Is cardiomegaly on chest radiograph representative of true cardiomegaly? A cross-sectional observational study comparing cardiac size on chest radiograph to that on echocardiography

Jane McKee, Katherine Ferrier

ABSTRACT

AIMS: To determine whether or not cardiomegaly identified on chest radiograph (CXR) is indicative of true cardiomegaly as determined using echocardiography (echo) as the gold standard tool, and therefore whether or not cardiomegaly on CXR should be investigated further.

METHODS: CXR and echocardiogram reports were reviewed for the presence of cardiomegaly in a population following non-ST segment elevation myocardial infarction (NSTEMI). Data was evaluated to determine whether cardiomegaly reported on CXR did indeed represent true cardiomegaly. Exploratory analysis was undertaken to determine whether or not Body Surface Area (BSA) was a significant explanatory variable.

RESULTS: Data was collected for 244 patients. Thirty-nine were reported to have cardiomegaly on CXR, 22 of those also had cardiomegaly on echo, giving a true positive rate of 56% and a false positive rate of 44%. Fifty-five were reported to have cardiomegaly on echo, of which 33 (60%) did not have cardiomegaly identified on CXR. Sensitivity of CXR to identify cardiomegaly was 40% and specificity was 91% with a positive predictive value of 56% and negative predictive value of 84%.

BSA does not appear to be a significant explanatory variable for the discrepancy between the CXR and echo estimates of cardiomegaly.

CONCLUSIONS: In patients following an NSTEMI, the true positive rate of cardiomegaly identified on CXR is not too dissimilar to the false positive rate, thereby suggesting that reporting “cardiomegaly” based on CXR findings is inaccurate and rather reporting should simply focus on the cardiothoracic ratio and defining this as an enlarged cardiac silhouette rather than true cardiomegaly. In clinical practice the data indicates that the number needed to investigate to identify true cardiomegaly on echo is only two, thereby concluding that all patients post-NSTEMI with cardiomegaly on CXR should go on to have an echo, consistent with current national guidelines. As the study population were all post-MI, further study is necessary to evaluate whether this association holds true in a wider population.

It has long been accepted that a cardiothoracic ratio (CTR) greater than 50% on a posterior-anterior (PA) chest radiograph (CXR) is representative of cardiomegaly. An increased CTR on CXR has been associated with an increased rate of morbidity and mortality in middle-aged and elderly patients, with a linear association between increasing heart size and coronary heart disease risk factors as well as increased risk of mortality from coronary heart disease, stroke and all causes. Given this, individu-
als with such CXR findings are often referred for further investigations. Numerous studies have been undertaken to determine whether this association holds true, many producing negative findings.

In a resource-limited setting, therefore, it is important to determine whether or not further investigations are indeed warranted. Echocardiography is becoming a widely used tool as part of a workup for a multitude of conditions and complaints. It is therefore important that it is used appropriately to ensure patients truly requiring it are not subject to long waiting lists in order to receive appropriate assessment and management in a timely manner. In our district health board (DHB), we identified “cardiomegaly on CXR” as a reason for an increasing number of echocardiogram requests. Given the conflicting evidence as to whether or not an increased CTR on CXR is indeed representative of true cardiomegaly, we undertook this study to confirm or refute this hypothesis.

Method

The most likely patient group in our DHB that have both a chest x-ray (CXR) and an echocardiogram (echo) in close succession are patients who present with acute coronary syndrome (ACS), in particular NSTEMI. Therefore, all patients discharged with a primary diagnosis of “NSTEMI” were collated between 2011 and 2013. Patients were excluded if there was no CXR, no echo, or the timeframe between CXR and echo was greater than two months. If the CXR was an AP film and the radiologist was therefore unable to determine whether or not there was cardiomegaly, these too were excluded from the study. If the echocardiographic sonographer was unable to assess LV or RV size, these too were excluded.

The CXR reports of the remaining patients were reviewed for the presence of cardiomegaly, defined as a cardiothoracic ratio on the posterior-anterior view of greater than 50%. All CXRs were reported by experienced consultant radiologists. For those formal CXR reports where there was no comment on cardiac size, these were reviewed for the presence of cardiomegaly with an experienced consultant radiologist from the local department.

