



Analysis of Preoperative Transthoracic Echocardiographic Parameters in Elderly Patients Undergoing Emergency Orthopedic Surgery

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Abstract

The number of elderly patients undergoing orthopedic surgery is continuously increasing in Japan. Very elderly patients have limited cardiopulmonary reserves, and complications may induce intraoperative hemodynamic compromise, particularly in an emergency setting. This retrospective study investigated the hemodynamic characteristics of very elderly patients undergoing either emergency or elective orthopedic surgery using preoperative Transthoracic Echocardiography (TTE). We enrolled 125 patients and compared the following TTE parameters between 64 elective and 61 emergency patients using the 2-D Teichholz method: end-diastolic volume, end-systolic volume, stroke volume, ejection fraction, and fractional shortening. Patients undergoing emergency surgery had a significantly lower stroke volume and stroke index, but a significantly higher heart rate than elective patients. The ejection fraction and fractional shortening were not significantly different, and the cardiac index was almost identical between the two groups. Our results suggest that elderly patients undergoing emergency orthopedic surgeries are volume depleted, and their cardiac output is maintained primarily by compensatory activation of the sympathetic nervous system. Preoperative non-invasive TTE examination was capable of evaluating the hemodynamic status of elderly patients undergoing emergency orthopedic surgery. Both general and regional anesthesia may induce cardiovascular instability to varying degrees. Anesthesiologists should respect the importance of preoperative fluid administration and meticulously monitor and manage these patients perioperatively.

Keywords: Elderly; Emergency treatment; Hip fractures; Preoperative care; Transthoracic echocardiography

Introduction

With the continuous aging of populations worldwide, patients undergoing surgery are also getting older. In Japan, the number of orthopedic procedures, particularly for hip fractures, has drastically increased during the past two decades and is expected to rise exponentially [1]. At our hospital, the amount of very elderly patients (meaning those over 80 years old) undergoing orthopedic surgery is rapidly increasing. In addition to their decreased cardiopulmonary reserve [2], elderly patients often experience severe complications that can make their anesthetic management rather challenging. Particularly in emergency settings, maximum vigilance during the induction and maintenance of anesthesia is required to recognize cardiovascular compromise in aged patients. It has been implied that intraoperative hypotension is associated with complications such as acute renal failure and myocardial damage after non-cardiac surgery [3,4]. Considering the narrow safety margin in elderly patients, the maintenance of adequate respiratory and circulatory dynamics during surgery is critically important. Similar to the electrocardiogram and chest X-ray, Transthoracic Echocardiography (TTE) is a non-invasive and useful diagnostic test to assess a patient's status. However, it is still controversial whether preoperative TTE leads to a better prognosis of elderly patients undergoing surgery. Routine preoperative TTE examination is not recommended in non-cardiac surgery [5]. A large cohort study in Canada suggested that preoperative TTE does neither lead to improved survival nor a shorter hospital stay after major non-cardiac surgery [6]. More recently, Yonekura *et al.* [7] reported that, based on a Japanese nationwide database, preoperative TTE was not related with reduced in-hospital mortality or less postoperative complications in hip surgery patients. On the other hand, preoperative cardiac assessment using TTE is recommended

