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3rd Congress of the ISFRI: Abstracts

Session 1 – Ballistics and miscellaneous

1.1. MSCT and micro-CT analysis in a case of "dyadic-death". Homicide-suicide or suicide-homicide?

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Objectives: The application of post-mortem multislice computed tomography (MSCT) and micro-CT analysis to the reconstruction of a singular case of "dyadic death", where a single gunshot was fired.
Materials and methods: Crime scene investigation and criminalistics analysis were performed at death scene. Prior to the forensic autopsy of the 38-year-old policeman and the 50-year-old female victim, an unenhanced MSCT was performed. The gunshot wounds were collected for micro-CT analysis.
Results: At crime scene investigation a self-loading Glock pistol, mod. 17 Austria 5180, cal. 9 mm, was found between the two corpses, near the left forearm of the man. The unenhanced MSCT identified the entrance and exit gunshot wounds in the male victim, the entrance wound and the bullet retained in the skull of the female victim. At micro-CT all the analyzed gunshot wounds exhibited radiopaque material. Autopsy and histology findings allowed us to determine that the murderer died immediately after the shot (for a lethal brainstem injury), whereas the female victim survived for a few minutes, dying after her husband and murderer.
Conclusions: The radiological and medico-legal data allowed us to reconstruct the trajectory of the gunshot, the most probable dynamics of the event, and to classify the incident as a "homicide-suicide" or better to say as a "suicide-homicide", because the female victim died after her murderer. The presented case is a valid example of the importance of an interdisciplinary cooperation between police investigators, forensic pathologists and radiologists for differentiating murder-suicides from double homicides.

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1.2. A novel approach to automated bloodstain pattern analysis using an active bloodstain shape model

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Objectives: Conventional blood pattern analysis is a tedious and time- consuming process due to the many actions that must be performed by the pattern analyst. Digital photographs can now be employed to aid in the process of scene analysis, by letting computer programs perform some of the required steps. However, current computerized methods are all based upon the assumption that any stain can be approximated by a simple ellipse, while manual work is still required.
Materials and methods: This work presents a novel approach, employing a regressed active shape model to approximate bloodstains. This Active Bloodstain Shape Model (ABSM) uses a regression to correlate the shape of a stain's approximation to its impact angle. This model is then deployed in a software pipeline, aiming to eliminate any user-input from the process. Fiducial markers are positioned in a crime scene, allowing for fully automated pattern analysis. Images are cleaned of any perspective distortions, after which stains are segmented and analyzed using said model. A robust principal component analysis (PCA) is then used to analyze the intersections of the reconstructed flight paths.
Results: Experimental results have demonstrated that the ABSM is able to better approximate stains, while accuracy on predicted impact angles is increased. Both simulated as well as real crimes scenes have confirmed the working of the automated pipeline.
Conclusion: Because the ABSM learns from experimental data, it is able to better approximate stains, resulting in an increased accuracy. The addition of the software pipeline removed the need for almost all user-input.

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1.3. Estimation of the depth of stab wounds by magnetic resonance imaging (MRI). A pilot experimental study reproducing *intra vitam* conditions

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Objective: This study aims at testing MRI for estimating the depth of stab wounds.
Material and methods: Six stabbing trials were performed on surgically amputated human calves using a knife. After the extraction of the knife the wound cavity was instilled with fresh human blood and subsequently with contrast medium. MRI scans were performed before and after blood instillation (MRI-b) and contrast medium instillation (MRI-cm). Radiological measurements of the length of the cavity (MRI-esteem, MRI-b-esteem and MRI-cm-esteem) were compared to the length of the penetrated blade measured directly on the knife (pBL).
Results: The mean pBL ranged between 4.8 and 5 cm (mean: 4.9 cm). The mean MRI-esteem, MRI-b-esteem and MRI-cm-esteem were 3.8 cm, 4.1 cm, and 4.5 cm, respectively.
Discussion: MRI-cm measurements were the most accurate esteem of pBL, confirming the results obtained in a previous study performed on a larger population. MRI-b measurements, although less accurate than MRI-cm-esteem, gave a better prediction of the pBL than the MRI-esteem. The key strength of MRI-b-esteem is that the blood filling the cavity mimics vital bleeding, simulating realistic conditions occurring in living subjects. Moreover, MRI-b does not need any contrast medium instillation, being less invasive and more suitable for a potential forensic application in the living.
Conclusion: A systematic underestimation of pBL occurs at MRI-b. In order to confirm its potential accuracy and suitability for pBL estimation in living subjects, further experiments are necessary.

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1.4. Comparison between radiologist and pathologist in determining trajectories in gunshot victims

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Purpose: Traditionally the pathologist describes gunshot trajectories as a part of the post-mortem examination in gunshot victims. Forensic radiology has shown to be accurate in determining the trajectories using computed tomography (CT). The goal of this study is to investigate if there are discrepancies between the trajectories describe by the pathologist and radiologist and if these discrepancies can be attributed to characteristics of the trajectory.
Subjects and methods: The data of all shooting incidents between 2010 and 2013 were collected, in which both a forensic radiological and pathological examination were performed by means of a total body CT-scan and a full post mortem respectively. From the final independent report of these examinations we determine the number of trajectories, the tract of the trajectories, if these trajectories crossed the lung, abdomen, skull, spine, bone and whether the trajectory was linear.
Results: The data of 13 incidents were collected with a total of 48 trajectories. Nine trajectories went through the lung, seven through the abdomen, thirty through bone, six through the spine and 10 through the head. In 19 out of the 48 trajectories there was a discrepancy between the radiologist and the pathologist. There was no association between the course of the trajectory and the discrepancies.
Conclusion: In almost 40% of the trajectories there is a discrepancy between the radiologist and pathologist. The literature shows that radiology has a higher diagnostic value for determining a trajectory. A more detailed analysis of each trajectory is needed to determine the cause of the discrepancies.

