Accuracy and interrater agreement in identifying cause of death on postmortem CT: prospective study in a forensic setting

University of Zurich, Institute of Forensic Medicine, Zurich, Switzerland

Since the introduction of postmortem computed tomography (PMCT) to forensic death investigations, numerous scientific manuscripts have been published comparing PMCT to forensic autopsy, underlining the strengths and weaknesses of each. However, variables like experience and expertise of the investigators, scanning protocols, distinct for each study and incomparable between study populations (e.g. traumatic versus natural causes of death, pediatric versus adult populations), led to a great variability of results. These factors affect the reported accuracy of PMCT in defining cause of death, compared to full autopsy - which varies widely in the literature and ranges from 6% to 70%.

We conducted a prospective study over a 5 months period, including 101 adult decedents in our study population. Routine whole-body PMCT and forensic autopsy was performed in every case. One radiologist and one forensic pathologist independently completed a standardized check-list with 110 distinct, predefined PMCT findings in each case and defined the cause of death based on PMCT findings in an additional consensus reading. This approach was mirrored by the two forensic pathologists who also determined the cause of death after autopsy. Both teams independently noted their respective level of confidence regarding the cause of death in each case. To enable statistical evaluation of data, causes of death were pooled in distinct categories. PMCT-based cause of death and autopsy-based cause of death was compared to the cause of death, as stated in the final forensic report, which also included results of histological, toxicological and/or further analysis.

Agreement between the final report and PMCT and autopsy was 82% (83/101 cases) and 89% (90/101 cases), respectively. There was full agreement between the final report and both PMCT and autopsy in 80/101 cases (79%). On PMCT, the highest sensitivity was achieved for cardiac causes of death (92%), and the highest specificity for central nervous system (CNS) and vascular causes of death (100%). At autopsy, highest sensitivity and specificity was also reached for vascular causes of death (100%). The lowest sensitivity for both PMCT and autopsy was found in the miscellaneous causes of death (50% and 78% respectively). Diagnostic specificity for both PMCT and autopsy was high throughout all categories; the lowest value was 83% and 95%, respectively, for cardiac causes of death. Overall, levels of confidence of the investigators reflected the level of agreement between PMCT and the cause of death as determined in the final report, whereas levels of confidence regarding the diagnosis of the cause of death after autopsy did not correlate with the accuracy of diagnosis.

Every PMCT rater (radiologist and forensic pathologist) assessed 110 findings in each case on the standardized check-list. They only did differ in 1.9% (211/11110) of all findings. This study reveals that experienced PMCT raters are able to correctly identify the cause of death - including cardiac death - in 83% of all cases based on non-contrast PMCT with a high correlation between subjective levels of diagnostic confidence and diagnostic accuracy.

The 'pseudo-CT myelogram sign': an aid to the diagnosis of underlying brain stem and spinal cord trauma in the presence of major cranio-cervical region injury on post-mortem computed tomography

B. Daly1, F. Bolster1, Z. Ali2
1University of Maryland, Baltimore, United States of America, 2Office of the Chief Medical Examiner, Baltimore, United States of America

Introduction: The 'Pseudo-CT Myelogram Sign' describes the visibility of the cervical spinal cord and brain stem due to the presence of high attenuation subarachnoid hemorrhage (SAH) in the upper cervical spine and posterior fossa regions on postmortem computed tomography (PMCT) after blunt cranio-cervical trauma. This finding simulates the appearance of a CT myelogram study where hyper-attenuating contrast material is injected into the subarachnoid space to outline the spinal cord and associated structures. This study documents our experience in the detection of associated underlying low attenuation spinal cord or brain stem injuries in the presence of the PMCT Myelogram sign on PMCT.

