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Transverse dimension measurement of the heart is a good estimator for heart weight

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ABSTRACT

Heart weight is a routine measurement during a post-mortem examination. An increased heart weight is associated with preexisting heart disease and sudden cardiac death. In cases where the heart is partially fragmented, it may be hard to obtain an accurate heart weight by weighing it. If a compromised/fragmented heart size can be approximated, assessing the heart dimensions may provide a heart weight estimation. This study examined 46 fresh Caucasian adult hearts and found a high and significant correlation between heart dimensions and heart weight. Using linear regression modelling, heart weight can be estimated using only the transverse dimension (or width) of the heart with a relatively high accuracy. The established equation in estimating heart weight was heart weight (g) = −298 + 5.92 * heart width (mm), R^2 = 0.71.

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Post mortem; autopsy; heart weight; cardiomegaly; hypertrophy

Introduction

Cardiac hypertrophy is defined as an increase in heart weight[1]. Cardiac hypertrophy leads to electrical instability and is associated with several preexisting cardiac diseases and sudden cardiac death[2,3]. The hypothesized mechanism of death in cases with cardiac hypertrophy is from fatal cardiac arrhythmia[2,3]. Obtaining an accurate heart weight measurement is therefore crucial in post-mortem examination[4–6]. However, in the authors' experiences, in cases where the heart is compromised or partially fragmented with missing parenchyma (such as from penetrating or blunt trauma), the obtained heart weight might not reflect the heart weight at the time of death. If the compromised or fragmented heart can be reapproximated or where certain parts of the heart remain intact, assessing the heart dimensions may give an estimate of the actual heart weight. This study investigated the association between heart dimensions and heart weight and whether heart dimensions can accurately estimate heart weight.

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Materials and methods

To be clinically useful, a moderate to strong correlation is needed between heart dimensions and heart weight. Assuming parametric and monotonic correlation, Pearson's correlation was used (r_p) in this study. With a null hypothesis of having no correlation, to detect a correlation coefficient of 0.4 (moderate) with $\alpha = 0.05$ and $\beta = 0.8$, a sample size of 46 is needed (a stronger correlation would need fewer samples). This study, therefore, prospectively sampled 46 consecutive Caucasian adult cases. Age, sex, height (m) and weight (kg) were recorded. Body mass index (BMI, kg/m^2) and body surface area (BSA, Du Bois & Du Bois formula: [weight $(kg)^{0.425} \times$ height $(cm)^{0.725}$] $\times$ 0.007184, m^2) were also calculated.

A previous study has shown that including age, sex, and BSA increased the accuracy of estimating heart weight (Wt) when using heart dimensions obtained from post-mortem computed tomography (PMCT)[7]. As such, these parameters were used to estimate Wt. Cases excluded in this study were:

(1) Paediatric population (<18 years old), due to ethical constraints.
(2) Cases with incomplete data set.
(3) Suspicious and/or homicidal deaths due to potential legal implications.
(4) Non-Caucasian ethnicity (as documented in the reporting police file), due to ethics constraints.
(5) Compromised bodies (e.g. bodies found in fire, decomposed bodies, and bodies with significant trauma), as these would impede the anthropometric data.
(6) Cases where previous open-heart surgery was performed due to altered anatomy

Heart dimensions

The heart dimensions were taken before the heart was dissected and were measured in millimetres (mm), with two standard measurements taken[1]. The transverse dimension (width, W) of the heart was measured obtuse to the acute margin at the posterior atrio-ventricular sulcus. The longitudinal dimension (length, L) was measured as the distance between the crux cordis (the point at which the atrio-ventricular sulcus meets the posterior interventricular sulcus) and the apex of the heart on the posterior aspect (Figure 1).

Assuming the ventricles are in a cone shape, the dimensions of the heart (W and L) were transformed into a three-dimension parameter ($V = W^2 \times L$). The normal equation for a cone shape is 1/3 * $[\text{diameter}/2]^2$ * [height], the constants of the equation would be factored into the correlation and regression analysis. The weight of the ventricles of the heart is consistently 70% of the entire heart weight, and the atrial dimensions were not included when measuring the heart dimensions[8].

