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The heart function during general anesthesia in patients with or without hypertension through echocardiography

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Key words: **Echocardiography; Hypertension; General anesthesia; Heart function; left atrial pump function**

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Abstract

OBJECTIVE: To explore the heart function by echocardiography during induction of General anesthesia with or without hypertension.
DESIGN: Thirty-seven subjects were enrolled to this study. According to blood pressure, patients were allocated to normal group (n=18) and hypertension group (n=19). The Hitachi HI VISION PREIRUS color echocardiography system was used to trace heart function before and after General anesthesia.
SETTING: Affiliated Hospital of a University.
RESULTS: Before and after General anesthesia in the normal group, the E peak and Aa peak were reduced, and the difference was statistically significant ($P<0.05$). The other indexes were not statistically significant. E peak, A peak, Ea peak, and Aa peak were reduced, and the difference was statistically significant ($P<0.05$) before and after General anesthesia in the hypertension group. The left atrial function, left atrial duct function, and left atrial pump function reduced after General anesthesia in hypertension group, and the differences were statistically significant ($P<0.05$). And there was no significant difference in the Tei index which reflected whole cardiac function after General anesthesia.
THE MAIN FINDINGS: In the hypertension group, the left atrial function was influenced during the induction of General anesthesia compared with normal group.
CONCLUSIONS: The effect of General anesthesia on the atrium is greater than that of the ventricle.

ORIGINAL ARTICLE

Abbreviations:

ECG	- electrocardiogram
NIBP	- non invasive blood pressure
CVP	- central venous pressure
PAWP	- pulmonary artery wedge pressure
PCWP	- pulmonary capillary wedge pressure
PADP	- pulmonary artery dystolic pressure
TDI	- tissue doppler imaging
LVEF	- left ventricular ejection fraction
STI	- speckle tracking imaging
TEE	- transesophageal echocardiography
LAVT	- left atrial volume tracking
ASA	- American Society of Anesthesiologists
CTT	- color tissue tracking
BSA	- body surface area

INTRODUCTION

The prevalence of essential hypertension is as high as 18%, which is one of the common diseases that endanger human health and life (Xiong *et al.* 2015). Hypertension due to long-term afterload (increased pressure load), causing myocardial centripetal hypertrophy, at this time myocardial fibers in parallel hyperplasia, muscle fibers become thicker, ventricular wall thickness increases, left ventricular geometry changes, eventually leading to left ventricular weight Structure and hypertrophy (Hinderliter *et al.* 2002; Weiner *et al.* 2013; Li *et al.* 2019). It is well known that there is a close relationship between elevated arterial pressure and cardiovascular disease, and it remains one of the most important preventable risk factors for concurrent cardiovascular disease and stroke. Hypertensive patients have a pathophysiological basis for increased cardiovascular instability, and General anesthesia induction is greatly increased (Hazari *et al.* 2017; Masoudifar *et al.* 2013). During induction of General anesthesia, systemic vasodilation accompanied by General anesthesia, decreased blood pressure, coronary artery reserve capacity and decline in hypertensive patients, and myocardial oxygen supply is highly dependent on coronary perfusion, so when blood pressure is lower than the autoregulation range of the myocardium, it is prone to myocardial ischemia (Zuin *et al.* 2018; O'Connor *et al.* 1989). Normal blood pressure increased by 30mmHg due to tracheal intubation stimulation. For patients with hypertension, blood pressure may increase by 90mmHg. Due to left ventricular remodeling, wall thickness, and heart rate increase in patients with hypertension, myocardial oxygen consumption will increase. When the oxygen supply and oxygen consumption are imbalanced, it may cause myocardial ischemia, arrhythmia, and even cardiac arrest.

General anesthesia induction is a very critical and important process throughout the perioperative period. It is a risky period of general General anesthesia. There may be some thrilling situations, such as a drop in blood pressure, arrhythmia, myocardial ischemia, cardiac arrest, endotracheal intubation and so on. In the past, the monitoring of General anesthesia induction focused on heart rate, blood pressure, hemodynamics, and little research on cardiac function during General anesthesia

