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ORIGINAL ARTICLE

# Body weight estimation based on postmortem CT data—validation of a multiplication factor

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**Abstract** Postmortem computed tomography (pmCT) is increasingly applied in forensic medicine as a documentation and diagnostic tool. The present study investigated if pmCT data can be used to estimate the corpse weight. In 50 forensic cases, pmCT examinations were performed prior to autopsy and the pmCT data were used to determine the body volume using an automated segmentation tool. PmCT was performed within 48 h postmortem. The body weights assessed prior to autopsy and the body volumes assessed using the pmCT data were used to calculate individual multiplication factors. The mean postmortem multiplication factor for the study cases was 1.07 g/ml. Using this factor, the body weight may be estimated retrospectively when necessary. Severe artifact causing foreign bodies within the corpses limit the use of pmCT data for body weight estimations.

**Keywords** Postmortem computed tomography · pmCT · Autopsy · Forensic medicine · Body weight

## Introduction

Postmortem computed tomography (pmCT) is increasingly applied in forensic medicine as a documentation and diagnostic tool [1–3]. PmCT is mostly performed prior to autopsy and documents the admission state of the corpse as it was delivered to the forensic institute. Archived on a Picture Archiving and Communication System (PACS), the pmCT data remain available for a second look, especially when the body has been autopsied and released [4, 5].

In 2014, the publication's host institute was involved in a case of a 1.5-year-old boy who died from an unknown cause. Prior to autopsy, a pmCT examination was performed as part of the autopsy routine at our institute. Image reading did not reveal any pathologic findings aside from regular postmortem alterations. At autopsy, no macromorphological findings explaining the death were found. A myocardial virus infection was confirmed histologically. Prior to the autopsy, the corpse weight was documented as being 8 kg.

Three days after the autopsy, the forensic pathologist noticed that within the clinical records, the last documented weight of the living child was 10.7 kg, and that this measurement had been taken 4 days before the child had passed away. At that time, the corpse had already been released and buried. Based on that information, a weight loss of almost 3 kg over the last 4 days was assumed, which could not be supported by the autopsy findings. However, a weight loss down to 75 % in a few days is life-threatening for children [6]. Therefore, the district attorney wanted to know whether the parents or the grandmother as well as the pediatrician had overlooked the relevant weight loss. The question arose as to whether the weight loss was real and somehow related to the cause of death, or if there was a relevant measurement error in one of the two documented weight measurements.

The present publication shows how the problem could be solved using the pmCT data of the individual case as well as of a control population. In the literature, a soft tissue multiplication factor is described as 1.04 g/ml for the living [7]. Therefore, the aim of the present study was to investigate if this factor can also be applied postmortem, using pmCT data to estimate the corpse weight when necessary.

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**Table 1** All segmented study cases and their individual multiplication factors

