

RESEARCH

A comparative analysis of British and American Society of Echocardiography recommendations for the assessment of left ventricular diastolic function

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Abstract

At present there are two recognised guidelines for the echocardiographic assessment of left ventricular diastolic function provided by the British Society of Echocardiography and American Society of Echocardiography/European Association of Cardiovascular Imaging. However, no direct comparison of these guidelines has been performed to establish whether they provide similar diastolic grading. One hundred and eighty-nine consecutive patients in sinus rhythm who underwent transthoracic echocardiography for a primary indication of either heart failure assessment or assessment of left ventricular systolic function were extracted from our database (McKesson Cardiology). Left ventricular diastolic function assessment was performed using both guidelines and the results were compared. Chi-square, Kappa score and one-way ANOVA were used to evaluate the data at a level of $P < 0.05$. The most frequent outcome was unclassifiable diastolic function with significantly more patients being labelled unclassified with the British compared to American guidelines (47.4 vs 20.5%, $P < 0.0001$). Having excluded all unclassifiable patients, a significant difference still existed between the two guidelines with a higher proportion of grade one outcomes awarded by the ASE/EACVI guidelines. When grading subcategories were individually compared, there was significantly more grade one diastolic gradings awarded by American compared to the British guidelines (40.7 vs 20.1%, $P < 0.0001$). In 47% of patients it was not possible to grade diastolic function using the British guidelines, compared to 21% using the American guidelines. For those patients where grading was possible, there was a significant difference in patients classified with normal and grade one diastolic function when using British and American guidelines.

Key Words

- ▶ diastolic function
- ▶ echocardiography
- ▶ diastolic guidelines

Introduction

Echocardiographic assessment of left ventricular diastolic function (LVDF) remains a challenging entity. The assessment of LVDF is part of the minimum dataset for

transthoracic echocardiography (TTE) as defined by the British Society of Echocardiography and is vital in evaluating patients with suspected heart failure or unexplained dyspnoea. Impaired left ventricular relaxation, limited myocardial relaxation and reduction

