Interchangeability in Left Ventricular Ejection Fraction Measured by Echocardiography and cardiovascular Magnetic Resonance: Not a Perfect Match in the Real World

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Abstract: Comparisons of transthoracic echocardiography (TTE) and cardiovascular magnetic resonance (CMR) derived left ventricular ejection fraction (LVEF) have been reported in core-lab settings but are limited in the real-world setting.

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We retrospectively identified outpatients from 4 hospital sites who had clinically indicated quantitative assessment of $LVEF_{TTE}$ and $LVEF_{CMR}$ and evaluated their concordance. In 767 patients (mean age 47.6 years; 67.9% males) the median inter-modality interval was 35 days. There was significant positive correlation between the 2 modalities (r = 0.75; $P < 0.001$). Median LVEF was 54% (IQR 47%, 60%) for TTE and 59% (IQR 51%, 64%) for CMR, ($P < 0.001$). Normal $LVEF_{TTE}$ was confirmed by CMR in 90.6% of cases. Of patients with severely impaired $LVEF_{TTE}$, 42.3% were upwardly reclassified by CMR as less severely impaired. The overall proportion of patients that had their LVEF category confirmed by both imaging modalities was 64.4%; Cohen's Kappa 0.41, indicating fair-to-moderate agreement. Overall, CMR upwardly reclassified 28% of patients using the British Society of Echocardiography LVEF grading, 18.6% using the European Society of Cardiology heart failure classification, and 29.6% using specific reference ranges for each modality. In a multi-site "real-world" clinical setting, there was significant discrepancy between $LVEF_{TTE}$ and $LVEF_{CMR}$ measurement. Only 64.4% had their LVEF category confirmed by both imaging modalities. $LVEF_{TTE}$ was generally lower than $LVEF_{CMR.}$ $LVEF_{CMR}$ upwardly reclassified almost half of patients with severe LV dysfunction by $LVEF_{TTE}$. Clinicians should consider the inter-modality variation before making therapeutic recommendations, particularly as clinical trial LVEF thresholds have historically been guided by echocardiography. (Curr Probl Cardiol 2023;48:101721.)

Introduction

Left ventricular ejection fraction (LVEF) is an established measure of systolic function and despite its limitations, is widely used due to its simplicity, extensive validation and prognostic value. It is referenced in multiple clinical guidelines, and is key to therapeutic decision-making, such as whether to consider implanting a cardioverter defibrillator or cardiac resynchronization therapy, and to grade the severity of heart failure (HF).[1-3] It is a well-validated prognostic biomarker after myocardial infarction (MI),[4-8] in HF,[9-11] and following aortic valve replacement.[12-14] Furthermore, LVEF assessment is key for prospective monitoring of cardiotoxicity of cancer therapeutic drugs.[15]

Cardiovascular magnetic resonance (CMR) enables multiplanar imaging without the limitation of imaging acquisition windows and can be an alternative to transthoracic echocardiography (TTE) in patients with poor TTE imaging windows due to an increased body habitus or a postsurgical state (eg, postbreast surgery).[15] LVEF can be calculated by CMR imaging using volumetric coverage of the left ventricle (LV) and is not dependent on geometric assumptions, resulting in high accuracy and excellent reproducibility in normal, hypertrophied and dilated hearts and superior to 2D-echocardiography.[16] While CMR is the "reference standard" for the assessment of LV volumes and ejection fraction, it lacks portability to be a bedside test, is not as widely available and accessible as TTE, has higher costs, and, consequently, is used less often. In clinical practice, LVEF is primarily measured with TTE which enables greater portability and ease of access.[17,18]

Awareness that distinct imaging modalities may yield discordant LVEF is important for optimum management of patients as it may otherwise lead to different clinical classifications and treatment recommendations, depending on the modality used.[19] Accordingly, the study of intramodality variation is explicitly recommended by guidelines.[3] Nevertheless, the clinical significance and interchangeability of echocardiography and CMR measurements remain under-investigated, and clinical decision-making rarely considers which imaging test is used for LVEF assessment. In particular, studies for advanced heart failure therapies were largely based on 2D echocardiography and not CMR. In this multisite study, we aimed to assess the correlation and agreement of LVEF by TTE ($LVEF_{TTE)}$ compared with LVEF by CMR ($LVEF_{CMR}$) in a "real-world" clinical setting.

