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ORIGINAL ARTICLE
Vascular and cardiac imaging

Diagnostic value of left ventricular layer strain and specific regional strain patterns in cardiac amyloidosis and Fabry disease

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Aims Layer-specific left ventricular (LV) strain alterations have been suggested as a specific finding in Fabry disease (FD). Our study aimed to assess the diagnostic value of layer-specific radial strain (RS) indices compared to the established LV regional strain pattern in cardiac amyloidosis (CA) and FD, i.e. apical sparing and posterolateral strain deficiency (PLSD).

Methods and results We retrospectively analysed the global, subendocardial, subepicardial LV radial strain, the corresponding strain gradient, as well as the regional and global longitudinal strain. The diagnostic accuracy of the diverse LV strain analyses was comparatively assessed using receiver operating characteristic curve and multivariable regression analyses. In 40 FD and 76 CA patients, CA featured more reduced layer strain values [global RS −12.3 (−15.6 to −9.6) in CA vs. −16.7 (−20.0 to −13.6) in FD; $P < 0.001$; subendocardial RS −22.3 (−27.4 to −15.9) vs. −28.3 (−31.8 to −23.6), $P < 0.001$; subepicardial RS −6.6 (−8.6 to −4.7) in CA vs. −8.9 (−11.7 to − 6.5) in FD; $P < 0.001$]. Global radial and longitudinal strain held an area under the curve (AUC) of 0.75 (0.66–0.84) and AUC 0.73 (0.63–0.83). While the apical sparing and PLSD strain pattern showed the highest accuracy as single parameters [AUC 0.87 (0.79–0.95) and 0.81 (0.72–0.89), $P < 0.001$], the combination of subendocardial RS and the apical sparing pattern featured the highest diagnostic accuracy [AUC 0.92 (0.87–0.97)].

Conclusion Combining radial strain-derived parameters to the established strain pattern apical sparing and PLSD improve the diagnostic accuracy in the echocardiographic assessment in suspected storage disease.

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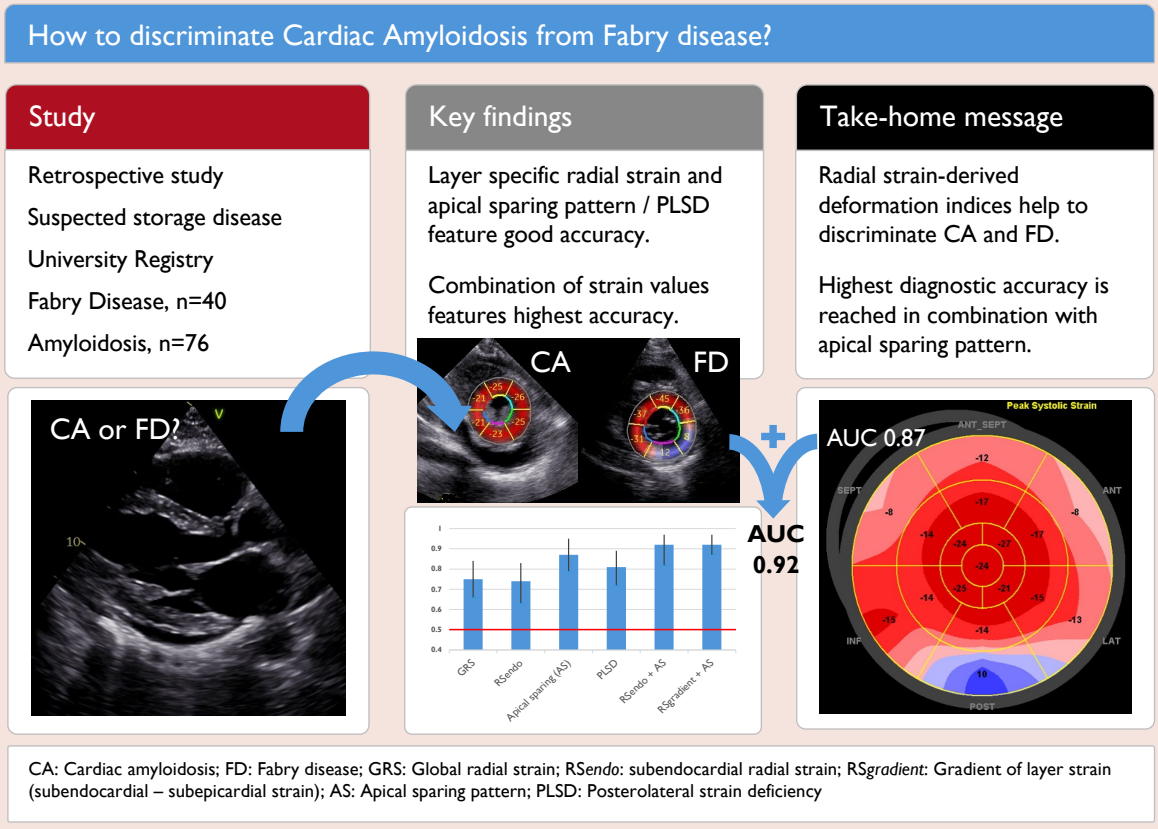
Graphical Abstract



