Ain-Shams Journal of Anesthesiology

ORIGINAL ARTICLE Open Access

Sevoflurane effects on left atrial performance: a transesophageal echocardiographic study on patients undergoing coronary artery bypass grafting

Ahmad Mahmoud Hasseb[1], Ibrahim Mamdouh Esmat[1*] and Tarek Mohamed Ashoor[1]

Abstract

Background Patients presenting for coronary artery bypass grafting often have left ventricular diastolic dysfunction. These patients are in need for a well contracting left atrium (LA) to generate the required cardiac output. Sevoflurane affects the overall cardiac contractility. This study aimed at evaluating sevoflurane effects on left atrial performance and left ventricular diastolic function for patients undergoing coronary artery bypass graft (CABG) using transesophageal echocardiography (TEE).

Results Out of 40 enrolled patients, analysis was made for 31 patients. Results after exposure to one MAC sevoflurane revealed a decrease of left atrial functional area change ($P=0.001$), left atrial active emptying fraction ($P=0.038$), and A wave velocity by transmitral pulsed wave Doppler ($P=0.019$) while left ventricular diastolic function was unaffected despite a significant decrease in left ventricular ejection fraction ($P=0.008$).

Conclusions Sevoflurane at one MAC affected the left atrial performance without affecting left ventricular diastolic function in patients with grade I and II diastolic dysfunction undergoing CABG.

Trial registration NCT03999463.

Keywords TEE, CABG, Left atrial performance, Diastolic dysfunction, Sevoflurane

Background

Left atrium (LA) contributes to the overall myocardial performance throughout three phases. First, during ventricular systole and isovolumetric relaxation; it acts as a reservoir for the blood arriving from the pulmonary veins; second, during early ventricular diastole, it serves as a conduit for blood flow from the pulmonary veins to the left ventricle; third, near the end of ventricular diastole, it actively pumps blood to the left ventricle that contributes to the overall left ventricular stroke volume by 15 to 30% (Dean Boudoulas et al. 2014; Marino et al. 2019).

Left atrial performance (LAP) is affected by the preload as well as the afterload. The preload is the volume of blood received via the pulmonary veins, which is crucial to generate a good LAP and hence good left ventricular filling. The afterload represents the left ventricular end-diastolic pressure which increases in stiff ventricles. The increased LA afterload renders the LV filling more pump dependent (Erol et al. 2001; Hoit 2014).

The left atrial function was not always considered of much clinical importance. Given the effects of LAP on the overall left ventricular function and cardiac output, more studies are conducted to focus on the left atrial

*Correspondence:
Ibrahim Mamdouh Esmat
Ibrahim_mamdouh@med.asu.edu.eg
[1] Department of Anesthesia and Intensive Care, Faculty of Medicine, Ain-Shams University, Cairo, Egypt

function. Even more studies interrogated the LAP as a tool for risk stratification of certain group of patients in terms of prognosis (Hoit 2014).

The effect of inhalational anesthetics on LAP was addressed in some recent studies. Animal studies showed a decline in both left atrial and left ventricular functions (Gare et al. 2001). They referred to impaired intracellular calcium transport and availability (De Hert et al. 2001). Human studies on the other hand confirm that volatile anesthetics did impair late diastolic function with no effect on the early diastolic filling (Bolliger et al. 2010; Filipovic et al. 2005). Others confirm the negative effects of different volatile anesthetics and positive pressure ventilation on LAP (Freiermuth et al. 2014).

Left atrial volumetric measures tend to be more accurate than linear measurements. Echocardiographic assessment of the LA volumetric measures is comparable to that of cardiovascular magnetic resonance (CMR) with clinically irrelevant difference. This makes echocardiographic assessment of LA volumes reliable, cheaper and easier to obtain (Blume et al. 2011).

In this study the authors used the intraoperative transesophageal echocardiography (TEE) to test the effect of sevoflurane on left atrial contractility. Different echocardiographic parameters were used in this study, of which the left atrial active ejection fraction was chosen as the primary outcome. The authors assumed that sevoflurane anesthesia may compromise the left ventricular filling—secondary to impaired atrial contraction—especially in patients with impaired left ventricular relaxation. Left ventricular diastolic function (LVDF) was assessed as a secondary outcome. This study was done on patients with preserved left ventricular systolic function undergoing coronary artery bypass grafting (CABG).

Methods

Ethics

This study was conducted on patients who underwent coronary artery bypass grafting (CABG) from 1st of July 2019 to 31st of December 2019. Ethical approval for this study was provided by the Research Ethics Committee (REC) on 23/6/2019. Written informed consents were obtained from all patients. This study was prospectively registered at Clinical Trials.gov Identifier: NCT03999463 on 26/06/2019 and followed the STROBE Checklist of items.

Study protocol

Forty patients who met the inclusion criteria were prospectively enrolled in this study which was conducted at operating rooms of Ain-Shams University Hospitals. This study included adult patients of both sexes, aged between 40 and 70 years, maintaining sinus rhythm undergoing elective CABG with normal diastolic function, or with grade I or II diastolic dysfunction (DD) as diagnosed by the preoperative transthoracic echocardiography. The exclusion criteria included patients with atrial or ventricular arrhythmias, mitral valve disease, pericardial disease, grade III DD, patients who had acute or recent myocardial infarction, and patients with contraindications to perform a TEE (Hahn et al. 2013).

