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Brief Communication

# Efficacy of automated three-dimensional image reconstruction of the femur from postmortem computed tomography data in morphometry for victim identification

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ABSTRACT

Besides conventional radiology, postmortem computed tomography (PM-CT) is nowadays widely used for victim identification in forensic routines to detect anatomical characteristics and specific pathologies as well as to estimate the stature and sex. A major advantage of PM-CT is virtual reconstruction of skeletal structures independent of the status of recovered remains. The present study investigated the efficacy of a recently provided automated analyzer to reconstruct three-dimensional (3-D) images using CT data for skeletal morphometry, measuring the whole bone mass volume of the femur (60 bones in 30 cases) as an index of reproducibility. Manual cursoring could reconstruct bilateral femurs with high reproducibility, showing mass volume fluctuations by repetition and between two independent observers of 0.2–2.1% and 3.5–6.7%, respectively, partly depending on the data analysis system, but was time-consuming, while automated reconstruction was very rapid and highly reproducible virtually without detectable fluctuation; there was a high correlation between bone mass volumes reconstructed by manual and automated procedures ($r = 0.9976$, $p < 0.0001$). The reproducibility of the automated procedure was 98.64–100.81% in 5 cases scanned twice under the same CT conditions. Preliminary analysis showed a substantial correlation of the whole femur mass volume with the body height and a significant sex-related difference in the femur mass volume/body height ratio (males > females). These findings indicate the accuracy and practical feasibility of the automated procedure to reconstruct single bone 3-D CT images for virtual skeletal morphometry in victim identification.



## 1. Introduction

Forensic radiology contributes to victim identification by detecting anatomical characteristics, specific pathologies of bones and foreign bodies including surgical materials as well as in estimating the stature and sex by morphometry [1–5]. Besides conventional radiology, postmortem computed tomography (PM-CT) is nowadays widely used in forensic routines [2,6,7]. Major advantages of PM-CT in victim identification include virtual reconstruction of skeletal structures independent of the status of recovered human remains for investigating fetal development [7], estimating age and body stature [3,8,9], and sex discrimination [8], as well as for superimposing [10,11]. In the manual reconstruction of three-dimensional (3-D) bone images, however, the validity, including reproducibility and interobserver deviation, should be assessed to establish practical feasibility, which also depends on the time required for data processing. In respect to this, an automated procedure is expected to reduce interobserver deviation and processing time, and improve reproducibility and practical reliability.

The present study investigated the efficacy of a recently provided automated analyzer to reconstruct 3-D images using CT data for virtual skeletal morphometry to estimate the stature in victim identification, measuring the bone mass volume of the femur as an index of reproducibility.

## 2. Materials and methods

### 2.1. Postmortem CT data

PM-CT scans were routinely performed immediately before forensic autopsy at our institute, employing a scanner (ECLOS,