CA: Cardiac amyloidosis; FD: Fabry disease; GRS: Global radial strain; RS*endo*: subendocardial radial strain; RS*gradient*: Gradient of layer strain (subendocardial – subepicardial strain); AS: Apical sparing pattern; PLSD: Posterolateral strain deficiency

Keywords Amyloidosis • Fabry disease • Echocardiography • LV strain • Radial strain

Introduction

Cardiac amyloidosis (CA) is caused by a deposition of amyloid fibrils within the myocardium resulting in a still often underdiagnosed cause of heart failure.[1] Cardiac involvement is the main driver for prognosis.[2] The advent of specific therapeutic approaches enabled a significant improvement of prognosis in CA patients along with an attenuated deterioration of the global longitudinal strain (GLS).[3,4]

Fabry disease (FD) is an X-linked lysosomal storage disorder. It is caused by an absent or deficient activity of α-Galactosidase A due to abnormalities in the GLA gene and results in a deposition of glycosphingolipids. In cardiomyocytes, this leads to ventricular hypertrophy and fibrosis.[5,6] Even though patients may initially present with a preserved left ventricular ejection fraction (LVEF) without signs of hypertrophy, an impairment in radial strain patterns may precede.[7] Cardiomyopathy is one of the most common causes of death in these patients. Since an effective enzyme replacement therapy is available and may lead to a prognostically relevant reduction of the glycosphingolipid deposition within the myocardium, a timely diagnosis is crucial for improving the clinical course in FD.[8]

Left ventricular (LV) wall thickening is a typical echocardiographic finding in CA and FD assigning conventional echocardiographic measurements a low diagnostic performance to discriminate both cardiomyopathies.[9,10] The importance of speckle-tracking based echocardiography has recently been highlighted in the new ESC guideline on cardiomyopathies.[10] Regional LV strain patterns such as the apical sparing pattern in CA and the phenomenon of posterolateral strain deficiency (PLSD) in FD have been proposed as more sensitive and specific echocardiographic findings.[11–14] In clinical practice, both strain patterns, however, may be observed in CA and FD, respectively, limiting their specificity to rule-in CA or FD. Recently, the use of apical sparing as a specific biomarker for CA has been questioned.[15] Moreover, the presence of (mild) pericardial effusion is considered as a possible 'red flag' in the diagnostic work-up of suspected CA.[16] The discrimination of both cardiomyopathies hence remains challenging.

Layer-specific strain analysis has been described before to detect regional impairment of myocardial function in patients with CA and FD.[17,18] Esposito *et al.*[18] reported a high diagnostic utility of analysing the gradient of endocardial and epicardial layer strain (RS*endo*–RS*epi*) to discriminate FD and healthy controls, suggesting a more severe affected subepicardial layer in FD patients. In contrast to FD, the interstitial deposition of amyloid leading to fibrosis may affect all layers of the myocardium in CA.[19,20] Moreover, cardiac MRI studies have suggested an even more severely affected subendocardial layer in CA.[21] Furthermore, several studies suggested radial strain alterations in relation to the disease stage of CA and strain impairments preceding LV hypertrophy and myocardial fibrosis in FD.[7,22]

We therefore hypothesized that layer-specific LV strain alterations may be of diagnostic utility to discriminate CA and FD.

To the best of our knowledge, there was no published direct comparison of CA and FD patients regarding layer-specific strain analysis. Differentiating CA and FD can be challenging in clinical practice. Particularly in the age range of 50–60 years, both FD and CA (especially ATTRv) can be considered as aetiologies of cardiomyopathy. Typical signs such as pericardial effusion and apical sparing, indicative of CA,[16] can potentially occur in FD patients, for example, as uraemic pericardial effusion. The timely suspicion of CA as the underlying diagnosis of mild LV wall thickening may potentially be at a comparable age of patients with a history of FD, especially in patients with ATTRv. Since there is effective treatment available, additional parameters of strain analysis may help to differentiate between cardiomyopathies and improve the diagnostic pathway to initiate disease-specific therapy early.

The aim of the present study was therefore to investigate differences in and the diagnostic value of layer-specific 2D speckle-tracking echocardiography (STE)-based LV strain indices in CA and FD and to compare the diagnostic performance of these strain values to the one of the more established regional apical sparing strain patterns and the PLSD phenomenon in CA and FD.

