

Impact of right ventricular systolic pressure in elderly patients admitted to intensive care unit after femur fracture surgery

A retrospective observational study

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Abstract

The number of femoral fractures is expected to continue to increase as the size of the older population rapidly grows. However, old age is accompanied by various comorbidities and is an important postoperative risk factor in itself, meaning that patients who undergo surgery for a femur fracture may require admission to an ICU. We investigated pulmonary complications in patients over the age of 65 admitted to the ICU after femur fracture surgery.

In this single-center retrospective observational study, 289 patients over 65 years who admitted to the ICU after femur fracture surgery between June 2008 and December 2016 were investigated.

Pulmonary complications occurred in 97 of these patients (33.6%) after surgery. Mean hospitalization days (34.1 ± 25.7 vs 23.1 ± 15.7 , $P < .001$) and mean ICU length of stay (8.4 ± 16.1 vs 2.5 ± 1.1 , $P = .001$) were significantly longer for patients with pulmonary complications than for patients without pulmonary complications after femur fracture surgery. Patients with pulmonary complications were significantly more likely to have pulmonary disease (19.6% vs 8.9%, $P = .009$) and exhibit sequelae on preoperative chest X-rays (9.3% vs 3.6%, $P = .048$) than were patients without pulmonary complications. In addition, significant differences were observed in the right ventricular systolic pressure (RVSP) measured during preoperative echocardiography (37.4 ± 10.9 mmHg vs 40.7 ± 9.3 mmHg for patients without and with pulmonary complications, $P = .010$) and in the proportion of each group that had an RVSP of >35 mmHg, which is a marker for pulmonary hypertension (55.2% vs 76.3% for patients without and with pulmonary complications, $P < .001$). In multivariate analysis, an RVSP of >35 mmHg during preoperative echocardiography was associated with pulmonary complications after femur fracture surgery (OR, 2.6; 95% CI, 1.45–4.53).

In conclusion, Pulmonary complications in older patients admitted to the ICU after femur fracture surgery was associated with longer hospitalization and ICU stays. Preoperative RVSP measurement could identify those older patients with a high risk of pulmonary complications following transfer to the ICU after femur fracture surgery.

Abbreviations: ASA = American Society of Anesthesia, BMI = body mass index, CCI = Charlson comorbidity index, CI = confidence interval, E/E' = ratio of the mitral peak velocity of early filling to early diastolic mitral annular velocity, ICU = intensive care unit, OR = odds ratio, PTE = pulmonary thromboembolism, RVSP = right ventricular systolic pressure.

Keywords: aged, femoral fractures, hip fractures, intensive care units, pulmonary complication

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1. Introduction

Femur fractures are rare in the younger population, especially those under 50,^[1,2] but increase with age.^[2,3] These fractures can lead to various health problems, such as difficulty walking and mortality.^[4–6] According to recent data, the number of people over the age of 65 has increased rapidly worldwide; it is predicted to increase from ~500 million in 2010 to ~1.5 billion in 2050, with the population older than 65 predicted to exceed the population under 5 years old by the same year.^[7] As a result of this trend, the incidence of femur fractures is expected to increase continuously to reach 4.5 million cases in 2050.^[8]

In 2000, South Korea became an aging society, which means that the proportion of the population that was aged over 65 years exceeded 7%.^[9] South Korea has since become an aged society, defined as one in which 14% of the population is over the age of 65, just 17 years after becoming an aging society.^[9] Yoon et al reported that the incidence of femur fractures in South Korea was high among the older population.^[10] As the size of the older population grows, the incidence of femur fractures is also expected to increase in South Korea.^[10,11]

The main treatment for femur fractures is surgery,^[12,13] thus the frequency of this type of surgery will also increase among the older population. However, older patients are likely to present various comorbidities, including diabetes mellitus, hypertension, and other chronic diseases, while old age is an important postoperative risk factor in itself.^[14,15] Therefore, patients who undergo surgery for a femur fracture may need admission to an intensive care unit (ICU) for the monitoring or management of postoperative complications. Of the many possible postoperative complications, One of the most common postoperative complications is pulmonary complications.^[16]

There have been few studies on patients admitted to the ICU after surgery for a femur fracture. We, thus, investigated the demographic characteristics and pulmonary complications of patients over the age of 65 who were admitted to the ICU after femur fracture surgery.