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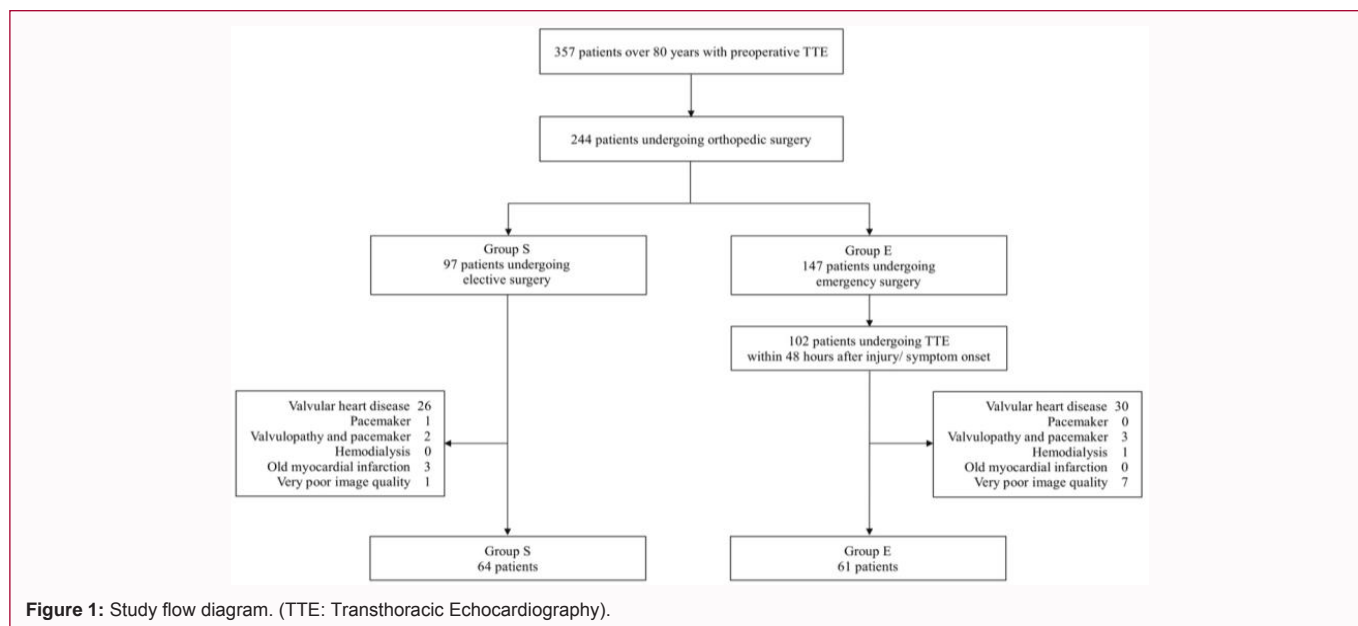


Figure 1: Study flow diagram. (TTE: Transthoracic Echocardiography).

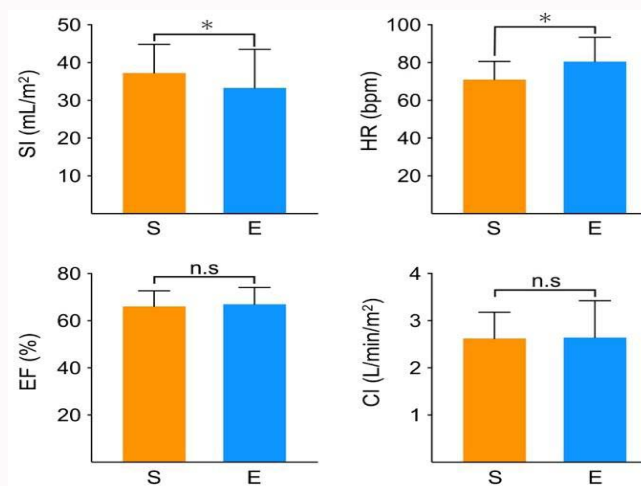


Figure 2: Main results in the present study. Although the SI was significantly lower among patients in group E, their CI was well maintained by a compensatory increase in HR. There was no significant difference in EF between the two groups. Group S includes orthogeriatric patients undergoing elective surgery, whereas group E includes those undergoing emergency surgery.

Data were shown as the mean ± standard deviation.