For each patient, their echo reports were then reviewed for heart size and deemed cardiomegalic if the left ventricle (LV) or right ventricle (RV) was reported as enlarged. Biplane echocardiographic measurements were undertaken by experienced cardiac sonographers with Australasian diplomas in echocardiography. The measurements and reports were then ratified by experienced consultant cardiologists. These measurements of chamber size and definitions of ventricular enlargement (ie, above the upper normal limits) were defined according to the internationally agreed guidelines and standardised to BSA.3

Data was recorded in a binomial fashion. Although left ventricular dilatation and right ventricular dilatation are two distinct conditions, for the purposes of this study no distinction was made between left and right ventricular enlargement, as either would warrant further investigation, and the question was simply to determine if CXRs were adequate at accurately identifying cardiomegaly, regardless of the ventricle or pathology involved.

BSA was recorded on the echo reports. The software calculated BSA using the Dubois formula, whereby BSA (m²) is calculated as weight (kg)\(^{0.425}\) x height (cm)\(^{0.725}\) x 0.007184.4

Data was then evaluated to determine whether cardiomegaly reported on CXR did indeed represent true cardiomegaly, and therefore to determine whether cardiomegaly on CXR should indeed undergo further evaluation in the clinical context.

Exploratory analysis was undertaken to determine whether or not BSA was a significant explanatory variable for the discrepancy between the CXR and echo estimates of cardiomegaly in patients with NSTEMI.
Results

Four hundred and seven patients had a primary diagnosis of “NSTEMI” on discharge between 2011 and 2013 inclusive. Of these, 16 were wrongly coded and 163 were excluded for the reasons outlined above (Figure 1).

Basic demographics for the two groups are outlined below (Table 1). The mean ages of the study population and the population excluded were 67.2 and 71.7 years respectively (P=0.99).

Data was collected for the remaining 244 patients. Of those, 39 patients were reported to have cardiomegaly based on CXR, while 55 were reported to have true cardiomegaly based on the gold standard of echo.

Of those, 39 reported to have an enlarged heart on CXR, 22 (56%) did have true cardiomegaly based on echo, while 17 (44%) did not actually have true cardiomegaly (Table 2).

The kappa coefficient is 59%, indicating moderate agreement between these two tools.

Table 1: Population demographics.

<table>
<thead>
<tr>
<th></th>
<th>Study sample</th>
<th>Sample excluded</th>
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<tr>
<td>N</td>
<td>244 (62%)</td>
<td>147 (38%)</td>
</tr>
<tr>
<td>Male, N (%)</td>
<td>158 (65%)</td>
<td>91 (62%)</td>
</tr>
<tr>
<td>Age (years) Mean (SD)</td>
<td>67.2 (12.6)</td>
<td>71.7 (13.6)</td>
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Using echo as the gold standard, CXR as a tool for measuring cardiomegaly was accurate in 80% of cases (95% CI 74.8–83.9%). The true positive rate was 56% with a false positive rate of 44%. The sensitivity of CXR to determine cardiomegaly was 40% (95% CI 27.0–54.1%) with a specificity of 91% (95% CI 86.0–94.7%). The positive predictive value was 56% (95% CI 39.6–72.2%) while the negative predictive value was 84% (95% CI 78.1–88.7%).

Of the 244 datasets collected, 206 had available BSA data. Of these, 163 (79%) did not have cardiomegaly on CXR, while 43 (21%) did have cardiomegaly. The mean BSA for both these groups was 1.9 (SD 0.24 and 0.32 respectively). According to echo, 175 (85%) did not have cardiomegaly while 31 (15%) did have cardiomegaly. The mean BSA for these groups was 1.9 (SD 0.25) and 2.0 (SD 0.28) respectively.

Comparing these two groups, BSA does not appear to be a significant explanatory variable for the discrepancy between the CXR and echo estimates of cardiomegaly.

