

**Original
Article**

Trunk Muscle Cross-Sectional Area as a Predictive Factor for Length of Postoperative Hospitalization after Surgical Aortic Valve Replacement

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Purpose: We investigated the utility of trunk muscle cross-sectional area to predict length of hospitalization after surgical aortic valve replacement (AVR) for aortic stenosis (AS).

Methods: Adult AS patients who underwent isolated AVR at a single institution were studied. The cross-sectional area of the erector spinae muscles (ESM) at the first and second lumbar vertebrae and that of the psoas muscle (PM) at the third and fourth lumbar vertebrae were measured on preoperative computed tomography (CT). Each was indexed to body surface area. Risk factors for prolonged postoperative hospitalization (>3 weeks) were assessed using multivariate regression analyses.

Results: Of 56 patients (mean age 76 ± 9 years; 25 men), 20 (35.7%) patients required prolonged hospitalization. A smaller indexed ESM cross-sectional area at the first lumbar vertebra (per 1 cm², odds ratio [OR] = 0.71, 95% confidence interval [CI] = 0.57–0.88, $P < 0.01$) and lower preoperative serum albumin level (per 0.1 g/dL, OR = 0.83, 95% CI = 0.70–0.99, $P < 0.05$) were shown as independent predictors. Indexed PM cross-sectional area was not statistically significant.

Conclusion: The cross-sectional area of the trunk muscles can be used to identify patients at risk for prolonged hospitalization after AVR for adult AS.

Keywords: sarcopenia, erector spinae muscles, psoas muscle, aortic stenosis, aortic valve replacement

Introduction

Conventional surgical aortic valve replacement (AVR) has been safely performed in high-risk patients with

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aortic stenosis (AS) with acceptable short- and long-term results.^{1,2} Transcatheter aortic valve implantation, however, has emerged as a less invasive treatment option^{3,4} which can result in earlier recovery and shortened hospitalization time. This newer therapeutic modality is particularly appealing for elderly or frail patients whose physical performance is easily influenced by prolonged bed rest.^{5,6} To better identify the proper candidates for this, less invasive option is important.

Sarcopenia, one of the most important characteristics of frailty, has recently been reported to be associated with worse outcomes after cardiovascular surgery^{7–9} and the cross-sectional area of the psoas muscle (PM) measured on preoperative computed tomography (CT) has been reported as a surrogate marker of sarcopenia to predict prolonged stay after cardiovascular surgery.^{8,10} In

contrast, the clinical utility of the cross-sectional area of the erector spinae muscles (ESM), which are known to be closely associated with the daily physical activity level,^{11,12} has not been well studied.

The present study was performed to determine whether the preoperative status of the ESM can predict prolonged postoperative hospitalization in patients undergoing surgical AVR and thus become a better objective indicator for sarcopenia, which could help identify candidates for transcatheter aortic valve implantation rather than surgical AVR in the future.

Methods

Study patients

This retrospective study was approved by the Kansai Medical University Medical Center Institutional Review Board. We evaluated consecutive cases of adult patients who underwent surgical AVR for AS in our institute from July 2013 to August 2018. Patients who underwent concomitant cardiac surgery, emergency surgery, and/or re-do surgery were excluded. Each patient's demographic and preoperative clinical data (age, sex, body weight, height, comorbidities, heart failure symptoms, laboratory data, echocardiographic data, and cross-sectional areas of the ESM and PM), length of the postoperative hospital stay, and reasons for a prolonged postoperative hospital stay, which we defined as >3 weeks, were obtained through a comprehensive review of the medical records.

Among 110 patients who underwent surgical AVR for AS during the study period, 54 patients were excluded according to the exclusion criteria. The remaining 56 patients (mean age, 76 ± 9 years; 45% men) were included in the study (Table 1). In all, 16 (29%) patients had symptoms of New York Heart Association (NYHA) functional class III or IV. The mean operation time, cardiopulmonary bypass time, and cross-clamp time were 278 ± 78 , 146 ± 51 , and 107 ± 37 minutes, respectively. There was no 30-day mortality, and the mean length of the postoperative hospital stay was 21 ± 10 days. In all, 36 patients (64%) with a length of stay ≤ 3 weeks were labeled Group S, and the 20 (36%) patients with a length of stay >3 weeks were labeled Group L. The reasons for the prolonged postoperative hospital stay of Group L were prolonged rehabilitation ($n = 13$ [68%]), pneumonia ($n = 3$ [16%]), cerebral infarction ($n = 1$ [5%]), delayed cardiac tamponade ($n = 1$ [5%]), arteriovenous access failure requiring surgical intervention ($n = 1$ [5%]), and transfer to a rehabilitation hospital ($n = 1$ [5%]).

