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ORIGINAL RESEARCH

# Utility of inferior vena cava diameter ratio on computed tomography scan among low-risk elderly patients in the emergency department

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## Abstract

Hypovolemia is a major risk factor for morbidity and mortality among elderly older patients. The inferior vena cava (IVC) diameter is known to predict the fluid volume status in ill patients. This study aimed to evaluate the predictive performance of the IVC diameter ratio, as determined by computed tomography (CT), for poor outcomes among low risk patients 65 years of age and older. This single-center retrospective study was conducted on patients who taken CT during the clinical process between January 2019 and December 2020. IVC diameter ratio measurement was estimated by dividing the maximum value of the anteroposterior diameter from the maximum value of transverse diameter at the level right above the renal vein. The IVC diameter ratio's prognostic performance was evaluated by using the area under the receiver operating characteristic (AUROC) curve. The mean IVC diameter ratio was 1.78. Multivariable logistic regression analysis revealed age, pulse rate, aspartate aminotransferase level, and IVC diameter ratio as significant risk factors for in-hospital death. The area under the receiver operating curve for predicting death using the IVC diameter ratio of patients with pulse rates under 95 was 0.701 and the cut-off value was 1.638, with an 88.9% sensitivity and 45.2% specificity. The odds ratio for higher IVC diameter ratio values was statistically significant ($p$ = 0.031) for predicting in-hospital death. IVC measurement using abdomen& pelvic computed tomography (APCT ) demonstrated capability for predicting poor outcomes, including all-cause mortality among older patients with low risk in the emergency department.

## Keywords

Dehydration; Emergency medicine; Geriatric; Inferior vena cava ratio; Computed tomography

## 1. Introduction

In the emergency setting, older patients are particularly vulnerable, and their symptoms are particularly nonspecific, leading to difficulties with diagnoses and establishing treatment plans. Therefore, prognostic prediction tools and algorithms are crucial for emergency physicians and their patients [1–3].

Hypovolemia is a major risk factor for morbidity and mortality among older patients [4]. Clinically, hypovolemia refers to various conditions resulting in a loss of body water to a level below a patient's physiological requirements [5]. Fluid depletion has been demonstrated as a common risk factor for not only various diseases but also trauma [6–9]. Hypovolemia is a difficult clinical diagnosis to ascertain because of ambiguous diagnostic criteria and because hypovolemic patients are often disoriented, delirious, or incoherent. Despite the lack of a gold-standard diagnostic tool for dehydration, various methods have been employed [10]. The clinical features of dehydration include mucosal dryness as well as abnormal skin turgor [11], body temperature, heart rate, blood pressure, and respiratory rate. Pertinent laboratory tests include serum osmolality and sodium concentration, blood urea nitrogen, hematocrit, and urine osmolality [12]. Fluid administration should be properly implemented by determining the volume status of the patients. However, this decision can be complicated since heart rate, blood pressure, and urine out may be hard to identify at the early phase of dehydration. Moreover, pulmonary edema can be detected late sign fluid overload.

Thus it's important to asset methods to determine the volume status of patients without clinical signs of dehydration. Inferior vena cava (IVC) measurements are the most conclusive method for determining a patient's volume status using imaging, even though this method for evaluating intravascular volume is limited by respiratory variation [13]. The advantages of using bedside sonography for IVC measurement include noninvasiveness, the lack of associated radiation exposure, rapidity, and repeatability. However, the utility and interpretation of ultrasonography are hindered by its dependence on the operator and the patient's body habitus [14]. Moreover, the IVC might be difficult to find using ultrasonography, as only 48% of emergency physicians can accurately perform the required technique [15].

Recently, diagnostic computed tomography (CT) has been used extensively in emergency departments (EDs). Several studies have demonstrated that IVC diameter could be useful as a valid marker for hypovolemia and to predict mortality among critically injured trauma patients [9, 16, 17]; however, to our knowledge, there is no such published evidence specifically supporting the use of this marker for patients older than 65 years of age.

This study designed to evaluate the performance of the IVC diameter ratio for predicting poor outcomes among older patient, especially with normal initial vital sign, in emergency settings.

## 2. Methods & material

### 2.1 Patients and data collection

This study was conducted at a teaching hospital, tertiary medical centers in South Korea. We retrospectively reviewed the electronic medical records (EMRs) of patients, between January 2019 and December 2020. The study was reviewed and approved by the Institutional Review Board and Ethics Committee.

We included patients aged 65 and older in this study who visited the emergency department for internal medical reasons and performed abdominal and pelvic CT (APCT). We excluded patients who presented to ED with traumatic reasons or who had insufficient EMR data.

One board-certified emergency physician collected data from the EMRs of coded patients without knowledge of this study's aim. We analyzed the following variables: demographics (sex and age), initial clinical manifestation (systolic blood pressure, diastolic blood pressure, pulse rate, respiratory rate, body temperature, and mental status), laboratory findings (white blood cell, hemoglobin, hematocrit, platelet, C-reactive protein, blood urea nitrogen, creatinine, albumin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), glucose, sodium, potassium, prothrombin time (international normalized ratio), and partial thromboplastin time), and the ED treatment results (discharge, general ward admission, and intensive care unit [ICU] admission), length of hospital stay, and mortality.

To analyze the IVC ratio, we collected data from patients who went through the APCT in the ED during the research period. For the IVC diameter ratio evaluations, cross-sectional images were obtained using a picture archiving and communication system (Maroview 5.4, Infinitt, Seoul, Republic of Korea). Two board-certified emergency physicians, each with five and ten years of experience, analyzed captured images with blindness of all patient's information such as diagnoses and outcomes. All measurements were made in the same environment, such as same window, contrast, and brightness. The two reviewers agreed to measurement points and methods before initiate the image review process.

The IVC diameter ratio measurement was determined by maximal transverse diameter divided by the maximal anteroposterior diameter at a level directly below the renal vein (Figs. 1,2). This location was selected for the study because it is not associated with respiration-dependent IVC diameter changes [18].

The primary outcome was the ability of the IVC diameter ratio to predict in-hospital deaths. The secondary outcome was the ability of the IVC diameter ratio to predict in-hospital deaths of patients among normal rage heart rate.

