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Cardiac dimensions measured from post-mortem photographs: are they accurate?

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ABSTRACT

Peer reviewing post-mortem reports, photographs and histology is a mandatory process in the everyday practice of forensic pathology. In the context of organ measurement/dimensions, comparing the dimensions measured from a post-mortem photograph and what was recorded in the post-mortem report is sometimes necessary. However, there are limited studies validating the accuracy of dimensions measured from a photograph in forensic pathology. This study examined the cardiac dimensions measured from a standard post-mortem photograph of a heart section. It showed that although there was acceptable intra- and inter-rater reliability, the overall accuracy was low compared with gross measurement at post-mortem examination. The results from this study suggest that measurements taken from a post-mortem photograph have limited utility in assessing cardiac dimensions. The reasons for this discrepancy and recommendations on how to improve the accuracy are provided.

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Post-mortem; peer review; cardiac dimensions; photograph; imaging

Introduction

Peer reviewing in forensic pathology is an important cornerstone of continuous quality improvement[1]. This is achieved by having another pathologist review the post-mortem images, histology slides, and reports[2]. To execute this, materials for peer review should ideally be 'reviewable' or 'transparent'[1]. However, not all data captured during the post-mortem examination are reviewable. Using post-mortem digital images (radiology, photographs, and digital histology) would aid in the reviewing process by providing permanent reviewable and reproducible data. Amongst these three imaging techniques, interpretation of radiology and histology images requires specialized training. In terms of photography, it is a common practice (especially in routine coronial casework) to have the pathologists, who may have variable photography training, capturing and interpreting post-mortem photographs using commercially available 'point and shoot' cameras.

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In the context of organ dimensions, comparing what was recorded in the post-mortem report (from macroscopic measurement) and the photographs taken by the pathologist is sometimes necessary, especially in cases with questionable data and conclusions. However, there is no study that examined the congruency between macroscopic measurement and measurements taken from a photograph. Given the nature of how these photographs can be captured, it is unclear whether post-mortem photographs are acceptably accurate in recording organ dimensions.

Standard measurements for heart examinations at post-mortem include ventricular dimensions and wall thicknesses, where an increase (together with other macroscopic and microscopic findings) would indicate possible underlying cardiac hypertrophy[3–8]. When a diagnosis of cardiac hypertrophy is made, these measurements should ideally be reviewable, reproducible and, most importantly, accurately reflect those measured at post-mortem examination. Although we intuitively assume a post-mortem photograph of the heart reflects the macroscopic measurement, it is not well documented whether that is truly the case.

This study explored whether post-mortem cardiac dimensions measured from a photograph is reliable, reproducible and accurate when compared with macroscopic measurements in routine coronial casework.

Material and methods

Case selection

This study prospectively examined 20 consecutive adult cases at the Forensic Pathology Department, Gold Coast University Hospital, Queensland where an internal examination and dissection of the heart was performed.

Exclusion criteria

- Paediatric population (less than 18 years old) due to no published data on heart dimensions and ventricular wall thickness.
- Cases with incomplete data set.
- Suspicious and/or homicidal deaths, due to potential legal implications.

Heart examination and macroscopic measurements

In the cases examined, both the left and right ventricular dimensions and wall thicknesses were measured as standard post-mortem heart examination procedure.

The hearts were examined using the short axis method as recommended by the European guidelines[9]. The atria and coronary arteries were first examined, and the ventricles were serially sectioned from apex to base in 10 mm intervals up to the mid-ventricular level. Following the standard guidelines, the left and right ventricle cavity dimensions and free wall thicknesses were measured, discounting the trabeculae muscles. The measured ventricular dimensions included the diameter of the left ventricle, and the anterior–posterior and medial-lateral length of the right ventricle. The ventricular wall thickness included the anterior free wall of the left ventricle, interventricular septum, and posterior free wall of the right ventricle. These measurements were taken by two qualified forensic pathologists and the data were retrieved from case files.

Acquiring ventricular dimensions via post-mortem photographs

Using the same cross-section for macroscopic measurements, an image of the cardiac ventricles was captured using a commercially available digital camera (Olympus TG-6, Olympus corporation, Tokyo, Japan) by the attending pathologist at the time of post-mortem examination after the cardiac dimensions were taken as part of routine documentation. The setting of the camera was on 'P' mode which automatically adjusts the aperture and shutter, with no flash and exposure compensation, and is at its widest angle. The digital photograph was taken immediately after measuring the ventricular dimensions. The camera was manually placed vertically on top of the section at a height that maximizes the cross-section on the camera preview screen. A calibrated ruler was placed directly below the cardiac section and included in the photograph (Figure 1). When translated to single-lens-reflex camera configuration, it was in concordance with the recommendation for post-mortem photography[10]. This was the local standard in photographing the heart cross section.