Heart weight

The Wt was measured in grams using a calibrated scale. The time point when the heart was weighed was after the heart dimensions were taken, dissected using the short axis method, rinsed and washed, blood and blood clots in the heart chambers removed, and

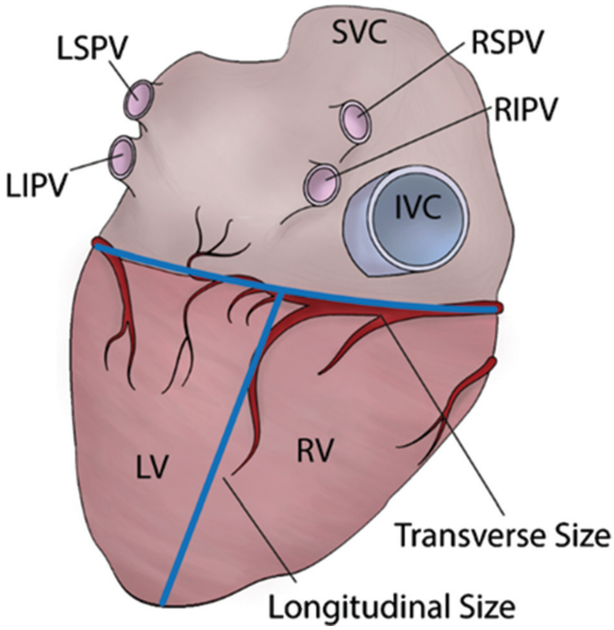

Figure 1. An illustration on how the transverse and longitudinal size/dimensions were taken (illustration taken from Basso et al[1]).

gently pat dried to remove excess water. This was in concordance with the standard European guidelines and recent recommendations for weighing the heart at post-mortem examination[9–11].

Statistical analysis

Statistical analysis was performed using R (open source, R studio 2022.07.01, Build 554). Continuous variables were presented as mean, median, minimum, maximum and standard deviation (s.d.). Discrete variables were represented as counts. Initial scatter plot and subsequent Pearson's correlation coefficient (r_p) was determined between Wt and continuous variables (W, L, V, age, BMI and BSA). Student's t-test was used to compare Wt between sexes.

Best subset multivariate linear regression analysis with sex, age, height, weight, BMI, BSA, W, L and V were used to estimate Wt to choose the best model by optimizing the residual sum of squares.

Ethics

This study was approved by the Forensic Scientific Services Human Ethics Committee (FSS-HEC) (EC00305) reference number HEC 22–18.

Results

In the 46 cases, there were 26 males and 20 females. The mean age was 55.8 years (s.d.: 17.7, median: 56, min: 18, max: 93). The mean height, weight, BMI, and BSA were 170.4 cm

