, the probability of their receiving multiple wounds was correspondingly increased. Finally, autopsy findings of close-range gunshot wounds of the head, corroborated with eyewitness testimony of the hostages, might confirm the allegations of extrajudicial executions.

Conclusion

The MRTA mortality rate observed during the hostage rescue mission at the Japanese Embassy in Lima is significantly higher than the range observed in modern military conflicts in which conventional arms are employed. While this finding is not evidence *per se* of a war crime, it lowers the threshold of suspicion that at least some wounded or captured MRTA combatants may have been executed. As wounded combatants are protected by the first Geneva Convention and prisoners of war by the third, the further investigation of this case as a possible war crime is justified.*

* The remains of all fourteen MRTA victims were disinterred in March 2001 and brought to the *Instituto Medicolegal de Lima (IML)*. There they were examined jointly by two authors of this report (CC Snow & JP Barybar), assisted by members of the *Equipo Peruano de Anthropologia Forense (EPAF)* and *IML* pathologists. Examination of cranial gunshot wounds indicate that, indeed, several of the victims had been extra-judicially executed. These findings will be published elsewhere (Snow and Baraybar, *manuscript in preparation*).

Differential Diagnosis of Skeletal Injuries

2

What are all the possible causes of a pathological condition and which one is the most likely cause?

Don Ortner[*]

Contents

Accuracy in the skeletal diagnosis of injuries around the time of an individual's death relies on the integration of as many lines of evidence as possible. Data from a variety of sources should be used in combination—the anthropologist's examination of the skeletal tissues, microscopic analysis of the affected bone surfaces, radiographic data, the assessment of the individual's clothing, the evaluation of the physical evidence of weaponry, etc. After all the evidence is considered, deduction is used to classify each injury category, identify the mechanism of the injury, and determine the most likely cause of death.

The objectives of this chapter are to demonstrate the techniques for reconstructing fragmented skeletal remains and outline the methodology for identifying skeletal trauma. First, fractures resulting from possible injuries are differentiated from normal skeletal variation and nontraumatic skeletal pathology. Second, a brief overview of fracture classification and mechanisms of injury provide a framework for interpreting trauma data. Third, the timing of fractures is established to differentiate antemortem injuries, perimortem

[*] Ortner 2003, 4.

trauma, and postmortem modification or taphonomic processes. Fourth, supporting evidence for trauma identification from radiographic data and clothing analysis are presented. Additionally, the characteristics of burned bone and features used to differentiate peri- from postmortem burning and microscopic techniques for interpreting fracture evidence are discussed. (Refer to case study 2.1.)

Reconstructing Skeletal Fractures to Identify Trauma

A postmortem examination of skeletal remains begins with radiography or fluoroscopy,* followed by detailed examination of each bone and associated clothing, to ensure that all evidence, even the smallest skeletal fragments, are recovered. The skeletal remains are washed and laid out in anatomical order. Adherent tissues are removed either through washing or boiling. The anthropologist then reconstructs fractured bones so that the fracture type, pattern, and overall distribution of wounds are evident. Adhesive material is used to bind fractured skeletal remains.† The strongest and easiest adhesives to use are "instant adhesives" or commercial grade cyanoacrylates composed of methyl methacrylate, which are activated with a catalyst or accelerator. This type of adhesive is instantly binding and creates a very strong bond that allows reconstructed skeletal elements to be handled, photographed, and if necessary, radiographed without the need of external support structures. In our experience, this type of glue often remains bonded even after reconstructed skeletal elements are placed in body bags, transported, and later reexamined.

Skeletal reconstructions of fractured remains, depends on the amount and type of fracturing, subsequent warping or deformation due to burial, or other postmortem damage. Experience has shown that creating two units, the face and vault, and then uniting the two segments create an accurate and stable reconstruction. When reconstructing fragmented cranial remains, each bone is put together as completely as possible before uniting different structures to one another. Once each bone is reconstructed, then aspects of the vault should be articulated, beginning with the left and right parietals. The occipital should then be added to the parietals followed in order by the frontal, temporals, and sphenoid. We recommend reconstructing the facial bones by first attaching the nasals and zygomatics to the maxilla. Depending on the location and nature of the fractures, it is sometimes necessary to first attach the zygomatics to the frontal and temporal bones and then add the maxilla. Approaching the cranium anatomically as two units, the vault and the face, and uniting them with the sphenoid create an accurate and strong reconstruction. Figures 2.1–2.2 depicts a cranial reconstruction following a gunshot wound to the skull. Extreme fragmentation is consistent with high-velocity trauma, particularly when multiple injuries are present. Through the reconstruction, the fracture patterns are elucidated and enough information about the injuries is available to accurately interpret the mechanism and number of injuries.

* Although scanning the remains with an x-ray machine or a fluoroscope is recommended, it is not always possible in cases where such equipment is not available. Close examination of remains and clothing will recover metal fragments and is recommended (Baraybar and Gasior 2006).

† It is recommended that samples for DNA or histology are taken prior to the use of adhesives or any chemical agent for processing. The protocol described here for skeletal reconstruction is based on practical experience; varying contexts may require modification to laboratory methods. It may not always be possible to reconstruct skeletal remains due to deformation from burial or incomplete recovery (Refer to Steadman et al. 2006 for discussion of lab methods.)

Figure 2.1 Fractured cranial remains are washed and laid out in anatomical order. Two circular entry wounds are present on the right parietal. The first cervical vertebra is fractured and the left maxilla exhibits a circular defect indicating additional injuries. Extreme fragmentation is consistent with high-velocity trauma. (Printed with permission from International Criminal Tribunal for the former Yugoslavia.)

