Three Dimensional Echocardiographic Determinations of Global and Segmental Functions in Patients with Left Ventricular Aneurysm

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Abstract:

Objectives: To determine the global and regional functions of the left ventricle (LV) in patients with LV aneurysm (LVA) utilizing reconstructed three dimensional echocardiography (3DE), that can help for making the decision for aneurysmectomy.

Materials &Methods: Computer algorithms and suitable visual basic program were used to reconstruct 3DE LV images of a patient with LVA who underwent two dimensional echocardiography (2DE). Quantitative LV volumes and wall motions analysis were performed and compared to a computerized LV model**.**

Results: The results obtained from the 2DE analysis of the patient studied were used to reconstruct 3DE LV images at end systole (ES) and end diastole (ED) that showed apical dyskinesia. LV volumes and their indices, % ejection fraction (%EF), and LV wall motions of the patient studied and 3DE LV model were calculated and plotted superimposed.

Discussion: 2DE approach is based on geometric assumptions for calculating LV volumes and wall motions, while 3DE technique requires no geometric assumptions that limit accuracy in patients with LVA. So the present method can potentially overcome these limitations.

Conclusion: LV volumes and wall motion in the present method were calculated accurately, and can be used in diagnosing and following the therapeutic managements in patients with LV aneurysm**,**

Keywords: Three dimensional, ECG, Global, segmental function, Ventricular aneurysm

Introduction:

An aneurysm is a common complication of myocardial infarction. A true aneurysm may form at the site of the infracted myocardium where the wall is thinned and scarred [1]. LVA is defined as LV dyskinesis or akinesis [2].

An LV aneurysm occurs in between 10 and 35% of the patients experiencing a transmural myocardial infarction, and results in both diastolic and systolic ventricular dysfunction (reduced ejection fraction (%EF) and cardiac output (LV wall tension increases according to laplace's law) [3].

Quantitative measurement is especially important for patients with LVA because the prognostic ability of measures of LV dysfunction for risk of surgery (aneurysmectomy) [4,5]. Determinations of global systolic function with the use of 2DE techniques face the greatest limitations in patients with LVA [6]. 3DE techniques can potentially overcome these limitations [7]. There are many recent methods for volume measurements using 3DE of the LV based on magnetic field partition sensing system [8], 3D freehand ultrasound LV reconstruction [9]. Automated LV motion [10], real-time 3DE (RT3DE) (11), RT3DE (wavelet–based methods) [12], and 3DE (using ultrasound contrast) [13].

The purpose of the present study is therefore to explain the steps of the clinical application to generate 3DE images from the 2DE images of a patient with LVA utilizing a reconstructed 3DE LV model (14) ,without using geometric assumptions ,to determine LV volumes at end diastole and end systole (EDV and ESV),stroke volume (SV) ,% EF ,cardiac output (COP),cardiac index (CI),and LV wall motion as % regional shortening (%RSH), % regional shrinkage (%RSK), and % regional shortening (%REF).

Materials & methods

LV 2DE images of a male patient with LVA (his age ,body surface (BSA), and heart rate are 55 year, 1.86 m² , and 70 beats/min respectively), were performed by phased–array 2 DE system (Philips) with a 3-MHz transducer in a transthoracic apical four chamber views (4ch) ,and left parasternal short axis views (Shx) at the level of basal ,mid, and apical parts **(Fig.1).** The reconstructions of the 3DE LV images in the present study are made according to the following steps:

1-2DE images of the subjects studied were projected using the screen of a personal computer and suitable visual basic program. The outline of the endocardium at ES and ED were traced (computerized tracing technique with manual tracking of the endocardium).

2- The results obtained from the analysis of 2DE images in step 1(geometrical dimensions) were used to reconstruct 3DE LV images the patient investigated with quantification LV volumes and their indices (EDV,ESV,SV, EDVI, ESVI, SVI),%EF,CO,CI, and LV wall motions (%RSH, %RSK, and %REF) utilizing the computer algorithms of the 3DE LV model [14]. The method used for calculation of LV volumes depends on the disc summation [15].

3-LV wall motions of the reconstructed 3DE LV images are computed for each part and for each site of the LV (there are three parts, basal, mid and apical, and eight sites of each LV parts at ES and ED) [16].