SI; Stroke Index, CI; Cardiac Index, HR; Heart Rate, EF; Ejection Fraction; * statistically significant

for patients with known valvular heart disease, particularly aortic stenosis, since these patients have an increased risk of hemodynamic instability during surgery [8]. Furthermore, a recent systematic review concluded that preoperative focused echocardiography by the anesthesiologist considerably changed the diagnosis (in 17% to 78% of cases) and patient management (in 12% to 82%) [9]. Consequently, TTE plays a major role in the evaluation of valvular heart disease and ventricular dysfunction. It may help anesthesiologists to adapt the anesthetic technique accordingly and consider the use of inotropes or vasopressors. At our institution, surgery patients over 80 years undergo preoperative TTE whenever time and their condition allow. Several authors have used invasive monitoring to report preoperative hemodynamic parameters such as stroke volume and cardiac output in elderly patients undergoing emergency orthopedic surgery [10,11]. However, few studies have discussed the preoperative status of these patients by focusing on their TTE parameters. This study aimed to analyze the TTE parameters in very elderly patients prior to emergency

orthopedic surgery and identify pathophysiological characteristics that may predict intraoperative hemodynamic instability. The results suggest that these patients suffer from reduced circulatory blood volume, and their cardiac output is maintained primarily by compensatory activation of the sympathetic nervous system.

Materials and Methods

This retrospective study was approved by the Ethics Committee of the Japanese Red Cross Shizuoka Hospital (Approval Number: 2018-14). Instead of obtaining written informed consent from every patient, we had been published an opt-out option on the internet, which allowed patients to decline their participation in the study.

Study population

The study population was selected from all patients over 80 years old who underwent orthopedic surgery at the hospital between April 1, 2018, and March 31, 2019. The emergency surgery group patients

Table 1: Diagnosis of patients in each group. Group S includes orthogeriatric patients undergoing elective surgery, and group E includes those undergoing emergency surgery.

	Group S (n=64)
Lumbar spinal canal stenosis	37
Lumbar disk herniation	2
Lumbar spondylolisthesis	2
Cervical spondylotic myelopathy	7
Ossification of posterior longitudinal ligament	1
Scoliosis	1
Osteoarthritis of the hip joint	1
Osteoarthritis of the knee joint	4
Osteoarthritis of the foot joint	1
Spinal cord tumor	2
Finger tumor	1
Carpal tunnel syndrome	3
Others	2
	Group E (n=61)
Femoral neck fracture	23
Femoral trochanteric fracture	30
Femoral shaft fracture	1
Fracture of upper limb	4
Acute purulent arthritis	2
Intra-articular fracture of the foot	1

were defined those who required early surgical treatment at the time of coming to the hospital and underwent TTE examination within 48 h after the injury or the onset of symptoms. We applied the following exclusion criteria because they distort the focused parameters of TTE: (1) moderate or severe valvular heart disease, (2) pacemaker, (3) maintenance hemodialysis, and (4) old myocardial infarction. A further exclusion criterion was a very poor image quality of the TTE results preventing proper evaluation. Based on their history, patients were divided into two groups: scheduled elective surgery (Group S) and emergency surgery (Group E). The patient flow is depicted in the diagram in Figure 1. A total of 357 patients aged over 80 years underwent preoperative TTE and subsequently underwent surgery. Of these, 244 patients were operated at the Department of Orthopedics. We assigned 97 patients to group S (scheduled elective surgery) and 147 patients to group E (emergency surgery). In group E, 102 patients underwent TTE examination within 48 h after their injury or the onset of symptoms. After excluding 33 and 41 patients in group S and E, respectively, we enrolled 64 patients in group S and 61 patients in group E.

Data collection

Patients' baseline characteristics were recorded and included sex, age, height, body weight, body surface area (BSA, determined with the DuBois formula), diagnosis, and β -blocker, anticoagulant, or antiplatelet therapy. In this study, we defined anticoagulant therapy as warfarin or direct oral anticoagulants, whereas antiplatelet therapy included low-dose aspirin, ticlopidine hydrochloride, clopidogrel sulfate, and cilostazol. Two-dimensional TTE was performed by experienced laboratory medical technologists with the Philips iE33 ultrasound system (Philips Ultrasound Inc., Bothell, WA, US). For this analysis, the data were extracted from the examination reports.

Table 2: Demographic and echocardiographic characteristics among patients in both groups. Group S includes orthogeriatric patients undergoing elective surgery, and group E includes those undergoing emergency surgery. Since heart rate was not reported in only 1 patient of group E, the number of patients for the analysis of HR/CO/CI in the group was 60. Data were shown as the mean \pm standard deviation.