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1.5. Micro-CT analysis of gunshot wounds contaminated with bone fragments

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Objective: To develop a method for differentiating Gunshot Residues (GSR) from bone fragments (BF) at micro-CT analysis, when BF contaminate the entrance gunshot wound. Indeed, when the latter involves an anatomical area in proximity to the bone (e.g. head, thorax, etc.) calcium deposits could contaminate the skin and be misinterpreted as GSR at micro-CT analysis.
Material and methods: Four different types of decalcifying agents (DEC1 and DEC2 based on chelating agents; DEC3 and DEC4 based on hydrochloric acid), and one radiological method (employing different Grayscale thresholding) were compared. BF before/after decalcification, human skin samples covered by BF (SkinBF), GSR (SkinGSR) and/or GSR/BF (SkinGSR/BF) were analyzed through micro-CT.
Results: The decalcifying trials performed on BF and SkinBF revealed that DEC1 and DEC3 (applied for 4 h and 30 min, respectively) were unable to completely remove the calcium deposits, whereas DEC2 and DEC4 (applied for 4 h and 30 min, respectively) were effective for the above-mentioned purpose. All the decalcifying solutions, however, highly reduced the GSR amount when applied on SkinGSR and SkinGSR/BF samples. The radiological method underestimated both BF and GSR amounts on SkinBF, SkinGSR, SkinGSR/BF specimens.
Conclusion: Our pilot study showed that the decalcifying solutions routinely used at histology are effective for removing BF fragments contaminating the gunshot wound, but they significantly reduce the amount of metal particles present.

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1.6. Forensic safety of MRI in gunshot victims

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Purpose: Multi-detector computed tomography (MDCT) has proven to be of value for the reconstruction of trajectories of projectiles and the assessment of the injuries. However for the depiction of soft tissue injury MRI is superior to MDCT and MRI may be of value to assess trajectories through soft tissue. In a clinical setting there are guidelines for the application of MRI in patients with projectiles or fragments and with certain precautions MRI is safe for these patients. However this has not been studied from a forensic point of view.
Subjects and method: To assess the behaviour of three projectile types in a 1.5 and 3 T MRI system, projectiles were placed in seven gelatine phantoms with mechanical characteristic of human muscle tissue. Projectiles were placed with and without a simulated trajectory. Before and after exposure to the magnetic field the gels were scanned on CT assess of the projectiles.
Results: The ferromagnetic projectiles tend to rotate parallel to the *z*-axis of the magnetic field and 5 out of the 7 projectiles moved through the phantom, either through the simulated trajectory or a new trajectory. This was observed in both the 1.5 and 3 T system. Due to extensive susceptibility artefacts the anatomy around the projectile was not visible.
Conclusion: Ferro-magnetic projectiles rotate and migrate in a gelatine phantom. It is very likely these projectiles will also migrate in a human body in a MRI system. Therefore we conclude that MRI is not forensic safe in these instances.

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1.7. Use of radiopaque markers in reconstruction of gunshot injuries

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Objectives: The identification of the trajectory of a projectile through the body is one of the most important issues to be solved in any case of gunshot injuries. Despite the advancements in modern cross-sectional imaging techniques those injuries still pose a challenge in forensic investigation. The exact identification of the entry and exit wound on the body surface, which is of great importance for the reconstruction of events, can be challenging on postmortem computed tomography (PMCT). This fact gives raise to requirement for an additional and highly reliable assisting technique. In response, a simple system was used, which adds information on entry and exit wound to standard PMCT images.
Material and method: A radiopaque rubber-seal ring was selected for external marking of gunshot wounds. It was placed around the wound and adhered to the body with double sided tape. A whole-body PMCT scan was performed after this preparation. Each ring was visible on the cross-sectional images surrounding the body surface wound, with the skin defect located centrally, and served as a permanent record of the anatomical location of the wound.
Results: This method has proven to be a quick and easy procedure for locating body surface gunshot wounds on PMCT scans. In contrast to other methods proposed for this purpose, this technique profits from higher accuracy and is non-invasive. The determination of the center of the rings allowed for identification of the entry and exit wound defects, contributing to the reconstruction of the injury.
Conclusion: The need for an accurate and simple method for marking entry and exit gunshot wounds was addressed yielding good results. It aids the initial investigation of gunshot injuries, as well as enables the three-dimensional visualization of acquired PMCT data.

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1.8. PMCT findings in hanging

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Objectives: Compare findings seen at autopsy and PMCT in cases of uncomplicated suicidal hangings.
Materials and methods: Retrospective search of forensic and PACS database for adult hanging deaths returned 47 cases that underwent whole body PMCT, where autopsy was blinded to imaging. Autopsy findings collected from autopsy reports by a board certified forensic pathologist. Whole body PMCT performed using a 16 slice big bore CT scanner. Images interpreted by a board certified radiologist with forensic imaging experience, blinded to autopsy results. Data reconciliation and analysis performed by consensus.
Results: Subcutaneous gas collections in the head and/or neck out of proportion to decomposition in 12 cases (25.5%), seen only at PMCT. Neck muscle hemorrhage found in 5 cases, 3 (6.4%) detected at autopsy and 2 (4.3%) by PMCT. 3 cases (6.4%) of hyoid injury identified, seen only by PMCT. 2 cases (4.3%) of thyroid injury, seen only at autopsy. 3 (6.4%) head/neck fractures identified only by PMCT. Various findings encountered in the brain, chest and abdomen by autopsy, PMCT or both, which were unrelated to the cause of death. No unexplained serious trauma detected by either modality.
Conclusion: Subcutaneous gas in the head and neck was common and seen only at CT, possibly related to the mechanism of death or altered gas distribution during decomposition in hangings. Neck muscle hemorrhage, thyroid injury or hyoid injury occurred in the minority of cases. A small percentage of potentially relevant head/neck fractures were identified at CT that were not seen at autopsy. Findings in the brain, chest and abdomen were generally noncontributory.

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1.9. Can post-mortem multidetector CT use for cervical spine clearance?