4-The details of various steps are given as block diagram in **Fig.2.**

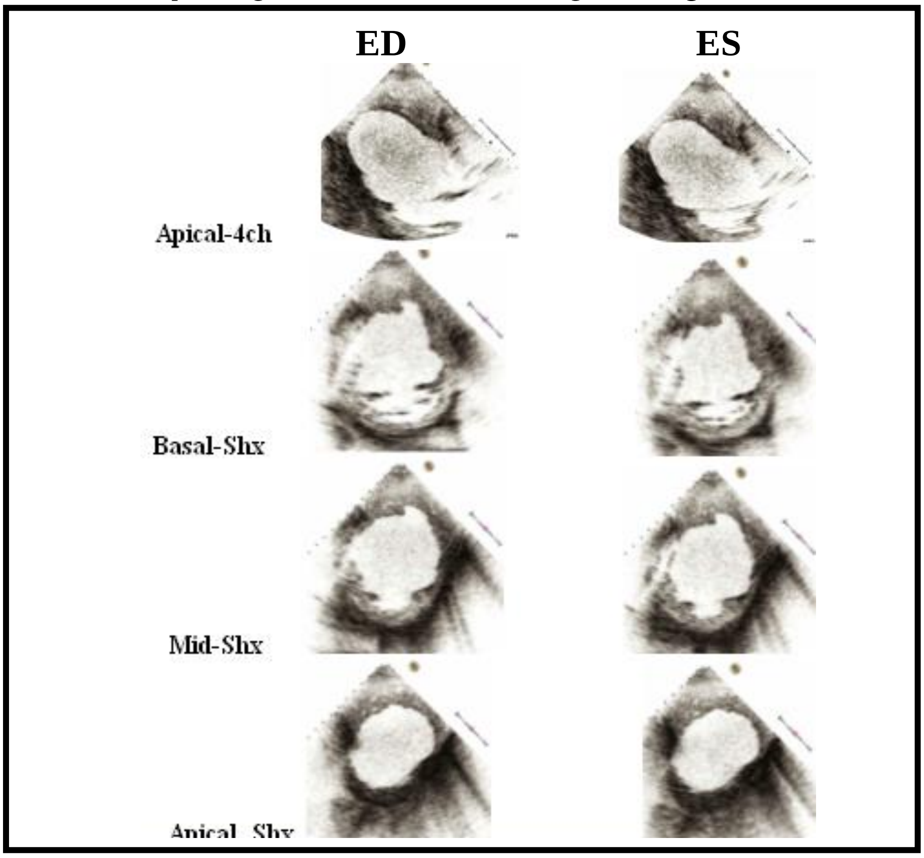

Fig.1: 2DE images at ED and ES and of the LV of the patient studied in apical 4ch and Shx views at the basal, mid, and apical LV parts.

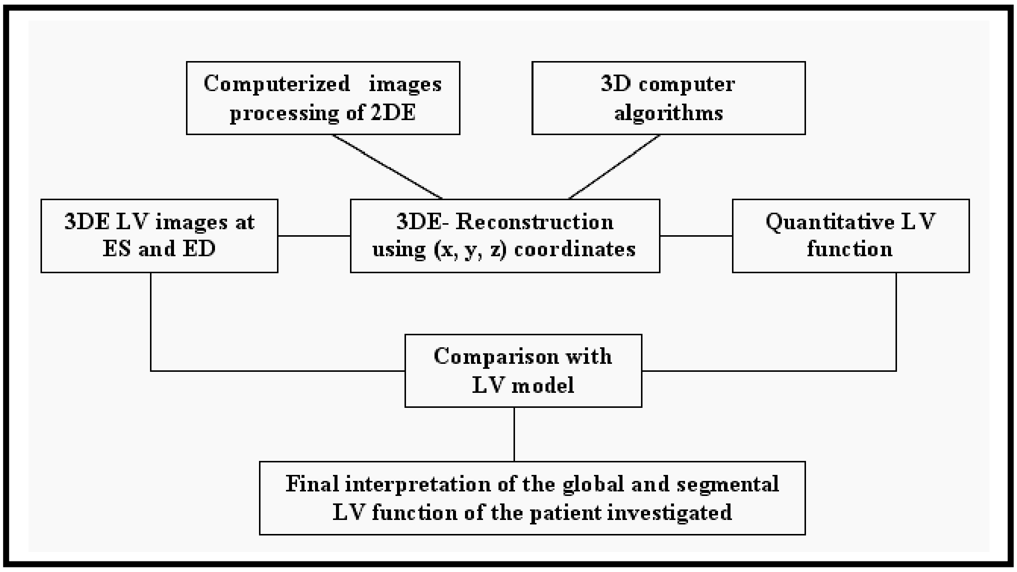

Fig. 2: Block diagram of the technique used for 3DE reconstruction

Results:

