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Author: Barry Daly M.D., F.R.C.R., David R. Fowler, M.D.

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Utility of Whole-Body Computed Tomography Imaging in Post Mortem Detection of Elder Abuse and Neglect: Comparison with and Potential Substitution for Standard Autopsy

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Authors:

Barry Daly, MD–Principal Investigator
Professor, Department of Diagnostic Radiology and Nuclear Medicine
University of Maryland School of Medicine
22 S. Greene St.
Baltimore, MD 21201
Phone: 410-328-1285
Fax: 410-328-0641
E-mail: bdaly@umm.edu

David R. Fowler, MD
Chief Medical Examiner, State of Maryland
Office of the Chief Medical Examiner
900 W. Baltimore St.
Baltimore, MD 21201
Phone: 410-333-3225
E-mail: ocmemd@aol.com

Bios: Barry Daly, MD, is a professor and vice chair for research in the Department of Diagnostic Radiology and Nuclear Medicine at the University of Maryland School of Medicine. He heads the department's developing program in forensic imaging. David R. Fowler, MD, is chief medical examiner for the state of Maryland. An assistant professor of pathology and of pediatrics at the University of Maryland School of Medicine at Baltimore, he is on the faculty of the National Study Center for Trauma and Emergency Medical Services.

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Abstract

Purpose: Physical abuse as a contributing factor in the death of an elderly individual is difficult to exclude without a full conventional autopsy, even when allegations of abuse are focused on nonphysical issues. We investigated the potential for use of whole-body post mortem computed tomography (PMCT) as a triage tool to determine the need for conventional autopsy, based on detection of injuries suggestive of physical abuse and/or evidence suggestive of neglect.

Methods: This prospective study included 58 decedents (14 men, 44 women; mean age, 76 years, range 52–93 years), all of whom were referred to the Office of the Chief Medical Examiner for the State of Maryland following allegations of elder abuse. Each case underwent PMCT imaging and subsequent conventional autopsy within 24 hours after death. PMCT imaging results were interpreted by two radiologists with consensus readings. Conventional autopsy studies were performed and interpreted by state medical examiners. Interpretation of PMCT studies was made by radiologists without knowledge of the results of conventional autopsy, and the medical examiners were likewise unaware of the results of PMCT imaging. Sensitivity of PMCT for injuries suspicious for abuse, evidence of potential neglect, and other related findings were determined with conventional autopsy results serving as the standard of reference.

Results: PMCT agreed with conventional autopsy on the presence or absence of elder abuse in 100 percent of cases (evidence suggestive of elder abuse in one case, absence of evidence for elder abuse in 57 cases). In the single case suggestive of elder abuse, PMCT demonstrated multiple unreported fractures of varying ages. Other notable findings were acute rib fractures with patterns consistent with cardiopulmonary resuscitation etiology in 21 (36 percent) of decedents. These were detected on PMCT in 20/21 and on autopsy in 11/21 cases. Other musculoskeletal pathology overlooked at PMCT included a cervical and rib fracture and at autopsy included a cervical spine, hip, clavicle, and two sternal fractures. PMCT missed superficial decubitus ulcers in 9/17 cases but was more accurate than autopsy for characterization of deeper stage 4 ulcers with osteomyelitis or abscess complications. Cause of death was determined by conventional autopsy in all 58 cases but by PMCT in only 24 (41 percent) cases. PMCT was unable to detect vascular pathologies and less reliable than autopsy for detection of soft tissue pathologies, especially where the lesions were small. These included cerebral infarction, intracranial hemorrhage, pulmonary lesions, and tumors, with sensitivities of 0–50 percent.

Conclusion: PMCT was reliable for detection or exclusion of skeletal injuries suspicious for elder abuse. In correlation with clinical history, scene investigation, toxicology and external examination, PMCT may be used as a triage tool to determine the need for conventional autopsy in such cases. Superficial decubitus ulcerations are not detectable on PMCT studies but were easily detected on external examination of the skin either as part of external examination or a conventional autopsy. Deep decubitus ulcers and associated abscesses suggestive of neglect are more accurately characterized by PMCT than conventional autopsy. PMCT was unreliable for detection of vascular or soft tissue pathologies compared with autopsy. Determination of the cause of death was not a goal for PMCT in this study and, as expected, was not reliable for this purpose.

Executive Summary

Statement of the Problem

Reports of abuse and neglect of elderly individuals in residential care or within their own home have escalated along with the increasing number of older individuals in the United States (*1–3*). Authoritative researchers suggest that up to 10 percent of individuals over the age of 65 years will be victims of abuse or neglect and that approximately 80 percent of incidents of abuse will go unreported either before or after death (*4*). Physical, psychological, and financial abuses of the elderly have been explored in detail in the medical and legal literature (*5–12*). The literature is particularly rich with descriptions of screening strategies that physicians, nurses, and others can adopt for the systematic detection and reporting of abuse or risk of abuse in elder patients in nursing home and other long-term care (*13–29*). Yet identification of all but the most egregious incidents remains a challenge to physicians, social workers, and those charged with ensuring compliance with local, state, and federal regulations covering appropriate care (*30–42*).

Increasing public awareness of cases of abuse and neglect has created an atmosphere of suspicion in which many families fear the worst when loved ones die in nursing homes and other institutional long-term care settings (*55*). Law enforcement, legislative, and advocacy groups, too, are lobbying for routine autopsy of elders to discover possible elder abuse and homicide (*56,57*). The result is growing pressure on medical examiners to perform complete autopsies in decedents who would once have received simple visual inspection and death certificates (*58–60*). Elder individuals who die in hospitals are less and less likely to receive autopsies, as hospital autopsy rates continue to decline (*61*). Fewer than 1 percent of all nursing home deaths are currently autopsied in the United States (*47*), at a time when many medical examiners' offices are already stretched to and beyond capacity in managing workloads (*62–65*). Most medical examiners are ill equipped to handle the workloads that even a modest percentage increase in elder autopsies would require.

The significant challenge for medical examiners and their partners in the medical and legal communities is to identify cost- and time-effective methods for the identification of elder abuse and neglect that will provide reliable, validated information in cases of abuse and neglect, that can rule out suspicion of abuse or neglect in negative cases, and that can provide verifiable evidence to support the pursuit of justice. Such a test or tests also should ideally identify general and validated "markers" of elder abuse and neglect and offer a feasible, reproducible approach that streamlines and enhances assessment of elder decedents in whom abuse and neglect are suspected.

The current situation, then, is one in which the crime of elder abuse contributing to death is considered difficult to exclude without a full conventional autopsy, even when allegations of abuse may be of indeterminate reliability or are limited to nonphysical complaints. A full autopsy is a time consuming and expensive procedure. In the setting of limited capacity for expansion, the already overextended and understaffed medical examiner system is ill prepared to undertake even more such procedures.

Purpose

The purposes of this study were: (a) to determine the sensitivity of whole-body post mortem computed tomography (PMCT) for detection of injuries suggestive of physical abuse and/or neglect in deceased elders who were referred for investigation to the Maryland Office of the Chief Medical Examiner (OCME); and (b) to investigate the potential for use of PMCT as a triage tool to determine the need for conventional autopsy, based on detection of injuries suggestive of physical abuse and/or neglect and on information from other components of the medical examiners' routine initial investigations and assessment, including medical and police reports, external body examination, and toxicology studies. We also investigated whether PMCT was reliable for detection and characterization of decubitus ulcerations, with particular emphasis on the ability to characterize the severity of deep ulcerations that may be complicated by infectious involvement of underlying bone structures or abscess formation. Such deep ulcers and underlying bone infection (osteomyelitis) are findings that are suggestive of severe physical neglect that may also be associated with elder abuse.

Research design

The study was performed as a partnership between an academic radiology department and a state medical examiner's office. The study was prospective in nature and included the bodies of 58 decedents (14 men, women; mean age 76 years, range 52–93 years) in which allegations of elder abuse had been made by family members, caregivers, police, or physicians. Each body underwent whole-body PMCT imaging and subsequent conventional autopsy by state medical examiners within 24 hours after death. PMCT imaging results were interpreted with consensus readings by two radiologists with 3–24 months experience in forensic imaging. Conventional autopsy studies were performed and interpreted by state forensic medical examiners and included full medical and police reports, external body examinations, and toxicology studies. Performance and interpretation of PMCT studies were made by radiologists without knowledge of the results of conventional autopsy, and the medical examiners were likewise unaware of the results of PMCT imaging. Sensitivity of PMCT for injuries suspicious for abuse, evidence of potential neglect, and other major findings was determined with conventional autopsy considered as the standard of reference.

Key Findings

PMCT agreed with conventional autopsy on the presence or absence of elder abuse in 100 percent of cases (evidence of elder abuse in one case, absence of evidence of elder abuse in 57 cases). In the single case considered to be the result of elder abuse, PMCT demonstrated multiple unreported fractures of varying ages. PMCT identified decubitus ulcers possibly associated with neglect or abuse in 9 of 17 decedents with such findings. In three decubitus ulcer cases, deep ulcers with associated osteomyelitis or abscesses seen on PMCT were not detected at conventional autopsy. PMCT was insensitive for 8 cases with superficial decubitus ulcers. Other notable findings on PMCT were acute bilateral upper rib fractures consistent with known attempted cardiopulmonary resuscitation (CPR), seen in 20 of 21 such cases. Eleven of these 21 were overlooked at autopsy. Other fractures typical for accidental trauma (hip, cervical, clavicular, and 2 sternal fractures).were noted on PMCT in five decedents. These findings were overlooked on conventional autopsy. Conversely, PMCT failed to detect two fractures (cervical spine and rib) identified on conventional autopsy. Cause of death determination was made by PMCT in 24 of 58 (41 percent) and by conventional autopsy in all 58 cases. PMCT was insensitive for detection of natural vascular pathologies and less reliable for detection of cerebral infarction, intracranial hemorrhage, pulmonary lesions, and tumors.

The sensitivity of whole-body PMCT compared with autopsy for a range of vascular and soft tissue findings was poor and ranged from 0 to 50 percent. These findings overlooked at PMCT included eight small foci of subdural or subarachnoid hemorrhage, seven small areas of cerebral infarction, and two tumors (lung and gastric carcinoma).

Conclusions

PMCT appears to be reliable for detection or exclusion of skeletal injuries suspicious for elder abuse and, in correlation with clinical history, toxicology, and external examination, may be used to determine the need for additional investigation with conventional autopsy in the presence of allegations and/or suspicion of abuse. However, the single case positive for findings suggestive of elder abuse in this study (one of a total of 58) is a limiting factor. Deep decubitus ulcers and associated abscess or osteomyelitis suggestive of neglect are more accurately detected by PMCT than by conventional autopsy. Superficial decubitus ulcerations are not detectable on PMCT studies but were easily detected on external examination of the skin or as part of a conventional autopsy. Acute upper anterior bilateral rib fractures were more reliably detected on PMCT than at autopsy. This fracture pattern was unexpectedly seen in all decedents who underwent full CPR procedures and was likely related to the high prevalence of brittle osteoporotic bone in this elderly study population. Full autopsy, including medical and police reports, external body examination, and toxicology studies, was much more reliable for determination of cause of death than PMCT in this decedent group. This is an expected result given the well-recognized limitations and lack of sensitivity of CT for cardiovascular and malignant disease when performed without the increased sensitivity provided by intravenous and oral contrast, techniques routinely employed for CT examinations in the living. Subtle intracranial lesions, such as small infarcts or bleeding detectable at autopsy, may be undetectable on nonenhanced PMCT. The natural process of lung collapse after death also makes evaluation of pulmonary pathology on PMCT difficult.

Current practice in the Maryland OCME and Implications for Future Practice

After an analysis of the findings in this study, the Chief Medical Examiner (CME) for the State of Maryland has decided to continue the current institutional policy which includes performance of a PMCT study followed by full autopsy in all suspected cases of elder abuse or neglect. Despite the positive outcome of this study with respect to the sensitivity of PMCT for presence or absence of skeletal injuries suspicious for elder abuse, the very limited number of positive cases encountered has restricted the experience gained from the project, if not the conclusions that may be drawn with respect to clinical practice. David Fowler, MD, the Maryland CME believes that more experience should be gained with positive cases of elder abuse before the routine introduction of PMCT as a triage tool. The Maryland OCME is well positioned to introduce this process, because the facility now has a CT scanner installation on site suitable for all PMCT studies. After increased experience and familiarity with PMCT and continued demonstration of a high sensitivity in detection of suspicious injuries and/or evidence of neglect, it is considered very likely that this change will occur within the next year. This additional research will be the subject of an addendum to the current report. It is also expected that this additional time period will allow the accumulation of wider and deeper experience in forensic imaging among both the medical examiner staff and consulting radiologists at the University of Maryland School of Medicine, leading to improved sensitivity of PMCT studies for the entire spectrum of findings encountered in this cohort of 58 decedents.

Implications for Future Nationwide Policy

Global policy and practice implications of the successful completion of this evaluation of whole-body CT imaging in post mortem assessment can be seen in 2 distinct spheres of activity: (a) medical examiners' activities (including forensic radiologists' contributions); and (b) law enforcement and justice activities associated with identification and prosecution of elder abuse and neglect. Implications for each of these groups are discussed here.

Medical Examiners' Activities. For medical examiners facing an escalating demand to investigate cause of death in elderly individuals, one of the most promising benefits suggested by these results is that of greater efficiency, supported by compelling visual evidence. This is of considerable relevance in a setting in which authoritative publications estimate the prevalence of elder abuse at between 2 and 20 percent, based on various sampling, survey methods, and case definitions (4). Moreover, public exposure of cases of abuse and neglect has created an atmosphere of suspicion in which many families fear the worst when loved ones die in nursing homes and other institutional long-term care settings (*55*). Law enforcement, legislative, and advocacy groups, too, are lobbying for routine autopsy to discover possible elder abuse and homicide (*56,57*).

