Left Ventricular Geometry and All-cause Mortality in Advanced Age

Ruth OTeh, PhD\textsuperscript{a}, Ngaire M Kerse, PhD\textsuperscript{a}, Elizabeth M Robinson, MSc\textsuperscript{b}, Gillian A Whalley, PhD\textsuperscript{b}, Martin J Connolly, MD\textsuperscript{d}, Robert N Doughty, MD\textsuperscript{e}

\textsuperscript{a}Department of General Practice and Primary Health Care, University of Auckland
\textsuperscript{b}Department of Epidemiology and Biostatistics, University of Auckland
\textsuperscript{c}Faculty of Social and Health Sciences, Unitec Institute of Technology
\textsuperscript{d}Freemasons' Department of Geriatric Medicine, University of Auckland
\textsuperscript{e}Dept of Medicine and National Institute for Health Innovation, University of Auckland

Address for correspondence:

Ruth Teh

Dept of General Practice and Primary Health Care
Faculty of Medical and Health Sciences
The University of Auckland
Private Bag 92019
Auckland Mail Centre
Auckland 1142
New Zealand

Phone: 64 (09) 9237517
Fax: 64 (09) 3737624
Email: r.teh@auckland.ac.nz
Abstract

**Background:** Abnormalities of cardiac structure and function are common in a wide range of populations including those with and without established clinical cardiovascular disease (CVD). This study reports the prevalence of left ventricular hypertrophy (LVH), the four patterns of LV geometry and establishes clinical characteristics and five-year outcomes of each group in people of advanced age.

**Method:** A study conducted in general practices and Māori Health Services in three New Zealand North Island locations. One hundred participants had a full clinical echocardiogram performed and analysed in 2008 by one experienced cardiologist blinded to the participant’s clinical history.

**Results:** Two-thirds of the participants had CVD. Thirty-two participants had echocardiographic LVH. Those with LVH had higher left atrial area [median (IQR) 26.4cm² (10.9) vs. 22.0cm² (7.0), p<0.01] and E/e’ [median (IQR) 13 (6.8) vs.10.8 (4.1), p=0.01] than those without LVH. Of those with LVH, 10 demonstrated concentric hypertrophy (CH) and 22 eccentric hypertrophy (EH); 12 concentric remodelling (CR) and 40 normal geometry (NG). Both CR and EH were independently associated with higher risk of all-cause mortality (p<0.01) and hospital admissions (p<0.05) than those with NG. Those with EH also had a higher risk of CVD events (p=0.029).

**Conclusions:** Despite a high prevalence of CVD and hypertension in this sample, half had normal LV geometry. Concentric remodelling and eccentric hypertrophy were associated with higher mortality and adverse CVD outcomes in people of advanced age.

Keywords: Aged, Left ventricular hypertrophy, Ventricular remodelling, Mortality, Cardiovascular diseases
ntroduction

The oldest old are the fastest growing population segment in New Zealand but have been under-represented in previous studies describing the prevalence and prognostic importance of abnormalities of cardiac structure and function.[1, 2] Abnormalities of cardiac structure and function occur in a wide range of populations including those with and without established clinical cardiovascular disease (CVD). One of the most common adaptations is left ventricular hypertrophy (LVH) which is also a well-recognised marker of adverse outcome in populations with and without hypertension and coronary artery disease.[3, 4]

LVH can be further subdivided into different geometric patterns using the relative wall thickness (RWT), which may be a better measure of LVH since it takes into account the overall size and wall thickness of the left ventricle.[5] Using this methodology, for those with LVH, two geometric patterns are defined: concentric hypertrophy (CH) and eccentric hypertrophy (EH). Those without LVH can be further categorised into normal geometry (NG) and concentric remodelling (CR), i.e. increased relative wall thickness without increase in LV mass. Concentric remodelling has been associated with adverse outcome in patients with hypertension [6] and importantly a reversal of the concentric remodelling pattern to NG has been associated with improved clinical outcome.[7]

Understanding the prevalence of abnormalities of cardiac structure and function, and its implication among people of advanced age is important, as it cannot be assumed that similar prevalence and prognostic importance of such abnormalities will apply to this population as they do for younger populations. The aims of this study were to determine the prevalence of LVH and the four patterns of LV geometry among
people of advanced age and establish the clinical characteristics and five-year outcomes (all-cause mortality, CVD events and hospital admissions) of each group.