Materials and Methods

We conducted a retrospective review of consecutive patients who had undergone both TTE and CMR across 4 hospital sites (3 secondary care and 1 tertiary care) within Barts Health NHS Trust. CMR scans were performed at the central tertiary cardiac center. The study was approved by the institution review board (audit ID 13298). The need for written consent was waived due to the retrospective nature of the study. Data files were extracted from the electronic records between November 2015 and July 2019 with details of all TTE and CMR imaging in the study period.

Inclusion Criteria

Study participants needed to be 18 years of age or older, both sexes, and were only included if the scans were performed on an elective or outpatient basis, thus reducing the confounding from hemodynamic variations in acute admissions. CMR and TTE needed to be performed $\leq$90 days of each other to avoid confounding and potential changes in LVEF over a longer time frame. In patients who had multiple scans, we selected the pair of scans separated by the shortest available time interval. Quantitative measurement of LVEF needed to be included in the report, thus removing potential bias from visual assessments alone or where image quality was poor.

TTE

Patients had a clinically indicated, comprehensive echocardiographic examination, according to the British Society of Echocardiography (BSE) minimal dataset using commercially available echocardiography machines.[20] All physiologists performing the studies were certified by national/international societies. Normal practice for echo LVEF quantification is to include LV papillary muscle and trabeculae in the blood pool. Where the option was available, patients also had a 3D volume acquisition. $LVEF_{TTE}$ was calculated using the biplane method of discs; where a 3D dataset was available $LVEF_{TTE}$ was calculated using the on-cart proprietary software or offline. The use of contrast has been shown to increase endocardial resolution, accuracy and interobserver reproducibility,[21] but in our cohort it was only reported as being used in 2 studies (<0.3%).

CMR Imaging

Scans were performed on Siemens 1.5T and 3T scanners (Aera and Prisma, Erlangen, Germany) with ECG-triggered retrospective gating when in sinus rhythm (prospective gating in cases such as significant arrhythmia) for acquiring balanced standard steady-state free precession (bSSFP) cine images. $LVEF_{CMR}$ was measured by volumetric coverage of the LV using short-axis cines and the disk summation method. LV papillary muscles were included in the LV end-diastolic and systolic volumes with resultant smooth contouring of endocardial borders.

Reclassification Analysis

We classified patients according to their $LVEF_{TTE}$ and $LVEF_{CMR}$ according to (1) BSE recommendations (guidance from 2015 were used at our institution given the period of the studies rather than the recent updated version; ≥55%, normal; 45%-54%, mildly impaired; 36%44%, moderately impaired; and ≤35%, severely impaired); and (2) European Society of Cardiology (ESC) heart failure (HF) grading (HF with reduced ejection fraction, LVEF ≤40%; HF with mildly reduced ejection fraction, LVEF 41%-49%; HF with preserved ejection fraction, LVEF ≥50%).[22-24] We also compared BSE thresholds for TTE with specific CMR categories from the European Association of Cardiovascular Imaging (EACVI; severely abnormal, <30%; moderately abnormal, 30%-40%; mildly abnormal, 41%-56%; reference, 57%-77%; opposite/ hyperdynamic, ≥78%).[18] We grouped patients in a 2-way table: $LVEF_{CMR}$ vs. $LVEF_{TTE}$, and then calculated the proportion of patients where the 2 modalities concurred on classification and those where classifications differed.

