ANALYSIS OF RIGHT VENTRICULAR STRAIN IN HEART FAILURE WITH PRESERVED EJECTION FRACTION

ABSTRACT :

Introduction: The complexity of the geometry and unique architecture of the right ventricular (RV) myocardial fibers make the study of its function a real challenge. However, the advent of new imaging techniques such as RV strain mode has improved our understanding of its function. The aim of our study is to specify the principles of studying right ventricular deformation and its impact on the prognosis of patients with preserved ejection fraction heart failure (HFpEF).

Materials and Methods: This is a two-year prospective study comparing echocardiographic parameters of right ventricular function in 87 patients followed in our unit for HFpEF at the Cardiology Department of ERRAZI Hospital, CHU Mohammed VI, Marrakech.

Results: Over the past two years, our unit has hosted 87 patients diagnosed with HFpEF. The average age was 68 years and 5 months with a female predominance. The most common cardiovascular risk factors were hypertension and obesity (BMI > 30). Symptomatic presentations were dominated by exertional dyspnea, observed in 84% of cases, with rest dyspnea and cough affecting about half of the patients. Signs of left heart failure, such as crackling rales, were present in 44% of patients, while signs of right heart failure such as lower limb edema were noted in 41%, with jugular distension and hepatojugular reflux in 19%. Echocardiography revealed left ventricular hypertrophy in 57% of patients and left atrial dilatation in 65%. Right ventricular function was markedly impaired, with significant observations of TAPSE, S' wave, and Tei index values, highlighting a marked correlation between the Tei index and the deformation of the right ventricular lateral wall. Rehospitalization for heart failure occurred in 40.2% of the cohort, highlighting the severe clinical implications of right ventricular dysfunction in this patient population.

Discussion and Conclusion: RV strain in HFpEF is an analysis that has not yet revealed all its secrets. This study has shown that there is an alteration in the RV strain in patients with HFpEF, which has a prognostic impact on mortality and rehospitalization for cardiac decompensation. This suggests that this parameter should be integrated into the routine parameters for evaluating RV systolic function.

Key words : Heart failure, Preserved ejection fraction, Right ventricle, Strain, Prognosis

Introduction :

The complex geometry and unique myocardial fiber architecture of the right ventricle (RV) make the study of its function a significant challenge. However, the advent of new imaging techniques such as RV strain imaging has enhanced our understanding of its function.

The objective of our study is to delineate the principles of right ventricular deformation analysis and its prognostic contribution in patients with heart failure with preserved ejection fraction (HFpEF).

Materials and methods:

1 - Methodology :

This was a two-year prospective study comparing the echocardiographic parameters of right ventricular function among 87 patients managed for heart failure with preserved ejection fraction at the Cardiology Department of Errazi Hospital, Mohammed VI University Hospital in Marrakech. The records of hospitalized patients diagnosed with this condition were compiled from the department's registers and archives.

2 - Evaluation criteria:

2.1. Clinical and paraclinical evaluation criteria:

The parameters analyzed included age, sex, comorbidities, and the clinical history of patients diagnosed with heart failure with preserved ejection fraction. We specifically assessed functional symptoms at the time of diagnosis, including exertional dyspnea, rest dyspnea, and paroxysmal nocturnal dyspnea.

The clinical examination documented signs of both right and left heart failure. Results from transthoracic echocardiographies were meticulously collected, focusing on the left ventricular ejection fraction (LVEF), analysis of the kinetics and longitudinal function of the right ventricle (TAPSE, S'VD), and its radial function (RV Strain), as well as the presence of pulmonary arterial hypertension (PAH).

Particular attention was given to the left ventricle in terms of kinetics and the presence of associated valvular diseases.

2.2. Inclusion and exclusion criteria:

The inclusion criteria for our study specified that no patient should have experienced cardiac decompensation in the month prior to their inclusion in our database. Additionally, we excluded patients who had undergone cardiac surgery or the implantation of right ventricular hardware.