Methods

Study design

We retrospectively screened patients with CA from the amyloidosis registry at Charité—Universitätsmedizin Berlin and patients with FD who were at least 18 years of age and obtained a comprehensive transthoracic echocardiographic examination between August 2019 and May 2022 for study enrolment. Cardiac amyloidosis was diagnosed using echocardiography, laboratory testing, cardiac scintigraphy, magnetic resonance tomography, and/or biopsy.[16] The verification of FD diagnosis was established through genetic testing of GLA mutations, in compliance with the expert consensus provided by the ESC.[23]

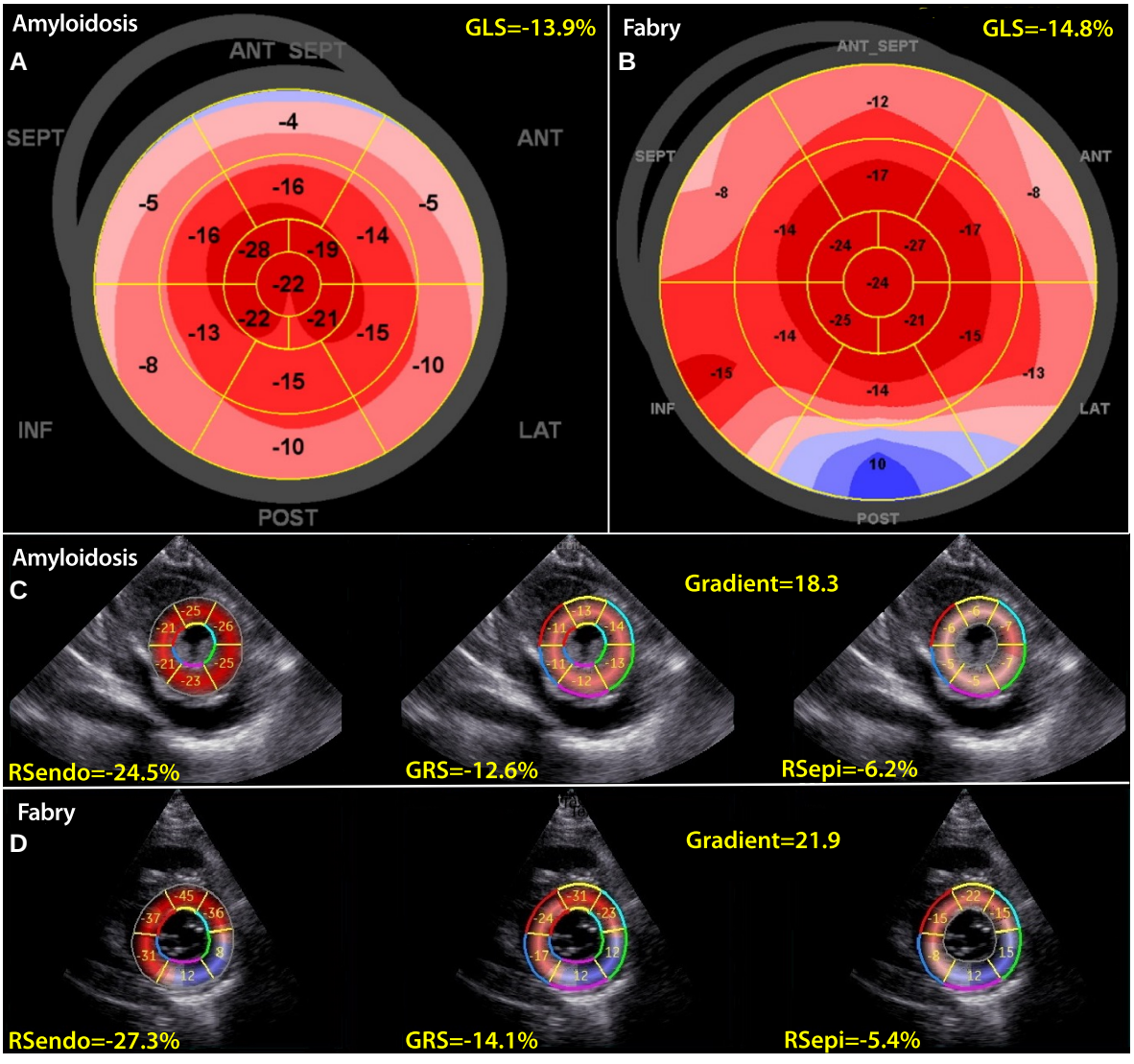


Figure 1 (*A* and *C*) Typical finding in a patient with cardiac amyloidosis showing the apical sparing pattern in the LV strain analysis and reduced global radial strain-derived values. (*B* and *D*) Example of a patient with Fabry disease showing PLSD but the apical sparing pattern as well as, and less impaired radial-derived strain values. GLS, global longitudinal peak systolic LV strain; RS*endo*, subendocardial radial layer strain; GRS, global radial LV strain; RS*epi*, subepicardial radial layer strain; RS*gradient*, RS*endo*–RS*epi*; PSLD, posterolateral strain deficiency.