All patients were anesthetized according to the same institutional protocol. Patients were sedated by 2 mg midazolam upon arrival to operating room (OR). After establishing of invasive blood pressure monitoring, every patient received 2–5 μg/kg fentanyl, 0.5–1 mg/kg propofol, and 0.6 mg/kg rocuronium. IV anesthetics were titrated to achieve adequate anesthesia level before endotracheal intubation. Two sets of data were collected, the first set before starting sevoflurane with a zero MAC sevoflurane (sevoflurane was packed by KAHIRA pharmaceuticals and chemical industries company under license for Abbvie UK). During which, anesthesia was maintained via intravenous propofol (50 to 100 mcg.$kg^{-1}.min^{-1}$) and fentanyl (1–2 mcg.$kg^{-1}.h^{-1}$) infusions. The second set of data were collected after discontinuing propofol infusion and starting sevoflurane to keep an age corrected one MAC on the gas analyzer (Draeger primus side stream gas analyzer) which was the study end point. TEE image acquisition was done 10 min after propofol infusion has stopped to avoid the confounding effect of propofol on hemodynamics. Given that the *half-time plasma effect site equilibration time* of propofol is 5 and up to 10 min in young and elderly patients respectively, the propofol infusion—for a short period of time—in this study was not contributing to any recorded hemodynamic derangements (Sahinovic et al. 2018).

Infusion of human albumin 5% "Buminate (Baxter)" 500 ml/h was instituted for all patients as a part of our institutional protocol. Human albumin infusion was adjusted to keep a target CVP of 8–12 cm H_2O. At time of data collection, the hemodynamic parameters were recorded.

Data recorded during this study were collected while stopping ventilation (end-expiratory) to avoid the confounding effects of mechanical ventilation on the left atrial contractility. Data were collected from the mid-esophageal four chamber view (Siemens Acuson 2000, Z6M TEE probe). After cessation of mechanical ventilation, adjustment was done on the mid-esophageal four chamber view to obtain most of the LA cavity. Resection property was utilized (Zoom) while using Color wave Doppler and dual image property for better visualization and delineation of LA borders. LA volumes were measured using the modified Simpson's method using the machine software (Cimadevilla et al. 2015). Two

echocardiographers who are EACTAIC certified for adult transesophageal echocardiography were involved in this study.

Study parameters

A) The LA performance was assessed by measuring: LA Fractional area change (LA-FAC) measured as the (Maximum atrial area (A max) – Minimum atrial area (A min)/Maximum atrial area (A max) × 100). Measurement of maximum LA volume (LAV1), minimum LA volume (LAV2) and, pre P wave LA volume (LAV3) was done then volumetric LA function throughout the cardiac cycle was calculated as (i) LA reservoir function (LA total emptying fraction) (LA-TEF) [(LAV1 − LAV2)/LAV1], (ii) LA conduit function (LA passive emptying fraction) (LA-PEF) [(LAV1 − LAV3)/LAV1] and, (iii) LA active emptying fraction (LA-AEF) (LAV3 − LAV2)/LAV3.

B) The LV diastolic function and filling status were assessed via recording (i) transmitral pulsed wave Doppler including A wave maximum velocity (A), E wave maximum velocity (E), E/A ratio, and E wave deceleration time (E-DT). (ii) Pulmonary venous pulsed wave Doppler including S wave maximum velocity (S), D wave maximum velocity (D), reversed A wave velocity (AR) and reversed A wave duration (ARd). (iii) Tissue Doppler at lateral mitral valve annulus including a' wave maximum velocity (a'), e' wave maximum velocity (e'), propagation velocity through mitral valve (PV), and E/e' ratio was then calculated.

C) LV systolic function (LVEF) was measured via the "Simpson Mode of Discs method" (MOD).

All measurements were taken according to the American Society of Echocardiography guidelines and were calculated as the mean of three consecutive cardiac cycles. All study parameters were collected during preparation for surgery, before skin incision (Dernellis and Panaretou 2003; Hahn et al. 2013).

To determine intra-observer and inter-observer variability, a random sample of 8 patients' data sets were collected twice by the same anesthetist and after a time period of 10 min, by a different anesthetist. Readings collected by the two operators were collected separately. Variability was then calculated as the mean absolute difference between both readings divided by their mean and expressed as percentages and their 95% confidence intervals (CIs). Both operators are certified by the EACTAIC and accredited to do adult transesophageal echocardiography independently.

The mean LA-AEF changes before and after sevoflurane anesthesia were set to be the primary outcome, while the remaining parameters of left atrial performance, left ventricular systolic, and diastolic functions were set to be secondary outcomes.

Statistical analysis

Based on a previous study, the Mean (SD) of LA-EF (%), MOD 61.0 (9) and 50 (11.0) at basal and intermittent positive-pressure ventilation (IPPV) respectively (Freiermuth et al. 2014) and assuming the correlation coefficient (r) between before and after findings = 0.0, the power = 0.80 and α = 0.05, the minimal sample size using G*Power 3.1.9.4 program (Erdfelder et al. 2009) was 15 cases. The research team recruited 40 cases for possible attrition and higher precision.

The collected data were coded, tabulated and statistically analyzed using IBM SPSS statistics (Statistical Package for Social Sciences) software version 18.0, IBM Corp., Chicago, USA, 2009. Descriptive statistics were done for quantitative data as minimum and maximum of the range as well as mean (SD) (standard deviation) for quantitative normally distributed data, while it was done for qualitative data as number and percentage.

Inferential analyses were done for quantitative variables using Shapiro–Wilk test for normality testing and paired *t*-test in cases of two dependent groups with normally distributed data. The level of significance was taken at P value < 0.050 was significant, otherwise was non-significant.

Results

Forty patients scheduled for CABG were randomly selected for this study. Six patients were excluded before being enrolled; two patients had concomitant moderate to severe mitral regurgitation, three patients had grade III DD, and one patient had atrial fibrillation. After having enrolled in the study, two patients had moderate mitral regurgitation diagnosed after insertion of the TEE probe in the OR and one patient was hemodynamically unstable, and the study parameters were not recorded. Total number of cases who finished the study were 31 patients (Fig. 1).