	Group S (n=64)	Group E (n=61)	P-value
Age, year	83 \pm 5	87 \pm 5	<0.001*
Sex, female, n (%)	33 (51.6)	53 (86.9)	<0.001*
Height, cm	153 \pm 10	150 \pm 7	0.059
Weight, kg	54 \pm 10	47 \pm 9	<0.001*
BSA, m ²	1.50 \pm 0.17	1.39 \pm 0.14	<0.001*
Beta-blocker medication, n (%)	6 (9.4)	6 (9.8)	>0.999
Anticoagulant or antiplatelet therapy, n %	15 (23.4)	10 (16.4)	0.376
EF, %	66.1 \pm 6.6	67.0 \pm 7.1	0.446
FS, %	36.4 \pm 4.8	36.9 \pm 5.3	0.621
SV, mL	55.9 \pm 13.0	46.3 \pm 14.7	<0.001*
SI, mL/m ²	37.2 \pm 7.6	33.3 \pm 10.2	<0.05*
EDV, mL	85.0 \pm 18.9	69.3 \pm 21.4	<0.001*
ESV, mL	29.1 \pm 9.7	23.8 \pm 10.0	<0.01*
Heart rate, beat/min	71.1 \pm 9.7	80.6 \pm 12.9	<0.001*
Cardiac output, L/min	3.93 \pm 0.86	3.66 \pm 1.15	0.145
Cardiac index, L/min/m ²	2.62 \pm 0.26	2.64 \pm 0.78	0.877

BSA: Body Surface Area; EF: Ejection Fraction; FS: Fractional Shortening; SV: Stroke Volume; SI: Stroke Index; EDV: End-Diastolic Volume; ESV: End-Systolic Volume; * statistically significant

Any regurgitant valvular disease was assessed with the color Doppler method by more than one expert, and the severity of valvular stenosis was evaluated using the continuous wave Doppler method. Each valvulopathy was classified based on its degree of severity into four classes: trivial, mild, moderate, and severe. TTE parameters reflecting volume status such as End-diastolic volume (EDV), End-Systolic Volume (ESV), and Stroke Volume (SV) were calculated with the 2-D Teichholz method [12] as were the Ejection Fraction (EF) and Fractional Shortening (FS). The left ventricular outflow tract Doppler method [13] may also be used to obtain stroke volume, in which case Cardiac Output (CO) is calculated by a recently described method reported to correlate with the value measured with thermodilution method [14]. We calculated SV by subtracting ESV from EDV, both of which were calculated using the 2-D Teichholz method. Further, we collected data on the heart rate (HR) during the examination noted in the TTE report and the CO (SV \times HR). The SV was divided by the BSA to obtain the Stroke Index (SI) corrected for sex and body size in each group. The Cardiac Index (CI) was calculated as SI \times HR.

Data analysis

Continuous variables were expressed as the mean \pm Standard Deviation (SD) unless otherwise mentioned and compared using the Student's *t*-test. Qualitative variables were compared using Fisher's exact test. A *p*-value of less than 0.05 was considered to be statistically significant. All statistical analyses were performed with the Prism software version 7 (GraphPad Software, La Jolla, CA, US).

Results

Patients characteristics and TTE parameters

Table 1 shows the clinical diagnoses of patients in each group. Patients in group S had diverse diseases ranging from lumbar and

Table 3: Demographic and echocardiographic characteristics among patients in group S and group EH (only including patients with hip fractures in group E). Group S includes orthogeriatric patients undergoing elective surgery, and group E includes those undergoing emergency surgery. Hip fractures indicate femoral neck and trochanteric fractures. Since heart rate was not reported in only 1 patient of group EH, the number of patients for the analysis of HR/CO/CI in the group was 52. Data were shown as the mean \pm standard deviation.

