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# Utility of Psoas Muscle Area in Selecting Older Patients Feasible for Thoracic Endovascular Aortic Repair

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## ABSTRACT

**BACKGROUND** The impact of psoas muscle area on overall survival is unknown for older patients undergoing elective thoracic endovascular aortic repair.

**METHODS** We retrospectively reviewed 105 patients aged 75 years or more who underwent elective thoracic endovascular aortic repair for descending thoracic aortic aneurysm between January 2010 and December 2019. Psoas muscle area was measured at the L3 level with preoperative computed tomography and adjusted by height squared to derive psoas muscle mass index. The patients were stratified into two groups, sarcopenia and nonsarcopenia. sarcopenia was defined as a psoas muscle mass index less than 5.40 $cm^2/m^2$ for men and less than 3.56 $cm^2/m^2$ for women. The overall survival was compared with the age- and sex-matched general population using the one-sample log rank test. The propensity score adjusted Cox proportional hazards model was applied to determine the hazard ratio for all-cause mortality.

**RESULTS** Twenty-three patients died during the follow-up period (median, 3 years). Thirty-eight patients (36%) were classified as sarcopenia. The 5-year overall survival rate was 46% (95% confidence interval, 29% to 73%) for sarcopenia and 84% (95% confidence interval, 74% to 94%) for nonsarcopenia. The overall survival was significantly lower in the sarcopenia group than in its matched general population ($P = .004$), whereas no statistically significant difference in overall survival was found between the nonsarcopenia group and its matched general population ($P = .417$). Sarcopenia was an independent risk factor for all-cause mortality (adjusted hazard ratio 2.64; 95% confidence interval, 1.02 to 6.82; $P = .045$).

**CONCLUSIONS** Psoas muscle mass index may be a good predictor of mortality among older patients undergoing elective thoracic endovascular aortic repair for descending thoracic aortic aneurysm.

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Nowadays, thoracic endovascular aortic repair (TEVAR) is the standard treatment for descending thoracic aortic aneurysm (DTAA).[1-3] Since TEVAR is less invasive and believed to be more suitable for older patients than traditional open surgical repair, its use has been increasing, reflecting the overall changes in demographics.[1,2,4,5] However, older patients, especially those aged more than 75 years, have been shown to have higher mortality after TEVAR than younger patients.[6-9] Patients aged 75 years and more had a 2.3 times higher mortality rate at 1 and 3 years,

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**Abbreviations and Acronyms**

CI = confidence interval
CT = computed tomography
DTAA = descending thoracic aortic aneurysm
HR = hazard ratio
IQR = interquartile range
PMI = psoas muscle mass index
SMR = standardized mortality ratio
TEVAR = thoracic endovascular aortic repair

and a 1.9 times at 5 years, compared with younger patients.[6-8]

The latest international guideline suggests using higher aortic diameter thresholds for TEVAR in patients deemed to have a particularly high risk of death, where the benefit of treatment is lower than the risk posed by the natural history of the DTAA.[3] As such, preoperatively identifying patients at high risk for mortality has become more important. However, most previous studies merely compared survival after TEVAR between older and younger patients.[6-9] Furthermore, these studies included patients with different levels of urgency.[6-8] Hence, there are few reports focusing on risk factors for mortality in older patients undergoing elective TEVAR.[6,10]

Sarcopenia has been described as an age-related decline in skeletal muscle mass and function.[11,12] Sarcopenia is associated with increased adverse outcomes including falls, functional decline, frailty, and mortality.[11,12] Psoas muscle area measured with computed tomography (CT) has been reported to be an indicator for sarcopenia and to be associated with mortality after pancreatic, cardiac, and aortic surgery.[13-18] Psoas muscle area was associated with adverse events after TEVAR in a previous study.[14] However, there are few reports focusing on survival after TEVAR.[14,18] In this study, we assessed usefulness of psoas muscle area measured with preoperative CT in selecting patients aged 75 years or more who may obtain a survival benefit from elective TEVAR for DTAA.