The photographs were deidentified and the dimensions of the ventricles were measured blinded (i.e. without knowing the details of the case and the measured dimensions and wall thickness at post-mortem examination) on the computer screen utilizing the calibrated ruler captured in the photograph. The measurements were done by two different observers with various post-mortem experience (a medical student with minimal forensic pathology training, and a forensic pathologist). The medical student was

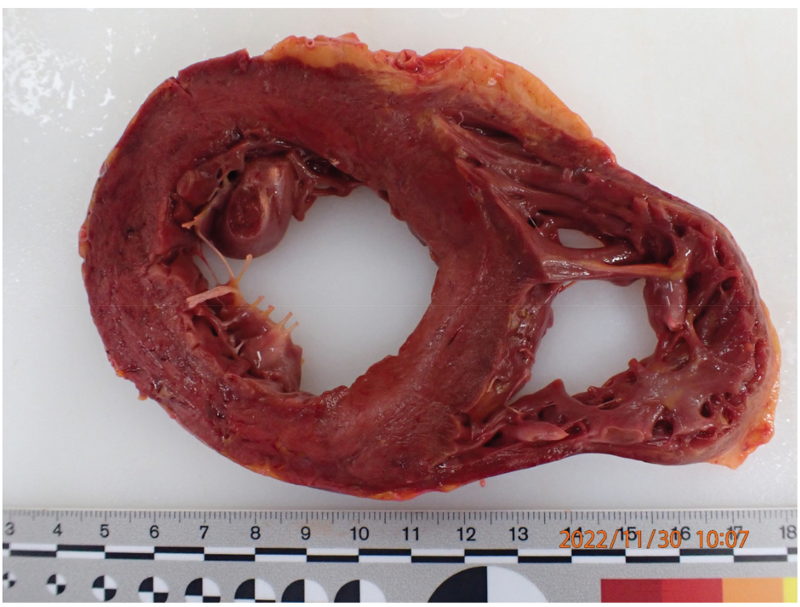

Figure 1. Illustration of a heart cross-section photograph taken at post-mortem examination with a calibrated scale used to measure cardiac dimensions.

educated on how the dimensions were taken at the post-mortem examination during placement. Two sets of measurements were taken by the two observers to assess inter- and intra-rater reliability. The overall mean dimensions were used to compare with measurements from post-mortem examination.

Statistical analysis

Statistical analysis was performed using packages in R (open source, R studio 2022.07.01, Build 554, R version 4.2.2), and a p value of <0.05 will be considered significant. Categoric variables were presented as counts and continuous variables were presented in mean, median, standard deviation (SD), min and max.

To explore inter- and intra-rater reliability, initial Pearson's correlation test (cor.test() function) was used, with subsequent intraclass correlation test (icc() function in the 'irr' package), using two-way random effects model for absolute agreement and single measure statistics (due to assessing actual dimensions). Similarly, to explore the reliability for raters to actual heart dimensions, Pearson's correlation and intraclass correlation tests were used.

The difference between the post-mortem examination and photographic dimensions (average of both raters) was calculated and analysed using paired student's t-test, and the 95% confidence intervals were also presented. Maximum and minimum differences were also presented and scaled to a mean of 0.

Ethics approval

This study was approved by the Forensic Scientific Services Human Ethics Committee (FSS-HEC 22-34).

Results

A summary of the results is shown in Table 1, documenting the intra-inter reliability of cardiac dimensions measured from a photograph and their accuracy.

Intra- and inter-rater reliability

The initial Pearson's correlation test showed high correlation within both rater's results, ranging from 0.75 to 0.98, all with $p < 0.05$. Intraclass correlation coefficient also demonstrated strong intra-rater reliability, with results ranging from 0.74 to 0.98, all with $p < 0.05$.

Pearson's correlation and intraclass correlation was also generally consistent, with ranges from 0.59 to 0.97 (each had $p < 0.05$), and 0.56 to 0.97 (each had $p < 0.05$), respectively.

Accuracy of using post-mortem photographs

Both Pearson's and intraclass correlation coefficients showed high variability in correlation between measurements taken at post-mortem and via photographs, by both student

Table 1. Statistical analysis of cardiac measurements for six different dimensions taken at post-mortem examination and from post-mortem photography by a medical student and a forensic pathologist (blinded to each other).