3 - Statisticalanalysis:

A descriptive analysis of the study population was conducted. Quantitative variables were presented as medians and ranges, and qualitative variables were presented as frequencies and percentages.

Results :

We recorded 87 patients hospitalized in our unit over the past two years, all diagnosed with heart failure with preserved left ventricular ejection fraction (LVEF). The average age of participants was 68 years and 5 months, ranging from 55 to 79 years. The majority of the patients, 63%, were in the age range of 60 to 70 years, as illustrated in Figure 1. A clearfemalepredominancewasobserved in ourstudy.

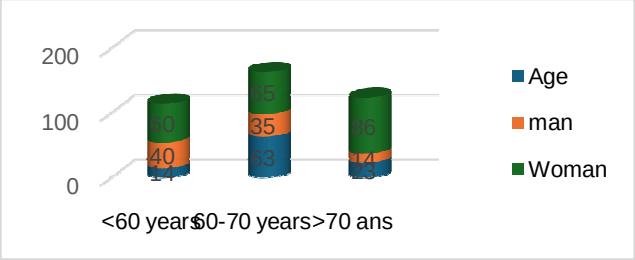

Figure 1: Epidemiological profile of our patients.

In this cohort, hypertension emerges as the predominant cardiovascular risk factor, followed by obesity characterized by a body mass index (BMI) over 30. Additionally, diabetes is present in 10% of the patients, while sleep apnea syndrome is observed in 15% of cases (Figure 2).

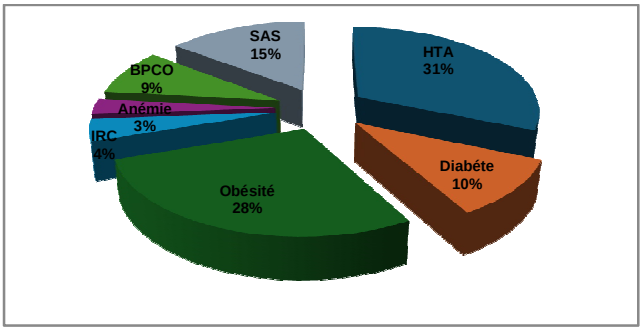

Figure 2: Comorbidity in our patients

All patients in our study exhibited functional symptoms, with exertional dyspnea being the primary reason for consultation in 84% of cases. It is also worth noting that resting dyspnea and cough were present in nearly half of the patients. Regarding physical signs, manifestations of left-sided heart failure, such as crackles, were observed in 44% of patients. For right-sided heart failure, lower limb edema was present in 41% of cases, while jugular venous distension and hepatojugular reflux were noted in 19% of cases, as indicated in Table 1.

Table 1: Functional and physical signs in our patients

Signes et Symptômes	Patients	%
Dyspnée d'effort	27	84%
Dyspnée de repos	13	41%
Dyspnée paroxystique nocturne	6	19%
Toux	13	41%
Œdèmes des membres inférieurs	13	41%
Tachycardie	14	43%
Bruit de galop	4	13%
Râles crépitants	14	44%
Râles sibilants	2	6%
Hépatomégalie	9	28%
Turgescences des veines jugulaires	6	19%
Reflux Hépato-jugulaire	6	19%

All our patients underwent transthoracic echocardiography. This revealed left ventricular hypertrophy in 57% of patients, with an average left ventricular mass of 114.40 ± 27 g/m2. The left atrium was dilated in 65% of patients, with an average volume of 28.6 ± 10 ml/m2. Mitral flow patterns were classified as pseudonormal, restrictive, or indicative of relaxation abnormalities in 13 (41%), 10 (31%), and 9 (25%) patients, respectively.

Table 2:Cardiographicechoparameters

PARAMETRE	
PAPS: MMHG	**30 +/- 10 mmhg**
MASSE VG	**114 +/- 27 g/m2**
TDE, MS	**236 +/- 91**
VITESSE E CM/S	**87 +/- 11**
E/E'	**14+/-5**
VOLUME OG	**28,6 +/- 10 ml/m2**

Most of our patients had a left ventricular ejection fraction (LVEF) between 60-70%, with a range from 51% to 85%.