Statistics

Continuous variables were expressed as mean ±standard deviation (SD) or median and interquartile range (IQR), as appropriate. We used the Anderson-Darling test for normal distribution. Categorical variables were expressed as frequency and percentage. The sign test was used to compare continuous variables, while categorical variables were compared using the χ^2 test where appropriate. We assessed the correlation of LVEF measurements by TTE and CMR using scatterplots and correlation coefficients. The agreement of results was assessed using graphical representations of distributions (Supplementary Fig 2) and Bland-Altman plot analysis (Supplementary Fig 3).[25] This analysis was repeated for the subsets of 2D-biplane and 3D TTEs. Reclassification analysis was performed with Cohen's Kappa statistic.[26] We performed sensitivity analysis to assess the impact of time elapsed between TTE and CMR, the presence of irregular rhythms, age and body mass index on LVEF discrepancy between the 2 modalities. We set the significance threshold at $P < 0.05$; 95% confidence intervals (CI) were determined. Statistical analysis was performed using Microsoft Excel 2013 Version 15.0, Redmond, WA, USA.[27]

Results

Clinical Characteristics

A total of 767 patients were included in the analysis, of adults who had both CMR and TTE within the inclusion timeframe (Fig 1). The biplane method was used to calculate $LVEF_{TTE}$ in 693 2D-TTE studies and in 74 $LVEF_{TTE}$ was calculated using 3D volumes. The median interval between the 2 investigations was 35 days (IQR 2.7-50 days). Contrast was recorded as being used in only 2 studies ($<0.3\%$), as not being used in 1 study, and was otherwise not mentioned in the other reports. The indications for CMR scanning were taken from the CMR report and listed in *Supplementary Table 1*.

Correlation and Agreement

There was significant positive correlation between the 2 modalities ($r = 0.75$, $P < 0.001$) (*Supplementary Fig 1*). Median LVEF was 54% (IQR 47%, 60%) and 59% (IQR 51%, 64%) for TTE and CMR, respectively ($P < 0.001$ for comparison; median difference -4%; IQR -9%, 1%) (*Supplementary Fig 2*). Median LVEF values remained significantly different regardless of the time elapsed between the 2 studies (Table 1). Median $LVEF_{TTE}$ was significantly lower than median $LVEF_{CMR}$ in the normal ($P < 0.0005$) and mildly impaired ($P = 0.018$) subgroups. Median LVEFs were similar within the moderately and severely impaired subgroups ($P = 0.526$ and $P = 0.311$, respectively).

Bland-Altman analysis demonstrated the 95% confidence interval (CI) limit-of-agreement range was wide (31.5%) and highlighted 38 outliers (4.95% of the total group) with $LVEF_{TTE}$-$LVEF_{CMR}$ outside the 95% CI, without any apparent grouping and without statistical significance (two-tailed $P = 0.490$) (Supplementary Fig 3).

Reclassification Analysis

The overall proportion of patients that had their LVEF category confirmed by both imaging modalities was 64.4% (494/767) (Table 2, Fig 2, central illustration). The Cohen's Kappa was 0.41 (95%CI 0.34-0.47; weighted Kappa 0.55), indicating fair-to-moderate agreement between the 2 modalities.[26] Of 381 patients with a normal $LVEF_{TTE}$, 345 were similarly classified by $LVEF_{CMR}$ (90%). With regards to other BSE categories, there was significant disagreement between modalities.