Locations*		LV wall	Septum	RV wall	LV diameter	RVAP Diameter	RVML Diameter
Intra-rater correlation							
Pearson's	Student	0.8 ($p < 0.05$)	0.82 ($p < 0.05$)	0.92 ($p < 0.05$)	0.95 ($p < 0.05$)	0.93 ($p < 0.05$)	0.98 ($p < 0.05$)
	Pathologist	0.75 ($p < 0.05$)	0.89 ($p < 0.05$)	0.89 ($p < 0.05$)	0.86 ($p < 0.05$)	0.92 ($p < 0.05$)	0.97 ($p < 0.05$)
ICC	Student	0.8 ($p < 0.05$, 0.57–0.92)	0.8 ($p < 0.05$, 0.56–0.92)	0.92 ($p < 0.05$, 0.82–0.97)	0.95 ($p < 0.05$, 0.88–0.98)	0.93 ($p < 0.05$, 0.84–0.97)	0.98 ($p < 0.05$, 0.95–0.99)
	Pathologist	0.74 ($p < 0.05$, 0.44–0.89)	0.89 ($p < 0.05$, 0.75–0.96)	0.88 ($p < 0.05$, 0.74–0.95)	0.86 ($p < 0.05$, 0.69–0.94)	0.91 ($p < 0.05$, 0.79–0.96)	0.97 ($p < 0.05$, 0.93–0.99)
Inter-rater correlation							
Pearson's		0.59 ($p < 0.05$)	0.75 ($p < 0.05$)	0.6 ($p < 0.05$)	0.93 ($p < 0.05$)	0.95 ($p < 0.05$)	0.97 ($p < 0.05$)
ICC		0.56 ($p < 0.05$, 0.18–0.8)	0.74 ($p < 0.05$, 0.46–0.89)	0.61 ($p < 0.05$, 0.24–0.83)	0.90 ($p < 0.05$, 0.73–0.96)	0.92 ($p < 0.05$, 0.67–0.98)	0.97 ($p < 0.05$, 0.90–0.99)
Post mortem vs photo measurement							
Pearson correlation	Student	0.7 (<0.05)	0.38 ($p = 0.10$)	0.2 ($p = 0.40$)	0.56 ($p < 0.05$)	0.26 ($p = 0.27$)	0.43 ($p = 0.05$)
	Pathologist	0.28 (0.22)	0.22 ($p = 0.36$)	0.19 ($p = 0.41$)	0.62 ($p = <0.05$)	0.22 ($p = 0.35$)	0.45 ($p < 0.05$)
ICC correlation	Student	0.65 ($p < 0.05$, 0.28–0.85)	0.3 ($p = 0.06$, −0.083–0.63)	0.19 ($p = 0.2$, −0.24–0.57)	0.56 ($p < 0.05$, 0.17–0.80)	0.23 ($p = 0.14$, −0.21–0.61)	0.44 ($p < 0.05$, 0.01–0.73)
	Pathologist	0.27 ($p = 0.11$, −0.17, 0.63)	0.2 ($p = 0.18$, −0.22–0.57)	0.17 ($p = 0.21$, −0.24–0.55)	0.57 ($p < 0.05$, 0.19–0.80)	0.19 (p0.18, −0.21–0.56)	0.46 ($p < 0.05$, 0.03–0.75)
Paired t-test of post-mortem measurements vs photos							
	Mean difference	0.9625	1.963	0.5625	2.775	5.6	−1.913
	SD	2.726	4.008	1.738	8.225	15.26	12.77
	Min**	−4.2125	−7.963	−4.5625	−26.275	−23.6	−28.837
	Max**	6.2875	6.537	3.4375	14.225	31.65	19.163
	p-value	0.1308	<0.05	0.0914	0.1478	0.1173	0.7492

*Locations: LV wall – left ventricle wall, RV wall – right ventricle wall, RVAP – right ventricle anterior-posterior diameter, RVML – right ventricle medial-lateral diameter.
**Minimum and maximum difference scaled to mean of 0.

and pathologist. Pearson's coefficient ranged from 0.19 to 0.70, with only four out of the 12 tests (both student and pathologist for six locations) having a p value of <0.05. Intraclass correlation also demonstrated unreliability, with a range from 0.17 to 0.65, with five out of 12 having $p < 0.05$.