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Objective: To clarify feasibility of the post-mortem multidetector CT (PMMDCT) for using cervical spine clearance.
Material and methods: Thirty consecutive forensic cases with spinal cord injuries (SCIs) as cause of death identified by forensic autopsies in our department were yielded for this study. PMMDCT was performed in each case prior to autopsy. Two board-certified radiologists interpreted PMMDCT images.
Results: PMMDCT images in 24 of 30 cases had findings suggesting SCIs including bone fractures, dislocations and hematoma around the vertebral spine. However, remaining 6 of 30 cases showed no remarkable findings associated with SCIs on CT images.
Conclusion: Our results showed some of fatal SCIs are missed by PMMDCT. Forensic radiologists must be aware of this entity to avoid excluding SCIs based solely on PMMDCT especially in cases with unknown circumstances of death. The presence of this kind of entity could be a pitfall of PMMDCT screening of cause of death.

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1.10. Postmortem interval estimation: Value of postmortem cerebral CT

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Objective: After death a series of changes naturally occurs in the human body. Understanding these changes and the contributing factors will lead to a better understanding of the normal process of hypostasis and decomposition, a better estimation of the postmortem interval (PMI) and thus to a better diagnosis of cause and time of death.

The aim of this study was to investigate the correlation between the PMI and postmortal intracranial density measurements.
Materials and method: We retrospectively investigated 61 postmortal cerebral CT scans. We measured the density in Hounsfield units (HU) of the dorsal part of the superior sagittal sinus, vitreous humor left and right and the anterior and posterior horn of lateral ventricles left and right. Correlation between density and PMI was determined using linear regression and is reported using the Pearson's correlation coefficient.
Results: The PMI range was 3.0–45.1 h. All densities showed increase over time. This was not significant for the dorsal part of the superior sagittal sinus and vitreous humor (resp. 0.19 h per HU; $p=0.18$; HU 56.1–112.0; Pearson's $r=0.20$ and 0.51 h per HU; $p=0.12$; HU 7.5–29.8; Pearson's $r=0.23$). However, the lateral ventricles showed significant increase of density over time (1.7 h per HU; $p<0.0001$; Pearson's $r=0.65$; HU 4.7–18.8).
Conclusion: The normal postmortal changes are detectable in density of the intracranial structures. This goes especially for the HU increase of liquor during the postmortem interval. This could be of great value for forensic methods to estimate the PMI and needs further prospectively investigation, which we are currently performing.

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1.11. Skull fractures in post mortem CT: VRT, flat and skin surface projections in comparison

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Background: Different visualization techniques vary in their advantages and disadvantages. VRT (volume rendering technique) is widely used, but may not be optimal for any type of problem. So in addition to VRT, we employ flat projection of the skull, as well as projecting it onto the skin surface. Ease of fracture identification and ease of reconstructive consideration is evaluated with 10 subjects in a forced choice rating.
Method and material: Four cases of gunshot injuries and five cases of blunt trauma to the head are evaluated using (1) VRT, using projection of skull related data to (2) flat surfaces and (3) projection of skull related data to a CT-derived skin surface of the head, all performed using the same DICOM data. Subjective ease of fracture identification and subjective rating of reconstructive aspects are evaluated with 10 subjects in a forced choice rating. VRT is performed using standard CT reconstruction software (syngovia, Siemens, Switzerland). Flat surface projection is performed using an experimental protocol. Skin surface projection is performed using vector tracing in IDL (Interactive Data Language, Exelis Visualisation Solutions, Boulder CO, USA).
Results and discussion: VRT is widely available and as that, it has practical advantages. However, other reconstructive techniques appear to offer the potential for easier identification of fractures, or, easier matching to skin findings. At the same time, they may come at additional costs (data transfer, time, searching for best parameters). In the presentation, advantages and technical issues as well as results will be shown and discussed from point of view of applied forensic pathology.

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Session 2 – Perinatal Virtopsy and miscellaneous

2.1. Diffusion-weighted imaging of the PM fetal abdomen

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Objectives: Fluid distribution within body organs may change with post mortem interval (time since death). Therefore we evaluated fetal abdominal organ ADC values at Diffusion-Weighed post mortem MRI (DW-PMMR), compared to normal infant controls.

Methods: We retrospectively analysed ADC values in body organs in a group of fetal and neonatal PM cases, compared to a group of normal infant controls. DW-PMMR was performed using axial single-shot EPI with diffusion gradient values $b=0$, 500, and 1000 s/mm². Mean ADC values were calculated using a region of interest for the liver, spleen, kidney and muscle.

Results: We performed DW-PMMR on 15 fetal and childhood cases (mean age 33 ± 7.8 weeks gestation), compared to 44 controls (mean 75.5 ± 53.4 days). Mean ADC values (10^{-3} mm²/s) were significantly lower in PM cases than in normal controls for each organ, including liver (0.38 ± 0.17 vs 1.13 ± 0.13; $p < 0.05$), spleen (0.30 ± 0.13 vs 0.79 ± 0.09; $p < 0.05$), kidney (0.38 ± 0.14 vs 1.19 ± 0.13; $p < 0.05$) and muscle (0.52 ± 0.17 vs 1.12 ± 0.12; $p < 0.05$). Mean ADC values did not correlate well with post mortem interval or gestational age.

Conclusion: Fetal abdominal organ ADC values are lower in PM cases than in live infants of similar gestation, but do not correlate with post mortem interval. Further research is needed to understand the drop in organ ADC which occurs soon after death.

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2.2. Assessment of fetal maceration at PMMR

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Objectives: The extent to which fetal decomposition affects imaging findings at post mortem MRI (PMMR) is unknown, and fetal autolysis is further complicated by intra-uterine retention, leading to maceration. Here, we assess whether PMMR can accurately determine the level of maceration determined by conventional autopsy.

Methods: We performed PMMR in 75 fetuses at 1.5 T before conventional autopsy. PMMR images were reported blinded to the clinical history and autopsy data using a numerical severity scale (0 = no maceration changes to 2 = severe maceration changes) for 6 different visceral organs and then added to make a composite score (0 – 12). External maceration at autopsy was categorized according to severity on a numerical scale (1 = no maceration to 4 = severe maceration). Intra-uterine and post mortem intervals were also calculated from clinical data, where available.