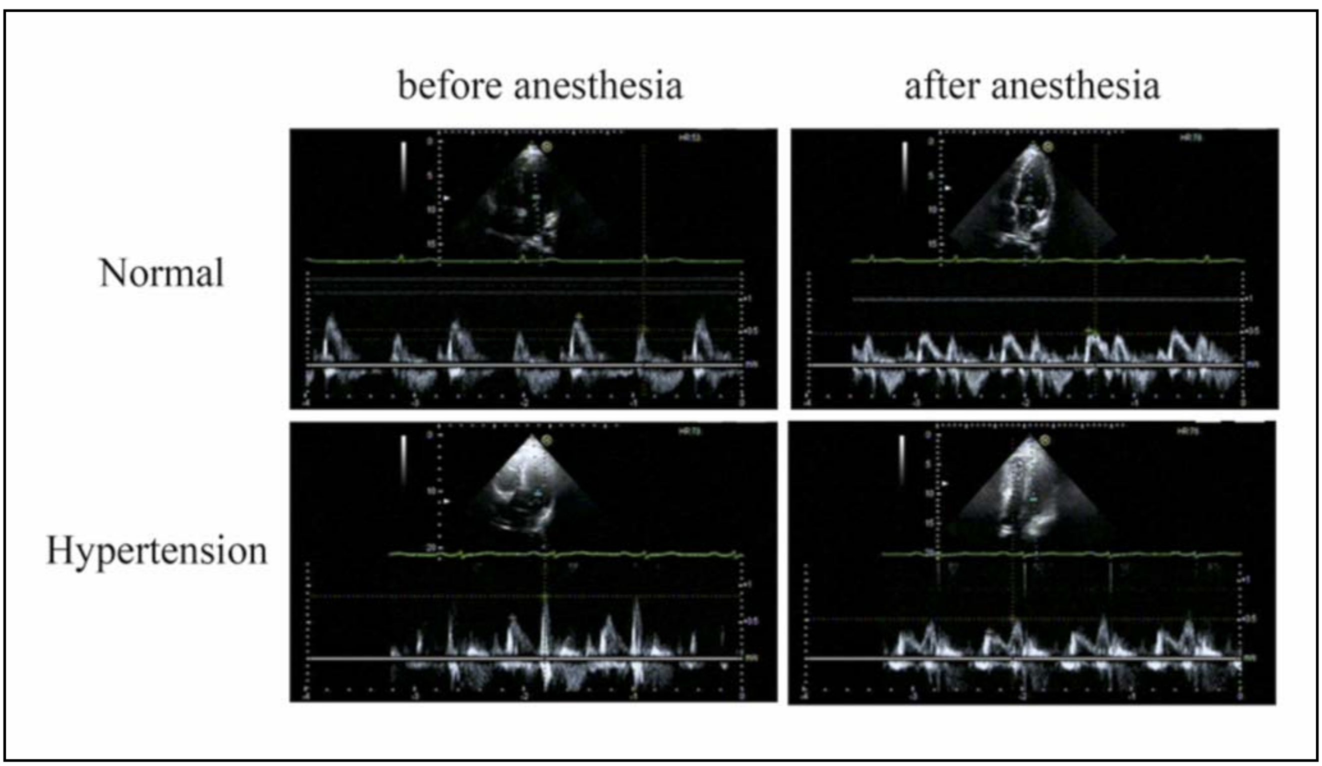

Fig. 1. Mitral valve mouth blood flow Doppler before and after General anesthesia in two groups. In hypertension group, E/A is lower than 1 (E/A <1). In both group, E peak all decreased after General anesthesia. While A peak reduced after General anesthesia in hypertension group.

Tab. 1. Patients characteristics

Variable	Normal	Hypertension	T value	*P* value
Male	7	9	--	--
Female	11	10	--	--
Age(years)	40.11±12.43	54.61±9.92	-0.542	-0.251
Height (cm)	160.67±8.37	161.68±7.42	-0.392	0.698
Weight (kg)	59.03±15.09	64.55±11.71	-1.248	0.220
BSA (m^2)	1.58±0.23	1.66±0.19	-1.120	0.270
SBP (mm Hg)	112.56±11.13	146.42±12.30	-8.767	0.000*
DBP (mm Hg)	70.39±6.93	84.79±20.78	-2.795	0.008*
Heart rate (beats/min)	82.78±9.75	80.05±11.00	0.795	0.432

* $P<0.05$ vs. Normal group

induction. With the rapid development of ultrasound technology and the deepened study of cardiac function, echocardiography has gradually become an important monitoring method in General anesthesia monitoring (Langesæter *et al.* 2015; Ashes & Roscoe, 2015; Júnior *et al.* 2016). Also, the use of echocardiography in the perioperative period of General anesthesia has the following advantages: non-invasive, timely and dynamic observation of various physiological and pathological parameters, dual evaluation of cardiac anatomy and function, and visual evaluation valve, capacity, myocardial contractility, collecting hemodynamic parameters, and no consumables can be used repeatedly. It is still unknown how the cardiac function will change during General anesthesia induction. Therefore, the application of echocardiography technology in the study of hypertension patients is more beneficial to solve the clinical General anesthesia of hypertension patients.

In the present study, the clinical data of 37 patients were enrolled and the results of echocardiography were

Tab. 2. Comparison of conventional ultrasound measurement results before and after General anesthesia in two groups（$\bar{x} \pm s$）

