The Utility of Forensic Anthropology in the Medical Examiner's Office

Christian M. Crowder, Jason M. Wiersema, Bradley J. Adams, Dana E. Austin, Jennifer C. Love

ABSTRACT

Over the past few decades, the field of forensic anthropology has seen major advancements and experienced a considerable growth of professionals in medical examiner/coroner offices. Despite this expansion, misconceptions regarding the role and utility of the anthropologist in the medicolegal setting still exist. This article brings together practitioners employed full-time in four medical examiner's offices, with each practitioner providing a unique perspective and emphasis regarding their role as an anthropologist. Discussed is the history of the anthropology division in each office as well as the types of casework and ancillary duties completed by the anthropologists. Consistently, the anthropologists are involved in the search and recovery of human remains, managing long-term unidentified cases, facilitating disposition of unclaimed decedents, and developing mass disaster protocols for their respective agency. Also consistent across the four offices is the fact that the anthropologists receive far more consult requests for trauma evaluation of nonskeletonized cases than any other type of case. *Acad Forensic Pathol. 2016 6(3): 349-360*

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INTRODUCTION

The evolution of the field of forensic anthropology is signified by the broadening of the discipline's scope of work and the growing presence of anthropologists in medical examiner/coroner offices. These two aspects are interrelated considering that the increasing representation of anthropologists in the medicolegal context correlates with the burgeoning breadth of forensic anthropological applications. In medicolegal death investigation, the utility of anthropology has grown beyond traditional skeletal analysis involving the construction of the biological profile (age, sex, ancestry, and stature). More common roles today include skeletal trauma analysis and decedent identification. Despite advancements of training and research in forensic anthropology, the misconception appears to persist that the utility of the forensic anthropologist is limited to the analysis of unidentified skeletal remains or simply the application of physical anthropology methods and theory to medicolegal skeletal casework. Therefore, the perceived need for anthropology staff in medical examiner and coroner offices may often be gauged by how many unidentified skeletal cases are received annually.

Medical examiners and coroners (ME/C) typically consult a forensic anthropologist who is on staff at their facility or employed by a local university or museum. Further, the Federal Bureau of Investigation (FBI) Laboratory and The University of North Texas Health Science Center - Center for Human Identification are federally funded agencies that provide anthropology services to ME/C upon request through law enforcement. There are numerous advantages to having a full-time anthropologist working at ME/C offices. These include rapid response for scene or autopsy consultations, prompt completion of case reports, and continuity with chain of custody within the same agency. In addition, full-time forensic anthropologists often assume additional roles in the ME/C office. Currently, anthropologists employed by ME/C offices are responsible for daily tasks such as supervising other divisions within the office, managing long-term unidentified decedent cases, facilitating final disposition for unclaimed decedents, submitting and tracking DNA submissions for decedent identifications, and coordinating tissue procurement agencies. Staff anthropologists in many offices have handled larger projects such as the development or enhancement of existing mass disaster response protocols along with contributions toward training and implementation. Contributions to training and research programs have allowed for creation of postdoctoral fellowship programs and enhancements to pathology fellow learning opportunities.

Currently, there are fewer than 15 forensic anthropologists certified by the American Board of Forensic Anthropology (ABFA) who hold full-time positions in a ME/C office. The number of nonboard-certified anthropologists with full-time positions in ME/C offices is not well documented. There are several offices that employ an anthropologist primarily in another role, such as death investigator or autopsy technician, who are consulted for skeletal cases when needed. In these instances, the anthropologists are typically not ABFA board-certified and may have a master's degree rather than a PhD. The largest employer of forensic anthropologists is the Department of Defense POW/MIA Accounting Agency. Other federal agencies that employ full-time forensic anthropologists include the FBI and the Armed Forces Medical Examiner System.

This article brings together anthropologists employed full-time by four large medical examiner's offices, either as sole practitioners or within multi-staffed divisions, to review the breadth and variation of their contributions. Each practitioner provides a perspective of their roles based on the context and region in which they work. The following information is provided by each practitioner regarding their office: 1) the history and structure of the anthropology position, 2) the roles of the anthropologist(s), 3) a summary of casework activity and statistics, and 4) non-casework activities (database management, research, teaching, and training). The goal of this paper is to demonstrate the utility of the anthropologist in the medicolegal setting.

DISCUSSION

Harris County Institute of Forensic Sciences–Houston, Texas

The Harris County Institute of Forensic Sciences (HCIFS) serves primarily Harris County, a population of four million, and provides limited services to several surrounding counties. The HCIFS is organized into the Crime Laboratory Service and the Medical Examiner Service, which consists of five divisions: Forensic Pathology, Forensic Investigations and Emergency Management, Morgue Services, Forensic Imaging, and Anthropology. The Medical Examiner Service is accredited by the National Association of Medical Examiners and the Texas Medical Association Continuing Medical Education program, and offers a Forensic Pathology Fellowship accredited by the Accreditation Council for Graduate Medical Education. In addition to these accreditations, the HCIFS holds three other accreditations within its crime laboratory: American Society of Crime Laboratory Directors/Laboratory Accreditation Board - International (ASCLD/LAB-International), the Texas Forensic Science Commission, and the American Board of Forensic Toxicology. In 2015, the Forensic Anthropology Laboratory was the first medical examiner's office in the United States to achieve accreditation under the American National Standards Institute – American Society for Quality (ANSI-ASQ) National Accreditation Board (ANAB) ISO/IEC 17020 Forensic Inspection Agency Accreditation program.

In 2006, three PhD-level anthropologists were hired at the HCIFS, resulting in the establishment of the Forensic Anthropology Division (FAD). The mission of the FAD is to provide anthropological consultation to the medical examiner for active cases, 24-hour scene response capability to assist with scene investigations, and to assist with the decedent identification. The FAD also maintains leadership of the Identification and Disposition Committee, which was developed to resolve identification issues in current cases, submit and track DNA samples, review and maintain long-term unidentified decedent case files, and assist with decedent referrals to county burial. Currently, the FAD consists of four doctoral-level forensic anthropologists, three of which are board-certified. Three of these positions have additional responsibilities outside of the FAD. One member manages tissue procurement activities and county burial referrals for unknown or unclaimed decedents, another directs the forensic investigations and emergency management division, and the third is a training coordinator for the Quality Division.

In 2015, the FAD received over 300 requests for anthropologic analysis, representing a 35% increase from its first full year of service in 2007. These requests include consultation resulting in verbal and written reports, scene recoveries, trials, and pretrial consultations. **Figures 1 and 2** demonstrate the breadth of anthropological casework at the HCIFS. The bulk of FAD caseload (69% in 2015) is trauma analysis, which has steadily increased from 53% in 2007. It should be noted that the majority of the trauma analyses involve fleshed and/or moderately decomposed remains. Interestingly, the number of skeletonized cases varies significantly on an annual basis, from a low of six in 2007 to a high of 34 in 2012. While these cases tend to require more in-depth analysis and time for examination, they constitute a small percentage of the overall caseload.

The anthropologists at the HCIFS are highly active in research and publication. They regularly present research findings at scientific meetings such as the American Academy of Forensic Sciences, International Association of Identification, and National Association of Medical Examiners. The division conducts original research and has post-doctorate and summer internship training programs. The anthropologists are also active as members of scientific working groups in forensic anthropology. The FAD has a robust training program for Anthropology staff and fellows at the HCIFS and has obtained grant funding for forensic anthropology fellowships and research positions.

At the HCIFS, the FAD is also involved in the training of various forensic practitioners and students. The FAD provides lectures for the rotating medical residents and students, law enforcement, legal personnel, new HCIFS employees, interns, and some members