**Methods**

This study was initiated as part of the feasibility study[8] leading to the Life and Living to Advanced Age, a cohort study in New Zealand (LiLACS NZ).[9] The study was initiated in January 2008 and data on hospital admission and mortality were collected in 2013. Participants were recruited through general practices and Māori Health Services from three New Zealand North Island locations and were stratified by ethnicity. The inclusion criteria were Māori born between 1929 and 1933 (aged 75 to 79 years in 2008) and all other ethnicities born in 1922 (aged 85 years in 2008). Māori participants were recruited at a younger age as there is an eight years gap in life expectancy between Māori and non-Māori.[10] The study was approved by the Multi-Region Ethics Committee, Ministry of Health New Zealand on 1 June 2007 (MEC/06/10/135). All study participants provided written informed consent.

**Measures**

Socio-demographic, smoking status, use of prescribed medications and medical history were ascertained through a face-to-face interview. Physical assessments (height, weight and blood pressure) were completed by trained research nurses using standardised procedures. Fasting blood samples were collected and analysed for serum glucose, lipids and NT-proBNP. Echocardiography was performed by an experienced echocardiographer using a portable echocardiography machine (Sonosite MicroMaxx, Fuji Sonosite, Bothell, WA) according to the recommendations of the American Society of Echocardiography.[5] Images were recorded in digital format for offline analysis.
Echocardiographic Measurements

All echocardiograms were analysed by one experienced cardiologist (who had no knowledge of the participant’s clinical history) at the University of Auckland using an off-line workstation (Digiview®, Digisonics, Houston, TX). Each variable was measured in triplicate and the average of the three measurements used. The following measurements were made: i) LV mmode: LV end-diastolic dimension (LVEDD), LV end-systolic dimension (LVESD), interventricular wall (IVS) and posterior wall (PW) thickness both at end-diastole, ii) apical four-chamber left atrial area (LA area), iii) Mitral valve Doppler peak early filling velocity (E), iv) medial mitral annular tissue Doppler early diastolic (e’) velocity. The following variables were calculated:

LV mass=0.8*[(LVEDD+PW+IVS)^3-(LVEDD)^3]+0.6 g; relative wall thickness= (2xPW)/LVEDD; LV fractional shortening (LVEDD-LVESD)/LVEDDx100%; E/e’. LVM was indexed to height^{2.7} (LVMi), and LV hypertrophy (LVH) defined as LVM/height^{2.7} ≥44g/m^{2.7} for women and ≥48g/m^{2.7} for men. LVM was also indexed to body surface area (BSA), and LVH defined as LVM/BSA ≥95g/m^{2} for women and ≥115g/m^{2} for men.[5] LV geometry was categorised into four groups based on LVMi and RWT: normal geometry (NG: RWT≤0.42 without LVH), concentric remodelling (CR: RWT>0.42 without LVH); concentric hypertrophy (CH: RWT>0.42 with LVH) and eccentric hypertrophy (EH: RWT≤0.42 with LVH).[5]

Clinically manifest CVD was established by self-report CVD and from review of nationally held hospitalisation records.[8] Outcomes were ascertained through review of the nationally held mortality and hospitalisation records including and up to five years after initial assessment. Type 2 diabetes mellitus was ascertained from self-reported diabetes, records of glucose-lowering medications from the questionnaire, fasting serum glucose >7.0mmol/L,[11] or hospitalisation records of diabetes. Hypertension was defined as self-reported hypertension, records of prescribed
medications indicated for hypertension from the questionnaire, an average of three seated blood pressure measurements with blood pressure >140/90mmHg, isolated systolic hypertension (SBP>140mmHg, DBP<90mmHg),[12] or hospitalisation records of hypertension. Dyslipidaemia was defined as receiving treatment with lipid-lowering agents identified from the interview, hospitalisation records of hyperlipidaemia, or high fasting serum lipids for people aged 75+ according to the New Zealand Guidelines.[13] Medical records from the general practices were not available for viewing for the study.