The demographic variables of the enrolled patients were presented in (Table 1). Results obtained after statistical analysis of the two sets of data revealed that sevoflurane exposure significantly increased minimum LA area (P=0.018) and minimum LA volume (P=0.014) (Table 2) (Fig. 2). LA FAC (P=0.001) and LA-AEF (P=0.038) were also statistically significantly decreased after exposure to sevoflurane, while LA-TEF and the LA-PEF did not statistically change after exposure (Fig. 3) (Table 2).

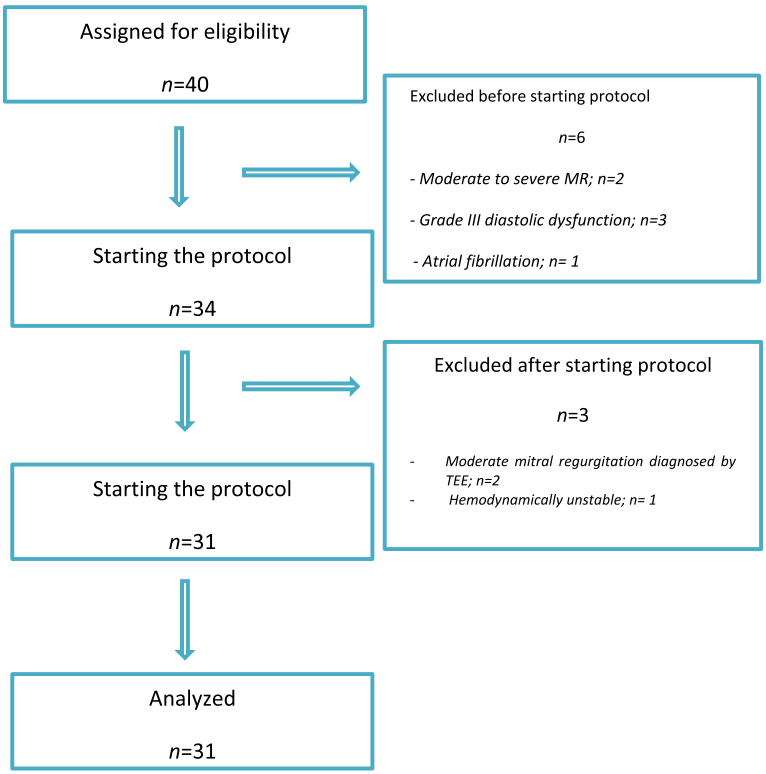

Fig. 1 The study flow diagram

Table 1 Demographic characteristics among the studied cases

Variables	Mean (SD)
Age; years, mean ± SD	58.5 ± 8.4
BMI; kg/m^2, mean ± SD	28.9 ± 4.1
EF; %, mean ± SD	49.6 ± 3.0
Male/female; *n*	22/9
Smoker; *n*, %	7 (22.6)
DM; *n*, %	18 (58.1)
HTN; *n*, %	14 (45.2)
CLD; *n*, %	5 (16.1)

Data are presented as mean and standard deviation (mean ± SD), or frequency (percentage)

Total number of patients = 31

BMI body mass index, *EF* left ventricular ejection fraction, *DM* diabetes mellitus, *HTN* hypertension, *CLD* chronic liver disease

A wave velocity of the transmitral pulsed wave Doppler statistically significantly decreased after exposure to sevoflurane ($P=0.019$). Despite the significant decrease in the A wave velocity on the TMPWD, the E/A ratio did not show a statistically significant increase after exposure to sevoflurane. As for the lateral mitral annular tissue Doppler, a' wave velocity trace dropped significantly after sevoflurane exposure ($P=0.021$) (Fig. 4) (Table 2).

There were no statistically significant differences before and after exposure to sevoflurane as regards the LVDF (Table 2). Twenty-five patients showed grade (I) DD and 6 patients showed grade (II) DD. All patients stayed within the same grade of LVDF before and after exposure to sevoflurane as evidenced by the readings of the TMPWD, pulmonary venous pulsed wave Doppler, transmitral flow propagation velocity, and lateral mitral annular TDI (Table 2). Left ventricular ejection fraction decreased significantly after exposure to sevoflurane ($P=0.008$) (Table 2).

Bland–Altman plot for both intra-observer and inter-observer variabilities, showed that all points lie within ± 1.96 SD denoting high intra-observer and inter-observer agreements of all left atrial volumetric readings (Fig. 5).

Discussion

This study was conducted to evaluate intraoperative transesophageal echocardiographic (TEE) effects of sevoflurane on left atrial performance (LAP) and the left ventricular diastolic function (LVDF) in patients undergoing CABG, and concluded that exposure to 1 MAC sevoflurane did decrease LA active emptying fraction, LA FAC, the A wave velocity of the TMPWD and the a' wave velocity on the mitral annular tissue. Doppler Echocardiography tends