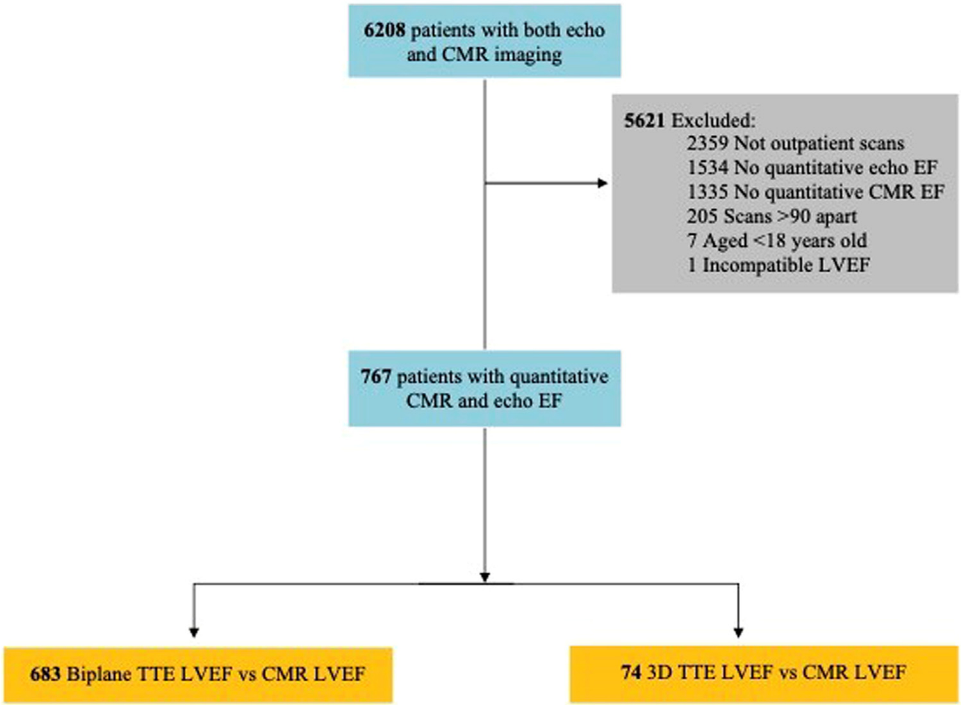

FIG 1. Study flow diagram. (Color version of figure is available online.)

TABLE 1. Median and IQR of LVEF values by TTE-CMR

	TTE vs CMR (n = 767)	3D TTE vs CMR (n = 74)	2D TTE vs CMR (n = 693)	AF+ (n = 48)	SR (n = 699)	TTE vs CMR ≤30 d (n = 269)	TTE vs CMR ≤10 d (n = 126)
Overall	−4 [−9,1]	−2 [−7.8,2.8]	−4 [−10,0]	−3 [−10,2]	−4 [−9,1]	−5 [−10,1]	−5 [−10,1]
LVEF ≥ 55%	<0.001 −6 [−11,−1]	0.096 −4 [−11,−0.8]	<0.001 −6 [−11,−1]	0.111 −3.5 [−10.8,0.5]	<0.001 −6 [−11,−1]	<0.001 −7 [−12,−2]	<0.001 −7 [−12,−2.5]
LVEF 45%-54%	−2 [−6.3,3]	3 [−3.5,5.5]	−2 [−7,3]	−6 [−12.3,0]	−1 [−6,3.5]	−3 [−7,4]	−2 [−7,4]
LVEF 36%-44% LVEF ≤35%	−1 [−4.5,3] 1.5 [−2,4]	2.5 [−1.5,4] 4 [2,8]	−2 [−5,3] 0 [−4,3.8]	0 [−3.3,3.5] 2 [−4,6.8]	−1 [−5,3] 1 [−2,4.3]	−2 [−4.5,3] 2 [−1,4]	1.5 [−3,3.3] 1.5 [−0.5,2]

AF, atrial fibrillation; CMR, cardiovascular magnetic resonance; LVEF, left ventricular ejection fraction; SR, sinus rhythm; TTE, transthoracic echocardiography. TTE and CMR performed within 90 days, unless otherwise indicated. Data represented as median [IQR].

TABLE 2. Reclassification analysis according to BSE grading

LVEF category		CMR				Total	Disagreement between modalities	
		Normal (≥55%)	Mild impairment (45%-54%)	Moderate impairment (35%-44%)	Severe impairment (≤35%)		CMR > TTE	CMR < TTE
TTE	Normal (≥55%)	345	35	1	0	381	-	36 (9.4%)
	Mild Impairment (45%-54%)	129	79	13	1	222	129 (58.1%)	14 (6.3%)
	Moderate Impairment (35%-44%)	25	39	40	8	112	64 (57.1%)	8 (7.1%)
	Severe Impairment (≤35%)	2	7	13	30	52	22 (42.3%)	-
Total		501	160	67	39	767	215 (28%)	58 (7.6%)

CMR, cardiovascular magnetic resonance; LVEF, left ventricular ejection fraction; TTE, transthoracic echocardiography.