### 2.2 Statistics and analysis

Categorical variables were analyzed using Pearson's chi-square test. A $p$-value $< 0.05$ was considered statistically significant. Continuous variables were analyzed using the independent-samples $t$-test or the Mann–Whitney U-test, and they are presented as means with standard deviations and ranges. Logistic regression analysis was used to assess the association between variables and mortality or the need for ICU admission. Differences in the performance of the IVC diameter ratio for predicting outcomes were evaluated using area under the receiver operating characteristic (AUROC) curve analysis [19]. An AUROC curve between 0.8–0.9 is considered good, a curve between 0.7–0.8 is considered adequate, and a curve between 0.6–0.7 is considered poor.

The intraclass correlation coefficients (ICCs) with 95% confidence intervals (CIs) were calculated to determine the reliability of the reviewers' measurements. ICCs of 0–0.20 indicated poor agreement, 0.21–0.40 indicated fair agreement, 0.41–0.60 indicated moderate agreement, 0.61–0.80 indicated good agreement, and 0.81–1.00 indicated excellent agreement [20].

The statistics program used for this research was SPSS for Windows version 26.0 (IBM Corp., Armonk, N.Y., USA). The AUROC curve analysis was performed with the DeLong method by using STATA Software version 17 (StataCorp., LLC, Texas, USA). The significance level was set at $p < 0.05$.

## 3. Results

### 3.1 Demographic, laboratory and clinical characteristics of patients (Table 1)

The EMRs of 279 patients were reviewed and analyzed for this study. The mean age of the included patients was 77.02 $\pm$ 7.0 years, and 121 patients (43.2%) were men. The mean systolic blood pressure, diastolic blood pressure, pulse rate, respiratory rate and body temperature of the included patients were 130.32 $\pm$ 31.80 mmHg, 73.54 $\pm$ 13.99 mmHg, 89.36 $\pm$ 18.61, 20.87 $\pm$ 3.42 and 36.78 $\pm$ 0.89 °C. The mean of white blood cell (WBC) was 11.51 $\pm$ 6.18 $\times$ $10^9$ cells/L, C-reactive protein was 7.39 $\pm$ 8.77 mg/dL, Blood urea nitrogen was 24.22 $\pm$ 17.02 mg/dL and Creatinine was 1.14 $\pm$ 1.04 mg/dL. There were 31 patients (11.1%) who presented with altered mentation. There were 200 patient (71.4%) admitted to general ward 56 patients (20.1%) were admitted to the ICU and 51 patients (18.2%) who died in the hospital. The diagnosis of patients is as follows. 33 gastroenteritis. 14 gastritis/duodenitis, 5 constipation, 33

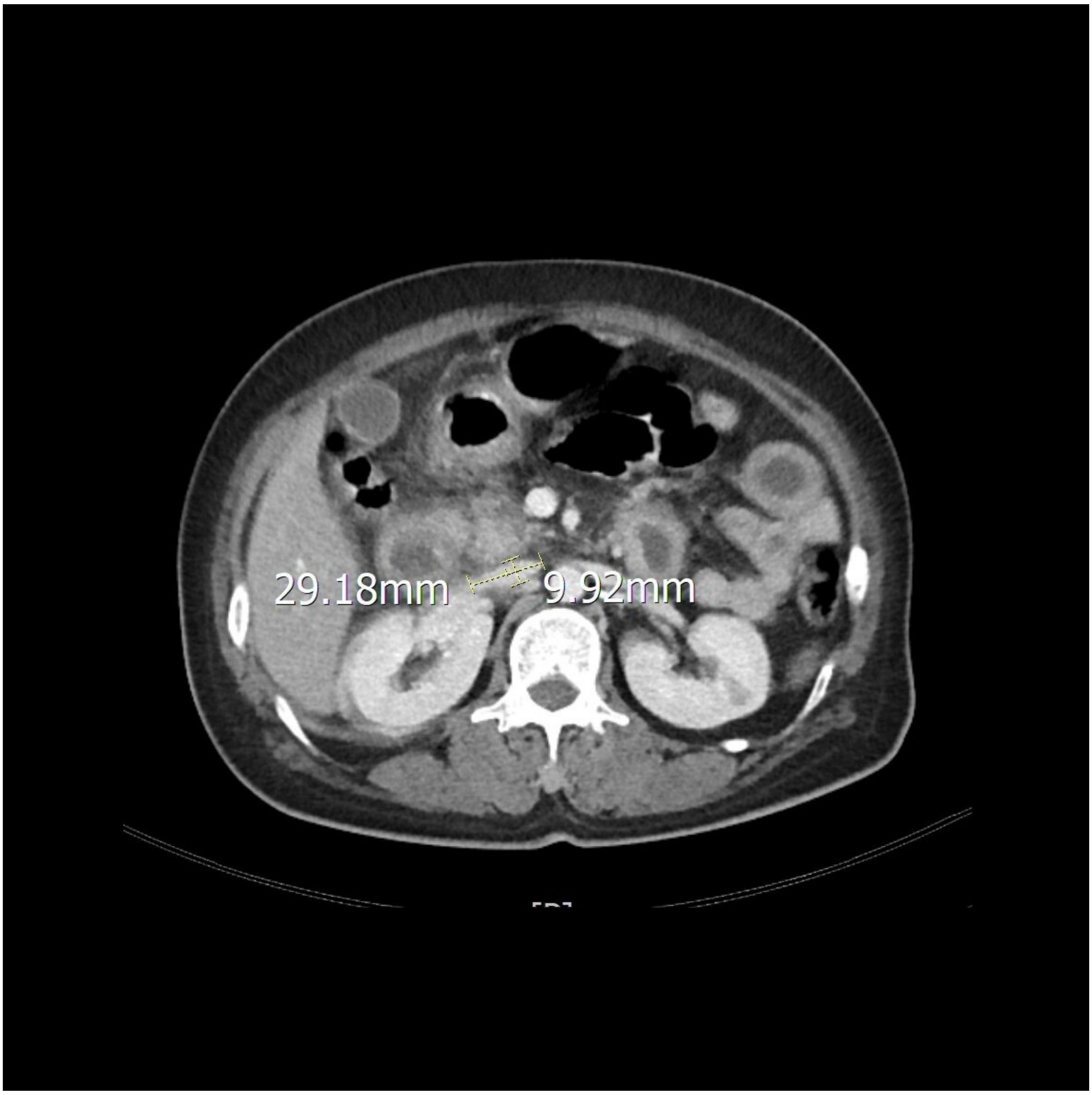


**FIGURE 1. The IVC diameter ratio of 78-year-old female patient who was expired in the emergency department was 2.94.**

gastrointestinal (GI) bleeding, 3 liver abscess, 3 pancreatitis, 21 cholecystitis, 2 cholangitis, 2 diverticulitis, 4 abdominal aortic aneurysm, 4 superior mesenteric artery thrombosis, 14 appendicitis, 2 hernia, 27 ileus, 4 post-operative obstruction, 14 GI perforation, 29 acute pyelonephritis, 12 ureter stone, 2 renal infarction, 1 ovarian torsion, 14 GI origin cancer, 2 obstetrics and gynecology (OBGY ) origin cancer, 18 pneumonia, 9 unknown origin sepsis 9, 35 others.