Significance of difference between post-mortem to photo measurement

The paired t-test shows insignificant difference for five of the six locations, which implies that the null hypothesis is not to be rejected and therefore there is no significant difference between measurements taken at post-mortem examination and from post-mortem photograph. However, there is very high variability between the maximum and minimum differences for each location, as can be seen in Table 1, where they have been scaled to a mean of 0. Most notable is the right ventricular anterior-posterior diameter with a range of −23.6 to 31.7 with standard deviation of 15.26.

Discussion

This study showed that cardiac dimensions and free wall thickness measured from photographs were reproducible and had moderate to high correlation within and between the two raters but was inaccurate when compared with macroscopic measurements taken at post-mortem examination. Our results suggest post-mortem photograph only have limited use in obtaining an accurate cardiac dimensions and wall thickness.

Reviewing cases in forensic pathology is routine and it is paramount to have case materials that are reviewable, reliable and accurate. This is especially important for data that are used to establish the cause of death. Cardiac hypertrophy is associated with sudden cardiac death which can be assessed macroscopically and microscopically. Cardiac dimensions, including the ventricular wall thickness and cavity dimensions, are taken into consideration to establish cardiac hypertrophy. These dimensions have recommended thresholds (i.e. a left ventricular wall thickness >14 mm, a right ventricular wall thickness >5 mm, a ventricular septal thickness >15 mm), and when the chamber dimension is >40 mm is suggestive of cardiac hypertrophy[3,8,11]. If a diagnosis of cardiac hypertrophy is made, these dimensions should ideally be reviewable (by means of post-mortem photographs), reliable (do not vary within and between raters) and should accurately reflect macroscopic measurements. Although intuitively assumed, this is not statistically validated.

In the presented study, there was moderate to high Inter- and intra-rater reliability correlation, indicating that the data gathered was reliable/reproducible and consistent, which was unrelated to post-mortem training/experience. However, values for Pearson's correlation test and subsequent intraclass correlation test for the correlation of photograph measurements to those from actual post-mortem were low, indicating inaccuracy. Although paired t-test showed no statistical significance for five of the six cardiac measurement locations, the range and high standard deviation demonstrated a high amount of random inaccuracy between post-mortem examination and photograph. Reasons for the inaccuracy between measurements taken from a photograph compared with post-mortem examination maybe due to the combination of:

Figure 2. An example of the recommended method in placing a scale on the same plane and location where a cardiac dimension should be measured (in this case lateral free wall of left ventricle).

- Difficulty in appreciating trabecular muscles on photographs, especially when the ventricular wall is slightly folded.
- Choosing a different site at the measurement location between data sets (for example, the portion of left ventricle wall that is anterior may vary in thickness).
- Choosing a different site on the ruler to check the measurement taken, as this could be affected by camera distortion.
- Ruler was lying on a different plane to where measurements were taken from (cardiac slices were 10 mm thick and ruler was placed on board, not on tissue).

From the results of our study, to have cardiac dimensions reviewable, repeatable/reliable, and accurate on a photograph for review process, we recommend placing a scale on where the post-mortem measurement was taken, such that the scale is on the same plane and location (Figure 2) and consider arrows to indicate where the cardiac trabeculae is located. This would ensure the location of the taken measurement is the same for both post-mortem and photograph, and both ruler and cardiac site are the same distance from the lens for the photograph measurements. This would be in addition to the routine photograph of the cross-section of the heart.

Limitations

The aim of this study was to illustrate possible errors in peer reviewing post-mortem photographs. This study used a non-professional point-and-shoot camera with a specific setting operated by a pathologist capturing a photograph with specific parameters. Transferring the results to other settings should be done with caution.

The published gold standard in capturing images is using a single-lens-reflex camera, however, this is not always available in all forensic pathology departments due to resource constraints. This is compounded by the variable photographic training the pathologist has and the continued advancement of digital photography with the introduction of mirrorless cameras and built-in artificial intelligence capabilities.

Conclusion

This study implies that dimensions measured from a post-mortem photograph in routine practice may have limited utility in the peer review process apart from providing proof that the heart was dissected, examined and a rough estimate of heart dimensions taken. Because of the discrepancy between measurements taken at post-mortem examination and that from post-mortem photographs, great caution is needed in using photographs alone in the peer review process for measurement purposes. Further studies should be performed to test whether recommendations made improve the accuracy of post-mortem cardiac photograph measurements, and to investigate new advanced digital photographic techniques and/or artificial intelligence applications.

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Disclosure statement

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

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