Materials and Methods: The Pseudo-CT Myelogram sign was identified on PMCT in 20 decedents (11 male, 9 female; age 3-83 years, mean age 35.3 years) following fatal blunt trauma over a 5 year period at a single forensic center. Osseous and ligamentous cranio-cervical region injuries and brain stem or spinal cord trauma detectable on PMCT were recorded. PMCT findings were interpreted with consensus readings by 2 board certified radiologists who had a combined total of 7 years of PMCT imaging experience. PMCT results were compared to conventional autopsy in all cases.

Results: PMCT detected transection of the brain stem or high cervical cord in 9 of 10 cases compared to autopsy (Sensitivity-90%). PMCT was 92.86% sensitive in detection of Atlanto-Occipital joint injuries (n=14), and 100% sensitive for Atlanto-Axial joint (n=8) injuries. PMCT detected more cervical spine and skull base fractures (n=22, and n=10 respectively) compared to autopsy (n=13, and n=5 respectively).

Conclusion: The Pseudo-CT Myelogram sign is a novel description of a diagnostic finding, that if present in fatal cranio-cervical region trauma, is very sensitive for underlying spinal cord and brain stem injuries not ordinarily visible on PMCT. Its presence may also predict major osseous and/or ligamentous injuries in this region when anatomic displacement is not evident on PMCT.
O.1.03
Differences between postmortem CT and autopsy findings in forensic investigation of cervical spine injuries
Y. Makino¹, H. Yokota², E. Nakatani³, D. Yajima⁴, G. Inokuchi², A. Motomura³, F. Chiba¹, S. Torimitsu¹, H. Iwase⁴
¹The University of Tokyo, Tokyo, Japan, ²Chiba University Hospital, Chiba, Japan, ³Foundation for Biomedical Research and Innovation, Kobe, Japan, ⁴Chiba University, Chiba, Japan

Background: As cervical spinal injuries (CSIs) can lead to death even as an isolated injury, accurate postmortem evaluation for CSIs is important in forensic medicine. However, due to complicated anatomy, the cervical spine is sometimes difficult to be evaluated by conventional autopsy. Although the additional evaluation of postmortem computed tomography (PMCT) can address to this problem, there are few studies about effectiveness of PMCT for CSIs with mixed results and, no study has clarified differences between PMCT and autopsy findings in CSI cases.

Objective:
To clarify differences between PMCT and autopsy findings in postmortem detection of CSIs.

Materials and methods: Forensic pathologists’ database at our department was searched from October 2009 through December 2012. In each case, pathologists’ autopsy data and radiologists’ reports were reviewed in terms of presence or absence of bone fractures and intervertebral injuries. The reviews were performed separately on 14 bones (anterior and posterior part of C1-C7 bones) as for bone fractures, and 14 intervertebral structures (anterior and posterior part of the occiput-atlas and C1/2-C6/7 intervertebral structures) per each case.

Results: The study included 42 CSI cases, which means inclusion of 588 bones and 588 intervertebral structures. In both bone fractures and intervertebral injuries, no substantial concordance between PMCT and autopsy findings was observed (McNemar's test: p<0.001 and p<0.001 respectively). As for bone fractures, CT-detected injuries were larger in number than autopsy-detected injuries (CT: 74, autopsy: 23). The proportion of autopsy-missed bone fractures to CT-detected fractures and CT-missed fractures to autopsy-detected fractures were 77% (57/74) and 26.1% (6/23), respectively. As for intervertebral injuries, CT-detected injuries were smaller in number than autopsy-detected injuries (CT: 40, autopsy: 80). The proportion of autopsy-missed injuries to CT-detected injuries and CT-missed to autopsy-detected injuries were 35% (14/40), and 67.5% (54/80) respectively.

Conclusions: As substantial numbers of CSIs were only detected by either PMCT or autopsy, accurate evaluation for CSIs requires both modalities.