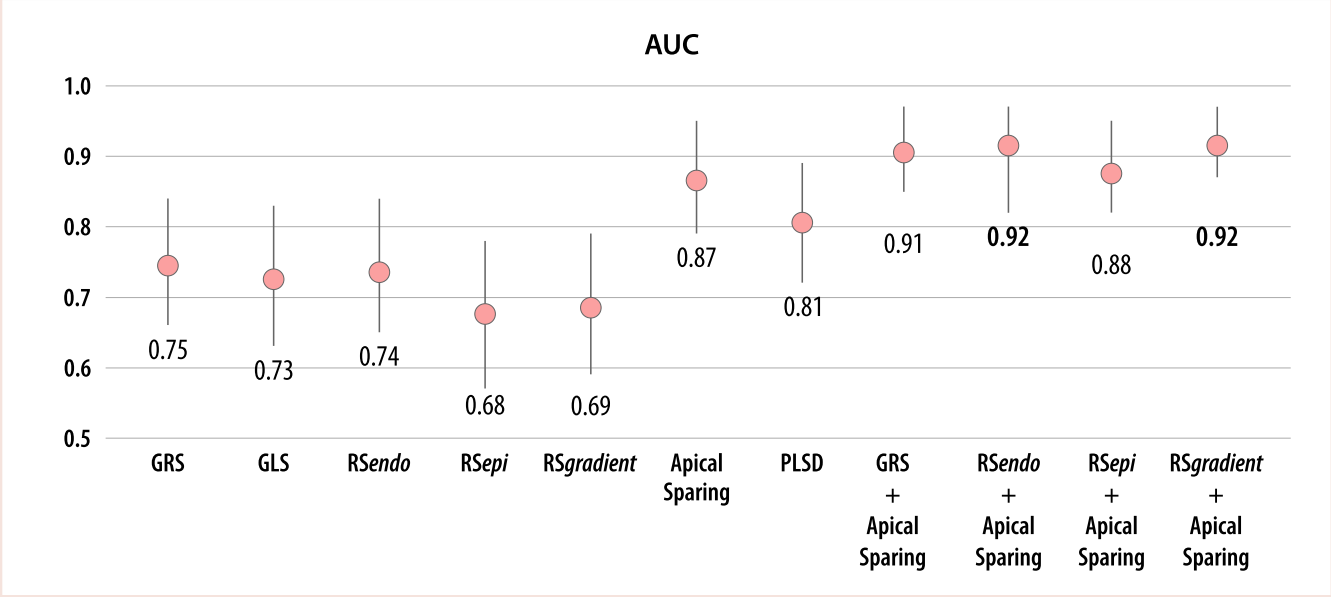


Figure 2 Diagnostic value of *LV* strain-derived values to discriminate CA and FD

With respect to the study protocol, the investigators were not blinded to the diagnosis CA or FD since patients were retrospectively screened from the institutional Amyloidosis and Fabry registry.

Patients with no cardiac involvement or insufficient acoustic window to perform the required analyses were excluded from the study. The conduction of the study and collection of pseudonymized medical records were approved by the institutional ethics committee (EA4/224/21 and EA1/014/20).

Echocardiography

Echocardiograhic assessment was carried out using a GE Healthcare Vivid E9 or E95 ultrasound machine equipped with an M5Sc 1.5–4.5 MHz transducer (GE Vingmed, Horton, Norway). Standard echocardiographic assessments were executed following the current guidelines provided by the European Association of Cardiovascular Imaging (EACVI) and the American Society of Echocardiography (ASE).[24,25] Global and regional 2D STE-based analyses were subsequently examined in accordance with the EACVI recommendations.[26] Global radial LV strain (GRS) was measured using parasternal short-axis views at the papillary muscle level as described before. The selection of the region of interest was established in a semi-automated manner, with manual adjustments applied to ensure the inclusion of the complete myocardium when tracking quality fell short of the required standards.[8,27] Three separate iterations of both longitudinal and radial strain analyses were carried out for each patient in order to compute the average values. The image analysis, measurements, and strain analyses were performed using a vendor-specific software (EchoPAC PC, GE, Vingmed, Norway). Based on the strain measurements, the software automatically created a graphical bull's eye based on a 17-segment model (*Figure 1*).