2. Methods

2.1. Study design and patients

This analytical single-center clinical study with an evidence level of II was conducted retrospectively with patients admitted to the ICU after surgery for a femur fracture at Ewha Womans University Mokdong Hospital, a referral hospital with a 759-bed capacity, from July 2008 to December 2016. During this period, a total of 1592 patients underwent surgery for a femur fracture, and 337 of these patients were admitted to the ICU after surgery. Of this sub-group, we excluded patients with pulmonary problems prior to surgery, those under the age of 65, and those who received emergency femur fracture surgery (i.e., only those patients who received elective surgery were enrolled). This was because an emergency preoperative status, which often involves multiple bone injuries or organ injury, might significantly affect the postoperative outcomes. We defined elective surgery as those cases in which a preoperative evaluation had been completed and the surgery had been scheduled in advance, while emergency surgery was defined as those cases in which surgery was performed urgently without a pre-operative evaluation because of the high risk to life and/or the high probability of disability.

In total, 289 patients over the age of 65 who were patients to preoperative evaluation were included in this study. They were

then divided into two groups based on whether or not they experienced pulmonary complications in the ICU.

2.2. Data collection and covariates

Data for all enrolled patients were collected from the electronic medical records of the hospital. The demographic characteristics that were considered were age, sex, medical history, and the cause and the site of the femur fracture. The operating and anesthesia time and the method of surgery were determined by referring to the patient's anesthesia and surgical records. The potential effect of pre-existing comorbidities was calculated using the Charlson comorbidity index (CCI),^[17] and the physiological status of the patient before surgery was evaluated using the American Society of Anesthesia (ASA) classification.^[18]

Echocardiography data were obtained within 2 weeks before surgery, including the ejection fraction, right ventricular systolic pressure (RVSP), and ratio of the mitral peak velocity of early filling to the early diastolic mitral annular velocity (E/E'). Preoperative cardiomegaly was defined as a cardio-thoracic ratio over 0.5 and evaluated using posteroanterior chest X-rays within a week before surgery. In this study, pneumonia, atelectasis, pulmonary edema, pulmonary embolism, pleural effusion, and respiratory failure requiring mechanical ventilation were investigated as postoperative pulmonary complications.^[19] Pneumonia was defined as patients having a higher sputum volume, new infiltration in radiography, and signs of systemic infection.^[20] Atelectasis, pulmonary edema, and pleural effusion were confirmed by radiography or ultrasonography. Pulmonary embolism was defined only for those patients for which it was confirmed using computed tomographic pulmonary angiography. Respiratory failure was defined as requiring invasive mechanical ventilation for any reason.

2.3. Ethics approval and consent to participate

This study protocol was approved by the Institutional Review Board of Ewha Womans University Mokdong Hospital (IRB File No: 2018-06-042). All methods were performed in accordance with the relevant guidelines and regulations. Informed consent was waived by the IRB because of the study's retrospective nature.

2.4. Statistical analysis

All statistical analyses were performed using SPSS version 23.0 (IBM, Armonk, NY). All continuous data are presented as the mean \pm standard deviation, and all categorical data are presented as counts and corresponding percentages. Univariate analyses were conducted on groups according to the presence or absence of pulmonary complications using Student's *t* tests or χ^2 tests. Multivariate analysis was used to identify risk factors for pulmonary complications based on logistic regression. In this analysis, age, sex, body mass index (BMI), CCI, and ASA classification were controlled for, while those variables found to be significant in the univariate analysis were included. In all comparisons, a *P*-value of $<.05$ was considered statistically significant.