O.1.04
Optimisation of post mortem coronary computed tomography angiography compared to histopathology using a novel alignment procedure
H. Precht, P.M. Leth, A. Broersen, J. Lambrechtsen, K. Egstrup, J. Thygesen, P. Kitslaar, J. Dijkstra
University College Lillebelt, Odense, Denmark

Introduction: Cardiovascular disease is a significant cause of sickness and mortality in the western world. The disease is based on a hardening of the heart arteries that normally take decades to develop leaving possibilities to discover it and possibly prevent the disease. Hardening of arteries is caused by sediments on the inside of the arteries, called plaque. Plaque can be classified as stable or unstable. The unstable plaque is the most important to diagnose, as they are in risk of rupture and can therefore cause a critical blood clot in the heart, which is responsible for several cardiovascular diseases every year.

Diagnosing plaque can be done using CT scanning of the heart. This examination is a technical challenge, as the chest is constantly moving (due to breathing and heartbeat) and small details should be imaged clearly. A new CT technique using a different energy level of x-rays to image the patient could improve the possibility to diagnose cardiovascular disease. Whether this new technique in CT scanners can show certain components from plaque composition is not investigated yet. Another possible optimization technique is the iterative reconstruction software, given the possibilities to lower the radiation dose. Will this show positive results, it will be possible to differentiate if the plaque in the heart arteries is stable or not. Diagnosing unstable plaques would make it possible to treat and potentially prevent more patients from a cardiovascular death and therefore provide great possibilities for future patients.

Materials & methods: Twenty human hearts obtained from autopsies were used. A contrast agent that solidifies after cooling was injected into the coronary arteries. CT scanning was performed on the heart alone as well as with the heart in a chest phantom. We used eight different CT protocols and the newest CT technique to image every heart. All CT images were analyzed with quantitative coronary plaque analysis software. The CT images analyses results were compared with their corresponding histological sections. A comprehensive procedure for ensuring the correct alignment of the images was developed as both a physical measure tool and a software program.

Results: We have succeeded in developing a new method for post-mortem coronary CT angiography to simulate clinical CT with the use of a human phantom. Preliminary results are available and showed a tendency of statistical based iterative reconstruction to have an increasing effect on size of the calcified plaques using coronary CT angiography compared to the gold standard of histopathology.

The comprehensive analyses and alignment process is still ongoing. Hopefully we will be able to characterize coronary plaques and discuss if the new techniques allow for detection of rupture-prone plaques at a low dose level in the near future.

O.1.05
The reliability of neck approach for whole body postmortem angiography in the cause of sudden death: a validation study
A.P. Abdul Rashid
Introduction: Post mortem computed tomography angiogram (PMCTA) using ‘groin approach’ or femoral vessels is commonly practiced. However, PMCTA using the Carotid Artery (CA) and Internal Jugular Vein (IJV) or ‘neck approach’ has only been done for selective angiogram and not for whole body angiogram.

We focused on the cause of sudden death (COSD) as it is the commonest cause of death in Malaysia and the world and the most difficult to diagnose using post mortem computed tomography (PMCT).

The goal of this study is to determine reliability and effectiveness of PMCTA in the diagnosis of COSD using a modified neck approach.

Materials and Methods: This prospective study involved 80 sudden death cases undergone PMCT followed by PMCTA and finally autopsy. Infusion of contrast solution using an embalming machine and via catheters inserted into the CA and IJV. The pathological findings relevant to the COSD were documented and compared with autopsy. Advantages and disadvantages of this approach were also documented.

Results: This approach has shown that it could opacified the whole body as good as femoral approach with better opacification of the coronary arteries and pulmonary trunk as well as the lower limbs. Opacification of the coronary arteries is better with left sided cannulation of the neck compared to right side. We also noted that the amount of contrast solution, rate and pressure needed for Asian sample is lower compared to western population as published previously. Nearly 60 % of all positive findings visualized on both PMCT and PMCTA we confirmed with autopsy. PMCTA also demonstrates a higher sensitivity for identifying skeletal and vascular lesions. We documented shrinking or ‘embalming effect’ of the lungs and kidneys as well as dissection of the aorta using this technique which have never been documented previously with ‘groin approach’.