## 3.2 Measurement of the IVC diameter ratio

The maximal transverse diameter and maximal anteroposterior diameter of the IVC were measured in the 247 patients by two reviewers. For Reviewer 1, the mean maximal transverse and maximal anteroposterior diameters of the IVC were 24.50 mm and 14.67 mm. The mean IVC diameter ratio was 1.78. For Reviewer 2, the mean maximal transverse and maximal anteroposterior diameters of the IVC were 24.50 mm and 14.67 mm, and the mean IVC diameter ratio was 1.73.

The ICCs of the two reviewers for maximal transverse diameter and anteroposterior diameter were excellent, at 0.915 (95% CI: 0.893–0.933) and 0.958 (95% CI: 0.946–0.966), respectively. The ICC for the IVC diameter ratio was also excellent, at 0.967 (95% CI: 0.958–0.974).

## 3.3 Clinical factors associated with the poor prognosis

In the univariate logistic regression analysis, age, pulse rate, respiratory rate, altered mental status, AST, and IVC diameter ratio were statistically significantly higher among patients who died in the hospital than among those with other outcomes. The IVC diameter ratio of patient who died in hospital (2.17 $\pm$ 0.85) is higher than non-mortality group (1.67 $\pm$ 0.42), and a statistically significant difference was found ($p < 0.001$). Multivariable logistic regression analysis revealed older age and higher pulse rate, AST level, and IVC diameter ratio as significant risk factors for in-hospital death. The Odds ratio of IVC diameter ratio was 2.88, and a statistically significant difference was found ($p < 0.001$) (Table 2).

