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Identification of deceased based on sternal bone computed tomography features

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ABSTRACT

Identification of deceased with unclear identity is a common problem in forensic science, whereby radiologic comparison can be applied as method for identification. As this comparison is mostly made on a visual basis, it is highly dependent on the examiner and often lacks standardized procedures and statistical support. The aim of this study therefore was to develop a reproducible and examiner independent method for radiologic identification (RADid) based on morphometric and morphological features of sternal bone computed tomography (CT). Furthermore, the feasibility of an automated comparison of a post-mortem (PM) case against a database of ante-mortem (AM) cases was evaluated.

44 in situ PM CT scans of sternal bone and their corresponding AM CT scans were analysed and reproducible features were selected based on intra- and interrater reliability assessments. The selected features were further tested by contrasting AM and PM data. Moreover, an automated identity evaluation was developed by calculating the number of matching features between each PM case and an AM database consisting of 94 cases including the 44 with corresponding PM scans.

Several features showed to be reliable according to their resulting correlation coefficient values (greater or equal to 0.60). The suitability and stability of these features was confirmed by contrasting AM and PM CT scans. Finally, the automated comparison was successful in 76.7% of the cases, whereby an unambiguous identification was possible in 65.1%.

The present study reflects the benefits of a standardized and statistically established identification method and demonstrates the high potential of the sternal bone as a suitable structure for RADid.

1. Introduction

Forensic medicine frequently has the task to identify deceased persons of unclear identity. In 2015, 4755 cases of death were registered in the two Swiss cantons Basel-Stadt and Basel-Land [1,2]. Of those 4755 cases, 535 cases were listed as unusual death and required forensic investigation. Furthermore, the identity was unknown for 76 cases. Projected onto Switzerland with 67′606 cases of death registered in 2015, identification was required in about 1000 cases [3].

Different procedures exist to identify deceased of unclear identity. Thereby, a distinction is made between secure and insecure methods. Insecure methods such as visual recognition, personal belongings (for example jewellery, clothing or identity documents), or body characteristics (for example scars or surgery) can only serve as a hint towards the identity as they are not sufficient for reliable identification. Secure identification methods however offer the possibility to adequately proof the identity of the deceased person and include procedures like odontology, forensic genetics, dactyloscopy or radiologic comparison [4,5]. If unique, also serial numbers from medical implants are reliable [4,5]. Nevertheless, all these methods require the existence of comparison material, meaning ante-mortem (AM) data, such as DNA samples, radiological images or fingerprints, which can be compared to post-mortem (PM) findings. The difficulty thereby is to obtain the required AM and corresponding PM material, as the body could for example be in a condition where fingerprints cannot be taken or no AM radiological images are present.

Abbreviations: AM, ante-mortem; CT, computer tomography; ICC, intraclass correlation coefficient; Kappa, Cohen's Kappa coefficient; PACS, picture archiving and communication system; PM, post-mortem; RADid, radiologic identification; SD, standard deviation; SEM, standard error of measurement.

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The comparison of radiological material is a favoured method for identification, as it is fast and cost-efficient and goes hand in hand with performing PM radiologic examinations. Usually, radiologic identification (RADid) is made by visual comparison of AM and PM images of teeth or frontal sinuses [6]. This method, however, is highly dependent on the experience of the examiner and lacks standardized procedures and statistical support [7–9]. In daily routine, a suitable radiological image, especially one of the head, is not always present for comparison. Nevertheless, from the 76 cases mentioned in the first paragraph, around two thirds of the cases could be identified by radiologic comparison (one half each by comparing the teeth and other body parts as well). For identification of the remaining third, several other identification methods like dactyloscopy or forensic genetics were applied.

In various studies [10–19], the sternal bone has been shown to have a high range of morphological variation concerning number and shape of ossification centres of the three parts manubrium, corpus and xiphoid, thereby indicating the potential for being used for identification. For example, incomplete fusion of ossification centres results in foramina and clefts. Moreover, several other features can arise through variations in development [15–19].

Unfortunately, there are no clear guidelines established on how many features are required to make a positive identification. The general opinion however is "the more, the better" [7,8,19]. The mentioned insecurity is due to the lack of appropriate investigations concerning this problem. It has been stated that the number of concordant points is not as important for an accurate identification as the likelihood ratios of each feature used [19].

Besides the uniqueness of the structures used, a successful identification is based on two conditions. Firstly, there has to be comparison material present, e.g. AM radiological images. Secondly, there has to be a suspicion about the identity. However, sometimes there is no suspicion and for this reason it is unknown if AM data is available. Hence, there should be a way to search for matching cases in an undefined group of AM data.