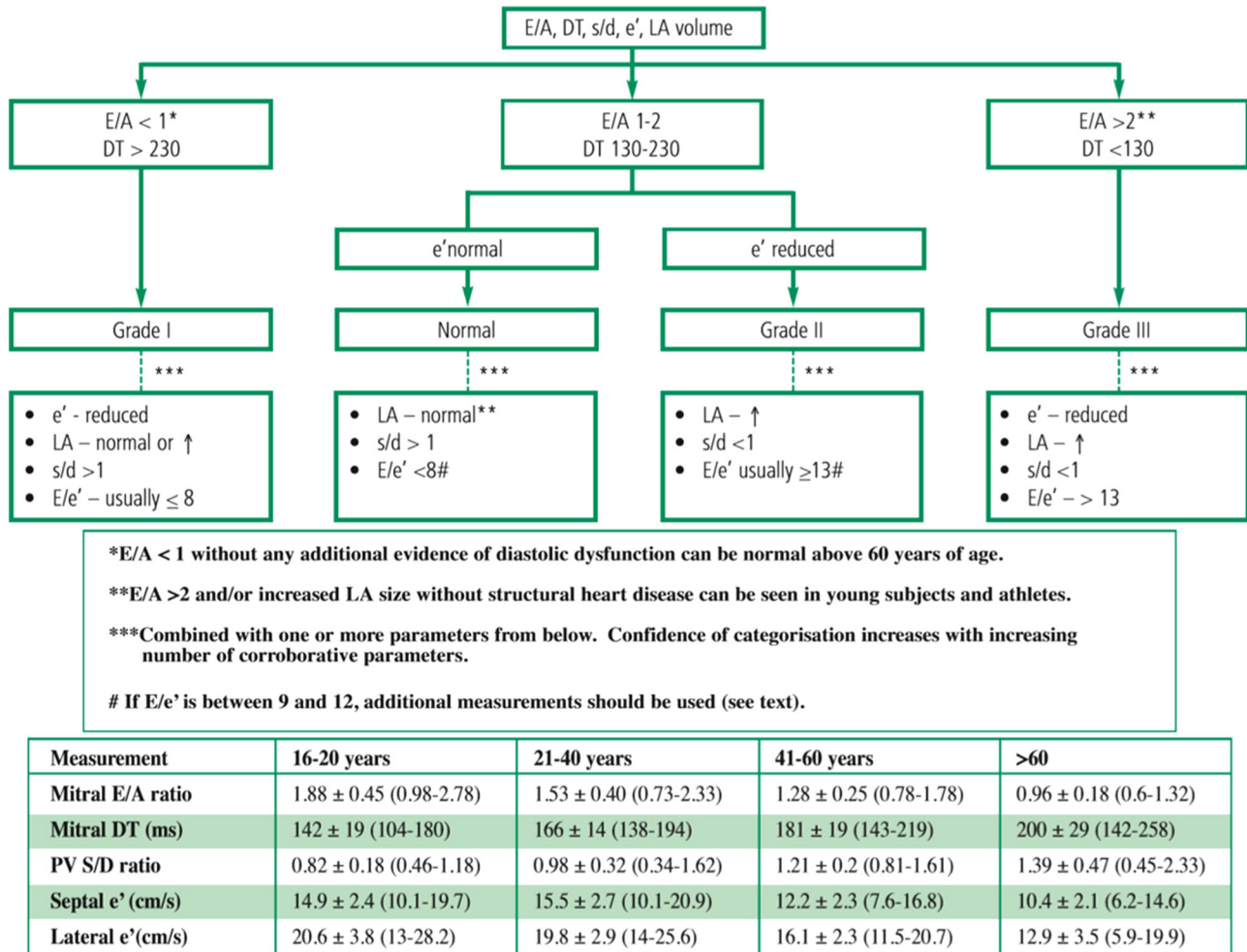


Figure 1

Representing the British Society of Echocardiography algorithm for the assessment of diastolic function including expected range of measurements based on age (https://www.bsecho.org/media/112942/dd_protocol_final.pdf). Reproduced with permission from the British Society of Echocardiography. Copyright 2013, British Society of Echocardiography.

in restoration forces have all been identified as pathophysiological mechanisms for the development of diastolic dysfunction (1). The clinical manifestation of LVDF is variable and includes fatigue secondary to reduction in cardiac output and exertional dyspnoea. Symptoms associated with LVDF are often caused by pulmonary vein retrograde flow attributed to elevated end-diastolic pressures, which can have a profound impact on quality of life (2). A systematic review performed by van Riet and colleagues (3) concluded that the prevalence of diastolic dysfunction is high in patients aged over 60 years within the western general population with a median prevalence of 36%. While cardiac catheterisation is the gold standard for measuring LV end-diastolic pressure and pulmonary capillary wedge pressure, it is impractical to use this technique for the routine assessment of diastolic function. TTE is a non-invasive alternative to invasive

cardiac catheterisation which has been shown to have a reasonable predictive ability when evaluating left ventricular filling pressures (4, 5).

The simplest technique for assessing diastolic function is the E/e' ratio (ratio of the peak mitral inflow E wave velocity and peak mitral annular early diastolic velocity e'). However, this strategy has been considered unreliable and in isolation E/e' is poorly correlated with left ventricular filling pressures in some patients (6). The British Society of Echocardiography (BSE) and American Society of Echocardiography/European Association of Cardiovascular Imaging (ASE/EACVI) have developed more detailed algorithms incorporating more parameters used to evaluate diastolic function. The rationale for creating such diastolic algorithms is to provide a simplified, systematic and standardised approach which attempts to improve and quantify diastolic function assessment. While various