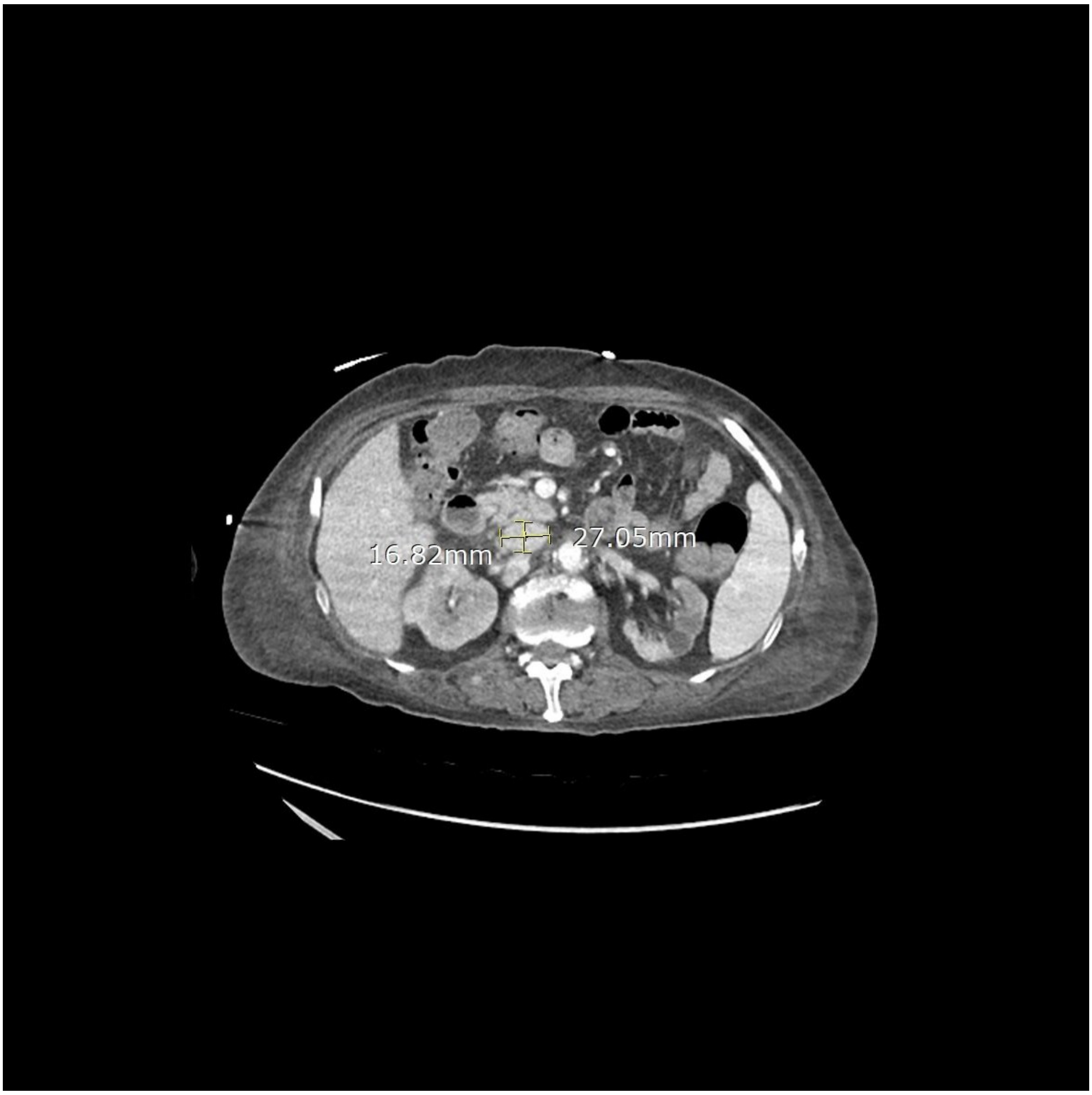


**FIGURE 2. The IVC diameter ratio of 67-year-old male patient who was survived in the emergency department was 1.61.**

The associations between the need for ICU admission and the clinical and laboratory data are presented in Table 3. Univariate logistic regression analysis revealed systolic blood pressure, diastolic blood pressure, pulse rate, respiratory rate, altered mental status, AST, and C-reactive protein status as significant risk markers for ICU admission. The IVC diameter ratio of ICU admission group (1.95 $\pm$ 0.74) is higher than non-mortality group (1.74 $\pm$ 0.49), but a statistically significant difference was not found ($p$ = 0.057). Multivariate logistic analysis demonstrated that the IVC diameter ratio was the only marker that could be used to predict death. The AUROC for the IVC diameter ratio of patients with pulse rates under 100 for predicting in-hospital death was 0.701 (95% CI: 0.641–0.822) and the AUROC for the IVC diameter ratio of patients with pulse rates over 100 for predicting in-hospital death was 0.475 (95% CI: 0.314–0.636) (Fig. 3). The cut-off value was 1.628 for predicting in-hospital death based on the maximum sum of sensitivity and specificity.

The overall diagnostic accuracy of the cut-off value for the IVC diameter ratio ($\geq$1.628) was 50.2%. The sensitivity, specificity, positive predictive value, and negative predictive value of the cut-off value were 88.9%, 45.2%, 22.8%, and 88.0%, respectively.

### 3.4 Comparison between the patients with higher and lower IVC diameter ratios

Based on the IVC diameter ratio cut-off of $\geq$1.638, we divided patients into low IVC diameter ratio groups and high IVC diameter ratio groups (Table 4).

There were no statistically significant differences in age, sex, and initial vital signs between the two groups. Statistically, the K level was significantly higher in the higher IVC diameter ratio group than the lower one. Also, in-hospital mortality has critically higher in the group with an IVC diameter ratio $\geq$1.638 compares to those with has lower IVC ratio. (in-hospital mortality rate, 12.0% vs. 22.8%, respectively ($p$ = 0.020). The odds ratio for higher IVC diameter ratio values (2.10 [95% CI: 1.08–4.13]) was statistically significant ($p$ =

**TABLE 1. Demographic, laboratory and clinical data of all patients (Total n = 279).**

| Variable | Value[a] |
|---|---|
| Age (years) | 77.02 ± 7.0 |
| Sex | |
| Male | 121 (43.2) |
| Female | 158 (56.4) |
| Systolic Blood Pressure (mmHg) | 130.32 ± 31.80 |
| Diastolic Blood Pressure (mmHg) | 73.54 ± 13.99 |
| Pulse rate (beats/min) | 89.36 ± 18.61 |
| Respiratory rate (breath/min) | 20.87 ± 3.42 |
| Body temperature (°C) | 36.78 ± 0.89 |
| Mental status | |
| Alert | 248(88.6) |
| Verbal response | 24 (8.6) |
| Painful response | 7 (2.5) |
| Unresponsive | 0 (0.0) |
| Laboratory test | |
| Hemoglobin (g/dL) | 11.86 ± 2.62 |
| Hematocrit (%) | 35.22 ± 7.13 |
| White blood cell ($10^9$/L) | 11.51 ± 6.18 |
| Platelet ($10^9$/L) | 233.45 ± 102.62 |
| C-reactive protein (mg/dL) | 7.39 ± 8.77 |
| Aspartate aminotransferase (IU/L) | 48.08 ± 79.78 |
| Alanine aminotransferase (IU/L) | 32.84 ± 80.55 |
| Blood urea nitrogen (mg/dL) | 24.22 ± 17.02 |
| Creatinine (mg/dL) | 1.14 ± 1.04 |
| Glucose (mg/dL) | 150.15 ± 63.69 |
| Albumin (g/dL) | 3.60 ± 0.67 |
| Sodium (mmol/L) | 134.83 ± 5.42 |
| Potassium (mmol/L) | 3.93 ± 0.63 |
| Prothrimbin time (INR) | 1.15 ± 0.33 |
| Partial thromboplastin time (sec) | 30.67 ± 8.14 |
| Hospitalization | 200 (71.4) |
| Hospital Length of stay (day) | 9.24 ± 17.39 |
| ICU admission | 56 (20.1) |
| ICU Length of stay (day) | 5.11 ± 6.37 |
| In-hospital mortality | 51 (18.2) |
| IVC diameter ratio[†] | |
| Reviewer 1 | 1.78 ± 0.55 |
| Reviewer 2 | 1.73 ± 0.53 |

[a] *Data are mean (standard deviation) or number (%).*
[†]*IVC diameter ratio is calculated in maximal transverse diameter divided by maximal anteroposterior diameter.*
*ICU, Intensive Care Unit; IVC, Inferior Vena Cava.*

0.031) for predicting in-hospital death.

## 4. Discussion

In this study, we found that poor IVC diameter ratios determined using CT scans in emergency department patients aged