**Discussion**

According to this study, the association between the CXR groups and the echo groups in reporting cardiomegaly in patients with NSTEMI is statistically significant, with BSA not appearing to be a significant explanatory variable in this population.

One hundred and forty-seven patients were excluded from the study. Twelve did not have a CXR. This is likely reflected in the rapid transfer of patients to a tertiary centre for angiography and/or percutaneous intervention. By the time they returned to the local facility for follow-up, an echocardiogram had been performed, rendering a CXR unnecessary. One hundred and eight did not have an echo. This is likely to reflect pragmatic local practice, where an echocardiogram would not have changed the patient's management, most commonly because the patients were more unwell or frail. There was no significant difference between the mean ages of the group studied and those excluded. Ethnicity and BSA data of the group excluded from the study were not recorded, however it is clear that there is a wide range of BSAs included in the study population (1.3–3.06m²) indicating that patients were not declined an echo based on size alone. Ethnicity likewise is not taken into account when a clinical decision is being made, so it is unlikely that there was any selection bias in the study.

Although 244 patient studies were analysed, representing a reasonable sample size, only 39 were reported to have cardiomegaly on CXR and it is this cohort that invokes the more interest as it is these patients who are referred on for further investigation. Taking just this cohort of patients then, the data shows that 22 (56% with 95% CI 40.4–71.6%) did go on to have true cardiomegaly, whereas 17 (44% with 95% CI 28.4–59.6%) did not have true cardiomegaly. Obviously with a much smaller sample size, the confidence intervals are much wider and clearly overlap quite significantly, suggesting that there may in fact be no significant difference between the two groups, but that cardiomegaly reported on CXR has roughly a 50% chance of indicating true cardiomegaly. This would suggest that reporting “cardiomegaly” based on CXR findings is therefore inaccurate and rather reporting should simply focus on the cardiothoracic ratio and defining this as an enlarged cardiac silhouette rather than a diagnosis of true cardiomegaly.

In clinical practice, however, this can be interpreted as the number needed to investigate to pick up true cardiomegaly is two, therefore advocating that all patients post-NSTEMI with cardiomegaly on CXR should go on to have an echo. Current recommendations are that

<table>
<thead>
<tr>
<th>N</th>
<th>CXR</th>
<th>Total</th>
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<tbody>
<tr>
<td></td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Echo</td>
<td>172</td>
<td>17</td>
</tr>
<tr>
<td>Y</td>
<td>33</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>205</td>
<td>39</td>
</tr>
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Y = cardiomegaly; N = no cardiomegaly.
all patients presenting with NSTEMI should go on to have an echo, regardless of the CXR, therefore this does not actually add anything new in practice in terms of guidelines in this particular patient population.5

Our findings are similar to several previous studies. Satou et al looked at heart size on CXR as a predictor of cardiac enlargement by echocardiography in children (median age 5 years old). Sixteen out of 95 children were identified to have cardiac enlargement on CXR. The sensitivity of CXR identifying cardiomegaly by echo was higher than our study at 58.8%, but with a very similar specificity at 92.3%. The negative predictive value was a little higher at 91% with a similar positive predictive value of 62.5%. They similarly concluded that “the assessment of CE [cardiac enlargement] on CXR to predict CE by echocardiography has a relatively high specificity and negative predictive value, but a low sensitivity and positive predictive value.”6

And in another study by Biharas Monfared A et al, again a high specificity (84.5%) was identified with a poor sensitivity (34%).7

In comparison, in a study of 36 healthy children and 85 children with heart disease, Davidson et al concluded that cardiothoracic ratio and cardiac frontal area did not correlate with echocardiographic data but that such CXR estimates are unreliable.8 Clark and Coats suggest that a poor inspiration can give a spuriously raised cardiothoracic ratio, and the apparent size of the heart on a plain film can be very misleading. In their study of 91 patients, there was a poor correlation between cardiothoracic ratio and left ventricular size (r=0.32).9 Hammermeister et al looked at chest radiographs of 320 patients who had quantitative angiographic measurements of left ventricular volume. They found a poor correlation between cardiothoracic ratio and end-diastolic volume (r=0.29) and similarly poor correlations with other angiographic measurements of left ventricular overload. Interestingly they calculated a CTR of greater than 50% as having a specificity in the detection of left ventricular dilatation of only 41%.10