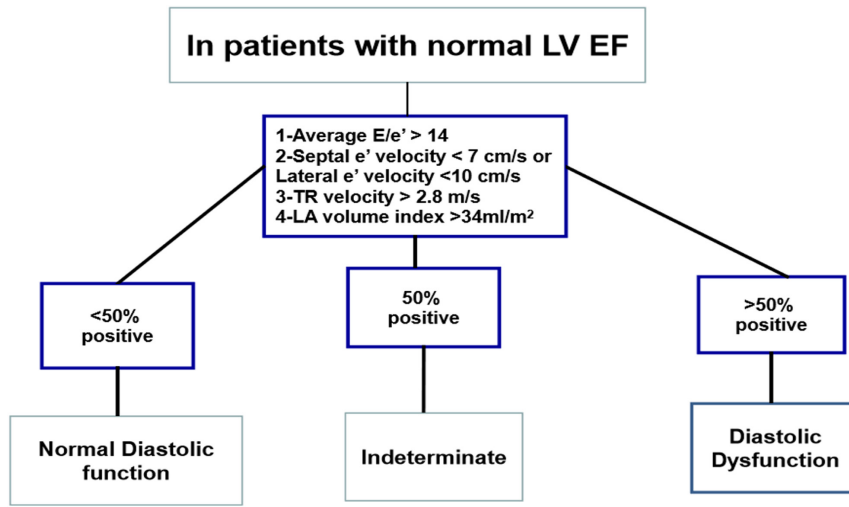


Figure 2
ASE LVDF algorithm for patients with normal
LVEF (1).

algorithms exist to assess LVDF, little is known about the agreement between the available guidelines. Both BSE and ASE/EACVI guidelines incorporate indexed left atrial volume, E/A ratio, peak mitral E wave velocity and E/e' into their respective algorithms to enhance the predictive capabilities of diagnosing diastolic dysfunction. However, each set of guidelines have small differences that make them unique. For example, the BSE template classifies all measurements according to age and includes mitral deceleration time (DT) and pulmonary vein Doppler flow (PVD). The ASE/EACVI algorithm includes tricuspid regurgitation peak velocity (TR Vmax) and left ventricular systolic function but makes no reference to age, DT and PVD. Given these differences, it is likely that there will be variability in the assessment of diastolic function between the two sets of guidelines. However to date there has been no direct comparison of the guidelines to determine the extent of agreement or disagreement in the identification of patients with diastolic dysfunction or in the grading of diastolic dysfunction.

Aim

The aim of the investigation is to directly compare BSE and ASE/EACVI diastolic guidelines to establish if they provide similar results.

Methods

Three hundred and thirty-two (male 55%, age 67 ± 17 years) consecutive patients in sinus rhythm undergoing transthoracic echocardiography for a primary

indication of heart failure assessment or assessment of left ventricular systolic function between the 1st and 31st of January 2017 were extracted from our local database (McKesson Cardiology). The involvement of retrospective data and the specific search criteria involving anonymised patient parameters constitutes this project as a clinical audit and as such requires no patient consent or ethical consideration. We selected patients from the database with no history of a mitral valve replacement or repair and no more than moderate left-sided valvular disease. From the total population, 43% of patients were excluded due to left bundle branch block (2.1%), no indexed left atrial volume (35.6%) and mitral annular calcification (5.4%). Patients with left bundle branch block (LBBB) were excluded as the ASE guidelines indicate that diastolic function cannot be accurately assessed in the presence of LBBB. LVDF assessment using the BSE (Fig. 1) and ASE/EACVI guidelines (Figs 2 and 3) was performed on the remaining 189 patients. E/A ratio, DT, E/e', indexed left atrial volume (LAVi), left ventricular ejection fraction (LVEF), tricuspid regurgitation peak velocity, septal and lateral tissue Doppler data were all included in the analysis to determine diastolic grading. To complete the diastolic guidelines for the BSE algorithm, age-related reference values provided by the BSE were used to identify if e' Doppler velocities were considered normal or abnormal. The use of the reference table provided additional support to award either normal or grade II diastolic function using the BSE algorithm (Fig. 1). TTE imaging was performed with GE Vivid E9 and Phillips Epic 7 equipment. Apical four- and two-chamber echocardiographic windows were used to measure left atrial volumes using the biplane area-length