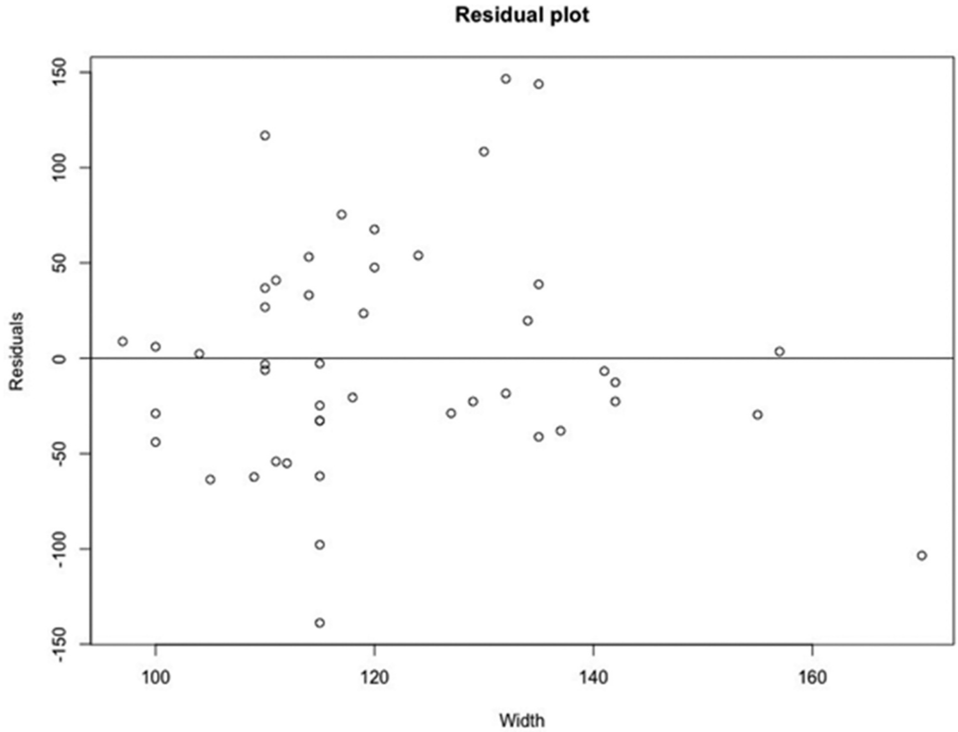

Figure 2. Residual plot in estimating heart weight (g) using the transverse dimension (width, mm) of the hear.

(s.d.: 11.8, median: 170.5, min: 142, max: 201), 87.6 kg (s.d.: 23.1, median: 88.5, min: 48, max: 138), 29.8 kg/m^2 (s.d.: 6.1, median: 30.34, min: 18.0, max: 44.1), and 2.0 m^2 (s.d.: 0.3, median: 2.0, min: 1.4, max: 2.7), respectively.

The mean Wt, W, L and V were 420 g (s.d.: 110.7, median: 417.5, min: 244, max: 645), 121.4 mm (s.d.: 15.8, median: 115, min: 97, max: 170), 102.8 mm (s.d.: 16.2, median: 100, min: 80, max: 175), and 1,588,316 mm^3 (s.d.: 686570.6, median: 1,363,492, min: 790,356, max: 4,204,375), respectively.

The mean Wt was significantly higher in males than females (476.6 g vs 347.6 g, t-test $p < 0.05$). Pearson's correlation coefficients (r_p) between Wt and age, height, weight, BMI, BSA, W, L, and V were 0.07 ($p = 0.64$), 0.57 ($p < 0.05$), 0.66 ($p < 0.05$), 0.48 ($p < 0.05$), 0.68 ($p < 0.05$), 0.84 ($p < 0.05$), 0.64 ($p < 0.05$), and 0.78 ($p < 0.05$), respectively.

The best subset multivariate linear regression showed heart width (W) was the best predictor. Linear regression analysis using W had a coefficient of 5.92 ($p < 0.05$) and in intercept of −298 ($p < 0.05$). This translated to the equation in predicting heart weight being Wt = −298 + 5.92 *W. The residual plot showed random distribution (Figure 2) and had an R^2 of 0.71.

Discussion

This study showed that heart dimensions had a high and statistically significant correlation with heart weight. The heart weight for Caucasian adults can be estimated with good accuracy with only the transverse dimension (width) of the heart.