Table 1 Patients' profiles

Age, years	76.4 ± 9.2
Male sex	24 (43)
Body mass index, kg/m ²	23.3 ± 3.8
Hypertension	48 (86)
Dyslipidemia	35 (63)
Diabetes mellitus	22 (39)
End-stage renal disease	8 (14)
NYHA class III or IV	16 (29)

Data are presented as mean \pm standard deviation or n (%). NYHA: New York Heart Association

Measurement of muscle cross-sectional area

All study patients had undergone preoperative CT scans, the mean duration between CT scan and surgery was 35 ± 29 days. The cross-sectional areas of the ESM (multifidus, longissimus, and iliocostalis muscles) and PM were determined by manual planimetry of the muscle cross-section on the CT images using an area measurement tool on a picture archiving and communication systems (PACS) workstation (Carestream Vue PACS v11.4.1; Carestream Health Inc., Rochester, NY, USA) as shown in Fig. 1. The area of the ESM was obtained at the level of the inferior borders of the first and second lumbar vertebrae (L1 and L2), and that of the PM was obtained at the third and fourth lumbar vertebrae (L3 and L4). The measured cross-sectional areas of the left and right sides were totaled, which was defined as the ESM cross-sectional area, and each was indexed to the body surface area, which was defined as the indexed ESM area or indexed PM area, respectively.

Statistical analysis

Continuous variables are expressed as mean and standard deviation, and categorical variables are expressed as frequency number and percentage when appropriate. Clinical variables of Groups S and L were compared using the Mann–Whitney *U*-test for continuous variables or the chi-squared test for categorical variables. Univariate and multivariate associations of baseline characteristics with a prolonged postoperative hospital stay were assessed using logistic regression models, and the odds ratio (OR) and 95% confidence interval (CI) were calculated. The independent variables were selected in a stepwise manner according to the *P* values. The relation between the indexed ESM area at L1 and the serum albumin level was analyzed by Pearson's correlation test, and the correlation coefficient (*r*) was calculated. All statistical analyses were performed using IBM SPSS Statistics software version 24.0 (IBM

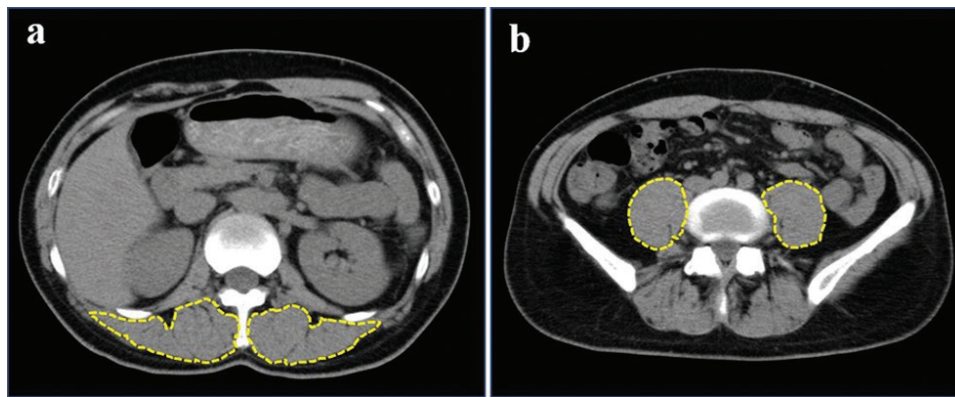


Fig. 1 Measurement of the cross-sectional area of the (a) ESM and (b) PM by manual planimetry. ESM: erector spinae muscles; PM: psoas muscle