**Statistical Analysis**

Socio-demographic data are presented as frequencies and percentages. Continuous data was examined with histogram and box-plots, and are presented as mean and standard deviations (SD), or medians and interquartile ranges (IQR) for variables with a skewed distributions. ANOVA and Kruskal-Wallis with Scheffe’s post hoc test were used for comparisons among multiple groups. A listwise deletion approach was adopted.  Cox’s proportional hazard regression analysis was used to determine the association between LV geometry and five-year all-cause mortality and logistic regression models for association between LV geometry and CVD events and hospital admissions adjusting for age, sex and variables found to be different across the four LV geometry groups. A p value <0.05 was considered statistically significant. Statistical analyses were performed with SPSS 18.0 for Windows.

**Results**

**Sample**

A total of 186 eligible older adults were invited to participate of which 112 were enrolled. Reasons for the 74 who declined include: refused personally or their family
members refused on their behalf without giving any reason (n=65), died before enrolment (n=4), not contactable (n=4), and one was excluded by the study coordinator because of ill-health. No further follow-up was undertaken for those who declined, thus no comparison was possible between the 74 who declined and those enrolled in the study. Four of the 112 enrolled participants withdrew consent during the course of the study. All remaining 108 participants completed the questionnaire, 103 had physical assessments and 100 had an echocardiogram performed; 90 gave blood samples for analysis.

**Demographics and Medical History**
In this sample, 33 were Māori and 79 non-Māori. Forty-eight (56%) were women, half were widowed, and 38% were married/de facto. Most of the participants lived in a private residence (86%) and three-quarters had received secondary (38%) or tertiary (36%) education.

Half of the study participants (n=55) had never smoked tobacco cigarettes. Ninety-two (85%) participants had dyslipidaemia, 91 (84%) had a history of hypertension, 22 (20%) had type 2 diabetes, 72 (67%) had CVD, and 69 (64%) were receiving BP-lowering medication.

**LV Structure**
Sixteen (16%) echocardiograms were done in the participants’ residences, of which three were found to be technically very limited due to poor echocardiographic views. Eighty-four (84%) echoes were performed in a local health centre, of which 10 were found to have technically difficult views. All echoes (n=100) were included in the analysis.
For the whole group, mean LVEDD=5.1cm (SD=0.70cm), mean LVESD=3.1cm (SD=0.69cm) and mean FS=39% (SD=10%). LV systolic function was semi-quantitatively assessed in 97 participants, of whom five had abnormal LV systolic function (three mild, one moderate and one severe LV systolic impairment). LV mass and RWT were measurable for 84 participants. When LV mass was indexed to height^{2.7} 32 (38%) met echocardiographic criteria for LVH [5] and when indexed to BSA 28 (33%) met echocardiographic criteria for LVH. LV mass was not statistically different between those with and without CVD: LVM/height^{2.7} median (IQR) 43.0g/m^{2.7} (31.2) vs. 36.9g/m^{2.7} (17.3); LVM/BSA 92.5g/m^{2} (57.2) vs. 78.7g/m^{2} (41.9), both p values=0.14.

Compared to those with no LVH (LVM/height^{2.7}), in participants with LVH, smoking was more common (nil vs. 10%, p=0.046) and use of vitamin/mineral supplements less common (60% vs. 37%, p=0.045). No differences were seen in the prevalence of hypertension (91% vs. 81%), diabetes (22% vs. 10%), nor use of BP lowering medications (72% vs. 62%) between those with LVH and no LVH. Left atrial area was higher among those with LVH than without LVH, 26.4cm^{2} (IQR=10.9) and 22.0cm^{2} (IQR=7.0), p<0.01. E/e' was also higher among those with LVH, 13 (IQR=6.8) and 10.8 (IQR=4.1), p=0.01. NT-proBNP levels were marginally higher among those with LVH than those without LVH, median (IQR) 58pmol/L (86) and 34.5pmol/L (37.3) respectively, p=0.051 (Figure 1).

