Journal of Forensic and Legal Medicine 38 (2016) 111–115

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Original communication

Estimation of *post mortem* interval by tomographic images of intra-cardiac hypostasis

Talita Zerbini [a,*], Luiz Fernando Ferraz da Silva [a], Pedro Artur Lobato Baptista [b], Eduardo Seigo Ikari [c], Marina Rodrigues de Araujo [b], Carmen Diva Saldiva de André [d], Julio da Motta Singer [d], Francisco Marcelo Monteiro da Rocha [d], Edson Amaro Junior [e], Carlos Augusto Gonçalves Pasqualucci [a], Paulo Hilario Nascimento Saldiva [a]

[a] *Department of Pathology from Faculty of Medicine of São Paulo University, São Paulo, São Paulo, Brazil*
[b] *Department of Legal Medicine from Faculty of Medicine of São Paulo University, São Paulo, São Paulo, Brazil*
[c] *Heart Institute of Hospital das Clínicas of Faculty of Medicine of São Paulo University, São Paulo, São Paulo, Brazil*
[d] *Department of Statistics from Institute of Mathematics and Statistics of São Paulo University, São Paulo, São Paulo, Brazil*
[e] *Department of Radiology from Faculty of Medicine of São Paulo University, São Paulo, São Paulo, Brazil*

ARTICLE INFO

Article history:
Received 16 February 2015
Received in revised form
25 November 2015
Accepted 1 January 2016
Available online 11 January 2016

Keywords:
Autopsy
Computed tomography
Post mortem changes
Post mortem interval
Forensic
Hypostasis

ABSTRACT

The determination of the *post mortem* interval (PMI) is important in many instances, especially in criminal investigations. So, we consider *post mortem* tomographic evaluation of intra-cardiac hypostasis as an additional method for such purpose. Tomographic images of the thoraces of the corpses of 23 patients who died in a hospital were obtained sequentially at one hour intervals to allow the analysis of changes in density due to hypostasis over time. The right and left atria, which appear in the mediastinal window, were selected for measurements of the average organ density. An exponential model was used to relate the difference between the attenuation coefficients of the anterior segment of the right atrium and the posterior segment of the left atrium to the PMI. In spite of the large variability of the data from this observational study, PMI estimates during the first 12 h after death can be estimated with a margin of error smaller than two hours. The results suggest that the difference between the attenuation coefficients stabilizes around 12 h *post mortem* and may be used as an additional method to estimate the PMI.

1. Introduction

The estimated time from death, known as *post mortem* interval (PMI), is fundamental in many instances such as in criminal investigations, because the finding may acquit or condemn a suspect, as the data will be compared with the alibis provided by the people under investigation. The estimated PMI in the first 6 h following death has an error margin of at least 2 h, increasing to a margin of at least 3 h in the next 14 h and to 4.5 h in the subsequent 10 h.[1]

The concentration of red cells in the vascular system result in a reddish-purple color, which is called hypostasis[2–4] or *livor mortis*.[5] According to Dolinak et al. (2005), hypostasis begins to develop at the moment of cardiac arrest, becoming perceptible after 3–4 h and more obvious after 6–8 h, with full development in the skin occurring after 10–12 h.[4] Fávero (1991), on the other hand, suggests that the first signs of hypostasis occur within 10 min after death, becoming obvious after 1–3 h and stabilizing after approximately 8–12 h.[6] Such differences in tissue density may be visualized via *post mortem* computer tomography (PMCT). Hypostasis is a reflection of the sedimentation of the cellular elements of the blood and can be detected in the heart and in the great vessels, allowing visualization of the superior *vena cava*, the right atrium, the right ventricle, the thoracic aorta, the left atrium and the left ventricle.[7] Ishida et al. (2011) examined 50 cases, concluding that hypostasis was easily observed with PMCT in 55% of the patients, with the best sites for analysis being the right atrium (88%), the left atrium (88%) and the thoracic aorta (76%).[7] To our knowledge, authors of studies related to virtual autopsy did not consider using complementary imaging to facilitate estimating the PMI; published studies concerning tomographic analysis of hypostasis in the heart and in the

* Corresponding author. 455 Doutor Arnaldo Avenue, Oscar Freire Institute, São Paulo, São Paulo 01246-903, Brazil. Tel.: +55 11 987525482, +55 11 30617254.
E-mail address: tazerbini@yahoo.com.br (T. Zerbini).

http://dx.doi.org/10.1016/j.jflm.2016.01.001
1752-928X/

great vessels used a single image for each case, rather than a series of timed images at increasing *post mortem* instants.[7–9] Our objective is to propose a method for estimating the PMI based on a series of tomographic analysis of intra-cardiac hypostasis.

2. Methods

This prospective observational study with the purpose of designing a new method was approved by the responsible Ethics Committees. The data were collected from 23 corpses of patients of both genders who died of natural causes while under medical care, but were routed to autopsy by the physicians for definition of the exact cause of death. Since all patients died during treatment, this guarantees the knowledge of the exact time of death.

The corpses were selected during night shifts of the researchers over a six month period, with the exclusion of those who had diseases that might interfere with the interpretation of PMCT, such as chest tumors or pneumonia.

For each subject, epidemiological data (age, gender and ethnicity), disease history, the hypothetical cause of death and the time of death observed by the physician were recorded. A pathologist was responsible for specifying the causes of death as well as writing the autopsy reports.