Table 2 Parameters among the studied cases

Items	Before sevoflurane	After sevoflurane	Change#		^*p*
			Mean ± SE	95% CI	
Left atrial performance parameters					
Maximum LAA; cm^2	12.9 ± 3.3	13.1 ± 3.5	0.2 ± 0.4	− 0.6–1.0	0.599
Minimum LAA; cm^2	**8.6 ± 3.8**	**9.6 ± 3.6**	**1.0 ± 0.4**	**0.2–1.7**	**0.018***
Pre-A wave LAA; cm^2	10.6 ± 2.7	11.1 ± 3.0	0.5 ± 0.4	− 0.2–1.2	0.155
LAV1; cm^3	34.0 ± 14.0	36.0 ± 13.7	2.1 ± 1.8	− 1.7–5.8	0.270
LAV2; cm^3	**18.7 ± 11.6**	**22.1 ± 11.0**	**3.4 ± 1.3**	**0.7–6.0**	**0.014***
LAV3; cm^3	25.8 ± 9.8	26.8 ± 11.1	1.0 ± 1.6	− 2.4–4.4	0.543
LA-FAC; %	**35.0 ± 17.7**	**27.9 ± 18.1**	**− 7.1 ± 10.3**	**− 10.9 to − 3.2**	**0.001***
LA-TEF; %	47.5 ± 17.3	42.1 ± 15.1	− 5.4 ± 16.1	− 11.3–0.5	0.071
LA-PEF; %	15.9 ± 40.6	17.6 ± 40.7	1.7 ± 21.0	− 6.8–10.1	0.692
LA-AEF; %	**32.2 ± 24.2**	**18.0 ± 36.8**	**14.1 ± 6.5**	**0.8–27.5**	**0.038***
Left ventricular diastolic function parameters					
I) Transmitral PWD					
E; cm/s	58.5 ± 18.7	58.0 ± 17.9	− 0.5 ± 2.1	− 4.8–3.9	0.827
A; cm/s	43.0 ± 18.5	38.6 ± 14.5	− 4.4 ± 1.8	− 8.1 to − 0.8	0.019*
E/A	1.5 ± 0.7	1.7 ± 0.8	0.2 ± 0.1	0.0–0.3	0.117
E-DT; ms	203.2 ± 59.3	192.6 ± 59.5	− 10.6 ± 9.6	− 30.3–9.2	0.282
II) Pulmonary venous PWD					
S; cm/s	38.5 ± 14.1	35.1 ± 11.7	− 3.4 ± 2.0	− 7.6–0.8	0.108
D; cm/s	43.8 ± 63.5	34.4 ± 14.6	− 9.4 ± 12.2	− 34.4–15.6	0.448
AR; cm/s	14.6 ± 5.2	14.3 ± 5.8	− 0.3 ± 1.1	− 2.6–2.0	0.803
ARd; ms	116.6 ± 35.0	111.7 ± 31.2	− 4.9 ± 5.9	− 16.9–7.2	0.412
III) Tissue Doppler at lateral mitral area					
e'; cm/s	8.0 ± 3.4	7.9 ± 4.4	− 0.1 ± 0.8	− 1.8–1.6	0.885
a'; cm/s	**7.3 ± 2.5**	**6.2 ± 1.6**	**− 1.1 ± 0.4**	**− 1.9 to − 0.2**	**0.021***
E/e'	8.5 ± 3.8	10.9 ± 9.4	2.3 ± 9.5	− 1.3–6.0	0.202
PV cm/s	34.6 ± 11.0	31.8 ± 9.1	− 2.8 ± 1.8	− 6.4–0.8	0.126
Left ventricular systolic function parameters					
LVEF %	**50.1 ± 7.7**	**48.8 ± 8.2**	**− 1.2 ± 0.4**	**− 2.1 to − 0.4**	**0.008***

Minimum LAA and minimum LAV were significantly increased, while A-Vmax, A', LVEF and LA- FAC were significantly decreased

SE standard error, *CI* confidence interval, *LAA* left atrial area, *LAV* left atrial volume, *LA-FAC* left atrial functional area change, *LA-TEF* left atrial total emptying fraction, *LA-PEF* left atrial passive emptying fraction, *LA-AEF* left atrial active emptying fraction, *E* E wave maximum velocity, *A* A wave maximum velocity, *E/A* ratio between A and E, *E-dt* E wave deceleration time, *S* S wave maximum velocity, *D* D wave maximum velocity, *AR* reversed A wave velocity, *ARd* reversed A wave duration, *a'* a' wave maximum velocity, *e'* e' wave maximum velocity, *PV* propagation velocity through the mitral valve, *LVEF* left ventricular ejection fraction, *E/e'* ratio between E and e'

Change = After-before

Negative values indicate reduction

^Paired *t* test

* Significant

to underestimate LA volumes when compared with cardiac MRI or CT, yet it is easier to use, more cost effective and, the differences between both modalities are clinically irrelevant (Hoit, 2014). It is more practical to obtain results online while performing routine perioperative TEE studies, offering the technique more clinically useful (Filipovic et al. 2007).

The effects of sevoflurane on the LAP and LVDF were studied in animals and humans, yet the results were not always conclusive and sometimes contradictory. The study designs used were sometimes retrospective and the methodologies were not taking into consideration real time TEE examinations (Kehl et al. 2003; Rupert et al. 2010). Similarly, positive pressure ventilation is known to substantially affect the LA performance, even in healthy subject (Couture et al. 2009; Freiermuth et al. 2014).

Hence, the need of testing sevoflurane effects on the LAP and LVDF using the intraoperative TEE in a

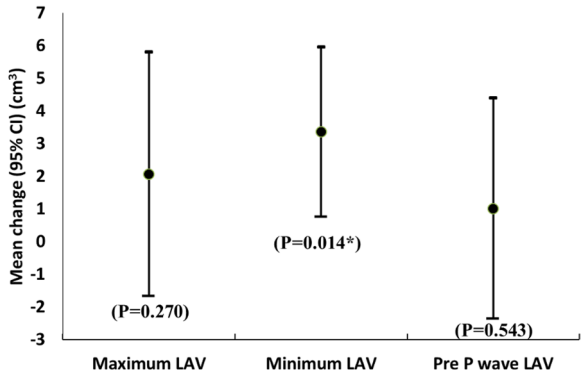

Fig. 2 Mean changes and its 95% confidence interval (CI) of the maximum, minimum and pre-P wave left atrial volumes before and after 1 MAC sevoflurane anesthesia. LAV; left atrial volume. * Denotes significance

