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Alternative Indexing of Left Ventricular Diastolic Volume in Obesity: Identifying Potential Unrecognised Left Ventricular Dilatation

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Abstract

Background

Use of Standard body surface area (BSA) indexing in cardiac echocardiography of obese patients may underestimate left ventricular (LV) dilatation. This study evaluated two novel indexing methods in a large real-world Canadian cohort.

Methods

72,925 echocardiographic studies from the Syngo echocardiography database (2018–2023) were analysed. Left ventricular end-diastolic volume (LVEDV) was indexed using standard DuBois BSA, idealised BSA (iBSA), and allometric (height$^{1.44}$) methods across three body mass index (BMI) groups.

Results

In Class I/II obesity, 13.0% (iBSA) and 14.0% (allometric) of patients were reclassified from normal to dilated. In Class III obesity, reclassification rates reached 27.5% (iBSA) and 28.8% (allometric), exclusively in the normal to dilated direction.

Conclusions

Evaluation of novel indexing methods identified clinically significant LV dilatation missed by standard BSA indexing in obese patients, with reclassification rates increasing progressively with BMI.

Background

Obesity rates are growing significantly as a global and Canadian public health problem with worldwide obesity having nearly tripled since 1975, and in Canada over 26% of adults are currently classified as obese.(1,2) Obesity is independently associated with serious cardiovascular conditions including hypertension, heart failure, and cardiac arrhythmia.(3,4) Echocardiography is the gold-standard tool for non-invasive assessment of cardiac structure and function in this patient population, but obesity creates specific challenges in interpreting the imaging it provides. Two distinct challenges arise when performing echocardiography in obese patients: degraded image acquisition due to increased chest wall tissue, and inaccurate chamber size indexing due to disproportionate body surface area.(5)

The current American Society of Echocardiography (ASE) standard is to index cardiac volume to body surface area (BSA) using the DuBois formula, and this approach assumes a linear relationship between cardiac chamber size and body size.(6) In obese patients, however, this approach no longer provides an accurate clinical picture; BSA is inflated by excess adipose tissue, artificially increasing the denominator and causing cardiac chamber size to be systematically underestimated.(7,8) This systematic

underestimation likely results in left ventricular (LV) dilatation going unrecognised in obese and severely obese patients when standard BSA indexing is applied, with potential consequences for clinical management.

Height-based and allometric indexing methods have previously been proposed for LV mass and left atrial (LA) volume, and have been shown to better account for the confounding effects of obesity than standard BSA indexing.(9,10) One study found that specifically for LA volume, alternative indexing methods including idealised BSA (iBSA) and height-based measures better predicted clinical outcomes than standard BSA indexing in overweight and obese patients.(11) To our knowledge, while allometric and iBSA indexing approaches have been explored for other cardiac chambers, their application to LV diastolic volumes and the resulting clinical reclassification implications in a large real world cohort have not been investigated, and no such analysis has been performed in a Canadian population.(7,8,11)

In this study, iBSA and allometric height-based ($height^{1.44}$) indexing methods were applied to LV diastolic volumes in a large single-centre Canadian echocardiographic cohort, with the hypothesis that a significant proportion of obese (body mass index [BMI] 30–40) and Class III obesity (BMI >40) patients classified as normal by standard BSA indexing would be reclassified as having dilated ventricles. Failure to identify LV dilatation in obese patients has real clinical consequences including unrecognised heart failure, particularly heart failure with preserved ejection fraction (HFpEF), and missed target organ damage in hypertensive patients.(12)

Methods

This project was structured as a retrospective observational study at St. Paul's Hospital, Vancouver, BC. The data was sourced from the Syngo echocardiography database. Ethics approval was obtained from the University of British Columbia/Providence Health Care Research Ethics Board (H26-01075).

The study population consisted of all available echocardiographic exams recorded in the Syngo echocardiography database during the study period (April 2018 – December 2023). Studies were included if complete data were available for the following variables: height, weight, left ventricular end-diastolic volume (LVEDV), indexed LVEDV (LVEDVI), and biological sex. Studies were excluded if any of these fields were missing, if sex was not recorded as male or female, if height was ≤ 100 cm or weight was ≤ 20 kg, or if LVEDV was ≤ 0 mL. Of 73,305 studies initially identified, 380 were excluded due to incomplete or invalid data, yielding a final analysable cohort of 72,925 studies.