We further analysed the subendocardial radial LV strain (RS*endo*) and the subepicardial radial LV strain (RS*epi*). We then calculated a strain gradient as difference between RS*endo* and RS*epi* (RS*gradient*) as described before.[28]

Statistical analysis

We used SPSS Statistics for Windows (Version 28 IBM Corp., Armonk, NY, USA) for statistical analysis including *t*-test (continuous, normal distributed values), Mann–Whitney *U* test (continuous, not-normally distributed values), and χ^2 test (categorical values) to compare both cohorts. Receiver operating characteristic (ROC) curve analyses were performed to assess the diagnostic accuracy of the respective LV strain value, the layer-specific strain gradient, and the combination of strain measurements to discriminate FD and CA. Uni- and multivariable logistic regression analyses were performed including covariates to assess the association with the diagnosis of CA and FD. The intraclass correlation coefficient (ICC) was used to assess the inter- and intraobserver variability in 20 randomly selected patients of both cohorts who were independently analysed by two experienced echocardiographers. Statistical significance was established at a *P*-value of <0.05.

Results

A total of 100 patients with CA from the institutional Amyloidosis registry, Charité—Universitätsmedizin Berlin, were screened for study participation. Twenty-four patients had to be excluded due to an insufficient acoustic window or a lack of high-quality parasternal short-axis views enabling layer-specific strain analysis. Of these 76 CA patients, 52 (68.4%) patients had wild type (ATTRwt) CA, 17 (22.4%) hereditary (ATTRv) CA, and 7 (9.2%) light chain (AL) CA.

Out of a total of 78 FD patients screened, 40 patients were included in the final analysis of radial and longitudinal LV strain based on a sufficient acoustic window and high-quality apical and short-axis views to perform layer-specific strain measurements.

The baseline characteristics as well as standard echocardiographic parameters are shown in *Table 1*. Patients in the CA cohort were significantly older. Ten per cent of the FD patients presented with a pericardial effusion compared to 25% of the CA cohort ($P = 0.054$).

The apical sparing pattern was significantly more often observed in CA but was also present in FD patients [66 out of 76 patients (86%) in CA vs. 5 of 40 (12.5%) in FD, $P < 0.001$]. Vice versa, the PLSD pattern was significantly more often detected in the FD compared to the CA group [16 out of 76 patients (21%) in CA vs. 32 out of 40 (80%) in FD, $P < 0.001$].

Global radial LV strain and layer-specific strain values were significantly reduced in CA in comparison to FD [GRS −12.3 (SD −15.6 to −9.6) in CA vs. −16.7 (−20.0 to −13.6) in FD; $P < 0.001$; RS*endo* −22.3 (−27.4 to −15.9) vs. −28.3 (−31.8 to −23.6), $P < 0.001$; and RS*epi* −6.6 (−8.6 to −4.7) in CA vs. −8.9 (−11.7 to −6.5) in FD; $P < 0.001$; *Table 2*]. RS*gradient* was significantly lower in patients with CA (15.7 ± 6.5 in CA vs. 19.4 ± 6.2 in FD, respectively, $P = 0.004$; *Table 2*). Global radial LV strain held the highest diagnostic accuracy

Table 1 Demographic and echocardiographic characteristics of patients with cardiac amyloidosis and Fabry disease

	CA ($n = 76$)	FD ($n = 40$)	*P*-value
Clinical characteristics			
Female gender (%)	15 (20)	21 (52)	<0.001
Age (years)	76 ± 11	53 ± 14	<0.001
BMI (kg/m^2)	25 ± 3	25 ± 4 $n = 38$	0.896
NYHA class (%)			
I	4 (5)	22 (55)	
II	13 (17)	5 (13)	
III	28 (37)	4 (10)	<0.001
IV	2 (3)	0	
Not assessed	19 (25)	9 (23)	
NT-proBNP (ng/L)	2953 (1585–5929)	214 (68–1016) $n = 30$	<0.001
Creatinine (mg/dL)	1.1 (0.9–1.5)	0.9 (0.7–1.2)	0.02
GFR (mL/min)	57 ± 24	73 ± 23	0.02
Coronary heart disease (%)	26 (36)	5 (14)	0.013
Atrial fibrillation (%)	36 (47)	5 (12)	<0.001
Arterial hypertension (%)	56 (73)	15 (37)	<0.001
Disease-specific medication (%)	36 (47) Tafamidis 34 (50), patisiran 2 (3)	23 (57) Agalsidase alpha 7 (20), agalsidase beta 3 (8), chaperone 10 (28), unknown type 3 (8)	0.35
Echocardiographic characteristics			
LVEF (%)	50 ± 10	57 ± 9	<0.001
IVSd (mm)	18 ± 4	16 ± 4	<0.001
LVPWd (mm)	17 ± 6	14 ± 3	<0.01
TAPSE (mm)	18 ± 5	20 ± 4	0.013
E (m/s)	0.9 ± 0.4	0.7 ± 0.2	<0.001
e′ (cm/s)	5.9 ± 2	7.9 ± 2.8	<0.001
E/e′	16.6 (12.4–21.5)	8.5 (6.7–12.2)	<0.001
LAVI (mL/m^2)	46 (37–57)	40 (29–50)	0.015
Pericardial effusion (%)	19 (25)	4 (10)	0.054

Values are presented as frequency (percentage), median (inter-quartile range), or mean (±standard deviation) where appropriate.
BMI, body mass index; NYHA, New York Heart Association; GFR, glomerular filtration rate; LVEF, left ventricular ejection fraction; IVSd, end-diastolic interventricular septum thickness; LVPWd, end-diastolic left posterior wall thickness; TAPSE, tricuspid annular plane systolic excursion; LAVI, left atrial volume index; CA, cardiac amyloidosis; FD, Fabry disease.