## PATIENTS AND METHODS

**STUDY POPULATION AND STUDY DESIGN.** This study enrolled 105 consecutive patients aged 75 years or more who underwent elective TEVAR for DTAA in four institutions between January 1, 2010, and December 31, 2019. The total case volume of TEVAR for DTAA during this period was 282 in our institutions. Patients who had previously undergone TEVAR (n = 21), patients with urgent or emergent indications (n = 36), patients with mycotic aneurysm (n = 6), and patients aged less than 75 years (n = 114) were excluded from the study population. The patient characteristics, operative details, and follow-up data were retrospectively collected from the medical records of each participating institution as of June 30, 2021.

In this study, the patients were stratified into two groups, sarcopenia and nonsarcopenia, based on psoas muscle area measured with preoperative CT. The primary outcome was 5-year overall survival, which was compared between the two groups and compared with the age- and sex-matched general population for each group. The propensity score adjusted Cox proportional hazards model was applied to determine the hazard ratio (HR) of sarcopenia for all-cause mortality.

This study complied with the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board of each participating institution. Patients who were alive and being followed up provided written informed consent. For the patients who were dead or lost to follow-up, we posted an explanation of the study on our institutional websites and allowed them or their families to decide whether they would participate in the study.

**TEVAR PROCEDURES.** The TEVAR procedures were performed with the patients under general anesthesia using commercial devices (Supplemental Table 1). A femoral or iliac artery was surgically isolated. The delivery system was introduced through the femoral arteriotomy or iliac conduit and advanced using a stiff guidewire. In cases with a short proximal landing zone (less than 20 mm), coil embolization of left subclavian artery, chimney stenting to left subclavian artery or left common carotid artery, and/or debranching and bypass (right axillary artery to left axillary artery bypass, or right axillary artery to left common carotid artery to left axillary artery bypass) was performed to create a sufficient proximal landing zone.

**MEASUREMENT OF PSOAS MUSCLE AREA AND DEFINITION OF SARCOPENIA.** The preoperative CT images were evaluated by a single radiologist (T.O.) using the medical viewing system EV Insite (PSP Corp), blinded to outcomes. The measurement of psoas muscle area was based on the methodology described in previous studies.[13,15,16,19] The right and left psoas muscle areas were separately measured at the lower part of the L3 level. The observer manually outlined the muscle, and the software calculated the area within the limits of the boundary drawn. The sum of right and left psoas muscle areas was adjusted by height-squared to be able to standardize the measurement between individuals with different heights to derive psoas muscle mass index (PMI). The unit for psoas muscle area was $cm^2$ and for PMI, $cm^2/m^2$. This measurement was performed twice, and the mean value was used.

Sarcopenia was defined as a PMI less than 5.40 $cm^2/m^2$ for men and less than 3.56 $cm^2/m^2$ for women, according to the previous study.[19] These cutoffs were selected because the international working groups of sarcopenia suggest the use of cutoffs derived from healthy young adults.[11,12]

**STATISTICAL ANALYSES.** Reliability of PMI was quantified as the intraclass correlation coefficient(1, 2) for mean measurements using the one-way random effects model. To assess interobserver reliability of PMI, two radiologists (H.K., K.N.) independently calculated PMI for 25 CT scans randomly selected from the whole cohort. Interobserver reliability of PMI was quantified as the intraclass correlation coefficient(2, 1) for single measurements using the two-way random effects model.

Continuous variables were summarized as median and interquartile range (IQR) and compared between the two groups using the Mann-Whitney *U* test. Categoric variables were summarized as numbers and percentages and compared using Fisher's exact test. Overall survival was estimated using the Kaplan-Meier method and compared between the two groups using the log rank test. Overall survival was also compared with the age- and sex-matched general population using the one-sample log rank test and standardized mortality ratio (SMR).[20] The matched general population was obtained from the Japanese population life table for fiscal year 2015 (available at the website of the Japanese Ministry of Health, Labor, and Welfare: https://www.mhlw.go.jp/toukei/saikin/hw/life/22th/index.html). The maximum time-to-event was set at 5 years, and the entire study population was therefore censored at that point. Events were defined as death from any cause occurring within 5 years of TEVAR.