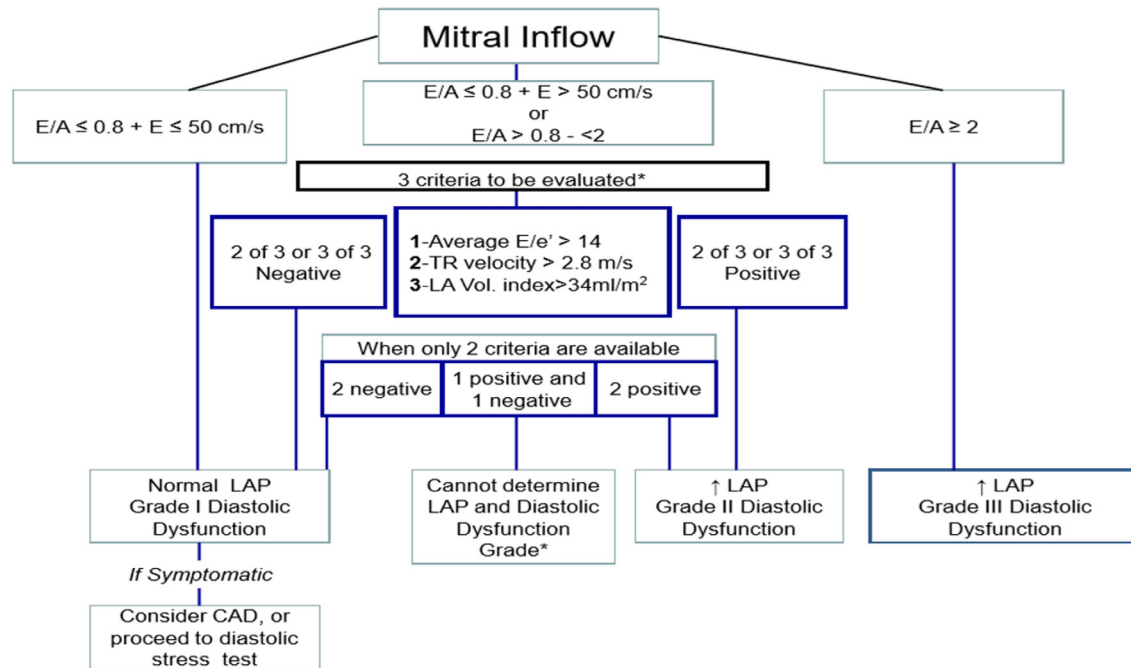


Figure 3
The ASE/EACVI LVDF algorithm for patients with depressed LVEF and patients with myocardial disease and normal LVEF (1).

method, which were indexed to body surface area. Pulsed-wave Doppler located at level of the mitral valve leaflet tips was used to measure mitral inflow. Pulsed-wave tissue Doppler was performed by placing the sample volume at the region of the septal and lateral mitral valve annulus to obtain an average e' used to calculate E/e' . Where tricuspid regurgitation (TR) was identified on colour flow Doppler imaging, continuous wave Doppler was used to measure peak TR velocity. The largest peak TR velocity was selected from the apical four chamber, modified parasternal long-axis and short-axis views of the tricuspid valve. Left ventricular systolic function was measured by either visual estimate or biplane Simpsons method and graded in accordance to ASE/EACVI and BSE guidelines.

PVD was not included as it is not routinely measured within our department (see 'Limitations' section below). All measurements during each scan included in the investigation were performed by BSE accredited staff with at least 3 years independent scanning experience and each diastolic assessment performed by one operator (PL) to minimise inter-observer bias. Once the results for each patient were obtained they were directly compared.

Statistical analysis

When evaluating overall normal, abnormal and indeterminate diastolic classifications, the data were

expressed as proportional percentages and compared using chi-square. Differences between diastolic gradings for BSE and ASE algorithms were compared using chi-square. Kappa score was used to determine if there was agreement between the two algorithms. A comparison of TR Vmax between diastolic grading groups was determined by a one-way ANOVA. SPSS version 17 was used at a P value <0.05 , which was considered significant.

Results

Comparison between normal, abnormal and indeterminate grading

Significantly more patients were labelled as unclassified by the BSE algorithm compared to indeterminate by the ASE/EACVI diastolic guidelines (47.4 BSE vs 20.5% ASE/EACVI, $\chi^2=20.1$, $df=1$, $P<0.0001$). The number of patients classified as having abnormal LVDF was significantly higher with the ASE/EACVI guidelines (50.5% patients graded abnormal by ASE/EACVI vs 32.1% by BSE, $\chi^2=7.803$, $df=1$, $P=0.005$). No significant difference was observed between the two algorithms in the number of patients classified as having normal LVDF (29% by ASE/EACVI vs 20.5% by BSE, $\chi^2=2.723$, $df=1$, $P=0.099$) (Fig. 4). The baseline characteristics are shown in Table 1.