Results: PMMR maceration score showed a good correlation with the autopsy maceration score ($R^2 = 0.93$), but neither scores correlates well with either intra-uterine retention interval or post mortem interval. PMMR pleural fluid accumulation ($R^2 = 0.93$), ascites ($R^2 = 0.84$), and subcutaneous oedema ($R^2 = 0.83$) showed the best correlation with autopsy maceration score, but also did not correlate with intra-uterine nor post mortem interval.

Conclusion: Whilst autopsy and imaging estimates of maceration were in good agreement, neither score accurately reflected either intrauterine retention or post mortem interval. Better markers of these indices are needed to reliably interpret post mortem changes.

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2.3. Can we use *T2* relaxometry MRI to assess post-mortem maceration in fetuses and neonates?

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Objective: Magnetic resonance spin – spin relaxation time (*T2*) is sensitive to tissue degradation, and could be useful in assessing maceration severity in post-mortem MRI (PMMR). We aimed to assess body organ *T2* values using quantitative MRI relaxometry and compare these with pathological assessments of maceration at autopsy.

Materials and methods: We performed pre-autopsy PMMR in foetuses and neonates at 1.5 T (Siemens Avanto), including an 8-echo turbo spin – echo sequence, from which images were fitted to a mono-exponential decay function. Fitted *T2* values were used to generate quantitative whole-body maps, and mean *T2* values in the lungs and liver were compared to global pathological maceration scores (1 – 4; none to severe) at autopsy. The Mann – Whitney *U*-test was used to compare variables.

Results: Ten fetuses and neonates were imaged after death which occurred at a median (interquartile range, IQR) gestational age of 36 (19) weeks.

Median (IQR) *T2* was higher in both the lungs and liver for higher maceration scores (3 and 4) compared to lower grades (1 and 2; lung 142(24) vs 82(14)ms; $p < 0.05$; liver 110(20) vs 50(4)ms; $p < 0.05$). However, *T2* also correlated inversely to the gestational age at death (lung: $R^2 = 0.75$; liver: $R^2 = 0.72$) so these changes may not be attributed to maceration alone.

Conclusion: Increasing fetal maceration is associated with higher body organ *T2* values, but as younger fetuses had higher maceration scores in our population, there may be a confounding effect of gestational age. These data may help to optimise PMMR sequences.

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2.4. Can lung aeration on postmortem MR determine live or stillbirth?

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Objectives: To investigate whether lung assessment on postmortem MR imaging is able to reliably determine if a child has breathed spontaneously and to develop an imaging technique for determining live versus still-birth as part of the minimally-invasive autopsy, rather than invasive autopsy methods such as the lung flotation test.
Materials and methods: We retrospectively assessed a group of late fetal terminations (neither breathed nor resuscitated) and early neonatal deaths (breathed spontaneously). PM MR and autopsy findings were reviewed for evidence of lung aeration, blinded to other data. Cases with abnormal lungs at autopsy were excluded.
Results: 17 neonatal deaths (mean age 3.4 ± 3.2 weeks of life) and 15 fetal terminations (mean age 30.7 ± 3.9 weeks gestation) were compared. Absence of lung aeration on PM MR had a sensitivity of 93% (95% confidence intervals: 70.2, 98.8) and specificity of 100% (81.6, 100) for stillbirth, with positive and negative predictive values of 100% and 94.4% respectively.
Conclusions: Our study demonstrated a high overall accuracy for lung aeration seen on PM MR as an indicator for spontaneous breathing in fetal and early neonatal deaths, and should now be tested in a larger cohort of patients.

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2.5. Evaluation of vascular diameter and cases of pulmonary embolism sudden death

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Objective: Cases of fatal pulmonary embolism (PE) represent a diagnostic challenge to post-mortem imaging. The aim of this study was to investigate the relationship between the diameter of the inferior cava vein and cases of fatal pulmonary embolism on post-mortem CT (PMCT).
Material and methods: We retrospectively measured the diameter of the inferior cava vein (ICV) at the level of the superior mesenteric artery in 164 cases on PMCT (26 cases of confirmed pulmonary embolism, 24 age and sex matched cases of myocardial infarction (MI), and 114 randomized control cases (CC)) and investigated levels of significance between these groups and the diagnostic power of a cut-off value for the ICV.
Results: Mean ICV diameters were 7 mm (SD 8.1 mm) in the CC, 7 mm (SD 5.5 mm) in the MI, and 11 mm (SD 8.1 mm) in the PE group. Mann–Whitney *U*-Test revealed a significant difference in ICV diameters between PE and CC ($p=0.004$) and between PE and both CC and MI together ($p=0.006$), but not between MI and CC ($p=0.40$), and between PE and MI ($p=0.11$). The receiver operating characteristics (ROC) curve revealed the optimal cut-off value: at 12.5 mm the diameter of the ICV features a specificity of 83% and a sensitivity of 54% to indicate the presence of pulmonary embolism.
Conclusion: This study revealed that increased diameter of the inferior cava vein is an indicator of pulmonary embolism on PMCT. However, this radiologic sign has a poor prognostic value and further research is needed to reliably distinguish between cases of PE and MI.

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2.6. Postmortem computed tomography findings in the thorax

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Objective: To investigate findings of postmortem imaging using objective data and to define the time-related course of lung changes using postmortem CT (PMCT).
Materials and methods: From April 2013 to October 2013, 12 bodies (8 men, 4 women; age, 27–81 years [mean, 60.0 years]) were examined two times in a >4-hour interval (4–164 h [mean, 30.8 h; median, 17.5 h). We compared pleural space fluid volume, decreased aerated lung volume (DLV), and pulmonary volume between the two postmortem CT scans. We divided the subjects into 2 groups according to the postmortem period (30 h) and compared the time-related changes between the SHORT and LONG postmortem periods. To evaluate the volume change rate, we plotted the volume rate (ml/h) against pleural space fluid volume and DLV according to the postmortem period.
Results: At the 2nd PMCT, the pleural space fluid ($p=0.0425$) and DLV ($p=0.0186$) increased and pulmonary volume ($p=0.0229$) decreased. Between the SHORT and LONG groups, there were statistically significant differences in DLV ($p=0.0374$) and DLV rate (ml/h) ($p=0.0104$). The pleural space fluid increase peaked at 30 h and continued until 42 h. The DLV rate consistently decreased throughout the postmortem period until the 30-h mark.
Conclusion: The time-related course of lung changes on postmortem CT can be assessed using time-interval PMCT.