Table 2 Patients' characteristics stratified by hospitalization status

Variables	Group S (n = 36)	Group L (n = 20)	P
<i>Clinical data</i>			
Age, years	73.8 ± 8.2	81.1 ± 9.3	<0.01
Male sex	17 (47)	7 (35)	0.38
Body surface area, m ²	1.52 ± 0.20	1.50 ± 0.16	0.71
Hypertension	30 (83)	18 (90)	0.50
Dyslipidemia	25 (69)	10 (50)	0.15
Diabetes mellitus	16 (44)	6 (30)	0.29
End-stage renal disease	4 (11)	4 (20)	0.36
NYHA class III or IV	7 (19)	9 (45)	<0.05
<i>Laboratory data</i>			
Hemoglobin, g/dL	13.0 ± 2.0	12.1 ± 1.2	0.05
Lymphocyte count, /μL	1779 ± 752	1344 ± 393	<0.05
Albumin, g/dL	4.3 ± 0.4	3.9 ± 0.4	<0.01
Cholinesterase, U/L	293 ± 62	246 ± 90	<0.05
Brain natriuretic peptide, pg/mL	392 ± 720	633 ± 854	0.06
<i>Echocardiographic data</i>			
LV ejection fraction, %	65 ± 12	64 ± 8	0.24
Aortic peak flow velocity, m/s	4.8 ± 0.7	4.7 ± 0.4	0.35
<i>Muscle cross-sectional area</i>			
ESM area at L1, cm ²	32.0 ± 8.1	23.1 ± 7.7	<0.001
ESM area at L2, cm ²	34.0 ± 9.2	26.4 ± 8.7	<0.01
Indexed ESM area at L1, cm ²	20.8 ± 3.9	15.2 ± 4.5	<0.0001
Indexed ESM area at L2, cm ²	22.2 ± 4.5	17.4 ± 4.9	<0.001
PM area at L3, cm ²	8.7 ± 4.1	7.6 ± 3.6	0.32
PM area at L4, cm ²	14.3 ± 2.0	13.3 ± 4.1	0.55
Indexed PM area at L3, cm ²	5.6 ± 2.1	5.0 ± 2.0	0.35
Indexed PM area at L4, cm ²	9.2 ± 2.4	8.8 ± 2.3	0.57
<i>Intraoperative data</i>			
Operation time, min	282 ± 87	269 ± 56	0.88
CPB time, min	149 ± 57	140 ± 36	0.79
Cross-clamp time, min	111 ± 40	101 ± 29	0.59

Data are presented as mean ± standard deviation or n (%). CPB: cardiopulmonary bypass; ESM: erector spinae muscles; LV: left ventricular; NYHA: New York Heart Association; PM: psoas muscle

Table 3 Univariate and multivariate analyses for prediction of prolonged hospitalization

Variables	OR (95% CI)	P	OR (95% CI)	P
<i>Clinical data</i>				
Age, per 10 years	3.11 (1.32–7.34)	<0.05		
Male sex	0.60 (0.20–1.86)	0.38		
Body surface area, per 0.1 m ²	0.94 (0.69–1.27)	0.69		
Hypertension	1.80 (0.33–9.89)	0.18		
Dyslipidemia	0.44 (0.14–1.36)	0.15		
Diabetes mellitus	0.54 (0.17–1.71)	0.29		
End-stage renal disease	2.00 (0.44–9.01)	0.37		
NYHA class III or IV	3.39 (1.01–11.35)	<0.05		
<i>Laboratory data</i>				
Hemoglobin, per 1 g/dL	0.73 (0.52–1.03)	0.07		
Lymphocyte count, per 100 cells/ μ L	0.88 (0.78–0.99)	<0.05		
Albumin, per 0.1 g/dL	0.79 (0.67–0.92)	<0.01	0.83 (0.70–0.99)	<0.05
Cholinesterase, per 10 U/L	0.91 (0.83–0.99)	<0.05		
Brain natriuretic peptide, per 100 pg/mL	1.04 (0.97–1.12)	0.29		
<i>Echocardiographic data</i>				
LV ejection fraction, per 10%	0.86 (0.52–1.43)	0.56		
Aortic peak flow velocity, per 1 m/s	0.69 (0.28–1.67)	0.41		
<i>Muscle cross-sectional area</i>				
ESM area at L1, per 1 cm ²	0.87 (0.79–0.95)	<0.01		
ESM area at L2, per 1 cm ²	0.90 (0.84–0.97)	<0.01		
Indexed ESM area at L1, per 1 cm ²	0.68 (0.55–0.84)	<0.001	0.71 (0.57–0.88)	<0.01
Indexed ESM area at L2, per 1 cm ²	0.78 (0.66–0.92)	<0.01		
PM area at L3, per 1 cm ²	0.92 (0.79–1.07)	0.30		
PM area at L4, per 1 cm ²	0.95 (0.84–1.08)	0.43		
Indexed PM area at L3, per 1 cm ²	0.87 (0.66–1.16)	0.35		
Indexed PM area at L4, per 1 cm ²	0.92 (0.73–1.17)	0.52		
<i>Intraoperative data</i>				
Operation time, per 10 min	0.98 (0.91–1.06)	0.58		
CPB time, per 10 min	0.96 (0.86–1.10)	0.90		
Cross-clamp time, per 10 min	0.92 (0.77–1.10)	0.77		