As anticipated, the finding in whole-body CT imaging of most decedents was "negative"; that is, no evidence of abuse or neglect was found by CT. **Every case of negative findings on CT was substantiated with corresponding findings on conventional autopsy, leading us to suggest that routine imaging of elder individuals may be proposed as a method for avoiding complete autopsy in more than 2/3 or more of elder decedents in whom abuse and neglect are suspected.** Using this whole-body CT protocol, the medical examiner's decision not to proceed to complete autopsy would be supported by detailed images interpreted by specialist board-certified physicians, ruling out fractures, internal bleeding, and other common findings in abuse and neglect. The acceptance of a written policy and protocol for eliminating the need for complete autopsy (but including, of course, visual inspection, toxicology studies, and other tests at the medical examiner's discretion) would not only have implications for cost efficiency and more timely processing of the overall medical examiner workload but would carry compassionate benefits for those families who, for religious or cultural reasons, are reluctant to have decedent relatives undergo invasive autopsy procedures. In those decedents in whom CT findings indicate evidence of abuse or neglect, these findings may serve to direct and expedite the medical examiner's performance of autopsy and the compilation of a complete report that will be supported by novel visual evidence.

The need to train additional radiologists (and forensic pathologists) nationally in the subspecialty of forensic imaging is an imperative for further growth. The experience and lessons learned from this study also will provide a template for dissemination of information about this topic, both through planned publication of manuscripts in appropriate forensic and radiology journals and through existing forensic medicine and innovative forensic imaging educational programs at the Maryland OCME, which are currently scheduled for the spring and fall of 2012.

Nationwide there is considerable interest in the outcome of this study, as evidenced by feedback from medical examiners attending the annual conference of the National Association of Medical Examiners (NAME), at which the final results of the study were presented in August 2011. The results did not produce unexpected findings, other than the high rate of rib fractures seen in decedents following attempted CPR and the clear advantage of PMCT over autopsy in that setting. Attendees volunteered that if PMCT were available at their offices, they would definitely use it for suspected elder abuse. Elder abuse should now become one of the accepted list of indications for PMCT; however, it must be acknowledged that the number of medical examiners facilities in which PMCT is available remains quite small. Several medical examiners at the NAME meeting pointed out that the presence of deep (stage 3–4) decubitus ulcers may of themselves be evidence for criminal neglect in a health care facility (53) and that PMCT offers excellent pictorial evidence.

This study should also be seen in the context of the broader potential of PMCT for investigation of accidental and non-accidental death by medical examiners: elder abuse is one of many potential indications, including but not limited to suspected homicide from blunt or penetrating trauma, child abuse, drowning, burns, unidentified remains, and indeterminate causes of death. In such situations high-resolution 3D imaging may have a valuable role in forensic work. As medical examiners become more familiar with the value of PMCT it is likely that more jurisdictions will acquire CT equipment to assist in forensic diagnosis (143), possibly on a regional basis, given the small size of many medical examiners offices. Although such a situation is unlikely to evolve in the immediate future, the recommendations to modernize death investigation outlined in the 2009 Institute of Medicine report on forensic science in the United States, strongly support updating the technological basis for forensic investigation over the next decade.

While the kind of detailed information that would inform a comparison of the relative costs of PMCT and autopsy is not readily available, the potential economic impact of introducing PMCT into forensic practice should be given appropriate consideration. Autopsy examinations are usually funded by local county, city or state jurisdictions in the setting of a medical examiners or coroners investigation and the actual costs of the autopsy procedure are not routinely separated out from other necessary expenses for such services. However the cost of a private autopsy performed at the request of a decedent's family has been noted to lie in the $2,000-4,000 range. Other anecdotal information has put the cost of autopsy as between $1,000 and $2,000. By comparison, the total cost of PMCT at the University of Maryland Medical Center is $600, comprising $500 for performance of the scan and $100 for its interpretation by the radiologist. Assuming this figure quoted at our institution is extrapolated to other centers, PMCT appears to be a cost-effective alternative to autopsy, even when the lowermost figure of $1,000 for autopsy quoted above is considered to be the most accurate. It must be borne in mind that the use of PMCT as a triage tool implies that an undetermined percentage of decedents with positive PMCT findings will proceed to full autopsy, potentially increasing the overall costs of investigation. However, the low percentage of suspicious cases on PMCT noted in our study suggests that this is unlikely to be a realistic concern. Regarding the time efficiency of PMCT, the duration of the scan itself should be no more than 10-15 minutes on any CT scanner machine capable of doing whole body examinations. 3-dimensional image generation and interpretation by a moderately experienced radiologist should require no more than 30 minutes. Therefore the entire PMCT study and interpretation should be completed routinely in less than one hour, and should logistically fit well with the current timeframe for the medical examiners death investigations.

Law Enforcement and Successful Prosecution

Both negative and positive post mortem imaging findings have implications and benefits for law enforcement and successful prosecution of perpetrators of elder abuse and neglect. Positive findings provide clear visual evidence, easily understood by legal authorities and increasingly expected by juries, of the commission of a crime. Moreover, such imaging provides additional information about each type of injury; for example, the angle at which such an injury was inflicted, the presence and likely age of past injuries, and other pertinent data. Negative findings (i.e., the findings of no evident abuse on CT) may serve a useful purpose in assisting law enforcement authorities in convincing grieving families and friends that no abuse has occurred. As indicated in our study, significant number of autopsies requested by families and friends, particularly when the decedent was in institutional or third-party care prior to death, are found to be negative for signs of physical abuse and/or neglect. The establishment of a rapid and widely accepted imaging method for ruling out physical abuse can be beneficial to grieving families, to medical examiners, and to law enforcement agents who handle complaints of suspected abuse.

Unexpected Implications for Elder Care

The results of this study make it clear that routine whole-body CT imaging has the potential to provide ongoing and novel insights into evidence of abuse and neglect that can have direct implications for clinical practice. Findings on location, age, and frequency of fractures and findings of decubitus ulceration in our post mortem studies provide compelling visual reference examples for physicians caring for elder patients. Other findings, such as the startling fact that all individuals who underwent CPR suffered rib fractures, deserve not only further study and wider dissemination but focused discussion by the elder care community. Should CPR techniques in these patients be refined to minimize the possibility of fractures? Should caregivers and families balance the consequences of painful recovery from such fractures when considering decisions on future resuscitation? These findings point to the importance of continued partnerships in forensic imaging between practitioners in the hospital and medical examiners' offices. As such partnerships expand, it is likely that growing databases of exemplar cases and published studies on specific features will inform and enhance the knowledge base on elder abuse for both groups, and for the invested legal and social science communities.

MAIN BODY OF REPORT

I. Introduction

A significant challenge for medical examiners and their partners in the medical and legal communities is to identify cost- and time-effective methods for identification of elder abuse and neglect that will: (a) yield proximal results in providing reliable, validated information in cases of abuse and neglect, that can rule out suspicion of abuse or neglect, and that can provide verifiable evidence to support the pursuit of justice; and (b) provide distal results in identifying general and validated “markers” of elder abuse and neglect and offer a feasible, reproducible approach that streamlines and enhances assessment of elder decedents in whom abuse and neglect are suspected.

In 2007 we proposed a collaborative study to assess the utility of a noninvasive medical imaging protocol using multislice computed tomography (CT) imaging to provide accurate, rapidly available information to aid medical examiners in the detection or exclusion of abuse and/or neglect. Multislice CT imaging, interpreted by experienced radiologists, had sufficiently advanced to suggest the potential for rapid assessment of a range of markers for abuse and neglect, as well as datasets of scientific and legal evidence, that might complement, expedite, or, in many cases, rule out the need for complete autopsy. The exploration and refinement of a replicable protocol for elder abuse and neglect showed promise to provide far-reaching results that could respond to the specific challenges involved in routine “virtual autopsy” imaging of older decedents.

I.1. Statement of the Problem

Reports of abuse and neglect of elderly individuals in residential care or within their own home have escalated along with the increasing number of older individuals in the United States

(*1–3*). Authoritative researchers suggest that up to 10 percent of individuals over the age of 65 years will be victims of abuse or neglect and that approximately 80 percent of incidents of abuse will go unreported either before or after death (*4*). Physical, psychological, and financial abuses of the elderly have been explored in detail in the medical and legal literature (*5–12*). The literature is particularly rich with descriptions of screening strategies that physicians, nurses, and others can adopt for the systematic detection and reporting of abuse or risk of abuse in elder patients in institutional and long-term care (*13–29*). Yet identification of all but the most egregious incidents remains a challenge to physicians, social workers, and those charged with ensuring compliance with local, state, and federal regulations covering appropriate care (*30–42*). At the same time, the courts are redefining the nation's long-term care policies through the Olmstead Decree and other directives, requiring maximal community placement in the least restrictive environments, laudable quality-of-life efforts that nevertheless carry additional challenges for the identification and investigation of elder abuse and neglect.

Several authorities in this area of research, most notably those who have prepared formal reports for the National Institute of Justice (NIJ) and the National Academies, have observed that "the science, education, and clinical practice associated with elder abuse and neglect are 30 to 40 years behind those associated with other problems, such as child abuse and domestic violence" (*2*,*3*,*43*). Such a lag is also seen in the post mortem evaluation of abuse and neglect in elderly decedents, where a host of confounding physical and jurisdictional challenges may blur the lines between natural causes of death, homicide, neglect, and suicide (*44–48*). Among the many impediments to the pursuit of justice identified by researchers in these areas are: the lack of a scientific "gold standard" by which abuse and neglect can be judged in individuals who may already be or have been compromised by failing health and mental status, the lack of specific sets of scientific “markers” that would point to neglect and abuse, and an atmosphere in which physicians and medical examiners who review deaths of elder individuals are not encouraged or supported in vigilance for signs of abuse (*2,43,47*).

Nursing home and long-term care deaths have been the focus of scientific studies, review articles, congressional investigations, and editorials that have focused attention on the range and types of common abuses (*50–54*). Public exposure of cases of abuse and neglect has created an atmosphere of suspicion in which many families fear the worst when loved ones die in nursing homes and other institutional long-term care settings (*55*). Law enforcement, legislative, and advocacy groups, too, are lobbying for routine autopsy to discover possible elder abuse and homicide (*56,57*). The result is growing pressure on medical examiners to perform complete autopsies in decedents who would once have received simple visual inspection and death certificates (*58–60*). Elder individuals who die in hospitals are less and less likely to receive autopsies, as hospital autopsy rates continue to decline (*61*). Fewer than 1 percent of all nursing home deaths are currently autopsied in the United States (*47*), at a time when many medical examiners’ offices are already stretched to and beyond capacity in managing workloads (*62–65*). Most medical examiners are ill equipped to handle the workloads that even a modest percentage increase in elder autopsies would require.

The challenge for medical examiners and their partners in the medical and legal communities is to identify cost- and time-effective methods for the identification of elder abuse and neglect that can provide reliable, validated information in cases of abuse and neglect, that can rule out suspicion of abuse or neglect, and that can provide verifiable evidence to support the pursuit of justice. In addition, such efforts should provide more generalizable results in identifying general and validated “markers” of elder abuse and neglect and offer a feasible, reproducible approach that streamlines and enhances assessment of elder decedents in whom abuse and neglect are suspected.

Imaging-Assisted Autopsy

One potential approach to provide solutions to these challenges is the integration of more recent and sophisticated imaging techniques into routine post mortem examination protocols. Imaging is not a new addition to the armamentarium of investigative tools at the medical examiner's disposal. Among the first images acquired by physicians and experimenters after the announcement of Wilhelm Röntgen's discovery of the X-ray in 1895 were "roentgenographs" of cadavers (*66*). The first X-ray machine west of the Mississippi River was acquired in Kirksville, MO, expressly for the purpose of using images of cadavers to teach anatomy (*67,68*). Throughout the 20th century, radiologists worked with medical examiners to explore causes of death, provide evidence for trial and conviction, and offer expert testimony. These imaging investigations have covered all types of trauma and disease, all organ systems, the tiniest of fragmentary remains, and in some notable cases, have even uncovered crimes that were thousands of years old (*69–75*). These interactions also provided the field of radiology with advances based on research in an imaging population in which radiation burden and associated sequelae were not concerns.

Plain-film radiography and fluoroscopy, which for most of the 20th century were the only imaging modalities applied in post mortem imaging, also made the transition to many medical examiners offices, where staff were trained to look for fractures, foreign bodies, and other markers indicating causes of death. These approaches were and continue to be limited by the 2-dimensional nature of plain-film imaging and the radiation risks associated with fluoroscopy. Nevertheless, radiographic evidence, obtained by medical examiner staff and supported at trial by expert physician testimony, has been and remains a mainstay in homicide and other death investigations and prosecution. Specific rules of law and evidence pertain to radiologic evidence, and these rules continue to evolve with changing technologies (*76,77*).

With the advent of CT in the 1970s and wide availability by the 1980s, a new tool was available. It was almost immediately applied to forensic imaging, where multiple views provided new perspectives on injury and disease (*78–80*). Today, the ability of CT to reveal the inside of both living and dead bodies has been exponentially expanded by the introduction of multislice CT technologies.

Multislice CT imaging, interpreted by experienced radiologists, holds the potential to provide rapid assessment of a range of markers for abuse and neglect, as well as datasets of scientific and legal evidence, that can complement, expedite, or, in many cases, rule out the need for complete autopsy. The technique has already been extensively investigated in a range of cause-of-death investigations in nonelderly populations by investigators in Switzerland (*81–89*). In the United States, only a few groups have initiated such investigations, most notably the group at the Armed Forces Institute of Pathology, which has worked with post mortem analysis of wounds received in military combat (*90*). Not only does the technique provide clear images of fractures from a range of perspectives and in 3D reconstructions, but the paths of bullets, knives, and other foreign bodies can be clearly visualized, traced, and evaluated for angle of entry and exit in ways that conventional autopsy cannot approach. The technique can detect water and blood inhalation, air and gas pockets, and internal bleeding. These results can be merged with other data (such as photogrammetric data) and tool mark analysis software.

Despite the impression given by the ubiquitous appearance of 3D CT navigable or “fly-through” images in movies and on television shows such as *CSI*, most medical examiners’ offices do not have routine access to this technology. Limiting factors are the expense of the apparatus, the expertise needed to reconstruct and interpret the images, a lack of verified acquisition protocols that can be replicated, and a lack of relevant imaging databases to which forensic scans can be compared. Yet it is almost certain that multislice CT, now becoming the standard in clinical imaging, will become faster, less expensive, and more powerful in the near future. The exploration and refinement of a replicable protocol for elder abuse and neglect continues to have promise to yield far-reaching proximal and distal results that respond to the specific challenges described here. Legal analysts have already reported positively on the prospect for widespread acceptance of multislice CT technologies as novel scientific evidence in death investigations and criminal proceedings (*91,92*).

With this study, the first of its kind to be federally funded, we hoped to create a new and validated approach with which medical imaging specialists and medical examiners could partner to increase scientific knowledge, decrease the growing burden of autopsies likely to come with the graying of America, and enhance the effectiveness of investigation and prosecution of crimes against elder individuals.