The Cox proportional hazards model was applied to determine the hazard ratio (HR) of sarcopenia for all-cause mortality. The propensity score, which predicted the probability of being assigned to the sarcopenia group, was entered into the Cox proportional hazards model to adjust differences in baseline characteristics. The multivariate logistic regression model including 20 preoperative variables (Table 1) was constructed to calculate the propensity score. In addition, debranching and bypass, which was reported as a risk factor for all-cause mortality in the previous study,[21] was entered into the Cox proportional hazards model to adjust the difference in invasiveness of procedure. All variables were checked with log-minus-log plots to confirm the proportional hazards assumption.

To increase the robustness of our findings, we performed two sensitivity analyses. In the first, the sex-specific first quartiles in PMI were used as cutoffs in accordance with what was done in previous

**TABLE 1 Baseline Characteristics**

| Characteristics | Total (n = 105) | Sarcopenia (n = 38) | Nonsarcopenia (n = 67) | *P* Value |
|---|---|---|---|---|
| Age, y | 81 (78-83) | 82 (77-84) | 81 (78-83) | .88 |
| Female | 33 (31) | 6 (16) | 27 (40) | .01 |
| Body surface area, $m^2$ | 1.506 (1.447-1.623) | 1.541 (1.440-1.614) | 1.500 (1.454-1.652) | .74 |
| Ever smoker | 63 (60) | 30 (79) | 33 (49) | .004 |
| Serum creatinine, mg/dL | 0.89 (0.72-1.11) | 0.96 (0.70-1.24) | 0.88 (0.74-1.06) | .51 |
| Hemoglobin, g/dL | 12.6 (11.5-13.6) | 12.3 (10.9-13.1) | 12.6 (11.9-13.7) | .15 |
| Hypertension | 91 (87) | 33 (87) | 58 (87) | >.99 |
| Diabetes mellitus | 22 (21) | 7 (18) | 15 (22) | .80 |
| Dyslipidemia | 41 (39) | 12 (32) | 29 (43) | .30 |
| COPD | 27 (26) | 12 (32) | 15 (22) | .36 |
| Congestive heart failure | 7 (6.7) | 4 (11) | 3 (4.5) | .25 |
| Coronary artery disease | 45 (43) | 17 (45) | 28 (42) | .84 |
| Atrial fibrillation | 9 (8.6) | 2 (5.3) | 7 (10) | .48 |
| Old cerebral infarction | 19 (18) | 10 (26) | 9 (13) | .12 |
| Prior thoracic aortic repair[a] | 18 (17) | 6 (16) | 12 (18) | >.99 |
| Prior abdominal aortic repair[b] | 22 (21) | 12 (32) | 10 (15) | .05 |
| Prior malignancy | 27 (26) | 10 (26) | 17 (25) | >.99 |
| Aneurysm etiology | | | | .57 |
| Arteriosclerosis | 91 (87) | 32 (84) | 59 (88) | |
| Postdissection | 14 (13) | 6 (16) | 8 (12) | |
| Aneurysm shape | | | | .41 |
| Fusiform | 45 (43) | 14 (37) | 31 (46) | |
| Saccular | 60 (57) | 24 (63) | 36 (54) | |
| Aneurysm max diameter, mm | 55 (46-60) | 55 (48-58) | 55 (46-61) | .72 |

[a]Prior thoracic aortic repair included ascending aortic replacement and total arch replacement; [b]Prior abdominal aortic repair included open surgical repair and endovascular aneurysm repair. Values are median (interquartile range) or n (%). COPD, chronic obstructive pulmonary disease; max, maximum.

studies.[13,16,17] In the second, independent variables were selected from 20 preoperative variables and debranching and bypass through the forward stepwise selection method based on Akaike information criteria and entered into the Cox proportional hazards model. Statistical analyses were performed using R 4.0.4 (R Foundation for Statistical Computing). All tests were two-sided and significance level was set to *P* value less than .05.

## RESULTS

**PSOAS MUSCLE MASS INDEX.** The median interval between preoperative CT and TEVAR was 73 days (IQR, 50 to 97). Intraclass correlation coefficient(1, 2) showed excellent reliability of PMI at 0.95 (95% confidence interval [CI], 0.93 to 0.97). Furthermore, intraclass correlation coefficient(2, 1) showed excellent agreement among the three observers at 0.93 (95% CI, 0.86 to 0.97). The distribution of PMI is shown in Figure 1. The median PMI was 5.50 (IQR, 4.56 to 6.41) in men and 4.29 (IQR, 3.75 to 4.92) in women. Thirty-eight patients (36%) were classified as the sarcopenia group.