3. Results

3.1. Clinical characteristics of patients with femur fractures admitted to the ICU after surgery

During the study period, 337 femur fracture patients were admitted to the ICU after surgery. Of these, 308 (91.4%) were

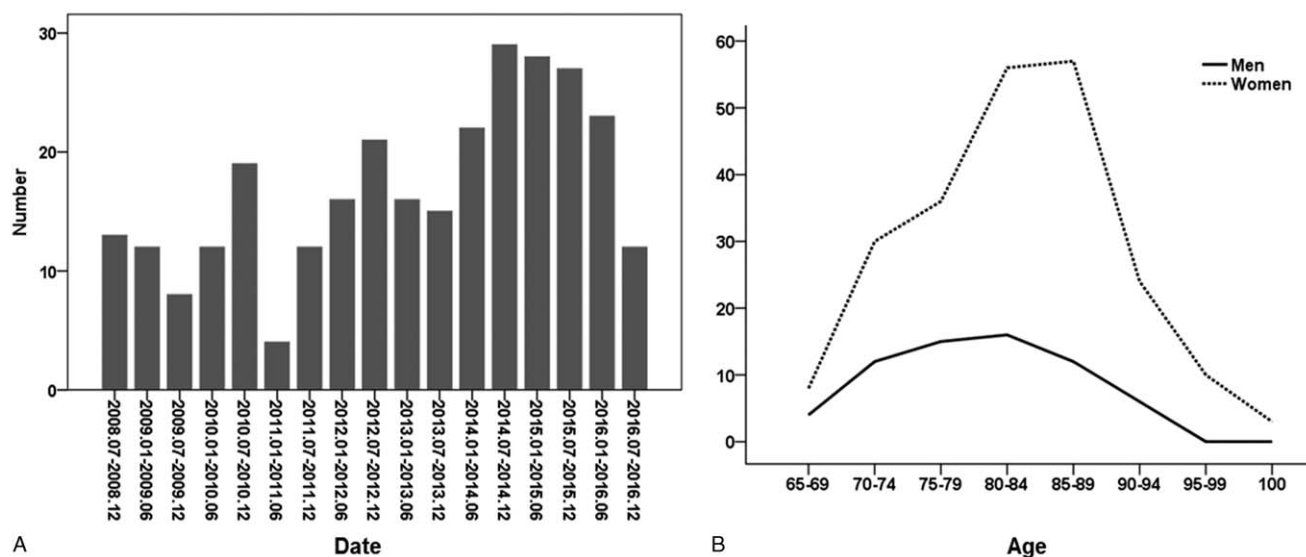


Figure 1. Number of patients admitted to the intensive care unit after femur fracture surgery .

over 65 years old, and 245 (72.7%) were women. The 29 patients under 65 years of age consisted of 21 (72.7%) men, and traffic accidents (10/29, 34.5%) and slipping (9/29, 31%) were the primary causes of fractures for those under 65 years old. Of the 308 patients over 65 years old, 237 (70.1%) were women, and slipping (274/308, 89%) was the most common cause of fractures.

Preoperative evaluation, including echocardiography, was conducted on 289 of the patients aged 65 years and older admitted to the ICU after elective femur fracture surgery; these patients were enrolled in the present study. The number of patients admitted to the ICU after femur fracture surgery has been recorded at the center since 2006 (Fig. 1A). Women aged 80 to 89 years old and men aged 75 to 84 years old represented the largest proportion of patients admitted after femur fracture surgery (Fig. 1B). Slipping was the main cause of femur fractures, and the fractures were evenly distributed between the right and left leg. During surgery, 166 (57.4%) received closed reduction internal fixation, 33 (11.4%) received open reduction internal fixation, and 90 (31.1%) received hemiarthroplasty as treatment for their fractures. At the time of ICU admission, 31 patients required intubation. Of these patients, 10 were extubated within 24h, while 17 patients contracted pneumonia. Pulmonary complications, including pneumonia, atelectasis, pulmonary edema, pulmonary embolism, pleural effusion, and respiratory failure, were observed in 97 patients (33.6%) after surgery. A total of nine patients died after surgery due to pan-peritonitis, cerebrovascular accident, myocardial infarction, pneumonia, or asphyxia. Other baseline characteristics for the study population are presented in Table 1.