I.2 Additional Literature Citations and Review

Medical and forensic publications on incorporation of imaging into the autopsy process have been added to the body of supporting literature in the past 3 years, although multislice CT imaging in routine partnerships with medical examiner activity remains relatively rare. The literature on the frequency, demographics, and detection of elder abuse in its many forms has grown as well, with a substantial bolus of work engendered as part of NIJ projects. Efforts to connect researchers with intersecting interests in elder abuse topics have also led to new collaborations. This newer literature is briefly summarized and referenced here.

Although the Elder Justice Act was signed into law in March 2010, not all of its policies have been implemented. A number of studies published in 2010 suggest that elder abuse is a growing problem and one that has been exacerbated by economic hard times (*93*). Public policy on elder abuse remains a focus for a number of organizations and agencies, although particularly at the state level funds to address elder abuse (including funds to identify victims, prosecute abusers, and study preventive alternatives) have seen severe cuts (e.g., in New York and California).

Reviews on the current status of elder abuse studies (*94,95*) and on the demographics and understanding of elder abuse (*96–104*) have provided systematic overviews of current status and useful syntheses of published resources and databases. One area of special focus has been on identification of self-neglect and the challenges of differentiating self-neglect from abuse, particularly in noninstitutional settings (*105–109*), a body of literature that strikes a cautionary note for those characterizing injuries as abuse at either conventional or imaging autopsy. A second area of special focus has been on gender differences in elder abuse, with attention to the status of elder abused men (*110–113*). The creation of dedicated forensic centers on elder abuse promises to not only continue to expand investigations in these areas but to create a new cadre of researchers trained in interdisciplinary perspectives (*114–117*).

The use of advanced imaging techniques in assisting and enhancing conventional autopsy has grown remarkably in the 3 years since the initiation of our project. A number of studies, from several nations and originating within both the medical examiner and imaging communities, have focused on the utility of CT and other advanced imaging approaches in post mortem assessment (118–129). Although the ability of imaging to enhance and in some cases replace conventional autopsy has been highlighted in several small case studies, data on systematic comparisons across large samples or routine use remains scarce. An encouraging note is that several studies have explored new techniques and technologies related to imaging autopsy, including robotic instrumentation, novel contrast media, and different modalities (magnetic resonance imaging, ultrasound, etc.) (*130–134*).

Several authors, particularly Thali et al. in Switzerland, the group that pioneered virtual autopsy approaches, have published useful articles on standardized protocols for imaging, incorporation of post mortem imaging into normal workflow, and educational activities (*135–145*). Several of these articles have proposed the creation of a new subdiscipline of forensic imaging that encompasses knowledge and techniques from radiology and forensic pathology. A few authors have explored the medicolegal implications of post mortem imaging, including the question of whether and under what circumstances CT imaging is admissible in court proceedings (*146–152*).

By far the largest numbers of articles on post mortem imaging continue to be accounts of its use in specific cases studies or in specific types of disease or injuries (*153–185*). The articles represent a broad range of countries and medical settings (with China recently showing great interest in post mortem imaging), as well as a wide range of causes of accidental death and disease types. One area of special focus has been on techniques that can noninvasively assess cardiac causes of death.

I.3 Statement of Hypothesis, Aims, and Goals

The general and original hypothesis to be explored in this study was that multislice CT imaging of decedents in whom elder abuse was suspected or reported might enhance the work of the medical examiner by providing novel information not readily available at conventional autopsy and/or by ruling out the need for complete conventional autopsy in cases in which abuse findings were negative, thereby providing: time and cost efficiencies, additional evidentiary support in the form of state-of-the-art images, and, in some cases, compassionate support for families whose religions or cultures required more rapid and/or noninvasive techniques.

This project was realized through an established partnership between the University of Maryland Department of Diagnostic Radiology and the State of Maryland, Office of the Chief Medical Examiner (OCME), and the hypothesis was elaborated through the following primary aims:

Primary aim 1: To determine whether a noninvasive protocol, consisting of an examination by a forensic pathologist for evidence of external injuries and a whole-body CT scan evaluated by a diagnostic radiologist for evidence of internal injuries, is a sensitive and accurate method for the detection or exclusion of physical abuse and/or neglect in elder individuals.

Primary aim 2: To determine whether the use of the optimized version of the CT scanning protocol would obviate the need to perform complete autopsy in some percentage of cases in which elder abuse was suspected.

Primary aim 3: To determine whether the use of the optimized version of the PMCT scanning protocol would provide appropriate justification for full autopsy in cases in which external visual inspection was negative.

Primary aim 4: To determine to what extent the optimized version of the PMCT scanning protocol would provide a time- and cost-efficient model for rapid investigation of suspected elder abuse and neglect.

Primary aim 5: To the extent that aims 1–4 were successful, to prepare a database of freely available images and descriptive technical reports that would facilitate the reproduction of this scanning protocol in other medical examiners' offices.

Successful completion of these aims and the associated investigations and analyses of results were designed to serve in support and fulfillment of the following project goals, which included:

(1) Creation of a time- and cost-efficient post mortem whole-body CT imaging protocol with validated utility in the assessment of abuse and neglect in elder individuals.

(2) Provision of verified and validated means to: eliminate complete autopsy in some cases of suspected abuse, offer additional information to facilitate cause-of-death investigations in others, and serve as a source of valuable visual forensic evidence for the pursuit of justice.

(3) Dissemination of a detailed and freely available description of this protocol to assist in implementation of the forensic imaging approach in other institutions and settings.

(4) Initiation of an ongoing database through which post mortem images of elder abuse and neglect could be studied, compared, and evaluated for more thorough understanding of forensic investigations as well as an enhanced understanding of the prevalence and type of findings that can inform efforts to identify and prevent abuse and neglect in the living elderly.

II. Methods

II.1. Preliminary Studies

As preparatory work for the proposed studies, a partnership between the Department of Diagnostic Radiology at the University of Maryland Medical Center and the OCME, State of Maryland, was initiated in 2006 to explore: (a) whether routine post mortem imaging studies were feasible within the already busy routines of their respective clinical care and death investigation activities; (b) to identify optimal transport methods, routes, and body handling techniques in transferring decedents to and from the imaging facility; (c) to conduct preliminary training and orientation sessions for radiologic technologists in managing post mortem imaging; (d) to secure institutional approval and IRB exemption for such studies; (e) to enlist the support and participation of radiologists, trauma specialists, infectious disease specialists, mass casualty analysts, and others in investigating the range of possible applications of post mortem imaging; (f) to explore optimal timing and methods for communication of imaging results to the medical examiner's staff; and (g) to acquire initial studies in decedents with a variety of causes of death and to explore optimal display, navigation, and interpretation of such studies.

As of January 2007, each of these goals had been successfully realized. Staff and administration from both the University of Maryland Medical Center and the OCME extended their enthusiastic support to these preliminary investigations. Together they devised, refined, and tested all necessary protocols for body transport and handling; conducted successful training sessions with the cadre of radiologic technologists who would provide technical support in image acquisition; secured appropriate IRB exemptions and incorporated requisite health information identifier protections into the study plans; secured substantial departmental support, including the provision of a dedicated server for data storage and the services of a large and experienced radiology IT staff; and enlisted the support of specialists throughout the medical center, many of whom offered suggestions for possible indicia in which post mortem imaging might be beneficial in their own areas of interest. Dr. Daly and research staff also made site visits to confer with military forensic experts at Dover Air Force Base, where multislice CT is used to provide additional information in the autopsy and cause-of-death determination for individuals killed in combat.

As part of preliminary work for the proposed project, 12 decedents were imaged, with indications including gunshot wounds, multiple fractures, suspected child abuse, blunt force trauma, motor vehicle collision, and others. Exhibit 1 shows a decedent enclosed in a body bag immediately before a whole-body CT scan performed for investigation of death.

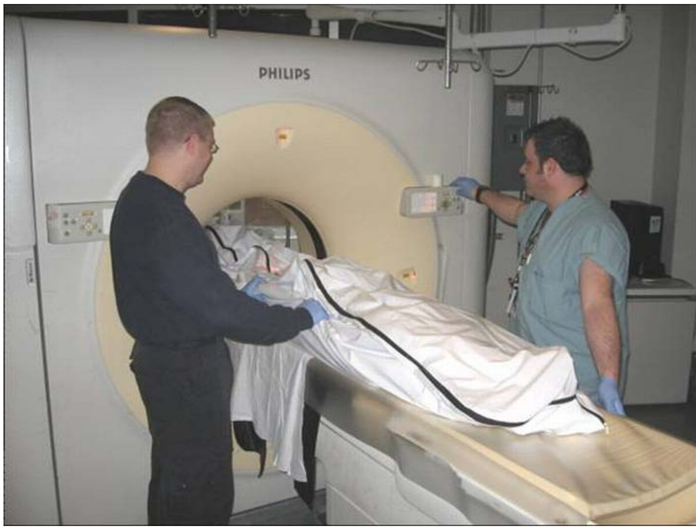

Exhibit 1. Decedent enclosed in a body bag immediately before whole-body CT scanning for investigation of death. The forensic investigator (left) is charged with custody of the body. The radiologic technician (right) performs the CT study before the radiologist interprets the imaging findings.

II.2 Research Design

Note: The research design as described here is the original design. Deviations from the original design are described at the end of the methodology section.

Study Group and Selection.

The study group for all phases of this 2-year investigation included elderly decedents (>65 years old) in whom abuse as a direct factor, contributing factor, or suspected long-term antecedent was suggested or suspected. A total cohort of 80 individuals was to be imaged over the 20-month time period of phases 1 and 2. This total was selected based on volume of cases of suspected elder abuse or neglect referred each year to the State of Maryland OCME office (~70 cases/year). The OCME is centralized in Maryland, with a single chief medical examiner having jurisdiction over all deaths in the state.

Decedents come under the OCME's jurisdiction after (a) visual inspection by the medical examiner's staff at a nursing home, long-term care center, or at the decedents home suggesting evidence of abuse, neglect, or suspicious contributory circumstances leading to death; (b) relatives or other advocates for the deceased voice concerns about possible abuse or neglect; or (c) law enforcement officials request forensic investigation and/or the recovery of physical evidence.

Study Sites: Imaging acquisition, interpretation, data analysis, and preparation of materials for study dissemination were performed at the University of Maryland Medical Center (Baltimore); autopsies, related investigations, and additional data analyses and assessment were performed at the State of Maryland OCME (Baltimore).

Exemption for Use of Human Bodies in Medical Research and Data Collection and Information Privacy Considerations: Section 46.102(f) of the Common Rule defines "human subjects" as living individuals and thereby does not govern the use of human bodies in medical research. This and earlier documentation indicating that our databases of images and associated information would be anonymized to protect private health information on decedents led the Institutional Review Board of the University of Maryland School of Medicine to grant an exemption to our proposed study of forensic imaging (see exemption, Appendix 2).

Section 28 Part 22 of the Common Rule, which requires applicants for NIJ funding to outline plans for protection of private information, does not make a specific distinction between living persons and decedents. For the purposes of this project, access to protected (identifying) data was limited to: (a) those employees who would normally have such access as part of the performance of their routine duties in the office of the medical examiner; and (b) radiologists and researchers specifically assigned to this project. Each of these individuals was advised of the regulations governing privacy in this research. All identifiable data were removed from imaging studies before these were stored on a secure server in a locked room; in the short interim before such anonymizing, such data were accessible only by the researchers assigned to this project. Project findings and reports prepared for dissemination did and do not contain information that can reasonably be expected to be identifiable to a private person except as authorized under §22.22 (c).

Phase I Methods, Procedures, and Materials: When an elderly decedent was brought to the medical examiner's office with indications of suspected abuse or neglect, the medical examiner's staff notified radiology staff. The decedent, already in a body bag, was placed in a second (double) bag and transported by van 2 blocks to the medical center, where the body was transported to the CT suite for imaging, at all times in the custody of medical examiner's staff. As detailed in Appendix G, provisions were made for secure waiting areas, for separation of decedents from the clinical population, and for accommodating the presence of law enforcement officers in cases in which evidentiary chain of custody documentation was necessary. The intent of this study was to image consecutive elder decedents presented to the medical examiner's office. In some isolated instances (when medical examiner staff workload or medical center workload precludes transport and expedient imaging), such consecutive imaging was not always possible (see results).

No additional preparation of the body was necessary before imaging. Each decedent underwent full-body CT on a multislice (40 detector row; Philips Medical Systems) scanner that generated detailed, high-resolution images. Because radiation risk is not a factor in post mortem imaging, the quality of images acquired was as or more detailed than that usually seen in clinical images.

A separate, secure, coded, and Health Insurance Privacy and Portability Act–compliant electronic data archive provided storage of all images of study subjects. This is a separate, restricted-access component of the medical center's radiology picture archive and communication system (PACS). A backup archive was provided for all images to avoid loss of data in the event of catastrophic system failure.

Images were obtained in standard axial 2- and 3-dimensional reconstructed formats to aid in diagnosis. Approximately 3,000–4,000 individual images were generated in axial (transverse), coronal (frontal), and sagittal (lateral) projections, with different computer imaging software programs on an imaging computer workstation (TeraRecon) utilized to depict different tissues and injuries to best advantage. This computer imaging software is the same as that used for standard clinical diagnosis. These images were tailored to each individual case and were obtained primarily by the radiologists interpreting the case. Careful attention was given to working with the imaging techniques to develop an ideal and replicable protocol (see results). The resulting images were sent to a special state-of-the-art electronic PACS for final interpretation, permanent storage, and, where appropriate, for communication to the medical examiners office. After imaging, medical examiner's staff returned the decedents to the OCME, where each decedent underwent a complete autopsy, in which the examiner was unaware of (blinded to) CT findings.

Each set of images was interpreted individually by 2 radiologists experienced in whole-body CT imaging, with subsequent consensus agreement on major findings, and, if evident, cause of death. Throughout the study, the radiologists were without (blinded to) supplementary history or investigative documentation on the decedents. Only a limited history of "suspected elder abuse" was provided to the radiologists.

All imaging findings and conclusions were compared with autopsy findings obtained within 12 hours of CT imaging. All findings on the decedents were entered in an Excel database and stored, with images, on a secure server. The sensitivity, specificity, accuracy, and positive and negative predictive values of whole-body CT for subdural hematomas, fractures, and other findings were compared with autopsy findings obtained within 12 hours of CT imaging.