Variable	Normal				Hypertension			
	before General anesthesia	after General anesthesia	*t* value	*P* value	before General anesthesia	after General anesthesia	*t* value	*P* value
LVEdD (mm)	44.13±3.83	42.92±4.88	0.818	0.419	44.98±3.36	44.90±4.02	0.059	0.953
LVEsD (mm)	27.81±2.97	26.42±3.37	1.299	0.203	27.85±2.45	28.01±3.10	-0.164	0.871
LVEdV (ml)	90.35±16.70	84.22±21.50	0.945	0.352	92.98±15.31	93.14±18.33	-0.027	0.979
LVEsV (ml)	29.59±7.41	26.29±8.34	1.241	0.223	28.93±6.71	30.14±7.91	-0.477	0.637
SV (ml)	59.55±11.53	57.36±16.49	0.458	0.650	63.46±11.65	62.99±12.53	0.111	0.912
COL/min	4.13±1.60	6.5±4.51	-1.908	0.067	5.82±3.42	5.92±1.58	-0.104	0.918
EF%	66.97±4.20	68.62±6.03	-0.940	0.354	68.21±4.48	67.77±4.41	0.282	0.780
FS%	37.01±3.17	38.34±4.90	-0.959	0.344	38.01±3.50	37.69±3.48	0.267	0.791
LA (mm)	27.56±4.79	27.35±4.27	0.132	0.896	28.47±3.37	28.00±3.24	0.415	0.681
IVS (mm)	8.33±0.97	8.24±0.97	0.299	0.767	8.65±1.06	8.81±0.83	-0.497	0.623
LV (mm)	42.72±4.00	42.71±4.59	0.699	0.489	44.47±4.03	44.75±4.14	-0.196	0.846
LVPW (mm)	8.5±1.25	8.18±1.13	0.802	0.428	8.82±0.63	9.00±0.73	-0.742	0.464
E peak (m/s)	0.84±0.15	0.69±0.16	2.722	0.010*	0.68±0.15	0.54±0.14	2.783	0.009*
A peak (m/s)	0.60±0.31	0.50±0.22	1.046	0.303	0.80±0.21	0.57±0.16	3.626	0.001*
E/A	1.71±0.95	1.59±0.57	0.466	0.645	0.93±0.43	1.04±0.53	-0.648	0.521
Ea peak (cm/s)	11.47±2.83	13.06±19.16	-0.349	0.729	7.98±1.65	6.32±1.58	2.997	0.005*
Aa peak (cm/s)	8.99±2.51	6.98±1.67	2.830	0.008*	9.96±1.71	7.74±1.98	3.511	0.001*
Ea/Aa	1.43±0.48	1.40±0.66	0.139	0.891	0.83±0.27	0.88±0.34	-0.439	0.664