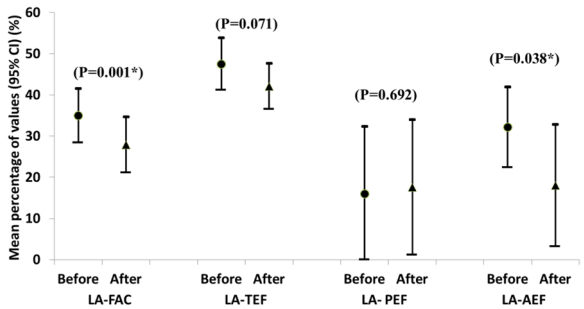

Fig. 3 Comparative changes of left atrial volumetric function throughout the cardiac cycle before *(filled circle)* and after *(filled triangle)* 1 MAC sevoflurane anesthesia. LA-FAC (%); left atrial functional area change, LA-TEF (%); left atrial total emptying fraction (left atrial reservoir function %), LA-PEF (%); left atrial passive emptying fraction (left atrial conduit function %), LA-AEF (%); left atrial active pump function. * Denotes significance based on paired *t* test

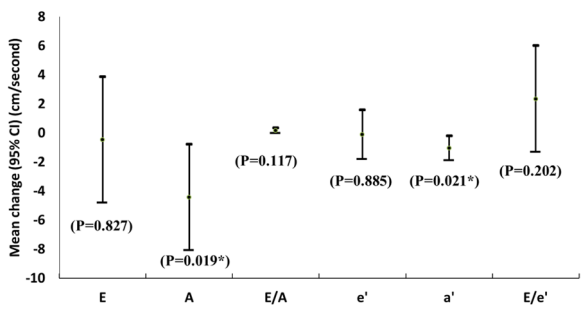

Fig. 4 Mean changes and its 95% confidence interval (CI) of trans-mitral of pulsed wave Doppler, and tissue Doppler at lateral mitral annulus variables before and after anesthesia with 1 MAC sevoflurane, E; E wave maximum velocity (cm/sec), A; A wave maximum velocity(cm/sec), E/A; ratio between A and E, a'; a' wave maximum velocity(cm/sec), e'; e' wave maximum velocity(cm/sec), E/e'; ratio between E and e'. * Denotes significance

prospective design and during cessation of mechanical ventilation.

Meir Gare et al. in 2001 concluded that sevoflurane did affect the LA active ejection fraction while the LA reservoir and conduit functions were maintained. The overall ejection fraction was not affected which may be attributed to the preserved and even augmented passive LA contribution to the LV filling (Gare et al. 2001). Similarly, Freiermuth et al. described a significant drop of LA active emptying volume caused by volatile anesthetics, with no such effect on both conduit and reservoir functions (Freiermuth et al. 2014). Those findings were in agreement with our results, with a drop of LA active emptying fraction and preserved LA total emptying fraction. This could be attributed to the preserved LA passive emptying fraction which actually increased yet was non-statistically significant. May be a larger sample size was needed to get a statistically significant result.

The LA FAC in this study significantly declined after exposure to sevoflurane. This finding was in agreement with Freiermuth et al., who found a decline in the LA FAC after exposure to sevoflurane during spontaneous and mechanical ventilation (Freiermuth et al. 2014). These results were in contrast to that obtained by Bolliger et al. who found no change in the LA FAC after exposure to sevoflurane (Bolliger et al. 2010).

The TMPWD A wave and the a` velocity are important parameters that correlate with atrial contractility. Bolliger et al. examined the a' velocity changes in healthy volunteers exposed to 1 MAC of sevoflurane. The results obtained were consistent with results obtained in this study, with a decrease of both the TMPWD A wave and the a' velocity after exposure to sevoflurane (Bolliger et al. 2010).

Added to the decline in LA active ejection fraction using the Simpson's MOD technique, the decline in both TMPWD A wave and a` wave velocities, the authors of this study concluded that sevoflurane significantly decreased the LA active emptying fraction.

There was no significant effect on LVDF under sevoflurane anesthesia in this study. The results obtained from the TMPWD, pulmonary PWD and tissue Doppler were statistically non-significant after exposure to sevoflurane. The significant drop of the A wave velocity after exposure to sevoflurane was associated with a non-significant drop in the E wave velocity. Hence, the E/A ratio wasn`t changed after sevoflurane anesthesia. The effects of volatile anesthetics on LVDF were not always consistent in previous studies. In one study done by Filipovic et al. on patients with no previous cardiovascular disease found no effect of sevoflurane on LVDF (Filipovic et al. 2005).