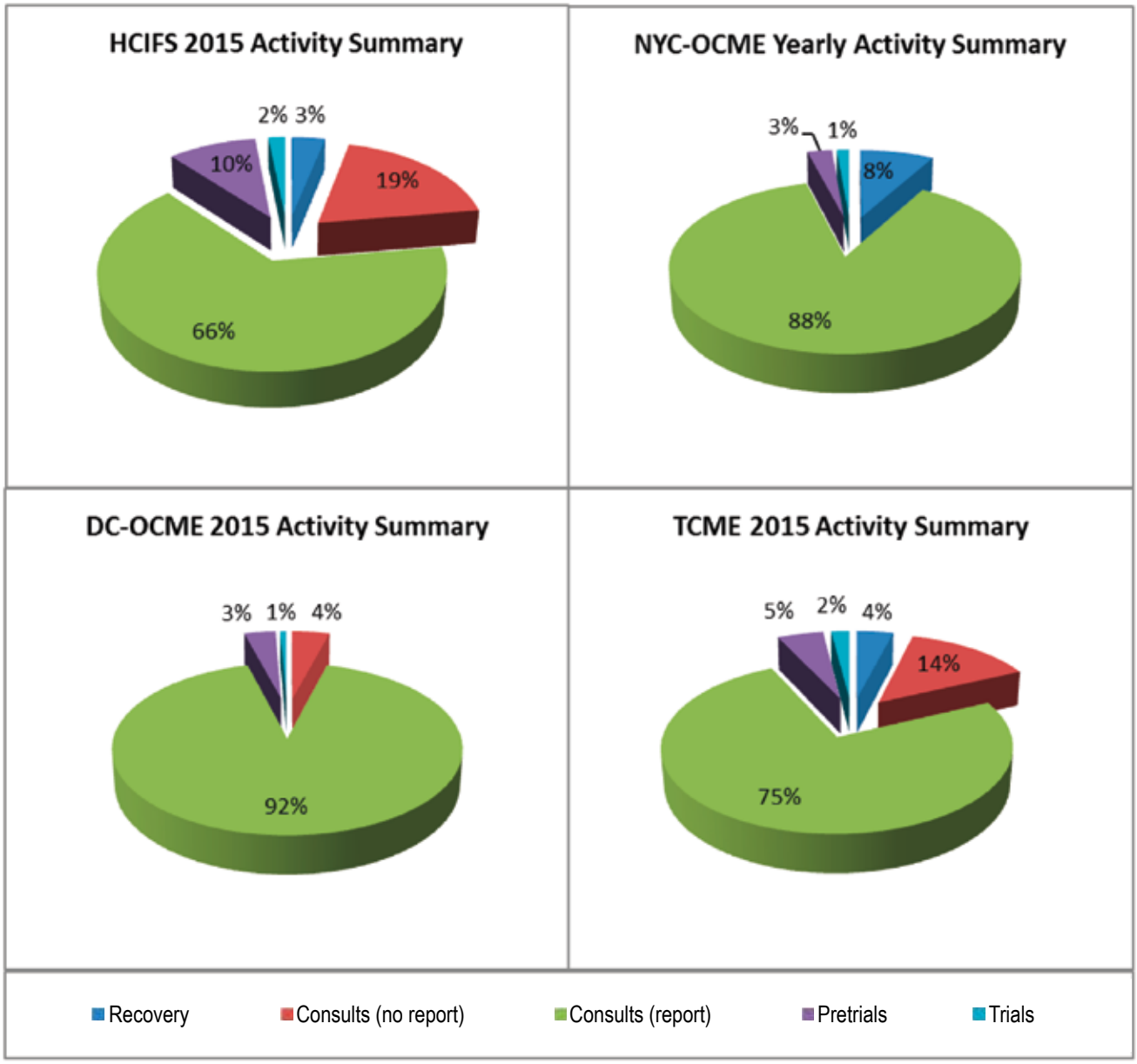

Figure 1: Breakdown (in percent) of typical anthropological activity in 2015 for Harris County Institute of Forensic Sciences (HCIFS), District of Columbia Office of the Chief Medical Examiner (DC-OCME), and the Tarrant County Office of the Chief Medical Examiner and Forensic Laboratories (TCME), while New York City Office of Chief Medical Examiner (NYC-OCME) shows the average activity over multiple years. The percentages do not reflect the volume of casework, but rather the distribution of workload. The activity categories are considered mutually exclusive even though a single case depicted in the percentage may be counted in more than one category (e.g., field recovery, consult-report, and pretrial). These activities represent significantly different interactions with casework.

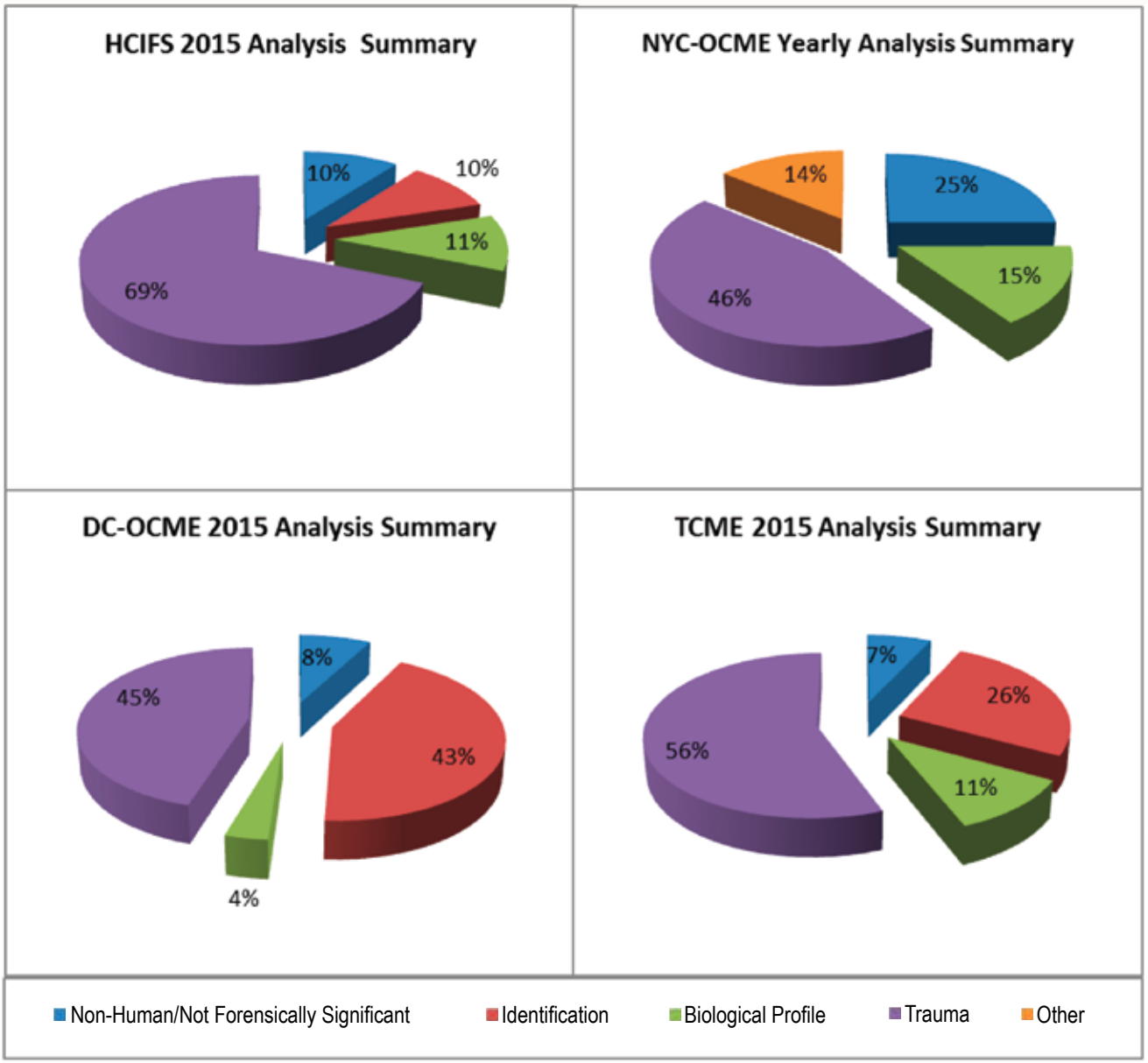

Figure 2: Breakdown (in percent) of anthropological analysis requested in 2015 for Harris County Institute of Forensic Sciences (HCIFS), District of Columbia Office of the Chief Medical Examiner (DC-OCME), and the Tarrant County Office of the Chief Medical Examiner and Forensic Laboratories (TCME), while New York City Office of Chief Medical Examiner (NYC-OCME) shows the average over multiple years. In order to provide continuity between the offices depicted, the analyses performed were distilled into five categories, with four representing specific types of analyses requested. The identification category includes cases in which the anthropologist performed antemortem and postmortem comparisons. The "Other" category for NYC-OCME represents analyses such as reassociation of fragmentary remains and evaluation of exhumation cases from City Burial. The data are presented in percentages considering that the categories are not mutually exclusive, meaning that a case submitted for analysis may involve multiple categories.

of the general public. The forensic pathology fellows are provided hands-on training in anthropological techniques. Each year, the FAD mentors one anthropology intern, typically a graduate student, who observes the anthropologists during their daily casework and is mentored in a research project that they present at the end of their internship. When grant funding is available, the FAD offers a Forensic Anthropology Postdoctoral Fellowship with the purpose of training individuals to be practitioners. The FAD personnel conduct other training courses and hands-on workshops for specialized law enforcement groups, such as FBI Evidence Response Teams, and participate in the annual Topics in Forensic Science Conference hosted by the HCIFS.

In addition to internal and external training the FAD is involved in community outreach projects. One example of this was the development of "Missing in Harris County Day." The program was designed to raise awareness of missing persons in the Harris County area and provide members of the community, who have missing loved ones, a place to file a missing persons report with law enforcement officers, have the missing person's information entered into the National Missing and Unidentified Persons System (NamUs) database, and voluntarily provide familial DNA samples for identification purposes. More information on this initiative and similar programs can be found in the article authored by Derrick and Figura within this issue (1).

In order to improve mass fatality preparedness and streamline daily operations, emergency management, forensic investigations, and forensic anthropology have integrated roles at the HCIFS. Emergency management in the medicolegal setting is, at least in part, synonymous with mass fatality response. The methods employed in the mass fatality context are simply modifications of the same methods employed to manage daily cases by the operational areas (Pathology, Anthropology, Investigations and Morgue). In order to best prepare the HCIFS to accommodate a surge in cases associated with a mass fatality incident, the agency has elected to incorporate techniques for the management of large numbers of remains into the daily operations of the Investigations Division. The primary changes made to accommodate this integration were 1) to completely integrate the Forensic Investigations and Emergency Management into a single division, which is directed by a staff anthropologist, and 2) to modify the agency's identification procedures to reflect the daily adoption of emergency management concepts. As part of this process, the identification policies for the office were integrated into a single multidisciplinary strategy that operates under the administrative supervision of the Director of Forensic Anthropology and the operational direction of the Identification Manager, a newly created ancillary position also filled by a staff anthropologist. This arrangement benefits the efficiency of the identification of daily cases, and by extension, better positions the HCIFS to manage its operations in the emergency context.

New York City Office of Chief Medical Examiner

Originally established in 1918, the New York City Office of Chief Medical Examiner (NYC-OCME) currently employs approximately 30 medical examiners and performs an average of 5500 autopsies each year. The agency also offers the country's largest forensic pathology fellowship program, having produced 100 board-certified forensic pathologists since 1990. Headquartered in Manhattan, the NYC-OCME has operations in all five boroughs of New York. In addition to standard medical examiner services, the NYC-OCME is home to the largest public DNA crime laboratory in North America, a toxicology laboratory, a histology laboratory, a forensic anthropology laboratory, and the nation's only public molecular genetics laboratory. The NYC-OCME also maintains a division of specially trained experts to respond to any mass fatality event.