Heart weight is the first and important piece of information to indicate any underlying cardiac pathology during post-mortem examination[1,9]. It is obtained after the heart is removed from the body cavity, with the aorta and pulmonary artery transected 10 mm above their origin, and post-mortem clots removed from the heart chambers. The heart is commonly weighed unfixed in routine forensic workload, despite much of the literature being based on measurements of formalin-fixed specimens[1,9,12]. An increased heart weight (cardiac hypertrophy) can lead to electrical instability, precipitating fatal cardiac arrhythmia and sudden cardiac death. Thus, having an accurate heart weight can be crucial in establishing the cause of death at post-mortem examination, especially in cases without definite morphological causes of death. The weight of the heart can be compared to reference tables, charts, and online calculators to determine whether it is increased or not (taken formalin fixation into account)[1,12–19]. In cases of a traumatic death where the event was unwitnessed, and the heart is fragmented with potential loss of parenchyma, it can be challenging to provide an opinion regarding the possibility of a cardiac event contributing to the death as a precipitant to the trauma. If the fragmented heart dimensions can be re-approximated or where enough parts of the heart remain intact to obtain the dimensions of the heart and estimate the heat weight accurately, it would help to provide a more definitive opinion regarding the heart's contribution to the death. This had been implied in a recent study, however the study did not exhaustively investigate other epidemiological and anthropometric variables[20].

Our study showed that W, L and V correlated strongly and significantly with heart weight. This is expected as the larger the dimension of the heart, the heavier it would be. In terms of predicting heart weight, our study showed that W, the transverse dimension (width) of the heart, alone was able to estimate heart weight with high accuracy (i.e. able to predict >70% of the heart weight, $R^2 = 0.71$). Although male, a higher BMI, BSA, L, and V were associated with a higher heart weight, these factors were not included in our best subset multivariate analysis in predicting heart weight. This is explained by the high accuracy in using W alone in predicting heart weight. Further adding less accurate variables to the regression model made no improvement in heart weight prediction by statistical evaluation. Unexpectedly, V was not more accurate in estimating heart weight than W. This may be explained by the lower accuracy of L in estimating heart weight and also that the ventricles are not a perfect solid cone. W is a measurement of the fibrous annulus, which is less affected by post-mortem changes such as rigour mortis, whereas L contains the length of the muscular septum which may be affected by rigour mortis.

When compared to using more sophisticated radiological techniques, a simple macroscopic dimension (with W alone) had a comparable accuracy in estimating heart weight[7,21,22]. Data transformation and adding more parameters have been shown to increase the accuracy in estimating heart weights using radiological dimensions (R^2 between 60% and 80%). However, using radiological dimensions can add technical challenges in estimating heart weight. Most of the radiological studies in the estimation of heart weight require radiological experience and infrastructure, require deceased's characteristics (age, sex, height, and weight), can be labour intensive, and may require high computational power. Furthermore, radiological techniques have not been shown to be able to estimate the weight of a fragmented heart. These may limit the utility of radiological techniques in estimating heart weight.

The result of this study is useful in predicting heart weight via a practical method. Using only one macroscopic measurement (i.e. transverse dimension/width of the heart) to estimate heart weight is particularly useful in situations when the heart is partially fragmented with missing parenchyma. Furthermore, if a photograph of the heart can be taken, advancement in artificial intelligence/machine learning/deep learning may even allow the possibility of automatically measuring the heart dimensions to estimate heart weight[23].

Limitations

This study assessed the relationship between heart dimensions and heart weight. The limitations of the study are as follows:

(1) Reference range for heart dimension and weight: This study focused on the correlation between heart dimensions and heart weight. It was not designed to establish a reference range or threshold for cardiomegaly or cardiac hypertrophy.
(2) Population group: This study examined unfixed post-mortem Caucasian adult hearts and the results cannot be extrapolated beyond this population group.
(3) Margin of error: The results of the regression analysis showed that the >70% of the heart weight can be explained by the heart width. A margin of error should be expected when using the equation provided and can be determined from the residual plot provided. Adding other non-standard heart dimensions, such as the height of the heart, may increase the accuracy; however, this would require further investigation.
(4) Application of our results: This study explored whether heart dimensions can predict heart weight. The results were intended to be applied to estimate fragmented heart weight. The method of fragmented heart approximation and whether the weight of a fragmented heart can be truly estimated with heart dimensions were not directly investigated in this study due to the limitations in using human subjects. This could be explored using animal models in the future.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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