Phase II Methods, Procedures, and Materials: When an elderly decedent was brought to the medical examiner's office with indications of suspected abuse or neglect, the noninvasive imaging protocol comprising whole-body CT scanning and an external examination conducted by the medical examiner was utilized. The medical examiner's staff notified radiology staff and set in motion the same sequence of actions for whole-body CT scanning as described for phase I. As far as possible, consecutive subjects were to be included in this study, although the unpredictable workload of the medical examiner's staff and periods of scanner unavailability caused certain lapses in consecutive inclusion (see results). Each decedent underwent full-body CT as described for Phase I. In this phase of the study, radiologists had access to all supplementary history and investigative documentation on the decedents.

Images were interpreted within 1 hour by one of the trained radiologists who participated in phase I of the study. Images were evaluated for evidence of subdural hematoma, unrecognized fractures, organ injuries, and decubitus ulcers as specific markers suggestive of abuse or neglect. Evidence for other injuries or causes of natural death was also noted. Results were communicated to the medical examiner staff officer responsible for the case. The decedent was returned to the OCME, where the body underwent a detailed external examination for detection of signs of abuse or neglect. If either the imaging scan or external examination detected findings suggestive of abuse or neglect, the body underwent autopsy. To inform and expedite the autopsy process, images obtained during whole-body CT were available to assist and direct the medical examiner during autopsy, using a secure intranet imaging network provided to the Maryland

OCME by the University of Maryland Department of Radiology and Nuclear Medicine. The duration of the external examination and autopsy were recorded. If neither the whole-body CT scan nor the external examination detects findings were suggestive of abuse or neglect, the medical examiner determined the cause of death to have been natural, and autopsy was not performed. As noted in phase I, images generated during whole-body CT scanning of all decedents in this study were permanently stored within a secure database in the PACS at the University of Maryland Department of Radiology and Nuclear Medicine and made available for appropriate medicolegal and judicial purposes. The guidelines in Exhibit 2 were used to detect evidence suggestive of elder abuse or neglect.

Exhibit 2. Study Guidelines for Detection of Evidence Suggestive of Elder Abuse and/or Neglect

Injuries considered suspicious for abuse	Unsuspected or unreported injuries Fractures: of differing ages; especially of long bones and ribs; and of atypical types (e.g., spiral fracture of the humerus suggesting inflicted injury rather than a fall) Injuries in locations unlikely to be self inflicted or the result of a fall Intracranial trauma—subdural and other intracranial hematomas Evidence for thoracic injury associated with rib fractures (e.g., pneumothorax) Evidence for abdominal organ injuries or intra-abdominal hemorrhage
Evidence of potential neglect	Decubitus sacral or ischial tuberosity ulcers, especially if deep, which may be signs suggestive of neglect and of importance for the medical examiner's investigation

<u>Phase III Methods, Procedures, and Materials:</u> Phase III focused on evaluation and dissemination of study results and practice implications for the forensic investigation of death in suspected elderly victims of abuse and neglect. Materials were prepared for dissemination and presentation at national meetings by both the radiology and medical examiner principals. The replicable protocol for the techniques used in these investigations was prepared for presentation and dissemination. A database of accompanying images was prepared for medical examiners who wish to replicate these findings and incorporate CT imaging into routine assessment of elder abuse and neglect. Scientific papers were prepared for submission to peer-reviewed journals. Phase III also included research into the implications of the study results, as well as applications of the data in other projects.

The individual products/projects originally targeted in the dissemination strategy were designed to have relevance for at least three separate groups: medical examiners charged with assessing elder decedents for signs for abuse and neglect, physicians who routinely assess patients for possible abuse and neglect, and law enforcement and justice professionals who investigate and prosecute both specific instances and patterns of abuse and neglect. Among the products/projects originally targeted were:

Publications and presentations:

- Summary highlighting research findings on advanced forensic imaging and the policy issues these findings inform;
- Full technical report, including a discussion of the use of forensic CT imaging, a review of more recent literature, detailed description of methodology and findings, conclusions, and policy recommendations.
- Brief project summary, for use by NIJ in preparing annual reports to the President and Congress.
- Requisite interim reports, including quarterly financial reports and semi-annual progress reports, as required by the NIJ solicitation.
- Scientific presentations on findings at 2008–2011 meetings of the Radiological Society of North America, the National Association of Medical Examiners, and the American Academy of Forensic Sciences..

- Peer-reviewed publications submitted to leading journals in medical imaging, forensics, and law enforcement.
- One or more press releases, prepared with joint approval from staff at the OCME, the University of Maryland School of Medicine, and the University of Maryland Medical Center, to disseminate significant findings and sample images to the scientific and public media.
- Invited presentations to law enforcement groups, grand rounds at medical schools, and professional meetings of social workers, long-term care givers, and elder advocates.

Other products:

- A downloadable, automated database of CT images generated through this project, and associated records (appropriately anonymized), for physicians and medical examiners who wish to replicate these findings and incorporate CT imaging into routine assessment of elder abuse and neglect.
- A prototype curriculum for basic instruction in the acquisition, interpretation, and use of the multislice 3D CT imaging protocol as an adjunct to forensic investigation.

Statistical Methods: With conventional autopsy as the standard of reference, the sensitivity of PMCT for evidence of elder abuse, decubitus ulcers and associated complications, CPR-related rib fractures, other fractures, and for a range of vascular and soft tissue findings was calculated. Two-tailed Fisher's exact test was employed to determine statistical significance. Although all CT findings were determined by consensus of two radiologists, only one reader completed all the cases because of withdrawal of the other original reader. Interobserver agreement was therefore not determined. As noted above, the level of experience of the radiology readers with forensic imaging varied from 3 to 24 months.

Variations in Methodology for Phases I and II: The study was opened, and initial developments, including logistics, techniques, and database creation, were completed in a timely manner. The logistic challenges in transporting, CT scanning, and then performing conventional autopsy in a time frame that fit into the medical examiners routine workflow were met in a manner that, with few exceptions, has proven quite satisfactory. However, the rate of case accrual was slower than initial projections made by the CME. Consequently, with NIJ approval, the age range criteria for the study were expanded after 9 months to include deceased younger residents of long-term care facilities (aged 18–65 years) who were suspected victims of abuse.

After the first year of the study the investigators determined that the protocol for Phase I of the study should be continued through Phase II. The original plan for Phase II required guaranteed access to CT scanning and rapid whole-body scan interpretations that may have resulted in loss of study recruits because of logistic issues. The Phase I protocol was subsequently utilized for the remainder of the study (with NIJ approval).

Because of persistently slow accrual of decedents into the study, no-cost extensions totaling 24 months were requested from and approved by NIJ during the grant period.

III. Results

III.1 Statement of Results

Over a 28-month period, 58 decedents (14 men, 44 women; mean age, 76 years, range 52–93 years) underwent PMCT imaging and subsequent conventional autopsy by state medical examiners within 24 hours of death. Conventional autopsy was performed within 12 hours of PMCT in all cases. In all cases allegations of elder abuse had been made by family members, caregivers, police officers, or physicians with knowledge of the cases. Four decedents in long-term care who were younger than 65 years old were included under the expanded inclusion criteria. All cases were not consecutive, because three decedents could not undergo PMCT because the scanner was not available. In six additional cases whole-body CT was performed but the subsequent conventional autopsy was incomplete as a result of miscommunication. These cases were not included in the final dataset of 58 decedents.

The sensitivities of PMCT and conventional autopsy for major parameters in the study are summarized in Exhibit 3.

Exhibit 3. Sensitivity (%) of PMCT and Autopsy for Major Study Parameters

Major study parameters	No. of cases (n = 58)	No. identified at PMCT (% sensitivity)	No. Identified at autopsy (% sensitivity)
Evidence suspicious for elder abuse	1	1 (100)	1 (100)
Decubitus ulcers ± osteomyelitis/abscess	17	9 (53)	13 (76)
Fractured ribs resulting from CPR	21	20 (95)	10 (48)
Other fractures	7	5 (71)	2 (28)

The sensitivity of PMCT for evidence of elder abuse compared with conventional autopsy as the standard of reference was 100 percent in this study. The sensitivity of whole-body CT and autopsy for decubitus ulcers and associated complications were 53 percent and 76 percent, respectively (P = 0.28). The sensitivity of whole-body CT and autopsy for CPR-related rib fractures were 95 percent and 48 percent, respectively (P = 0.0014). The sensitivity of whole-body CT and autopsy for other fractures were 71 percent and 28 percent, respectively (P = 0.29).

Major findings identified on individual PMCT studies and conventional autopsy in all cases are included in Exhibit 4.

Exhibit 4. Major Findings Detected on PMCT and Autopsy and Cause of Death Determined by Autopsy

Case #	Age	Sex	Cause of death determined by ME	Evidence for abuse	Major medical examiner findings	Major PMCT findings
1	78	F	Pulmonary embolism Liver cirrhosis	No	• Two contusions in right upper chest with healing abrasion	• C2-C5 acute spinous process fractures • Upper sternum and

					• Left rib fractures • Left pleural effusion	rib fractures • Hemothorax • Left pleural effusion
2	72	M	Amyotrophic lateral sclerosis (ALS)	No	• Spinal cord atrophy consistent with ALS • Emphysematous lungs	• Rib fractures • Bronchopneumonia
3	77	F	Coronary artery disease (CAD)	No	• Healing abrasion on chest	• Negative
4	83	M	Coronary artery disease and pneumonia	No	• Rib fractures • CAD	• Rib fractures • Lung consolidation and collapse • Large pleural effusions
5	72	M	Coumadin toxicity Coronary artery disease	No	• Atherosclerosis of cerebral vessels • Severe CAD	• Bilateral aspiration/pneumon ia
6	88	F	Pneumonia	No	• Bronchopneumonia • Facial contusions • Extremity contusions	• Lower lobe aspiration • Bronchopneumonia
7	79	F	Atherosclerotic cardiovascular disease + COPD + diabetes.	No	• Lung congestion • LAD calcification • COPD	• Rib fractures • Aspiration • Bronchopneumonia
8	83	F	Coronary artery disease	No	• Facial contusion and abrasions • CAD	• Rib fractures • Atelectasis • Pleural effusion
9	76	F	Atherosclerotic cardiovascular disease; Chronic ETOH abuse	No	• ETOH abuse liver disease • Atherosclerotic cardiovascular disease	• Superficial decubitus ulcers • Rib fractures
10	54	F	Coronary artery disease	No	• Rib fractures • CAD	• Rib fractures • Aspiration • Bronchopneumonia
11	60	M	Organizing pneumonia and chronic obstructive pulmonary disease (COPD)	No	• Bilateral pneumonia • COPD • Renal nodule	• Rib fracture • Aspiration • COPD • Hemorrhagic left renal cyst
12	80	F	Pulmonary embolism	No	• Pulmonary embolism • CAD • Extremity contusions	• No major findings
13	83	F	Head and neck injuries (accidental)	No	• Parietal contusions on forehead • Scalp hemorrhage • C5 fracture • Extremity contusion	• Subarachnoid hemorrhage • Degenerative cervical spinal disease
14	64	M	Coronary artery disease	No	• Decubitus ulcers • Subcutaneous sternal mass • CAD	• Bronchopneumonia
15	88	F	Acute pontine infarction secondary to atherosclerosis and thrombosis of vertebral arteries	No	• Pons infarction • Vertebral artery thrombosis	• Lung atelectasis • Pleural effusion
16	83	F	Aspiration pneumonia Coronary artery disease	No	• Hypoxic ischemic encephalopathy • Congested lungs	• Osteomyelitis • Spinal compression fractures

			Ischemic encephalopathy		• CAD	• Rib fractures
17	69	F	Cardiac arrhythmia secondary to coronary artery disease	No	• Congested lungs • CAD	• Pleural effusion • Lung collapse
18	88	F	Coronary artery disease Bronchopneumonia	No	• CAD • Bronchopneumonia	• Rib fractures • Humeral shaft fracture
19	78	M	Coronary artery disease Complications secondary to sepsis	No	• Congested/edematous lungs • CAD	• Decubitus ulcers • Aspiration • Bronchopneumonia
20	77	M	Coronary artery disease Emphysema .	No	• Sacral decubitus ulcers • Emphysema • CAD • Extremity contusions	• Bilateral pneumothorax • Emphysema
21	88	M	Atherosclerotic cardiovascular disease	No	• Cardiovascular disease • Scalp hemorrhage • Multiple chest contusions • Multiple extremity /back abrasions	• Coronary calcifications
22	89	F	Pneumonia Atherosclerotic cardiovascular disease	No	• Cardiovascular disease • Pneumonia	• Rib fractures • Bronchiectasis • Pulmonary edema
23	90	F	Renal infection Atherosclerotic cardiovascular disease	No	• Temporal scalp hematoma • Renal infection • Extremity contusions • Cardiovascular disease	• Coccygeal decubitus ulcers • Spinal compression fractures
24	68	F	Pulmonary embolism Emphysema.	No	• Subdural hematoma • Rib fractures • Pulmonary embolism • Emphysema. • Extremity contusions	• Brain edema • Rib fractures • Aspiration • Bronchopneumonia
25	77	F	Atherosclerotic cardiovascular disease Emphysema.	No	• Scalp hemorrhage • CAD • Emphysema	• Compression fractures of spine • Emphysema
26	77	F	Pneumonia Atherosclerotic cardiovascular disease Hypertension	No	• Scalp hemorrhage • Subdural hematoma • Cardiovascular disease • Abdominal contusion • Extremity contusions	• Cerebral atrophy • Groin contusion
27	80	F	Coronary artery disease Atherosclerotic cardiovascular disease Hypertension.	No	• Edematous lungs • CAD • Cardiovascular disease	• Rib fractures • Cardiomegaly
28	66	F	Atherosclerotic cardiovascular disease Lung cancer	No	• Lung mass • cardiovascular disease	• Bilateral lung atelectasis
29	58	F	Complications of multiple sclerosis MRSA sepsis and pneumonia	No	• Demyelination/MS • Pneumonia • Sacral ulcer • Lower extremity ulcer	• Rib fractures • Pneumonia