When LVM was indexed to BSA, similar trends between those with and without LVH were observed as above, except for NT-proBNP levels which were statistically higher among those with LVH than without LVH, median (IQR) 61pmol/L (74) vs. 34pmol/L (38.5) (p=0.023), and the proportion of use of vitamin/mineral supplements between those with and without LVH became not statistically significant (39% vs. 57% vs. 39%, p=0.115).
LV Geometry

Forty participants displayed normal geometry (NG), 12 concentric remodelling (CR), 10 concentric hypertrophy (CH) and 22 eccentric hypertrophy (EH) (Figure 1 and Table 1). Table 1 shows the clinical characteristics of participants in each LV geometry group: the history of CVD and hypertension, BP lowering medications and blood pressure did not differ significantly across the four geometry groups. Participants with EH had higher BMI than those with NG (28.0kg/m² vs. 23.8kg/m², p=0.002). The CH and EH groups had higher left atrial area than the NG or CR groups, although only the EH group had higher E/e’. Fractional shortening was similar across all LV geometry groups. When LVM is indexed to BSA, 44 had normal geometry, 12 concentric remodelling, 10 concentric hypertrophy and 18 eccentric hypertrophy.

LVH, LV Geometry, Mortality and Morbidity

Over five years, 41 (37%) participants died, 27 participants had at least one CVD event (five new and 22 recurrent), and the number of all cause hospital admissions ranged between 0 and 23 admissions, median (IQR) was 2 (4); 45 (42%) participants had three or more hospital admissions.

Table 2 shows the number of events in those with and without LVH and in each LV geometry group. Univariate analyses show abnormal LV geometry was related to all-cause mortality and CVD event. Adjusting for age, sex, BMI, LA area (and separately for E/e’), participants with LVH had a higher risk of all-cause mortality [HR (95% CI) 2.6 (1.0-6.8), p=0.046] but LVH was not associated with CVD event risk (p=0.082) and all-cause hospital admission (p=0.159). Further analyses were completed for LV geometry. Participants with CR and EH had higher risk of death from any cause [HR (95% CI) 5.5 (1.8-17.1), p=0.003; 4.8 (1.5-14.6), p=0.006] and
higher risk of hospital admission [OR (95% CI) 6.4 (1.2-33.8, p=0.029; 6.2 (1.4-28.1), p=0.018] than those with NG. Those with EH also had a higher risk of having a CVD event compared with those with NG [OR (95% CI) 6.6 (1.2-35.6), p=0.029].

Figure 2 shows participants with LVH, and specific LV geometry, i.e. CR and EH exhibited an early and incremental increased mortality compared to those with NG (p<0.01). Adding systolic and diastolic blood pressure to the model did not alter these findings. Echocardiographic indices of left ventricular systolic and diastolic function (LA, E/e’ and FS) were not associated with all-cause mortality, CV events nor hospital admission. Analyses were repeated with LVM indexed to BSA and findings did not differ materially.

Discussion

The results from this study of cardiac structure among people of the oldest old demonstrated that approximately half had normal LV geometry, more than one-third had LVH (between 33% and 38% depending on method of indexation) and LV systolic dysfunction was only seen among 5% of elderly people whereas most had a history of hypertension (84%) and two-thirds a history of CVD. When present, LVH was associated with larger left atrial size and (marginally) higher NT-proBNP levels and higher mortality compared with those without LVH. In nonagenarians, NT-proBNP levels have been observed to be higher and associated with LVH.[14]

LV Hypertrophy in Advanced Age

LVH is well-recognised as a marker of adverse outcome in populations with and without hypertension and coronary artery disease.[3, 4] The prevalence of LVH has been reported from a large number of studies including many different populations and the current data are consistent with the prevalence rates of LVH observed from
the Framingham study, which 49% women and 33% men aged 70+ years developed LVH,[15] although the Framingham cohorts recruited very few of the oldest old adults. In a prospective study of 318 adults aged 80+ years, echocardiogram was completed in 55 participants, of whom 41 (75%) had echocardiographic LVH; the all-cause seven-year mortality rate was 54% among those with LVH.[16] The current data demonstrate that eccentric hypertrophy independently predicts five-year all-cause mortality, CVD event and all-cause hospital admissions.