Schlett et al in a study of 45 patients likewise concluded poor correlation between CTR and end-diastolic left ventricular volume, mass or size, hypothesising that a possible explanation of such poor correlation may be related to the geometry of the thoracic shape and the right ventricle.11 Screaton in his editorial of the aforementioned paper, also hypothesised that other reasons for such poor correlation include the large cardiothymic shadow in infancy, the shrinking of the thoracic cage in later life, especially in elderly kyphotic females, congenital variations such as pectus excavatum and lung diseases such as emphysema.12

It may be, therefore, that our study produced a higher level of accuracy of the CXR at determining true cardiomegaly compared to these studies, due to our inclusion of right ventricular dilatation in the echocardiographic findings and definition of “true cardiomegaly”.

One study by Baker et al looked at patients with structurally normal hearts on echocardiogram and then looked at cardiothoracic ratio on CXR and epicardial adipose tissue (EAT) by cardiac computed tomography (CCT) to determine whether enlarged cardiac silhouettes on CXR are being dismissed inappropriately. They concluded that an enlarged cardiac silhouette on CXR, despite a structurally normal heart on echo, can be caused by excessive EAT.13 This is interesting given the apparent lack of association in our study of increased BSA, which presumably would be present with increased EAT. Kaya et al looked at EAT volumes compared with BSA and other factors and found a positive correlation between BSA and EAT volume.14 Only three patients were excluded from our study due to no LV and/or RV measurements. These measurements were not obtained due to technical difficulties with the echocardiogram, but only two of these had a BSA indicative of obesity, therefore making bias in our results in this regard less likely. However, the fact that our population was post-infarct may explain the apparent lack in association.

Several studies have looked at the correlation between EAT and coronary artery disease and found positive correlations,13,14,15 although one Japanese study by Dagvasumberel et al only found this positive correlation in men.16 This was outside the scope of this study, as we were looking solely at echocardiograms requested purely for...
cardiomegaly on CXR, not taking into consideration associated cardiac risk factors.

Limitations of the study

Given our patient cohort was a post-NSTEMI population and therefore by definition had known coronary artery disease, they may have been more likely to have cardiomegaly, therefore increasing the population prevalence in this study compared to the general population.

CXR reports were written by individual radiologists and reviewed for the presence of cardiomegaly. A potential weakness of the study was that the chest x-rays were not independently reviewed by two reviewers.

CXR reports were scanned for cardiomegaly based on the traditionally accepted cardiothoracic ratio of >50% on a PA film, and recorded as binomial data rather than actual cardiothoracic ratio. This has been a long accepted cut-off and we did not look at whether there was in fact a linear correlation between cardiothoracic ratio on CXR and cardiomegaly on echocardiograph and whether another cut-off value should be accepted. Likewise, ventricular enlargement on echo was recorded as binomial data rather than actual measurements, thereby not permitting a linear correlation to be made between echo and CXR measurements.

Although cardiac MRI may be the absolute gold standard for assessing cardiac size, with limited access, high cost and examination time, and problems of claustrophobia, in clinical practice echocardiography is considered the clinical standard and therefore was the tool used to determine “true cardiomegaly” in this study.

Conclusion

According to this study, in patients who have had a NSTEMI there is a statistically significant correlation between heart size on CXR and true heart size when measured by echocardiography. However, the data indicated that cardiomegaly on CXR was indicative of true cardiomegaly only 56% of the time. Therefore we can conclude that, in our population, a diagnosis of cardiomegaly cannot be made purely based on a cardiothoracic ratio on CXR of greater than 50%.

In clinical practice, however, the number needed to investigate to identify true cardiomegaly on echo is only two, thereby concluding that all patients post-NSTEMI with cardiomegaly on CXR should go on to have an echo as per current guidelines. Further study is necessary to evaluate this association in a wider population.

Competing interests:

Nil.

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