30	93	F	Atherosclerotic cardiovascular disease Malnutrition and focal pneumonia (no evidence of neglect)	No	• Cardiovascular disease • Pneumonia	• Pneumonia
31	85	F	Pneumonia Coronary artery disease	No	• Extremity contusions • Rib fractures • Edematous lungs • CAD	• Rib fractures
32	79	M	Coronary artery disease Hypertensive atherosclerotic cardiovascular disease	No	• Cardiovascular disease • Subdural hemorrhage • Subarachnoid hemorrhage (small) • CAD	• Rib fractures
33	54	F	Hypertensive heart disease Chronic liver disease	No	• Cerebral infarcts • Hypertensive heart disease • Chronic liver disease	• No findings
34	52	F	Hypertensive cardiovascular disease	No	• Cerebral infarcts	• Aspiration/broncho-pneumonia
35	69	F	Emphysema	No	• Emphysema	• Cervical spine fractures • Tension pneumothorax, left side
36	52	F	Hypertensive cardiovascular disease.	No	• Hypertensive cardiovascular disease	• Bilateral patchy pneumonia
37	92	F	Atherosclerotic cardiovascular disease	No	• Atherosclerotic cardiovascular disease • Extremity contusions	• No findings
38	59	F	Cardiac arrest Myocardial fibrosis.	No	• Extremity contusions and abrasions • Myocardial fibrosis • Pulmonary edema	• Scalp hematoma • Fibrous dysplasia of skull base • Pulmonary edema
39	59	M	Hypertensive cardiovascular disease Aortic stenosis.	No	• Hypertensive cardiovascular disease • Subgaleal hemorrhage • Calcification of heart valves • Puljmonary edema	• Nasal bone fracture • Rib fracture • Puljmonary edema
40	86	M	Head and neck injuries (accidental) Coronary artery disease	No	• Forehead laceration • Cervical fracture • Small subdural/epidural hemorrhage • CAD	• Rib fractures • Congestive pulmonary changes
41	86	F	Cardiac amyloidosis Emphysema	No	• Lung emphysema • Cardiac Amyloidosis	• Subdural bleeding • Decubitus ulcers • Rib fractures • Atelectasis of lung • Comminuted fracture of left acetabulum
42	84	F	Hypertensive cardiovascular disease Coronary artery	No	• Scalp laceration • Hypertensive cardiovascular disease	• Rib fractures • Lung consolidation • Pulmonary effusions

			disease.		• Rib fractures • CAD	
43	93	F	Hypertensive atherosclerotic cardiovascular disease Coronary artery disease.	No	• Hypertensive cardiovascular disease • Cerebral infarct • CAD • Extremity contusions and abrasions	• Cerebral infarcts • Chronic interstitial lung disease • Humeral head fracture
44	90	F	Atherosclerotic cardiovascular disease, Metastatic cancer in brain & lungs (type of cancer undetermined).	No	• Subdural hemorrhage • Cerebral metastases • CAD • Atherosclerotic cardiovascular disease	• Parietal cortex metastases • Lung metastases • Renal mass
45	72	F	Sepsis due to decubitus ulcers Atherosclerotic cardiovascular disease	No	• Cerebral infarct • Pericardial effusion • Ducubitus ulcers • CAD • Extremity ulcers	• Decubitus ulcers • Bilateral lung aspiration • Pleural effusion
46	81	F	Hypertensive cardiovascular disease	No	• Subdural hemorrhage • Extremity contusions • Hypertensive cardiovascular disease	• Rib fractures, old • Partial collapse of lung
47	64	M	Stomach cancer Pneumonia Atherosclerotic vascular disease	No	• Atherosclerotic vascular disease • Focal bronchopneumonia • Stomach cancer	• • Lung fibrosis with superimposed pneumonia
48	63	F	Diabetic ketoacidotic coma Contributing factors: Multiple traumatic injuries Coronary artery disease Hydrocephalus	Yes	• Frontal lobe contusion • Multiple contusions on face/neck • Epidural hemorrhage • Rib fractures • Contusions of chest and extremities • Coronary artery disease • Displaced fracture left femoral neck • Diabetic ketoacidosis	• Old and resuscitation rib fractures • Diffuse pneumonia • Aspiration • Sternal fracture • Displaced fracture left femoral neck
49	93	F	Hypertensive cardiovascular disease	No	• Hypertensive cardiovascular disease	• Superficial decubitus ulcers • Compressive atelectasis of lungs • Pleural effusions
50	72	F	End-stage renal disease Chronic liver disease.	No	• Rib fractures • Nodular/fibrotic liver • End stage renal disease	• Superficial decubitus sacral ulcers • Rib fractures
51	84	F	Cardiovascular atherosclerotic disease	No	• Facial contusions • Extremity contusions • Cardiovascular atherosclerotic disease	• COPD changes • Atelectasis • Right femur comminuted fracture
52	68	F	Hypertensive cardiovascular disease	No	• Hypertensive cardiac hypertrophy • Hemorrhagic gastritis	• Infectious discitis • Osteomyelitis • Rib fractures

			Hydrocodone toxicity. Septicemia			
53	85	F	Hypertensive cardiovascular disease	No	• Facial laceration • Hypertensive cardiovascular disease • Cerebral infarct • Old rib fractures	• Old rib fractures • Pleural effusions
54	66	M	Cardiovascular atherosclerotic disease Coronary artery disease	No	• Rib fractures • CAD • Cerebral infarct • Cardiovascular atherosclerotic disease	• Rib fractures • Cerebral infarct
55	74	F	Hypertensive cardiovascular disease	No	• Hypertensive cardiovascular disease	• No findings
56	84	F	Pneumonia Cardiovascular atherosclerotic disease	No	• Cardiovascular atherosclerotic disease • Aspiration pneumonia	• Right acute clavicular fracture
57	86	F	Coronary artery disease	No	• CAD • Papillary carcinoma tumor of right kidney	• Cerebral infarct • Calcified right renal tumor
58	66	M	Coronary artery disease Pneumonia	No	• CAD • Pneumonia	• Right lung pneumonia

PMCT and conventional autopsy were interpreted as negative for evidence suspicious of elder abuse in 57 of 58 cases. PMCT and conventional autopsy were concordant in the detection of evidence suspicious for elder abuse in the single remaining case. In that case both investigations demonstrated multiple previously unreported rib fractures and other fractures of varying ages (Exhibit 5).

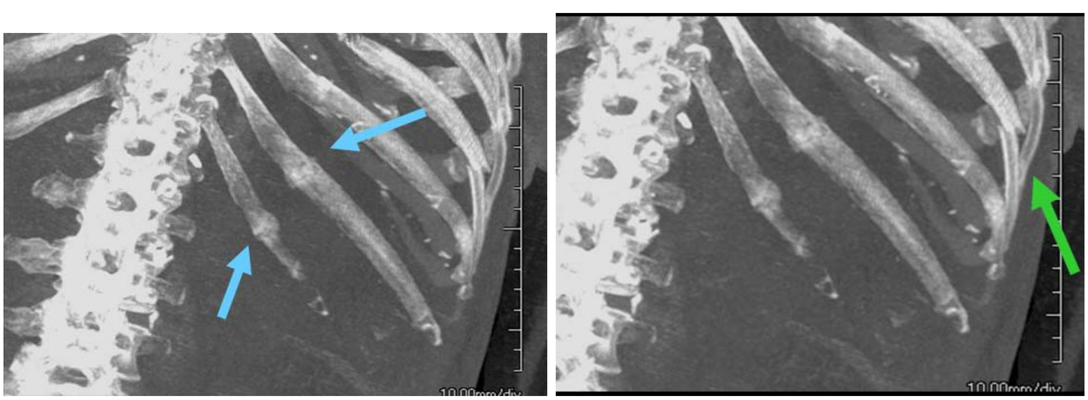

Exhibit 5. Left: Coronal CT image of the ribs in case #48 shows old healed fractures of the left 11th and 12th ribs (blue arrows). Right: Coronal CT image shows an acute fracture of the left 9th rib (green arrow).

Exhibit 6. Axial CT image shows bilateral upper anterior rib fractures (arrows) without evidence for bleeding or other changes, indicating that injuries occurred at the time of death. The decedent had CPR performed at the time of death. The appearance is typical for rib fractures occurring as a result of CPR, especially in elderly patients with brittle bones.

Neither these fractures nor other injuries had been brought to medical attention by the decedent's caregivers.

Acute fractures involving multiple bilateral upper anterior ribs consistent with cardiopulmonary resuscitation (CPR)–related injuries (Exhibit 6) were noted on PMCT in 20 of 21 cases but were undetected at autopsy in 11 of these. All such cases were associated with attempted CPR immediately prior to death.

Additional acute or subacute fractures typical for accidental trauma were noted on PMCT in five of 58 cases (Exhibits 7 and 8) but were undetected at conventional autopsy.

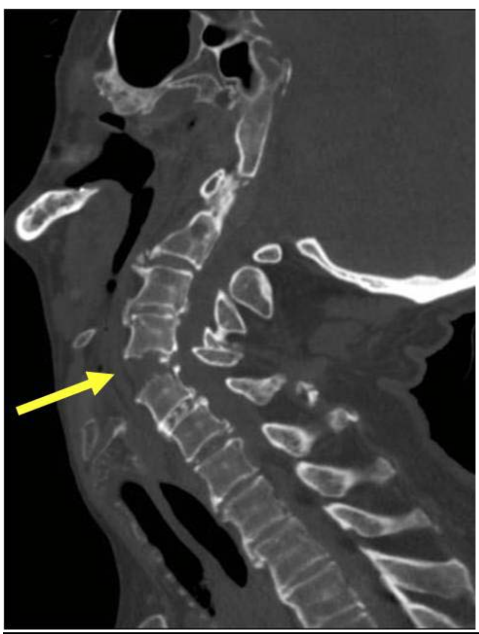

Exhibit 7. Sagittal lateral CT image shows severe dislocation of 4th and 5th cervical vertebrae (arrow) with marked narrowing of the spinal canal, indicating spinal cord injury and compression. This injury was not identified on autopsy, probably because death was believed to result from a large intracranial hemorrhage, and rigor mortis masked the neck findings.

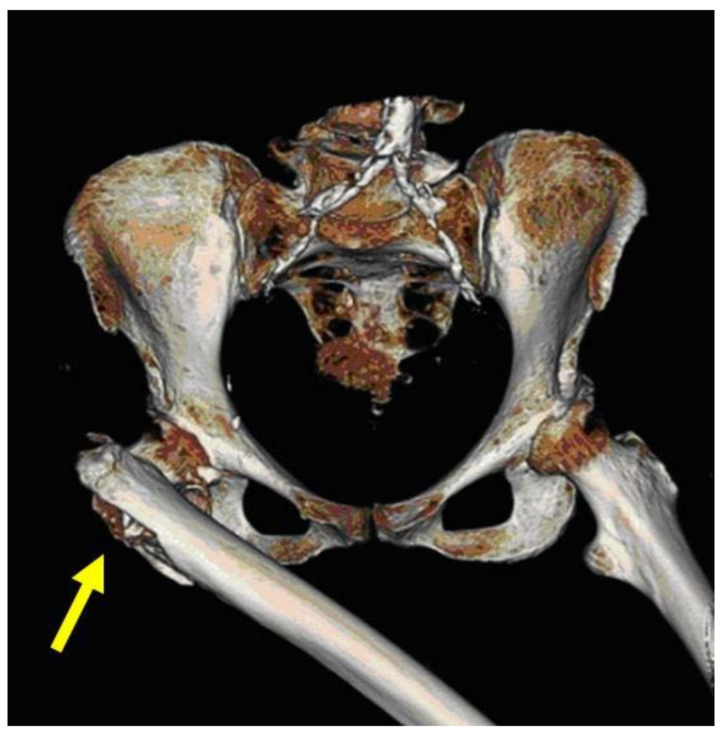

Exhibit 8. 3D image shows a comminuted fracture of the right femoral neck (arrow) in an elder decedent with a history of multiple falls. The patient had been immobile for several months following a cerebrovascular accident.

Pathologic skeletal findings overlooked at PMCT included two fractures (cervical and rib fractures) and at autopsy included five fractures (hip, cervical, clavicular and two sternal fractures).

PMCT failed to detect two fractures noted on autopsy (example, Exhibit 9). The cervical fracture was visible in retrospect and had been overlooked because of co-existing cervical spondylosis degenerative changes at the same site; the rib fracture was undisplaced and could not be identified, even on review.

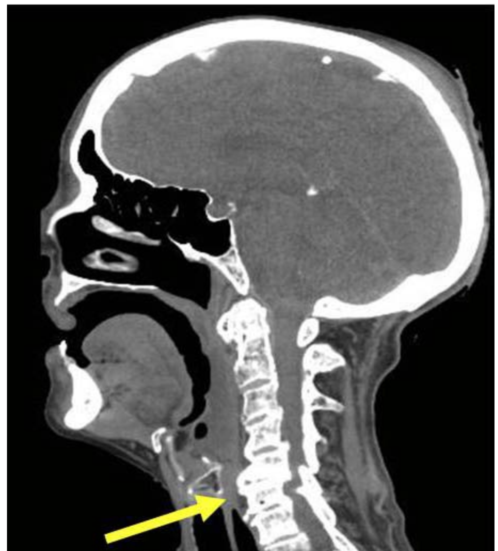

Exhibit 9. Sagittal lateral CT scan shows a dislocation of the 5th and 6th cervical vertebrae with associated degenerative arthritic change. The PMCT scan interpretation indicated only degenerative arthritic change. These findings were confirmed at autopsy.

Decubitus ulcers were identified in 17 (29 percent) of cases. Scanning with PMCT identified decubitus ulcers in 9 cases. Autopsy identified decubitus ulcers in all 17 decedents but failed to recognize osteomyelitis (Exhibit 10) or abscess formation (Exhibit 11) complicating deep grade 4 ulceration in four cases. Eight cases of superficial grade 1 or 2 decubitus ulceration were seen only at conventional autopsy.