* $P<0.05$ vs. before General anesthesia

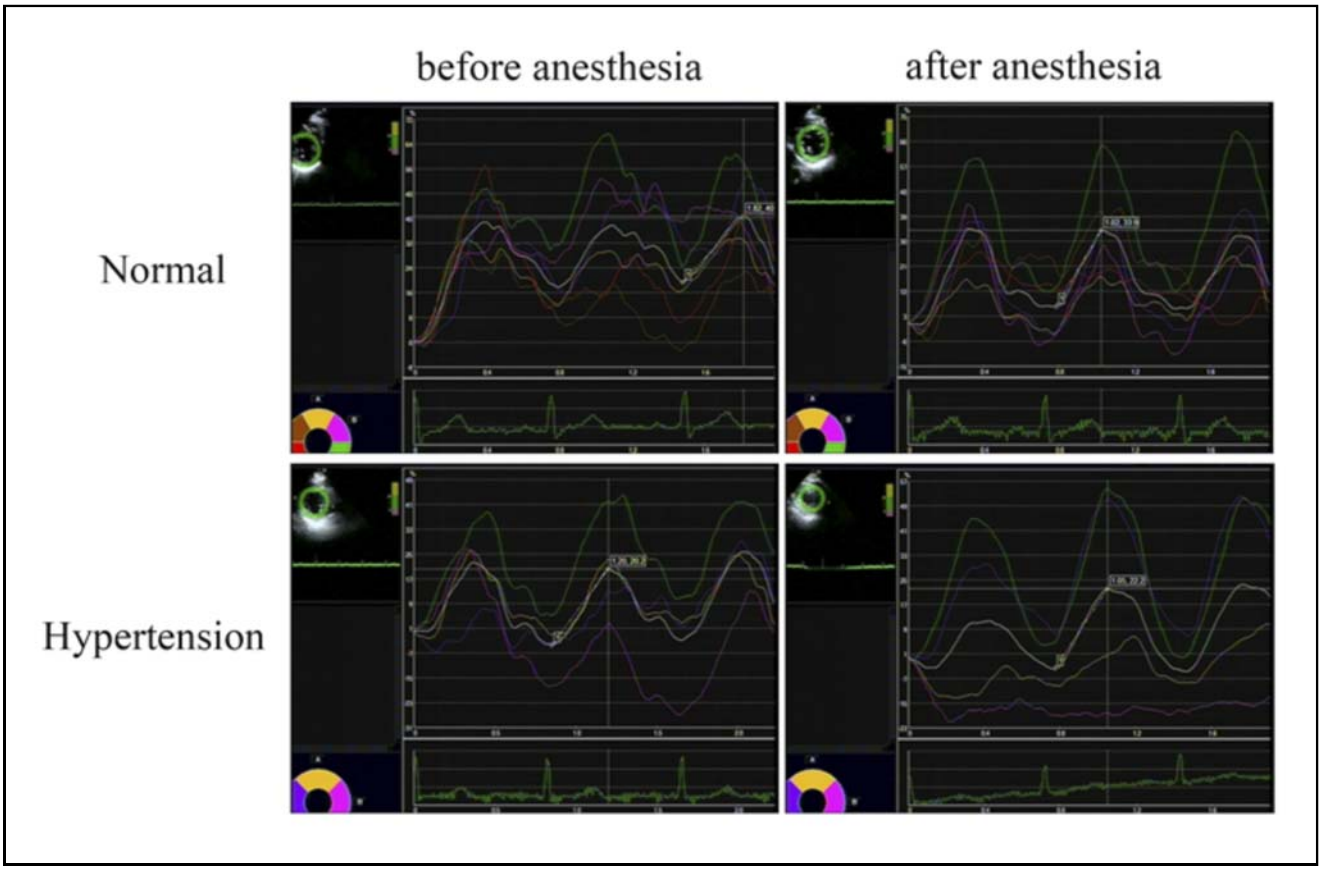

Fig. 2. Left ventricular short axis basal segment strain before and after General anesthesia in two groups. There was no significant difference before and after General anesthesia in both group.

compared with those of hypertension. Relationships between hypertension and General anesthesia were analyzed and discussed.

MATERIALS AND METHODS

Patient Population

The hospitalized patients were collected, including 19 patients in the hypertension group, aged 54.61 ± 9.92 years, 9 males and 10 women; 18 patients in the normal blood pressure group, aged 40.11 ± 12.43 years, 7 males and 11 females.

Definitions of hypertension patients according to the 2005 Chinese Guidelines for Prevention and Treatment of Hypertension (the hypertension group):

(1) Clinic systolic BP140-179 mmHg and/or diastolic BP 90-109 mmHg with a past history of hypertension.
(2) LVEF≥55% tested by bioplane-transesophageal echocardiography.
(3) Exclude other cardiovascular disease, diabetes, liver diseases and renal diseases according to the history, physical examination and laboratory findings.

Definitions of healthy population (the normal group):

(1) Exclude primary or secondary cardiopulmonary disease with examinations of physical examination, chest X-ray and echocardiography and so on.
(2) Normal blood pressure without hypertension history.

General anesthesia induction protocol

All patients were asked to fast preoperatively and premedication was withheld. On arrival at the operating theater, patients were placed in the left lying position. An ECG was used to monitor blood oxygen saturation, blood pressure, and heart rate. In two groups, General anesthesia was induced with fentanyl citrate (0.001 mg~0.004 mg/kg), propofol (1.5 mg~2.5 mg/kg), midazolam (1 mg~3 mg), atracurium (0.3 mg) ~ 1.2 mg/kg) by intravenous.

Echocardiography acquisition and measurement indicators

A Hi Vision Preirus ultrasonography system (Hitachi) with a 2.5–5 MHz probe (S70A) and software (TDI, LAVT, color tissue tracking) was used in this study. Transthoracic echocardiography was performed to measure several basic indexes, such as left ventricular end-diastolic dimension (LVEdD) (mm), left ventricular end-systolic diameter (LVEsD) (mm), left ventricular end-diastolic volume (left ventricular end-diastolic volume (LVEdV) (ml), left ventricular end-systolic volume (LVEsV) (ml), left ventricular posterior wall (LVPW) (mm), Stroke volume (SV) (ml), cardiac output (CO) (L / min) and so on (Morgan *et al.* 2017; Mitchell *et al.* 2019).

The left ventricular short-axis basal segment, middle segment of the left ventricle, the left ventricular short-axis apex, apical four-chamber and two-chamber dynamic images in three cardiac cycles were analyzed in the HI VISION PREIRUS color ultrasound diagnostic system (Zimmermann *et al.* 2015). Calculate the tissue spectrum Tei index by the corresponding parameters Peak diastolic tissue velocity Ea (cm/s) in early diastole, late mitral annulus tissue velocity peak velocities Aa (cm/s), Ea/Aa, the sum of isovolumetric contraction time (ICT) and isovolumic relaxation time (IRT) (a-b), ventricular ejection time (ET) (b)(Li *et al.* 2020; Bart *et al.* 2007).

Statistical analysis

All data are presented as the means ± standard deviation (SD). Comparisons between groups were made using independent sample t-tests. All analyses were performed with SPSS17.0 (Chicago, USA). $P < 0.05$ was considered to indicate a statistically significant difference.

RESULTS

Patients characteristics

Nineteen patients with hypertension and 18 patients with normal blood pressure were recruited, and their basic conditions were statistically analyzed, as shown in Table 1. The hypertension group had higher systolic and diastolic blood pressure than the normal blood pressure group, and the difference was statistically significant ($P < 0.05$), height, weight, BSA, heart rate and other differences were not statistically significant.

General echocardiography measurement before and after General anesthesia in two groups

In normal group, the E and Aa peaks were smaller than those before General anesthesia, and the differences were statistically significant as shown in Figure 1 (all $P < 0.05$). While the E, A, Aa and Ea peaks were reduced after General anesthesia in hypertension group, and the differences were statistically significant (all $P < 0.05$). There were no significant differences in other indexes ($P > 0.05$). (Table 2, Figure 1)

Comparison of left ventricular function in two groups

There was no significant difference in the a, b, a-b, and Tei indexes which reflected the overall function of the left ventricle before and after General anesthesia in both group ($P > 0.05$) in Table 4.