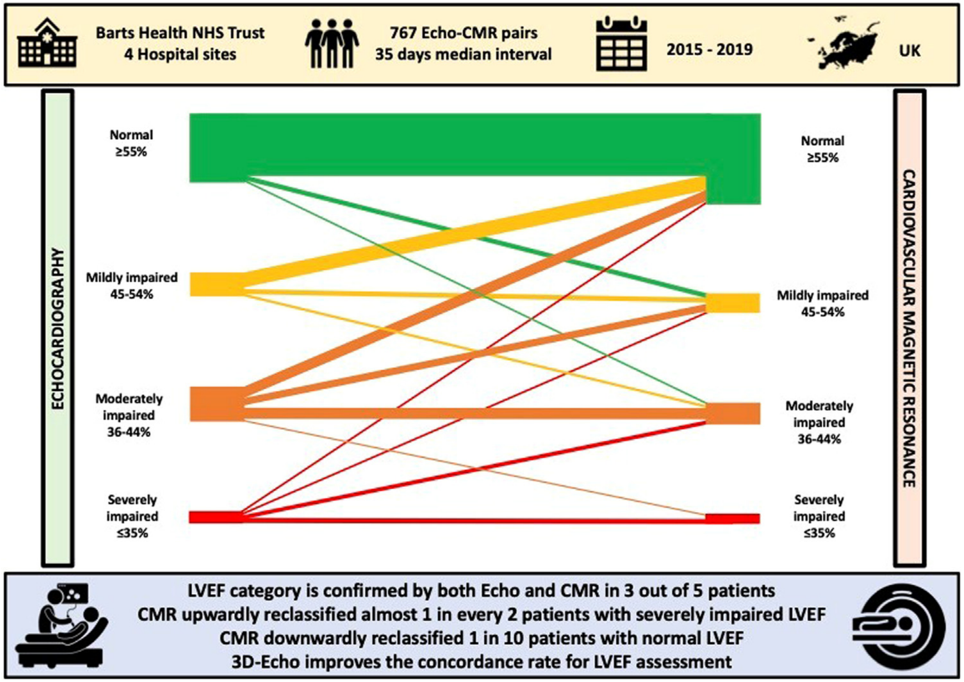

FIG 2. Central illustration. Left ventricular ejection fraction reclassification between echocardiography and CMR. (Color version of figure is available online.)

Of those 52 patients classified as having severely impaired $LVEF_{TTE}$, 22 (42.3%) received upward reclassification by $LVEF_{CMR}$. Of those 112 patients with moderately impaired $LVEF_{TTE}$, 8 (7.1%) had severely impaired $LVEF_{CMR}$ and 64 (57.1%) were reclassified upwards by CMR. Of those 222 patients with mildly impaired $LVEF_{TTE}$, 14 (6.3%) had lower $LVEF_{CMR}$ and 129 (58.1%) were reclassified upwards by CMR.

The overall number of observed agreements (76.9%) and Cohen's Kappa statistic (0.55) were both higher when using the HF classification (Table 3). Conversely, the overall number of observed agreements (59.8%) and Cohen's Kappa statistic (0.37) for LV function grading were both lower when using reference ranges specific to each modality (Table 4).

Overall, CMR reclassified upwards 28% of patients when using BSE grading, 18.6% of patients when using HF classification and 29.6% of patients when using specific reference ranges. Furthermore, CMR reclassified downwards 7.6% of patients when using BSE grading, 4.4% of patients when using HF classification and 8.2% of patients when using specific reference ranges.

3D and Biplane Echocardiographic LVEF Assessment

We had 3D-TTE data for 74 patients (53 males, mean age 56.8 years, range 18.1-87.8 years) and biplane-TTE data for 693 patients (468 males, mean age 46.7 years, range 18.1-86.9 years). There was a median interval of 11 days [IQR 1.1-35.1 days] and 36.9 days [IQR 4.0-52.0 days] between the 3D and biplane-TTE scans (respectively) and the CMR scan. $LVEF_{TTE}$ (both 3D and biplane) and $LVEF_{CMR}$ were positively correlated (3D: $r = 0.783$, biplane: $r = 0.752$) and with a high level of significance (3D: $P < 0.001$, biplane: $P < 0.001$), but with a trend for $LVEF_{TTE}$ to be lower than $LVEF_{CMR}$. $LVEF_{TTE}$ and $LVEF_{CMR}$ are "non-equivalent" measurements when $LVEF_{TTE}$ is calculated using the biplane method, however the inter-modality discrepancy disappears overall when the 3D method is used (biplane: $P < 0.001$, 3D: $P = 0.096$). It is of note that when the results are stratified by severity the normal group showed that 3D-$LVEF_{TTE}$ was still lower than $LVEF_{CMR}$ ($P < 0.001$), though remaining in the normal category.