Three indexing methods were applied to LVEDV for each patient: standard BSA-based indexing, iBSA indexing, and allometric height-based indexing. For standard indexing, BSA was calculated using the DuBois formula (BSA = 0.007184 × height^0.725 × weight^0.425, where height is in cm and weight in kg), and LVEDVI was derived as LVEDV divided by BSA. For iBSA indexing, an ideal weight was first calculated for each patient as the weight corresponding to a BMI of 25 kg/m² for their height (ideal weight = 25 × height(m)²), after which BSA was recalculated using the DuBois formula applied to this ideal weight, and LVEDVI derived as LVEDV divided by iBSA. For allometric indexing, LVEDVI was calculated as LVEDV divided

by height raised to the power of 1.44 (LVEDV/height^1.44, where height is in cm), an exponent derived from prior allometric scaling analysis of left heart chamber measurements in obese patients.(7)

LV diastolic volumes were classified as dilated or non-dilated according to ASE 2015 guidelines, using thresholds of > 74mL/m² for men and > 61mL/m² for women, applied to both standard and iBSA indexed values.(6) Alternatively, allometric indexing produces values in different units to mL/m2, so the ASE thresholds could not be applied directly. Therefore, thresholds were derived from the study data using mean + 2 standard deviations (SD) from a normal weight (BMI 18.5–25), non-dilated reference subgroup, yielding sex-specific upper limits of normal of > 0.0833 for males and > 0.0675 for females (Additional file 1). Reclassification was defined as a patient classified as normal by standard BSA indexing who was subsequently newly identified as dilated by either of the novel indexing methods (iBSA or allometric).

This project employed a descriptive analytical approach through application of the various indexes proportions and counts with no inferential statistics. The BMI groups were defined using World Health Organization classifications: non-obese (BMI < 30), combined obese classes I and II (BMI 30–40), and severely obese (BMI > 40). Reclassification rates, defined as the proportion of patients moving from normal classification under standard BSA indexing to dilated under either iBSA or allometric indexing, were reported as number and percentage within each BMI stratum. Claude (Anthropic) AI agent was used for editing of wording. All text was written by the authors, who take full responsibility for the content.

Results

A total of 72,925 echocardiographic studies were included in the final analysis, comprising 41,627 in males (57.1%) and 31,298 in females (42.9%). The echocardiographic results used were recorded between April 2018 and December 2023. The mean BMI of the cohort was 26.3 ± 5.5 kg/m². The majority of patients were non-obese (BMI < 30, n = 58,319, 80.0%), with 12,987 (17.8%) classified as obese classes I and II (BMI 30–40) and 1,619 (2.2%) as severely obese (BMI > 40).

As a result of implementing 3 different indexes, reclassification of LVEDV occurred across all 3 BMI groups tested. For patients with a BMI < 30, 23.1% of patients were classified as dilated using the standard model, 21.6% using iBSA, and 22.4% using allometric indexing. For patients with a BMI of 30–40, 22.3% of patients were classified as dilated using the standard model, 35.4% using iBSA, and 36.4% using allometric indexing. For patients with a BMI > 40 24.9% of patients were classified as dilated using the standard model, 52.4% using iBSA, and 53.7% using allometric indexing.

(Table 1)

Table 1
— LV Dilatation Classification and Reclassification by Indexing Method and BMI Group

BMI Group	N	% Classified as Dilated			iBSA Reclassification n (%)		Allometric Reclassification n (%)	
		Standard	iBSA	Allometric	Normal →Dilated	Dilated →Normal	Normal →Dilated	Dilated →Normal
BMI < 30	58319	23.1%	21.6%	22.4%	970 (1.7%)	1811 (3.1%)	1189 (2.0%)	1590 (2.7%)
BMI 30–40	12987	22.3%	35.4%	36.4%	1694 (13.0%)	**0 (0.0%)**	1824 (14.0%)	**0 (0.0%)**
BMI > 40	1619	24.9%	52.4%	53.7%	446 (27.5%)	**0 (0.0%)**	467 (28.8%)	**0 (0.0%)**

Note: Normal→Dilated = patients Normal by Standard but Dilated by novel method (missed by standard indexing). Dilated→Normal = patients Dilated by Standard but Normal by novel method. In obese (BMI 30–40) and severely obese (BMI > 40) groups, reclassification was exclusively Normal→Dilated (0 patients reclassified Dilated→Normal, shown in bold). Standard/iBSA thresholds: Males > 74 mL/m², Females > 61 mL/m² (ASE 2015). Allometric thresholds: Males > 0.0833, Females > 0.0675 (mean+2SD, normal-weight non-dilated reference population).