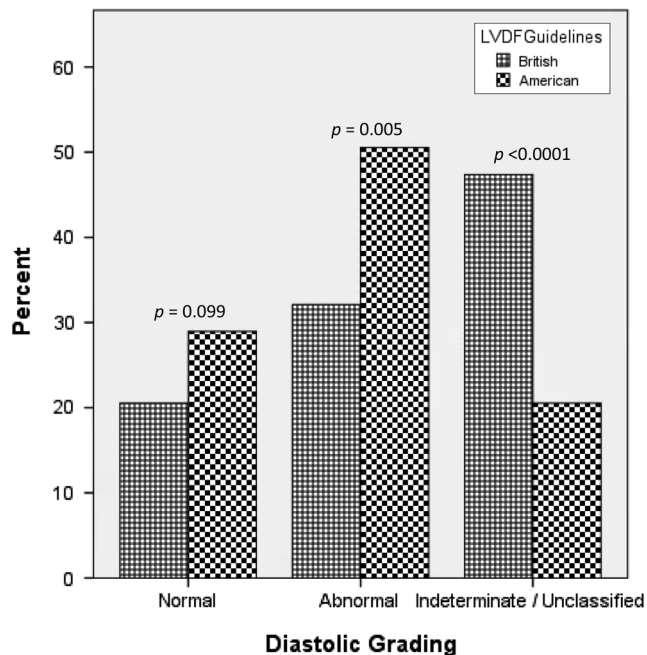


Figure 4 Illustrates the differences between ASE/EACVI and BSE guidelines when classified as normal, abnormal and indeterminate/unclassified. LVDF, left ventricular diastolic function.

ASE/EACVI and BSE comparative analysis

When the ASE/EACVI and BSE diastolic grading classifications were compared, the results suggested that the ASE/EACVI algorithm provided more diastolic gradings in each category except grade 2 (Fig. 5). There was

Table 1 Baseline data shown for the whole sample population.

Baseline data	n = 189
Age (years)	66 ± 16
Gender (%)	
Male	55
Female	45
BMI (kg/m ²)	29 ± 12.1
BSA (m ²)	1.9 ± 0.25
LVIDd (cm)	4.6 ± 0.7
LVIDs (cm)	3.1 ± 0.8
LV function	
Normal (>55%)	51%
Mild (54–45%)	26%
Moderate (44–35%)	10%
Severe (<35%)	13%
Left atrial volume indexed to BSA (mL/m ²)	28 ± 14
Tricuspid regurgitation present	51%
Tricuspid regurgitation peak velocity (m/s)	(2.44 ± 41.6)

BMI, body mass index; BSA, body surface area; LVIDd, left ventricular internal diameter in diastole; LVIDs, left ventricular internal diameter in systole.

significantly less indeterminate gradings when utilising the ASE/EACVI diastolic guidelines compared to unclassified by the BSE algorithm (20.5% vs 47.4%, $\chi^2=20.1$, $df=1$, $P<0.0001$). The removal of indeterminate and unclassified gradings did not impact upon the overall statistical difference between the two algorithms with a higher proportion of normal and grade one outcomes awarded by the ASE/EACVI guidelines ($\chi^2=137.6$, $df=9$, $P<0.0001$). When the individual gradings for each algorithm were compared (Fig. 5), there was a significant difference between ASE/EACVI and BSE grade one LVDF (40.7 vs 20.1%, $\chi^2=13.226$, $df=1$, $P<0.0001$). The reason for this difference was a high frequency of unclassifiable results by the BSE guidelines in this group (42 patients, Table 2). There was no significant difference between ASE/EACVI and BSE guidelines in the remaining normal ($P=0.081$), grade two ($P=0.223$) and grade three groups ($P=0.414$). Where there was disagreement, the discrepancy was mostly due to the BSE algorithm being unable to provide a classification. There was a small degree of variability in diastolic grading observed in normal and grade one diastolic classifications between the two algorithms (Table 2). However, on one occasion the BSE guidelines awarded a classification that differed more than one grading from the ASE/EACVI guidelines. An example of this is the ASE/EACVI algorithm awarding normal diastolic function but BSE guidelines recommending grade two for the same patient (Table 2). Kappa score indicated that there was fair but significant agreement between the two algorithms ($k=0.36$, $P<0.0001$). Discrepancy between E/A ratio and deceleration time (i.e. data unclassifiable by BSE algorithm) was observed 44.9% of the population when applying the BSE guidelines ($\chi^2=3.482$, $df=1$, $P=0.062$). Out of 90 patients labelled as unclassified by the BSE algorithm, 79 (88%) of those patients were described as having grade one diastolic function by the ASE/EACVI guidelines. A one-way ANOVA indicated that there was no significant difference in TR Vmax between all of the diastolic classification gradings ($P=0.875$).