1-The size and the pattern of the 3DE LV images of the patient studied at ED and ES are enlarged and deformed (subjectively) (**fig. 3.A**), in accordance to the normal size and pattern of the 3DE LV model (14) (**fig. 3.B**).

2-LV volumes and their indices, %EF, CO, and CI at ED and ES of the patient studied were calculated (**Table 1**). ESV and EDV volume are more than LV model by 140 cm^3 and 102.3 cm^3 respectively, which resulted in reduced global % EF **Results:**

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2-LV volumes and their indices, %EF, CO, and CI at ED and ES of the patient studied were calculated (**Table 1**). ESV and EDV volume are more than LV model by 140 cm^3 and 102.3 cm^3 respectively, which resulted in reduced global % EF of the patient (20.4%) in accordance to the %EF of the LV model (74.7%).

3-LV volumes of basal and mid LV parts (ESV and EDV) and %REF are reduced (severe dysfunction) in comparison with LV model (**Table 2**). Apical wall motions as %REF of the apical part of the patient and LV model were 9% and 73.1% respectively (apical akinesia).

4- LV wall motion (%RSH,%RSK, and %REF) were less than LV model in all LV parts (basal ,mid , and apical),and sites (postero-septum (PS), mid-septum (S), antero-septum (AS), anterior (A), antero-lateral (AL), Lateral (L), postero-lateral (PL), and posterior (P)), ,especially in apical part (the sites P, L, A were akinetic while the S site was dyskinetic) (**Table 3**).

5- %REF of the all LV parts and sites of the patient and LV model were plotted superimposed (**Fig. 4.A, B, and C**), to conclude the final interpretation about the LV wall motions of the patient studied.

So there were diffuse hypokinesia in all LV sites apart from the apical sites (P, L, and S sites were akinetic areas and A site was dyskinetic area).