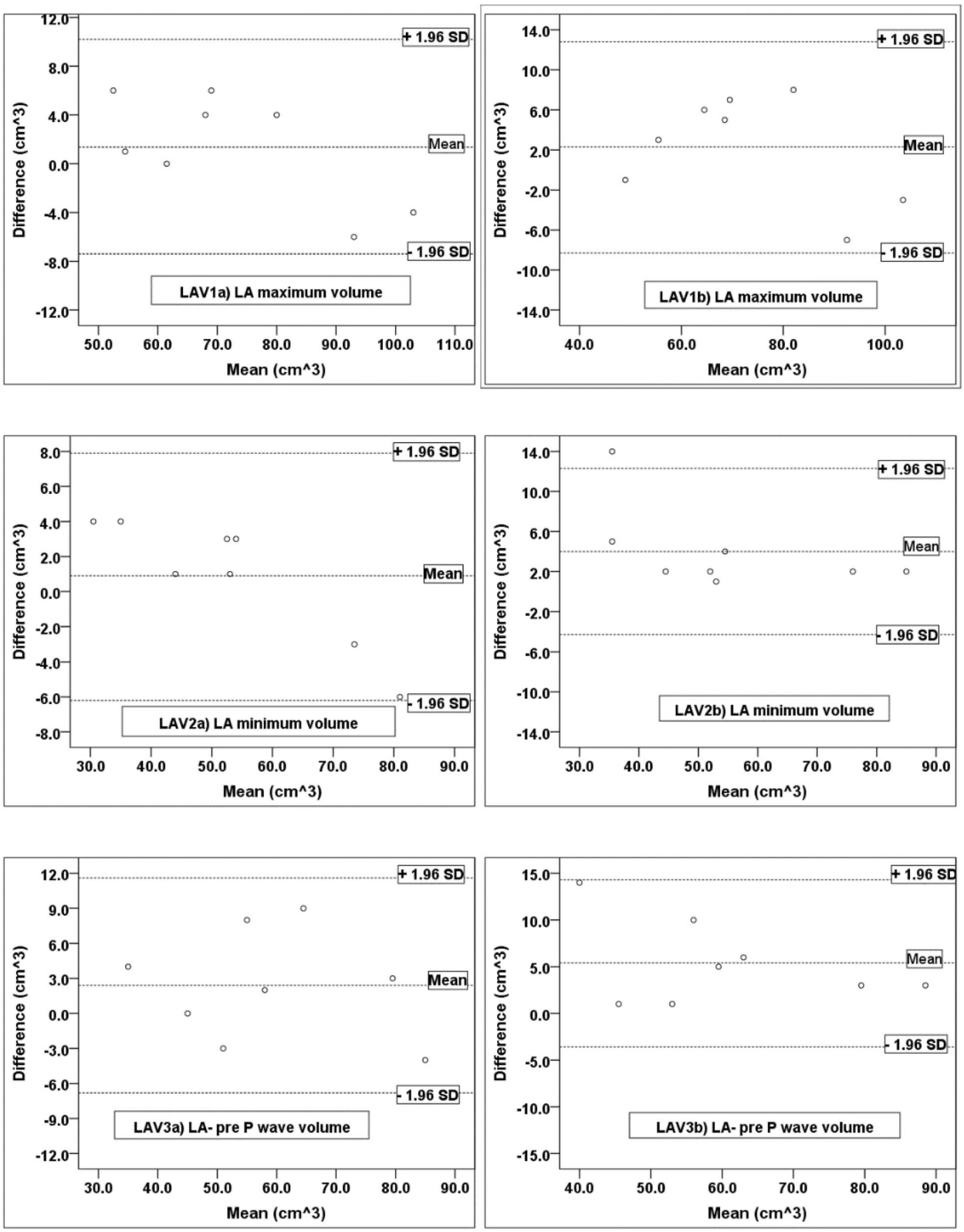

Fig. 5 Bland–Altman plots of intra-observer (LAV1a, LAV2a, LAV3a) cm^3, and inter-observer (LAV1b, LAV2b, LAV3b) cm^3, measurements of left atrial maximum volume, left atrial minimal volume and, left atrial pre-P wave volume respectively. Denoting high intra-observer and inter-observer agreements (cm^3 denotes cm^3)

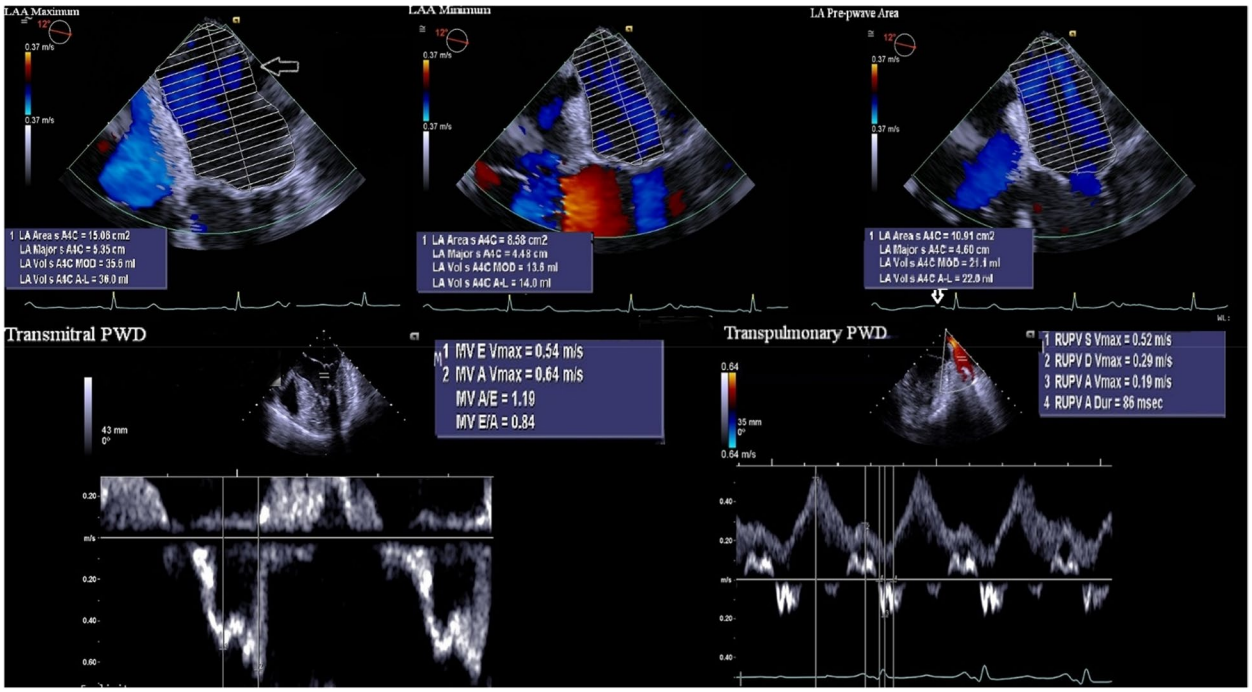

Fig. 6 LA area and PWD parameter evaluations. The uppe row showed maximum (left upper pulmonary vein was not included, labeled by arrow), minimum, and pre P-wave (just before the P wave on the ECG trace, labeled by arrow). LA area and volume evaluation via MOD. The lower row showed transmitral and transpulmonary vein PWD evaluation. All paramaters were measured in the four chamber view. LA, left atrium