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2.7. The physical basis of poor fat/muscle contrast observed at low temperatures in post-mortem MR (PMMR) imaging

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Introduction: To successfully apply MRI in the forensic setting, a better understanding of the temperature-dependence of MR image contrast is needed. For example, low fat signal and poor fat/muscle contrast has been observed in cold PM subjects imaged using typical clinical MR parameters. Because MR contrast is based on differences in the relaxation times *T*1 and *T*2 for different tissues, our goal is to explain MR contrast changes by measuring and analyzing the temperature-dependence of tissue *T*1 and *T*2 values.
Methods: Fresh, ex vivo mammalian tissues were imaged using a standard Spin Echo sequence by varying TR (with TE = 10 ms), or by varying TE (with TR = 3200 ms), over the temperature range 4 − 38 °C. For each tissue type, signal intensity was plotted vs. time (TR or TE) and fit with the appropriate function to extract the relaxation time constant (*T*1 or *T*2).
Results: In general, non-fatty body tissues exhibited a decreasing *T*1 with decreasing temperature, while fat and liver *T*1 values exhibited little temperature dependence. For nearly all tissues, the temperature-dependence of *T*2 was very weak; however, the fat *T*2 decreased substantially as temperature is reduced.
Conclusions: As subject temperature is decreased, the decreasing muscle *T*1 (with the fat *T*1 remaining approximately constant) results in a smaller difference in *T*1 between muscle and fat, while the large drop in the fat *T*2 increases *T*2-weighting, even in nominally *T*1-weighted sequences. Taken together, these findings explain poor fat/muscle contrast and low fat signal intensity previously observed at low temperatures in PMMR.

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2.8. Post-mortem CT (PMCT) imaging findings of pericardial tamponade due to hemopericardium

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Objectives: Hemopericardium (HP) is occasionally found at autopsy, but it represents a challenge for the forensic pathologist when having to assess its pathophysiological role in causing death, particularly in those cases where ante-mortem clinical and instrumental data are not available. The aim of this study was to individuate PMCT findings indicative for the diagnosis of pericardial tamponade (PT).
Materials and methods: We retrospectively revised PMCT images and autopsy reports of 14 cases with fatal HP and intact pericardium. From autopsy reports, we obtained volume and cause of HP. PMCT images were reviewed to describe: appearance of HP, presence of indirect signs of increased intrapericardial pressure. A control group of 11 cases submitted to PMCT prior to autopsy was selected with the following criteria: absence of relevant pericardial effusion, venous system congestion and bleeding.
Results: Of the 14 PT subjects, 13 had a double concentric stratification of HP and compression of the coronary sinus and/or of the pulmonary trunk, all showed a flattening of the anterior surface of the heart; other findings indicative of venous system congestion were variably detected. In the control group none of these findings was identified, with the exception of a distended superior vena cava equalling the ascending aorta (8/11 cases).
Conclusions: PMCT is able to provide some findings indicative of PT. Based on this evidence, in other instances HP could be judged circumstantial rather than fatal. This study suggests the possibility to use PMCT findings to retrospectively demonstrate an in vivo dynamic condition, such as PT.

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2.9. CT imaging as a valuable additional tool to establish drug abuse as cause of death

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Purpose: To establish drug abuse as cause of death is cumbersome due to sampling difficulties and equivocal lethal concentrations of drugs in blood/urine. Post-mortem CT can give insight into the pathophysiology leading to death, like pulmonary congestion. Therefore the aim of the present study was to identify the most important radiological criteria to detect intoxication as cause of death.
Subjects and method: Between November 2010 and July 2013 11 bodies (largest study in literature) with the suspicion of intoxication were scanned on a Dual Source CT-scanner with a slice thickness of 1 mm. All CT images were evaluated, blinded for toxicology, for pulmonary oedema without pleural effusion, fluid level in main bronchus and other causes of death. Bladder extension could not being measured due to standard urine sampling prior to imaging. Toxicology data and all case information were collected.
Results: Ten victims showed potentially lethal concentrations of drugs in their samples; amphetamine ($n=5$), opiate ($n=1$) and combination of amphetamine, cocaine and/or GHB ($n=4$). Massive lung embolism without pulmonary oedema was found in the remaining victim on CT imaging. For detecting intoxication as cause of death, pulmonary oedema without pleural effusion had a sensitivity/specificity of 100%, while a fluid level in a main bronchus showed a sensitivity and specificity of 80% and 100%, respectively.
Conclusion: These results demonstrate that CT-imaging could be a valuable additional tool to establish intoxication as cause of death. In drug abuse victims pulmonary oedema (without pleural effusion) was often depicted in combination with a fluid level in a main bronchus.