In 1999, the NYC-OCME hired its first full-time forensic anthropologist. Since that time, the role of forensic anthropology within the agency has expanded. This expansion is largely due to New York City's high volume of cases, as well as the complex investigations associated with the 9/11/2001 World Trade Center (WTC) disaster. Since 1999, the core staffing level of full-time forensic anthropologists has fluctuated between one and eight people; however, this does not

account for the large number of anthropologists who have been temporarily hired to work on WTC related projects. Currently, the Forensic Anthropology Unit (FAU) consists of five full-time anthropologists (three assigned exclusively to the FAU and two who have additional responsibilities). Four of the anthropologists have PhD degrees and one has an MS degree. Two of these anthropologists are board-certified by the American Board of Forensic Anthropology.

Although headquartered in Manhattan, the FAU is responsible for coverage of all five boroughs in New York City (Brooklyn, the Bronx, Manhattan, Queens, and Staten Island), with a population of over eight million. The FAU is available to assist the medical examiners with gross and radiographic analysis of bone and cartilage. Generally, the FAU performs analyses and writes reports at the request of the staff medical examiners. Cases that may warrant anthropological consultation include decomposed or skeletonized remains, remains of questioned human or nonhuman origin or forensic significance, unidentified individuals, skeletal trauma (including blunt force, sharp force, gunshot, dismemberment, and thermal alteration), and skeletal pathologies and anomalies. The FAU is also available on-call 24 hours a day to assist medicolegal investigators with scene search and recovery. Depending on the circumstances, the FAU will respond to certain types of death scenes (e.g., buried bodies, surface scatters, and mass fatality incidents). **Figures 1 and 2** demonstrate the breadth of anthropological casework at the NYC-OCME.

Between 2005 and 2015, the FAU analyzed over 1400 cases. The annual caseload has fluctuated from a low of 72 cases to a high of 189 cases and an average of 127 cases (note: in general, a "case" signifies that a formal report was generated; informal consultations with medical examiners or medicolegal investigators that did not result in the generation of an anthropology report are not routinely tracked by the FAU). Approximately 75% of the total cases involve trauma and/or biological profile analysis and the remaining 25% of the cases involve remains that are not forensically significant (e.g., nonhuman remains or historic cemetery remains). Approximately 15% of the cases submitted to the FAU also involve a scene visit by FAU staff. The FAU is also a critical component of NYC-OCME's disaster response team. The FAU fills several roles within the disaster response team, which can be divided into three operational areas: Field, Morgue, and the Family Assistance Center. FAU members are trained for various types of mass fatality events, including both routine and hazmat scenarios, through periodic large-scale, multi-agency drills that allow personnel to practice in a realistic context.

The FAU continues to play a lead role in the NYC-OCME's ongoing WTC operations. The various roles of the anthropologists involved with the WTC operations include forensic oversight of renewed search and recovery efforts (primarily conducted from 2006 to 2013), serving as custodians for the retention and release of over 11 000 WTC remains currently housed within the 9/11 Repository, being the primary point of contact for WTC victims' families, conducting DNA sampling, and completing an anthropological review of DNA results.

Members of the FAU are also involved in research and routinely present and publish research results. They are also active with various forensic organizations and have served as or currently serve as members on the Scientific Working Group of Forensic Anthropology, the Scientific Working Group on Disaster Victim Identification, the American Academy of Forensic Sciences, the American Board of Forensic Anthropology, the editorial board of the *Journal of Forensic Sciences*, and the Organization of Scientific Area Committees.

At the NYC-OCME, the FAU is very involved with both internal and external training for various forensic practitioners and students. The FAU provides training on basic forensic anthropology for the rotating medical residents and students as part of the NYC-OCME monthly lecture series. The FAU also works closely with the forensic pathology fellows each year, taking the opportunity to show young forensic pathologists how anthropologists can assist them with various aspects of their casework. Graduating fellows and pathologists who are slated to take the forensic pathology board examination are offered training in an-

thropological techniques. FAU personnel conduct other training courses, lectures, and hands-on workshops for groups such as the New York City Police Department (NYPD) Homicide Detectives, NYPD Crime Scene Unit, and the Fire Department of the City of New York Fire Marshalls. In addition, the FAU developed a Visiting Scientist Program that allows advanced graduate students and professionals with a forensic anthropology focus to gain professional development through immersion with the unit for one month. The Visiting Scientist Program was initiated in 2008 and as of the completion of the 2015/2016 program, 65 people have participated. Finally, the FAU mentors several interns per year. Most student interns are selected from the Human Skeletal Biology Masters Program in the Anthropology Department at New York University (of which several members of the FAU are affiliated faculty).

District of Columbia Office of the Chief Medical Examiner

The District of Columbia Office of the Chief Medical Examiner (DC-OCME) was established in 1971 and serves a population of approximately 650 000 residents. DC-OCME received full accreditation from the National Association of Medical Examiners in 2016. The office provides medical examiner and toxicology services to the District. The medical examiner services consist of five units: Anthropology, Identification, Investigation, Mass Fatality Preparation, and Pathology. In 2015, approximately 3000 deaths were reported to the office and DC-OCME accepted jurisdiction of 1085 cases. Of these, 714 cases were autopsied.

During a two-year interval (2002-2004) the office employed a master's-level anthropologist as the mortuary supervisor. In addition to managing the mortuary operations and staff, the anthropologist implemented methods to collect fingerprints from decomposed decedents thus greatly increasing the number of scientific identifications on these difficult cases. The anthropologist also processed all unclaimed decedents for final disposition and organized and reviewed long-term unidentified skeletal cases by compiling case data into a central database.

In 2014, a full-time forensic anthropology position and forensic anthropology laboratory were established in the office. Prior to 2014, traditional skeletal analyses and radiograph comparisons to establish identification were outsourced to forensic anthropologists at the National Museum of Natural History Department of Anthropology. With the hiring of a doctoral-level, American Board of Forensic Anthropology-certified forensic anthropologist, anthropological analyses came in-house and expanded from traditional skeletal cases to consultations of skeletal and fleshed decedents. The staff anthropologist responds to the autopsy suite to consult on skeletal findings and remove skeletal elements and cartilage, when necessary, for analysis. For example, the anthropologist is available to perform pediatric skeletal examinations (2) in cases suspicious for nonaccidental injury as well as fracture pattern analyses in cases of questionable fall versus assault. The on-site services reduced the anthropological analysis turnaround time from greater than a month to an average of 14 days. Furthermore, the anthropologist responds to death scenes that involve burned, skeletal, buried, or dismembered decedents to ensure thorough scene processing and decedent recovery. In 2015, the first full year of in-house anthropology services at the DC-OCME, the anthropologist received nearly 150 cases (**Figures 1 and 2**).

In addition to anthropology casework, the forensic anthropologist supervises the Identification Unit (ID Unit) and facilitates final disposition of unclaimed decedents. The ID Unit is a staff of six individuals who are responsible for facilitating visual identifications at the DC-OCME and fingerprint submissions to law enforcement. Also, the staff process death certificates through the electronic death reporting system, receive and process cremation requests, facilitate the release of decedents, and triage incoming telephone calls. In 2015, the anthropologist and ID Unit facilitated the final disposition of 98 unclaimed decedents. The average length of time between the date DC-OCME received the decedent and date of disposition was 56 days. The anthropologist, with the support of the ID Unit, reviews and processes unidentified decedent cold cases. Fingerprints are resubmitted to various agencies including the FBI and the Department of

Homeland Security. Decedent descriptions are entered into NamUs. DNA samples are submitted to the University of North Texas, Health Science Center for profile development and upload to CODIS, the Combined DNA Index System. To date, six unidentified decedent cold cases have been identified.

Finally, the forensic anthropologist played a large role in developing the office's mass fatality response plan; specifically, writing the mass fatality victim identification concept of operations (ConOp) and contributing to the scene response plan (SRP). The ConOp delineates acceptable identification methods under various circumstances, details antemortem and postmortem data collection protocols, defines the mechanism for systematic comparison of antemortem and postmortem data, and describes the case tracking and data management system. Relying on training in archaeological methods and techniques, the anthropologist made significant contributions to the SRP addressing fragmented decedents and decedent recovery from large structure collapses. The contributions included developing the search, documentation, and recovery of human remains protocol as well as a defining a numbering system for fragmented remains to be employed on scene.

Tarrant County Office of the Chief Medical Examiner and Forensic Laboratories–Fort Worth, Texas

The Tarrant County Office of the Chief Medical Examiner and Forensic Laboratories (TCME) in Fort Worth, Texas, provides autopsy, death investigation, and crime laboratory services for Tarrant, Parker, Denton, and Johnson Counties in North Texas. The office also provides autopsy services for multiple Justice of the Peace jurisdictions in surrounding counties and crime laboratory services for over 150 law enforcement agencies. The larger cities of Fort Worth, Arlington, Denton, and Weatherford are included in the region. A portion of the Dallas-Fort Worth International Airport, Texas Motor Speedway, multiple rail lines, U.S. Interstates, and multiple lakes fall within the jurisdiction.

The TCME divisions include Forensic Pathology, Forensic Death Investigation, Human Identification, Toxicology and Chemistry, Crime Laboratory, Morgue Services, Histology, Evidence, and Administration. The Crime Laboratories consist of Forensic Biology, Trace Analysis, Firearm and Toolmark Examination, Latent Fingerprints, and Forensic Photography. Forensic Anthropology falls under the Human identification division. The TCME is accredited by the Accreditation Council for Graduate Medical Education, The American Society of Crime Laboratory Directors/Laboratory Accreditation Board, and the National Association of Medical Examiners. In 2015, there were 11 013 reported deaths with 3567 Jurisdiction accepted cases. Over 3600 bodies were brought to the facility with 1494 receiving an external examination, 362 receiving a partial autopsy, and 1711 receiving a complete autopsy.