Comparison of left atrial function indexes in two groups

There were three indexes (LAVIt, dv/dtE, dv/dtA) decreased obviously after General anesthesia in hypertension group, while there was no significant difference in normal group in Table 5.

There was no significant difference ($P > 0.05$) in left atrial memory function indexes (LAVImax, LAVIpre,

Tab. 3. Comparison of left ventricular strain function indexes before and after General anesthesia in two groups（$\bar{x} \pm s$）

Variable	Normal				Hypertension			
	before General anesthesia	after General anesthesia	*t* value	*P* value	before General anesthesia	after General anesthesia	*t* value	*P* value
BASALmax	23.25±10.32	18.71±9.58	1.349	0.187	23.36±9.04	19.00±9.17	1.373	0.180
BASALmin	4.64±5.86	4.93±5.00	1.501	0.146	4.64±5.86	2.48±6.26	1.025	0.313
BASALS%	15.89±4.84	14.55±5.67	0.752	0.457	19.69±6.43	16.48±5.66	1.548	0.131
BASALT(s)	0.34±0.08	0.31±0.07	1.188	0.243	0.34±0.07	0.32±0.06	0.807	0.426
BASALTSR	50.05±19.36	47.90±16.40	0.355	0.724	60.08±23.93	51.32±16.60	1.240	0.224
MIDmax	27.09±7.15	24.32±9.63	0.982	0.333	24.33±8.20	26.55±12.80	-0.589	0.560
MIDmin	2.22±4.45	1.91±4.50	0.209	0.836	1.94±5.13	2.81±5.00	-0.492	0.626
MIDS%	24.89±6.26	22.13±9.43	1.033	0.309	22.70±7.30	23.72±10.56	-0.329	0.744
MIDT (s)	0.32±0.04	0.30±0.07	0.973	0.338	0.31±0.05	0.32±0.04	-0.392	0.697
MIDSR	79.52±23.36	74.30±29.24	0.592	0.558	74.82±29.50	74.76±33.32	0.005	0.996
APICALmax	21.96±11.53	19.34±9.53	0.718	0.478	23.59±9.42	23.99±11.31	-0.109	0.914
APICALmin	2.82±5.20	2.11±3.40	0.464	0.646	0.58±5.62	2.62±5.87	-1.023	0.314
APICALS%	19.10±9.74	17.21±8.54	0.600.	0.553	23.36±6.70	21.35±8.41	0.771	0.446
APICALT (s)	0.30±0.04	0.30±0.05	-0.207	0.837	0.34±0.07	0.32±0.04	0.841	0.406
APICALSR	64.04±31.74	57.76±27.43	0.613	0.544	72.31±27.95	68.00±30.13	0.432	0.669

Tab. 4. Comparison of global cardiac function indexes before and after General anesthesia in two groups （$\bar{x} \pm s$）

Variable	Normal				Hypertension			
	before General anesthesia	after General anesthesia	*t* value	*P* value	before General anesthesia	after General anesthesia	*t* value	*P* value
a	386.56±34.76	393.17±31.05	-0.602	0.551	399.71±56.86	390.29±38.68	0.564	0.577
b	285.00±21.99	286.61±22.36	-0.218	0.829	286.53±39.77	283.06±29.60	0.289	0.775
a- b	101.56±15.66	106.56±11.94	-1.077	0.289	113.17±21.41	107.24±14.58	0.946	0.351
Tei index	0.36±0.04	0.37±0.03	-1.264	0.215	0.39±0.04	0.38±0.05	0.313	0.756

LAVImin, LAVIt, LAVtEF, dv / dtS), left atrial duct function indexes (LAVIp, LAVpEF, CV, dv / dtE) and left atrial pump function indexes (LAVIa, LAVaEF, and dv / dtA) before and after General anesthesia in both group. (Table 5)

DISCUSSION

General anesthesia induction is a state when surgery can be performed after a patient has established a venous channel under full ECG monitoring, with the help of intravenous sedatives, analgesics and muscle relaxants. In this study, we used fentanyl, propofol, midazolam and atracurium. As known, fentanyl is the most commonly used narcotic analgesic in anesthesia. It has a mild effect on the cardiovascular system, does not inhibit myocardial contractility, and generally does not affect blood pressure. And the most significant effect of propofol is to reduce arterial pressure during the induction of General anesthesia. However, when fetanyl be used in combination with propofol, it will reduce blood pressure obviously. Midazolam has a dose-dependent effect on hemodynamics. Atracurium is eliminated by Hofmann and hypotension is caused by histamine release. And the hemodynamic changes during the General anesthesia induction period are obviously, which may easily lead to myocardial ischemia. In order to maintain a relatively stable state during the induction period, volume control and the use of vasoactive drugs are required to ensure a stable induction period and reduce the occurrence of myocardial ischemia.

In short, General anesthesia induction is a multi-stage influence on hemodynamic changes, which are mainly manifested by myocardial depression, hypotension, increased blood pressure and heart rate.