CI: confidence interval; CPB: cardiopulmonary bypass; ESM: erector spinae muscles; LV: left ventricular; NYHA: New York Heart Association; OR: odds ratio; PM: psoas muscle

Corp., Armonk, NY, USA). All tests were two-tailed, and a *P* value of <0.05 was considered statistically significant.

Results

Comparison between the two groups

Patients' characteristics stratified by hospitalization status are summarized in **Table 2**. The two groups showed significant differences in age, the number of patients with a preoperative NYHA class III or IV, the lymphocyte count, the serum albumin level, and the serum cholinesterase level. There were no significant differences between the two groups in echocardiographic variables or intraoperative variables. The patients in Group S had significantly larger indexed ESM area at both L1 and L2. However, there were no significant differences in indexed PM areas at either L3 or L4.

Predictors of prolonged postoperative hospital stay

The results of the univariate and multivariate logistic regression analyses are shown in **Table 3**. The univariate analysis showed that an older age, NYHA functional class III or IV, lower lymphocyte count, lower serum albumin level, lower serum cholinesterase level, and smaller indexed ESM area at both L1 and L2 were significantly associated with a prolonged postoperative hospitalization. In the multivariate analyses adjusted for covariates, lower serum albumin level (per 0.1 g/dL: OR, 0.83; 95% CI, 0.70–0.99; *P* <0.05) and smaller indexed ESM area at L1 (per 1 cm²/m²: OR, 0.71; 95% CI, 0.57–0.88; *P* <0.01) were shown to be significant independent predictors of a prolonged postoperative hospital stay. The indexed ESM area at L2 (per 1 cm²/m²: OR, 0.81; 95% CI, 0.68–0.96; *P* <0.05) was also a significant predictor independent of the serum albumin level (per

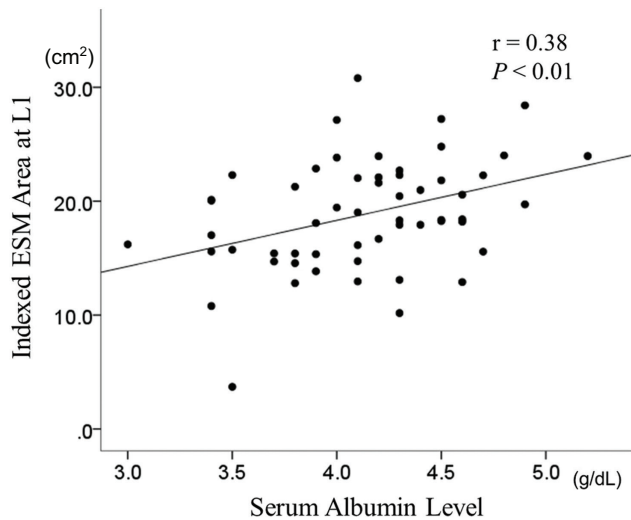


Fig. 2 Relationship between indexed ESM area at first lumbar vertebra (L1) and serum albumin level. There was a modest but significant positive correlation with Pearson's coefficient ($r = 0.38$). ESM: erector spinae muscles

0.1 g/dL: OR, 0.82; 95% CI, 0.69–0.97; $P < 0.05$). Age and preoperative NYHA functional class III or IV were not statistically significant predictors after adjusting for covariates. The correlation between the indexed ESM area at L1 and the serum albumin level is shown in **Fig. 2**. There was a modest but significant positive correlation between the indexed ESM area at L1 and the serum albumin level (Pearson's $r = 0.38$, $P < 0.01$).

Discussion

In this study, we investigated the clinical utility of the cross-sectional areas of the ESM and PM for prediction of a prolonged postoperative hospital stay after surgical AVR. Our study showed that the serum albumin level and indexed ESM area at both L1 and L2 on preoperative CT images were independent predictors of prolonged postoperative hospitalization. The PM cross-sectional area was not predictive.