3.2. Prognosis according to the presence and type of pulmonary complication

Hospitalization (34.1 ± 25.7 days vs 23.1 ± 15.7 days, $P < .001$) and ICU length of stay (8.4 ± 16.1 days vs 2.5 ± 1.1 days, $P = .001$) were significantly higher in patients with pulmonary complications than in those patients without pulmonary

complications after femur fracture surgery (Table 2). Pneumonia (29.7%) was the leading cause of pulmonary complications, followed by pulmonary edema (25.2%). Forty-six patients (47.4%) experienced two or more pulmonary complications. The all-cause mortality rate was significantly higher in patients with pulmonary complications (8.2%; 8/97) than in those without pulmonary complications (0.5%; 1/192).

3.3. Comparison between patients with and without pulmonary complications

The study patients were divided into two groups based on the presence or absence of pulmonary complications, and potential risk factors for pulmonary complications were then examined. Table 3 shows the results of univariate and multivariate analyses for the two groups. In the univariate analysis, there were no significant differences between the two groups in terms of age, sex, BMI, CCI, or the presence of various chronic diseases (diabetes mellitus, hypertension, heart failure, coronary artery occlusive disease, and previous cerebrovascular accident). The waiting time between fracture and surgery, cardiomegaly observed in preoperative chest X-rays, and ASA classification before femur fracture surgery were also not significantly different between the groups. During surgery, the operating time, anesthesia time, use of transfusion, and surgical procedures were also similar between the groups. However, a significantly higher number of patients with pulmonary complications after surgery had pulmonary disease, including chronic obstructive pulmonary disease, asthma, tuberculosis-destroyed lungs, and a history of recent pneumonia, compared to patients without pulmonary complications (19.6% vs 8.9%, respectively, $P = .009$). Similarly, patients who experienced pulmonary complications after surgery were more likely to have exhibit sequelae on preoperative chest X-rays than patients who did not experience complications (9.3% vs 3.6%, respectively, $P = .048$). In addition, preoperative echocardiography measures differed significantly between the two groups. Significant differences were observed in RVSP (37.4 ± 10.9 mmHg vs 40.7 ± 9.3 mmHg

Table 1
Demographic and clinical characteristics of the total study population.

Characteristics	N=289
Age, years	82.0 ± 7.4
Sex	
Men	65 (22.5)
Women	224 (77.5)
BMI, kg/m ²	21.9 ± 3.6
Interval between fracture and operation, days	5.8 ± 9.7
Hypertension	194 (67.1)
Diabetic mellitus	78 (27.0)
Old cerebrovascular accident	84 (29.1)
Dementia	63 (21.8)
CCI	1.81 ± 1.7
General anesthesia	288 (99.7)
ASA classification	2.51 ± 0.04
Operation time, min	92.8 ± 57.0
Anesthesia time, min	150.4 ± 60.7
Cause of fracture	
Slipping	258 (89.3)
Fall from bed	15 (5.2)
Traffic accident	8 (2.8)
Assault	1 (0.3)
Unknown vector	7 (2.4)
Site of femur fracture	
Proximal femur fracture*	263 (91.0)
Distal and shaft fracture	26 (9.0)
Right	149 (51.6)
Left	139 (48.1)
Both	1 (0.3)
Surgery procedure	
CR/IF	166 (57.4)
OR/IF	33 (11.4)
Hemiarthroplasty	90 (31.1)
Development of pulmonary complications after surgery	97 (33.6)
Hospitalization, days	26.8 ± 20.3
Mortality	9 (3.1)

Figures are presented as counts with the percentage in parentheses or the mean ± standard deviation, unless otherwise indicated.

ASA = American Society of Anesthesiologists, BMI = body mass index, CCI = Charlson comorbidity index, CR/IF = closed reduction internal fixation, OR/IF = open reduction internal fixation.