Table 2 Longitudinal and radial strain-derived parameter in patients with cardiac amyloidosis and Fabry disease

	CA ($n = 76$)	FD ($n = 40$)	*P*-value
GRS (%)	−12.3 (−15.6 to −9.6)	−16.7 (−20.0 to −13.6)	<0.001
RS*endo* (%)	−22.3 (−27.4 to −15.9)	−28.3 (−31.8 to −23.6)	<0.001
RS*epi* (%)	−6.6 (−8.6 to −4.7)	−8.9 (−11.7 to −6.5)	<0.001
RS*gradient* (RS*endo*–RS*epi*)	15.7 ± 6.5	19.4 ± 6.2	0.004
GLS (%)	−11.3 (−8.9 to −14.8)	−16.0 (−13.0 to −17.3)	<0.001
Apical sparing (%)	66 (86)	5 (13)	<0.001
PSLD (%)	16 (21)	32 (80)	<0.001

Values are presented as frequency (percentage), median (inter-quartile range), or mean (±standard deviation).
GRS, global radial LV strain; GLS, global longitudinal peak systolic LV strain; RS*endo*, subendocardial radial layer strain; RS*epi*, subepicardial radial layer strain, RS*gradient*, RS*endo*–RS*epi*; PSLD, posterolateral strain deficiency; CA, cardiac amyloidosis; FD, Fabry disease.

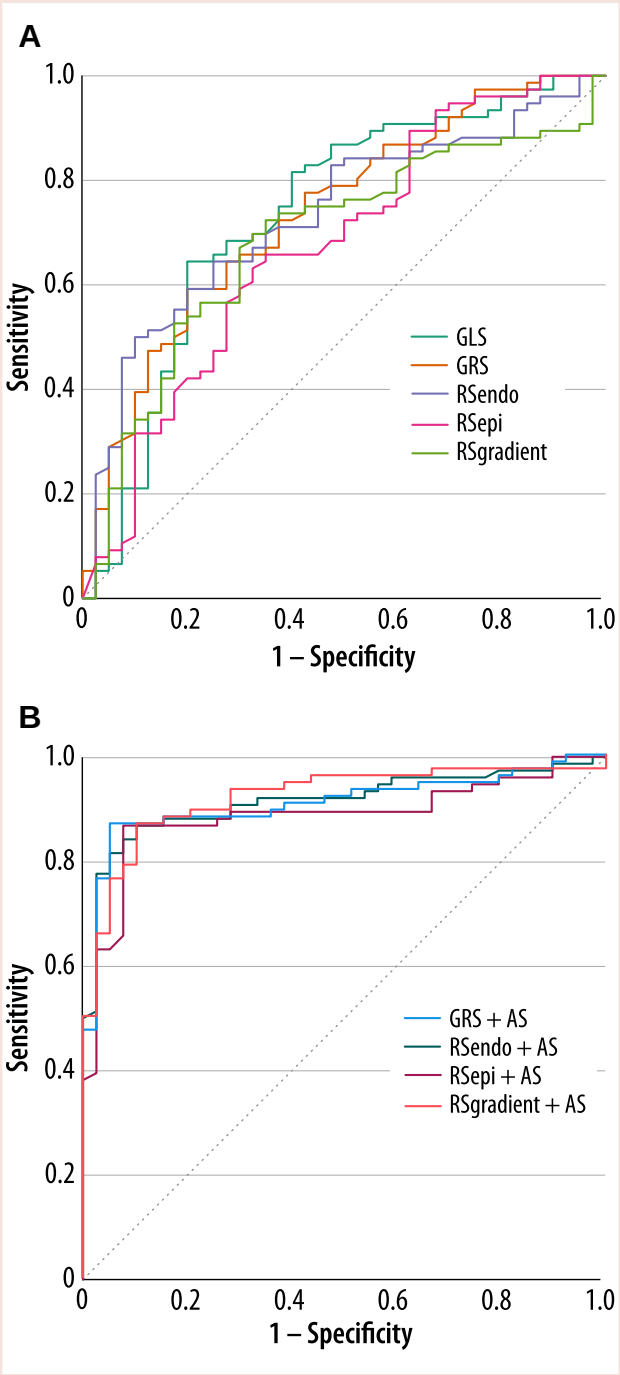


Figure 3 (*A*) Diagnostic performance of the diverse longitudinal and radial LV strain-derived parameters. The apical sparing pattern and PLSD phenomenon held the highest diagnostic accuracy to discriminate CA and FD. (*B*) Diagnostic performance of radial LV strain-derived parameters combined with the apical sparing pattern. The subendocardial radial LV strain (RS*endo*) and radial strain gradient (RS*gradient*) held the highest diagnostic accuracy in combination with apical sparing to discriminate CA and FD.