**TABLE 2. Logistic regression analysis of mortality predictors.**

| | Univariate analysis[a] | | | Multivariate analysis[b] | | |
|---|---|---|---|---|---|---|
| Variable | Non-mortality group | Mortality group | *p*-value | OR | B | *p*-value |
| | n = 228 | n = 51 | | | | |
| Age (years) | 76.58 ± 19.69 | 79.02 ± 6.39 | **0.024** | 1.05 (1.00, 1.11) | 0.052 | **0.040** |
| Sex; Male | 93 (40.8) | 28 (54.9) | 0.85 | | | |
| Systolic Blood Pressure (mmHg) | 131.72 ± 29.54 | 124.06 ± 40.44 | 0.205 | | | |
| Diastolic Blood Pressure (mmHg) | 74.24 ± 13.25 | 70.43 ± 16.70 | 0.079 | | | |
| Pulse rate (beats/min) | 87.03 ± 15.46 | 99.78 ± 26.57 | **0.002** | 1.03 (1.01, 1.05) | 0.031 | **0.001** |
| Respiratory rate (breath/min) | 20.58 ± 2.51 | 22.18 ± 5.88 | 0.062 | | | |
| Body temperature (°C) | 36.81 ± 0.88 | 36.65 ± 0.95 | 0.252 | | | |
| Altered mental status | 24 (10.5) | 7 (13.7) | **<0.001** | 1.175 (0.41, 3.38) | 0.161 | 0.765 |
| Laboratory test | | | | | | |
| Hemoglobin (g/dL) | 11.99 ± 2.50 | 11.29 ± 3.07 | 0.082 | | | |
| Hematocrit (%) | 35.52 ± 6.80 | 33.87 ± 8.40 | 0.136 | | | |
| White blood cell ($10^9$/L) | 11.65 ± 6.13 | 10.88 ± 6.41 | 0.419 | | | |
| Platelet ($10^9$/L) | 234.72 ± 95.27 | 227.75 ± 131.54 | 0.661 | | | |
| C-reactive protein (mg/dL) | 7.06 ± 8.52 | 8.88 ± 9.78 | 0.180 | | | |
| Aspartate aminotransferase (IU/L) | 38.31 ± 40.88 | 91.57 ± 158.01 | **0.021** | 1.01 (1.00, 1.02) | 0.005 | **0.024** |
| Alanine aminotransferase (IU/L) | 27.41 ± 70.86 | 57.10 ± 112.02 | 0.075 | | | |
| Glucose (mg/dL) | 148.22 ± 55.48 | 158.78 ± 92.14 | 0.434 | | | |
| Sodium (mmol/L) | 134.94 ± 5.59 | 134.33 ± 4.64 | 0.169 | | | |
| Potassium (mmol/L) | 3.91 ± 0.59 | 4.04 ± 0.76 | 0.277 | | | |
| PT (INR) | 1.14 ± 0.35 | 1.20 ± 0.28 | 0.230 | | | |
| PTT (sec) | 30.23 ± 8.19 | 32.60 ± 7369 | 0.610 | | | |
| IVC diameter ratio† | 1.67 ± 0.42 | 2.17 ± 0.85 | **<0.001** | 2.88 (1.62, 5.12) | 1.057 | **<0.001** |

[a] *Data are mean (standard deviation) or number (%).*
[b] *Data in parentheses are 95% confidence intervals, conducted on variables with a p value of <0.05 on univariate analysis.*
†*IVC diameter ratio is calculated in maximal transverse diameter divided by maximal anteroposterior diameter.*
*ICU, Intensive Care Unit; IVC, Inferior Vena Cava; OR, odds ratio; B, regression coefficient.*
*Boldface type indicates statistical significance ($p < 0.05$).*

65 and older with the medical diagnosis can be considered as one of the methods for predicting in-hospital mortality in particular. Furthermore, the IVC diameter ratio could be considered for risk prediction in patients who have a lower risk of mortality in an early phase of shock. The median IVC diameter ratio was greater among patients who died in the hospital than among those who survived until discharge or transfer to another hospital ward.

It is important to consider volume status to avoid overload during fluid resuscitation. Evaluating blood fluid volume status is a critical issue in the emergency department since both hypovolemia and fluid overload can lead to poor clinical outcomes, increase critical care periods, and mortality rate [21]. Clinically, there are some methods for determining volume status, including Central venous pressure (CVP), pulmonary artery occlusion pressure, end-diastolic volume, and IVC diameter.

CVP not only estimates the patient's volume state but also measures cardiac function and venous return [22]. CVP can be evaluated using the inserted central venous catheter and pressure of the manometer. But central venous catheter insertion is invasive and is associated with complications, such as infection, thrombosis, and air embolism formation [23]. Pulmonary capillary wedge pressure (PCWP) has been generally used to estimate volume status and fluid responsiveness. However, some studies have shown that PCWP has a poor correlation with volume status and the responsiveness of fluid resuscitation [24, 25]. So, pulmonary artery catheters tend to be infrequently used because their placement does not improve patient outcomes, and catheter placement carries the risk of mechanical and infectious complications [26].

On the other hand, imaging-based IVC diameter measurements are noninvasive and safe relative to the methods mentioned above. Ultrasonographic measurements of the IVC diameter have been proposed as a tool to help guide fluid management. There are ways to measure the IVC diameter using ultrasound and CT.

The advantage of ultrasonography (USG ) is for evaluating

**TABLE 3. Logistic regression analysis of ICU admission predictors.**

| | Univariate analysis[a] | | | Multivariate analysis[b] | | |
|---|---|---|---|---|---|---|
| Variable | Non-ICU admission group | ICU admission group | *p*-value | OR | B | *p*-value |
| | n = 223 | n = 56 | | | | |
| Age (years) | 76.8 ± 7.19 | 77.9 ± 6.31 | 0.281 | | | |
| Sex; Male | 94 | 27 | 0.452 | | | |
| Systolic Blood Pressure (mmHg) | 133.77 ± 29.77 | 116.61 ± 36.00 | **0.002** | 1.01 (0.99, 1.02) | 0.007 | 0.386 |
| Diastolic Blood Pressure (mmHg) | 75.14 ± 13.00 | 67.18 ± 15.97 | **<0.001** | 1.02 (0.98, 1.06) | 0.020 | 0.288 |
| Pulse rate (beats/min) | 86.70 ± 14.84 | 99.95 ± 26.82 | **0.001** | 0.98 (0.96, 1.00) | –0.018 | 0.074 |
| Respiratory rate (breath/min) | 20.41 ± 2.09 | 22.71 ± 6.10 | **0.001** | 0.90 (0.80, 1.00) | –0.108 | 0.054 |
| Body temperature (°C) | 36.75 ± 0.82 | 36.90 ± 1.14 | 0.277 | | | |
| Altered mental status | 20 (9.0) | 11 (19.6) | **0.032** | 1.24 (0.47, 3.26) | 0.211 | 0.670 |
| Laboratory test | | | | | | |
| Hemoglobin (g/dL) | 11.96 ± 2.67 | 11.49 ± 2.37 | 0.232 | | | |
| Hematocrit (%) | 35.45 ± 7.22 | 34.30 ± 6.72 | 0.282 | | | |
| White blood cell ($10^9$/L) | 11.73 ± 6.14 | 10.64 ± 6.30 | 0.249 | | | |
| Platelet ($10^9$/L) | 235.03 ± 90.9 | 227.16 ± 140.79 | 0.692 | | | |
| C-reactive protein (mg/dL) | 6.43 ± 7.88 | 11.24 ± 10.94 | **0.003** | 0.97 (0.93, 1.00) | –0.036 | 0.052 |
| Aspartate aminotransferase (IU/L) | 39.96 ± 57.83 | 81.00 ± 132.36 | **0.028** | 1.00 (0.99, 1.00) | –0.004 | 0.065 |
| Alanine aminotransferase (IU/L) | 26.31 ± 49.71 | 58.82 ± 148.20 | 0.111 | | | |
| Glucose (mg/dL) | 149.52 ± 59.62 | 152.68 ± 78.43 | 0.740 | | | |
| Sodium (mmol/L) | 135.03 ± 4.93 | 134.01 ± 7.05 | 0.220 | | | |
| Potassium (mmol/L) | 3.19 ± 0.539 | 4.03 ± 0.90 | 0.319 | | | |
| PT (INR) | 1.13 ± 0.35 | 1021 ± 0.27 | 0.132 | | | |
| PTT (sec) | 30.13 ± 8.20 | 32.79 ± 7.60 | **0.029** | 1.05 (0.96, 1.12) | 0.051 | 0.298 |
| IVC diameter ratio† | 1.74 ± 0.49 | 1.95 ± 0.74 | 0.057 | | | |