* Proximal femur fracture included the femoral neck, intertrochanteric, pertrochanteric, and subtrochanteric areas.

for those without and with pulmonary complications, respectively, $P = .010$) and in the proportion of patients with an RVSP >35 mmHg (55.2% vs 76.3% for those without and with pulmonary complications, respectively, $P < .001$).^[21] E/E', representing the diastolic function of the left ventricle,^[22,23] was also significantly different between the two groups (13.2 ± 5.2 vs 15.2 ± 5.7 for those without and with pulmonary complications, respectively, $P = .008$), and an E/E' >15 was significantly more common in the group with pulmonary complications (44.7% vs 25.8%, $P = .003$). Multivariate analysis was conducted using significant variables from the univariate analysis (i.e., pulmonary disease, RVSP >35 mmHg and sequelae on chest X-ray) and the control variables age, sex, BMI, CCI, and ASA classification. E/E' was not included in this analysis because of missing values. In the multivariate analysis, only an RVSP higher than 35 mmHg during preoperative echocardiography was associated with pulmonary complications after femur fracture surgery (odds ratio [OR]: 2.6; 95% confidence interval [CI]: 1.45–4.53).

3.4. Subgroup analysis of patients admitted to the ICU after proximal femur fracture surgery

We conducted additional analysis of the 263 patients with a proximal femur fracture (i.e., a fracture of the femoral neck, intertrochanteric, pertrochanteric, or subtrochanteric area) to control for the effects of the fracture site because this has been shown to affect mortality and treatment methods.^[24,25] Baseline characteristics and prognosis according to pulmonary complications are described in Supplementary table 1, <http://links.lww.com/MD/F108> and 2, <http://links.lww.com/MD/F109>. Table 4 compares patients with or without pulmonary complications admitted to the ICU after proximal femur fracture surgery. Consistent with the findings for all of the femur fracture patients, those who underwent proximal femur surgery and experienced subsequent pulmonary complications were significantly more likely to have pulmonary disease (20.5% vs 8.6%, respectively, $P = .006$) and exhibit sequelae on preoperative chest X-rays (9% vs 4%, $P = .046$) compared with patients without pulmonary complications. In addition, a significant difference was observed in RVSP during preoperative echocardiography (37.9 ± 11.1 mmHg vs 41.3 ± 9.4 mmHg for those patients without and with pulmonary complications, respectively, $P = .015$) and the percentage of patients with an RVSP higher than 35 mmHg (57.1% vs 77.3% for those patients without and with pulmonary complications, respectively, $P = .001$). In the multivariate analysis, only RVSP >35 mmHg during preoperative echocardiography was significantly associated with pulmonary complications in this subgroup (OR: 2.5; 95% CI: 1.34–4.52).

4. Discussion

This study found that most patients admitted to the ICU after femur fracture surgery were women, and most fractures were caused by slipping. Although the mortality rate after ICU admission was low (3.1%), pulmonary complications developed in 33.6% of the patients. RVSP was the most powerful predictor of pulmonary complications among these patients.

Previous research in South Korea has reported that femur fractures are more than twice as frequent in women than in men, with a peak incidence age of 75 to 79 in women and 70 to 74 in men.^[10] Because our study patients included only patients admitted to the ICU, our patients were on average older than those in previous Korean studies. On the other hand, our mortality rate of 3.1% (9/289) was lower than previously reported femur fracture-associated mortality rates,^[26–30] which may be because we only included elective surgery and omitted emergency surgery, while the major cause of the fractures was slipping.

According to a recent large national database study (n = 31,738), various complications have been reported after femur fracture surgery, and pulmonary complications, including pneumonia and pulmonary thromboembolism (PTE), account for a significant proportion of these complications.^[30] Pulmonary complications for older femur fracture patients can be severe and life-threatening.^[28,31] We found that patients with pulmonary complications after femur fracture surgery experienced higher mortality rates and longer hospitalization and ICU stays compared to patients without pulmonary complications. In the multivariate analysis of variables found to be significant in univariate analysis, RVSP during preoperative echocardiography was revealed to be predictive of pulmonary complications. RVSP indirectly estimates pulmonary artery systolic pressure in patients

Table 2**Comparison of prognosis between patients with or without pulmonary complications.**