We therefore aimed on establishing a reliable alternative for radiological identification using the morphometric and morphological appearance of the sternal bone by selecting suitable CT features as well as investigating their reproducibility. A method was created for an automated comparison of a PM case against a group of AM data to minimize the group of potential matches and the feasibility of finding the corresponding matching case within a database by only using the sternal bone parameters could be demonstrated.

2. Material and methods

2.1. Radiologic data

This study was designed based on 300 PM CT scans of the sternal bone that were measured and analysed to define nominal and metric features [10,11]. Fig. 1 illustrates the schematic representation of the sternal bone and Table 1 shows an overview of the collected features. In order to find corresponding AM data, the picture archiving and communication system (PACS) database of the local university hospital was searched by using PACSCrawler (www.pacscrawler.org). PACSCrawler is a set of software tools developed at the local university hospital that enables systematic querying of PACS systems and subsequent pulling of radiologic datasets. About 800 PM cases from the database of the local institute of forensic medicine from the years 2011 to 2016 were compared to the PACS database of the local university hospital according to names and birthdates. By filtering for CT thorax scans and excluding CT angiographies, 44 matching AM cases could be found. Time between AM and corresponding PM scan was between one day and 91 months with an average of 24.2 months.

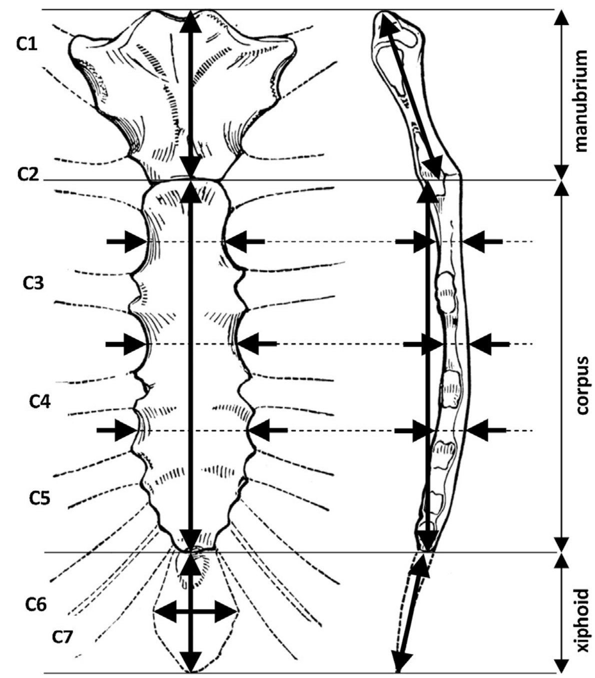

Fig. 1. Anatomic structure of the sternal bone with its three parts. C1–C7 describe the adjoining ribs, the arrows reflect the measuring points [25].

PM data were acquired on a Siemens Somatom Emotion 16 slice CT scanner (Siemens Healthineers, Erlangen, Germany) based on different thorax imaging protocols with slice thicknesses between 0.75 and 2 mm. For the matching AM datasets, CT vendors and detailed imaging parameters differed considerably, slice thicknesses varied between 1 and 3 mm.

Both AM and PM data were fully anonymized directly after pulling with no patient information being saved (only the technical scan parameters, the time between the AM and corresponding PM scan and the information about the AM to PM correspondence were saved). Since no identity coding key was generated and only fully anonymized data was further used, ethical approval was not required for this project according to national legal standards on human research.

2.2. Analysis phase 1: evaluation of CT scans

The 44 PM and their corresponding AM CT scans were analysed by a first examiner (0.5 years experience in PM CT, no experience in forensic pathology) based on the features presented in Table 1 (using the CT console software Siemens Healthineers Syngo CT 2014 A VB42B and applying bone windowing). Fig. 2 illustrates the assessment of the metric features.

Nominal features were evaluated on a visual basis. Synostoses as osseous fusions can occur between manubrium and first rib (M-C1), between manubrium and corpus (M-C) and between corpus and xiphoid (C-X). M-C1 fusions were ranked as present when existing uni- or bilateral. Suprasternal bones (SB) were defined as isolated bones at the cranial manubrium end and were ranked as present when existing uni- or bilateral. Foramina of the corpus (FC) or the xiphoid (FX) had to be completely consistent over the entire thickness to be ranked as real foramen. Clefts (CLT) of the corpus were defined as wedge-shaped incisions lengthwise and crosswise originating from the sternal cortex. Notches (NTC) in the corpus were defined as depressions at the front or the back of the corpus surface. Sclerotic bands are bony fusion lines which show a higher density than the remaining bone and present as longitudinal (SBL) or transversal (SBT) band.