	Group S (n=64)	Group E (n=61)	P-value
Age, year	83 \pm 3	87 \pm 5	<0.001*
Sex, female, n (%)	33 (51.6)	46 (86.8)	<0.001*
Height, cm	153 \pm 10	150 \pm 8	0.101
Weight, kg	54 \pm 10	46 \pm 9	<0.001*
BSA, m ²	1.50 \pm 0.17	1.39 \pm 0.14	<0.001*
Beta-blocker medication, n (%)	6 (9.4)	6 (11.3)	0.767
Anticoagulant or antiplatelet therapy, n %	15 (23.4)	9 (17.0)	0.492
EF, %	66.1 \pm 6.6	66.7 \pm 7.4	0.642
FS, %	36.4 \pm 4.8	36.6 \pm 5.4	0.845
SV, mL	55.9 \pm 13.0	45.2 \pm 15.2	<0.001*
SI, mL/m ²	37.2 \pm 7.6	32.6 \pm 10.6	<0.01*
EDV, mL	85.0 \pm 18.9	68.0 \pm 22.4	<0.001*
ESV, mL	29.1 \pm 9.7	23.7 \pm 10.5	<0.01*
Heart rate, beat/min	71.1 \pm 9.7	81.2 \pm 13.2	<0.001*
Cardiac output, L/min	3.93 \pm 0.86	3.60 \pm 1.21	0.089
Cardiac index, L/min/m ²	2.62 \pm 0.26	2.60 \pm 0.83	0.873

BSA: Body Surface Area; EF: Ejection Fraction; FS: Fractional Shortening; SV: Stroke Volume; SI: Stroke Index; EDV: End- Diastolic Volume; ESV: End-Systolic Volume; * statistically significant

cervical spine disorders to minor extremity tumors. Fifty-three out of 61 patients in group E had hip fractures (femoral neck or trochanteric fracture). Table 2 compares patients' characteristics and TTE parameters between both groups. Patients in group S were significantly younger than those in group E (83 \pm 3 vs. 87 \pm 5, years old; $p < 0.001$). The proportion of females was significantly higher in group E (51.6% in group S vs. 86.9% in group E; $p < 0.001$), resulting in the lower mean body weight and smaller mean BSA of patients in group E. The SV was significantly lower among patients in group E compared with that of patients in group S, as were the EDV and ESV. While the SI was also significantly lower (by approximately 10%) in group E than that in group S, the CI was almost identical in both groups. Both the EDV and ESV corrected by BSA were significantly lower in group E than those in group S (data not shown). As shown in Table 1, patients with hip fracture comprised a large proportion of patients in group E. Therefore, we performed a subgroup analysis comparing hip fracture patients (N=53) with all patients in group S (Table 3). The results of this comparison corresponded to those shown in Table 2. Hip fracture patients had a CI (2.60 \pm 0.83 L/min/m²) in a similar range as patients in group S (2.62 \pm 0.26 L/min/m²; $p = 0.873$).

The SI (32.6 \pm 10.6 mL/m²) and CI (2.60 \pm 0.83 L/min/m²) of hip fracture patients (Table 3) were in agreement with the values reported by Messina *et al.* [10] who used the invasive LiDCO™ plus monitor (LiDCO, London, UK) to measure them. They demonstrated that in patients undergoing hip surgery, the baseline SI was about 30 mL/m², and the CI was 2.6 L/min/m². It seems that these results partly support the validity of those in our study. Our results for the comparison of the HR, EF, SI, and CI between group E and S are illustrated in

Figure 2. Although the SI was significantly lower among patients in group E, their CI was well maintained by a compensatory increase in their heart rate. The present study might provide insights into the pathophysiological characteristics of very elderly patients undergoing emergency orthopedic surgeries.