Conclusion: PMCTA with ‘neck approach’ is equally good as PMCTA with ‘groin approach’ with better opacification of the coronary arteries and pulmonary trunk as well as the lower limbs. Overall, PMCTA and conventional autopsy provide comparable findings.

Keywords: PMCT, PMCTA, Autopsy, Sudden Death

O.1.06
Early experience with the use of gas for postmortem angiographic computed tomography in lower extremity wounds
A. Borowska-Solonynko, A. Dabkowska, B. Solonynko
Medical University of Warsaw, Warsaw, Poland

Background: Postmortem computed tomography (PMCT) may significantly facilitate the diagnostic process in traumatic vascular damage. However, visualizing blood vessels in CT scans requires contrast administration. Typically, positive contrast agents are used for vessel enhancement. The Department of Forensic Medicine of Medical University of Warsaw in cooperation with the Chair and Department of General, Vascular and Transplant Surgery Medical University of Warsaw, began study with the use of negative contrast in the form of gas to visualize blood vessels.

Purpose: The purpose of this report was to present three cases of deaths due to lower extremity wounds, where gases were used to visualize wound channels and vascular damage.

Material and methods: There were two cases of stab wounds (to the thigh and leg) and one leg laceration. In each case, a forensic pathologist conducted a non-contrast PMCT. The examined areas included the head, torso, and lower extremities. Subsequently, following inguinal dissection (on the side of the wounded extremity), an endovascular 5-F pigtail catheter (in two cases) or a Foley catheter (in one case) was inserted via the femoral artery. In one case a 60-mL syringe was used to administer a total of 900 mL of air via an endovascular catheter. In the remaining two cases approximately one liter of helium each was administered from a pressurized container used for inflating balloons connected via a pressure regulator directly either to an endovascular or Foley catheter. One more PMCT scan of the lower extremities was conducted. In the cases where helium was used, in addition to the femoral arteries, the femoral veins were cannulated in a similar way and the gas was administered intravenously. However, only half of the volume was administered into the veins due to an observed artifact in the form of transient subcutaneous pneumatocele of the leg. In each case, a subsequent conventional postmortem examination was performed.

Results: The location of vascular damage was successfully visualized in all presented cases. Moreover, the wound channel in stab wounds, which was invisible or poorly visible on non-contrast PMCT scans, was additionally visualized. Vascular damage appeared as vascular outline discontinuation at the level of band-like gaseous extravasation stretching from the surface of the skin - and corresponding to the wound channel. The presence of a clear wound channel helps distinguish true vascular damage from a segmental lack of the vessel visibility due to other causes, e.g. the presence of a thrombus. We also observed significant gas extravasation in the soft tissues adjacent to the damaged blood vessels crossed by stab-wound channels, which corresponded to hemorrhagic sites found on the postmortem. Unfortunately, in one case the gas seeped in between fascia and subcutaneously in the distal part of the limb unaffected by hemorrhages, which may have been due to catheter tip migration beyond the vascular lumen at a vascular injury site.

Conclusions: A gas can be used in postmortem diagnostics of lower extremity wounds as a negative contrast agent in PMCT. Further studies are needed an improvement in the technical aspect of gas administration.

O.1.07
Classification of different kinds of foreign bodies revealed during PMCT examination
K. Wozniak, P. Kluza, A. Moskala, K. Romaszko
Jagiellonian University Medical College, Kraków, Poland
Introduction: Foreign bodies are common findings in forensic PMCT examination. Since PMCT is often used as screening method in most cases foreign objects are accidental findings, but in some cases the whole examination concentrates on finding the exact object (i.e. projectile). Our PMCT research has started in 2009, since then we have completed more than 2500 medico-legal examinations in which wide range of different kinds of foreign bodies had been revealed.

Objectives: Presentation and classification of different kinds of foreign bodies visualized with PMCT data evaluation.