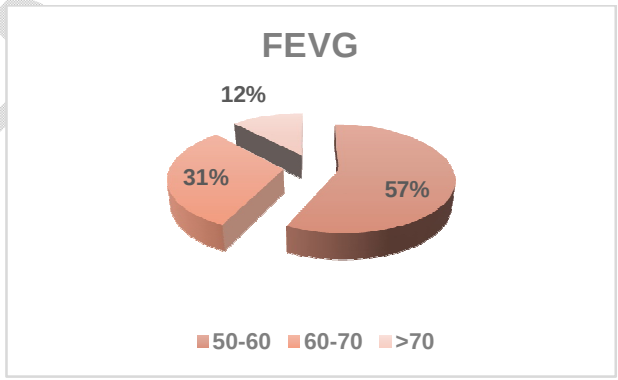

Figure 3: Left ventricular EF in our patients

The analysis of right ventricular function revealed dysfunction rates of 35% for TAPSE, 33% for S', and 41% for the Tei index. It should be noted that TAPSE relies on the assessment of a single segment, and the S' measurement is angle-dependent and also limited to a single segment. The Tei index is infrequently analyzed and is generally invalid in cases of irregular rhythm.

Table 3: Echocardiographic parameters of the right ventricle

	ONDE	TAPSE	INDICE DE TEI
VALUES	9+/- 3, cm/s	16+/- 5mm	0,48±0,24
PERCENTAGE	33%	35%	41%

The mean global right ventricular (RV) strain was significantly reduced in 55% of our patients, with altered longitudinal strain of the RV lateral wall in 68%. Apical, median, and basal segments showed impairments at 59%, 63%, and 69%, respectively. A significant correlation was noted between the Tei index and the lateral wall strain of the RV.

Normal strain values are 19 ± 6% for the basal, 27 ± 6% for the median, and 32 ± 6% for the apical segments. Additionally, data analysis in the parasternal short axis (radial function) is challenging due to the thin free wall of the RV and limited literature.

Poor visibility of the RV wall and loading conditions can also lead to erroneous values.

Table 4: Right ventricular strain echocardiography parameters

	SGVD(%	SLVD(%	SLAVD(%	SLMVD(%	SLBVD(%
VALUES	-19,17% +/- 4,69	-18,27% +/- 5,45	-24,11% +/- 3,87	-20,17% 6,36	-16,54% +/- 8,95
PERCENTAG	55%	68%	59%	63%	69%

Regarding patient outcomes, 40.2% of our patients experienced rehospitalization for heart failure. A total of 35 patients presented with heart failure decompensation, representing 40.2% of the cohort, with 15 of these cases (42.85%) occurring within the first six months.

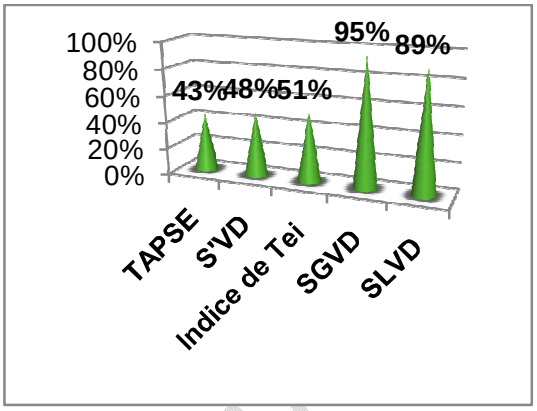

Figure 4: Profile of patients with notion of rehospitalization

In our study, we observed six deaths, five of which were due to heart failure decompensation, representing 5.74% of the cohort. All five of these patients had an altered strain, with a cutoff of -10.3% for global strain and -8.5% for the free wall.

TAPSE and S'VD were reduced in only two patients, and an elevated Tei index was noted in three, raising questions about the correlation.