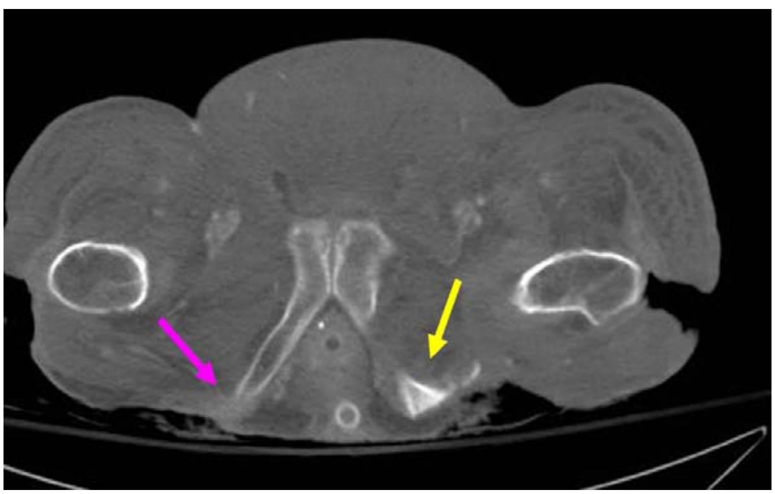

Exhibit 10. Axial transverse CT scan shows bilateral deep grade 4 decubitus ulcers with destruction of underlying ischeal tuberosity bone. Lytic change with loss of bone cortex (pink arrow) indicates the presence of acute osteomyelitis on the right side. Sclerotic dense change (yellow arrow) indicates the presence of chronic osteomyelitis on the left side. The bone destruction was not identified on autopsy. There is also a deep grade 4 decubitus ulcer in the left thigh extending to the underlying femur bone which is not obviously infected.

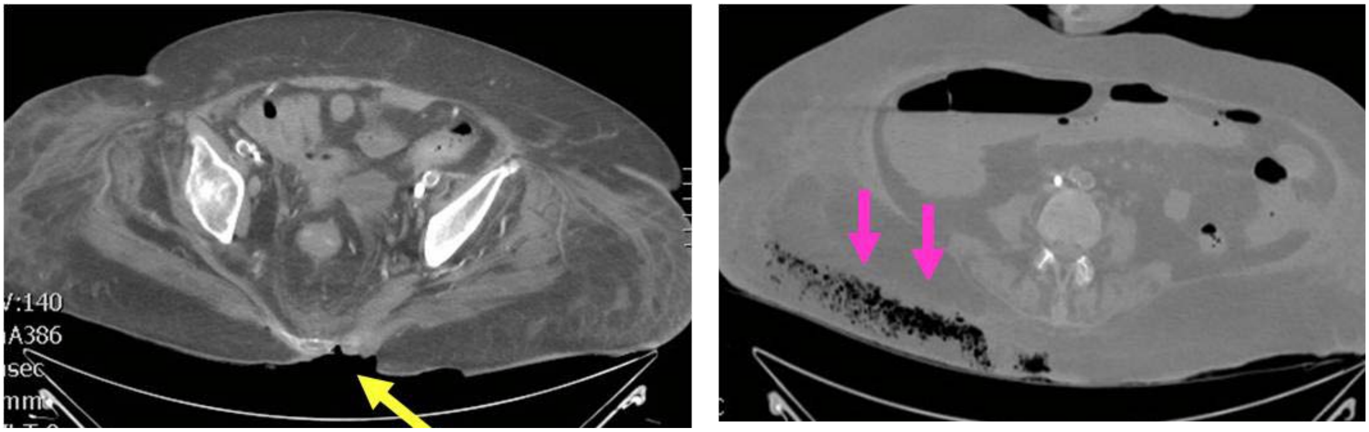

Exhibit 11. Left: Axial transverse CT scan shows a deep decubitus ulcer of the sacrum (arrow) seen on both CT and at autopsy. Right: Associated large subcutaneous gas-containing abscess in the right upper buttock region (arrows). This abscess was not identified at conventional autopsy. The cause of death in this decedent was infection of unknown cause, but very likely related to this abscess.

Other discordant findings between whole-body PMCT and autopsy included septic discitis (infection of a spinal disc space) identified only on CT (Exhibit 12), which was likely the cause of the decedent's death (attributed to infection of unknown cause). In an additional case the PMCT scan showed a large tension pneumothorax (a large amount of free gas in the chest cavity compressing the lung and causing respiratory failure, Exhibit 13). This was the cause of death in a decedent who was on chronic ventilator support for severe lung disease. Pneumothorax is not identifiable on autopsy because the thoracic cavity is routinely opened at autopsy, allowing trapped gas to escape. Two cases with pneumothorax or hemothorax seen on PMCT were overlooked at autopsy.

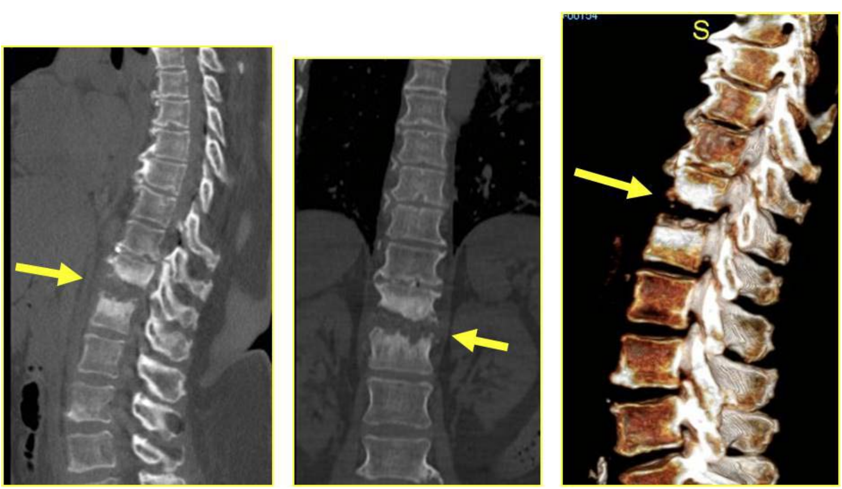

Exhibit 12. Whole-body CT lateral and frontal views demonstrate septic discitis in the T12–L1 (12th thoracic–1st lumbar) spinal disc space (arrows) with osteomyelitis and destruction of margins of adjacent vertebral bones.

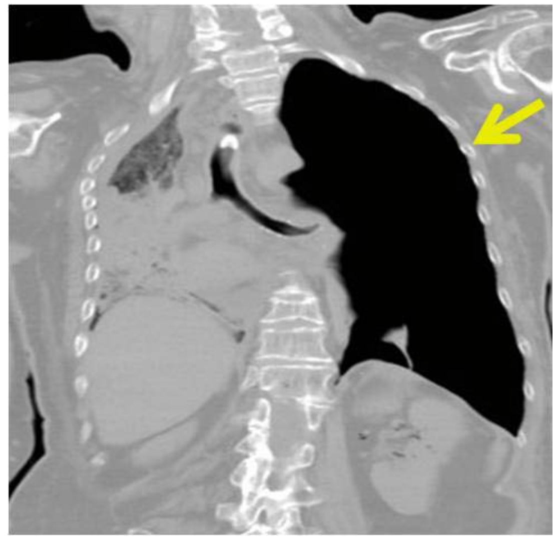

Exhibit 13. CT scan shows a large left-side tension pneumothorax (arrow), with free gas in the chest cavity completely compressing the left lung and most of the right lung. The heart has been displaced to the right side. This finding is not seen at autopsy because of technical reasons (related to the manner in which the chest cavity is routinely opened at autopsy).

Exhibit 14. Sensitivity (%) of PMCT and Autopsy for Other Major Findings

Other major findings	No. of cases (n = 58)	No. identified at PMCT (% sensitivity)	No. identified at autopsy (% sensitivity)
Cardiac disease	15	0 (0)	15 (100)
Pulmonary emboli	3	0 (0)	3 (100)
Cerebral infarcts	10	3 (30)	10 (100)
Intracranial bleed	11	3 (27)	11 (100)
Pneumonia	6	2 (33)	6 (100)
Tumors	4	2 (50)	3 (75)
Pneumothorax/hemothorax	2	2 (100)	0 (0)

The sensitivity of whole-body PMCT compared with that of autopsy for a range of vascular and soft tissue findings (Exhibit 14) was poor and ranged from 0 to 50 percent, with the exception of detection of pneumothorax or hemothorax. Other pathologic findings overlooked at PMCT included eight small foci of subdural or subarachnoid hemorrhage, seven small areas of cerebral infarction, and two tumors (lung and gastric carcinoma). PMCT was insensitive for detection of vascular pathologies and less reliable for detection of cerebral infarction, intracranial hemorrhage, pulmonary lesions, and tumors.

Classification of cause of death as determined by autopsy for all 58 cases is included in Exhibit 15. Cause of death was accurately determined by PMCT in 24 of 58 (41 percent) and by conventional autopsy in all cases. In 35 (63 percent) cases the cause of death determined by autopsy was related to cardiac and/or other vascular diseases, including neurovascular diseases, which are common causes of death in the elderly. Although CT scanning in vivo using vascular contrast media (dye) is a sensitive test for cardiovascular disease in the living, the absence of the beating heart and normal vascular circulation after death makes such diagnoses difficult to determine with PMCT. The likely underlying cause of death in two cases of septicemic infection was noted only on PMCT: a large subcutaneous abscess associated with a deep decubitus ulcer of the sacrum (Exhibit 11) in one case and infectious discitis of the T12-L1 (12th thoracic-1st lumbar) spinal disc space (Exhibit 12) in another. Neither of these serious infections was noted at autopsy, and together they emphasize the superiority of PMCT over autopsy for detection of bone and spinal pathology as well as fractures.

Exhibit 15. Causes of Death Determined in the Study Population by Autopsy

Cause of death	No. of decedents (n = 58)
Cardiovascular	29
Chest infection	8
Accidental head injury/neurologic	5
Septicemia	4
Pulmonary embolism	3
Accidental medication overdose	2
Pneumothorax	1
Elder abuse + multiple other factors	1
Other causes	5

The manner of death in all 58 cases as determined by the medical examiner is included in Exhibit 18. The majority of deaths were determined as natural, although five were noted as accidental, resulting from falls or unintentional overdoses of medication. The solitary undetermined case (#48 in our database) was believed to be the result of multiple factors, with the primary one being diabetic ketoacidotic coma but with major contributing factors, including multiple traumatic injuries (suspected to be to the result of abuse), hydrocephalus, and coronary artery disease. In this case the presence of multiple serious contributing comorbidities prevented the medical examiner from reaching a determination that the manner of death was homicide.

Exhibit 16. Manner of Death Determined by the Medical Examiner

Manner of death	No. of decedents (total 58)
Natural	52
Accidental	5
Undetermined	1

Resulting CT Imaging Protocol. Our preliminary investigations and work performed in conjunction with the current study provided the opportunity to refine and improve our post mortem imaging protocol. The refined protocol (Exhibit 19) can be adapted for use on any CT scanner system and is freely available to any medical and or forensic facility that wishes to replicate our results.

Exhibit 17. Post Mortem CT Imaging Protocol: University of Maryland School of Medicine (Developed on Philips Medical 40 MDCT Scanner)

Three noncontrast series are obtained:

A. Standard nonhelical axial brain scan, 16 detectors × 0.625-mm collimation, 5-mm thick @ 5-mm interval reconstruction, small FOV, and dedicated brain filter.
B. The head and torso using helical technique, 40 detectors × 0.625-mm collimation, 0.9 pitch, 1-mm reconstruction @ 0.5-mm intervals, large FOV, and soft tissue filter.
C. The body is turned on the table to allow scanning of the lower limbs with an overlap of the lower pelvis, using similar parameters as for the torso in #2

2 options are also available:

D. Large body habitus, 32 detectors x 1.25-mm collimation, 0.9 pitch, 1.5 -mm reconstruction @ 0.75-mm intervals, largest FOV, and soft tissue filter.
E. Reduced volume of Images. Use head and torso series B above, substituting 1-mm reconstruction @ 1-mm intervals (no overlap).

The following images may be reconstructed from the helical digital data routinely, or at the radiologists discretion:

Axial whole-body 5 × 4-mm intervals with a soft tissue filter;
Sagittal and coronal multiplanar reconstructions (MPR) of the chest, abdomen, and pelvis with a soft tissue filter;
Coronal MPR of the face 3 × 3-mm with a bone filter; and
Sagittal and coronal 3 × 3-mm MPR of the cervical, thoracic, and lumbar spine with a bone filter.

All thin-section 1-mm data are sent to a 3D server or workstation (AquariusNet, TeraRecon; Brilliance, Philips) for additional 3D image generation as needed.

III.2 Limitations of the Study

A number of factors that limit this study must be considered here. First, the original study methodology with a separate Phase I and II had to be altered and Phase II had to be abandoned for the reasons noted above in the methods section. Therefore the study could not evaluate the practical impact on everyday forensic practice of using whole-body CT as a triage tool for the detection of cases suspicious for elder abuse. Such an evaluation will be the subject of a separate study in the near future.

Second, the study failed to enroll the higher number of 80 decedents originally predicted, with recruitment only reaching 72 percent of this number, an outcome that may be related to the application of more careful inclusion criteria than was applied previously to the question of suspected elder abuse at the State of Maryland OCME. Third, the withdrawal of one of the two experienced radiologists functioning as readers in the study because of serious health problems caused a delay in the study and resulted in the need to train another radiologist. This substitute radiologist had extensive clinical but no prior forensic experience, and the time required to provide appropriate training resulted in a delay in interpretation and analysis of the study cases. As a consequence, all CT studies were interpreted by two radiologists but not by the same pair. There was considerable difference in the overall experience level of the radiologists with respect to forensic imaging (3–24 months). Interobserver agreement was not measured because of this change in personnel.

In an ideal situation the PI would not have the role of a CT reader in the study, but the lack of radiologists trained in forensic imaging made this unavoidable. This is another weakness of the study that hopefully will be less likely to occur in the future with the growth of interest in and experience with forensic imaging in the radiology community. Regarding statistical measurement, the results showed that conventional autopsy did not provide a reliable standard of reference for skeletal injury: more fractures were undetected at autopsy than on CT scan. This was especially notable for CPR-related rib fractures, where a statistically significant difference (P = 0.0014) was noted for sensitivity of PMCT over autopsy. The ability of PMCT to clearly diagnose displaced fractures, especially in body regions that are difficult to dissect (such as the spine) confers advantages over autopsy in skeletal evaluation (81).

Consensus rather than individual interpretations were utilized for PMCT studies in this study. As a result of the novel nature of this imaging technique, the experience level of all the interpreting radiologists for detection of findings suggestive of elder abuse was limited. Although agreement was found between PMCT and autopsy for detection or exclusion of elder abuse in all cases in this study, it is also limited by the low number of positive cases; only a single positive case was identified in this series of 58 decedents. The true incidence of elder abuse in the United States is unknown and may vary with geographic location, time of year, and other factors. As noted previously, it has been suggested that up to 10 percent of individuals over the age of 65 years will be victims of abuse or neglect (*4*). The low percentage of positive cases in this study may reflect limited awareness of elder abuse among family members, caregivers, emergency medical technicians, funeral home workers and the health care system in general and subsequent failure to refer suspected cases. Alternatively, the patient population in this study was drawn mainly (71 percent) from decedents in nursing homes and other long-term care facilities where the presence of multiple caregivers in a supervised setting may be expected to reduce (although not to exclude) the potential for elder abuse to occur. Other cases of elder abuse are likely to occur in unsupervised settings in which elders cohabit with younger family members or are attended by visiting caregivers with less frequent oversight of care.