Left ventricular systolic function and diastolic function

All patients with systolic dysfunction had a minimum of grade one diastolic impairment when using the ASE/EACVI guidelines. All subjects with normal diastolic function graded by the ASE/EACVI algorithm also had normal left ventricular systolic function. Using the BSE guidelines 18% of patients with normal diastolic

Table 2 The number diastolic gradings awarded using the ASE/EACVI and BSE guidelines.

BSE diastolic guidelines	ASE/EACVI diastolic guidelines					Total
	Normal	Grade 1	Grade 2	Grade 3	Indeterminate	
Normal	28*	3	0	0	3	39
Grade 1	8	22*	0	0	8	38
Grade 2	1	5	6*	0	8	20
Grade 3	0	0	0	2*	0	2
Indeterminate	18	42	6	2	22*	90
Total	55	77	12	4	41	189

*Values in agreement with both the ASE/EACVI and the BSE guidelines. The other values represent where a discrepancy exists between the two algorithms.

function also had left ventricular systolic impairment while none of the ASE/EACVI graded patients had systolic impairment with normal diastolic function ($\chi^2=16.026$, $df=1$, $P<0.0001$). Significantly more patients with normal LVEF had diastolic impairment (grade one to grade three) using the BSE algorithm compared to the ASE diastolic guidelines (BSE: 26.2 vs ASE: 15.5%, $\chi^2=18.6$, $df=1$, $P<0.0001$). Using the ASE/EACVI guidelines, 87% of patients with an abnormal LVEF were labelled with grade one LVDF compared to 57.6% using the BSE algorithm ($\chi^2=26.7$, $df=1$, $P<0.0001$). No significant differences was observed between LVEF (normal or abnormal), grade two ($\chi^2=1.19$, $df=1$, $P=0.275$) and three ($\chi^2=3.33$, $df=1$, $P=0.564$) diastolic impairment for each algorithm.

Discussion

A significant proportion of the sample population assessed with the BSE algorithm were labelled as unclassified compared to indeterminate using the ASE/EACVI algorithm (47.4% vs 20.5%, $P<0.0001$). One reason for the disagreement between the two guidelines could be the inclusion of left ventricular function and TR peak velocity with the ASE/EACVI algorithm making these guidelines more sensitive to detect LVDF. The advantage of including LVEF and/or the presence of myocardial disease when attempting to quantify LVDF is that patients with abnormal left ventricular structure (left ventricular hypertrophy, reduced LVEF) will not have normal diastolic function and at best will have grade 1 diastolic dysfunction. This was shown in the current study as all patients with reduced LVEF had a minimum of grade one diastolic impairment with the ASE/EACVI, while 18% of patients with an abnormal LVEF were considered to have normal diastolic function using the BSE guidelines. These findings are interesting as you would expect that a reduction in LVEF would also have both impaired relaxation and increased myocardial stiffness due to myocardial fibrosis accumulation and loss of myocardial myocyte contribution. The inclusion of LVEF into the ASE/EACVI guidelines ensures that patients with abnormal systolic function or regional wall motion abnormalities must also have diastolic impairment. However, the lack of LVEF into the BSE guidelines means that at times there can be a disparity between LVEF and diastolic function which raises questions over validity of the BSE algorithm. The main reason for the high rate of unclassifiable outcomes in the BSE pathway was discordant E/A ratio and DT which could not be fitted to one of the initial boxes in the BSE pathway (E/A ratio of <1 and $DT < 230$ ms cannot be classified, Fig. 1, BSE pathway). This scenario was observed in 44.9% ($P=0.062$) of patients when using the BSE algorithm meaning that there was no clear route through the algorithm to determine