Due to the chronically high blood pressure in patients with hypertension, the left ventricular afterload continues to increase, and myocardial hypertrophy gradually appear, which increases myocardial stiffness, resulting in decreased myocardial relaxation

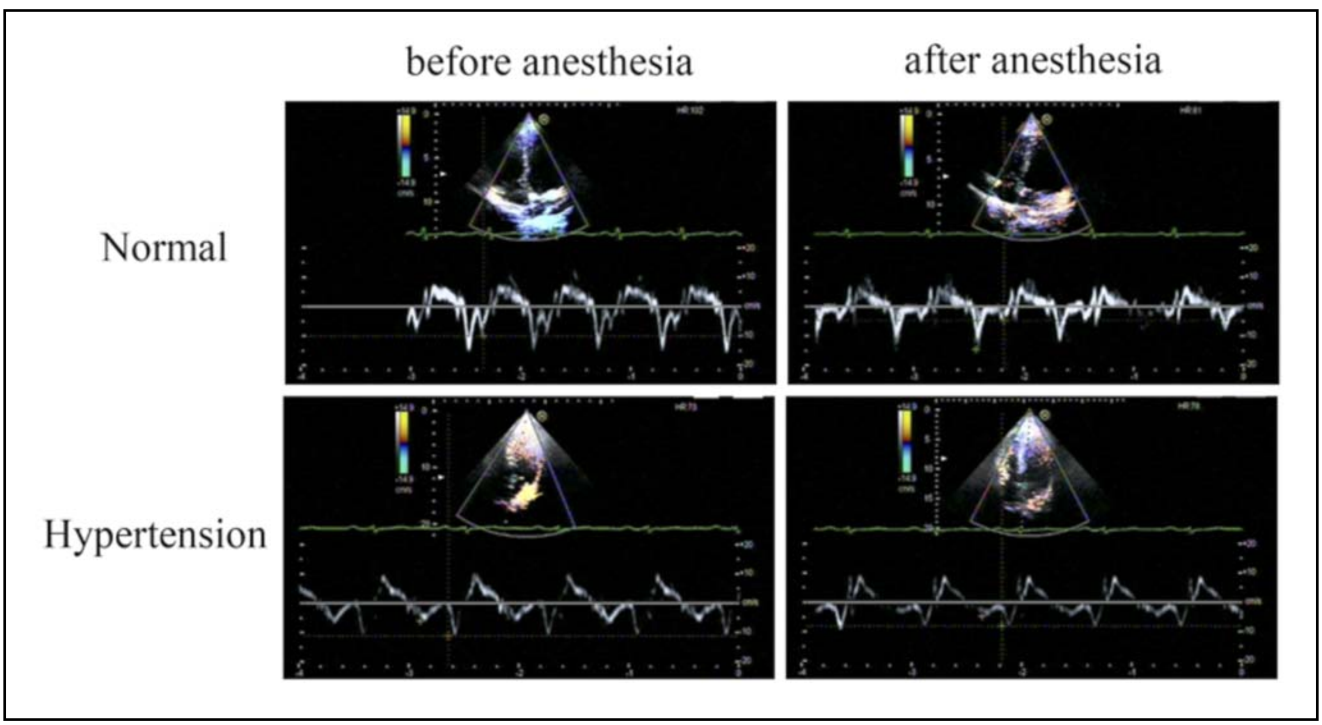

Fig. 3. Mitral annulus tissue Doppler before and after General anesthesia in two groups. In hypertension group, E/A is lower than 1 (E/A <1). In both group, Aa peak all decreased after General anesthesia. While Ea peak reduced after General anesthesia in hypertension group.

Tab. 5. Comparison of left atrial function indexes before and after General anesthesia in two groups（$\bar{x} \pm s$）

Variable	Normal				Hypertension			
	before General anesthesia	after General anesthesia	*t* value	*P* value	before General anesthesia	after General anesthesia	*t* value	*P* value
LAVImax (ml/m^2)	32.18±10.16	25.57±12.10	1.619	0.117	35.87±9.58	30.74±9.16	1.689	0.100
LAVIpre (ml/m^2)	24.11±8.59	19.03±9.79	1.508	0.143	29.59±8.01	25.64±8.19	1.503	0.141
LAVImin (ml/m^2)	18.53±8.38	16.14±8.47	0.777	0.444	22.94±6.53	20.86±7.32	0.926	0.361
LAVIp (ml/m^2)	8.07±3.52	5.91±3.22	1.754	0.090	6.28±3.71	5.1±2.85	1.101	0.278
LAVIa (ml/m^2)	3.64±1.53	2.90±2.18	1.078	0.290	8.40±6.52	6.59±8.59	0.730	0.470
LAVIt (ml/m^2)	11.71±4.36	9.46±4.38	1.425	0.165	12.40±4.50	9.55±3.78	2.114	0.042*
LAVtEF (%)	0.37±0.11	0.37±0.10	0.086	0.932	0.35±0.09	0.32±0.10	1.147	0.259
LAVpEF(%)	0.25±0.10	0.24±0.10	0.362	0.702	0.17±0.08	0.17±0.08	0.308	0.760
CVI (ml/m^2)	23.83±8.71	24.08±10.67	-0.073	0.943	22.36±12.34	22.15±13.57	0.052	0.959
LAVaEF(%)	0.16±0.06	0.14±0.07	0.779	0.443	0.27±0.18	0.24±0.19	0.620	0.539
dv/dtS (ml/s)	195.41±111.54	146.15±110.39	1.216	0.234	235.99±199.58	170.81±94.13	1.288	0.206
dv/dtE(ml/s)	-206.39±122.74	-128.34±85.63	0.244	0.053	-196.09±145.53	-118.69±55.83	-2.164	0.041*
dv/dtA(ml/s)	-104.29±57.98	-102.88±68.98	-0.061	0.952	-227.95±164.44	-132.70±48.65	-2.421	0.025*