LV Geometry in Advanced Age

Normal LV Geometry

The current data demonstrate that half of this sample of the oldest old has normal LV geometry. The definition of LV geometry depends on the definition of LV hypertrophy used, which depends on the method of indexation (allometric indexation to a power of height or to body surface area), and in turn the cut-off used to define hypertrophy. While debate continues regarding the optimal method for indexation of LV measurements we have followed those currently recommended in contemporary guidelines.[5] A recent study of 106 nonagenarians and centenarians in a residential home in Italy reported that only 16% of their population had normal LV geometry.[17] The current study used similar echocardiographic methods and LVH definitions to the Italian study. Both the Italian and our study cannot determine the relative time exposure to risk factors (e.g. diabetes, hypertension, and BP-lowering medications) associated with development of LVH and abnormal LV geometry. The time course of further progression across the worsening patterns of LV geometry clearly also cannot be determined. It is not unreasonable to speculate that the normal geometry may be related to optimal management of hypertension.

Concentric Remodelling
Concentric remodelling is of relevance as this geometric pattern of increased wall thickness but without LVH has been shown to be associated with adverse outcome among patients with hypertension.[6, 18, 19] In clinically healthy adults, ageing has been associated with the development of LV concentric remodelling, although these data are based on only small numbers of older people over the age of 65 years.[20] A more recent study, utilising an echocardiographic database and including only patients over 70 years of age (mean age 78 years), demonstrated that CR was the commonest geometrical pattern, seen among 43% of this population, with a further 16% having LVH. The study found higher RWT and LV mass were predictors of total mortality independent of age, BMI and gender.[21]

Compared to normal LV geometry, CR is a significant independent predictor of CV events in middle-age adults with mild hypertension.[22] In a study involving adults with an average age of 62 years without clinical CVD, CR was predictive of stroke and coronary heart disease over a four-year follow-up period.[23] Our current data demonstrate that CR was present in 14% of the sample and characteristics of this group were similar to those with normal LV geometry at baseline. However, CR conferred a higher risk of death from any cause and hospitalisation compared to those with normal geometry. These findings confirm people of advanced age with CR have an adverse prognosis as observed in younger population.[6, 7]

**LV Geometry and LV Diastolic Function**

Abnormalities of LV diastolic filling are commonly associated with LVH and increased LV mass is a predictor of the development of heart failure.[23] The current data demonstrate that markers of LV diastolic function (LA area and E/e') were abnormal among those with LVH compared with those without LVH, and in particular the participants with EH had highest E/e’. This is in line with the population-based
LOLIPOP (London Life Sciences Prospective Population) Study, involving >1000 participants aged 35-74 years, which found that participants with CH and EH had higher LV filling pressure (assessed using E/e’) than those with NG.[24] In the LIFE (Losartan Intervention For Endpoint reduction hypertension) Study, patients with hypertension (mean age 67 years) with increased LV mass had abnormal LV diastolic function.[25] Although our study found LV diastolic dysfunction was related to LVH, LV diastolic function was not related to all-cause mortality, CVD events and adverse clinical outcomes resulting in hospitalisation, whereas the type of remodelling was, perhaps suggesting that the LV shape and size is more important in predicting outcome than the diastolic filling pattern.

Limitations
The study is limited by the small sample size but is valuable because of the five-year follow-up duration of the oldest old. Selection bias may mean these data are not representative of all older people in New Zealand. Portable echocardiography provided access for this population but may be limited due to proportion of unreadable echocardiograms attributed to technical limitations. Additionally, echocardiography in the oldest old may be challenging due to person agility, weight and limited echocardiographic window. These factors reflect the real-world challenges of this population.

Conclusion
This study has demonstrated that despite a high prevalence of CVD and hypertension, half of the sample had normal LV geometry, CR was present in 14% and approximately one in three had LVH. LV geometry predicts five-year all-cause mortality and was associated with CVD events and adverse clinical outcomes. Findings from this study extend the limited data already available on LV geometry in
the oldest old. Larger prospective studies assessing the prognostic significance of LV geometry in this advanced age group are needed to confirm the clinical relevance of LV geometry in older people.

**Acknowledgements:**

The authors acknowledge all participants for their commitment to this study and all community organisations that facilitated the study (He Korowai Oranga Rotorua; Māori Health Services, Whakatāne Hospital; Whakatohea Iwi Social and Health Services; Rotorua General Practice Group; and Kaitiaki Advisory Group, Ngā Pae O Te Māramatanga). We are grateful to Helen Walsh (research echocardiographer) for undertaking some of the echocardiograms.