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2.10. Racking the brain! Cerebral edema on postmortem computed tomography compared to forensic autopsy

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Objective: Cerebral swelling is a typical finding on postmortem computed tomography (PMCT). Detection of pre-existing brain edema despite normal postmortem changes is merely based on visual judgment, dependent on the investigator's experience, as there are no standards yet. The purpose of this study was to evaluate the diagnostic reliability in differentiation between of pre-existing cerebral edema and physiological postmortem brain swelling on PMCT compared to forensic autopsy and to establish diagnostic criteria for intoxication or asphyxia as cause of death.
Methods and materials: The study collective included 200 deceased (142 males and 58 females), ranging from 20–88 years. In retrospect 109 cases (out of 200 deceased) were evaluated regarding the following parameters: tonsillar herniation, the width of the outer and inner cerebrospinal spaces and by Hounsfield (HU) measurements of the gray and white matter related to the distinct age groups and causes of death. Results were compared to the findings of subsequent autopsy as gold standard for diagnosing cerebral edema.
Results: Cerebral edema (despite normal postmortem swelling) can be assessed reliable by PMCT based on narrowed temporal horns and with symmetrical herniation of the cerebral tonsils ($p < 0.001$). In cases of intoxication or asphyxia a significant difference ($p < 0.001$) could be found if difference in attenuation between white and grey matter (DGW) was > 20 HU and the grey to white matter ratio (GWR) was higher than > 1.58.
Conclusion: Generalized brain edema despite normal postmortem changes can be differentiated on PMCT and white and grey matter HU measurement helps to determine the cause of death in cases of intoxication or asphyxia.

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2.11. Report on 14 years' experience in forensic radiology; an overview of more than 1500 cases

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Objective: The number of research publications in forensic radiology increases tremendously. However, well-founded retrospective databases are scarce, which hampers research on large numbers of cases in this field. We present an overview of our forensic radiological database, covering 14 years and including 1540 forensic cases.
Material and method: 1540 cases were presented by the Netherlands Forensic Institute, to the radiological department of the Groene Hart Hospital between 2000 and 2014. 17% of the cases were living victims, in all other cases a forensic autopsy was designated. In retrospect, information from autopsy and radiology reports, such as patient characteristics, assumed cause of death and imaging modalities, was incorporated in a database. Male female ratio is 2:1, mean age is 35 years (range 0–98). Statistics were performed in SPSS version 20.
Results: Reported occasions (max. 3 per case) were: violence (383), sharp/blunt weapon (302), strangulation (264), body discovery (143), traffic accidents (142), ballistic trauma (118), submersion (82), sudden infant death (70), airplane crash (30) and excavation (25). In 422 cases other occasions, such as illness or fire were noted. The most reported imaging modalities (max. 3) were: cranial CT (533), total body CT (524), diverse radiographs (481), skeletal X-ray (338) and larynx X-ray (305).
Conclusion: This annually growing database is the largest and longest-established forensic radiological database in the Netherlands. Due to the clear disaggregation of imaging modalities and cause of death, the database has proven itself to be a useful source for retrospective research in forensic radiology. We encourage scientific collaboration.

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2.12. A moot point! A case report on potential projectile movement on postmortem MR

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Objective: This homicide case we investigate potential projectile movement on postmortem MR (PMMR) in a lodged ricochet projectile in the skull. The purpose of this case report is to evaluate the different aspects of PMMR-related properties of projectiles in gunshot wounds.
Material and method: The case underwent whole body postmortem computed tomography (Somatom Definition Flash Dual Source, Siemens Medical Solutions, Forchheim, Germany) in supine position, 3D-suface scanning (Atos Compact Scan 5 m, GOM mbH, Braunschweig, Germany) with reposition of the corpse to prone position and PMMR (Achieva 3.0 TX MR scanner, Philips Medical System, Best, The Netherlands). For validation purposes a later head CT-scan in supine position and subsequent autopsy was performed. Ferromagnetic properties of the projectile were tested.
Results: Imaging revealed projectile movement between PMCT and PMMR. The ricochet projectile showed bullet migration along the wound channel on PMMR from midbrain position to a frontal location of the bullet. The bullet did not produce susceptibility artifacts on PMMR. Autopsy revealed no heating effects of the adjacent tissue indicating no thermal effects by the PMMR scanning. The bullet showed no ferromagnetic properties after being tested by a magnet and literature review of the metallic compounding of this specific projectile. Therefore, the bullet migration was caused by repositioning of the corpse from supine to prone position along the ricochet wound channel.
Conclusion: Presence of susceptibility artifacts on PMMR images depend on the material compounds of the projectile. PMMR allows for better anatomical detail of bullet path within the soft tissue and may be performed in the vast majority of projectiles.

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2.13. It's all in the Details: The effect of CT slice thickness on 3D modeling for forensic analysis

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Objective: Forensic practitioners are becoming more reliant on virtual models for identification, analysis, and evidence preservation. Image slice thickness can affect the quality of 3D reconstructions derived from medical images. Thinner slices result in higher quality models preserving critical anatomical details but can cause unnecessary wear on the scanner's tube. With limited standard imaging protocols and variation between technicians, it becomes essential to understand what level detail is lost with lower resolution scans.

Materials and methods: A series of cranial CT scans were acquired with a 0.625 mm slice thickness. The DICOM volumes were re-sliced into 1 mm, 1.25 mm, 3 mm, and 5 mm increments. The five different slice-thicknesses were imported into Mimics 17.0 for 3D reconstruction of the boney structures. Landmarks were placed to acquire standard cranial forensic measurements. These measurements were then compared among the five thicknesses. The 3D models were visually and numerically analyzed for overall differences in detail with 3-Matic 9.0.

Results: The greatest visual and numerical discrepancies were observed between 0.625 mm and 3–5 mm. Measurements along the axial plane were the most stable across slice-thicknesses. Vertical measurements showed the greatest range for inconsistency. Thinner, or air-filled sections of bone were obliterated with thicker slices.

Conclusion: Study shows that heads can be scanned safely at 1–1.25 mm so that critical detail for 3D modeling is preserved. With lower resolution models, there is a risk of losing data that can alter forensic findings.

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Session 3 – Anthropology and miscellaneous

3.1. Mandibular sexual dimorphism analysis in CBCT scans of a Brazilian population

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Objective: Human identification has been performed for many years within forensic dentistry. The aim of this study was to evaluate sexual dimorphism using anthropometric measurements on mandibular images obtained by cone beam computed tomography (CBCT).
Material and methods: The sample consisted of 159 CT scans collected from a Brazilian population (74 males, 85 females) aged 18–60 years. The CBCT images were analyzed by five reviewers. Six measurements (ramus length, gonion – gnathion length, minimum ramus breadth, gonial angle, bicondylar breadth, and bigonial breadth) were collected for the sexual dimorphism analysis. For the statistical analysis, intraclass correlation was used to evaluate intra- and inter-observers, analysis of variance was used to compare the mean values of these measurements, and binary logistic regression equations were created to determine sex.
Results: Using these four variables, the rate of correct sex classification was 95.1%.
Conclusion: The formula developed in this study can be used for sex estimation in forensic settings.