[a] *Data are mean (standard deviation) or number (%).*
[b] *Data in parentheses are 95% confidence intervals, conducted on variables with a p value of <0.05 on univariate analysis.*
†*IVC diameter ratio is calculated in maximal transverse diameter divided by maximal anteroposterior diameter.*
*ICU, Intensive Care Unit; IVC, Inferior Vena Cava; OR, odds ratio; B, regression coefficient.*
*Boldface type indicates statistical significance ($p < 0.05$).*

inferior vena cava (IVC) diameter in mechanical ventilated and hemodynamic unstable patients. The advantage of USG is for evaluating inferior vena cava (IVC) diameter in mechanical ventilated and hemodynamic unstable patients. The advantage of using bedside ultrasonographic measurement of the IVC is rapid, non-invasive, repetitive, and determining fluid status in real-time. Yet, USG is subjective and EM physician may not be proficient at the ultrasound. Moreover, in a case when the patient is too obese or has bowel gas, the quality of the examination can be degraded [27, 28]. Therefore, we decided to use CT for this study.

Diagnostic CT is used extensively in emergency settings for older patients with vague symptoms and who pose diagnostic challenges. CT is particularly useful for detecting infection foci among older ED patients [29]. Although CT is associated with radiation exposure risk, it is a noninvasive, objective, cost-effective, and simple method. Another advantageous aspect of measuring IVC diameters using CT is that it is possible to perform these measurements with existing CT images that have already been captured for diagnostic purposes, so no further examination is required. Furthermore, the IVC is a detectable structure in nonenhanced CT images, so such measurements can apply to patients with high creatine levels for whom contrast injection is contraindicated.

One strength of this study is that the IVC diameter ratio in hypovolemic older patients, especially with normal rage heart rate can be considered to predict their prognosis by using snapshot cross-section images. We suggest that if CT is performed to find an infection source, then the IVC diameter ratio should be considered concurrently, with particular attention given to this variable during fluid resuscitation. If the ratio is ≥1.628, even with normal heart rate, more aggressive, prompt, and timely resuscitation is required to prevent a poor prognosis.

Another study investigating patients with sepsis found that the IVC diameter could be used as a marker of tissue hypoperfusion and that this finding could guide appropriate fluid administration. Similarly to our study, the investigators used an infrarenal IVC diameter measurement location; however,