**BASELINE CHARACTERISTICS AND OPERATIVE DETAILS.** Baseline characteristics are summarized in Table 1. The median patient age was 81 years (IQR, 78 to 83). The oldest patient was 96 years of age. Sixty-two patients (59%) were octogenarians, and 6 (5.7%) were nonagenarians. Proportions of female and ever-smoker were significantly different between the two groups (*P* = .010 and *P* = .004, respectively). The proportion of patients who had previously undergone abdominal aortic repair (open surgical repair or endovascular aneurysm repair) was higher in the sarcopenia group than in the nonsarcopenia group, although it was not significant (*P* = .051). The other preoperative variables did not differ significantly between the two groups.

Operative details are summarized in Table 2. Seven patients (6.7%) underwent coil embolization of left subclavian artery, 9 (8.6%) underwent chimney stenting (left subclavian artery, n = 8; left common carotid artery, n = 1), and 22 (21%) underwent debranching and bypass (right axillary artery to left axillary artery bypass, n = 12; right axillary artery to left common carotid artery to left axillary artery bypass, n = 10). The operative variables did not differ significantly between the two groups.

**OVERALL SURVIVAL.** The median follow-up period was 3 years (IQR, 1.2 to 5.0). Twenty-three patients died during the follow-up period, and included 2 inhospital deaths (both in the nonsarcopenia group). The causes of late death are summarized in Table 3. One patient in the sarcopenia group underwent re-TEVAR for sac expansion 2 years after the initial TEVAR and died of disseminated intravascular coagulation. Another 13 patients died of causes not associated with aorta or procedure; the remaining 7 died of unknown causes.

The 5-year overall survival rate was 71% (95% CI, 61% to 82%) in the entire study population (Figure 2). The overall survival was slightly lower in the study population than in the age- and sex-matched general population, although it was not significant (*P* = .286; SMR 1.25; 95% CI, 0.79 to 1.98). When stratifying the patients based on PMI, the 5-year overall survival rate was significantly lower in the sarcopenia group (46%; 95% CI, 29% to 73%) than in the nonsarcopenia group (84%; 95% CI, 74% to 94%; *P* = .006; Figure 3). Moreover, the overall survival was significantly lower in the sarcopenia group than in its matched general population (*P* = .004; SMR 2.11; 95% CI, 1.17 to 3.81). No statistically significant

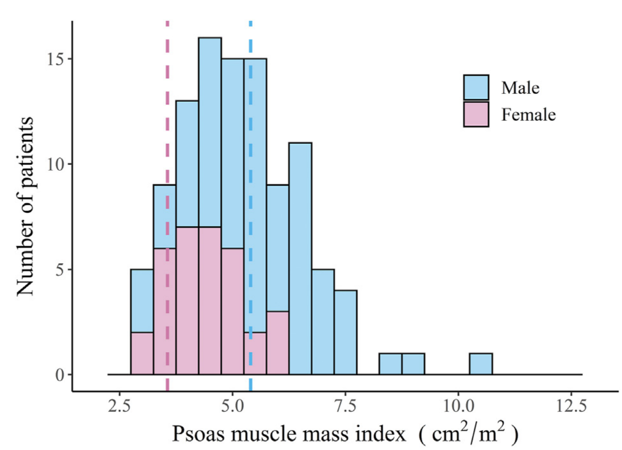


**FIGURE 1** Distribution of psoas muscle mass index. Dashed lines indicate sex-specific cutoff for sarcopenia—male (blue) less than 5.40 $cm^2/m^2$; female (red) less than 3.56 $cm^2/m^2$.