Discussion

The aim of our study was to analyze the pathophysiological TTE characteristics that may predict intraoperative hemodynamic instability in very elderly patients undergoing emergency orthopedic surgery. We demonstrated that these patients had a significantly lower SI compared with those undergoing elective surgery. The EF and FS were not significantly different between the two groups. The maintained CI in emergency patients resulted from a compensatory increase in their heart rate. These findings imply that these patients were volume-depleted when TTE was conducted, and the hypovolemia had activated their sympathetic nervous system. We focused on patients with femoral neck and trochanteric fractures undergoing emergency surgery because hip fractures are a worldwide concern with high morbidity, mortality, and cost, particularly in aged populations [15]. Some authors claimed that preoperative TTE is time-consuming, costly, and does not improve prognosis in elderly patients with hip fractures [16,17]. Furthermore, a delay of surgery in these patients of more than 48 h is reported to increase all-cause mortality and postoperative morbidity [18,19]. Consequently, routine preoperative TTE is not recommended in these patients undergoing non-cardiac surgery, including emergency hip surgery. At the same time, TTE plays a significant role in identifying cardiac pathology, such as valvular heart disease and abnormal wall motion, which may prompt anesthesiologists to reconsider the planned anesthetic technique. Some authors advocate preoperative TTE to be conducted in all hip surgery patients with undiagnosed cardiac murmurs [20]. At our hospital, preoperative TTE is undertaken as a routine screening in all surgical patients over 80 years old whenever feasible. Recently, a large cohort study in Japanese patients with hip fractures showed that preoperative TTE was not associated with reduced in-hospital mortality [7]. However, this in-hospital mortality was still much lower than that reported in other countries [21,22] despite a longer delay of surgery in Japanese patients. These findings imply that the usefulness of preoperative TTE in elderly patients undergoing hip surgery varies depending on the socioeconomic development and accessibility to healthcare in different countries, and we should not dismiss preoperative TTE imprudently. It is reasonable to assume that our patients with hip fractures undergoing emergency surgery were hypovolemic because of bleeding from the fractured bone and/or inadequate fluid administration. It has been reported that general anesthesia reduces the CI and Mean Arterial Pressure (MAP) more than spinal anesthesia in aged patients with hip fractures. It was also demonstrated that the heart rate did not adequately increase to counterbalance the MAP reduction under general anesthesia [10]. Furthermore, the mechanism of hypotension during spinal anesthesia in hip surgery patients over 80 years is primarily a decrease in systemic vascular resistance rather than a low CO [11]. In our study, emergency patients received TTE within 48 h after the injury and then underwent surgery within 1.79 days (mean) after the examination (data not shown). Unless adequate volume resuscitation is performed during this period, anesthesia-induced depression of sympathetic activity is bound to induce substantial hemodynamic compromise in these patients. As for the patients who we excluded because of pre-existing severe comorbidities, we hypothesize that

they were also volume-depleted and would have been even more susceptible to anesthesia-related hemodynamic instability. There are several limitations to our study. First, because of its retrospective nature, the characteristics of patients differed between the two groups with regard to the gender ratio, body size, and diagnoses. Only a few patients underwent elective hip surgery during the study period. However, we believe that the reason for elective surgery is not critical in this comparison. Further, we converted the SV and CO into the SI and CI, allowing a comparison of the volume status regardless of these differences between the two groups. Second, patients with β -blocker, anticoagulant, or antiplatelet therapy were included in the analysis. However, the ratio of patients taking these drugs was not significantly different between the groups (Table 2). Usually, β -blockers are continued until the day of surgery to avoid rebound hypertension, whereas anticoagulant and antiplatelet therapy is often changed to bridging heparinization before surgery. We think that analyses including these patients should reflect real-world settings. Third, it cannot be excluded that pain from the fracture influenced the sympathetic activation in patients undergoing emergency surgery. However, very elderly patients with hip fractures rarely complain of pain unless the fractured limb is moved by an external force. Finally, although the latest hemoglobin level before the TTE in group E was significantly lower than that in group S (data not shown), we did not refer to this result since hemoglobin levels are largely determined by sex and substantially affected by the volume status.

Conclusion

Preoperative TTE examination is useful in evaluating the hemodynamics of elderly patients undergoing emergency orthopedic surgery. Our results show that these patients are volume depleted, and their cardiac output is maintained primarily by compensatory activation of the sympathetic nervous system. Anesthesiologists should be aware of the importance of preoperative fluid administration and carefully monitor and manage the hemodynamics in these patients.

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