The Forensic Anthropologist position at TCME initially began as a Trace Evidence Analyst position. In 1993, a newly hired trace analyst with a master's degree in forensic anthropology replaced a consulting academic-based forensic anthropologist. This hiring practice continued as another master's-level anthropologist with duties in trace analysis and anthropology replaced the first trace analyst/anthropologist. In 1996, the current anthropologist was hired with a doctorate in anthropology, specialized training in forensic anthropology, and many years of graduate level casework experience that included morgue consultation with forensic pathologists. It should be noted that the anthropologist had a bachelor's of science in biochemistry that fulfilled the trace position minimum requirement of 30 hours of chemistry. The position remained a dual role within the trace analysis laboratory until 2003. Trace duties for the anthropologist primarily included collection of trace evidence from decedents, clothing, vehicles, and other items of evidence; hair and fiber identification and comparison; and fracture pattern matching. In 2003, the increased demand for anthropology services led to a single role position focused entirely on managing the anthropology laboratory. In 2006, the anthropologist was moved out of the Crime Laboratory administratively and placed within the newly constructed Human Identification Laboratory. The new unit consisted of a forensic odontology director, fingerprint specialists, and the forensic anthropologist.

The TCME Anthropology Laboratory is responsible for multiple tasks within the office. In 2015, the Anthropology Laboratory received nearly 90 cases (**Figure 1**). The evaluation of human remains originates with a request for assistance in the case by the assigned pathologist. The bulk of the anthropology laboratory casework is skeletal trauma analysis of decomposed, skeletal, burned, and fresh human remains (**Figure 2**). The climate in North Texas leads to a high number of decomposed remains that are examined at TCME. In fresh bodies, common trauma analyses for adult decedents include fracture documentation in the hyoid bone and neck cartilages in suspected strangulation cases, evaluation of gunshot wounds, blunt force trauma, and sharp force injury. Pediatric trauma cases are evaluated by analyzing skeletal segments of the body after removal and cleaning. In these cases, the pathologist and anthropologist determine which injuries to examine histologically and remove those sections prior to skeletal processing. Analysis combining histological cellular data with gross bone evidence is discussed jointly with the pathologists.

Traditional skeletal analysis to create a biological profile comprises about 10% of the casework (**Figure 2**). Metric data from the skeleton are collected with a digitizer and calipers and are analyzed with software to estimate sex, ancestry, and stature. Procedures including digital radiography, stereomicroscopy, and visual examination are used to evaluate the skeleton for antemortem conditions, perimortem trauma, and taphonomic indicators.

Positive identification by comparison of antemortem radiographic images with postmortem images is a common request, although the majority of the unidentified cases at TCME are resolved through fingerprint comparison (87% in 2015). In addition, the anthropologist maintains the database containing information on long-standing unresolved identity cases (3). This database includes the pertinent information on the circumstances of the case, the biological profile of the individual, and the results of comparisons with missing persons. This database was created in 2005 in response to the launch of the CODIS database for missing persons and unidentified bodies and a national impetus to resolve cold identity cases. The Anthropologist obtained all available fingerprint and DNA samples on the older cases and submitted them for processing and inclusion in various databases. Multiple identifications immediately resulted with additional identifications facilitated by the inclusion in CODIS.

Nonhuman bone identification and scene response are regularly requested services. Digital photography allows analysis of images of suspected nonhuman bones sent via telephone text message or email. This is a valuable service to any law enforcement agency that could potentially expend valuable resources on a case of no consequence. In cases of known human remains at a scene or suspected burials, the TCME anthropologist responds within the jurisdiction. The forensic anthropology field team at TCME is comprised of volunteer scientific staff who are given permission by their supervisors to respond to scenes at the request of the anthropologist. The occurrence of buried body and surface scatter recoveries ranges from two to seven annually. The extent of the recovery varies with each scene and time expenditure in the past has ranged from two hours to five days. Assistance to law enforcement agencies outside of the jurisdiction is offered remotely and involves the analysis of crime scene photographs and recommendations for best practices for an individual scene.

Additional duties for the forensic anthropologist include training of forensic pathology fellows and visiting scientists. The anthropologist also presents skeletal analysis findings to the pathologists when the case is reviewed. Court testimony, primarily limited to homicide trials, is required one to two times per year with an equal number of trial preparations for cases that end in plea agreements.

Summary

Examining the roles of the anthropologists in multiple medical examiner offices shows that the contribution of forensic anthropology far exceeds the role of simply examining skeletonized remains. Over several decades, there has been a paradigm shift in the conceptual framework by which the forensic anthropol-

ogist operates, with specific reference to the analysis of trauma and taphonomy, as well as the use of the anthropologist for recovery and death scene reconstruction (4). Furthermore, anthropologists assume supervisory positions beyond anthropology casework and are actively involved in other aspects of agency operations such as decedent identification, body disposition, and disaster preparedness. This shift has increased the need for anthropologists in the medical examiner's setting and has greatly expanded the role of forensic anthropology.

The authors have uniformly experienced that the anthropology caseload builds as medical examiners learn to appreciate the full range of assistance that forensic anthropologists can provide. In fact, as shown in **Figure 2**, skeletal trauma analysis is the most requested service, ranging from 45-69% of the total caseload received by the four forensic anthropology laboratories examined in this paper. Human identification for three of the offices comprised 10-43% of the annual caseload (**Figure 2**). The development of the biological profile was found to comprise 4-15% of the total case load and scene response occupied less than 10% of the total case load in all laboratories, with the majority below 5% (**Figures 1 and 2**). These percentages will vary somewhat from year to year, but the emphasis on assisting the pathologist with skeletal trauma analysis and identification of remains consistently comprises the bulk of the caseload.

As noted by Austin and Fulginiti (3) and exemplified in this paper, anthropologists within the medicolegal system frequently perform diverse roles in addition to laboratory analyses. These roles span into several operational areas; however, the areas that most frequently involve the anthropologist are mass fatality preparedness, management of long-term unidentified decedent cases, and research and training programs.

Regarding mass fatality incident (MFI) response, the anthropologist's skill set is typically employed in multiple operational areas including Field Operations, Morgue Operations, and the Family Assistance Center (FAC). During field operations, the anthropologist's training in archaeological methods is essential to ensure proper recovery and documentation of a scene, especially in complex instances involving body fragmentation. Regarding disaster morgue operations, the anthropologist assists in triage to evaluate remains and resolve any commingling of remains prior to examination by the forensic pathologist. The anthropologist also provides consultation for the pathologist during the examination of remains as described previously. Finally, anthropologists have been used in the FAC to assist with disaster victim identification, ensuring that the necessary antemortem records are collected. In addition to performing key roles during an incident, forensic anthropologists are frequently involved in the development of the agency's mass fatality response plan.

Long-term unidentified decedent database creation and maintenance is primarily undertaken by the anthropology laboratory in all of the offices discussed in this paper. The review of potential matches is assisted by fingerprint specialists, forensic odontologists, and forensic biologists, with the anthropologist guiding the process and tracking the results of the comparisons, as well as coordinating with law enforcement regarding these cases. The tracking of long-term unidentified decedent cases (i.e., cold cases) became a major consideration after 2005 when the National Institute of Justice supported medical examiner offices with grant opportunities to allow backlog reduction of these types of cases. Forensic anthropologists participate in national training and coordinate with state missing person clearinghouses to move these cases forward by entering accurate data into national databases, including NCIC (National Crime Information Center) and NamUs, as well as submitting DNA samples to CODIS. Anthropologists have proven to be well-qualified to review the case information, specifically the biological profile, and coordinate the efforts for the ME/C offices.

Knowledge in forensic practice is advanced through training and research. Furthermore, continuing education is essential for maintaining certification/licensure and facilitating professional development. The academic training of a forensic anthropologist emphasizes research and teaching, thus qualifying them to

contribute significantly in the education and training programs offered by the medical examiner's office. The training opportunities are an excellent way for various groups to understand the diverse roles of a forensic anthropologist. These may range from working with law enforcement on recovery scene protocols to introducing forensic pathology fellows to various types of laboratory analyses. The goal of this educational outreach is generally not to train personnel to become forensic anthropologists but rather for the participants to fully appreciate how forensic anthropologists can assist them in various aspects of their medicolegal death investigations.

CONCLUSION

As shown through the National Association of Medical Examiners accreditation checklist, utilization of forensic anthropology is an important component of medicolegal death investigation. More importantly, the contributions of forensic anthropology to a ME/C office far exceed consultation on unidentified skeletal remains. These contributions include, but are not limited to, scene response, skeletal trauma analysis, decedent identification, mass disaster response planning, long-term unidentified decedent case management, and other morgue operational tasks. The intent of this article is to showcase the various roles forensic anthropologists can play in a ME/C office. Perhaps with a better understanding of these roles by ME/C agencies, it will become more commonplace for ME/C offices to employ full-time forensic anthropologists.

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Skeletal Trauma: An Anthropological Review

Jennifer C. Love, Jason M. Wiersema

ABSTRACT

As anthropologists take on a larger role in medical examiner's offices, the incorporation of bone trauma analysis into the autopsy increases. The purpose of this invited review is to summarize recent anthropological literature that exemplifies the value of forensic anthropology in medicolegal death investigation, concentrating in the area of skeletal trauma analysis. Forensic anthropologists have a strong understanding of bone's response to trauma, gained through research and case studies. With this body of knowledge they are able to examine and interpret skeletal injury resulting from blunt, sharp, firearm, and thermal trauma. For example, toolmark class characteristics are recognized through sharp force injury examination, and fracture pattern analysis provides details of the impacting surface area. Interpretation of skeletal trauma allows for reconstruction of events surrounding death, and may inform the manner of death classification. *Acad Forensic Pathol. 2016 6(3): 463-477*

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INTRODUCTION

The forensic anthropologists' understanding of bone biomechanics position them to thoroughly and accurately evaluate skeletal trauma, which may provide information critical to the medicolegal death investigation. Anthropologists analyzing blunt force trauma fracture patterns can assess the minimum number of impacts, the direction of impacts, and details of the impacting surface. Tool mark analysis can lead to the recognition of class characteristics of a suspect weapon. Assessing thermal changes in bone allows for the conditions of the fire and the relationship of the body to the fire to be estimated. Anthropological consideration of ballistic defects can contribute to interpretation of projectile trajectory. Details obtained from skeletal analysis may have an impact on the manner of death classification, case investigation, and/or case adjudication.