In another study done by Filipovic et al. comparing the effects of sevoflurane and propofol in patients with aortic stenosis, revealed better effects on LVDF of sevoflurane than propofol during spontaneous ventilation (Filipovic et al. 2007).

The negative inotropic effect of volatile anesthetics including sevoflurane is well known. Yet this effect is not always clinically relevant unless a change in loading conditions occur. The LV ejection fraction was significantly affected after exposure to sevoflurane in this study, which could be attributed more to the decline in late LV filling caused by a significant drop in LA active atrial ejection fraction. These effects should be more evident in these subgroups of patients with grade I or II LVDD who were already suffering impaired LV relaxation. This drop in LVEF could be also attributed to the direct negative inotropic effect of sevoflurane on the left ventricle. A similar effect of sevoflurane was noticed by Kingwill et al., who concluded that sevoflurane has a direct negative inotropic effect on healthy subjects using the Tei index without a clinically relevant effect (Kingwill et al. 2017).

This study was the first to examine the left atrial performance using the TEE in a real time (Fig. 6) (Supplement: Normal echocardiographic measurements). It might be clinically helpful to consider the left atrial emptying fraction intraoperatively, especially in patients with DD who need fine tuning of the hemodynamics to obtain adequate cardiac output. This is getting more importance added to that the commonly used anesthetics—as sevoflurane—can influence the overall cardiac performance even in patients with preserved LV systolic function.

This study had several limitations. The first one was the small number of included patients. Second, the lack of baseline TTE study before induction of anesthesia and during spontaneous ventilation to measure the effect of positive ventilation on the LAP in this subgroup of patients. Third, the left atrial cavity cannot be entirely visualized using TEE, obviously because the probe is too much close to the LA cavity. Hence, The TEE assessment of the LA areas and volumes needs a well-trained operator to avoid foreshortening of the cavity and to obtain accurate readings. The Mid-esophageal four chamber view is not the best to trace most of the LA cavity, yet the view allowed the echocardiographers to record all study parameters in the available time window during surgery. Besides, the authors were not aiming to calculate the full volume of the left atrium, but were focusing on the changes in volume throughout the cardiac cycle, which were accurately traced at the same time as a ratio and not as an absolute figure. Fourth, in future studies,

the LV systolic function needs to be studied with other methods rather than the modified Simpson's MOD, to avoid the confounding effects of regional wall motion abnormalities in this group of patients. Lastly, it was not possible for the authors to include dynamic assessment of the cardiovascular system (e.g., leg elevation) in the methodology. This could have better neutralized the effects of hemodynamic changes during anesthesia on the obtained results.

The research team concluded that at a dose of one MAC, sevoflurane significantly affected the left atrial contractility in this cohort of patients without a significant effect on the LVDF. Despite that sevoflurane did not worsen the degree of DD, it did affect the left ventricular late filling and subsequently the LVEF. Given the results of this study, the authors assume that sevoflurane may not be the best choice for maintenance of anesthesia in such patients. In patients with grade, I and II LVDD, the left ventricular filling during late diastole is impaired during sevoflurane anesthesia. While these patients depend on the late active LV filling to achieve an adequate cardiac output, sevoflurane anesthesia at one MAC disrupts this compensatory mechanism. Accordingly, it is advised to avoid sevoflurane anesthesia in this cohort of patients when they are presenting with a low cardiac output state as a part of low cardiac output management protocol. More prospective studies, including larger group of patients are required in the future to validate these findings.

Conclusions

Sevoflurane at one MAC significantly affected the LAP without a significant effect on the LVDF in patients with preoperative grade I and II diastolic dysfunction undergoing CABG.

Abbreviations

LAA	Left atrial area
LAV	Left atrial volume
LA-FAC	Left atrial functional area change
LA-TEF	Left atrial total emptying fraction
LA-PEF	Left atrial passive emptying fraction
LA-AEF	Left atrial active emptying fraction
E	E wave maximum velocity
A	A wave maximum velocity
E/A	Ratio between A and E
E-dt	E wave deceleration time
S	S wave maximum velocity
D	D wave maximum velocity
AR	Reversed A wave velocity
ARd	Reversed A wave duration
a'	a' wave maximum velocity
e'	e' wave maximum velocity
PV	Propagation velocity through the mitral valve
LVEF	Left ventricular ejection fraction
E/e'	Ratio between E and e

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42077-023-00309-7.

Additional file 1. STROBE checklist.

Additional file 2. Supplement -Normal Echocardiographic Measurements.

Acknowledgements

The research team is grateful to residents of anesthesia and the nursing staff for all the help they have given us with our research work.

Authors' contributions

AM H and TM A were responsible for the conception and design of the study, analysis of the data, writing the manuscript, and revising the manuscript. IM E was responsible for clinical cases handling, collecting the data search the database, and revising the manuscript. All authors have read and approved the manuscript.

Funding

No funding was obtained for this study.