of the radial strain-derived parameters to discriminate CA and FD [area under the curve (AUC) 0.75, 95% confidence interval (CI) 0.66–0.84], RS*endo* held a high diagnostic accuracy to discriminate CA, as well (AUC 0.74, 95% CI 0.65–0.84; *Figure 2*). RS*gradient*, in contrast, featured a limited diagnostic performance (AUC 0.69; 95% CI 0.59–0.79). Global longitudinal strain was significantly reduced in CA compared to FD patients [−11.3 (−8.9 to −14.8) in CA vs. −16.0 (−13.0 to −17.3) in FD; $P < 0.001$; *Table 2*]. These results were mainly driven by significant differences in the basal and mid ventricular myocardial segments while there were no significant differences in apical strain values (see Supplementary material online, *Table S1*, *Figure S1*).

The diagnostic accuracy to discriminate both diseases, GRS performed similar to GLS [AUC 0.75 (95% CI 0.66–0.88) for GRS vs. AUC 0.73 (95% CI 0.63–0.83) for GLS] (*Figure 2*).

The presence of the apical sparing pattern and of the PLSD phenomenon held the highest accuracy of all investigated LV strain values to discriminate CA and FD [AUC 0.87 (95% CI 0.79–0.95), $P < 0.001$ for 'apical sparing' vs. AUC 0.81 (95% CI 0.72–0.89), $P < 0.001$ for PLSD; *Figures 2* and *3* and *Table 3*].

A combination of the apical sparing pattern with radial strain indices further increased the diagnostic accuracy. The highest accuracy was achieved by combining the apical strain pattern with RS*endo* [AUC 0.92 (95% CI 0.86–0.97)] or with RS*gradient* [AUC 0.92 (95% CI 0.87–0.97)].

In a univariate logistic regression analysis, the presence of the apical sparing or the PLSD pattern, advanced age, and reduced LVEF, GRS and GLS values were significantly associated with CA. However, in a multivariable logistic regression analysis, only the presence of the apical sparing and PLSD pattern, and age remained significantly associated with the diagnosis of CA.

Reproducibility

Intraobserver agreement of radial strain-derived parameters was very high with an ICC for RS*endo*, GRS, and RS*epi* of 0.98 (CI 0.97–0.99), 0.97 (CI 0.95–0.98), and 0.92 (CI 0.87–0.96), respectively. Intraclass correlation coefficient for interobserver agreement of RS*endo*, GRS, and RS*epi* were 0.96 (CI 0.93–0.98), 0.96 (CI 0.93–0.98), and 0.89 (CI 0.82–0.94).

Discussion

To the best of our knowledge, this study is the largest comparison of patients with confirmed CA and FD assessing the diagnostic value of diverse strain patterns of the LV and provides the following important observations: (1) patients with CA showed more impaired radial, radial strain-derived, and global longitudinal LV strain values; (2) layer-specific strain-derived values provided a good diagnostic performance to discriminate CA; (3) all radial strain-derived parameters were, however, of inferior diagnostic value compared to the more established analysis of specific regional strain patterns in the respective disease, i.e. the apical sparing pattern in CA and the phenomenon of PLSD in FD, even though each of the specific strain pattern was observed in a considerable number of patients in the respective other cardiomyopathy; (4) the diagnostic accuracy was further increased by combining the apical sparing pattern and radial strain-derived measurements while (5) the analysis of layer-specific strain gradient values yielded a low diagnostic performance. Pericardial effusion, another designated 'red flag' of CA, was not specific for CA and was observed in FD, as well.

Global longitudinal strain analysis is already well established in the echocardiographic diagnostic work-up of patients with unclear LV wall thickening, assigning regional LV strain patterns a high diagnostic value in the differential diagnosis of specific underlying aetiologies.[13,27] Typical findings for CA such as the 'relative apical sparing' strain pattern as well as an 'apex to base' gradient were a consistent finding in the CA group in this study.[12,16,29] Posterolateral strain deficiency as a typical yet not specific finding in FD was also reproduced in our study.[6,14,23] The presence of a pericardial effusion was previously not been considered as a typical echocardiographic finding in FD.[30] These results stress

Table 3 Discriminative values from ROC analysis of different strain measurements and patterns