As anthropologists take a larger role in medical examiner's offices, we see increased bone trauma analysis of skeletal as well as nonskeletal cases (1). The information gained through analysis informs not only the individual case but the field of forensic anthropology as well. The purpose of this invited review is to summarize recent anthropological literature that exemplifies the value of forensic anthropology in medicolegal death investigation, concentrating in the area of skeletal trauma analysis. The review is augmented with images taken from the authors' casework that demonstrate concepts discussed in the research.

DISCUSSION

Before reviewing recent anthropological literature in skeletal trauma analysis, a few concepts and terms need to be defined. Bone, like most material, is stronger under compressive rather than tensile stress. The compressive strength of bone is directly proportional to its density (2). The organic component of bone is elastic and capable of absorbing tensile and compressive forces. The load rate and duration dictate how bone will respond to stress. Continual slow loading stress causes elastic deformation (temporary bending of bonds between atoms), followed by plastic deformation (permanent bending of bonds between atoms) and finally failure. Rapid loading stress results in bone failure in absence of elastic and plastic deformation, behaving as a brittle material (2, 3). Slow loading stress is associated with blunt force trauma while rapid loading stress is associated with firearm trauma. Understanding fracture initiation and propagation is important to accurate fracture interpretation. Fracture initiation is the location of initial bone failure and fracture propagation is the course the fracture takes through the bone. Fracture propagation depends on the direction of force as well as bone microstructures and buttressing systems (3). Controlled impacts of bone have shown that fracture initiation and propagation are strongly affected by impact type, magnitude of force, and cortical thickness (2).

Blunt Force Trauma

Skeletal fractures resulting from blunt force trauma reflect the type, amount, and direction of the force causing the injury. Analysis of the fracture characteristics as well as the fracture distribution pattern is often informative to events surrounding death. For example, a rib fracture pattern resulting from a fall onto a broad surface area such as a floor is very different from a rib fracture pattern resulting from a physical assault with multiple strikes in various directions. In some cases, a fracture pattern analysis may assist the pathologist in the manner of death classification.

Bone biomechanical analysis and anthropological case studies have furthered our understanding of fracture mechanics. Both intrinsic and extrinsic factors affect how bone is fractured. Intrinsic factors include bone geometry, bone density, and stress risers (e.g., the buttresses system of the cranium) (2). Extrinsic factors include area of the impacting object, load velocity, and load weight (2, 3).

Cranial fracture patterns provide information on impact location and surface area of the impacting object. Fracture patterns are commonly described as linear, complex, and comminuted (4). Linear fractures have two end points and may be described as linear or curvilinear. Complex fractures have three or more end points; a stellate fracture is a common descriptor of a complex

fracture. Comminuted fractures are fractures that result in fragmentation of the bone. The different fracture patterns provide varying information regarding the impact.

Case reports illustrate anthropologists' success in linking cranial fracture patterns with suspect weapons. Love describes an anthropologic analysis of a cranial fracture pattern identifying a minimum of seven impact sites, consistent with strikes from an object of relatively small surface area (5). A bloodied hammer was recovered from the scene (**Image 1**). Ta'ala et al. presented ten cranial samples from a Cambodian skeletal collection of Khmer Rouge victims, each with a unique occipital fracture pattern that corresponded to the historical record of a particular execution method (6). The execution method described by several witnesses and an executioner as well as depicted in a prisoner's painting involves the victim kneeling over a large pit with his hands tied behind his back and an executioner striking him in the back of the neck with a blunt object. Further, documents discovered at the Tuol Sleng prison include terms related to kill or destroy that literally translate to "to smash" or "to shatter." The researchers examined 85 skulls held in a memorial at Choeung Ek, a mass grave used by the Khmer Rouge. Ten of the crania demonstrated substantial damage to the occiput that extended from the foramen magnum to the external occipital protuberance. The fracture pattern is consistent with the described execution method of striking a kneeling individual in the back of the neck.

Long bone and rib fractures provide information about the direction of force and type of impact as well and a significant amount of recent research is focused on these bones. For example, Reber and Simmons impacted 255 sheep femora with a pendulum apparatus using an accelerometer to measure the impact force magnitude and a high-speed camera to record the impact site and fracture propagation (7, 8). Evaluating

Image 1: Calotte with multiple impact sites consistent with strikes from an object of small surface area. The decedent was reportedly hit in the head with a hammer.

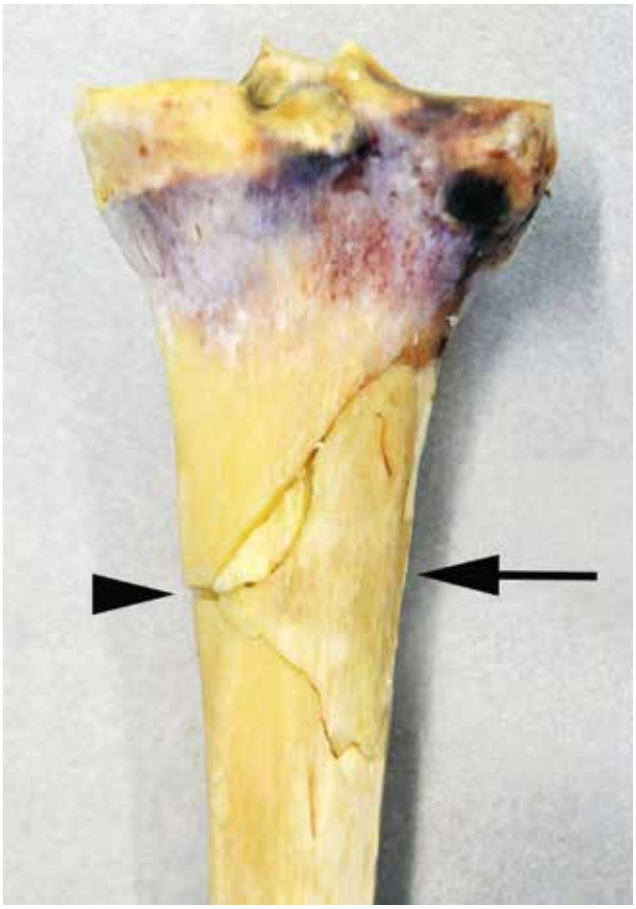

Image 2: Right tibia with a butterfly fracture. The triangle is marking the point of failure in tension and the arrow is indicating the direction of force.

the entire fracture pattern, including complete and incomplete fractures, the authors were able to pinpoint the impact location accurately on 98% of the samples. The authors described eight common fracture patterns. Each fracture pattern consisted of a complete fracture at the point of tension and radiating fractures coursing through the bone at various angles, acute and obtuse. The complete fracture at the point of tension was opposite to the point of impact in the majority of the specimens (**Image 2**). Christensen and Smith evaluated rib fractures resulting from blast trauma (9). The authors exposed 11 pigs to semi-controlled blast events. Tensile failures occurred along the pleural surface of the ribs in all of the pigs. The authors theorized that the blast created an expansive force causing the thorax to expand and the ribs to fail in tension on the pleural surface. The authors stated that blast fracture patterns are distinctive from ballistic and sharp force trauma patterns. Love and Symes examined rib fractures in 43 blunt force trauma cases and found, contrary to current biomechanical understanding, that ribs failed in compression prior to tension in the anterior region, an area of the rib with very thin cortical bone (10). The authors termed the fracture type "buckle fracture" and theorized that the failure was due to structural insufficiency as opposed to material properties. Furthermore, the authors equated these fractures with anterior to posterior forces applied to the anterior chest (**Image 3**).

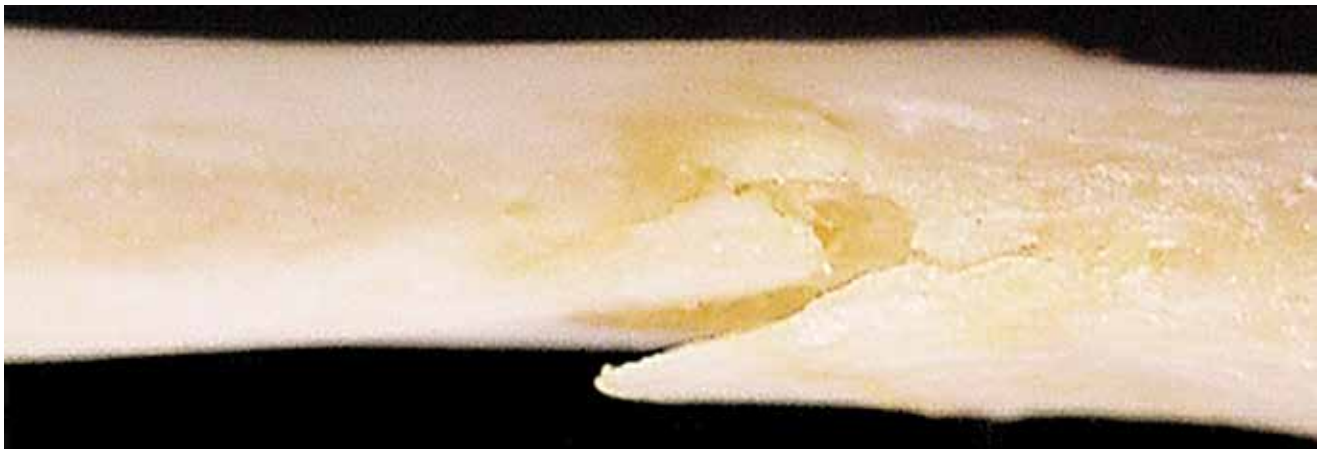

Image 3: Buckle fracture of an anterior rib. Note that the pleural surface (inferior) is folded onto itself, a failure from compressional forces.