**Funding:**

This study was funded by the Health Research Council of New Zealand and the National Heart Foundation. Both funders played no role in the design, execution, analysis and interpretation of data, nor manuscript preparation. RND holds the Heart Foundation Chair of Heart Health.
References


5. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, et al. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. *J Am Soc Echocardiogr* 2005;18:1440-63.


Figure 1 Cumulative survival plot on a) LVH, and b) 4 LV geometry
### Table 1: LV geometry and 5-year follow-up events

<table>
<thead>
<tr>
<th>Event</th>
<th>No LVH</th>
<th>Yes LVH</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause mortality</td>
<td>13/49 (27%)</td>
<td>13/31 (42%)</td>
</tr>
<tr>
<td>CVD event</td>
<td>11/49 (22%)</td>
<td>12/31 (39%)</td>
</tr>
<tr>
<td>Any hospital admission</td>
<td>35/49 (71%)</td>
<td>24/31 (77%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LV Geometry</th>
<th>Normal geometry</th>
<th>Concentric remodelling</th>
<th>Concentric hypertrophy</th>
<th>Eccentric hypertrophy</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause mortality*</td>
<td>7/39 (18%)</td>
<td>6/10 (60%)</td>
<td>4/9 (44%)</td>
<td>9/22 (41%)</td>
</tr>
<tr>
<td>CVD event*</td>
<td>6/39 (15%)</td>
<td>5/10 (50%)</td>
<td>3/9 (33%)</td>
<td>9/22 (41%)</td>
</tr>
<tr>
<td>Any hospital admission</td>
<td>27/39 (69%)</td>
<td>8/10 (80%)</td>
<td>8/9 (89%)</td>
<td>16/22 (73%)</td>
</tr>
</tbody>
</table>

*Fisher’s exact test p<0.05

Note:
- The numbers in each LV geometry group were smaller compared to the baseline data as not all participants gave consent to follow-up data
- CVD event is defined as CVD related hospital admission
Table 1: Clinical characteristics of study participants