Material and Methods: PMCT data acquired using 16-layer CT (clinical Siemens Somatom Sensation and, since the year 2012, own Siemens Somatom Emotion). Evaluation using OsiriX (Pixmeo, Switzerland). Found foreign bodies were categorized due to their localization, material and circumstances of appearance.

Results: Foreign bodies can be characterized by three parameters (1) - object localization, (2) - its material characteristics, and (3) - circumstances of presence of the object. As for localization objects can be divided into following groups: external to the body, free inside body cavities, tracks and localized inside tissues. As for material we can distinguish metallic and non-metallic objects. As for circumstances: post-explosion and ballistic, pounded, due to medical intervention, self-inflicted, other. The authors present a review of 2D and 3D images referring to groups of foreign bodies with different parameters.

Conclusion: PMCT examination adds new quality to forensic investigation when foreign objects are considered. Due to screening aspect of PMCT examination it has an important role in DVI cases. Objects can be localized before autopsy which makes finding them easier, or even possible. In some cases, based on HU value, type of material can be immediately estimated. Localization and identification of foreign objects with PMCT should be considered as one of most important aspects of this technique.

O.1.08
Post-mortem diffusion MRI of the cervical spinal cord and nerves roots
W. Haakma, L. Kuster, M. Froeling, L. Uhrenholt, M. Pedersen, A. Leemans, L. Warner Thorup Boel
Aarhus University, Aarhus, Denmark, 2University Medical Center Utrecht, Utrecht, The Netherlands

Aim: Diagnostic imaging investigation of the cervical spine post-mortem (PM) can be beneficial for the identification of death-related injuries in trauma cases, since dissection of the cervical spinal cord and nerves is difficult during autopsy. Diffusion tensor imaging (DTI) allows for the evaluation of microstructural properties of nervous structures and can be used for this purpose. Validation with histology is needed to assess the added value of DTI for investigating peripheral nervous tissue. The aim of this work is to examine the architectural configuration and the microstructural substrate of the cervical spinal cord and its nerve roots with PM DTI and histological dissection in non-fixated subjects.

Methods: Five non-fixated PM subjects with normal anatomy of the cervical spinal cord were included; 5 men (4-6 days after death) with a mean age of 51 years (range 25-90 years). Two DTI protocols were obtained with diffusion-weighted spin echo single-shot echo planar imaging (EPI) sequence, i.e., (1) an 'isotropic' protocol to investigate the nerves (C4-C8), and (2) a 'high in-plane resolution' protocol to investigate the spinal cord and ventral and dorsal nerve roots (C5-C7). As an anatomical reference, a multi-echo fast field echo (mFFE) was acquired. Tissue samples of the spinal cord and peripheral nerve roots at the level of C5-C7 were obtained during the autopsy on the following day. Processing of the diffusion MRI data was performed with ExploreDTI. DTI based fiber tractography (FT) was performed and estimates for the fractional anisotropy (FA), mean (MD), axial (AD), and radial (RD) diffusivity of the cervical nerves (C4-C8) were computed.

Results: With FT performed on DTI data obtained with the 'isotropic' protocol it was possible to reconstruct the 3D architecture of the spinal cord, and nerve roots in all 5 PM subjects. We were able to show the dorsal and ventral nerve roots in great detail using the 'high in-plane' resolution protocol and identified a low FA in the grey matter and a high FA in the white matter. Diffusion measures were approximately 5 times lower than in vivo results obtained in earlier studies. Histological examination identified normal anatomy of the spinal cord and peripheral nerve roots in all 5 cases.

Conclusion: This PM DTI and FT study shows that it is possible to identify the cervical spinal cord and its nerve roots using these techniques. Histological examination identified normal anatomy of the spinal cord and peripheral nerve roots, which was in accordance with the architectural configuration found with FT. We were able to quantify the diffusion properties of these nerves PM, and the dorsal and ventral nerve roots were shown in great detail. We expect that DTI may contribute to the forensic investigation of cervical trauma cases.