| | Age (y) | Sex | Segmented volume (ml) | Weight at autopsy (kg) | Multiplication factor (g/ml) | Multiplication factor in groups |
|---|---|---|---|---|---|---|
| Children | 2d | f | 1643 | 1.77 | 1.077297626 | |
| | 9d | m | 1961 | 2.247 | 1.145843957 | |
| | 3 m | f | 2896 | 3.15 | 1.087707182 | |
| | 1d | f | 3154 | 3.38 | 1.071655041 | |
| | 2d | f | 3287 | 3.53 | 1.073927594 | |
| | 4 m | m | 3274 | 3.6 | 1.099572389 | |
| | 1d | f | 3386 | 3.6 | 1.063201418 | |
| | 1.5 m | f | 3503 | 3.66 | 1.044818727 | |
| | 12d | f | 3514 | 3.8 | 1.081388731 | |
| | 1 m | m | 3599 | 3.84 | 1.066963045 | |
| | 3 m | m | 5184 | 5.3 | 1.022376543 | |
| | 6 m | f | 5160 | 5.4 | 1.046511628 | |
| | 4 m | f | 5200 | 5.5 | 1.057692308 | |
| | 2.5 m | m | 5296 | 5.6 | 1.057401813 | |
| | 3 m | f | 5632 | 5.75 | 1.020951705 | |
| | 4 m | m | 6139 | 6.425 | 1.046587392 | |
| | 11 m | f | 6124 | 6.5 | 1.061397779 | |
| | 8 m | f | 7044 | 7.4 | 1.050539466 | |
| | 8 m | f | 8534 | 8.85 | 1.037028357 | |
| | 3 | f | 11944 | 14 | 1.172136638 | 1.069249967 |
| 1.5 year old boy | 1.5 | m | 10414 | 8 | 0.768196658 | |
| Adultes | 26 | m | 39282 | 45 | 1.145562853 | |
| | 15 | m | 40129 | 46 | 1.146303172 | |
| | 56 | f | 42771 | 47 | 1.098875406 | |
| | 67 | m | 55376 | 64 | 1.155735337 | |
| | 28 | f | 58005 | 65 | 1.120593052 | |
| | 52 | m | 59569 | 65 | 1.091171583 | |
| | 61 | m | 63269 | 68 | 1.074775957 | |
| | 51 | f | 64551 | 68 | 1.053430621 | |
| | 68 | m | 68037 | 74 | 1.087643488 | |
| | 44 | f | 71594 | 74 | 1.033606168 | |
| | 86 | f | 76268 | 78 | 1.022709393 | |
| | 48 | m | 74559 | 80 | 1.072975764 | |
| | 83 | f | 80397 | 85 | 1.05725338 | |
| | 61 | m | 81732 | 85 | 1.039984339 | |
| | 44 | m | 85569 | 89 | 1.040096297 | |
| | 42 | m | 81779 | 89 | 1.088298952 | |
| | 81 | m | 83280 | 89 | 1.068683958 | |
| | 69 | m | 95039 | 104 | 1.094287608 | |
| | 69 | m | 114954 | 121 | 1.052594951 | |
| | 57 | f | 126795 | 129 | 1.017390276 | 1.078098628 |
| Hospital deaths | 90 | f | 43565 | 47 | 1.078847699 | |
| Adultes | 69 | m | 60560 | 66 | 1.089828269 | |
| | 91 | f | 68200 | 73 | 1.070381232 | |
| | 58 | m | 68470 | 74 | 1.080765299 | |
| | 75 | m | 76983 | 77 | 1.000220828 | |
| | 78 | m | 76277 | 79 | 1.035698835 | |
| | 61 | m | 85157 | 89 | 1.04512841 | |
| | 61 | m | 83246 | 89 | 1.069120438 | |

**Table 1** (continued)

| | Age (y) | Sex | Segmented volume (ml) | Weight at autopsy (kg) | Multiplication factor (g/ml) | Multiplication factor in groups |
|---|---|---|---|---|---|---|
| | 83 | m | 93394 | 99 | 1.060025269 | |
| | 79 | m | 92719 | 100 | 1.078527594 | 1.060854387 |
| Mean all (without 1.5 year old boy) | | | | | | 1.071110315 |

## Methods

### PmCT

Fifty corpses wrapped in body bags underwent CT scans in supine position. Whole-body pmCT examinations were performed using an Emotion 6 CT scanner ($n$=18) and a Somatom Definition AS CT scanner (n=32) (Siemens Medical Solutions, Erlangen, Germany). Examination time ranged between 10 min (Somatom Definition AS) and 30 min (Emotion 6), and image reconstructions took another 10 to 20 min. *CT parameters*: Emotion 6: 120 kV, care dose mAs, rotation time 0.5 s, slice thickness 1.0 mm, increment 0.5 mm, kernel B30; Somatom Definiton AS: 140 kV, care dose mAs, rotation time 0.5 s, slice thickness 0.6 mm, increment 0.3 mm, kernel I30.