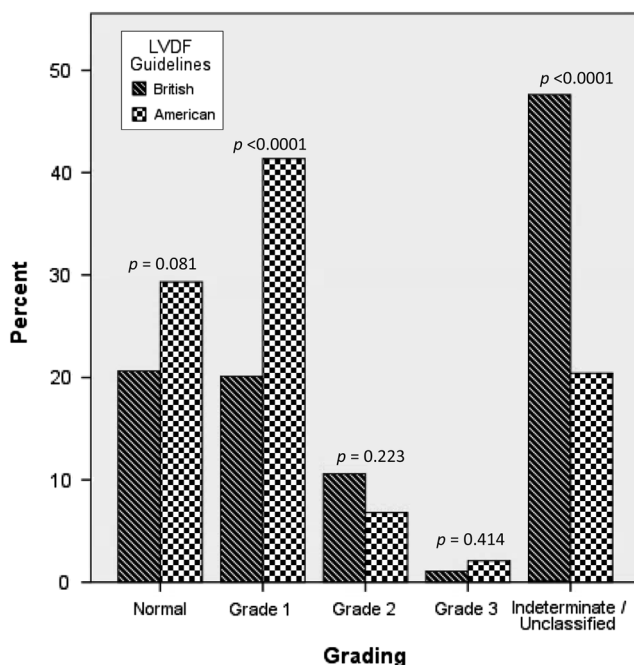


Figure 5 The percentage number of subjects classified as normal to grade three and indeterminate using both ASE/EACVI and BSE diastolic guidelines. LVDF, left ventricular diastolic function.

diastolic grading. Since there was a significant increase in the number of patients classified as grade one diastolic impairment using the ASE/EACVI guidelines compared to the BSE algorithm (40.7 vs 20.1%, $P < 0.0001$). The results of the current analysis confirm that out of 90 patients labelled as unclassified by the BSE algorithm, 88% of those patients were labelled as grade one by the ASE/ACVI guidelines. The results indicate that the BSE algorithm is inadequate at awarding grade one diastolic impairment compared to the ASE/EACVI guidelines. However, there was no significant difference observed in the remaining normal, grade two and grade three classifications between the two sets of guidelines. These findings suggest that the BSE guidelines are just as effective as the ASE/EACVI algorithm at highlighting either normal diastolic function or identifying the presence of significant diastolic impairment. To date the BSE algorithm does not appear to have been extensively validated. Another argument that could be offered for the high number of unclassified gradings within the BSE cohort is not incorporating pulmonary venous Doppler data as it is not routinely measured and recorded within our department. However in the BSE algorithm, pulmonary venous flow data are not used as part of the initial assessment as indicated above. Rather they are used further down the flow chart as additional confirmatory evidence for grading of diastolic function (Fig. 1). It is unlikely therefore that routine recording of pulmonary venous flow data would have reduced the number of unclassifiable results by the BSE algorithm. Pulmonary venous flow velocities which can be measured by TTE represent left atrial filling and compliance. While it should not be used in isolation to characterise diastolic function, it can provide a clue that pulmonary venous flow reversal is present due to high left atrial pressures. However, due to limitations such as small pulmonary venous velocities and variability in pulsed-wave signal quality this measurement is not often incorporated into an echocardiographer's scanning template (7). Variables within the BSE algorithm can also be conflicting, such as LAVi being 'normal or elevated' and E/e' is 'usually ≤ 8 ' in grade I diastolic dysfunction, introducing a degree of ambiguity into the interpretation of the guideline.

The ASE/EACVI algorithm on the other hand relies on four variables to determine diastolic function (E/A ratio, E/e' , tricuspid regurgitation and LAVi). If at least three of the four parameters are abnormal then diastolic dysfunction is present, while if none or one out of the four results in normal diastolic grading. A problem occurs if half of these parameters do not meet the