As demonstrated in Table 1, reclassification varied substantially between each BMI grouping. For the non-obese group (BMI < 30) reclassification from normal to dilated was minimal: 970 patients (1.7%) by iBSA and 1,189 (2.0%) by allometric indexing; however in this group reclassification also occurred in the opposite direction (1,811 (3.1%) and 1,590 (2.7%) patients respectively). In the obese group (BMI 30–40), reclassification was exclusively in the normal to dilated direction, with 1,694 patients (13.0%) reclassified by iBSA and 1,824 (14.0%) by allometric indexing; notably, zero patients were reclassified in the opposite direction by either method. In the Class III obesity group (BMI > 40), reclassification was exclusively from normal to dilated, with 446 patients (27.5%) reclassified by iBSA and 467 (28.8%) by allometric indexing; zero patients were reclassified in the opposite direction by either method. Novel methods showed comparable reclassification rates and the overall rate of reclassification increased progressively with BMI.

Discussion

This study demonstrates that standard BSA indexing systematically underestimates LV dilatation in obese patients, with the magnitude of underestimation increasing progressively with degree of obesity. In patients with Class III obesity, over 1 in 4 patients with a truly dilated LV were unidentified by standard BSA indexing, representing a clinically significant rate of underdiagnosis. The comparable reclassification rates produced by both iBSA and allometric indexing methods suggest that the finding is robust and independent of the specific novel indexing approach used.

The finding of missed LV dilatation in obese patients using standard indexing is consistent with findings in a study by Moukarzel et al. who demonstrated height-based indexing better accounts for obesity effects on LV measurements in a large cohort.(8) Furthermore, a study by Davis et al. demonstrated similar reclassification patterns for LA volume in obese patients; our study extends this finding to LV diastolic volumes for the first time.(11) The allometric exponent of 1.44 was derived by Zong et al. from a relatively small healthy population.(7) Our study is the first to apply this exponent in a large real-world clinical cohort, demonstrating its utility in identifying LV dilatation missed by standard indexing.

When assessing the results of implementing the 3 indexes on patients with BMI < 30, it can be seen that for underweight and normal weight patients these novel indexing methods can correct upward. This is in contrast to the novel indexing impact on obese and overweight patients where it corrects downward. The two effects partially cancel each other out highlighting that standard indexing may be sufficient for populations in the normal weight population however it underserves those with obesity.

The systematic failure to identify LV dilatation in obese patients has direct clinical consequences; patients with genuinely dilated ventricles are being managed as though their cardiac dimensions are normal, with the potential for adverse outcomes including progressive heart failure, myocardial infarction, and increased burden on the Canadian healthcare system. The obese population is at exceptionally high risk of HFpEF; so missing LV dilatation means potentially overlooking the early warning signs of this condition before it becomes symptomatic.(12) Additionally, LV dilatation is a key marker of target organ damage in hypertension; failing to identify it in obese hypertensive patients risks underestimating disease severity and compromising clinical management.(5)

The findings highlight the potential for improvement in cardiac assessment of obese patients. Future studies should investigate whether novel indexing methods predict mortality and heart failure admissions more accurately than standard BSA indexing. Both iBSA and allometric methods demonstrated comparable performance and should be considered for adoption in routine echocardiography laboratories serving obese populations, pending validation in outcomes based studies.

Limitations

There are several limitations to this study that affect its generalisability. First, data were obtained from a single centre and may not be representative of other populations. Second, no outcomes data were available, meaning the clinical impact of reclassification cannot be directly demonstrated. Third, allometric thresholds were derived from within this dataset and have not been externally validated in an independent cohort. Finally, the BMI < 30 group included both normal-weight and overweight patients, which likely explains the bidirectional reclassification observed in this group. Patient age was not available in the dataset, and its effect on LV volumes could not be assessed. Analysis was performed per echocardiographic study; as no patient identifiers were available, individuals who underwent more than one study during the study period may be included more than once.

Conclusions

This study demonstrates that Standard BSA indexing misses a significant proportion of LV dilatation in obese patients, with reclassification rates increasing progressively with BMI. Both iBSA and allometric indexing methods performed comparably, identifying 13–14% of patients with Class I/II obesity and 27–29% of patients with Class III obesity as having unrecognised LV dilatation. These findings support consideration of implementing novel indexing methods in echocardiography laboratories serving obese populations, pending further outcomes based validation.

Declarations

Ethics approval and consent to participate

Ethical approval was given by the University of British Columbia–Providence Health Care Research Ethics Board (REB) (approval number H26-01075). The REB approved the study without a requirement for individual patient consent, given the de-identified and retrospective nature of the data.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analysed during the current study are not publicly available because they are held by Providence Health Care, but may be available from the corresponding author on reasonable request, subject to institutional approval.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MJS prepared and coordinated the ethics application, performed the data analysis, and wrote the manuscript. RRM contributed the initial study proposal, applied for and arranged data retrieval, and provided editorial review of the manuscript. Both authors read and approved the final manuscript.

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