Variable	Without pulmonary complication (n = 192)	With pulmonary complication (n = 97)	P
Hospitalization, days	23.1 ± 15.7	34.1 ± 25.7	<.001
ICU stay, days	2.5 ± 1.1	8.4 ± 16.1	.001
Pulmonary complication			
Pneumonia		46 (29.7)	
Atelectasis		9 (5.8)	
Pulmonary edema		39 (25.2)	
Pulmonary embolism		8 (5.2)	
Pleural effusion		20 (12.9)	
Respiratory failure requiring mechanical ventilation		33 (21.3)	
≥2 pulmonary complications		46 (47.4)	
Mortality	1 (0.5)	8 (8.2)	.001
Immediate cause of death			
Pan peritonitis		1	
Cerebrovascular accident	1		
Myocardial infarction		1	
Pneumonia		5	
Asphyxia		1	

Figures are presented as counts with the percentage in parentheses or the mean ± standard deviation, unless otherwise indicated.
ICU = intensive care unit.

Table 3**Comparison of clinical and demographic parameters between patients with and without pulmonary complications.**

Variable	Univariate			Multivariate	
	Without pulmonary complication (n = 192)	With pulmonary complication (n = 97)	P	OR [†] (95% CI)	P
Age, years	81.8 ± 7.4	82.2 ± 7.4	.572	1.0 (0.97–1.05)	.580
Sex, men	37 (19.3)	28 (28.9)	.065	0.6 (0.35–1.19)	.159
BMI, kg/m ²	21.9 ± 3.6	21.8 ± 3.6	.906	1.0 (0.94–1.09)	.755
Diabetic mellitus	54 (28.1)	24 (24.7)	.541		
Hypertension	125 (65.1)	69 (71.1)	.303		
Heart failure	26 (13.5)	19 (19.6)	.181		
CAOD	27 (14.1)	17 (17.5)	.439		
Dementia	44 (22.9)	19 (19.6)	.517		
Old cerebrovascular accident	58 (30.2)	26 (26.8)	.547		
Pulmonary disease	17 (8.9)	19 (19.6)	.009	1.8 (0.87–3.85)	.114
CCI	1.7 ± 1.7	2.0 ± 1.8	.148	1.1 (0.94–1.30)	.234
Ever smoker	18 (9.4)	10 (10.3)	.800		
Interval between fracture and operation, days, median, IQR	3 (2–5)	3 (3–6.5)	.337		
RVSP	37.4 ± 10.9	40.7 ± 9.3	.010		
RVSP >35 mmHg	106 (55.2)	74 (76.3)	<.001	2.6 (1.45–4.53)	.001
EF	64.5 ± 11.3	62.5 ± 11.2	.167		
>55 mmHg	161 (83.9)	77 (79.4)	.614		
45–55 mmHg	17 (8.9)	13 (13.4)			
30–44 mmHg	10 (5.2)	6 (6.2)			
<30 mmHg	4 (2.1)	1 (1.0)			
E/E [*]	13.2 ± 5.2	15.2 ± 5.7	.008		
E/E [*] >15 [*]	42 (25.8)	34 (44.7)	.003		
Cardiomegaly on chest X-ray before operation	58 (30.2)	32 (33.0)	.630		
Sequelae on chest X-ray	7 (3.6)	9 (9.3)	.048	2.4 (0.81–7.08)	.114
ASA classification	2.50 ± 0.6	2.52 ± 0.6	.808	0.9 (0.56–1.38)	.571
Operation time, min, median, IOR	77.5 (60–110)	75 (60–100)	.967		
Anesthesia time, min, median, IOR	135 (115–165)	145 (120–167.5)	.299		
Input and output, mL	1105.8 ± 689.0	1035.6 ± 627.0	.401		
Transfusion	121 (63.0)	55 (56.7)	.298		

Figures are presented as counts with the percentage in parentheses or the mean ± standard deviation, unless otherwise indicated.

ASA = American Society of Anesthesiologists, BMI = body mass index, CAOD = coronary artery occlusive disorder, CCI = Charlson comorbidity index, CI = confidence interval, E/E^{*} = ratio of the mitral peak velocity of early filling (E) to early diastolic mitral annular velocity (E'), EF = ejection fraction, OR = odds ratio, RVSP = right ventricular systolic pressure.