Although a significant amount of anthropological research has enabled practitioners to accurately assess blunt force fracture patterns, other research has continued to raise questions. Most notably is research focused on fracture propagation within the cranium. Gurdjian and colleagues set the foundation for the research by evaluating the propagation of cranial fractures using a "stress coat" technique (11). The researchers coated dry human skulls with a brittle lacquer, dropped the skulls onto a hard surface and evaluated where the lacquer cracked. The team found that on the endocranial surface the cracks initiated at the impact site, regardless of the impact location on the skull. In contrast, the cracks of the ectocranial surface initiated at a location away from the impact site. Based on the lacquer cracking pattern, the researchers concluded that in-bending occurred at the impact site generating tensile forces on the endocranial surfaces and out-bending occurred around the impact site creating tensile forces on the ectocranial surface. Kroman and colleagues tested Gurdjian's theory using unembalmed human heads and a high-speed video camera (12). The researchers placed five human heads in a drop tower structure and struck each on the anterior parietal region with a mass weighing 8.58 kg. The complete skull was exposed except for a small patch of skin at the impact site. Evaluation of high-speed video showed that all fractures radiated out from the point of impact and no out-bending was observed. Baumer and colleagues also investigated fracture propagation using controlled impacts of infant porcine skulls (13). The researchers struck the parietal bone with either a rigid or compliant surface measuring the impact force, impact duration, and fracture length and documenting the location of each fracture. Of the 76 impacted crania, 70 crania were marked with fractures that initiated at the bone-suture boundaries and propagated towards the impact site. This finding is consistent with Gurdjian's theory and inconsistent with Kroman's theory. The use of different methods and human verses animal models limits the conclusions that can be drawn from the research. However, the difference in biomechanical response observed between the human adult and infant pig skulls is a cautionary tale that understandings developed using adult bone studies cannot be applied to pediatric bones without consideration for developmental differences.

Thermal Trauma

Thermal trauma poses unique challenges to decedent identification and recognition of sharp, blunt, or firearm traumata. The role of the forensic anthropologist in cases of thermal trauma often begins at the scene. Forensic anthropologists are trained to distinguish osseous from nonosseous material and human from non-human remains, skills necessary for sorting through fire debris. Furthermore, anthropologists are equipped to thoroughly document the scene, which is critical to maintaining fragment provenience and separating commingled remains. The importance of employing an anthropologist at the scene is best exemplified by the Black Saturday fires that occurred in Victoria, Australia on February 7, 2009 (14). The massive fires resulted in 145 separate scenes spread over 1500 square miles. Initial scene processing did not involve anthropologists. Ultimately, 86 of the scenes were revisited with an anthropologist and 56 additional victims were recovered.

Thermal destruction of bone results in the elimination of water, consumption of the organic components, color change, splitting, shrinkage, and warping (15); yet, significant information can be obtained from burned bone. Warping of bone precludes metric analysis for estimating the biological profile, but morphoscopic methods can be accurately applied (16). Osseous pathologic features are often recognizable in burned bone. For example, remnants of an ossified fracture callus remain adhered to bone despite destruction of soft tissue. Pathologic changes in bone shape (e.g., diffuse idiopathic skeletal hyperostosis) are visible in burned bone despite heat induced warping and shrinking (15). The color of the bone can provide information to the context of the burning and temperature (15, 17). For example green, yellow, pink, or red stains on bone signify that the bone was burned in the presence of metal such as copper, bronze or iron while blackened cortical bone suggest a lower temperature of approximately 300°C and white cortical bone suggests a higher temperature of approximately 800°C (15, 17).

Anthropologists have focused a notable amount of research on recognizing perimortem trauma in burned

bone. For example, Pope and Smith introduced sharp, blunt, and firearm traumata to forty donated unembalmed cadaver heads prior to thermal damage (18). Following the burning, the cranial bones were reconstructed and examined for signatures of trauma. Internal and external beveling and radiating fractures were observed in the crania subjected to ballistic trauma (**Image 4**). Impact sites and radiating fractures were observed in the crania subjected to blunt force trauma. Linear incisions and chop marks were observed in the crania subjected to sharp force trauma (**Image 5**). Herrmann and Bennett studied fracture patterns resulting from perimortem blunt, firearm, and sharp force traumata as well as thermal damage (19). Using pig femora, the team introduced sharp, blunt, and shotgun traumata prior to burning the remains. The researchers found that signatures of sharp force trauma were easily recognized on the burned bones, but radiopaque scatter was not observed in any of the specimens with shotgun trauma. They found differentiating between heat-induced and blunt force fractures was difficult. Marciniak evaluated saw marks for class characteristics in burned bone (20). The author created saw marks with manually and electrically power saws in pig femora prior to burning. She found that the false starts were well preserved, and diagnostic characteristics were observable in each saw mark after burning.

Sharp Force Trauma

When a knife or saw is used to cut bone or cartilage, signatures of the tool's cutting edge are recorded on the specimen (**Image 6**). A significant amount of research has focused on analyzing tool marks on bone and cartilage. Symes evaluated cut marks in bone made with 26 saws and serrated knives and described numerous features that reflected the class characteristics of the tools (21). The majority of the features reflected the design of the saw, most notably the tooth set and the distance between teeth (**Image 7**). Love et al. furthered Symes's work on saw marks by evaluating the discriminatory value of each characteristic (22). The team made experimental saw cuts in human femora using four saw types. They found that some features such as minimum kerf width, floor shape, and average tooth hop were highly replicable and informative class characteristics. Crowder and colleagues evaluated various class characteristics to assess associated error rates (23). The authors made cut marks in pig cartilage, deer femora, and casting material using serrated, partially serrated, and nonserrated knives.

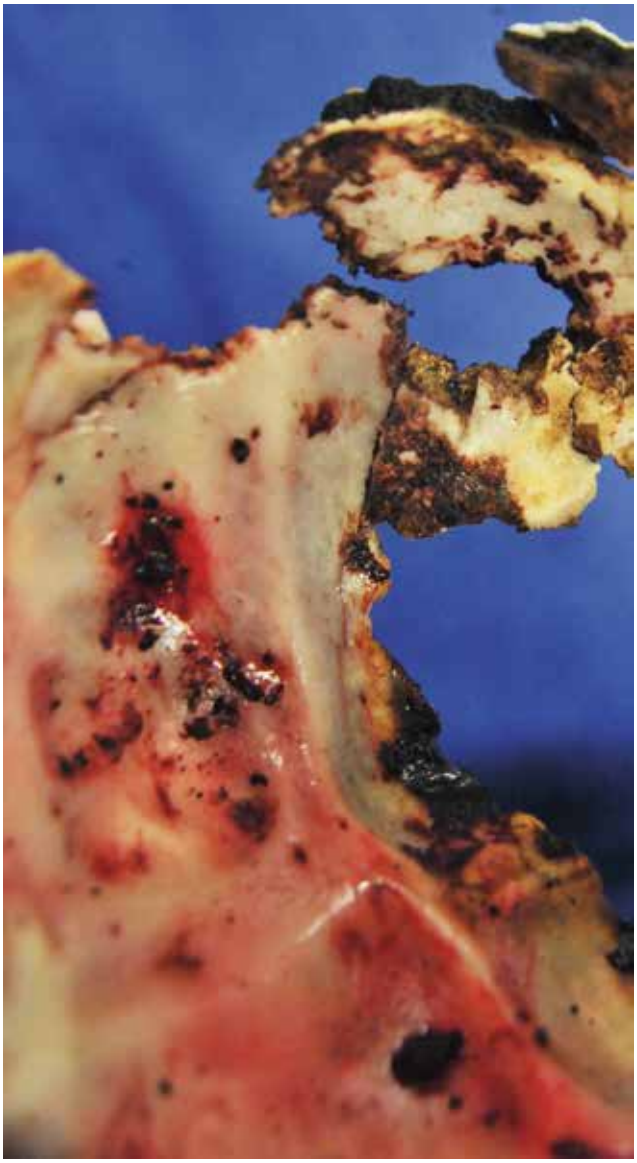

Image 4: Internal surface of a reconstructed occiput with an entrance gunshot wound (GSW). The decedent was burned in a car fire. The majority of the neurocranium was highly fragmented and required reconstruction to identify the GSW. Note the internal beveling of the wound margins.