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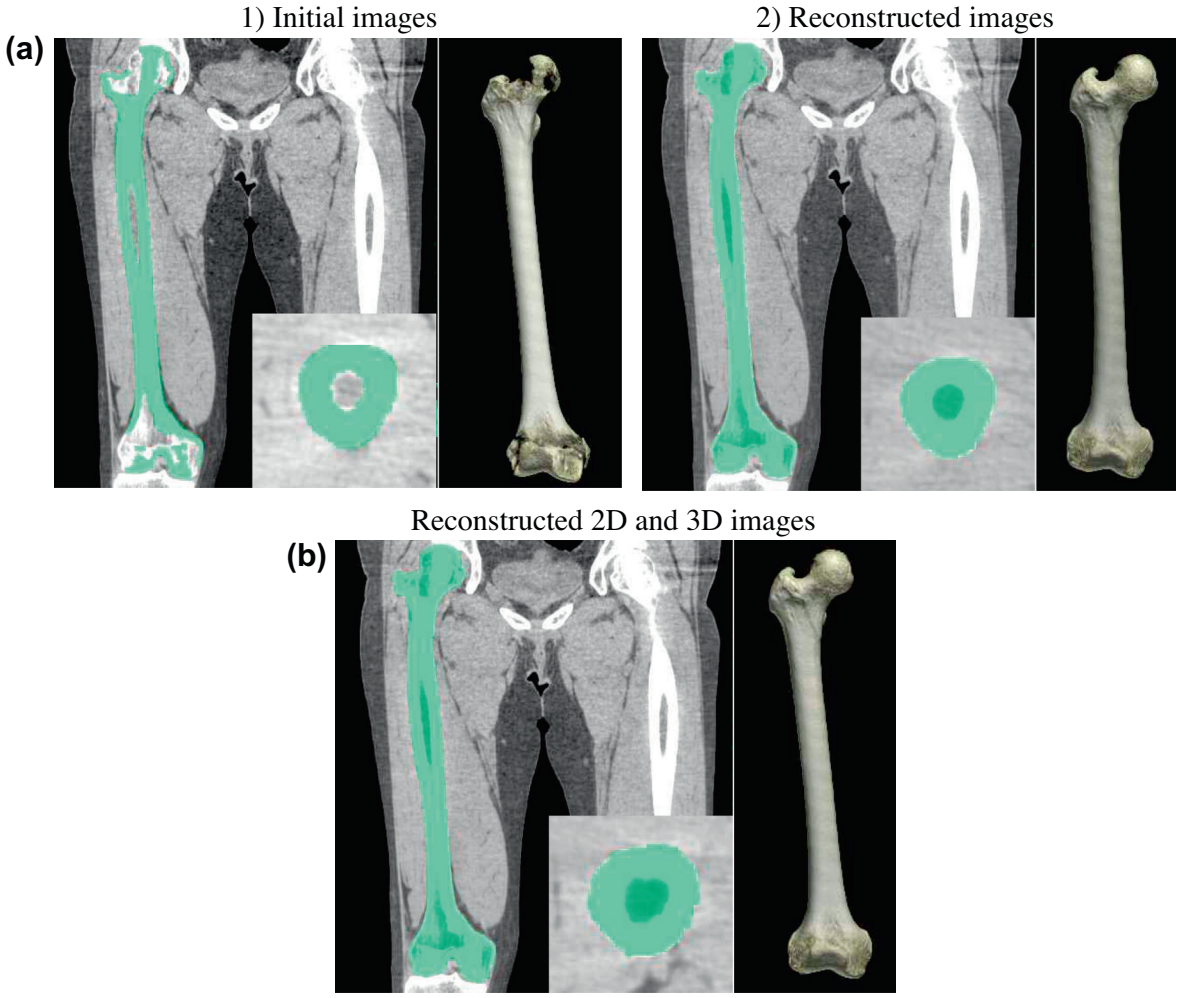


**Fig. 1.** Reconstructed CT images of the femur. (a) Manual extraction of the femur from reconstructed two-dimensional (2D) CT image of the pelvis and lower limbs (inset, cross section), and three-dimensional (3D) CT image of the femur. (b) Automated one-step reconstruction of the femur: reconstructed two-dimensional (2D) CT image of the pelvis and lower limbs, and three-dimensional (3D) CT image of the femur.

Hitachi Medical Co., Tokyo) with a 16 × 1.25 mm slice thickness within the framework of routine casework. From this autopsy database, CT data as well as demographic and physical data of 30 subjects (26–91 years of age; 15 males and 15 females) were collected retrospectively, to compare the manual and automated procedures described below. In addition, the cases where PM-CT was performed twice under the same scanning conditions ($n = 5$) were used to examine the stability of CT data. Cases involving fracture or postmortem destruction of the femur were excluded.

### 2.2. CT data analysis

Bilateral femurs were virtually reconstructed using the conventional and newly developed versions (Versions 2 and 3, respectively) of the CT image analyzing system Volume Analyzer SYNAPSE VINCENT (FUJIFILM Medical Co., Ltd., Tokyo). In the system of Version 2, the femur was extracted from the reconstructed 2-D image of the lower limb bone structures by manual cursoring, while the new Version 3 is equipped with an automated single bone reconstruction option: (a) The manual procedure involved (1) separation of the femur from the neighboring bones in the reconstructed 2-D image by repeated cursoring using the extract/remove option, monitoring the 3-D image, and (2) refining the extracted bone cortex using the threshold option, followed by filling the medulla of bone (Fig. 1a). (b) The automated procedure completed 3-D bone image reconstruction by one step using the bone separation option (Fig. 1b). For technical reason, the manual analysis using Version 2 was performed by an observer, and the manual and automated analyses using upgraded Version 3 were performed by two independent observers. Reconstructed bone volume was used as an indicator to examine the accuracy of each procedure to simplify and clarify the comparison.

### 2.3. Statistical analysis

Statistical analysis was performed using InStat3 (GraphPad Software, Inc., USA). Plot charts were created using Microsoft Excel 2003.

## 3. Results

### 3.1. Comparisons of manual and automated procedures

The manual cursoring procedure required about 2 h to reconstruct a 3-D image of a single bone, despite showing high reproducibility: Mass volume fluctuations were 0.2–2.1% by repetition on Version 2 or 3 (Table 1); however bone mass volumes reconstructed by the same observer were slightly larger (<1.0%) on Version 3 than on Version 2. The interobserver difference was