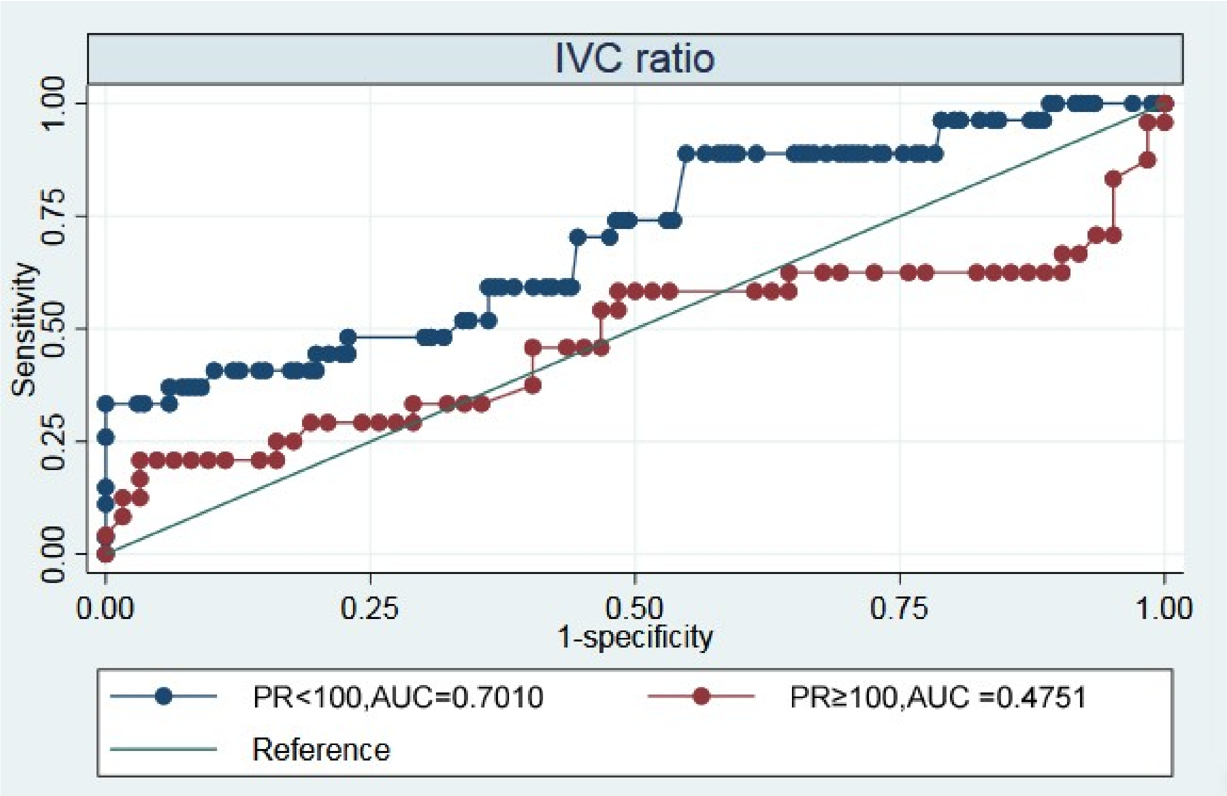


**FIGURE 3. The ROC curve of IVC ration of patients with heart rate under 100 and over 100.**

their IVC diameter ratio cut-off value was ≥1.3, which was lower than our cut-off value of ≥1.628. In our study, the target population was limited to older adults. The major aging-associated changes in blood vessels are the thickening of blood vessel walls, loss of elasticity, and loss of vascular endothelial cell function [30]. The structural and functional degeneration of these vessels increases the rigidity of the vessels [31]. The difference of IVC cut off value existed due to the age differences among study populations in the two journals.

We recognize some limitations to our study and the interpretation of its findings. First, we retrospectively included patients at only one general hospital. In the future, additional studies are required with multicenter, prospective designs. Second, we included patients with various medical conditions but excluded trauma patients; therefore, there may have been some selection bias. Third, selection bias may existed in our study because the diagnosis of the patients are too heterogeneous and patients with severe unstable vital signs could not take CT scans. Forth, to perform the CT scan, the patients should be stabilized with prompt treatment including fluid resuscitation. In this study, we did not consider (between-group differences in) the amount of fluid administered before patients underwent CT or the time between presentation or illness onset and CT scanning. There should be caution to generalize our results.

## 5. Conclusions

In this study, IVC diameter ratio measurement using APCT demonstrated capability for predicting poor outcomes, including all-cause mortality among older patients with low risk in the emergency department.

### AUTHOR CONTRIBUTIONS

Conception and design—JYL. Acquisition, analysis, and interpretation of data—JYL. Drafting the manuscript for intellectual content—SHL; SJB; KK. Statistical analysis—JSO; SJY. All authors reviewed, revised and approved the manuscript for submissions. Study supervision—JYL.

### ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the institutional review board of Ewha Womans University Seuol Hospital, and the requirement for written informed consent was waived (IRB No: 2021-03-025).

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**TABLE 4. Comparison between the patients with higher and lower IVC ration group.**

| | Low IVC group[a] | High IVC group[a] | *p-value*[b] |
|---|---|---|---|
| Variable | <1.68 cm | ≥1.68 cm | |
| | n = 117 | n = 162 | |
| Age (years) | 76.34 ± 0.68 | 77.52 ± 0.53 | 0.168 |
| Sex; Male | 56 (47.9%) | 65 (40.1%) | 0.198 |
| Systolic Blood Pressure (mmHg) | 130.85 ± 2.68 | 129.9 ± 2.65 | 0.813 |
| Diastolic Blood Pressure (mmHg) | 73.68 ± 1.24 | 73.4 5 ± 1.14 | 0.895 |
| Pulse rate (beats/min) | 89.85 ± 1.50 | 89.00 ± 1.59 | 0.706 |
| Respiratory rate (breath/min) | 20.71 ± 0.26 | 20.99 ± 0.30 | 0.504 |
| Body temperature (°C) | 36.86 ± 0.83 | 36.73 ± 0.69 | 0.234 |
| Altered mental status | 15 (12.8%) | 16 (9.9%) | 0.440 |
| Laboratory test | | | |
| Hemoglobin (g/dL) | 11.82 ± 0.25 | 11.89 ± 0.20 | 0.820 |
| Hematocrit (%) | 34.93 ± 0.70 | 35.43 ± 0.54 | 0.556 |
| White blood cell ($10^9$/L) | 12.21 ± 0.67 | 10.98 ± 0.41 | 0.093 |
| Platelet ($10^9$/L) | 230.15 ± 7.82 | 265.83 ± 8.96 | 0.649 |
| C-reactive protein (mg/dL) | 7.56 ± 0.84 | 7.27 ± 0.67 | 0.791 |
| Aspartate aminotransferase (IU/L) | 47.91 ± 7.21 | 48.21 ± 6.40 | 0.975 |
| Alanine aminotransferase (IU/L) | 40.62 ± 10.17 | 27.22 ± 3.86 | 0.171 |
| Glucose (mg/dL) | 153.13 ± 6.16 | 148.00 ± 4.84 | 0.508 |
| Sodium (mmol/L) | 134.97 ± 0.59 | 134.73 ± 0.37 | 0.726 |
| Potassium (mmol/L) | 3.83 ± 0.46 | 4.01 ± 0.55 | 0.015 |
| PT (INR) | 1.14 ± 0.28 | 1.15 ± 0.28 | 0.780 |
| PTT (sec) | 30.39 ± 0.74 | 30.86 ± 0.65 | 0.636 |
| Hospital mortality | 14 (12.0%) | 37 (22.8%) | **0.020** |
| ICU admission | 22 (18.8%) | 34 (21.0%) | 0.653 |

[a] *Data are mean (standard deviation) or number (%).*
[b] *Data in parentheses are 95% confidence intervals, conducted on variables with a p value of <0.05 on univariate analysis.*
[†]*IVC diameter ratio is calculated in maximal transverse diameter divided by maximal anteroposterior diameter.*
*ICU, Intensive Care Unit; IVC, Inferior Vena Cava; OR, odds ratio; B, regression coefficient.*
*Boldface type indicates statistical significance ($p < 0.05$).*

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon request.