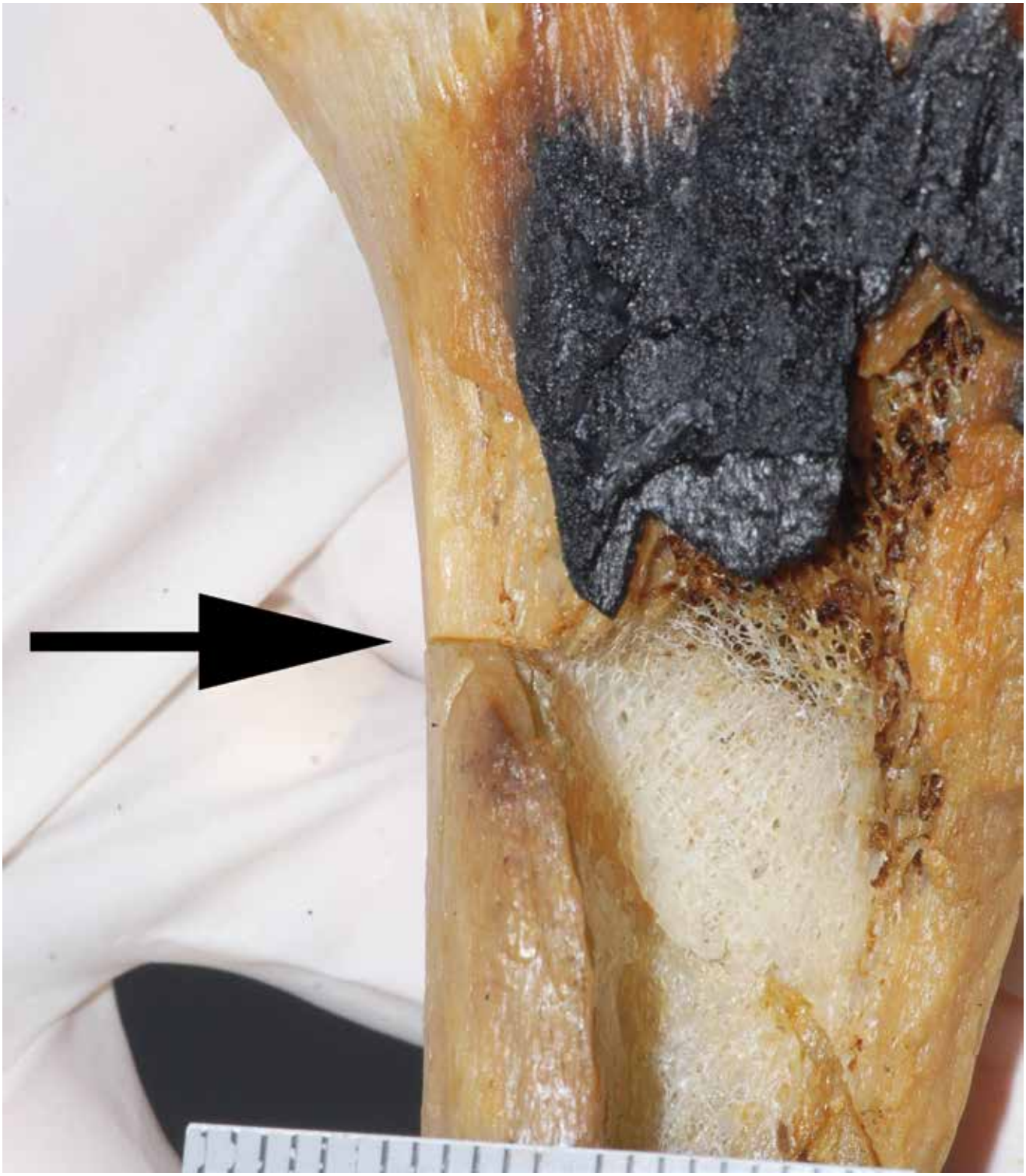

Image 5: Sharp force injury in a burned proximal femoral shaft. Note the straight margins of the cut mark (arrow).

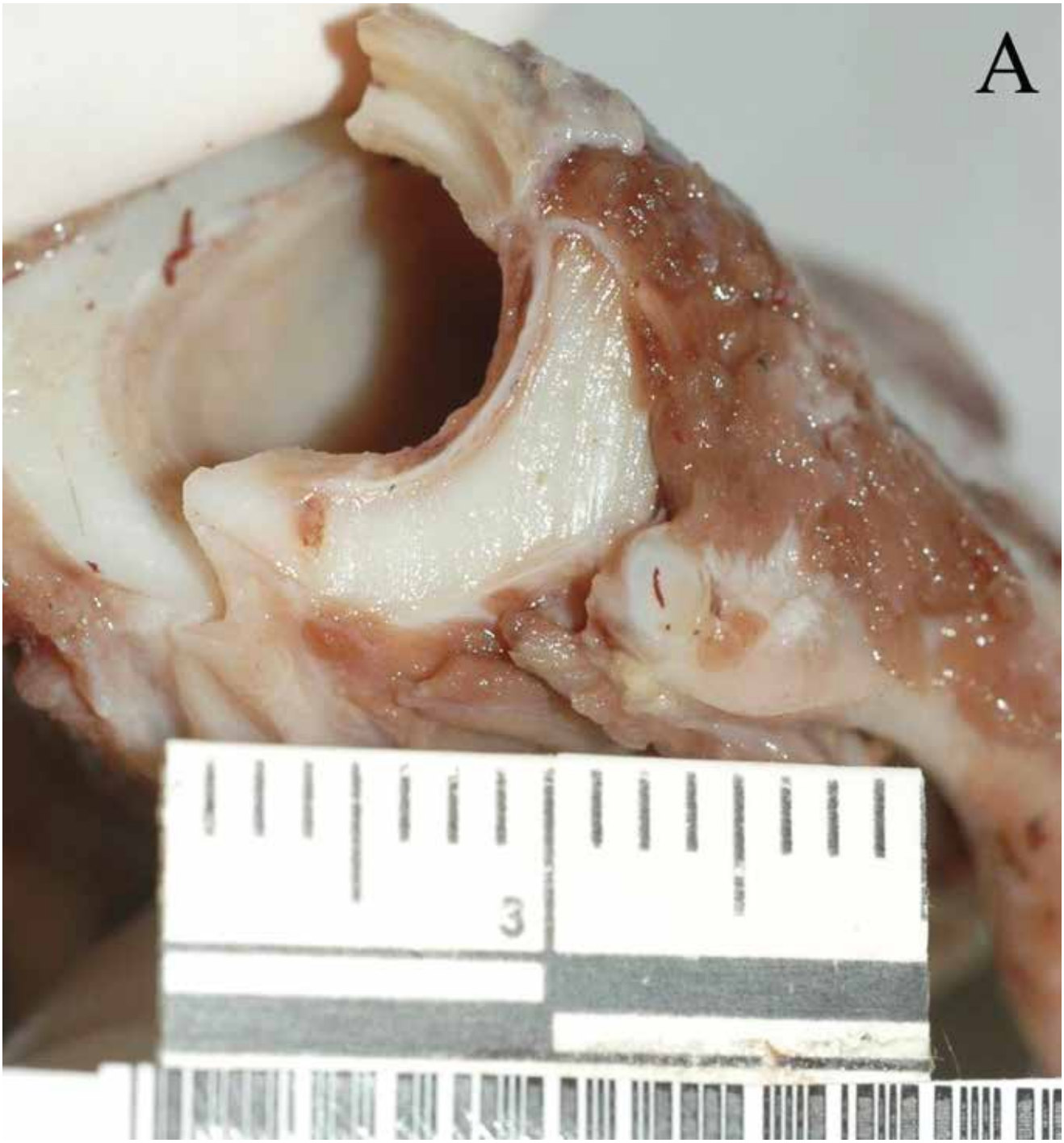

Image 6: A) Cut mark through the trachea.

Image 6: B) Cast of the cut mark through the trachea. Note the striation pattern indicating a tool with a major and minor serration pattern along the cutting edge.

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After combining serrated and partially serrated knives into a single group, the researchers found a 98% accuracy rate in recognizing the blade type from the cut mark.

Several sharp force trauma case studies illustrating tool mark analysis from bone and cartilage are published and tool mark analysis has been found admissible in court. For example, Reichs published six saw

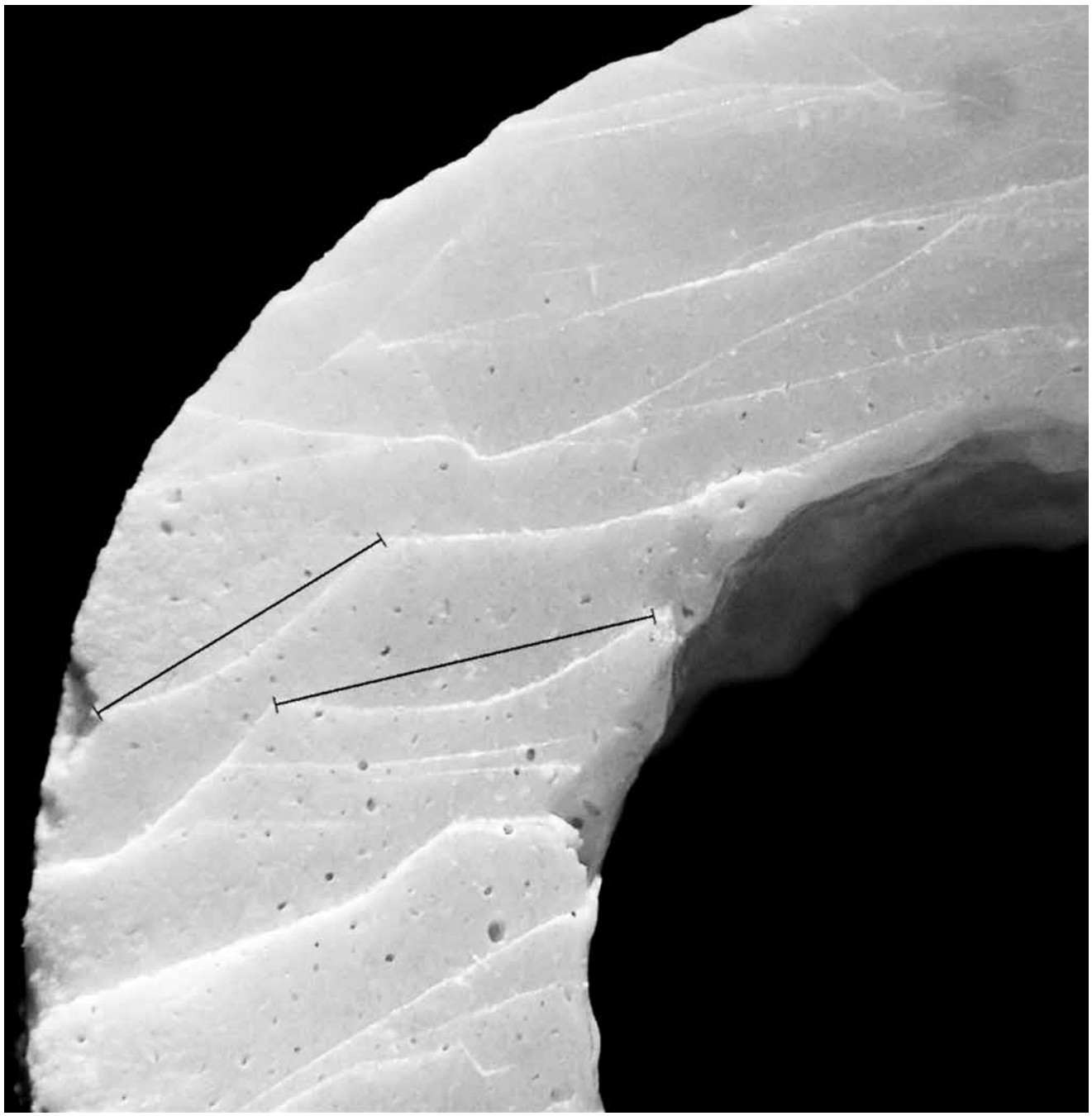

Image 7: Saw mark made with an eight teeth per inch alternating saw. The lines are marking the tooth hop. The peak to peak distance reflects the teeth per inch setting.