### Volume segmentation

PmCT dicom data were sent from the PACS to a Mac Pro computer equipped with Osirix. A threshold-based volume segmentation plugin (Mia Lite; available for free on http://www.mia-solution.com) was used to segment the whole-corpse volumes. The lower threshold was set to −270 and the upper threshold was set as high as possible. After setting seed ROIs (Regions of Interest) within the corpse, the program segmented the volume automatically. After segmentation, the corpse volume was documented in ml.

### Cases and evaluation

PmCT data (postmortem interval < 48 h) of 50 corpses (20 children, 20 adults and ten adults who died in a hospital setting, age 0–94 years, 23 females, 27 males, Table 1) were used. The segmented volume (ml) and the weight (g) at autopsy were used to calculate an individual multiplication factor (g/ml). The mean multiplication factor was used to verify the weight of the 1.5-year-old boy.

## Results

The individual multiplication factors (g/ml) of the 50 corpses ranged between 1.0 and 1.17 (Table 1, Fig. 1). The average of the 50 corpses was 1.071; for the female corpses it was 1.061, and for the male corpses, 1.077. The corpse with a multiplication factor of 1.0 was one of the ten hospital deaths, which ranged between 1.0 and 1.09. The mean multiplication factor of the corpses from the hospital was slightly lower than that of the others (1.06). The body with a multiplication factor of 1.17 was one of the children. The average of the 20 children was 1.07.

Comparing the weight of the 1.5-year-old boy with the rest of the children showed his weight as an outlier (Fig. 2). Using the mean multiplication factor for children, his correct postmortem weight would be estimated at 11.1 kg, which was in line with the last documented living weight of 10.7 kg. Therefore, the postmortem weight documented prior autopsy could retrospectively be revealed as incorrect.

## Discussion

Based on the presented investigations, the case-related problem could be solved, and it was found that a decalibration of the autopsy scale was the cause of the discrepancy. Thereby, any malpractices or mistreatment

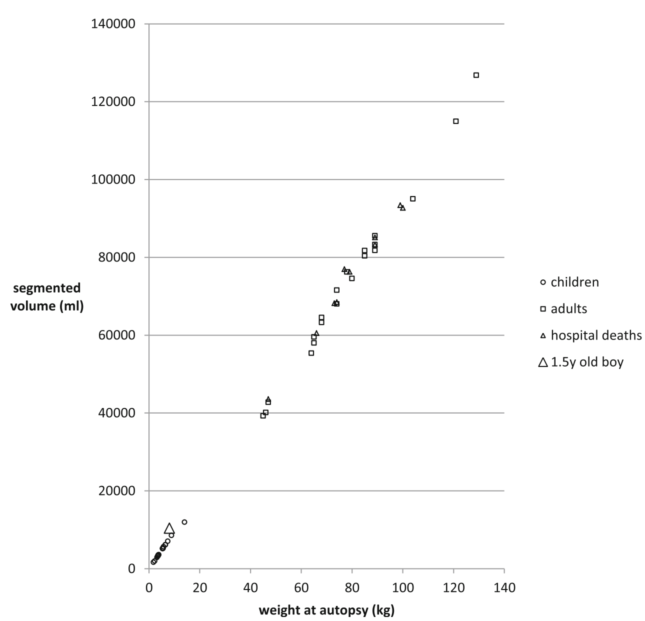


**Fig. 1** PmCT volumes compared to the weights at autopsy in all study cases

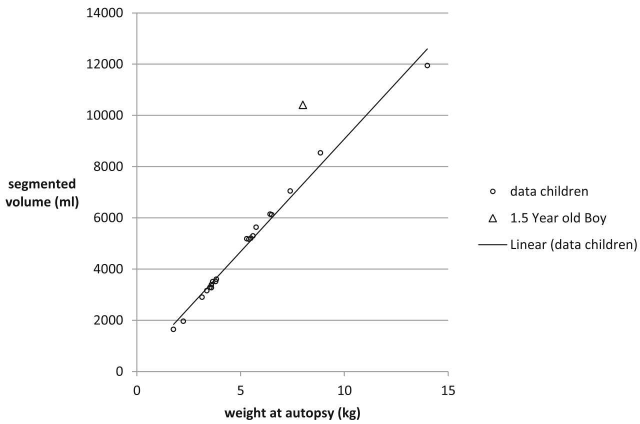


**Fig. 2** PmCT volume of children compared to the weight at autopsy. The triangle shows the 1.5 -year-old boy as a distinct outlier