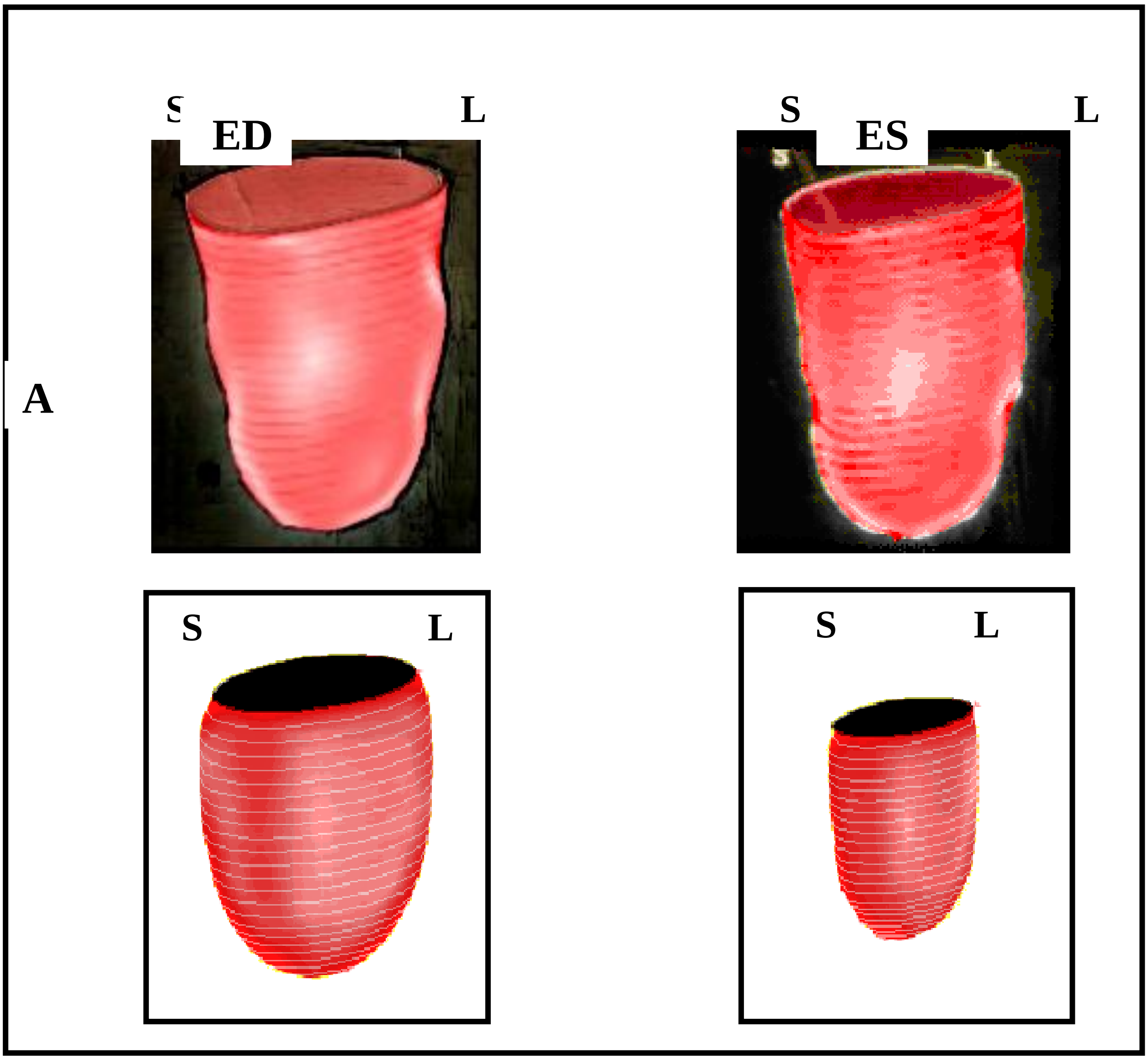

Fig. 3: Reconstructed 3DE LV images at ED and ES. A: 3DE images of the patient studied, B: 3DE images of LV model.

Table 1: Comparison of 3DE LV volumes and their indices between the Patient studied and LV model.				
Parameters at ES and ED		**LV (Patient)**	**LV model**	**Deviation between the patient and LV model**
ESV	ml	167.4	27.4	140
EDV	ml	210.4	108.1	102.3
SV	ml	42.9	80.8	-37.9
ESVI	ml/m²	90	15.1	74.9
EDVI	ml/m²	113.1	59.7	53.4
SVI	ml/m²	23.1	44.6	-21.5
CO	L/min	3	6.7	-3.7
CI	L/min/m²	1.6	3.7	-2.1
%EF	%	20.4	74.6	-54.2

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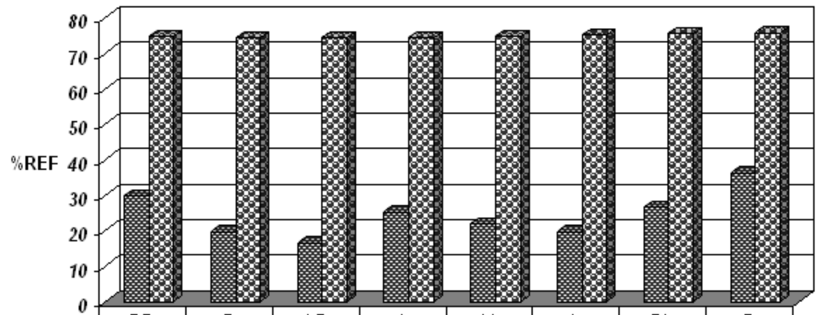
Table 2: 3DE LV volumes and their indices of the patient studied and LV model.							
LV parameters		**LV (Patient)**			**LV model**		
		basal	**mid**	**apical**	**basal**	**mid**	**apical**
EDV	**ml**	93.8	76.9	39.5	47.2	42.8	18.2
ESV	**ml**	70.8	60.5	35.9	11.8	10.6	4.9
%EF	**%**	24.5	21.3	9	74.9	75.3	73.1

Table 3: LV wall motions (%RSH, %RSK, and %REF) of all LV sites, at the basal, mid, and apical parts of the patient studied and 3DE LV model.