mark cases in her text *Forensic Osteology: Advances in the Identification of Human Remains* (24). In each case, she was able to identify class characteristic in the saw mark. In *Shepherd v. The State of Texas*, the anthropologist provided testimony regarding a tool mark analysis she performed on burned bone (25). During the trial, the defendant admitted to dismembering the victim with an electric jigsaw. The defendant was convicted and sentenced to 99 years of confinement. The defendant appealed the conviction on the grounds that the court erroneously admitted the tool mark testimony based on qualifications of the anthropologist and the reliability and relevance of the testimony. The appellate court found the anthropologist qualified to testify on the tool mark analysis and the testimony to be reliable and relevant under Texas Rule of Evidence 705.

Firearm Trauma

Forensic anthropologists are regularly asked to render their opinion on firearm injuries involving the skeleton. The specific questions asked typically involve projectile trajectory and number of separate impacts. The literature pertaining to the interpretation of ballistic wounds is fraught with problems (26), and has resulted in an oversimplified focus on projectile velocity as the primary factor influencing the characteristics of firearm injuries. For example, the terms "low velocity" and "high velocity" are commonly used to categorize penetrating firearm wounds. These are gradient terms and the thresholds used to demarcate them vary considerably. Ballistic definitions for low velocity vary from less than 400 feet per second to somewhere between 2000 and 3000 feet per second (26). By this definition, most handguns are considered low velocity, and many rifles are considered high velocity, but there is considerable overlap. In addition, velocity alone does not adequately account for variation in ballistic wounds. As with blunt trauma, the manifestation of ballistic injury is influenced by both intrinsic (e.g., bone density, geometry) and extrinsic factors (e.g., size, shape and velocity of impacting object) (2, 3, 26). This is true whether the impact material is soft tissue or bone. Bone exhibits considerable focal variability in its resistance to fracture based on morphology and structure. According to Young's Modulus, the capacity of a material (including bone) to resist fracture is dependent primarily on the rate at which a force is applied (2). In general, firearm projectiles impose rapid loads relative to blunt force impacts, and bone tends to respond to ballistic (rapid) loading as a brittle material. Regardless of the ballistic category of a particular weapon, there is no known biomechanical failure threshold that applies to all bones; but, the harder the tissue, the greater the amount of resistance it presents to an impacting projectile and the more destruction it will undergo upon failure (27). Bone is subject to reduced plastic deformation under higher velocity loads. Because of the relative lack of plastic deformation, the bone fragments resulting from ballistic impact are often numerous, but are more easily re-approximated to facilitate interpretation. Further, the lack of plastic deformation is suggestive of ballistic trauma in cases of incomplete reconstruction due to the extent of destruction or incomplete recovery of bone fragments.

The anthropological contribution to the interpretation of ballistic trauma is often through an anatomically informed reconstruction of bone fragments and subsequent interpretation of projectile trajectory. There is generally less tissue loss in bone than soft tissue, and with careful reconstruction, bones often present a detailed record of ballistic wound characteristics. Trabecular bone, as present in the ends of long bones and the bodies of flat bones like the innominate, and fragile cortical bone, as present in the ribs, the body of the scapula, and the midface, can provide an indication of projectile trajectory when carefully reconstructed. For example, anthropological reconstruction of the fragile bones of the midface can clarify the location and number of ballistic wounds.

Both gunshot and shotgun projectiles leave diagnostic defects in bone. Analysis of these defects enables projectile trajectory reconstruction (28-32). Kieser et al. examined experimental gunshot wounds in pig ribs and identified several consistent entrance and exit characteristics (32). The projectile created a cone within the rib with a smaller defect on the side of entry and a larger defect on the side of exit. Also, the exit

surface was beveled and radiating fractures extended outward from the wound (**Image 8**). However, experimental evaluation of gunshot wound size shows that caution should be exercised when using defect size to make inferences of projectile caliber (27, 34).

Anthropological interpretation of firearm trauma is dependent on recognizing diagnostic features that may be present on highly fragmented bone. Careful recovery of skeletal elements, some of which may appear too small to be of value, is important to wound reconstruction and subsequent interpretation of skeletal injury. Thus, the contribution of the anthropologist in cases of firearm injury may extend to the scene as well as collecting bone fragments in soft tissue during the autopsy.

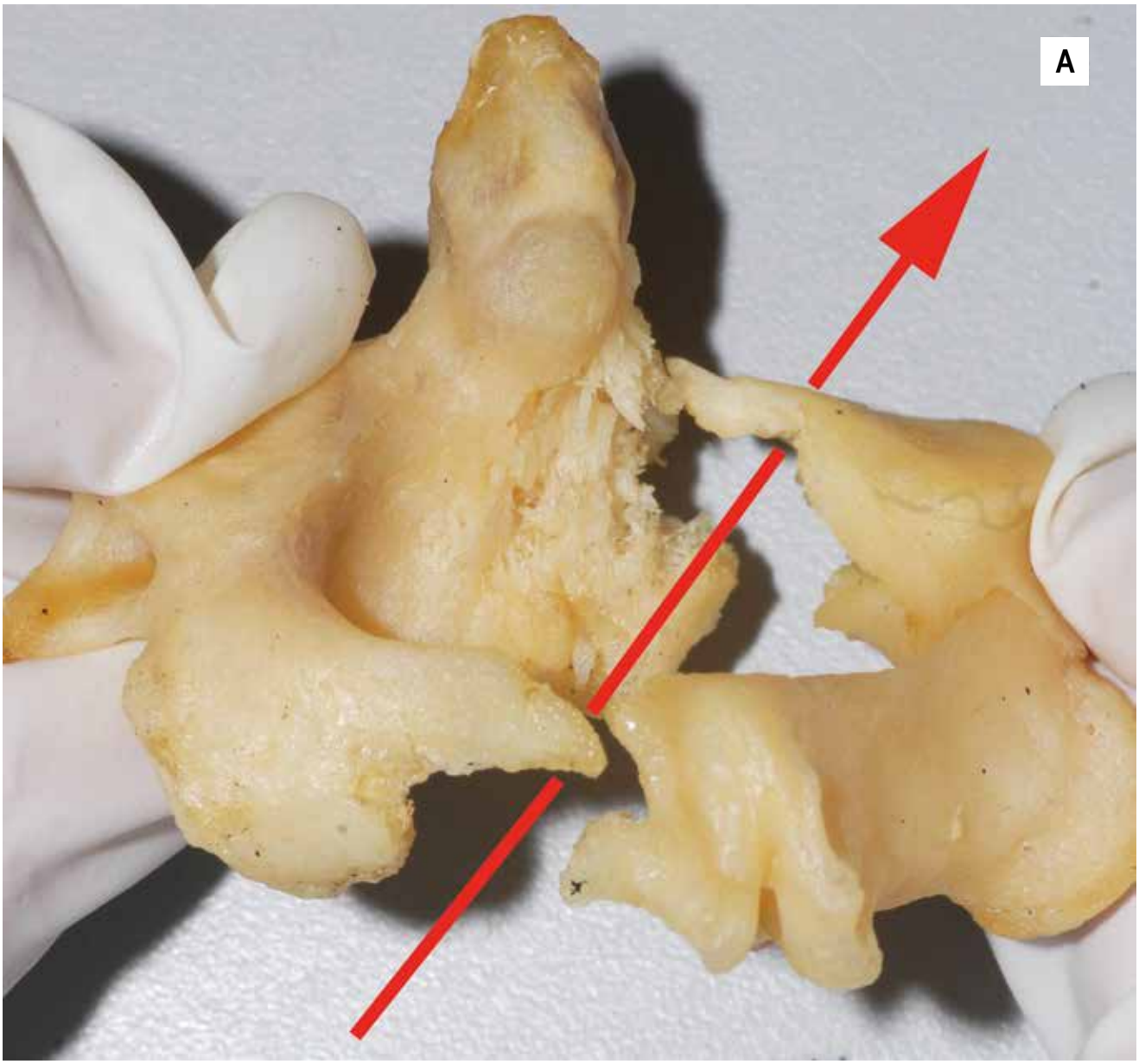

Image 8: A) Gunshot wound trajectory through a 2nd cervical vertebra.

CONCLUSION

Forensic anthropologists are well-trained to understand bone's response to trauma. Through careful reconstruction of fragmented bone and examination of fracture patterns and wound characteristics, anthropologists can interpret the type of force and minimum number of impacts as well as identify features of the tool. This information may allow for the events surrounding death to be reconstructed and may inform the manner of death classification, case investigation, and/or case adjudication.

Image 8: B) Gunshot wound trajectory through a 2nd cervical vertebra.