Irregular Heart Rhythms – Atrial Fibrillation and Frequent Ectopic Beats

Patients reported to have had an abnormal heart rhythm (atrial fibrillation, frequent ectopic beats, or other irregular heart rhythms) during TTE

TABLE 3. Reclassification analysis according to heart failure grading

LVEF Category		CMR			Total	Disagreement between modalities	
		HFpEF (≥50%)	HFmrEF (41%-49%)	HFrEF (≤40%)		CMR > TTE	CMR < TTE
TTE	HFpEF (≥50%)	491	21	3	515	-	24 (4.7%)
	HFmrEF (41%-49%)	89	39	10	138	89 (64.5%)	10 (7.2%)
	HFrEF (≤40%)	25	29	60	114	54 (47.4%)	-
Total		605	89	73	767	143 (18.6%)	34 (4.43%)

CMR, cardiovascular magnetic resonance; HFmrEF; heart failure with mildly reduced ejection fraction; HFpEF, heart failure with preserved ejection fraction; HFrEF, HF with reduced ejection fraction; LVEF, left ventricular ejection fraction; TTE, transthoracic echocardiography.

TABLE 4. Reclassification analysis according to reference ranges specific to each modality

LVEF Category		CMR					Total	Disagreement between modalities	
		Opposite (≥78%)	Reference (57%-77%)	Mildly abnormal (41%-56%)	Moderately abnormal (30%-40%)	Severely abnormal (<30%)		CMR > TTE	CMR < TTE
TTE	Normal (≥55%)	18	308	54	1	0	381	-	55 (14.4%)
	Mild Impairment (45%-54%)	1	110	106	4	1	222	111 (50%)	5 (2.2%)
	Moderate Impairment (35%-44%)	0	20	64	25	3	112	84 (75%)	3 (2.7%)
	Severe Impairment (≤35%)	0	1	12	19	20	52	32 (61%)	-
Total		19	439	236	49	24	767	227 (29.6%)	63 (8.2%)

CMR, cardiovascular magnetic resonance; LVEF, left ventricular ejection fraction; TTE, transthoracic echocardiography.

were analyzed both together with, and separately from the whole cohort to assess if the presence of irregular heart rhythms, such as atrial fibrillation or frequent ectopic beats, posed a challenge to effective cardiac imaging and impact $LVEF_{TTE}$-$LVEF_{CMR}$. In patients with irregular heart rhythm median $LVEF_{TTE}$ and $LVEF_{CMR}$ were not significantly different.

Discussion

In this multisite "real-world" study, we documented a significant difference between TTE and CMR in LVEF quantification, with $LVEF_{TTE}$ being significantly lower than $LVEF_{CMR}$. Over 40% of patients classified as being severe by $LVEF_{TTE}$ (LVEF <35%) were categorized as less severe by $LVEF_{CMR}$. Our comparison of 3D-$LVEF_{TTE}$ with $LVEF_{CMR}$ showed no significant difference between the 2 modalities, smaller bias and better correlation coefficient. 3D-$LVEF_{TTE}$ has a closer agreement with CMR over 2D biplane-$LVEF_{TTE}$. Furthermore, the presence of arrhythmias did not affect the agreement between $LVEF_{TTE}$ with $LVEF_{CMR}$.

3D-TTE acquires a pyramidal dataset, does not require any geometric assumptions and eliminates the risk of foreshortening of the LV, making it similar to $LVEF_{CMR}$ is derived and thus more accurate than 2D for LVEF measurement by TTE.[28] The feasibility of 3D-TTE is dependent on technical aspects of the scan such as 3D volume rate, and the resulting image quality, in particular the endocardial border definition.[29] In many cases the TTE reports were explicit that imaging quality was not good enough to allow the acquisition of meaningful 3D datasets. The 2D-biplane assessment of LVEF was carried out in many more instances than 3D-TTE, as echo labs and operators are more familiar with it. Technical difficulties and the additional time required may limit the proportion of cases where a quantitative $LVEF_{TTE}$ is obtained, which explains why many of the cases in our initial cohort only had a visual $LVEF_{TTE}$ estimate; with wide potential for inter-observer variation, they were excluded from our analysis.