Part	SITE	%RSHp	%RSHm	%RSKp	%RSKm	%REFp	%REFm*
Basal	**P**	19.5	39.4	35.7	63.3	36.3	75.8
	PL	14.9	39	25.9	62.9	26.5	75.5
	L	9.8	38.6	19	62.2	19.7	75.1
	AL	11	38	21.2	61.6	21.9	74.7
	A	13.4	37.6	24.5	61.1	25.1	74.4
	AS	8.1	37.5	15.6	60.9	16.4	74.3
	S	9.4	37.5	19	61	19.7	74.3
	PS	15.4	38	29	61.7	29.7	74.7
Mid - LV	**P**	17.8	40.3	33	64.5	33.6	76.2
	PL	13.1	40	22.8	64	23.4	75.9
	L	7.9	39.6	15.6	63.4	16.8	75.5
	AL	9.2	39	17.9	62.8	18.7	75.1
	A	11.6	38.6	21.3	62.3	21.6	74.8
	AS	6.1	38.5	12.1	62.2	12.8	74.6
	S	7.5	38.5	15.6	62.2	16.2	74.7
	PS	13.7	39	26.1	62.9	26.7	75.1
Apical	**P**	8	37	14.1	60.4	16	73.5
	L	6.4	36.1	12.1	59.3	14.1	72.8
	A	-2.7	35.3	-5.5	58.2	-3.2	72
	S	2.8	35.4	6.7	58.7	8.7	72.3

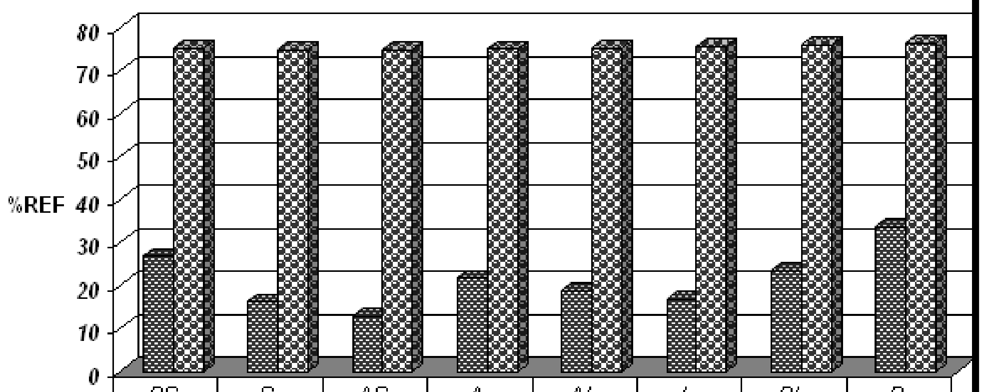
*** P = patient, m = LV model.**



	PS	S	AS	A	AL	L	PL	P
% REFmodel	74.7	74.3	74.3	74.4	74.7	75.1	75.5	75.8
% REFpatient	29.7	19.7	16.4	25.1	21.9	19.7	26.5	36.3

LV sites

Fig.4.A:LV wall motion (%REF) of the patient studied and 3DE LV model at the basal part.



	PS	S	AS	A	AL	L	PL	P
% REFmodel	75.1	74.7	74.6	74.8	75.1	75.5	75.9	76.2
% REFpatient	26.7	16.2	12.8	21.6	18.7	16.8	23.4	33.6

LV sites

Fig.4.B: LV wall motion (%REF) of the patient studied and 3DE LV model at the mid - LV part.