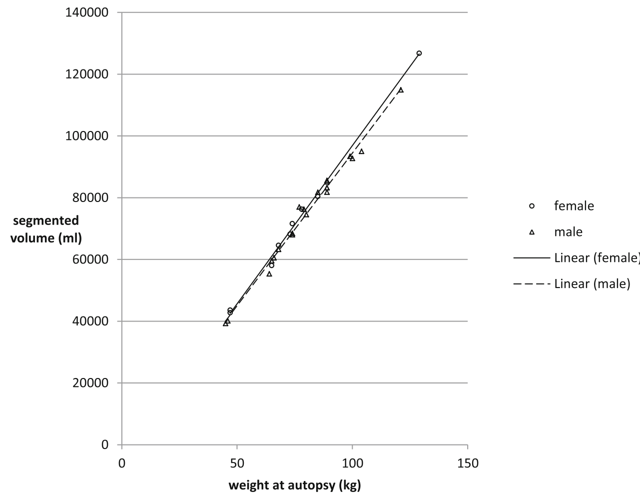


**Fig. 3** PmCT volume of male and female adult corpses compared to weight at autopsy. Note that the females within the study have a slightly higher volume per weight

by neglect could be definitively ruled out. Retrospectively, we asked our autopsy technicians if they could explain the decalibration. One then admitted that the scale bumped against a door frame while it was being moved within our facility shortly before the child was measured. Before the decalibration was realized, three adult corpses were also measured with that scale. Also these measurements were roughly 3 kg too low, as we could later show using the multiplication factor obtained within the study. However, these measurement errors had no consequences for the individual case work, in contrast to the child's case presented within the study. All this happened in between two regular scale calibrations, and of course these additional three cases did not become part of the study population.

The mean postmortem multiplication factor (1.07 g/ml) obtained within the present study is comparable to the soft tissue multiplication factor (1.04 g/ml) described for the living [7] (annotation: the authors of [2] wrote 1.04 mg/ml, which obviously was meant to be 1.04 g/ml).

The slightly higher multiplication factor in the deceased as compared to the living may be explained by the first postmortem drying processes. When the bodies lose water having a physical density of 1.00 g/ml, the mean multiplication factor of the body is expected to increase. This explanation may also be supported by the finding that the rather edematous hospital-death corpses showed a slightly lower mean multiplication factor compared to the control group, because in these cases, the mean multiplication factor should be lowered by the higher percentage of water. Furthermore, the postmortem multiplication factor is a whole-body density factor including other tissues such as bones, which may also explain the slight discrepancy [8].

The comparison of male and female adults did result in the expected minor difference in favor of males (Fig. 3). The males showed a slightly higher mean multiplication factor of 0.016 (+1.51 %). This result can be explained by body mass index (BMI). The study population showed a mean BMI of 26.7 for the females and 25.6 for the males. The females presented with more body fat than the males. Therefore, the expected influence of mean body fat content on the multiplication factor could be shown even within only 50 cases.

### Study limitations

The rather small study population limits the value of the presented mean multiplication factor.

Beam-hardening artifacts within the pmCT data are a relevant limitation for the use of this technique, because these artifacts can disturb the segmentation using Mia Lite distinctively. Bodies with a lot of metal (e.g., endoprosthesis) will cause the segmented volume values to be too high. Applying the multiplication factor will then result in weights that are too heavy. The same is true for any foreign body that comes along with the corpse on its exterior surface, such as medical casts.

In further studies, the influence of a longer postmortem interval may be investigated.

## Conclusion

Volume data of pmCT scans may be used to estimate the weight of corpses, with the use of a multiplication factor of 1.07 g/ml. Artifacts within the images limit the use of pmCT-data for weight estimation.

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