* 50 missing values.

† Odds ratios were obtained for pulmonary disease, RVSP >35 mmHg, and sequelae on chest X-rays while controlling for age, sex, BMI, CCI, and ASA classification.

Bold values mean P-value of <0.05.

Table 4
Comparison of patients with and without pulmonary complications admitted to the ICU after proximal femur fracture surgery.

Variable	Univariate		P	Multivariate	
	Without pulmonary complication (n=175)	With pulmonary complication (n=88)		OR [†] (95% CI)	P
Age, years	82.1 ± 7.5	82.5 ± 7.4	.696	1.0 (0.97–1.05)	.610
Sex, men	36 (20.6)	27 (30.7)	.070	1.5 (0.82–2.89)	.184
BMI, kg/m ²	21.8 ± 3.7	21.8 ± 3.5	.945	1.0 (0.94–1.09)	.765
Diabetic mellitus	52 (29.7)	24 (27.3)	.680		
Hypertension	115 (65.7)	60 (68.2)	.689		
Heart failure	25 (14.3)	19 (21.6)	.134		
CAOD	26 (14.9)	17 (19.3)	.356		
Dementia	41 (23.4)	19 (21.6)	.738		
Old cerebrovascular accident	51 (29.1)	24 (27.3)	.751		
Pulmonary disease	15 (8.6)	18 (20.5)	.006	1.9 (0.88–4.19)	.101
CCI	1.7 ± 1.7	2.1 ± 1.7	.070	1.1 (0.96–1.34)	.153
Ever smoker	16 (9.1)	10 (11.4)	.569		
Interval between fracture and operation, days, median, IQR	3 (2–5)	3 (2.00–7.75)	0.464		
RVSP	37.9 ± 11.1	41.3 ± 9.4	.015		
RVSP >35 mmHg	100 (57.1)	68 (77.3)	.001	2.5 (1.34–4.52)	.004
EF	64.7 ± 11.1	62.3 ± 11.6	.097		
>55%	148 (84.6)	68 (77.3)	.343		
45–55%	14 (8.0)	13 (14.8)			
30–44%	10 (5.7)	6 (6.8)			
<30%	3 (1.7)	1 (1.1)			
E/E [*]	13.3 ± 5.0	15.2 ± 5.8	.014		
E/E' >15 [*]	39 (26.2)	32 (46.4)	.003		
Cardiomegaly on a chest X-ray before operation	53 (30.3)	28 (31.8)	.799		
Sequelae on a chest X-ray	7 (4.0)	9 (10.2)	.046	2.4 (0.83–7.27)	.107
ASA classification	2.52 ± 0.6	2.55 ± 0.6	.666	0.91 (0.57–1.46)	.691
Operation time, min, median, IQR	75 (60–100)	70 (60–95)	.927		
Anesthesia time, min, median, IQR	130 (110–160)	137.5 (115–160)	.334		
Input and output, mL	1043.1 ± 582.1	989.7 ± 578.3	.482		
Transfusion	106 (60.8)	51 (58.0)	.683		

Figures are presented as counts with the percentage in parentheses or the mean ± standard deviation, unless otherwise indicated.

ASA = American Society of Anesthesiologists, BMI = body mass index, CAOD = coronary artery occlusive disorder, CCI = Charlson comorbidity index, CI = confidence interval, E/E' = ratio of the mitral peak velocity of early filling (E) to early diastolic mitral annular velocity (E'), EF = ejection fraction, OR = odds ratio, RVSP = Right ventricular systolic pressure.

* 45 missing values.

† Odds ratios were obtained for pulmonary disease, RVSP >35 mmHg, and sequelae on chest X-rays while controlling for age, sex, BMI, CCI, and ASA classification.