Table 5: Number of deaths in our patients

	Death from heart failure n=5
Age	81+/-4 ans
Diabetes	3
TAPSE	2
SGVD	5
SLVD	5
S'VD	2
Indice de Tei	4

Discussion :

The right ventricle (RV) was traditionally viewed as a less critical cardiac structure with limited contribution to overall cardiac function. However, over the past two decades, the volume of research affirming the role of RV remodeling in various cardiovascular conditions has significantly increased. The advent of Speckle-Tracking Imaging (STI) has revolutionized the analysis of myocardial deformation, providing detailed measurements of right ventricular function and mechanics(1).

Clinical evidence has validated the importance of RV function in heart failure, highlighting that RV dysfunction is associated with an increased cardiovascular risk and mortality in these patients, regardless of left ventricular ejection fraction (LVEF). While research on RV strain in patients with reduced LVEF is steadily growing, studies on RV mechanics in heart failure with preserved ejection fraction (HFpEF) remain limited.

The right ventricular (RV) dysfunction and pulmonary vascular remodeling are directly impacted by an increase in RV afterload. Pulmonary hypertension is common in patients with heart failure with preserved ejection fraction (HFpEF), especially during exertion, and is associated with a poor prognosis.

Research on RV strain in patients with heart failure with reduced ejection fraction (HFrEF) is continuously growing. Despite preserved tricuspid annular plane systolic excursion (TAPSE) and lateral tricuspid annular systolic velocity (S'RV), altered RV strain can still be observed(2).

A study on RV strain in HFrEF revealed that global strain is the only indicator significantly correlated with adverse clinical outcomes, such as cardiac mortality or hospitalization for heart failure exacerbation. RV dysfunction was more pronounced in patients with systolic dysfunction, particularly noted in S'RV and the Tei index, with no significant differences in TAPSE and RV strain. These findings suggest that TAPSE and strain are critical parameters for evaluating RV function, independent of LVEF(1).

Table 1 Demographic and clinical characteristics

Variable	Controls (n = 219)	HFpEF (n = 219)	HFrEF (n = 219)
Baseline characteristics			
Age, years	65 ± 9	68 ± 11*	65 ± 11†
Female sex	113 (52)	114 (52)	102 (47)
Ethnicity, Chinese	148 (68)	141 (64)	148 (68)
BMI (kg/m²)	25.0 ± 4	27.7 ± 6*	25.5 ± 5†
NYHA class III–IV	0 (0)	30 (14)*	39 (18)*
Smoker	19 (9)	25 (11)	31 (14)
Heart rate, b.p.m.	67 ± 9	72 ± 13*	76 ± 14*†
MAP, mmHg	97 ± 12	91 ± 13*	88 ± 14*
Creatinine, μmol/L	70 ± 22	119 ± 57*	117 ± 50*
eGFR, mL/min/1.73 m²	99 ± 28	61 ± 31*	60 ± 24*
Haemoglobin, g/dL	13.8 ± 2	11.8 ± 2*	12.5 ± 2*†
NT-proBNP, pg/mL	119 ± 172	2015 ± 3265*	5435 ± 6866*†
Co-morbidities			
CAD	0 (0)	72 (35)*	120 (57)*†
Hypertension	91 (42)	187 (87)*	155 (71)*†
Diabetes	27 (12)	127 (59)*	131 (60)*
AF	3 (1)	67 (31)*	50 (23)*
Valvular disease (>mild)			
Aortic stenosis	NA	0 (0)	3 (1)
Aortic regurgitation	NA	2 (1)	2 (1)
Mitral stenosis	NA	1 (1)	0 (0)
Mitral regurgitation	NA	10 (5)	37 (17)†
Tricuspid regurgitation	NA	18 (8)	29 (13)
Medication use			
ACE-inhibitor	NA	97 (44)	129 (59)†
Angiotensin receptor blocker	NA	33 (15)	31 (14)
Beta-blocker	NA	178 (81)	189 (86)
Diuretic	NA	181 (83)	195 (89)