	AUC	95% CI	*P*-value
GRS	0.75	0.66–0.84	<0.001
GLS	0.73	0.63–0.83	<0.001
RS*endo*	0.74	0.65–0.84	<0.001
RS*epi*	0.68	0.57–0.78	0.002
RS*gradient*	0.69	0.59–0.79	0.001
Apical sparing	0.87	0.79–0.95	<0.001
PLSD	0.81	0.72–0.89	<0.001
GRS + apical sparing	0.91	0.85–0.97	<0.001
RS*endo* + apical sparing	0.92	0.82–0.97	<0.001
RS*epi* + apical sparing	0.88	0.82–0.95	<0.001
RS*gradient* + apical sparing	0.92	0.87–0.97	<0.001

GRS, global radial LV strain; GLS, global longitudinal peak systolic LV strain; RS*endo*, subendocardial radial strain; RS*epi*, subepicardial radial strain; RS*gradient*, RS*endo*–RS*epi*; PSLD, posterolateral strain deficiency; ROC, receiver operating characteristic; AUC, area under the curve; CI, confidence interval.

the low diagnostic performance of classical echocardiographic red flags to discriminate both forms of infiltrative/storage disease.

Next to an impairment of global and longitudinal GLS, we found a significantly reduced GRS in CA compared to FD. Radial strain impairment was described before in CA patients.[31] Moreover, the strain impairment was shown to precede the hypertrophic stage in FD.[7] In addition to significant reductions of GRS in CA patients, our data suggest an equally good diagnostic accuracy of GRS and GLS to discriminate CA and FD. In this study, the combination of the apical sparing pattern with layer-specific strain measurements held the highest accuracy to discriminate both cardiomyopathies.

Recent studies have suggested that ATTRwt may be an unrecognized cause of heart failure in older adults in 10–15%.[32] In patients with LV wall thickening, the incidence of FD may be as high as 1%.[23] In both cardiomyopathies, specific therapeutic options impacting prognosis and morbidity are available. A disease-specific medication was present in a substantial proportion of CA and FD patients; this medication may have impacted on cardiac strain measurements in both groups. This highlights the importance of an early and comprehensive diagnostic work-up to rule in CA or FD in unclear LV wall thickening enabling an effective and timely therapeutic intervention in these patients.[3,33]

To sum up, the analysis of radial strain-derived parameters may contribute to an improved diagnostic accuracy in the diagnostic work-up of patients with suspected storage disease especially when the creation of a 'bull's eye plot' from all three apical views to assess possible regional strain alterations may be impeded, for example in patients with a limited apical acoustic window or atrial fibrillation. Importantly, while conventional regional strain patterns remain, despite showing a limited specificity, of superior diagnostic performance to discriminate FD and CA, their diagnostic accuracy can be improved by combining radial strain-derived myocardial deformation indices.

Limitation

Several limitations need to be considered. Our data derive from a retrospective single centre study comprising two universitary centres specialized in FD and CA. However, case numbers are, in the face of the still underdiagnosed diseases, comparable to other studies. Due to the design of this retrospective study, we did not include a control group. Furthermore, due to the register-based patient recruitment, there was no blinding of the study assessors to the diagnosis of the patient investigated. Our data were collected in the context of routine clinical patient care and hence mirror common demographical and clinical differences of both cardiomyopathy entities. This is related to a heterogeneity of both patient groups with a more advanced age in CA patients. However, regional strain patterns remained significantly associated with the diagnosis of CA after correcting for age in a multivariable logistic regression analysis.

Due to the retrospective design of our study, focused short-axis views at the papillary muscle level enabling radial strain measurements could not be obtained in all patients that were screened for study participation.

Like in other studies before, radial strain was measured as GRS and not analysed in individual LV segments. This approach might have contributed to a decrease in diagnostic accuracy in our study, and the diagnostic value of regional radial strain analysis may therefore be worth further investigations.

Conclusion

LV strain measurements are an easy to perform and reliable addition to a comprehensive echocardiography when facing the challenge to discriminate 'hypertrophic' cardiomyopathies like CA and FD. In synopsis with relevant comorbidities, it can be pointing the way towards the right differential diagnosis. Regional LV strain patterns, i.e. the apical sparing pattern and the PLSD phenomenon, showed the highest diagnostic performance to discriminate CA and FD even though each 'specific' strain pattern was diagnosed in the respective other form of cardiomyopathy, as well. A recent study has raised concern about the accuracy of the CA-specific apical sparing pattern alone.[15] In this study, the combination of the apical sparing pattern with layer-specific strain measurements held the highest accuracy to discriminate both cardiomyopathies. More studies should focus on improving the diagnostic value of the currently available cardiovascular imaging modalities to overcome the diagnostic gap still inherent to regional LV strain pattern analysis in unclear LV wall thickening.

Data availability

The data underlying this article will be shared on request for research purposes to the corresponding author.

Supplementary material

Supplementary material is available at *European Heart Journal Open* online.

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Conflict of interest: none declared.

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