Bold values mean P-value of <0.05.

with tricuspid regurgitation,^[32] and an RVSP of >35 mmHg is used as a marker for possible pulmonary hypertension.^[21] Pulmonary hypertension has been reported to be a predictor of both cardiac and non-cardiac surgery outcomes.^[33–36] The progression of pulmonary hypertension causes right ventricular failure, which influences left ventricular filling.^[36,37] Lower preloading may lead to a global reduction in oxygen delivery and multi-organ failure.^[36,37] Fluid management of these patients is often difficult, as both hypovolemia and hypervolemia can have detrimental effects on blood pressure, organ perfusion, and cardiac function.^[36,37] Changes in the effective volume during surgery and fluid management after surgery may thus influence outcomes. In our study, RVSP did not show any significant association with mortality but was associated with the development of pulmonary complications, particularly pulmonary edema. The association of RVSP with pulmonary complications rather than mortality is likely due to the fact that femur fracture surgery is relatively hemodynamically stable compare to thoracic and abdominal surgery.

Because different types of complication may have different causal mechanisms, we re-analyzed the association between RVSP and pulmonary complications (Supplementary table 3, <http://links.lww.com/MD/F110>). The results showed that RVSP

>35 mmHg were associated with pulmonary edema (RVSP ≤35 mmHg vs RVSP >35 mmHg: 8.3% vs 16.7%, respectively, $P = .043$), pneumonia (RVSP ≤35 mmHg vs RVSP >35 mmHg: 10.1% vs 19.4%, respectively, $P = .035$), and respiratory failure requiring mechanical ventilation (RVSP ≤35 mmHg vs RVSP >35 mmHg; 4.6% vs 15.6%, respectively, $P = .004$). PTE and atelectasis differ in terms of their development, which may explain these results.

E/E', which is correlated with left ventricular diastolic function, is known to be associated with fluid management.^[23,38] In the univariate analysis, both E/E' and E/E' >15 (which is used to indicate the diastolic dysfunction of the left ventricle^[23]) differed significantly between the patients with and without pulmonary complications. In the multivariate analysis of 239 patients, which excluded 50 patients for whom no E/E' measurements were taken, E/E' >15 remained a significant predictor of pulmonary complications (OR: 2.6; 95% CI: 1.37–5.12) (Supplementary table 4, <http://links.lww.com/MD/F111>). Interestingly, although the difference was not statistically significant, the group without pulmonary complications was more likely to receive a transfusion and exhibited a higher positive input/output compared to the group with pulmonary complications (actual transfusion volume without pulmonary complications vs with pulmonary compli-

cations: median 240 mL vs 100 mL, respectively, $P = .384$). These results suggest that the group with pulmonary complications might have a fluid-associated vulnerability. Accordingly, strict fluid monitoring and management is recommended for older patients with abnormal RVSP or E/E' who are admitted to the ICU after femur fracture surgery.

It should be noted that our study has a number of limitations, including its retrospective, single-center design. Due to its retrospective nature, the indications for ICU admission were not always clear after the operation, and some enrolled patients may not have required ICU admission. Furthermore, the larger interval between the fracture and subsequent operation between our study and other studies may have affected the results and needs to be considered when interpreting the results. However, unlike past studies, we focused on patients aged 65 years or older in the ICU after surgery, and our results may thus have important implications for an aging society, such as that in South Korea.

Another issue is that both RVSP and E/E' are indirect measurements taken during echocardiography and may differ from measurements taken using catheterization. However, echocardiography is much easier and safer than catheterization, and we believe that preoperative echocardiography assists in fluid management during and after surgery. Finally, we could not analyze all of the same variables, including history of osteoporosis and place of residence at the time of fracture, reported in other studies due to the limitations of our study design. As the population ages, prospective studies may be more helpful in this respect.

5. Conclusion

Pulmonary complications in older patients admitted to the ICU after femur fracture surgery led to longer hospitalization and ICU stays than it did for patients without pulmonary complications. A higher RVSP or E/E' recorded during preoperative echocardiography could be used to identify those older patients admitted to the ICU after femur fracture surgery who are at a high risk of pulmonary complications, possibly due to fluid-associated vulnerability. Accordingly, patients with abnormal RVSP or E/E' levels require stricter fluid monitoring and management.

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