Figure 2.2a Reconstruction begins with each bone individually. Bones of the vault are joined followed by the face. Fragments are joined posteriorly to anteriorly. The lateral fragments are then added to the vault and face. Pictured here is Edixon Quinones, OMPF (ICTY).

Figure 2.2b The vault is reconstructed and the smaller fragments are added to the vault (ICTY).

Figure 2.2c "Hot glue" adhesive material is used to reconstruct fractured elements together (ICTY).

Figure 2.2d The base of the skull is reconstructed once the calotte is in place. (Printed with permission from International Criminal Tribunal for the former Yugoslavia.)

Reconstruction of the mandible and most postcranial elements tends to be simpler than that of the cranium, although extreme damage in the form of crushing and comminuted fractures may shatter structures, such as areas of spongy bone in the distal femur or lower vertebra. Fractures through thick areas of trabecular bone from crushing mechanisms may be more difficult to reconstruct. Nevertheless, attention to the outer cortex of the remaining bone will often reveal typical wound characteristics that allow the mechanism of the injury to be estimated.

The largest fragments should be reconstructed first, followed by smaller sections of bone added to the primary or larger piece. To begin, investigators work through the fragments, uniting segments into units and then combining the units together. These units may then be combined to whatever extent possible and added to the bone from which it fractured. Figure 2.3 illustrates the reconstruction of a comminuted fracture to the femoral shaft fragmented by a gunshot wound in an autopsy case.

Successful reconstructions are dependent on expert knowledge of osteology and the ability to recognize and position small fragments of bone. Of equal importance is good

Figure 2.3a The projectile penetrated from the lateral aspect of the left thigh and exited through its medial wall, creating a keyhole defect on the anterior wall of the proximal one-third of the femoral shaft. Trajectory of the bullet demonstrates piercing of the femoral artery. (Reprinted with permission from Baraybar, J.P. and Gasior, M. 2006. Forensic anthropology and the determination of the most probable cause of death: an example from Bosnia and Herzegovina. *J Forensic Sci* 51(1): 103–108.)

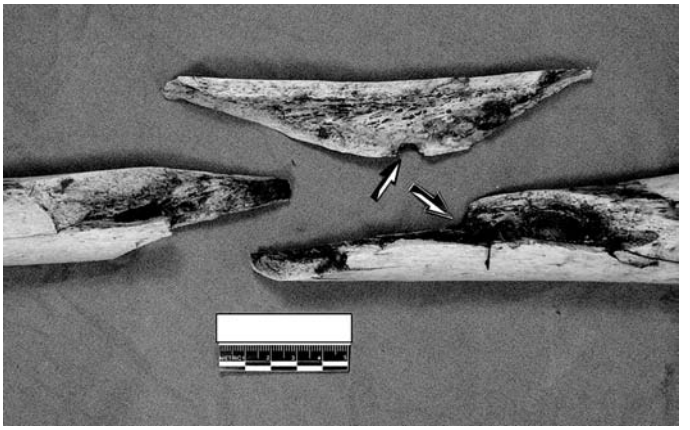

Figure 2.3b Comminute femoral shaft before reconstruction. (Reprinted with permission from Baraybar, J.P. and Gasior, M. 2006. Forensic anthropology and the determination of the most probable cause of death: an example from Bosnia and Herzegovina. *J Forensic Sci* 51(1): 103–108.)

archaeological recovery of all fragments. Therefore, careful excavation and assessment of clothing is crucial, as small fragments may be embedded in clothing or become disarticulated following decomposition of the soft tissues. The type of weaponry or blasting material used to create the injury may also compromise the recovery of fragments. Bone and tissue may be expelled at the time of injury or pass through the body as secondary projectiles and therefore not even be present at the time of burial. The use of *secondary burials*, in which graves are dug up and moved to new and different sites also results in a loss of materials as bone becomes exposed and small fragments disarticulated. Ultimately, complete recovery of all skeletal elements depends on the context and archaeological excavation of the grave. Despite great efforts in some cases to hide burials (Schmitt 2001; Skinner et al. 2001), skeletal fragments resulting from gunfire wounds to the head have been recovered from multiple sites and rearticulated in the laboratory.

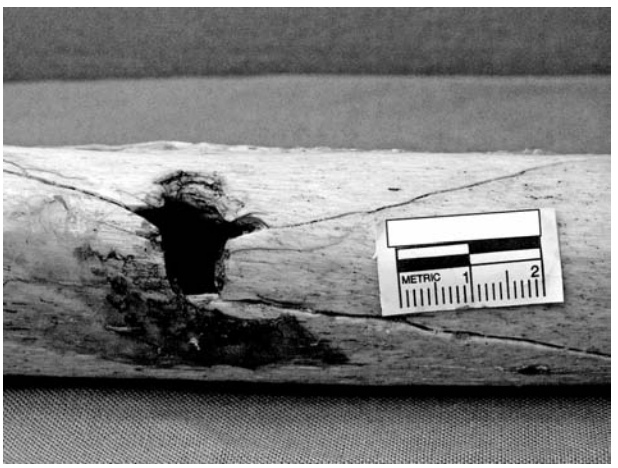

Figure 2.3c Reconstruction of a femur exhibiting a through-and-through single gunshot to the left thigh with high-velocity ammunition, 7.62 × 39 mm. (Reprinted with permission from Baraybar, J.P. and Gasior, M. 2006. Forensic anthropology and the determination of the most probable cause of death: an example from Bosnia and Herzegovina. *J Forensic Sci* 51(1): 103–108.)