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Post-mortem virtual estimation of free abdominal blood volume☆

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ABSTRACT

Purpose: The purpose of this retrospective study was to examine the reliability of virtually estimated abdominal blood volume using segmentation from postmortem computed tomography (PMCT) data.
Materials and methods: Twenty-one cases with free abdominal blood were investigated by PMCT and autopsy. The volume of the blood was estimated using a manual segmentation technique (Amira, Visage Imaging, Germany) and the results were compared to autopsy data. Six of 21 cases had undergone additional post-mortem computed tomographic angiography (PMCTA).
Results: The virtually estimated abdominal blood volumes did not differ significantly from those measured at autopsy. Additional PMCTA did not bias data significantly.
Conclusion: Virtual estimation of abdominal blood volume is a reliable technique. The virtual blood volume estimation is a useful tool to deliver additional information in cases where autopsy is not performed or in cases where a postmortem angiography is performed.

1. Introduction

Over the last decade imaging in forensics has become a complementary post-mortem examination, providing and documenting important forensic information [1,2]. Many research groups worldwide have implemented post-mortem imaging techniques in their forensic investigations and significant scientific work concerning this topic has been published during the recent years [3–6].

The volume of free abdominal blood is of great importance to the forensic pathologist as it may be directly related to the cause of death or be a proximate cause of it. Measuring the volume of free abdominal blood during autopsy has been established as a standard procedure and is recommended by the Committee of Ministers Recommendation No. R (99) 3, Council of Europe [7]. Post-mortem computed tomography (PMCT) allows for precise diagnosis of air/gas embolism, fractures, identification of the body or foreign objects and gross pathologies of the organs [1]. Additional post-mortem computed tomography angiography (PMCTA) after initial unenhanced postmortem computed tomography (PMCT) enhances quality whilst allowing for diagnoses of vascular pathology [8–12] and can be used as a supplementary post-mortem imaging tool. Clearly, in cases with abdominal extravasated free fluid/blood, the autopsy-measured free abdominal blood volume will not correspond to the pre-angiographic volume as it does not include the volume of extravasated contrast medium administered during PMCTA.

In this study the feasibility and reliability of the virtual estimation of free abdominal blood volume was evaluated. If this new segmentation method is reliable the initial free blood volume could be estimated by evaluating the pre-angiography (unenhanced) post-mortem computed tomography data and subsequent PMCTA could be performed without risking bias of the forensic pathologists' measurement of the abdominal blood volume. Additionally, it would be also possible to estimate the volume of free abdominal blood in cases where the deceased has not undergone autopsy but only PMCT and, of course, in living trauma patients with standard trauma scan.

2. Materials and methods

Retrospective evaluation of the forensic database during a 3-years period (February 2007 to February 2010) identified all cases that were likely to have free blood in the abdomen. Search criteria included: accidental or suicidal falls from heights, traffic accidents, aneurysm ruptures, and blunt or penetrating injuries

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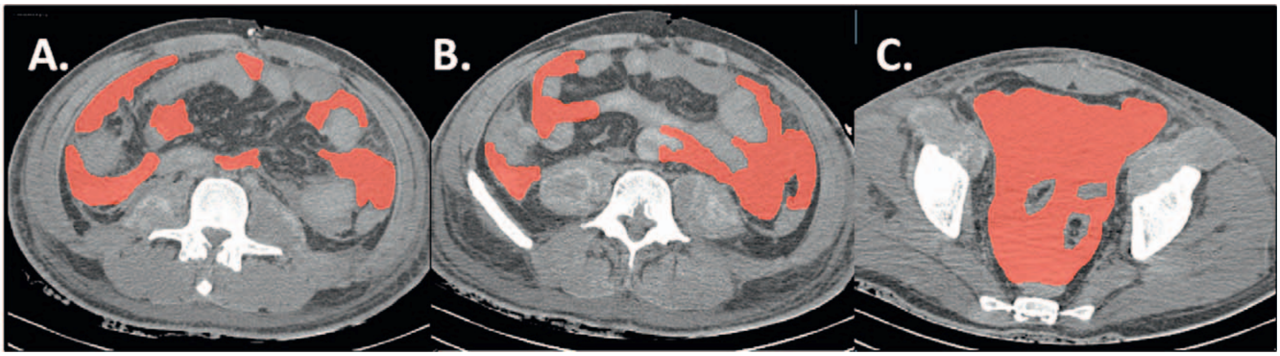

Fig. 1. Axial computed tomography images of the abdomen at three distinct levels (A–C). The free abdominal blood is manually marked during segmentation procedure (red colored areas in A–C).

to the abdomen. The inclusion criteria of the study were: the corpse underwent PMCT and free abdominal blood was reported in the autopsy report. 21 cases fulfilled these criteria and could be included in the study. 14 cases were traffic accident fatalities, 3 falls from height, 2 sharp object injuries, 1 blunt force injury and 1 aortic-aneurysm rupture. The male to female ratio was 14:7 and the mean age of the subjects was 45 years (range 3–75 years, standard deviation 19.1 years).