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3.2. Comparative study of the skeletal remains of San Felice (Italy, Sardegna, Sassari) using both multislice computed tomography and conventional techniques of human identification

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Objective: The Archbishop of Sassari requested the Department of Biomedical Sciences, Legal Medicine, University of Sassari, to coordinate an investigation identifying the human skeletal remains of Felice Martyr, patron saint of Sennori, preserved in an urn wooden reliquary. The purpose of this research was to determine, as accurately as possible, the biologic profile from the recovered remains. We proceeded involving multi-slice computed tomography (MSCT) and conventional techniques for reconstructive human identification.
Materials and methods: The research, leaded by legal medicine, required a specialized team of forensic scientists (anthropologist, odontologist, radiologist, paleontologist, and geneticist). First of all, conventional X-ray and multislice computed tomography MSCT allowed the morphological study and an image-guided virtual autopsy from two and three-dimensional bone reconstructions. Then, we performed biological samplings (DNA, dental and skeletal sample, radiocarbon dating) and anthropological analysis.
Results and conclusions: The findings of this investigation leaded to assess the valuable role of the MSCT images along with conventional techniques for human identification and these also validated the essential role of MSCT when skeletal remains must be preserved.

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3.3. Contribution of the computed tomography of the anatomical aspects of the sphenoid sinuses, to forensic identification

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Objective: Body identification is the cornerstone of forensic investigation. It can be performed using radiographic techniques, if antemortem images are available. This study was designed to assess the value of visual comparison of the CT anatomical aspects of the sphenoid sinuses, in forensic individual identification.
Material and method: The supervisor of this study randomly selected from the PACS, 58 patients who underwent one (16 patients) or two (42 patients) head CT. To avoid bias, those studies were prepared (anonymized, and all the head structures but the sphenoid sinuses were excluded), and used to constitute two work lists of 50 (42 + 8) CT exams of the sphenoid sinuses. An anatomical classification system of the sphenoid sinuses anatomical variations was created. In those two work lists, three blinded readers had to identify, using the anatomical system and subjective visual comparison, 42 pairs of matched studies, and 16 unmatched studies. Readers were blinded from the exact numbers of matching studies.
Results: Each reader correctly identified the 42 pairs of CT with a concordance of 100% [97.5% confidence interval: 91–100%], and the 16 unmatched CT with a concordance of 100% [97.5% confidence interval: 79–100%]. Overall accuracy was 100%.
Conclusion: Our study shows that establishing the anatomical concordance of the sphenoid sinuses by visual comparison, could be used in personal identification. This simple method, based on a frequently and increasingly prescribed exam, still needs to be assessed on a postmortem cohort. Integration of head CT examinations in missing person databases should be considered, for purposes of personal identification.

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3.4. Liver volumetry at post-mortem CT and liver weight at autopsy: a correlative study

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Objective: Post-mortem computed tomography (PMCT) is introduced as an adjunct or alternative to traditional autopsy. During autopsy, organ weights are of great value to pathologists interpretation of disease as any deviation in weight from the BMI-related normal range suggests certain pathology. The purpose of this study was to investigate the accuracy of PMCT in liver weight estimation.
Material and methods: 31 cases underwent PMCT examination before autopsy. Using the volume-analysis software Pinnacle v8.0 (Philips Healthcare, The Netherlands) liver volume was estimated at PMCT-scans. During autopsy, the liver weight was determined. Univariate ANOVA-analyses tested the difference in liver density within each subgroup of heart failure, liver steatosis, extended liver fibrosis, overweight (BMI > 25) and sex. The accuracy of PMCT in estimating liver weight was determined. Also the intra-observer variability of PCMT volumetry was calculated (N = 10).
Results: No differences in liver density were found within each subgroup. We found a very strong correlation ($r = 0.949$) between liver volume and liver weight at a density of 0.995 kg/L (95%-CI: 0.965–1.025 kg/L). The 95%-CI of estimated weights by volumetry was ± 296 g. PMCT volumetry showed an excellent mean intra-observer difference of -0.9 ml and repeatability-coefficient of 35.1 ml (95%-CI: 24.2 – 64.1 ml).
Conclusion: PMCT volumetry has an excellent repeatability and shows a high correlation with liver weight by autopsy. Considering the density of 0.995 kg/L, PMCT is able to estimate liver weight accurately at ± 296 g.These results support the potential for virtual autopsy as an alternative to conventional autopsy.

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3.5. The feasibility of measuring body weight on CT images and the first steps in anatomical mirroring

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Objective: To estimate body weight using the data of a post mortem total body CT scan and establish its efficacy in a forensic context.
Material and method: PMCT data were used to compute fat, soft tissue and bone volume using in house developed software based on density and HU. The digitally calculated body weight was then compared with the measured body weight on autopsy.
Results: Analysis of the obtained results showed a good correlation between the measured body weight and the CT-derived body weight. The highest discrepancies were noticed in children and decomposed bodies presumably due to different bone mineralization in children versus adults and putrefactive gas formation and liquefaction in decomposed bodies. In general, there was no distinct consistent over- or underestimation. In case of partial scans, where a body part was not scanned or was missing, mirroring the unaffected side was seen to give equally good results.
Conclusion: The weight of a body can be sufficiently estimated using volume measurements of different body tissues obtained from the PMCT data. This technique can be applied when concern is raised about the documented body weight, or if weighing was omitted all together. Furthermore the aforementioned body weight estimates can be useful in case of mass casualties, for victim identification purposes, or in case of traumatic deaths (e.g. dismemberments).