* $P<0.05$ vs. before General anesthesia

and diastolic function (Perilhão *et al.* 2020). Current research has shown that left ventricular diastolic function is reduced in patients with hypertension who have an intracardiac structure within the normal range (Gupta *et al.* 2015). Left ventricular hypertrophy caused by hypertension is one of the most important causes of left ventricular diastolic dysfunction.

We found the left atrial function decreased notably during General anesthesia in hypertension group. Comparing before and after General anesthesia in the normal group, there was no significant difference in the storage function, piping function, and booster pump function of the left atrium. However, the storage function, piping function, and booster pump function of patients with hypertension were reduced after General anesthesia. The changes of left atrial structure and function in hypertensive patients reduced atrial structural remodeling which includes atrial enlargement and atrial fibroplasia. Due to the persistent increase in postload, the persistently increased pressure in the atrium of patients with hypertension can increase the expression level of local angiotensin-converting enzymes in the atrial muscle and up-regulate the type I receptor mRNA of angiotensin II which greatly enhances the blood vessels. On the other hand, compared with ventricular muscle fibers, the atrial muscles are thinner, the muscle fiber bundles are grid-like, and the muscle fibers are shorter.

For this special anatomical structure of the atrial muscle fiber, it is more sensitive to pressure changes. Left ventricular postload increased, left ventricular filling pressure increased, left atrial postload increased, atrial muscle contractility increased are the main reasons of that left atrial enlargement can occur before left ventricular hypertrophy and enlargement (Seko *et al.* 2018; Gerdts, 2012). Qin Tingting *et al.* reported that the left atrial storage and piping function of patients with old myocardial infarction were significantly reduced, and the left atrial auxiliary pump function was significantly enhanced; the left atrial auxiliary pump function was well correlated with the overall left ventricular function (Qin *et al.* 20171). LAVT can well reflect the left atrium function in patients with myocardial infarction. Some studies have shown that drug intervention in the early stages of hypertension did not cause a significant dilation of the left atrial diameter or a dilated left atrium (Pierdomenicoi *et al.* 2014), but at the same time the function of the left atrium has changed. In this experiment, the ventricular septal mitral valve annulus was used to detect changes in the normal blood pressure and TDI spectrum of patients with hypertension, and to measure the changes in the mitral valve mouth blood flow spectrum to observe the abnormal left ventricular diastolic function(Amano *et al.* 2013; Mi *et al.* 2013).

In this research, we could well understand the effects of General anesthesia on cardiac function by comparing the changes in left ventricular systolic and diastolic function, left atrial function, and overall left ventricular function under echocardiography before and after induction in patients with normal blood pressure and hypertension. A more reasonable individualized General anesthesia program will be formulated according to blood pressure especially in hypertension patients. Thereby reduce the risk of General anesthesia surgery and increase the success rate of General anesthesia surgery.

Based on the above research, we will increase the number of researchers to further explore the effect of hypertension on cardiac function during induction of General anesthesia.

The overall heart function had no significant changes before and after General anesthesia in normal group. In hypertension group, the left ventricular function had no difference before and after General anesthesia, but the left atrial function was decreased. The effect of General anesthesia on the atrium is greater than that of the ventricle.

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N/A

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the ethics committee of the the First Affiliated Hospital of Jinan University. The study purpose was explained to the participants. Written informed consent was provided by the respondents, based on their willingness to participate in the study.

COMPETING INTERESTS

The authors declare that there are no competing interests associated with the manuscript.

REFERENCES

1 Amano H, Toyoda S, Arikawa T, Inami S, Otani N, Nishi Y, et al. (2013). Left ventricular function in pulmonary hypertension. Heart Vessels. **28**(4): 505–509.

2 Ashes C, Roscoe A (2015). Transesophageal echocardiography in thoracic General anesthesia: pulmonary hypertension and right ventricular function. Curr Opin Anaesthesiol. **28**(1): 38–44.

3 Bart B, Larina V, And AM, Bart J, et al. (2007). Clinical and diagnostic importance of Tei index in patients above age 60 years with chronic heart failure. European J Heart Failure. **10**: 23.

4 Gerdts E (2012). Left atrial enlargement: a prevalent marker of hypertensive heart disease. Blood Press. **21**(2): 71–72.

5 Gupta A, Schiros CG, Gaddam KK, Aban I, Denney TS, Lloyd SG, et al. (2015). Effect of spironolactone on diastolic function in hypertensive left ventricular hypertrophy. J Hum Hypertens. **29**(4): 241–246.