However, the results of this study may support the view that a substantial percentage of deaths referred to the medical examiner with allegations or suspicions of elder abuse may prove to have been the result of natural causes or accidents rather than criminal acts. PMCT, like conventional autopsy, cannot rule out nonphysical (emotional or financial) abuse. PMCT is unable to identify all of the potential abuse- or neglect-related causes of death that conventional autopsy can identify (most notably under- or overmedication). It is clear, however, that PMCT has the potential to make a significant contribution in guiding and/or eliminating the need for autopsy in a substantial percentage of individuals referred to the medical examiner for suspicion of abuse.

IV. Conclusions

The results of this study suggest that PMCT is reliable for the detection or exclusion of skeletal injuries suspicious for elder abuse and may be used (in correlation with medical history, death scene investigation, and external examination of the body), to determine the need for conventional autopsy when allegations or suspicion of abuse are raised. PMCT may be used as a triage tool by the medical examiner to screen out those decedents in whom physical abuse is suspected. If the percentage of individuals in whom abuse is suspected but ultimately unproven is as high elsewhere as in our study, the ability to use PMCT to screen for physical abuse has the potential to result in significant time and work savings for medical examiners and their staffs. At the same time, PMCT imaging in cases in which evidence suspicious for abuse and physical neglect are discovered provides permanent and compelling evidence of that abuse. Such evidence can become a permanent part of the medical examiner's record, be anonymized for use in forensic and medical education (including education targeted at enhancing identification of elder abuse in living patients), and be used in legal and judicial proceedings. Negative findings (i.e., the findings of no evident abuse on PMCT) may serve a useful purpose in assisting law enforcement authorities in convincing grieving families and friends that no abuse has occurred. As indicated in our study, significant number of autopsies requested by families and friends, particularly when the decedent was in institutional or third-party care prior to death, are found to be negative for signs of physical abuse and/or neglect. The establishment of a rapid and widely accepted imaging method for ruling out physical abuse can be beneficial to grieving families, to medical examiners, and to law enforcement agents who handle complaints of suspected abuse.

Deep decubitus ulcers and associated complications of osteomyelitis or abscess formation that are suggestive of neglect are more accurately detected and characterized on PMCT than at conventional autopsy. In addition to influencing conventional autopsy, these findings have direct implications for clinicians reviewing CT records of living elderly individuals and merit further exploration, particularly by the groups that NIJ is already funding to elucidate the association between decubitus ulcers and neglect.

Another important finding was the presence of acute upper anterior bilateral rib fractures in all decedents who underwent full CPR. These fractures are likely related to the force of direct CPR compressions on the sternum and ribs and the susceptibility of brittle osteoporotic bone to fracture in elderly patients. Although modern conventional autopsy is unlikely to confound these new fractures with fractures associated with physical abuse, the ability of PMCT to distinguish old from new fractures may provide useful information in some cases. Moreover, the finding that all decedents who had full CPR experienced fractures implies that a high percentage of all decedents in whom resuscitation is attempted—not merely those referred for suspicion of abuse or neglect—experience such fractures. This fact may provide a basis for further dialog about the use and degree of blunt force applied during CPR in elderly individuals in whom successful resuscitation is unlikely or may have been legally declined.

Determination of the cause of death in this elder decedent group was not one of the aims of this study, and PMCT was not reliable in this regard, establishing the etiology in only 41 percent of cases. The low detection rate for cause of death was an expected finding, given the well-recognized limitations and lack of sensitivity of CT for cardiovascular, neurovascular, and malignant disease when performed without the increased sensitivity provided by intravascular and oral contrast, techniques routinely employed for CT examinations in the living. As noted in Exhibits 4 and 15, the cause of death in a large percentage of the study cohort was cardiovascular, neurologic, or malignant disease. Moreover, medication-related causes of death could not be detected on PMCT scan. Full autopsy (including medical and police reports, external body examination, and toxicology studies) was much more reliable for determination of cause of death than PMCT, establishing this in 100 percent of cases.

Sensitivity of PMCT for vascular and soft tissue pathologies.

Subtle intracranial lesions, such as small infarcts or bleeding detectable at autopsy, may be undetectable on no-enhanced PMCT. The natural process of lung collapse after death also makes evaluation of pulmonary pathology on PMCT difficult.

IV.1 Discussion of Specific Findings of Note

Outcome of the single case with positive evidence suspicious for elder abuse on both PMCT and autopsy. This case did not reach the level at which law enforcement officials believed that a successful prosecution would result from prosecution. This was because of complicating medical factors, including the fact that the decedent was in diabetic ketoacidosis at the time of death and had both coronary artery disease and hydrocephalus. These major comorbidities made it difficult to attribute her deterioration in health and subsequent death to the effects of suspected trauma alone. The case was not prosecuted.

IV.2 Implications for Policy and Practice

Policy and practice results of the successful completion of this evaluation of whole-body CT imaging in post mortem assessment can be seen in two distinct spheres of activity: medical examiners' activities, and law enforcement and justice activities associated with identification and prosecution of elder abuse and neglect. Implications for each of these groups are discussed here.

Medical Examiners. The most promising benefit suggested by the results is that of greater efficiency, supported by compelling visual evidence, for medical examiners facing an escalating demand to investigate cause of death in elderly individuals. As anticipated, the finding in whole-body CT imaging of most decedents was "negative"; that is, no evidence of abuse or neglect was found by CT. **Every case of negative findings on CT was substantiated with corresponding findings on conventional autopsy, leading us to suggest that routine imaging of elder individuals may be proposed as a method for avoiding complete autopsy in more than 2/3 of elder decedents in whom abuse and neglect are suspected.** Using this whole-body CT protocol, the medical examiner's decision not to proceed to complete autopsy would be supported by detailed images interpreted by specialist board-certified physicians, ruling out fractures, internal bleeding, and other common findings in abuse and neglect. The acceptance of a written policy and protocol for eliminating the need for complete autopsy (but including, of course, visual inspection, toxicology studies, and other tests at the medical examiner's discretion) would not only have implications for cost efficiency and more timely processing of the overall medical examiner workload but would carry compassionate benefits for those families who, for religious or cultural reasons, are reluctant to have decedent relatives undergo invasive autopsy procedures. In those decedents in whom CT findings indicate evidence of abuse or neglect, these findings (including foreign bodies, location and number of fractures, location and type of internal bleeding, and others) may serve to direct and expedite the medical examiner's performance of autopsy and the compilation of a complete report that will be supported by novel visual evidence.

Although the kind of detailed information that would inform a comparison of the relative costs of PMCT and autopsy is not readily available, the potential economic impact of introducing PMCT into forensic practice should be given appropriate consideration. Autopsy examinations are usually funded by local county, city or state jurisdictions in the setting of a medical examiners or coroners investigation and the actual costs of the autopsy procedure are not routinely separated out from other necessary expenses for such services. However the cost of a private autopsy performed at the request of a decedents family has been noted to lie in the $2,000-4,000 range. Other anecdotal information has put the cost of autopsy as between $1,000 and $2,000. By comparison, the total cost of PMCT at the University of Maryland Medical Center is $600, comprising $500 for performance of the scan and $100 for its interpretation by the radiologist. Assuming this figure quoted at our institution is extrapolated to other centers, PMCT appears to be a cost-effective alternative to autopsy, even when the lowermost figure of $1,000 for autopsy quoted above is considered to be the most accurate. It must be borne in mind that the use of PMCT as a triage tool implies that an undetermined percentage of decedents with positive PMCT findings will proceed to full autopsy, potentially increasing the overall costs of investigation. However, the low percentage of suspicious cases on PMCT noted in our study suggests that this is unlikely to be a realistic concern. Regarding the time efficiency of PMCT, the duration of the scan itself should be no more than 10-15 minutes on any CT scanner machine capable of doing whole body examinations. 3-dimensional image generation and interpretation by a moderately experienced radiologist should require no more than 30 minutes. Therefore the entire PMCT study and interpretation should be completed routinely in less than one hour, and should logistically fit well with the current timeframe for the medical examiners death investigations.

Current practice in the Maryland OCME and implications for future practice. Following an analysis of the findings in this study, the CME for the State of Maryland OCME has decided to continue the use of PMCT followed by full autopsy in all suspected cases of elder abuse or neglect. Despite the positive outcome of this study with respect to the sensitivity of PMCT for presence or absence of skeletal injuries suspicious for elder abuse, the CME believes that more experience should be gained with positive cases of elder abuse before the routine introduction of PMCT as a triage tool, The Maryland OCME is well positioned to do this, because the facility now has a CT scanner installation on site suitable for all PMCT studies. With increased experience and familiarity with PMCT, it is considered very likely that this change will occur within the next year.

Law Enforcement and Successful Prosecution. Both negative and positive post mortem imaging findings have implications and benefits for law enforcement and successful prosecution of perpetrators of elder abuse and neglect. Positive findings provide clear visual evidence, easily understood by legal authorities and increasingly expected by juries, of the commission of a crime. Moreover, such imaging provides additional information about each type of injury; for example, the angle at which such an injury was inflicted, the presence and likely age of past injuries, and other pertinent data. Negative findings (i.e., the findings of no evident abuse on CT) may serve a useful purpose in assisting law enforcement authorities in convincing grieving families and friends that no abuse has occurred. A significant number of autopsies requested by families and friends, particularly when the decedent was in institutional or third-party care prior to death, are found to be negative for signs of physical abuse and/or neglect. The establishment of a rapid and widely accepted imaging method for ruling out physical abuse can be beneficial to grieving families, to medical examiners, and to law enforcement agents who handle complaints of suspected abuse.

Elder Care and Medical Treatment. The results of this study make it clear that routine whole-body CT imaging has the potential to provide ongoing and novel insights into evidence of abuse and neglect that can have direct implications for clinical practice. Findings on location, age, and frequency of fractures and findings of healed decubitus ulceration in our post mortem studies provide compelling visual reference examples for physicians caring for elder patients. However such findings should be considered along with other factors, such as the overall physical appearance of the decedent—the co-existence of bruising, especially in the trunk and facial areas, and cachexia/malnutrition may be suggestive of chronic neglect. Also, it must be recognized that severe decubitus ulcers may develop in bed-ridden patients with severe neurologic and other major medical problems despite optimal medical and nursing care. In settings in which the patient is totally dependant on nursing assistance, decubitus ulcers may develop rapidly and be difficult to treat.

Other findings, such as the startling fact that all individuals who underwent CPR suffered rib fractures, deserve not only further study and wider dissemination but focused discussion by the elder care community. Should CPR techniques in these patients be refined to minimize the possibility of fractures? Should caregivers and families balance the consequences of painful recovery from such fractures when considering decisions on future resuscitation?

These findings point to the importance of continued partnerships in forensic imaging between practitioners in the hospital and medical examiners' offices. As such partnerships expand, it is likely that growing databases of exemplar cases and published studies on specific features will inform and enhance the knowledge base on elder abuse for both groups.

Sophisticated databases, particularly ones that correlate examples of imaging findings with external findings and pathology, may suggest new approaches to examination, follow-up, and the performance of additional medical studies in elderly individuals in whom abuse or neglect is suspected. These forensic databases, because they will contain detailed and high-resolution imaging not previously possible in living individuals, will also provide numerous opportunities for research into degenerative and other processes associated with aging as well as the relationships among specific co-morbidities in elderly patients.

One example of a forensic database with direct implications for the living can be found in a research relationship our forensic imaging team has developed with the Allen Brain Foundation (Paul G. Allen Family Foundation). Our group collaborates in several ongoing projects to provide high-resolution magnetic resonance images of brain tissue as part of an effort to map genomic expression within the entire brain and to explore the characteristics of dementias and Alzheimer disease, among others.

Medical Education. Because advanced CT imaging clearly provides useful information for each of the three groups discussed here (medical examiners, law enforcement and prosecutors, and physicians caring for the elderly)—and because interest in forensic imaging is clearly on the rise—medical centers will be challenged to include forensic imaging as a collaborative service with medical examiners. Such services ideally would involve the participation of skilled and specifically trained radiologists and radiologic technologists, as well as the provision of specialized training for medical examiner’s staff members. The positive results of this study, including the ability to routinely perform forensic imaging without disrupting the schedules of either a busy clinical practice or medical examiner’s office, have led us to begin creating a prototype curriculum for specialist training in forensic imaging. As the result of presentations at imaging and forensic meetings, we have received numerous requests for such a curriculum (for both clinical practitioners and medical examiner staff), for advice on setting up regional and local forensic imaging programs, and for the availability of specialized fellowship training in this area. Our University of Maryland/OCME partnership plans to create such a curriculum as part of a Forensic Science Training Delivery and Research Program and has recently welcomed the first two trainee fellows in forensic imaging in the United States. Each fellow will spend 6 months in training both in forensic medicine and forensic radiology. It is likely that other U.S. centers will develop similar programs over time. At present there are few experts in forensic imaging in the United States. However, prior experience with the introduction of new radiological techniques such as mammography suggests that the development of promising applications such as PMCT is likely to be rapid. A plan that may be practical for the rapid provision of trained experts in forensic imaging will be the development of regional centers, likely based on partnerships between radiologists and forensic pathologists at academic medical centers. CT scanners may be placed at larger geographically dispersed medical examiners offices and the scans transmitted to the regional academic centers for rapid interpretation.

An unexpected and immediate use of the experience gained in completion of our current study has been in basic medical education. As a result of our proven experience in forensic imaging, the University of Maryland School of Medicine asked our department to join in a program in which every cadaver donated for use in Y1 medical school anatomy classes would undergo PMCT. Medical students receive special instruction in reconstructing the images, viewing them as slices or as 3D views, identifying key structures, etc. The result is the ability to visually "fly through" each cadaver before and during the dissection process. Sample images from the elder abuse study are being used to train automatic structure labeling software that will enhance this educational experience. We believe that over time, such training is likely to become a standard approach in the education of all medical students in the United States.