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3.6. Elementary aspects of postmortem pulmonary imaging: normal postmortem lung volume

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Objectives: It is well recognized that hyperinflation may occur in drowning deaths (emphysema aquosum). Early work by other investigators suggests hyperinflation may also occur in hypothermic fatalities. Additionally, background lung density at imaging depends on lung volume. This study establishes a baseline of expected postmortem lung volume (PMLV), as assessed by PMCT, to allow for recognition of departures from normal.
Materials and methods: A PACS database was retrospectively reviewed to accrue 10 consecutive male decedents who previously underwent PMCT. Exclusion criteria: < 18 years old, moderate or advanced decomposition, morbid obesity, and significant thoracic trauma, airway fluid or pulmonary pathology. PMLV determined using mixed automatic and manual segmentation in 3D visualization software. An accepted reference standard for lung volumes in the living was used to determine theoretical lung volumes.
Results: The mean PMLV was 2.15 L (range 1.66 – 2.78 L). The mean theoretical residual volume (RV), as calculated from reference standards, was 2.16 L (range 1.72 – 2.66 L).
Conclusion: This study establishes a quantitative baseline for PMLV. Average PMLV in this study corresponds closely to theoretical RV, the volume remaining at end maximum expiration in the living. We theorize this is due to complete diaphragmatic relaxation, with possible contributions from thoracic cage relaxation and decreased intravascular volume. Expected postmortem lung density should, therefore, correspond most closely with that seen on expiratory CT in the living.

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3.7. Radiation dosimetry comparison between ante-mortem and post-mortem animal tissue: Is post- mortem radiation dosimetry an adequate proxy for measurements in the living?

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Objectives: Radiation dose from diagnostic imaging procedures is a growing public health concern. Implanting dosimeters is a more accurate way to assess organ dose, relative to commonly used mathematical estimations. However, there are problems with performing accurate dosimetry using live subjects, including patient motion and patient safety considerations, which limit the radiation dose and placement of implanted dosimeters. Therefore, our objective is to assess whether radiation doses measured in post-mortem (PM) subjects are equivalent to doses measured in live subjects.

Material and methods: 4 MOSFET radiation dosimeters were placed enterically in each subject (2 sedated Rhesus Macaques) to measure the radiation dose at 4 levels (carina, lung, heart, and liver) during CT scanning. The CT scanning protocol was repeated three times for each condition, ante- mortem (AM) and 2 h after euthanasia, to obtain the average AM and PM dose to each organ.

Results: A two sample *z*-test was performed to evaluate the observed AM/PM differences. No significant difference was observed in 8/9 measurements between the AM and PM radiation doses. Only one individual measurement (liver of the first subject) showed a significant difference (7% lower on PM measurement), possibly attributable to repositioning of dosimeters.

Conclusions: We conclude that realistic radiation dosimetry can be performed PM as a valid alternative to dosimetry of live patients, which poses several problems. This study is an example of translational forensic research, with the potential for immediate and direct benefits to clinical medicine.

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3.8. Multiphase post-mortem computed tomography angiography – Preliminary results of a European Multicenter Validation Study

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Objective: Post-mortem CT-angiography is a valuable addition to post mortem diagnostics due to its ability to reliably discover discrete vascular pathologies. While different approaches are being pursued across the world, the need for validation and standardization of the method increases in order to facilitate its transition into daily routine. With this aim, an international working group has been performing a prospective multicenter study to validate the technique, define its indications and evaluate its advantages and limitations, especially compared to conventional autopsy.

Methods and materials: We report the results of the first 200 of 500 planned cases. All cases received previously published Multi Phase Post Mortem Angiography (MPMCTA) followed by conventional autopsy. All findings were recorded for each method and categorized by anatomical structure (bone, parenchyma, soft tissue, vascular) and importance for the forensic case (essential, useful, not important).

Results: Most findings were visualized with both techniques. MPMCTA was superior to autopsy at identifying skeletal and vascular lesions, where it detected a number of significant lesions not seen at autopsy. On the other hand, conventional autopsy provided better information about parenchyma lesions and was more accurate at distinguishing post-mortem and intra-vital vascular occlusions. Best results were obtained when combining both techniques.

Conclusion: MPMCTA can reveal important findings, not visible at conventional autopsy. Still, some diagnoses remain autopsy-diagnoses. Optimal results are obtained by combining both techniques. When finished, the ongoing study will provide researchers and practitioners with a solid data base and help promote the transition of MPMCTA into daily routine.

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3.9. Value of minimally invasive, whole body postmortem CT angiography in the assessment of massive haemoptysis

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Objective: Since the demise of advanced pulmonary tuberculosis in our community, fatal haemoptysis is unusual mostly seen after penetrating trauma including surgical procedures and advanced malignancy. Detection of the responsible vessel at autopsy can be technically difficult. Postmortem CT angiography (PMCTA) is routinely used at our institution to identify sites of bleeding.

Material and methods: 170 PMCTA procedures have been performed since 2010 utilizing a modified Bern technique including a solution of iodine-based radiographic contrast and PEG 200, infused via the femoral artery using a Dodge® embalming pump and dual energy CT imaging. 10 cases of massive haemoptysis were identified. PMCTA images were reviewed and correlated with autopsy findings.

Results: Of the 10 cases, 4 were ultimately shown at autopsy to be due to advanced malignancy and 6 traumatic (5 of these iatrogenic). PMCTA was able to detect a bleeding point in 9 of 10 cases, being negative in a case of post CT-guided lung biopsy. In one case, the PMCTA detected a bleeding point in the trachea following oesophagogastrectomy for caustic ingestion. At autopsy the pathologist was unable to detect any specific bleeding vessel.

Conclusion: PMCTA as applied at our institution is useful for identifying bleeding points in massive haemoptysis. Intervention to the body is remote to the site of pathology (avoiding artefact) and the whole body vascular opacification allows assessment of all possible responsible vessels including sites not necessarily suspected prior to autopsy. Localizing disrupted vessels prior to autopsy allows the pathologist to focus their dissection.

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