**TABLE 2 Operative Details**

| Variables | Total (n = 105) | Sarcopenia (n = 38) | Nonsarcopenia (n = 67) | *P* Value |
|---|---|---|---|---|
| Devices, more than 2 | 6 (5.7) | 3 (7.9) | 3 (4.5) | .67 |
| Proximal landing zone | | | | .62 |
| Zone 1 | 11 (10) | 4 (11) | 7 (10) | |
| Zone 2 | 26 (25) | 11 (29) | 15 (22) | |
| Zone 3 | 36 (34) | 12 (32) | 24 (36) | |
| Zone 4 | 20 (19) | 5 (13) | 15 (22) | |
| Zone 5 | 12 (11) | 6 (16) | 6 (9) | |
| Distal landing zone | | | | .25 |
| Zone 4 | 7 (6.7) | 4 (11) | 3 (4.5) | |
| Zone 5 | 98 (93) | 34 (89) | 64 (96) | |
| Coil embolization of LSCA | 7 (6.7) | 5 (13) | 2 (3) | .10 |
| Chimney stenting | 9 (8.6) | 2 (5.3) | 7 (10) | .48 |
| Debranching and bypass | 22 (21) | 8 (21) | 14 (21) | >.99 |

Values are n (%). LSCA, left subclavian artery.

**TABLE 3 Causes of Late Death**

| Cause of Late Death | No. of Patients |
|---|---|
| Sarcopenia group (n = 14) | |
| DIC after re-TEVAR | 1 |
| Brain hemorrhage | 3 |
| Cerebral infarction | 1 |
| Lung cancer | 1 |
| Pneumonia | 1 |
| Pulmonary embolism | 1 |
| Renal failure | 1 |
| Unknown | 5 |
| Nonsarcopenia group (n = 7) | |
| Brain hemorrhage | 1 |
| Neck cancer | 1 |
| Myelodysplastic syndrome | 1 |
| Pneumonia | 1 |
| Sepsis | 1 |
| Unknown | 2 |

DIC, disseminated intravascular coagulation; No., number; TEVAR, thoracic endovascular aortic repair.

difference in overall survival was found between the nonsarcopenia group and its matched general population ($P = .417$; SMR 0.76; 95% CI, 0.37 to 1.59).

**COX PROPORTIONAL HAZARDS ANALYSIS.** The univariate Cox proportional hazards model revealed that sarcopenia was a significant risk factor for all-cause mortality (crude HR 3.08; 95% CI, 1.33 to 7.15; $P = .009$; Table 4). To calculate the propensity score, the multivariate logistic regression model was constructed, and it achieved good discriminatory power (C-statistic 0.78; 95% CI, 0.68 to 0.87; Supplemental Figure 1). In the multivariate Cox proportional hazards model including the propensity score and debranching and bypass, sarcopenia was an independent risk factor for all-cause mortality (adjusted HR 2.64; 95% CI, 1.02 to 6.82; $P = .045$; Table 4). The model was significantly fitted to the data (likelihood ratio test, $P = .021$). No apparent violation of the proportional assumption was found (Supplemental Figure 2).

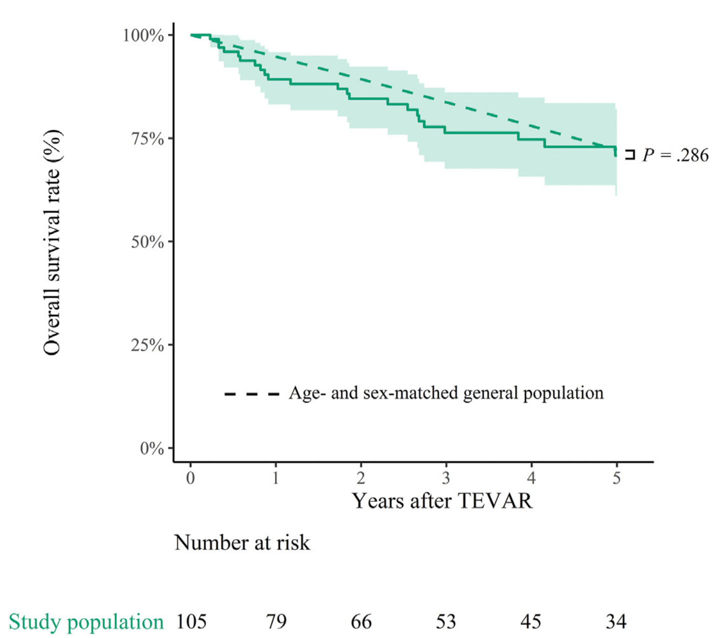


**FIGURE 2** Overall survival rate in study population of patients aged 75 years or more after elective thoracic endovascular aortic repair (TEVAR) for descending thoracic aortic aneurysm. Shaded area indicates 95% confidence interval; dashed line indicates survival rate in age- and sex-matched general population.