In a real-world setting 3D-TTE and CMR are more similar for the purpose of determining global LV systolic function, 3D and biplane when LVEF is below 45%, and for patients with irregular heartbeats. However, a note of caution is required as the overall proportion of patients that had their LVEF category confirmed by both imaging modalities was only 64.4%. Noticeably, of those patients classified by TTE as having severely impaired LV function, almost 50% were classified upwards by CMR and categorized as having less severe LV impairment. Our study was not designed to assess which modality best predicts outcomes or suitability for heart failure pharmacotherapy or advanced devices and requires further comparative outcome studies to help clarify this. However, guidelines and clinical trials for advanced cardiac devices have primarily been derived from 2D-TTE specific measures. Thus, if an LVEF of $\leq$35% is used to decide on advanced heart failure therapies, a lower proportion would be deemed eligible following CMR. The modality used also has implications for the use of medical intervention for heart failure. Indeed, CMR upwardly reclassified almost 50% HFrEF patients and more than 60% HFmEF patients adjudicated by TTE. Conversely, CMR reclassified downwards a smaller proportion of approximately 5% and 7% patients to worse HF subtypes.

Comparison With Previous Studies

Our results complement the literature. A large, international, multicentre retrospective secondary study of the diagnostic measurement of LVEF, part of the "Surgical Treatment for Ischemic Heart Failure" (STICH) randomized trial showed substantial variation among modalities for determination of LVEF in patient with coronary artery disease and severe LV dysfunction, even though these measures were made by specialized core laboratories, which followed specific protocols for image analysis and measurements.[30] In their selective cohort with LV dysfunction the mean $LVEF_{TTE}$ was 28.7% [(SD) 8.2%, (n = 897)] and 27.2% for $LVEF_{CMR}$ [10.8% (417)], and the correlation coefficient between modalities was 0.493, smaller than our study. However, correlation is a low bar in the assessment of equivalence of investigative modalities and agreement is more important.[19] There was less discrepancy between LVEF derived from the 2 modalities (mean signed difference, 2.5%) than in our study which is probably a consequence of the "real-world" setup studied here with a wider range of LVEF and more staff analyzing the echo and CMR studies, however this could also be due to the severely impaired LVEF that predominate in the STICH sample population, as our study found lower rates of discrepancy in the severely impaired LVEF population. Difference in the LVEF of the sample population may also contribute to the STICH study finding that $LVEF_{TTE}$ was higher than $LVEF_{CMR}$, whereas our study found the opposite trend. This could also result from differences in scanning methodology, for example the inclusion or not of papillary muscles and trabeculae in the blood pool.

In the study by Andre et al.[22] biplane-$LVEF_{TTE}$ was significantly lower than $LVEF_{CMR}$ in patients with LVEF>45%; there was no significant difference between the modalities in patients with LVEF between 35% and 45%, and $LVEF_{TTE}$ was significantly higher than $LVEF_{CMR}$ in patients with LVEF $<35\%$. Our study confirms that biplane-$LVEF_{TTE}$ can be significantly lower than $LVEF_{CMR}$ in patients with a LVEF $\geq 50\%$ but does also clearly show a smaller rate of upward reclassification by CMR in patients with both severely impaired and less impaired $LVEF_{TTE}$. Further, we observed a higher rate of reclassification when comparing reference ranges specific to each modality, which needs further assessment in external cohorts.