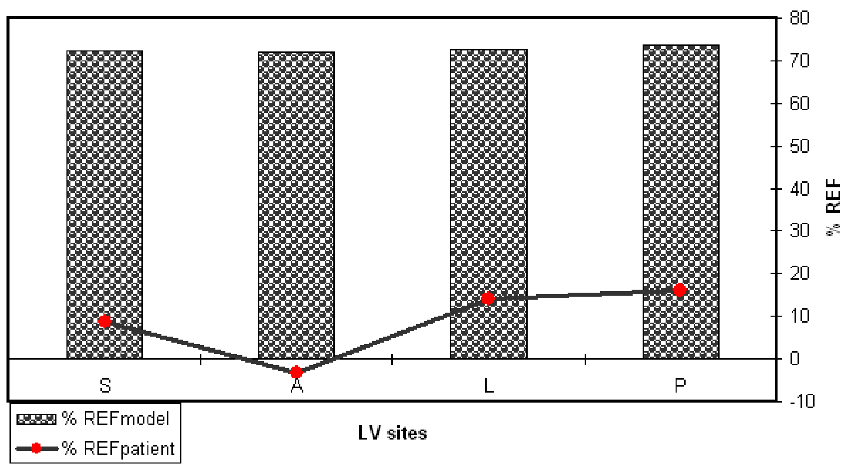


Fig.4 C:LV wall motion (%REF) of the patient studied and 3DE LV model at the apical part.

Discussion:

Accurate quantification of LV volumes and function is important in monitoring disease progression in patient with heart disease [8]. In patient with LVA, such quantification is of the utmost clinical importance for follow-up the patients with LVA and for preoperative selection of the patients with LVA for aneurysmectomy [7].

LV volume and mass measurements with 2DE rely on geometric assumptions of uniform chamber size, it is inadequate for ventricles affected by disease such as in cases of distorted LV geometry (e.g. aneurysm.3DE techniques can potentially overcome these limitations to determine LV chamber size and systolic function without geometric assumptions in patients with LVA [7,17] .

The recent 3DE and RT3DE methods require sophisticated computer facilities, with several techniques (such as scan head sensor to track the position and orientation of transthoracic scan head [8], 3DE rotational probe [9], segmentation algorithms for acoustic boundary detection method [10], matrix array transducer for RT3DE [11], deformable model with algorithms of wavelet-based methods [12], and contrast-enhancement to improve endocardial definition [13]. The calibration procedure of the scan head sensor is time consuming and tedious [8]. Cardiac translation secondary to respiration or patient movement during multiple cardiac cycles may contribute to the inaccuracy of the volume calculations. Also in 3DE techniques additional smoothing algorithms were applied to reduce noise and spatial artifacts [15]. 3DE is performed on off-line analysis, and requires manual tracing of endocardial borders. In RT3DE, automated border detection algorithms is used, but have a lower resolution, and this limit their use in patient with suboptimal ultrasound windows [17]. Contrast 3DE aims to delineate the outermost endocardial contour by filling up intertrabecular space (LV volumes are significantly larger when ultrasound contrast is used, but %EF remains unchanged [13].

In this study 3DE LV images were reconstructed for a patient with LVA from 2DE LV images to demonstrate the steps of the clinical application of the 3DE LV model [14], and to determine the segmental and global LV function with aid of a suitable computer algorithms, visual basic program, and small computer system. The quantification of LV volumes was performed using disc summation method (an alternative method of calculating LV volume from a RT3DE without using geometric assumptions) [15].

The descriptive curves and histograms of %REF of the patient and 3DE LV model were plotted superimposed and showed diffuse LV dysfunction with apical LVA (S, A, and P apical akinesia and L dyskinesia). Also the same findings with the quantification of LV volumes (reduced global %EF (20.4%),CI (1.6 L/min. m²), and apical %REF (9%) of the patient studied in comparison with global %EF (74.6%), CI (3.7 L/min. m²), and apical %REF (73.1%) of the 3DE LV model. Also CI and global %EF are important when the patients are managed medically or surgically (patient can be treated surgically even if the %EF is between 25 and 30% and the CI is greater than or equal to 2.1 L/min per m² (provided the mean pulmonary artery pressure is less than 40 mm Hg) [18].

Conclusion:

Computer algorithms of reconstructed 3DE LV model [14], were applied to a patient with LVA to reconstruct 3DE LV images from 2DE images (which is non-invasive, not using hazardous radiation and widely available technique). The 3DE LV model applied is simple to use by doctors and can be done with an ordinary 2DE phased array transducer without using expensive or sophisticated computer facilities or additional complicated algorithms for endocardial smoothing.

Also no contrast agents or complex scan head sensor are used (that needs long time for calibration). The reconstructed 3DE LV images of the patients were displayed as printed frames at ED and ES, with the quantification of global and segmental LV function without depending on geometrical assumptions. Thus this method can apply for follow-up patients with LVA and for making the decision for aneurysmectomy).

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