**SENSITIVITY ANALYSES.** Although we performed two sensitivity analyses, the results did not change. In the first sensitivity analysis, sarcopenia was defined as a PMI less than 4.56 $cm^2/m^2$ for men and less than 3.75 $cm^2/m^2$ for women. Twenty-six patients (25%) were classified as the sarcopenia group. The SMR in the sarcopenia group was 3.04 (95% CI, 1.65 to 5.61; $P < .001$), and the adjusted HR of sarcopenia was 5.67 (95% CI, 2.06 to 15.59; $P < .001$; Supplemental Table 2).

In the second sensitivity analysis, hemoglobin, dyslipidemia, prior abdominal aortic repair, maximum aneurysm diameter, and debranching and bypass were selected as independent variables and entered into the Cox proportional hazards model. The adjusted HR of sarcopenia was 2.53 (95% CI, 1.03 to 6.24; $P = .043$; Supplemental Table 3).

## COMMENT

We investigated the impact of PMI measured with preoperative CT on 5-year overall survival of patients aged 75 years or more who underwent elective TEVAR for DTAA. Sarcopenia defined based on PMI was an independent risk factor for all-cause mortality. Although no statistically significant difference in overall survival was found between the nonsarcopenia group and the age- and sex-matched general population, the overall survival was significantly lower in the sarcopenia group than in its matched general population.

In this study, PMI was measured based on the widely adopted methodology[13,15,16,19] and used as the criteria of sarcopenia. The PMI showed excellent reliability and agreement, which was consistent with the results of previous studies.[15] The PMI was slightly lower in this study than in previous studies,[13,16] likely because this study enrolled only patients aged 75 years or more. Because the optimal cutoff of PMI remains unclear for patients undergoing TEVAR,[14,18] we used two cutoffs: one was derived from healthy young adults, and the other was the sex-specific first quartile. However, the results did not change.

When stratifying the patients based on PMI, the overall survival was significantly higher in the nonsarcopenia group than in the sarcopenia group, in agreement with previous studies.[13-18] Moreover, the 5-year overall survival rate was higher in the nonsarcopenia group than in elective cases registered with the Japanese national registry (84% vs 53.1%).[22] In addition, no statistically significant difference in overall survival was found between the nonsarcopenia group and the age- and sex-matched general population. Indeed, most of deaths were not associated with aorta or procedure in the nonsarcopenia group. These results suggest that, for selected patients, even older patients have increased survival after elective TEVAR for DTAA.

Conversely, the 5-year overall survival rate was significantly lower in the sarcopenia group than in its matched general population. However, in the sarcopenia group, no inhospital death occurred after the initial TEVAR, with most of late deaths being not associated with aorta or procedure. A possible explanation of this discrepancy is that the sarcopenia by itself negatively influenced overall survival with or without DTAA and TEVAR. This hypothesis is supported by the meta-analysis, which showed an association between sarcopenia and all-cause mortality among community-dwelling older people.[23]

Based on the results of this study, we suggest including PMI as part of assessment on whether to advise older patients to have an elective TEVAR for DTAA. Patients with a low PMI may have a short life expectancy from the beginning. Moreover, TEVAR sometimes causes serious complications such as stroke and spinal cord ischemia.[22] The association between small psoas muscle area and adverse events after TEVAR was also reported.[14] Therefore, the application of TEVAR in older patients with a low PMI will need to be a carefully made decision. The latest international guideline also suggests using higher aortic diameter thresholds for TEVAR in patients deemed to have a particularly high risk of death.[3]

When considering the application of TEVAR in older patients with a low PMI, comparing their life expectancy with the expected natural history of their DTAA is required. Aortic height index, which was defined as aortic diameter divided by patient's height, was reported to be associated with the spontaneous incidence of rupture, dissection, and aortic death.[24] The 5-year freedom from rupture, dissection, and aortic death was 56.5% for patients with aortic height index of 3 to 3.5 cm/m, 27.1% for index of 3.6 to 4.1 cm/m, and 26.1% for index of 4.2 cm/m or larger.[24] The 5-year overall survival rate after TEVAR was 46% in patients with a low PMI in this study; the survival rate after TEVAR may be lower than the freedom from adverse events with no repair in older patients with a low PMI and an aortic height index less than 3.6 cm/m. Therefore, the TEVAR indication of these patients should be considered more deliberately.