<table>
<thead>
<tr>
<th></th>
<th>All (n=108)</th>
<th>Normal Geometry (n=40)</th>
<th>Concentric remodelling (n=12)</th>
<th>Concentric hypertrophy (n=10)</th>
<th>Eccentric hypertrophy (n=22)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender–Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.518</td>
</tr>
<tr>
<td>Men</td>
<td>48 (44)</td>
<td>17 (43)</td>
<td>7 (58)</td>
<td>4 (40)</td>
<td>7 (32)</td>
<td></td>
</tr>
<tr>
<td>Non-Māori</td>
<td>60 (56)</td>
<td>23 (58)</td>
<td>5 (42)</td>
<td>6 (60)</td>
<td>15 (68)</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>91 (84)</td>
<td>38 (95)</td>
<td>8 (67)</td>
<td>8 (80)</td>
<td>21 (96)</td>
<td>0.121</td>
</tr>
<tr>
<td>No</td>
<td>17 (16)</td>
<td>2 (5)</td>
<td>4 (33)</td>
<td>2 (20)</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td>Medications with effect on BP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>69 (64)</td>
<td>22 (55)</td>
<td>6 (50)</td>
<td>6 (60)</td>
<td>16 (73)</td>
<td>0.496</td>
</tr>
<tr>
<td>No</td>
<td>39 (36)</td>
<td>18 (45)</td>
<td>6 (50)</td>
<td>4 (40)</td>
<td>6 (27)</td>
<td></td>
</tr>
<tr>
<td>Cardiovascular disease</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>72 (67%)</td>
<td>24 (60%)</td>
<td>7 (58%)</td>
<td>7 (70%)</td>
<td>16 (73%)</td>
<td>0.743</td>
</tr>
<tr>
<td>No</td>
<td>36 (33%)</td>
<td>16 (40%)</td>
<td>3 (22%)</td>
<td>3 (30%)</td>
<td>6 (27%)</td>
<td></td>
</tr>
<tr>
<td>Systolic Blood Pressure</td>
<td>151 (21%)</td>
<td>153 (19%)</td>
<td>143 (19%)</td>
<td>143 (24%)</td>
<td>159 (19%)</td>
<td>0.089</td>
</tr>
<tr>
<td>Diastolic Blood Pressure</td>
<td>83 (12%)</td>
<td>83 (12%)</td>
<td>79 (10%)</td>
<td>80 (8%)</td>
<td>87 (10%)</td>
<td>0.130</td>
</tr>
<tr>
<td>Fractional shortening</td>
<td>39.3 (9.9)</td>
<td>41.5 (8.7)</td>
<td>35.4 (12.3)</td>
<td>36.7 (11.5)</td>
<td>38.4 (9.5)</td>
<td>0.237</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>27.1 (7.1)</td>
<td>23.8 (5.4)</td>
<td>28.3 (6.0)</td>
<td>28.7 (9.4)</td>
<td>28.0 (6.2)</td>
<td>0.002</td>
</tr>
<tr>
<td>N-terminal pro-brain natriuretic peptide</td>
<td>40 (45)</td>
<td>36 (36)</td>
<td>26 (174)a</td>
<td>58 (173)b</td>
<td>61 (99)</td>
<td>0.224c</td>
</tr>
<tr>
<td>Relative wall thickness</td>
<td>0.34 (0.13)</td>
<td>0.30 (0.07)</td>
<td>0.48 (0.20)</td>
<td>0.48 (0.20)</td>
<td>0.51 (0.18)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Left ventricular mass / Height</td>
<td>40.1 (28.5)</td>
<td>34.1 (9.9)</td>
<td>36.7 (17.8)</td>
<td>69.3 (21.9)</td>
<td>62.1 (20.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Left atrial area</td>
<td>23.0 (8.6)</td>
<td>20 (5.5)</td>
<td>23 (11.1)</td>
<td>28.5 (16.2)</td>
<td>26.4 (8.7)</td>
<td>0.002</td>
</tr>
<tr>
<td>Ratio of mitral E velocity to mitral annular E velocity</td>
<td>11.6 (5.0)</td>
<td>10.8 (4.3)</td>
<td>11.5 (6.6)</td>
<td>11.4 (6.1)</td>
<td>13.4 (6.9)</td>
<td>0.007</td>
</tr>
</tbody>
</table>

Note:
The total number of the 4 geometry groups does not add up to 108 because LV mass and RWT were measurable for only 84 participants.

a one participant had NT-proBNP level of 549 pmol/L. Excluding this outlier, median (IQR) = 21 (27)
b one participant had NT-proBNP level of 314 pmol/L. Excluding this outlier, median (IQR) = 41 (50)
c When LVM is indexed to BSA, p=0.041
### Concentric Remodelling
- n=12 (14%)
- Hypertension 67%
- BP 143/79
- LA area 23cm²
- E/e' 11.5

### Concentric Hypertrophy
- n=10 (12%)
- Hypertension 80%
- BP 143/80
- LA area 28.5cm²
- E/e' 11.4

### Normal Geometry
- n=40 (48%)
- Hypertension 85%
- BP 153/83
- LA area 20cm²
- E/e' 10.8

### Eccentric Hypertrophy
- n=22 (26%)
- Hypertension 96%
- BP 159/87
- LA area 26.4cm²
- E/e' 13.4

### LV Hypertrophy
- n=32 (38%)
  - LA area, cm²
    - 26.4 (10.9)
  - E/e’
    - 13 (6.8)
  - NT-proBNP (median)
    - 58pmol/L
  - P value (LVH vs. no LVH)
    - <0.01
    - 0.011
    - 0.051

### No LV Hypertrophy
- n=52 (62%)
  - LA area, cm²
    - 22.0 (7.0)
  - E/e’
    - 10.8 (4.1)
  - NT-proBNP (median)
    - 34.5pmol/L

RWT = relative wall thickness; BP = blood pressure; LA = left atrial area; E/e’ = ratio of mitral E velocity to mitral annular e velocity

Comparison among multiple groups: * p=0.12; ** p=0.089 and 0.13 for systolic and diastolic BP respectively; # p=0.002; † p=0.007

**Figure 1 LV geometry and clinical characteristics**
Figure 1 Cumulative survival plot on a) LVH, and b) 4 LV geometry