## REFERENCES

[1] Wu W, Li DX, Wang Q, Xu Y, Cui YJ. Relationship between high-sensitivity cardiac troponin T and the prognosis of elderly inpatients with non-acute coronary syndromes. Clinical Interventions in Aging. 2018; 13: 1091–1098.
[2] Gao J, Chen M, Wang X, Wang H, Zhuo L. Risk factors and prognosis of acute kidney injury in adult hospitalized patients: a two-year outcome. Minerva Urology and Nephrology. 2015; 67: 179–185.
[3] Manabe T, Teramoto S, Tamiya N, Okochi J, Hizawa N. Risk factors for aspiration pneumonia in older adults. PLoS ONE. 2015; 10: e0140060.
[4] Hu KM, Brown RM. Resuscitation of the Critically Ill Older Adult. Emergency Medicine Clinics of North America. 2021; 39: 273–286.
[5] Thomas DR, Cote TR, Lawhorne L, Levenson SA, Rubenstein LZ, Smith DA, *et al*. Understanding Clinical Dehydration and its Treatment. Journal of the American Medical Directors Association. 2008; 9: 292–301.
[6] Swerdel JN, Janevic TM, Kostis WJ, Faiz A, Cosgrove NM, Kostis JB. Association between Dehydration and Short-Term Risk of Ischemic Stroke in Patients with Atrial Fibrillation. Translational Stroke Research. 2017; 8: 122–130.
[7] El-Sharkawy AM, Sahota O, Lobo DN. Acute and chronic effects of hydration status on health. Nutrition Reviews. 2015; 73: 97–109.
[8] Manz F. Hydration and Disease. Journal of the American College of Nutrition. 2007; 26: 535S–541S.
[9] Johnson JJ, Garwe T, Albrecht RM, Adeseye A, Bishop D, Fails RB, *et al*. Initial inferior vena cava diameter on computed tomographic scan

independently predicts mortality in severely injured trauma patients. Journal of Trauma and Acute Care Surgery. 2013; 74: 741–746.
[10] Armstrong LE. Assessing Hydration Status: the Elusive Gold Standard. Journal of the American College of Nutrition. 2007; 26: 575S–584S.
[11] Shirreffs SM. Markers of hydration status. European Journal of Clinical Nutrition. 2003; 57: S6–S9.
[12] Bhave G, Neilson EG. Volume Depletion Versus Dehydration: how Understanding the Difference can Guide Therapy. American Journal of Kidney Diseases. 2011; 58: 302–309.
[13] Dipti A, Soucy Z, Surana A, Chandra S. Role of inferior vena cava diameter in assessment of volume status: a meta-analysis. The American Journal of Emergency Medicine. 2012; 30: 1414–1419.e1.
[14] Beier K, Eppanapally S, Bazick HS, Chang D, Mahadevappa K, Gibbons FK, *et al*. Elevation of blood urea nitrogen is predictive of long-term mortality in critically ill patients independent of "normal" creatinine. Critical Care Medicine. 2011; 39: 305–313.
[15] Favot M, Courage C, Mantouffel J, Amponsah D. Ultrasound training in the emergency medicine clerkship. Western Journal of Emergency Medicine. 2015; 16: 938.
[16] Milia DJ, Dua A, Paul JS, *et al*. Clinical utility of flat inferior vena cava by axial tomography in severely injured elderly patients. Journal of Trauma and Acute Care Surgery. 2013; 75: 1002–1005.
[17] Matsumoto S, Sekine K, Yamazaki M, Sasao K, Funabiki T, Shimizu M, *et al*. Predictive Value of a Flat Inferior Vena Cava on Initial Computed Tomography for Hemodynamic Deterioration in Patients with Blunt Torso Trauma. Journal of Trauma: Injury, Infection & Critical Care. 2010; 69: 1398–1402.
[18] Wallace DJ, Allison M, Stone MB. Inferior Vena Cava Percentage Collapse during Respiration is Affected by the Sampling Location: an Ultrasound Study in Healthy Volunteers. Academic Emergency Medicine. 2010; 17: 96–99.
[19] Hajian-Tilaki K. Receiver operating characteristic (ROC) curve analysis for medical diagnostic test evaluation. Caspian Journal of Internal Medicine. 2013; 4: 627.
[20] Landis JR, Koch GG. The Measurement of Observer Agreement for Categorical Data. Biometrics. 1977; 33: 159.
[21] Albani S, Pinamonti B, Giovinazzo T, de Scordilli M, Fabris E, Stolfo D. Accuracy of right atrial pressure estimation using a multi-parameter approach derived from inferior vena cava semi-automated edge-tracking echocardiography: A pilot study in patients with cardiovascular disorders. The International Journal of Cardiovascular Imaging. 2020; 1–13.
[22] Magder S. How to use central venous pressure measurements. Current Opinion in Critical Care. 2005; 11: 264–270.
[23] Jamshidi R. Central venous catheters: Indications, techniques, and complications. Seminars in Pediatric Surgery. 2019; 28: 26–32.
[24] Michard F, Teboul J. Predicting Fluid Responsiveness in ICU Patients. Chest. 2002; 121: 2000–2008.
[25] Wagner JG, Leatherman JW. Right Ventricular End-Diastolic Volume as a Predictor of the Hemodynamic Response to a Fluid Challenge. Chest. 1998; 113: 1048–1054.
[26] Kumar A, Anel R, Bunnell E, Habet K, Zanotti S, Marshall S, *et al*. Pulmonary artery occlusion pressure and central venous pressure fail to predict ventricular filling volume, cardiac performance, or the response to volume infusion in normal subjects. Critical Care Medicine. 2004; 32: 691–699.
[27] Arif Khammas A, Mahmud R. Ultrasonographic measurements of the liver, gallbladder wall thickness, inferior vena cava, portal vein and pancreas in an Urban Region, Malaysia. Journal of Medical Ultrasound. 2021; 29: 26.
[28] Sefidbakht S, Assadsangabi R, Abbasi HR, Nabavizadeh A. Sonographic measurement of the inferior vena cava as a predictor of shock in trauma patients. Emergency Radiology. 2007; 14: 181–185.
[29] Kim H, Kim JH, Kim JS, Hong DY, Han SB, Lee HJ. Acute nontraumatic abdominal pain in elderly patients: impact of abdominal CT evaluation. Journal of the Korean Society of Emergency Medicine. 2005; 16: 640–645.
[30] Kingwell BA. Large Artery Stiffness: Implications for Exercise Capacity and Cardiovascular Risk. Clinical and Experimental Pharmacology and Physiology. 2002; 29: 214–217.
[31] Vaitkevicius PV, Fleg JL, Engel JH, O'Connor FC, Wright JG, Lakatta LE, *et al*. Effects of age and aerobic capacity on arterial stiffness in healthy adults. Circulation. 1993; 88: 1456–1462.

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