The time interval between PMCT and autopsy varied. The mean interval was 974 min (16 h and 14 min) with a standard deviation of 929 min (15 h and 29 min). During this time all corpses were stored in refrigerators, to prevent decomposition.

The ethics committee of the university, where the study was done, approved this study.

For unbiased evaluation, segmentation would always be applied to unenhanced PMCT scans, but in order to increase the number of evaluable cases, six subjects with additional PMCTA prior to autopsy were also included in the study. In these cases, the final blood-volume that was measured during autopsy also included extravasated contrast medium that leaked into the abdominal cavity during PMCTA intervention. Standard PMCTA includes an arterial and venous scan after initial unenhanced PMCT. The segmentation method was performed with the CT data of the venous scans as this would be volume-equivalent to the final free abdominal blood volume measured during autopsy.

By knowing the presence of blood in the abdominal cavity (inclusion criterion), no further evaluation of the nature of the fluid seen on PMCT was performed. The delimitation of the blood from other organs in isolated PMCT slices was in many cases difficult. However, when scrolling the PMCT dataset, it was possible to determine the organs' limits and mark the free blood volume.

Volume segmentation based on PMCT/PMCTA datasets of the cases was performed on a dedicated software platform (Amira, Visage Imaging, Germany). Segmentation was carried out by assigning a distinct voxel-based material property (e.g. bone, vessel, liver) to the region of interest. Subsequent to determination of the material density, blood could be distinguished from other tissue within the dataset. By counting the number of voxels and multiplying the result with the volume of each single voxel, the final volume of the corresponding material could be calculated.

Different methods (automatic, semi-automatic and manual) exist to perform segmentation. Since it is not possible yet to use automatic or semiautomatic methods on free abdominal blood, a manual segmentation had to be performed, in other words, the free blood had to be marked manually in each slice of the PMCT dataset (Figs. 1 and 2).

The scan slice thickness was not the same in all PMCT data sets because of different scan protocols over the 3-years period. Moreover, segmentation of thin slice PMCT data sets was laborious and extremely time-consuming and therefore not practical. For these two reasons, all datasets were calculated with a slice thickness of 5 mm in order to eliminate bias and to provide evaluable data stacks. Thus, the datasets were homogenized and the segmentation time and complexity was reduced.

3. Statistical analysis

A statistical package, Predictive Analytics SoftWare (PASW18, SPSS Inc., Chicago, IL), was used for data analysis.

The first null hypothesis was that the blood volumes measured during autopsy do not differ significantly from the volumes measured with the segmentation process. The Shapiro–Wilk test of normality (N size <50) showed that the variables were not normally distributed ($p < 0.0001$). The Wilcoxon Signed Rank test was chosen as the non-parametric alternative to the repeated measures (paired samples) t-test.

The inclusion of subjects after PMCTA could introduce bias to the study if there was significant difference in variance between the group that underwent PMCTA and those who did not. Thus,

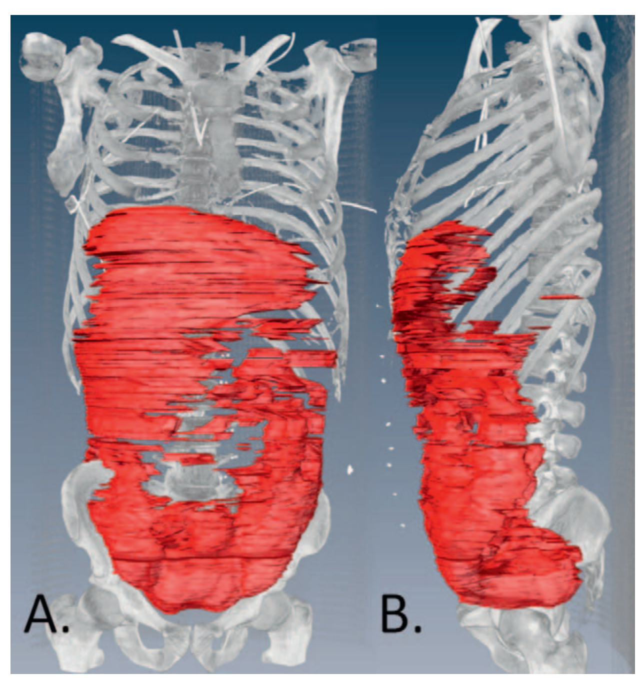

Fig. 2. Three dimensional volume rendering of the segmented abdominal blood volume. (A) Frontal view and (B) sagittal view. Slight edges appear due to a slice thickness of 5 mm.