Predictive value of cross-sectional muscle area

The ESM contains a high percentage of type I fibers and has an important role in stabilizing the body, maintaining posture, and controlling the movement of the trunk against gravity in both standing and sitting positions.^{13,14} Atrophy of the ESM is reportedly associated with prolonged bed rest or disability in activities of daily living in people of advanced age.^{6,11,12,15} However, the association between the preoperative ESM status and prolonged

hospitalization has not been well studied. In the present study, the indexed ESM area on preoperative CT images was found to be an independent predictor, but the indexed PM area was not statistically significant. Zuckerman et al.⁸⁾ reported that the cross-sectional PM area was associated with prolonged hospitalization after cardiac surgery, which is inconsistent with our results. The reason for this difference is unclear but may be related to the differences in the background of the study population and type of operative procedure. First, the mean age of the patients was higher in our study. In previous reports, the PM was shown to be associated with the level of physical performance.¹⁶⁾ However, the PM is mainly activated during walking¹⁷⁾ despite the activation of the ESM in standing and sitting positions.^{13,14} Therefore, in a group of advanced-age patients who likely spend most of their time sitting or lying in bed, the difference between the PM and ESM status may be relatively small. In addition, the cross-sectional area of the PM has been shown to be increased in patients with prolonged bed rest,^{12,15} probably because of the shortening of the muscle, which may lead to overestimation of the cross-sectional area of the PM. Second, we studied only patients who underwent AVR; however, the population in the above-mentioned study comprised patients who underwent various cardiac surgical procedures including coronary artery bypass grafting, aortic or mitral valve replacement or repair, and a combination of these. Therefore, we believe that the preoperative cross-sectional area of the ESM can be more useful than that of the PM as an indicator of preoperative sarcopenia, especially in patients of advanced age.

Nutritional status and prolonged hospitalization

As mentioned above, the serum albumin level was an independent predictor of prolonged hospitalization and was also significantly related to the cross-sectional area of the ESM in this study. Considering the fact that the serum albumin level is a well-known indicator of nutritional status¹⁸⁾ and that malnutrition is an important cause of sarcopenia,¹⁹⁾ it is not surprising that the serum albumin level was a predictor of prolonged hospitalization. Furthermore, our data suggest that the cross-sectional area of the ESM may partly reflect patients' nutritional status. If possible, the nutritional status should be improved or maintained before AVR to shorten the hospital stay.

Assessment of sarcopenia in patients with heart failure

Daily activities are limited in patients with heart failure symptoms.²⁰⁾ Therefore, it is sometimes challenging to evaluate the actual physical performance level or exercise

capacity in such patients based on conventional assessment methods, such as the gait speed test, eyeball test, or questionnaire-based assessment. In the present study, a preoperative NYHA class of III–IV was associated with prolonged hospitalization in the univariate analysis, but it was not significant after adjusting for covariates and the muscle cross-sectional area. Longstanding heart failure is suggested to induce sarcopenia²¹); however, acute symptoms are less likely to affect patients' actual level of physical performance potential. Similarly, the muscle cross-sectional area is less likely to be acutely changed by symptoms; thus, it seems to be a more stable indicator of the daily physical activity level. In addition, preoperative CT images can be obtained from almost all patients with any physical activity status. Furthermore, manual planimetric measurement of the cross-sectional area can be performed without special tools. Therefore, we believe that the cross-sectional area of the ESM is an objective and easily used scale of sarcopenia or recovery potential in patients even with heart failure.

Study limitations

There are several limitations in this study. Conventional physical performance tests such as the six-minute walk test were not routinely performed, and further study is needed to reveal the relationship of physical performance and ESM area. For the same reason as above and preoperative nutritional data other than serum albumin level were not routinely gathered, nutritional data other than serum albumin level were also not available. Finally, this study was conducted in a single center, and the total number of patients was relatively small, and thus, whether the findings can be generalized to other population groups needs to be verified in future studies.

Conclusion

A smaller cross-sectional area of the ESM was shown to be a predictor of prolonged postoperative hospitalization in patients who have undergone surgical AVR for AS. It is a simple, objective, and easily used risk assessment tool for frailty that can be helpful when making decisions regarding therapeutic strategies for AS.

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Disclosure Statement

The authors have no conflicts of interest to disclose.

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