Table 2 Echocardiographic characteristics

Echocardiographic parameter	Controls (n = 219)	HFpEF (n = 219)	HFrEF (n = 219)
LV and left atrial structure			
LVEDD, mm	47 ± 5	48 ± 7	58 ± 9*†
LVESD, mm	28 ± 5	31 ± 6*	48 ± 11*†
Septal thickness, mm	9.2 ± 1.7	11.4 ± 2.4*	10 ± 2.3*†
Posterior wall thickness, mm	8.9 ± 1.6	11 ± 2.3*	9.6 ± 2.4*†
LAVI	27.7 ± 7.0	37.9 ± 21.0*	44.9 ± 20.4*†
Left-sided haemodynamics			
LVEF, %	65 ± 4	59 ± 6*	31 ± 10*†
LV GLS, %	−16.6 ± 2.6	−14.5 ± 4.0*	−7.4 ± 7.3*†
Septal S', cm/s	6.5 ± 1.4	5.9 ± 1.8*	4.0 ± 1.4*†
Lateral S', cm/s	7.5 ± 1.8	6.8 ± 2.3*	4.8 ± 1.7*†
E/A ratio	1.0 ± 0.3	1.2 ± 1.0	1.7 ± 1.3*†
E, cm/s	70 ± 16	82 ± 29*	80 ± 31*
E/e' ratio	9.9 ± 3.2	14.4 ± 7.3*	18.5 ± 9.1*†
Right-sided haemodynamics			
TAPSE, mm	21.0 ± 3.9	17.5 ± 5.1*	14.7 ± 4.7*†
TAPSE <17 mm, %	10	42	67
RVLS, %	−26.7 ± 5	−22.7 ± 6.6*	−18.2 ± 6.7*†
RVLS > −20, %	8	32	60
RV basal strain, %	−26.6 ± 6.4	−23.7 ± 7.7*	−18.1 ± 7.5*†
RV strain rate, cm/s	−1.70 ± 0.46	−1.70 ± 0.65	−1.36 ± 0.98*†
RV S', cm/s	10.9 ± 2.6	10.9 ± 2.8	8.8 ± 2.7*†
RV FAC, %	43.8 ± 5.3	40.5 ± 5.8*	32.8 ± 9.0*†
TR velocity, m/s	2.2 ± 0.3	2.6 ± 0.5*	2.7 ± 0.6*†
PCWP, mmHg	14.2 ± 3.9	18.5 ± 6.6*	22.1 ± 8.2*†
PASP, mmHg	26.8 ± 7.1	34.5 ± 11.9*	39.3 ± 16.2*†
PASP >35 mmHg, %	15	39	52
MPAP, mmHg	19.2 ± 9.8	31.8 ± 15.9*	36.9 ± 15.5*†
PVR	1.7 ± 0.3	2.0 ± 0.7*	3.2 ± 1.6*†
TAPSE/PASP	0.83 ± 0.23	0.54 ± 0.24*	0.55 ± 0.29*†
RVLS/PASP	−1.06 ± 0.32	−0.75 ± 0.32	−0.56 ± 0.36*†

Figure 5: Variations in right ventricular function in heart failure patients, with particular emphasis on those with systolic dysfunction

In the same study, increased mortality rates were observed in relation to impaired right ventricular (RV) strain in heart failure patients across both groups, with a critical threshold set at -15.3% for strain and 14 mm for TAPSE. It is noteworthy, however, that all deceased patients had severe pulmonary hypertension (PAPs above 35 mmHg), raising questions about the study's conclusions. To address this limitation, our study intentionally excluded patients with PAPs above 35 mmHg to provide a more focused analysis of RV strain impact on mortality without the confounding influence of severe pulmonary hypertension(1).

Another study further supported the notion that RV dysfunction is associated with increased cardiovascular decompensation events and mortality in heart failure patients, independently of left ventricular ejection fraction (LVEF). This analysis reported values of 28% for TAPSE, 18% for respiratory rate, and 21% for S'. Regarding strain, 48% of abnormalities were global, with 42% localized to the RV lateral wall. The study also demonstrated a significant correlation between RV strain and dyspnea severity, outperforming other parameters, including TAPSE. Additionally, global strain proved to be a better predictor of adverse clinical events compared to longitudinal free wall strain (2).

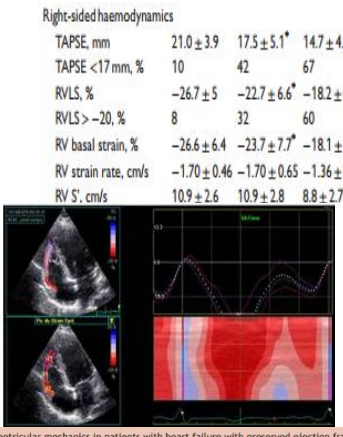

Table 2 Right ventricular mechanics in patients with heart failure with preserved ejection fraction.

Reference	Sample size	Age (years)	Women (%)	Ejection fraction (%)	RV GLS (%)	RV free wall longitudinal strain (%)	Echocardiographic device
Hasselberg et al. [30]	37	58 ± 11	32	62 ± 7	−22.8 ± 5.7		GE Healthcare[a] (Vivid)
Morris et al. [44]	201	71.2 ± 10.1	43.2	59.8 ± 7.2	−14.41 ± 3.80		GE Healthcare[a] (Vivid)
Morris et al. [32]	218	72.0 ± 10.5	52.3	61.9 ± 6.1	−20.7 ± 4	−24.6 ± 5.1	GE Healthcare[a] (Vivid)

Data are expressed as mean ± standard deviation unless otherwise indicated. GLS: global longitudinal strain; RV: right ventricular.
[a] Chicago, IL, USA.

Figure 6: Right ventricular mechanics in patients with heart failure with preserved ejection fraction (2).

The prognostic value of right ventricular dysfunction (RVD) in patients with heart failure with preserved ejection fraction (HFpEF) remains controversial. Melenovsky et al. (3) demonstrated that RVD, assessed by transthoracic echocardiography (defined by a fractional area change [FAC] < 35%), was the main predictor of mortality in an overweight population with advanced HF (96 HFpEF patients, average body mass index of 34 kg/m², and 71% in NYHA functional class III or IV). This was not the case in a population with less advanced HF (as observed in clinical trials such as PARAGON, with 28% of patients in NYHA class III or IV and only 9% of patients with FAC < 35%) (4). In a community-based HFpEF cohort, RVD defined by a semi-quantitative assessment was associated with poorer outcomes, even after adjusting for comorbidities (5).

Only a few studies have evaluated prognostic markers in HFpEF patients (6). A recent study (7) highlights the importance of considering RV function as a risk marker for poor prognosis and suggests that RV function assessment should be part of a comprehensive evaluation of HFpEF patients. Although no current treatment improves the prognosis of HFpEF patients, those at high risk of adverse events should benefit from closer monitoring and intensive management of comorbidities and congestion. The best parameter to assess RVD remains to be determined, but our study suggests that STE RVGLS could be of interest. It is well correlated with RV ejection fraction derived from CMR, is reproducible, and has prognostic significance compared to clinical and echocardiographic parameters. However, further efforts are needed to standardize software to implement strain analysis in clinical practice (7).

Conclusion :

Right ventricular strain (RV strain) in heart failure with preserved ejection fraction (HFpEF) remains an area with many unanswered questions. This study demonstrated that there is an alteration in right ventricular strain in patients with HFpEF, with prognostic implications for mortality and rehospitalization due to cardiac decompensation.

This raises the question of whether this parameter should be routinely included in the assessment of RV systolic function.

Systematic evaluation of RV function could help identify HFpEF patients at high risk of adverse events, who would benefit from closer monitoring and intensive management of comorbidities and congestion.

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