Clinical Relevance

In more than one-third of cases, the decision as to which modality to use in order to assess LV function would have resulted in a different severity classification. Of patients with "normal" $LVEF_{TTE}$, 90.6% would have that classification confirmed by $LVEF_{CMR}$, in contrast to the other categories of LVEF where they were confirmed in only 38.6% of cases. It is clinically relevant that, despite intermodality discrepancies, a "normal" $LVEF_{TTE}$ is thus likely to be confirmed by $LVEF_{CMR}$, supporting the use of TTE for ruling out LV systolic dysfunction. Over 60% of patients with an impaired LV function on TTE would have a conflicting LVEF category by CMR. This is likely to be influenced by the much smaller class intervals of the intermediate classes. The discrepancy may be clinically significant when treatments are allocated using LVEF severity cut-offs. Even where treatment criteria is $LVEF_{TTE}$ based, such as the 35% cut-off for implantable cardioverter defibrillator implantation for primary prevention or cardiac resynchronization therapy devices, this analysis would support the use of different criteria for $LVEF_{CMR}$.

The variation of LVEF quantification depending on the imaging modality is often not considered in clinical practice and raises challenges when LVEF is a major determinant of choice of therapy. Our results should act as a caveat to the practicing cardiologist and clinicians that there is no such thing as an 'absolute' LVEF. The dependence of inter-modality agreement on LVEF ranges should also inform clinical decision making by allowing appropriate weighing of LV systolic (dys)function according to imaging modality. Accordingly, standardization of parameters useful for the grading of severity, such as LVEF, is encouraged in order to streamline the communication with referring clinicians and to improve patient care.[18]

The seeming equivalence between 3D-$LVEF_{TTE}$ and $LVEF_{CMR}$ in general, and with impaired LVEF in particular suggests that these LVEFs cannot be used in evidence based practice as they are not interchangeable with the 2D-$LVEF_{TTE}$ based entry criteria used in studies which form the evidence base for advanced heart failure treatments.

In patients with atrial fibrillation and frequent ectopic beats, no significant difference between $LVEF_{TTE}$ and $LVEF_{CMR}$ was seen at any severity of LV systolic dysfunction suggesting that similar challenges exist between imaging modalities in the presence of arrhythmia.

Limitations

A prospectively designed study in a standardized core lab setting with more rigorous scanning timetables and a single observer across modalities may well have decreased data heterogeneity and allowed more insight into which factors influence LVEF discrepancies, such as an analysis of the impact of different pathologies, however this would be less generalizable to real-world clinical practice.

In this retrospective study, the TTEs and CMRs were analyzed by multiple different operators increasing data heterogeneity. We did not have a uniform distribution across the full spectrum of LVEFs; our data was biased to patients with normal LVEF, but reflective of clinical referrals. The number of patients who underwent 3D-$LVEF_{TTE}$ assessment was relatively low, limiting more robust analysis of 3D-TTE studies. The small subset of patients undergoing 3D-TTE and CMR imaging suggests they are used in relatively select indications: these select circumstances introduce further selection bias. The 2 most frequent indications for CMR scanning were cardiomyopathy (53%) and surveillance of patients with malignancy (13%); the predominance of the former indicates a likely selection bias. Certain patients do not lend themselves to producing images of sufficient quality to allow biplane-$LVEF_{TTE}$ or 3D-$LVEF_{TTE}$ calculations; indeed, a number of TTE reports were explicit that image quality was too poor for LVEF by means other than visual estimation. All visual estimate LVEF were removed from the study to reduce visual assessment bias. Imaging by the 2 modalities was separated by up to 90 days which introduces the possibility that discrepancies were due to genuine changes in LVEF between examinations rather than to factors intrinsic to the imaging modality, although we attempted to address this with inclusion criteria limiting to outpatient scans and with sensitivity analysis for shorter interscan durations.

Conclusions

In a multi-site "real-world" clinical setting, there was significant discrepancy between $LVEF_{TTE}$ and $LVEF_{CMR}$ measurement. Only 64.4% had their LVEF category confirmed by both imaging modalities.

$LVEF_{TTE}$ was generally lower than $LVEF_{CMR.}$ $LVEF_{CMR}$ upwardly reclassified almost half of patients with severe LV dysfunction by $LVEF_{TTE}$. Clinicians should consider the inter-modality variation before making therapeutic recommendations, particularly as clinical trial LVEF thresholds have historically been guided by echocardiography.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.cpcardiol.2023.101721.

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