All the corpses were placed in the same dorsal decubitus position with the arms placed behind the head to allow transition through the tomograph and to reduce the emission of radiation. Tomographic slices of the thoracic segment were acquired sequentially via a SOMATOM Emotion syngo CT 2012E instrument (Siemens, Munich/Germany), placed in a room with average temperature of 18 °C. The first image was obtained ten minutes after the body was positioned and repeated at intervals of one hour up to nine hours after the first acquired image. As hypostasis can be modified with changes of the position, the corpses were not moved between the PMCT exams. After the analytical period, all areas of cutaneous hypostasis were examined by finger pressing to determine the fixed time of this *post mortem* change in the skin. Finger pressing was always performed by the same researcher in the presence of a pathologist.

To achieve the calibration of the machine, the parameters were adjusted as follows in the mediastinal window: *B46s Sharp*, refmAs 70, 130 kV, *slice* 1.5 mm with 16 × 1.2 mm acquisition, *pitch* 0.8 and *recon increment* 0.7 mm. Each examination conducted for the automatic reconstruction of the window was completed in 10.14 s. The images were analyzed simultaneously by a forensic physician and by a radiologist and were reviewed by a pulmonary pathologist.

The acquired images were analyzed one by one, with the goal of choosing the most appropriate slice for the attenuation measurements. The slice obtained at the level of the inferior pulmonary vein was selected as the standard slice. The axial view was used to obtain the attenuation measurements because the bodies remained in the dorsal decubitus position and because obtaining the attenuation measurements in the antero–posterior axis was of interest. The right and left atria were selected because they exhibited the most distinct intra-cardiac contents. Each cardiac chamber was divided into two zones (anterior and posterior) and measurements were obtained in a circular area with average size of 1.4 cm^2 within each zone (Fig. 1). At each observation instant, the average tissue density (in Hounsfield units) of each zone was calculated and the attenuation values in each area were determined to obtain curves of their temporal evolution. The measurements were obtained using the Aquarius Intuition software (version 4.4.7.29.4070).

The images of the mediastinal window were excluded in two cases due to the presence of a cardiac pacemaker and of severe cardiac hypertrophy. In the first case, the images were excluded because of possible interference with the acquired image and in the second case, because it was not possible to visualize the intra-cardiac content. Both cases were initially admitted to the study because there was no previous information about the corresponding diseases. The 21 remaining images generated attenuation measurements for the anterior zone of the right atrium and for the posterior zone of the left atrium which were considered for analysis because they correspond to the locations used in previous studies. Also, as hypostasis is a blood sedimentation process, the distance between the zones under investigation facilitates visualization of the sedimentation process.[7] Considering that hypostasis begins when the heart stops beating,[4] the densities of the anterior and posterior zones of the atrium were considered equal at the moment of death. None of the patients that remained in the study had any known disease that could interfere with the initial density.

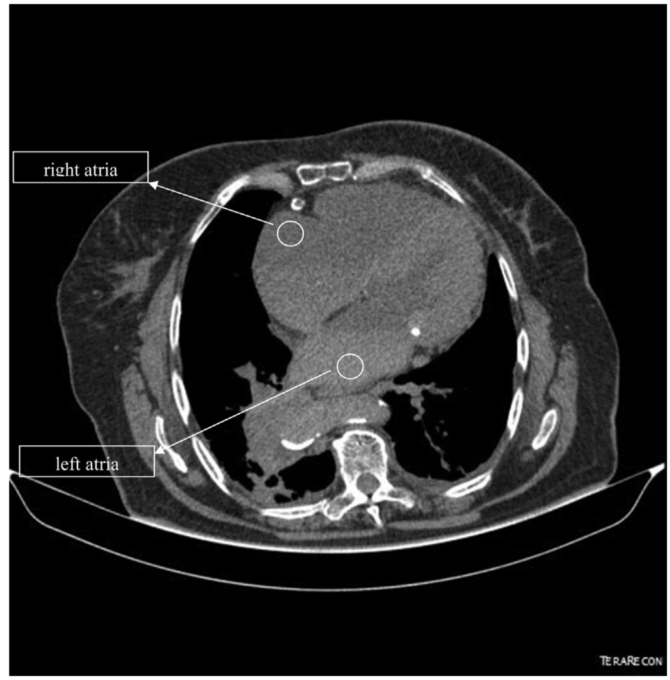

Fig. 1. Measurements obtained in a circular area with average size of 1.4 cm^3 in the right and left atria (showing distinct intra-cardiac contents).

As the densities showed a significant range in each zones, the difference between the attenuation measurements obtained from the anterior zone of the right atrium, located at 0.7 cm of the anterior wall and tricuspid valve, and the posterior zone of the left atrium, located at 0.7 cm of the posterior wall and at an equidistant position of the inferior pulmonary veins (labeled dif(ARPL)), in each selected image was used for statistical analysis.

To take the nature of hypostasis into account, an appropriate model to represent the relation between dif(ARPL) and PMI should satisfy the following requirements: i) dif(ARPL) should be null when the heart stops beating, i.e., when PMI equals zero; ii) it should contemplate the stabilization of hypostasis after a certain instant, i.e. it should contain an asymptote; iii) it should take individual variability into account, i.e., it should include subject specific parameters.

Three models with such features were considered as candidates: segmented regression, von Bertalanffy and exponential mixed effects models.[10,11] The models were fitted to the data and compared with respect to interpretability, goodness of fit (Akaike criterion