Availability of data and materials

The data that support the findings of this study are available from Ain-Shams University Hospitals record department but restrictions apply to the availability of these data. These data were used under license for the current study and so are not publicly available. However, data are available from the corresponding author upon reasonable request and with permission of Ain-Shams University Hospitals record department.

Declarations

Ethics approval and consent to participate

This study was conducted at Ain-Shams University hospitals on patients who underwent coronary artery bypass grafting (CABG) from 1st of July 2019 to 31st of December 2019. Ethical approval for this study (FMASU R 35 /2019) was provided by the Research Ethics Committee (REC) at the Faculty of Medicine of Ain-Shams University Hospitals, Cairo, Egypt (Chairperson Prof. Dr. Fathy Tash) on 23 June 2019. Written informed consents were obtained from all patients. This study was prospectively registered at Clinical Trials.gov Identifier: NCT03999463 on 26 June 2019 and followed the STROBE Checklist of items.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Received: 25 April 2022 Accepted: 4 March 2023
Published online: 06 April 2023

References

Blume GG, McLeod CJ, Barnes ME, Seward JB, Pellikka PA, Bastiansen PM, Tsang TSM (2011) Left atrial function: physiology, assessment, and clinical implications. Eur J Echocardiogr 12:421–430

Bolliger D, Seeberger MD, Kasper J, Bernheim A, Schumann RM, Skarvan K, Buser P, Filipovic M (2010) Different effects of sevoflurane, desflurane, and isoflurane on early and late left ventricular diastolic function in young healthy adults. Br J Anaesth 104:547–554

Cimadevilla C, Nadia B, Dreyfus J, Perez F, Cueff C, Malanca M, Brochet E, Iung B, Vahanian A, Messika-Zeitoun D (2015) Echocardiographic measurement of left atrial volume: Does the method matter? Arch Cardiovasc Dis 108:643–649

Couture P, Denault AY, Shi Y, Deschamps A, Cossette M, Pellerin M, Tardif JC (2009) Effects of anesthetic induction in patients with diastolic dysfunction. Can J Anesth 56:357–365
De Hert SG, Van der Linden PJ, Ten Broecke PW, Vermeylen KT, Rodrigus IE, Stockman BA (2001) Effects of desflurane and sevoflurane on length-dependent regulation of myocardial function in coronary surgery patients. Anesthesiology 95:357–363
Dean Boudoulas K, Paraskevaidis IA, Boudoulas H, Triposkiadis FK (2014) The left atrium: From the research laboratory to the clinic. Cardiol 129:1–17
Dernellis JM, Panaretou MP (2003) Effects of digoxin on left atrial function in heart failure. Heart 89:1308–1315
Erdfelder E, Faul F, Buchner A, Lang AG (2009) Statistical power analyses using G* Power 31: Tests for correlation and regression analyses. Behav Res Methods. 41(4):1149–60
Erol MK, Ugur M, Yilmaz M, Acikel M, Sevimli S, Alp N (2001) Left atrial mechanical functions in elite male athletes. Am J Cardiol 88:915–917
Filipovic M, Wang J, Michaux I, Hunziker P, Skarvan K, Seeberger MD (2005) Effects of halothane, sevoflurane and propofol on left ventricular diastolic function in humans during spontaneous and mechanical ventilation. Br J Anaesth 94:186–192
Filipovic M, Michaux I, Wang J, Hunziker P, Skarvan K, Seeberger M (2007) Effects of sevoflurane and propofol on left ventricular diastolic function in patients with pre-existing diastolic dysfunction. Br J Anaesth 98:12–18
Freiermuth D, Skarvan K, Filipovic M, Seeberger MD, Bolliger D (2014) Volatile anaesthetics and positive pressure ventilation reduce left atrial performance: a transthoracic echocardiographic study in young healthy adults. Br J Anaesth 112:1032–1041
Gare M, Schwabe DA, Hettrick DA, Kersten JR, Warltier DC, Pagel PS (2001) Desflurane, sevoflurane, and isoflurane affect left atrial active and passive mechanical properties and impair left atrial-left ventricular coupling in vivo: analysis using pressure-volume relations. Anesthesiology 95:689–698
Hahn RT, Abraham T, Adams MS, Bruce CJ, Glas KE, Lang RM, Reeves ST, Shanewise JS, Siu SC, Stewart W, Picard MH (2013) Guidelines for performing a comprehensive transesophageal echocardiographic examination: recommendations from the american society of echocardiography and the society of cardiovascular anesthesiologists. J Am Soc Echocardiogr 26:921–964
Hoit BD (2014) Left atrial size and function: Role in prognosis. J Am Coll Cardiol 63:493–505
Kehl F, Ladisa JF, Hettrick DA, Kersten JR, Warltier DC, Pagel PS (2003) Influence of isoflurane on left atrial function in dogs with pacing-induced cardiomyopathy: evaluation with pressure-volume relationships. J Cardiothorac Vasc Anesth 17:709–714
Kingwill AC, van der Westhuizen J, Turton EW (2017) The effect of sevoflurane induction on the myocardial performance index in healthy individuals. South African J Anaesth Analg 23:29–33
Marino PN, Degiovanni A, Zanaboni J (2019) Complex interaction between the atrium and the ventricular filling process: the role of conduit. Open Heart 6:e001042
Rupert E, Sarkar S, GuhaBiswas R (2010) Echocardiographic evaluation and comparison of the effects of isoflurane, sevoflurane and desflurane on left ventricular relaxation indices in patients with diastolic dysfunction. Ann Card Anaesth 13:130
Sahinovic MM, Struys MMRF, Absalom AR (2018) Clinical pharmacokinetics and pharmacodynamics of propofol. Clin Pharmacokinet 57:1539–1558

Publisher's Note