Wider Applications of Advanced Forensic Imaging. The results of this study of advanced forensic imaging in suspected elder abuse/neglect offer proof of principle for the effectiveness of advanced forensic imaging and provide valuable preliminary data to support future studies applying these techniques in: child abuse and neglect, trauma (including suspected homicide and suicide), infectious disease incident management, mass casualty management, terrorist acts resulting in deaths, and disaster preparedness.

Forensic imaging has potential beyond the clinic, morgue, and courtroom. The PI of this study, as a result of publicity about the NIJ project, was contacted by the Walters Art Gallery for assistance in analyzing ancient human artifacts. Dr. Daly subsequently imaged several of the Walter's Egyptian mummies and reported on his findings in well-attended public presentations covered by the national and international media.

IV.3 Implications for Further Research

The previous section highlighted many of the areas in which the results of this study point toward the need for additional research and exploration. This study was designed as a proof of principle exploration of the utility of forensic imaging in suspected elder abuse and neglect.

Although the planned use of PMCT as a triage tool to determine the need for autopsy in Phase 2 of the study did not materialize for reasons discussed earlier, such a study will be undertaken by our group in the near future. We expect that this should answer the question regarding the suitability of PMCT for this purpose. Many other promising extensions of this research are possible in elder abuse as well as in wider areas. Studies with larger numbers of decedents will be particularly helpful in answering key questions in this research. This project may be viewed in the wider context of a pressing need for extensive research into the development of new tools and markers for the detection of suspected elder abuse, a neglected area that has recently received attention in the mainstream U.S. medical literature (186).

In brief, areas for future research include but are not limited to the areas outlined in Exhibit 18.

Exhibit 18. Implications for Further Research in Forensic Imaging

Area of focus	Research question/study
Medical examiners (MEs)	Specific, quantitative studies aimed at answering to what extent does whole-body CT and/or other advanced imaging: Reduce ME staff time (and time to delivery of final reports) in specific types of cases? Reduce ME staff time (and time to delivery of final reports) in routine daily practice? Provide cost savings in staff time/overtime/materials? Enhance specific aspects of the ME's approach to conventional autopsy? Facilitate the development and effectiveness of written policies to guide integration of advanced imaging into everyday ME activities? Address the need to compassionately respond to requests from families/friends when decedents' cultural/religious requirements call for expeditious release of the body To what extent is the integration of whole-body CT and other advanced imaging practical "in-house" in larger ME's offices? As costs decrease, will there ultimately be practical aspects to "triaging" all elder deaths through in-house whole-body CT (providing a permanent visual record and eliminating the need for conventional autopsy in a substantial percentage of these decedents)? What are the best approaches to creating and sustaining partnerships between imaging specialists and ME's offices? Could regional specialist centers provide forensic imaging services for ME's offices using electronic image transfer via the Internet? What are the implications of the high numbers of decedents in our study referred for suspicion of abuse but ultimately with no evidence of abuse or neglect on either imaging or conventional autopsy?
Law enforcement/ prosecution	Studies with specific examples from a range of jurisdictions on the utility of whole-body CT and/or other advanced imaging to: Assist in determination and definition of criminal activity; Be used in conjunction with physical evidence to identify criminals and/or secure a conviction; Be used as evidence that may assist in securing a plea bargain or other pretrial resolution; Provide compelling visual evidence that supports expert testimony in court;

	Create a database of exemplar cases that can be used for comparisons and supporting documentation. A study of case law to determine current limitations on the use of whole-body CT and/or other advanced imaging in legal proceedings (specifically who can interpret the images, do specific reconstruction/viewing/archival requirements pertain, etc.)
Elder care and medical treatment	Specific research questions raised by our study include: To what extent should imaging findings of previous decubitus ulcers in living individuals be interpreted as evidence of past abuse? Is additional medical education needed about rib fractures after resuscitation efforts in older individuals (questions of refined technique in CPR, etc.)? If the percentage of negative (ie, nonabuse) determinations in cases of suspected abuse/neglect are routinely as high as those reported in our study, what implications does this have for response to reported suspicion of abuse in elder patients? A host of potential research studies could be launched to mine information from the large databases of forensic studies likely to be generated in the future. As noted previously, these databases are likely to include the most detailed imaging of elderly individuals available anywhere and could provide the "raw materials" for innovative studies in such areas as: Osteodegenerative conditions, such as arthritis; Frequency of old and healed fractures and association with other conditions Comorbidities (the existence of specific conditions in conjunction with others in elder individuals); In combination with medical histories, the effects of smoking/drug use/trauma/long-term stress or other factors on the human body; Long-term effects of specific medications or therapies; Long-term effects of specific dietary regimens or deficiencies.
Medical education	Studies aimed at determining useful answers to the following questions: Can a well-designed program of forensic imaging education be integrated into academic radiology departments (as part of resident, fellowship, and CME activities?) What are the best approaches to creating and sustaining partnerships between imaging specialists and ME's offices? What are the most effective ways to use what are likely in the future to be large databases of forensic imaging results to provide examples of elder abuse/neglect for education/point-of-care comparison by radiologists and other specialists? What types of forensic imaging education are needed by ME staff? Who will/should set professional standards and guidelines for forensic medical imaging?
Wider areas of application	Every aspect of this study could be easily extended to exploration of the use of forensic imaging in suspected cases of **child abuse/neglect**, and each of the potential research areas suggested above has direct relevance in that area. These same research questions/areas are relevant to decedents in whom **homicide/suicide** is a suspected cause of death. We are also currently exploring the use of rapid ultrasound-guided tissue sampling (in full protective clothing) for use in deaths in which **infectious disease and/or hazardous substances** are suspected; The use of a rapid-acquisition protocol for whole-body CT has potential in **mass casualty management** and merits research to determine whether readiness for such capability is a prudent preparatory measure for larger MEs' offices likely to receive high numbers of casualties in situations of natural or human-caused disasters.

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VI. Appendices:

1. **PMCT data collection form template (see attached pdf file)**

2. IRB Exemption (see attached pdf file)
3. Archiving of decedent image datasets Information:
Complete datasets of al PMCT studies have been submitted to
Inter-university Consortium for Political and Social Research (ICPSR)
National Archive of Criminal Justice Data (NACJD)
All studies are in DICOM format on CD/DVD with an inbuilt reader program.

4. Dissemination strategy.

In keeping with Primary aim 5 of our study, the following presentations and publications in peer-reviewed journals have been or will be undertaken to disseminate information on the findings of the study:

Presentations: To date the results of the study (in part or in full) have been presented as follows:

Knight N, Daly B, Fowler, DF. Whole-body CT imaging in post mortem detection of elder abuse and neglect. National Institute of Justice Elder Abuse Workshop: Elder Abuse Forensics, Reports from Current or Recently Completed Research Projects. February 25–27, 2008; Washington, DC. (preliminary activities)

Daly B. Panel participant. Is it old age, abuse, or homicide? Using forensic markers and technology to detect elder abuse and neglect. National Institute of Justice Conference. Washington, DC; 2009. (preliminary results)

Daly BD, Lin S, Ali Z, Lu M, Archer-Arroyo K, Sliker CW, Fowler DF. Utility of whole-body post mortem computed tomography imaging in detection of elder abuse and neglect: comparison with and potential substitution for standard autopsy**.** Presented at the annual meeting of the Radiological Society of North America. Chicago, IL, December 2010. (interim results)

Ali Z, Daly B, Knight N, Fowler DR. Utility of whole-body post mortem computed tomography imaging in detection of elder abuse: comparison with and potential substitution for standard autopsy. Presented at the annual meeting of the American Academy of Forensic Sciences. Chicago, IL, February 2011. (interim results)

Daly BD, Lin S, Ali Z, Lu M, Archer-Arroyo K, Sliker CW, Fowler DF. Utility of whole-body post mortem computed tomography imaging in detection of elder abuse and neglect: comparison with and potential substitution for standard autopsy. To be presented at the annual meeting of the National Association of Medical Examiners. Seattle, WA, August 2011 (final results).

Dissemination of Scanning protocol: The scanning protocol will also be published and made available on both the University of Maryland Department of Radiology and Nuclear Medicine Web site and the Maryland OCME Web site. The protocol is easily reproducible on any modern era multidetector CT scanner.

Future Publications *Peer-reviewed* **(currently in preparation):**

Utility of whole-body post mortem computed tomography imaging in detection of elder abuse and neglect: comparison with and potential substitution for standard autopsy**.** A manuscript in preparation for submission to *Academic Forensic Pathology.*

Musculoskeletal findings at whole-body post mortem computed tomography imaging for suspected elder abuse and neglect: comparison with standard autopsy**.** A manuscript in preparation for submission to *the American Journal of Roentgenology.*

Trade, non-peer-reviewed, and outreach.

Forensics go high-tech with CT autopsies. *Science Daily.* November 28, 2007. Available at: http://www.sciencedaily.com/releases/2007/11/071127111143.htm. Accessed on May 17, 2011.

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Scanning the dead: forensics go high tech with CT autopsies. *RT Image.* April 14, 2008. Available at: http://www.rt-image.com/Scanning_the_Dead_Forensics_go_high_tech_with_CT_autopsies/content=8804J05C485E588640B698764440A0441. Accessed on May 17, 2011.

Post-mortem CT aids in detecting suspected elder abuse. *RSNA News*. March 2010. Available at: http://www.rsna.org/Publications/rsnanews/March-2011/post-mortem_CT_feature.cfm. Accessed on May 17, 2011.

MEMORANDUM

To: Barry Daly, M.D.

Cc: Miek Siegers

From: UMB Institutional Review Board (IRB)

Re: "Virtual Autopsy Using 3 Dimensional CT and MRI Imaging"

Date: July 6, 2006

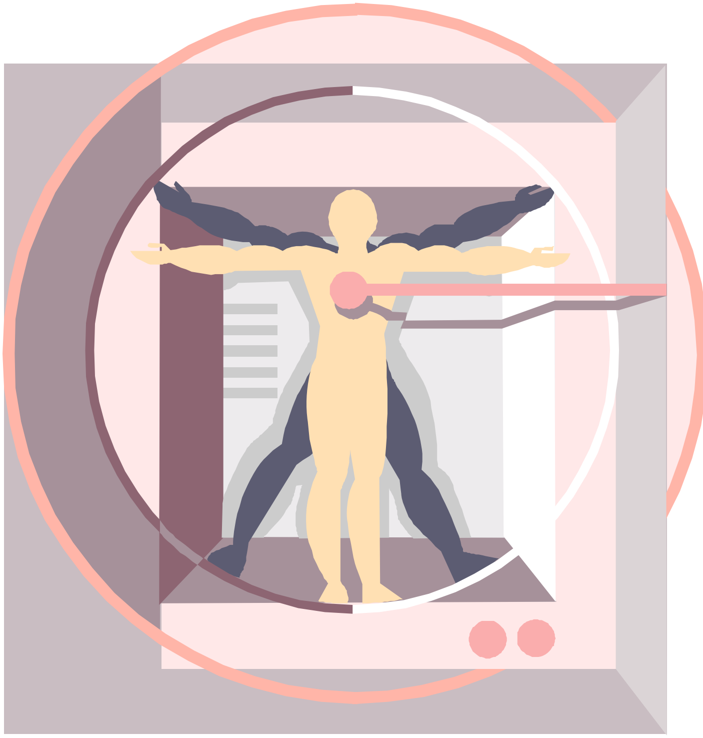
The IRB reviewed the information provided and determined that the protocol does not require IRB review. This determination has been made with the understanding that the proposed project is a scientific research project, which does not involve participation or information from human subjects and therefore is not a human subject research project.

Human subject is defined as "A living individual about whom an Investigator (whether professional or student) conducting research obtains either: data through intervention or interaction with the individual or identifiable private information. These individuals could be patients, healthy volunteers, students, employees, and/or members of the community." This project involves patients declared dead in the UMMC Emergency Room or Shock Trauma Admitting Unit who are the subjects of a medical examiners investigation. Therefore, this project involves deceased individuals receiving non-invasive CT and/or no-contrast MRI prior to the autopsy and does not require IRB oversight.

Please keep a copy of this letter for future reference. If you have any questions, please do not hesitate to contact the Human Research Protections Office at (410) 706-5037.

Robert Edelman, M.D.

Robert Edelman, M.D.
Chairman, UMB IRB



University of Maryland
Diagnostic Radiology
FORENSIC IMAGING STUDY

Medical Examiner ID# ______

MRN: Date of scan:

Age: Gender:

Time of death: Time of scan:

Post Mortem CT – Elder Abuse Protocol

MRN: ______________

Date of scan: _____/____/____

Age:

Gender:

Time of Death:

Time of Scan:

Body Storage Temperature (if known)

Clinical History:

Forensic Imaging Study

Police Report/ Clinical History:

Major CT Diagnosis

Vital Reactions (subcutaneous emphysema, blood or food aspiration):

Cause of Death (if determined by CT):

Major CT Diagnosis

Regional Findings:

Head:

Fracture? Yes or No

Bleed? Yes or No

Infarcts? Yes or No

Other findings?

Spine:

Decubitus sacral region ulcers? Yes or No

Decubitus ischeal tuberosity region ulcers? Yes or No

Complicated by osteomyelitis? Yes or No

Other findings?

Chest:

Rib fractures? Yes or No

Pneumothorax? Yes or No

Heart failure/cardiomegaly? Yes or No

Aspiration/ Bronchopneumonia? Yes or No

Other findings?

Abdomen & Pelvis:

Abdominal organ injuries? Yes or No

Intra-abdominal fluid or hemorrhage? Yes or No

Other findings?

Upper Limbs: Fractures? Yes or No   Other findings?
Lower Limbs: Fractures? Yes or No   Other findings?

Other Comments:

Major CT Diagnosis cont.

Vital Reactions:

Cause of Death (if this can be determined from PMCT):

Imaging Record

Imaging Procedure: The protocol and the imaging study must be recorded. All data from the study must be archived immediately at the end of the study and the data integrity must be checked before finishing the scan.

Protocol Name: ______________________________ (If protocol is modified note changes on back of page.)

Study Data Set Name: ____

Time Collection begun (hhmm): ____________________

Check if complete:

Data Transferred: ☐ Data Archived: ☐ 3D Images Generated:

Standard Protocol Used: Images Stored on PACS: Thin Data Stored on TERA Research Server:

Record any problem that may influence data analysis.

Notes on data collection:

Radiologist:

1.____

2.____

Notes: