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ORIGINAL PAPER

Patients with high left ventricular filling pressure may be missed applying 2016 echo guidelines: a pilot study

Matthieu Michaud[1] · Vincent Maurin[1] · Marc Simon[1] · Christophe Chauvel[1] · Emmanuel Bogino[1] · Eric Abergel[1]

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Abstract
2016 guidelines for the echographic evaluation of left ventricular filling pressure (LVFP) proposed a single algorithm with limited number of criteria (E/A ratio, tricuspid regurgitation velocity, left atrial volume index and average E/e′) mainly related to left atrial pressure. Pulmonary venous flow analysis, evaluating more specifically left ventricular end diastolic pressure (LVEDP) has been withdrawn. We aim to evaluate the proportion of patients diagnosed with normal LVFP according to 2016 recommendations, despite an abnormal pulmonary venous flow profile suggesting high LVEDP. We prospectively studied patients with stable ischemic cardiomyopathy and aortic stenosis, before cardiac surgery. Extensive echocardiography was performed including pulmonary and mitral A wave durations. We included 76 patients (mean age 72 ± 10 years, 78% were men), 37 (49%) with aortic stenosis and 22 (29%) with ischemic cardiomyopathy. Mean left ventricular ejection fraction was 67 ± 11%. Applying recommendations, 58 patients had normal LVFP and 15 patients had high LVFP. Among the 58 patients with normal LVFP, 26 patients had Apd–Amd duration > 30 ms highly suggestive of high LVEDP. These patients had higher LV mass (112 ± 30 g/m^2 vs. 86 ± 20 g/m^2, p = 0.004) and shorter A wave duration (120 ± 13.6 ms vs. 132 ± 16.5 ms, p = 0.006) as compared to the remaining 15 patients with concordant evaluation (normal LVFP and normal Apd–Amd). In the present study, we found that 26/58 patients with low LVFP according to the 2016 recommendations had Apd–Amd suggestive of high LVEDP. Pulmonary venous flow should be added to the algorithm, particularly in patients with unexplained symptom, high LV mass or truncated mitral A wave.

Keywords Diastolic function · Heart failure · Diastolic · Echocardiography · Doppler · Aortic valve stenosis · Myocardial ischemia

Introduction

Evaluation of left ventricular filling pressure (LVFP) is an integral part of routine echocardiographic examination, particularly in patients presenting with dyspnea.

This evaluation could be challenging and need the inclusion of many parameters, leading sometimes to a complex interpretation [1]. New recommendations for the evaluation of LVFP have been published in 2016 [2], endorsed by the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI). This is an update of the 2009 recommendations [1], endorsed by the same societies.

The primary goal of this update was to simplify the approach, using simple echocardiographic parameters with high feasibility. A single algorithm is proposed to determine LVFP, in depressed left ventricular ejection fraction (LVEF), or in normal LVEF with myocardial disease (Fig. 1). A limited number of criteria is required: E/A ratio, maximal tricuspid regurgitation velocity (TRV), left atrial volume index (LAVi), e′ lateral and septal values and average E/e′ ratio. Although entitled as a LVFP evaluation, the algorithm is presented as an expert consensus built to evaluate mean left atrial pressure (LAP).

However, beside LAP, LVFP encompasses many pressures, as measured invasively: pulmonary end diastolic pressure, mean pulmonary artery wedge pressure (mPAWP), end diastolic left atrial pressure (LAP), mean LAP, left ventricular diastolic pressure prior to left atrial contraction (LVDP

✉ Eric Abergel
abergel.eric@gmail.com

[1] Echocardiography Laboratory, Department of Cardiology and Cardiac Surgery , Clinique Saint Augustin , 114 avenue d'Arès, 33200 Bordeaux, France

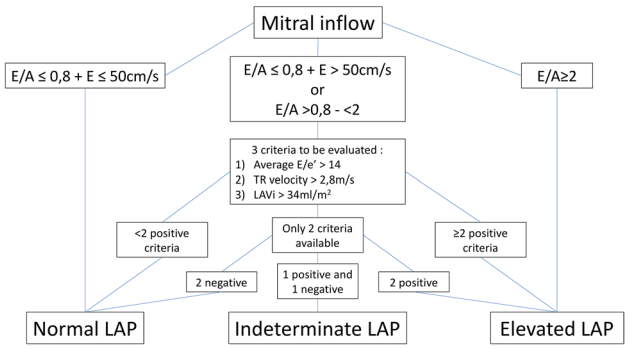


Fig. 1 Algorithm for estimation of left ventricular filling pressures in subjects with abnormal left ventricular ejection fraction and/or myocardial disease (*LAVi* left atrial volume index, *LVFP* left ventricular filling pressures, *TR* tricuspid regurgitation, *LAP* left atrial pressure adapted from Nagueh et al. [1]

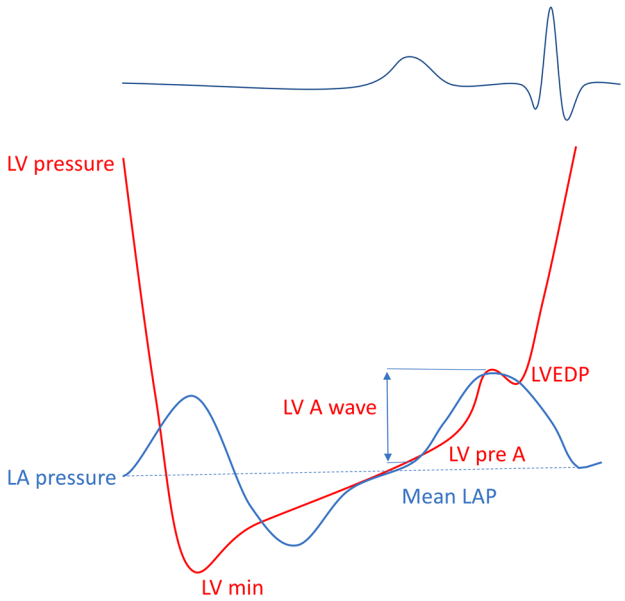


Fig. 2 LV and LA diastolic pressures: LV minimal pressure (LVmin), LV pre A diastolic pressure (LV pre A), LV end diastolic pressure (LVEDP), mean left atrial pressure (mean LAP). *LA* left atrial, *LV* left ventricular, *LVEDP* left ventricular end diastolic pressure

pre A), left ventricular end diastolic pressure (LVEDP) (Fig. 2). These different pressures are nearly equal and can be used interchangeably (left ventricular filling pressure may be a convenient term to refer to all this parameters) in the normal cardiovascular system [3]. However, once there is any type of cardiac disease, mean LAP and LVEDP cannot be assumed to be the same [4–7]. A strong atrial contribution to LV filling can occur in patients with LV disease and this can result in a LVEDP that is considerably higher than the mean LAP. This situation is particularly encountered in patients with myocardial ischemia and left ventricular hypertrophy.

In 2016 guidelines, pulmonary venous flow (PVF) analysis has been withdrawn from the algorithm. Theoretically, the time difference between pulmonary retrograde A wave and mitral A wave durations (Apd–Amd), is the only available index strongly related to LVEDP [8, 9]. In previous studies, Apd–Amd > 0 ms predicted nicely high LVEDP (sensitivity and specificity > 80%), with a higher specificity when Apd–Amd > 20 ms [8, 9].

The purpose of this study was to evaluate the proportion of patients diagnosed with normal LVFP according to 2016 recommendations, despite an abnormal pulmonary venous flow profile suggestive of high LVEDP.

Material and methods

Study protocol and patients

We conducted a prospective observational monocentric study. All patients aged 18 years or more referred for echocardiographic examination and undergoing cardiac surgery (Clinique Saint Augustin, Bordeaux, France) were eligible. Informed consent was obtained from all individual participants included in the study.

Exclusion criteria were tachycardia > 100 beats per minute (bpm) or bradycardia < 50 bpm, first degree AV block, permanent atrial fibrillation, significant mitral valvulopathy (moderate to severe mitral regurgitation or stenosis, heavy annular calcifications, mitral valve repair or replacement), permanent ventricular pacing, congenital cardiomyopathy or chronic constrictive pericarditis.

Anthropometrics measures were obtained for all participants (height, weight, age, sex category, heart rhythm), they were interrogated about their symptomatology (dyspnea described from 1 to 4 according to the semi quantitative New York Heart Association (NYHA) classification).

Transthoracic echocardiography (TTE) was performed using commercially available ultrasound system (General Electric Vivid E95 and Philips Epic 7) equipped with multi frequency transducer (1.5–4 MHz). Measurements and recordings were obtained according to the ASE Guidelines [10, 11]. The LV mass index was defined using the ASE formula, and LVEF was defined by Simpson's biplane method. LV hypertrophy was defined by LV mass index > 115 g/m^2 in men and > 100 g/m^2 in women. Assessment of aortic stenosis was performed following international recommendations [12]. Pulsed-wave and continuous-wave Doppler ultrasound was used to record velocities through the LV outflow tract and aortic valve, respectively. Aortic valve area

was calculated using the continuity equation. Semi quantitative assessment of mitral valvulopathy was performed using international recommendations [13]. Patients were classified according to the recommendations has having normal, elevated, or non-measurable LVFP. The following thresholds for elevated LVFP were applied: E/A ratio > 2, TRV > 2.8 m/s, LAVi > 34 ml/m^2, e′ lateral < 10 cm/s or e′ septal < 7 cm/s, average E/e′ > 14 (Fig. 1).

Pulmonary venous flow was obtained in the apical four-chamber view by placing a 2–3 mm pulsed Doppler sample volume 5 mm into the right upper pulmonary vein. Measurements of pulmonary venous waveforms include the duration of the atrial reversal (Apd) wave and the time difference between Apd and mitral A-wave duration (Apd–Amd). According to literature we defined three groups: a group «suggestive of elevated LVEDP» when Apd–Amd between 0 and 29 ms; a group «highly suggestive of elevated LVEDP» when Apd–Amd ≥ 30 ms; a group «suggestive of normal LVEDP» when Apd–Amd < 0 ms.

Our laboratory has a European Laboratory accreditation (EACVI) and cardiologists are well confident with Doppler measurements of LV diastolic function.

Statistical analysis

Continuous and qualitative variables are expressed as mean ± standard deviation (SD), discrete variables are presented as absolute numbers and percentages.

Descriptive data were analyzed for normality using Kolmogorov Smirnov test.

Clinical and echocardiographic variables were compared using two-sample Student *t* test or Wilcoxon test as appropriate according to the variance test.

For overall test, a P value of < 0.05 was considered significant.

All statistical analyses were performed with XLSTAT® 19.0 (Addinsoft) software.

Results

Patient characteristics

Between November 2017 and March 2018 a total of 76 patients were recruited. Baseline clinic and echocardiographic characteristic are presented in Table 1.

There was a majority of men (79%), with 96% of the patients presenting an LVEF ≥ 40%.

A majority of patients required intervention, 37 patients (49%) had a severe aortic stenosis (mean gradient of 51 ± 24 mmHg with a valve area of 1.0 ± 0.5 cm^2 (0.56 ± 0.27 cm^2/m^2) and 24 patients (32%) undergoing isolated coronary artery bypass graft surgery.

Table 1 Baseline characteristics of total population (n = 76)

Age, year (SD)	72 (10)
Male sex, n (%)	60 (79%)
Heart rhythm, bpm (SD)	66 (9)
Hypertension[a], n (%)	50 (66%)
Diabetes mellitus, n (%)	11 (14%)
Paroxysmal atrial fibrillation, n (%)	10 (13%)
New York Association functional class, n (%)	
I	8 (11%)
II	46 (60%)
III	22 (29%)
Pathology, n (%)	
Aortic valvulopathy	42 (55%)
Aortic stenosis	37 (49%)
Aortic regurgitation	4 (5%)
Infective endocarditis	1 (1%)
Coronary artery disease[b]	24 (32%)
Thoracic aortic diseases	2 (3%)
Others[c]	8 (10%)
Left ventricular ejection fraction,% (SD)	68 (10)
< 40%, n (%)	3 (4%)
> 40%, n (%)	73 (96%)

[a]On medications and/or having hypertension at time of study

[b]Indicated by wall motion abnormalities and/or coronary angiography results

[c]3 patients with coronary artery disease and 2 patients with aortic stenosis waiting for extracardiac surgery, 3 patients with coronary artery disease under medical treatment

Algorithm for estimating LVFP

Applying the 2016 algorithm for abnormal LVEF or myocardial disease (Fig. 2) 58 patients (76%) had normal LVFP and 15 patients (20%) had high LVFP (Table 2). Feasibility was high, LVFP were undetermined in 3 patients. In the 15 patients with elevated LVFP, only 3 patients had three positive criteria.

Pulmonary venous flow evaluation

PVF could be evaluated by transthoracic echography in 72 of the 76 patients (94%).

Among the 58 patients with normal LVFP according to the 2016 algorithm, according to Apd–Amd 15 patients had normal LVEDP. However, 26 patients had a profile highly suggestive of elevated LVEDP (Table 3). Moreover, in 14 patients Apd–Amd was suggestive of elevated LVEDP (sensitivity 85% and specificity 79% in the Rossvoll paper [8]). So, we found in our population at least a 34% rate of discordance between LVFP evaluation according to recommendations (which provide an estimation of LAP) and PVF analysis (which provide an estimation of LVEDP).

Table 2 Parameters values of 2016 algorithm according to LVFP group (normal, indeterminate, elevated)

LVFP group	2016 Algorithm	Patients (n)
Normal (n = 58)	E/A ratio < 0.8 and E < 50 cm/s	4
	0/3 or 0/2 criteria for high LVFP	36
	1/3 criteria for high LVFP	18
	TRV > 2.8 m/s	3
	LAVi > 34 ml/m^2	14
	Average E/E' ratio > 14	1
Indeterminate (n = 3)	1 criteria evaluable or 1/2 criteria for high LVFP	3
Elevated (n = 15)	E/A > 2	3
	2/3 or 2/2 criteria for high LVFP	10
	TRV > 2.8 m/s and LAVi > 34 ml/m^2	6
	TRV > 2.8 m/s and average E/E' ratio > 14	1
	LAVi > 34 ml/m^2 and average E/E' ratio > 14	3
	3 Criteria for high LVFP	2

LAVi left atrial volume index, *LVFP* left ventricular filling pressures, *RV* maximal tricuspid regurgitation velocity

Table 3 Repartition of Apd–Apm values according to LVFP groups (normal, indeterminate, elevated) according to 2016 recommendations

LVFP according to 2016 guidelines	Global population (n)	Apd–Amd < 0 ms (n)	Apd–Amd 0–29 ms (n)	Apd–Amd ≥ 30 ms (n)	Apd–Amd not evaluable (n)
Normal	58	15	14	26	3
Indeterminate	3	1	1	1	0
Elevated	15	2	4	8	1

Apd–Amd time difference between reversal A wave duration measured on pulmonary venous flow and A wave duration measured on trans mitral flow

Patient profile with normal LVFP but abnormal PVF

We compared patients presenting with normal LVFP (2016 algorithm) and patients suggestive of high LVEDP in one hand, and patients with normal LVFP (2016 algorithm) and patients highly suggestive of high LVEDP in the other hand (Table 4). As compared to the 15 patients with concordant evaluation, these 26 patients with isolated high LVEDP had significantly higher LV mass and higher proportion of LV hypertrophy, and shorter A wave duration. They also had higher systolic pulmonary pressure (sPAP) (32 ± 4.5 mmHg vs. 29 ± 4.4 mmHg), but it was not significant (p = 0.06).

Proportion of symptomatic patient was comparable in both groups: 73% in the group normal LVEDP versus 85% in the group highly suggestive of elevated LVEDP (Table 4). Moreover, combining patients suggestive and highly suggestive of elevated LVEDP, the proportion of symptomatic patients increases (90% were NYHA > 1 (36/40)), but comparison with the group normal LVEDP was not significant (p = 0.2).

There were no significant differences in term of age, LVEF, LAVi, E/A, E/E′ ratio and right ventricular function parameters (S′, estimated pulmonary resistance) between the two groups.

Two examples of echocardiographic evaluation in patients with isolated elevated LVEDP are presented in "Appendices 1 and 2".

Discussion

This study conducted in a selected population mainly with aortic stenosis and stable ischemic cardiomyopathy shows (1) Applying the 2016 recommendations, at least 26/76 patients may not be correctly classified. Indeed, we found normal LVFP in these 26 patients despite a PVF highly suggestive of elevated LVEDP (Apd–Amd ≥ 30 ms) (Fig. 3) Applying a less specific criteria (Apd–Amd = 0–29 ms) 40/76 were misclassified (2) Patients with isolated LVEDP elevation had significantly higher LV mass and shorter A wave duration, as compared to patients with normal LVEDP and LAP.

New recommendations of ASE/EACI for the evaluation of LVFP have been published in 2016 [2]. Previous recommendations were published in 2009 [1], with 2 main algorithms according to normal or low LVEF. The following parameters were required: E/A and E/e′ ratio, LAVi, estimation of sPAP, as well as E/Vp, S/D, E/A variation during Valsalva and Apd–Amd. The new 2016 recommendations proposed a simplified approach with a single algorithm and less parameters (Fig. 1). This approach has limitations:

Table 4 Among patients with normal LVFP (2016 guidelines), comparison of patients with normal Apd–Apm (n = 15) and with abnormal Apd–Apm (n = 26)

Characteristics	Normal LVFP and Apd–Apm < 0 ms (n = 15)	normal LVFP and Apd–Apm > 30 ms (n = 26)	P value
Age–year	70.8 ± 10.2	69.6 ± 11.2	0.35
Male sex, n (%)	13 (87%)	19 (73%)	0.62
Hypertension, n (%)	10 (67%)	16 (61%)	1.0
Diabetes mellitus, n (%)	4 (27%)	6 (23%)	1.0
Paroxysmal atrial fibrillation, n (%)	4 (27%)	2 (8%)	0.07
NYHA > class I	11 (73%)	22 (85%)	0.6
Aortic stenosis, n (%)	4 (27%)	14 (54%)	0.16
Coronary artery disease, n (%)	8 (54%)	8 (31%)	0.13
LVED diameter, mm/m^2 (SD)	26.5 (2.9)	27.9 (3.8)	0.85
LVEF, % (SD)	69.0 (9.8)	70.4 (10.3)	0.87
LAVi, ml/m^2 (SD)	26 (6.8)	32 (10.6)	0.60
Right ventricular S′, cm/s (SD)	13.4 (2.6)	13.2 (2.5)	0.82
sPAP, mmHg(SD)	29 (4.4)	32.6 (4.5)	0.06
E/A, ratio (SD)	0.90 (0.33)	0.94 (0.37)	0.43
E/e′ average, ratio (SD)	9.0 (2.0)	9.3 (2.3)	0.59
Am duration, ms (SD)	132 (16.5)	120 (13.6)	0.002
LV mass index, g/m^2(SD)	84 (20)	112 (30)	0.005
LVH, n (%)	2 (13%)	12 (46%)	0.04
LV geometry			
Normal, n (%)	12 (80%)	14 (54%)	
Concentric, n (%)	2 (13%)	9 (35%)	
Eccentric, n (%)	1 (7%)	3 (11%)	

LVH left ventricular hypertrophy, LAVi left atrial volume index, *LVED* left ventricular end diastolic, *LVEF* left ventricular ejection fraction, *sPAP* systolic pulmonary artery pressure

(1) The title of the algorithm is ambiguous "estimation of LVFP in patients with depressed LVEF and normal LVEF with myocardial disease" since "myocardial disease" is not defined in the text (2) The title of the algorithm indicates evaluation of LVFP, while the conclusion of the algorithm focuses on LAP (3) All the remaining criteria (E/A, E/e′ ratio, TRV, LAVi) are mainly correlated to LAP.

Our study focuses on Apd–Amd, withdrawn from 2016 guidelines. It is the only parameter strongly validated for evaluation of LVEDP [8, 9]. A common criticism expressed against pulmonary venous flow is the difficulty to obtain a measurable Ap wave. However, in the present study, we found a feasibility rate of 96% (72/76), similar to Rosvoll princeps [8] study (96% (48/50)), or Yamamoto [9] (84% (88/102)).

In the 2009 recommendations, the threshold applied for elevated LVFP is Apd–Amd ≥ 30 ms. In the O'Leary study dealing with 247 children [14], Apd–Amd ≥ 30 ms predicted high LVEDP with a sensitivity of 90% and a specificity of 86%. However, Apd–Amd > 0 ms has also a good diagnostic value. In Rosvoll study [8] (n = 45), Apd–Amd > 0 ms predicted a LVEDP > 15 mmHg with a 85% sensitivity and a 79% specificity. In his study, Yamamoto [9] reported a sensitivity of 82% and a specificity of 92% for the diagnostic of LVEDP > 20 mmHg with the same cut off value (Apd–Amd > 0 ms). In our study, applying this cut off leads to a diagnosis of isolated high LVEDP in 52% (40/76) of the population.

Surprisingly, despite Apd–Apm suppression in the algorithm, the 2016 manuscript [2] states that "in the early stages of diastolic dysfunction, LVEDP is the only abnormally elevated pressure because of a large atrial pressure wave, while mean PCWP and LAP remain normal". The literature confirms this possibility of discordance between LVEDP and LAP. In the early 60′s, Braunwald [4] showed that in 25/26 patients with LV hypertrophy, LVEDP was systematically higher than mean LAP. In 580 patients with pulmonary hypertension having right and left catheterization [15], half of them had elevated LVEDP despite normal PCWP. In the light of these data, we need to evaluate both LVEDP and

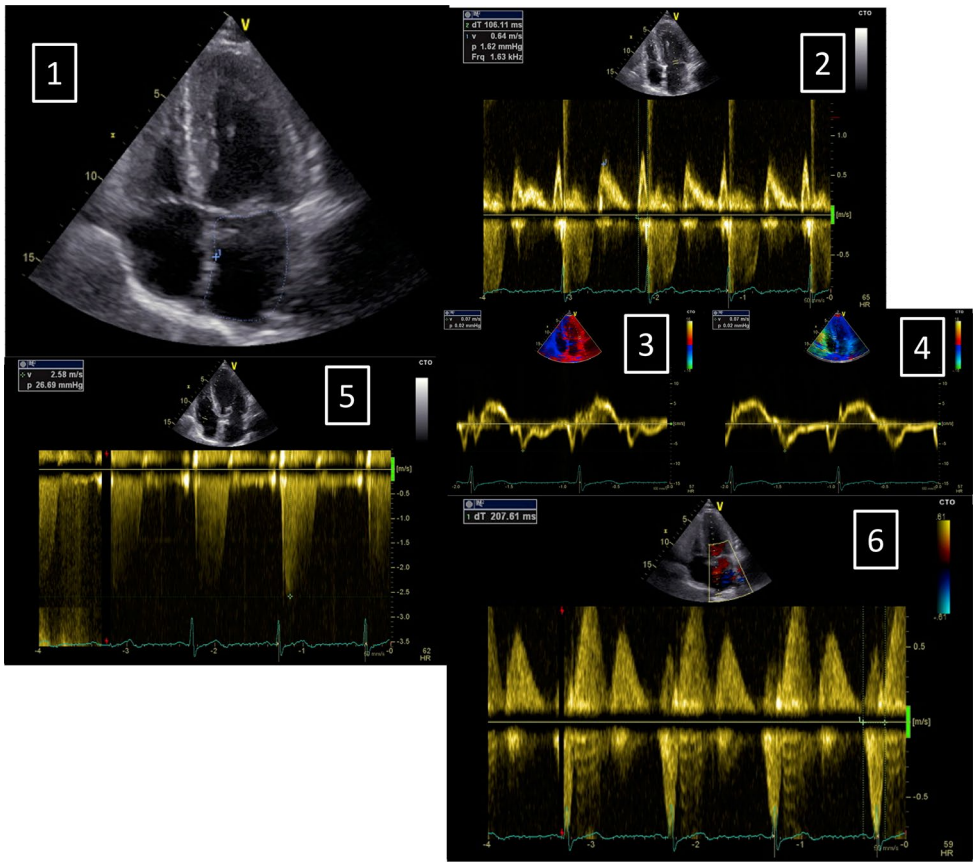


Fig. 3 71 years old woman, with a severe aortic stenosis (mean trans valvular gradient 92 mmHg, aortic valve area 0.56 cm^2 or 0.36 cm^2/m^2. LVEF = 82%. All 2016 criteria are in favor of a normal LAP (Average E/e′ = 9 (**2**, **3**, **4**); Max TRV = 2.6 m/s (**5**); LAVi = 31 ml/m^2 (**1**); however, Apd (207 ms) ≫ Amd (106 ms) (**2**, **6**) in favor of a high LVEDP. *Apd–Amd* pulmonary A wave duration-mitral A wave duration, *LAP* left atrial pressure, *LAVi* left atrial volume index, *LVEDP* left ventricular end diastolic pressure, *TRV* tricuspid regurgitation velocity

LAP to conclude in terms of LVFP. There are important physiological differences between LAP and LVEDP. LVEDP provides an estimate of LVEDV, an important determinant of stroke work via the Frank–Starling mechanism. LAP elevation is responsible for many of the manifestations of LV failure. Importantly, diuretic induced reduction in LAP is usually clinically efficient, while a diuretic-induced reduction in LVEDP when mean LAP is not elevated may have adverse consequences. In normal subjects, given that LAP and LVEDP are nearly equal [3], both could be referred to together as LV filling pressures [7]. However, in patients with left ventricular disorders such as hypertrophy, powerful atrial contraction may produce a LVEDP significantly higher than mean LAP [5, 6]. Elevation of LVEDP has the advantage of increasing preload of the LV, but at the same time minimizing effects on pulmonary pressure which would occur if there was a simultaneous increase in mean LAP. Our results are in line with these physiological considerations. We believe that our patients with normal LVFP (2016 algorithm) and abnormal Amd–Apd > 30 ms do not reflect an inconsistency, but an elective elevation of LVEDP.

Another important limitation of the 2016 guidelines is the absence of validation at the time of publication. However, in 2017, a multicentric study [16] conducted by the chairman and the co-chairman of the 2016 guidelines, evaluated the 2016 algorithm in 450 patients. The results were fair, with a 87% sensitivity and 88% specificity to diagnoses high PCWP or high pre A pressure (which can be considered as reflecting LAP). Other recent paper from Balaney [17] demonstrated poorer results, with a 69% sensitivity and 81% specificity to diagnose pre A pressure > 12 mmHg. Interestingly, when the gold standard was LVEDP, the results were disappointing: in 161 patients with pulmonary hypertension, having both right and left catheterization, sensitivity of 2016 guidelines to diagnose LVEDP > 15 mmHg was 51% and specificity was 67%. In the Euro-filling study [18], 108 patients had normal echo LVFP and 24 had high echo LVFP, applying 2016 guidelines. In the group of the 108 with normal echo

LVFP, 38 patients (35%) had invasive LVEDP ≥ 15 mmHg. Curiously, the conclusion of the study is that 2016 guidelines are reliable and clinically useful, despite a sensitivity of 33% (after recalculation) to diagnose high LVEDP. These results support our hypothesis, that all 2016 parameters are correlated to LAP (or PCWP), but with a poor diagnosis value to detect isolated high LVEDP.

Limitations

No invasive measurement has been performed in our study. However, Amd–Apd has been well validated in the literature [8, 9]. His diagnostic value to evaluate LVEDP is not questionable, explaining why Amd–Apd was included in the two main algorithms of 2009 guidelines [1]. Another limitation is the relatively limited number of patients, with a selected population of patients with aortic stenosis and coronary artery disease. The findings of the present study cannot be extrapolated to the population of patients with normal LVEF and no cardiomyopathy, and can't apply in patients with atrial fibrillation. Our results should be considered as preliminary data, and have to be confirmed with an invasive study.

Conclusion

High LVFP can refer to high LAP and/or high LVEDP, and these parameters can be discordant in pathological situations such as left ventricular hypertrophy or ischemic cardiomyopathy. In the present study, we found that 26/58 patients with low LVFP according to the 2016 recommendations are in fact suspicious of having isolated high LVEDP.

Our data are preliminary and may be very useful as substratum to propose a larger prospective multicentric study against invasive data.

In the meantime. We believe that pulmonary venous flow should be added to the algorithm [19], particularly in patients with unexplained symptom, high LV mass or truncated mitral A wave.

Compliance with ethical standards

Conflict of interest Dr Michaud Matthieu declares that he has no conflict of interest. Dr Maurin Vincent has received a speaker honorarium from Novartis. Dr Simon Marc declares that he has no conflict of interest. Dr Chauvel Christophe declares that he has no conflict of interest. Dr Bogino Emmanuel declares that he has no conflict of interest. Dr Abergel Eric has received a speaker honorarium from GE ultrasound, Novartis.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Appendix 1

Woman patient, 71 years old, presenting with calcific aortic stenosis (mean trans valvular gradient 92 mmHg, aortic valve area 0.56 cm^2 or 0.36 cm^2/m^2), LVEF 82%.

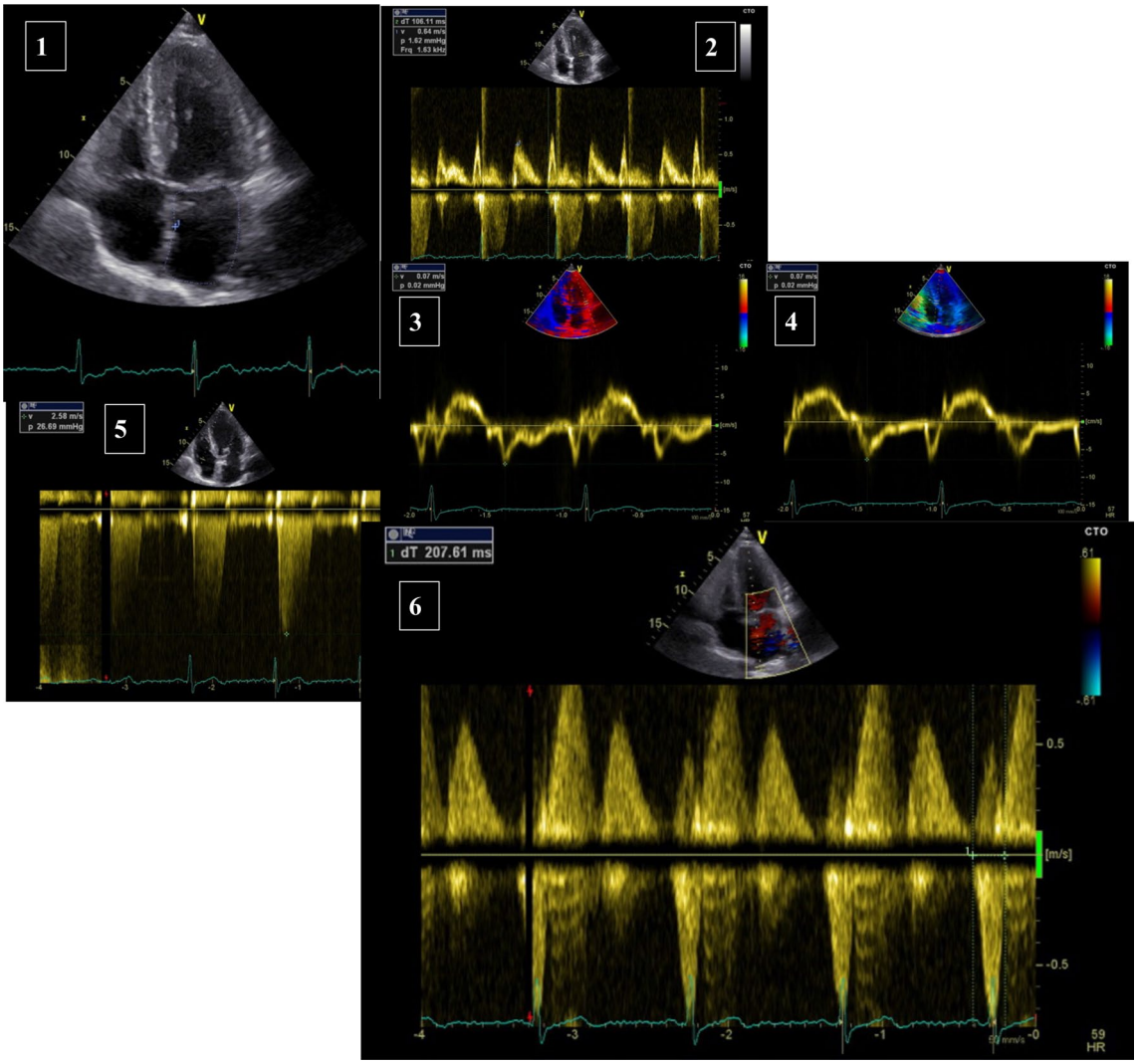
1-Normal LA surface with 17 cm^2 measured in apical four chamber view, LAVi 31 ml/m^2 assessed by Simpson biplane technique.

2-E/A ratio 0.8 with E = 64 cm/s, mitral A wave duration (Amd) 106 ms, to note amputation of A wave.

3/4-E′ lateral and septal=7cm/s average E/E′ = 9.

5-TRV = 2.58 m/s.

6-Pulmonary A reversal duration (Apd) = 207 ms, Apd–Amd =101 ms, note the particular amplitude of A retrograde wave duration (> 70 cm/s).



Appendix 2

Man patient, 79 years old, presenting an aortic stenosis due to calcified bicuspid valve (mean trans valvular gradient 45 mmHg, aortic valve area 0.82 cm^2 or 0.44 cm^2/m^2), normal LVEF (74%).

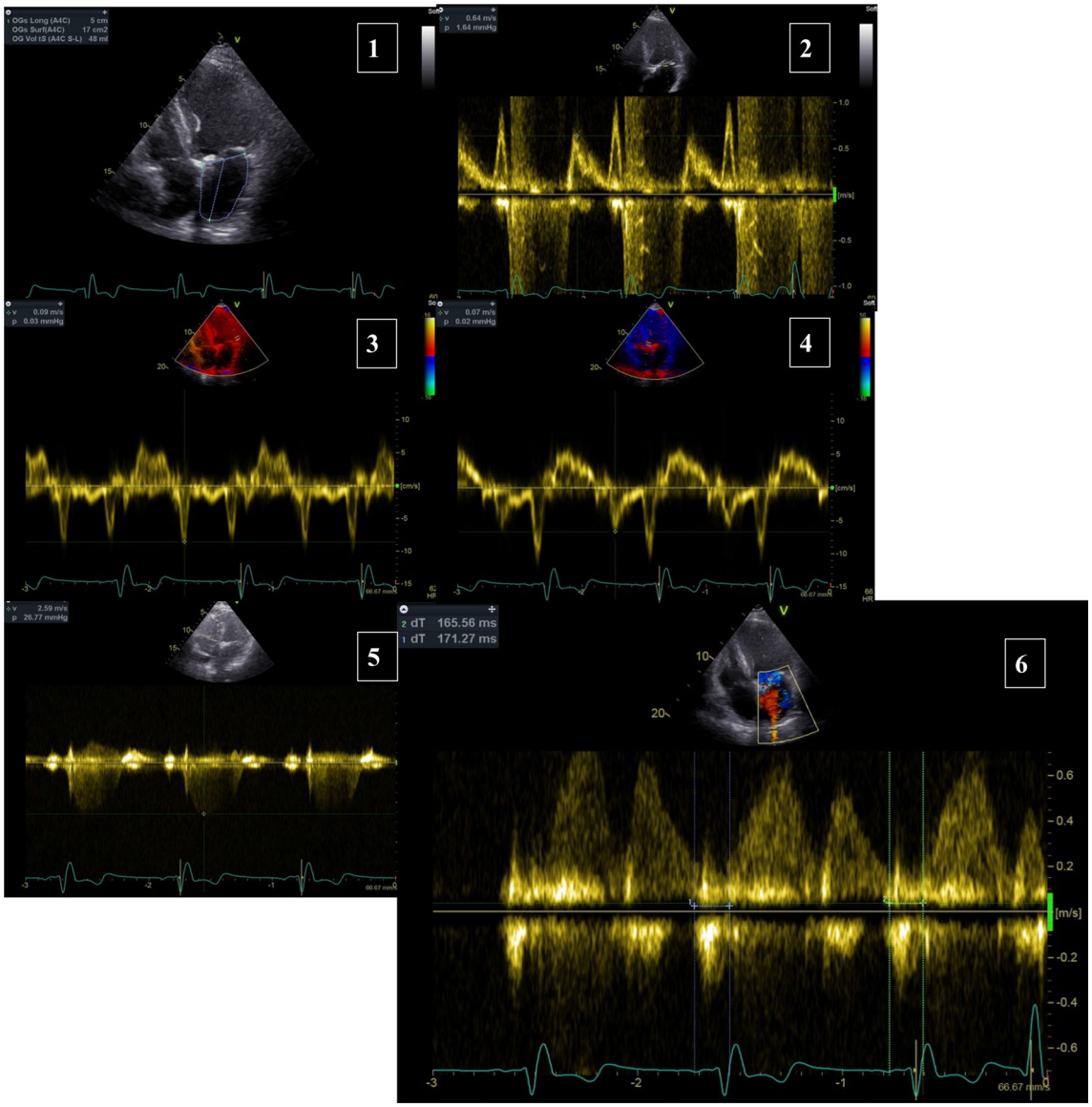
1-Normal LA volume index (23 ml/m^2 assessed by Simpson biplane technique).

2-E/A ratio = 0.7 with E wave = 64 cm/s, A wave duration = 114 ms.

3 and 4-Lateral E′ =10cm/s, septal E′ =7 cm/s, average E/E′ = 8.

5-Maximal tricuspid regurgitation velocity = 2.59 m/s.

6-Pulmonary reversal A wave duration = 165 ms, Apd–Amd = 51 ms.



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