required cut-off value or are not measurable, resulting in an indeterminate outcome. An example provided by Nagueh and colleagues (1) indicated that a 60 year old patient with a LA volume of 30 mL/m², $E/e' = 10$, septal e' velocity of 6 and no measurable TR would be labelled as indeterminate using the ASE/EACVI guidelines since two parameters were negative (LAVi < 34 mL/m² and $E/e' < 14$), one was positive (septal $e' < 7$ cm/s) and one unmeasurable (TR Vmax). Thus although two out of three measurable parameters were negative the result was still indeterminate. This phenomenon has also been highlighted by Mitter and colleagues (8) as there are numerous combinations which result in indeterminate outcomes when applying the ASE/EACVI guidelines. In spite of this a recent investigation by Balaney and colleagues validating the 2016 ASE/EACVI guidelines when compared to invasive catheterisation laboratory data concluded that only 10% of patients were classified as indeterminate using the ASE/EACVI algorithm estimating left ventricular filling pressures in the remaining 90% of the sample population (9). This is significantly lower than in our population where 21% of patients had indeterminate results with the ASE/EACVI algorithm. The discrepancy between our findings and those obtained by Balaney and colleagues (9) may be attributed to their sample selection as they only included patients undergoing left heart catheterisation whereas our study involved unselected patients attending for transthoracic echocardiography. In addition our study did not set out to evaluate the accuracy of the ASE/EACVI guidelines for assessing LV filling pressure, rather our aim was simply to determine the outcome of the application of the guideline in the clinical setting. Balaney and colleagues (9) concluded that the main cause of an indeterminate grading within their study was attributed to insufficient TR to allow assessment of TR Vmax. This finding was also observed in our analysis as 68.2% of patients labelled with an indeterminate grading had no measurable TR. In addition, for those patients who did have TR there was no significant increase in peak velocity in patients with normal LVDF and patients labelled as grade one to three diastolic impairment using the ASE/EACVI guidelines ($P = 0.875$). These findings suggest that TR Vmax has a limited role in the assessment of LV diastolic dysfunction. One suggestion may be the removal of the TR Vmax variable from the algorithm if no TR is found thus giving the remaining E/e' , LAVi, septal and lateral e' velocities more diagnostic power to determine the presence of LVDF, or complete removal of TR from the guidelines.

One advantage of the BSE algorithm over the ASE/EACVI guidelines was the incorporation of age to identify if diastolic parameters are normal as elderly patients over the age of 60 years without any risk of cardiovascular disease often have an impaired relaxation pattern (E/A ratio <1 and DT >200 ms). Including patient age offers the ability to differentiate between pathologically abnormal restrictive filling patterns caused by diastolic dysfunction and age related morphological cardiac changes in both structure and function due to age. The BSE guidelines attempt to address this issue by providing normal reference ranges for age groups, however they do not provide specific advice or recommendations regarding how to apply this information. In the current study we utilised the septal and lateral e' age related patient data to decide whether to accept a normal or grade two classification using the BSE algorithm. The ASE/EACVI guidelines offer advice on how to interpret findings in the context of an elderly population while the BSE guidelines quote expected figures for each age range but no discussion on how to specifically incorporate them. We also must consider that including age related data for all variables may increase the complexity of the BSE algorithm. In a busy echocardiography department this may make the BSE guideline less attractive for clinical use. An algorithm offered by Mitter and colleagues (8) attempts to evaluate LVDF by adjusting e' Doppler values by age (<55 years e' <10 cm/s, 55–65 years e' <9 cm/s, >65 years e' <8 cm/s). They incorporate parameters that are included in the ASE/EACVI guidelines but with some subtle modifications including the addition of DT and the redefinition of significant LA dilatation as LAVi >28 mL/m². However these new criteria have not yet been validated in a clinical capacity. Future investigations should attempt to clinically evaluate and assess the validity of the criteria developed by Mitter and colleagues (8) to establish if this algorithm enhances the predictive capabilities of determining LVDF.

Limitations

As this was a retrospective investigation comparing two diastolic algorithms, we were unable to include PVD data as this variable is not a routine measurement performed within our department. While this data point alone is unlikely to confirm LVDF, it can be combined with other variables in the BSE algorithm to further support or exclude the presence of diastolic impairment. However, as indicated above we feel it is unlikely that the non-inclusion of PVD data in our series contributed significantly to the

number of non-classifiable results in the BSE algorithm. The high number of patients without LAVi may have significantly reduced the overall sample size, potentially impacting on the power of the study. The study aim was not to evaluate the diagnostic accuracy of the BSE and ASE/EACVI guidelines but to assess the consistency of the grading outcomes between the two sets of guidelines.

Declaration of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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