6 Hazari MS, Lancaster JL, Starobin JM, Farraj AK, Cascio WE (2017). Diesel Exhaust Worsens Cardiac Conduction Instability in Dobutamine-Challenged Wistar-Kyoto and Spontaneously Hypertensive Rats. Cardiovasc Toxicol. **17**(2): 120–129.

7 Hinderliter A, Sherwood A, Gullette EC, Babyak M, Waugh R, Georgiades A (2002). Reduction of left ventricular hypertrophy after exercise and weight loss in overweight patients with mild hypertension. Arch Intern Med. **162**(12): 1333–1339.

8 Júnior CG, Botelho ES, Diego LA (2016). Intraoperative monitoring with transesophageal echocardiography in cardiac surgery. Rev Bras Anestesiol. **61**(4): 495–512.

9 Langesæter E, Gibbs M, Dyer RA (2015). The role of cardiac output monitoring in obstetric General anesthesia. Curr Opin Anaesthesiol. **28**(3): 247–253.

10 Li J, Kemp BA, Howell NL, Massey J, Mińczuk K, Huang Q, et al. (2019). Metabolic Changes in Spontaneously Hypertensive Rat Hearts Precede Cardiac Dysfunction and Left Ventricular Hypertrophy. J Am Heart Assoc. **8**(4): e010926.

11 Li TG, Nie F, Xu XY (2020). Correlation between ductus venosus spectrum and right ventricular diastolic function in isolated single-umbilical-artery foetus and normal foetus in third trimester. World J Clin Cases. **8**(23): 5866–5875.

12 Masoudifar M, Beheshtian E (2013). Comparison of cardiovascular response to laryngoscopy and tracheal intubation after induction of General anesthesia by Propofol and Etomidate. J Res Med Sci. **18**(10): 870–874.

13 Mi YP, Abdul-Khaliq H (2013). The pulsed Doppler and tissue Doppler-derived septal E/e' ratio is significantly related to invasive measurement of ventricular end-diastolic pressure in biventricular rather than univentricular physiology in patients with congenital heart disease. Clin Res Cardiol. **102**(8): 563–570.

14 Mitchell C, Rahko PS, Blauwet LA, Au A, Potts j, Morgan CJ, et al. (2019). Guidelines for Performing a Comprehensive Transthoracic Echocardiographic Examination in Adults: Recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr. **32**(1): 1–64.

15 Morgan, Charity J, Vetter, Imelda, Davis, Joshua, et al. (2017). Transthoracic Echocardiography for Diagnosing Pulmonary Embolism: A Systematic Review and Meta-Analysis. J Am Soc Echocardiogr. **30**(7): 714–723.e4.

16 O'Connor JP, Ramsay JG, Wynands JE, Ralley FE, Casey WF, Smith CE,et al. (1989). The incidence of myocardial ischemia during General anesthesia for coronary artery bypass surgery in patients receiving pancuronium or vecuronium. Anesthesiology. **70**(2): 230–236.

17 Perilhão MS, Krause Neto W, da Silva AA, Alves LLS, Antonio EL, Medeiros A, et al. (2020). Linear periodization of strength training in blocks attenuates hypertension and diastolic dysfunction with normalization of myocardial collagen content in spontaneously hypertensive rats. J Hypertens. **38**(1): 73–81.

18 Pierdomenico SD, Pierdomenico AM, Di Carlo S, Di Tommaso R, Cuccurullo F (2014). Left atrial enlargement and risk of ischemic stroke in elderly treated hypertensive patients. Am J Hypertens. **27**(9): 1179–1184.

19 Qin TT, Shen ZY, Qin ZP (2011). Left atrium tracking technique evaluates left atrial function in patients with myocardial infarction. CHINESE JOURNAL OF GERONTOLOGY. **31**(16): 3053–3055.

20 Seko Y, Kato T, Haruna T, Izumi T, Miyamoto S, Nakane E, Inoko M, et al. (2018). Association between atrial fibrillation, atrial enlargement, and left ventricular geometric remodeling. Sci Rep. **8**(1): 6366.

21 Weiner RB, Wang F, Isaacs SK, Malhotra R, Berkstresser B, Kim JH, et al. (2013). Blood pressure and left ventricular hypertrophy during American-style football participation. Circulation. **128**(5): 524–531.

22 Xiong XJ, Li SJ, Zhang YQ (2015). Massage therapy for essential hypertension: a systematic review. J Hum Hypertens. **29**(3): 143–151.

23 Zimmermann H, Rübenthaler J, Rjosk-Dendorfer D, Helck A, Reimann R, Reiser M, et al. (2015). Comparison of portable ultrasound system and high end ultrasound system in detection of endoleaks. Clin Hemorheol Microcirc. **63**(2): 99–111.

24 Zuin M, Rigatelli G, Dell'Avvocata F, Faggian G, Conte L, Giatti S, et al. (2018). Ketamine and midazolam differently impact post-intubation hemodynamic profile when used as induction agents during emergency airway management in hemodynamically stable patients with ST elevation myocardial infarction. Heart Vessels. **33**(3): 213–225.