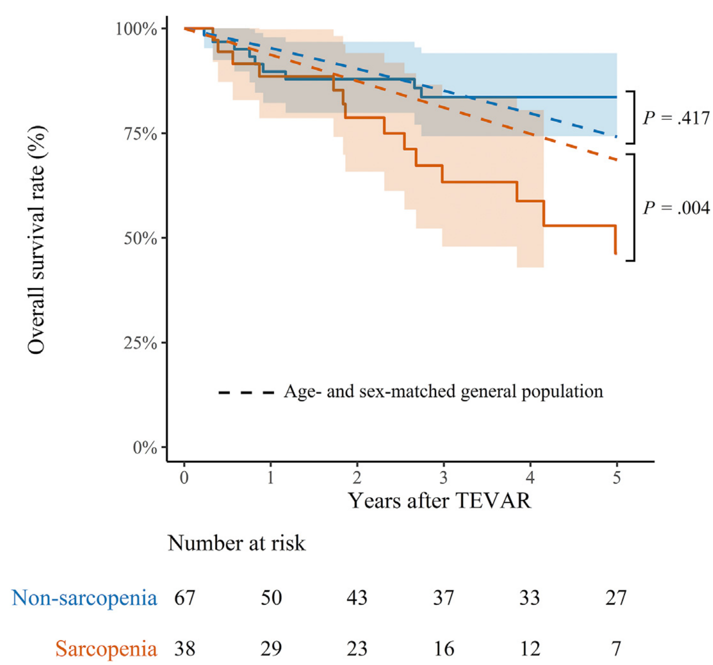


**FIGURE 3** Overall survival rate in sarcopenia group (orange) and nonsarcopenia group (blue). Shaded areas indicate 95% confidence interval for each group; dashed lines indicate survival rate in age- and sex-matched general population for each group. (TEVAR, thoracic endovascular aortic repair.)

**STUDY LIMITATIONS.** This study has several limitations. First, it is a retrospective study. Second, the small sample size in this study could have generated skewed results. The small sample size also limits the propensity score matching and weighting. Third, although some patients had long-term follow-up, the median duration of follow-up only allows midterm conclusions to be drawn. Fourth, we used PMI as the criteria of sarcopenia, although whether PMI reflects whole-body muscle mass and is a representative of sarcopenia is

**TABLE 4** Cox Proportional Hazards Model

| | Univariate | | | Multivariate | | |
|---|---|---|---|---|---|---|
| Variables | HR | 95% CI | *P* Value | HR | 95% CI | *P* Value |
| Sarcopenia | 3.08 | 1.33-7.15 | .009 | 2.64 | 1.02-6.82 | .05 |
| Propensity score | 6.23 | 1.13-34.47 | .04 | 2.01 | 0.29-13.93 | .48 |
| Debranching and bypass | 2.12 | 0.83-5.41 | .12 | 2.01 | 0.78-5.21 | .15 |

The multivariate model was significantly fitted to the data (likelihood ratio test, $P = .02$). CI, confidence interval; HR, hazard ratio.

controversial.[12] Because this study is a retrospective study, we could not obtain data on other indicators of sarcopenia such as grip strength and gait speed.[11,12] Fifth, we compared survival with the age- and sex-matched general population, which was not the best to assess whether older patients have increased survival after elective TEVAR. To assess the true effect of TEVAR in older patients, randomized controlled studies are needed.

**CONCLUSION.** Psoas muscle mass index measured with preoperative CT may be a good predictor of mortality among older patients undergoing elective TEVAR for DTAA. The application of TEVAR in older patients with a low PMI will need to be a careful decision.

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**Supplementary Table 1**

The stent grafts used in the study population

| Stent graft model[a] | Whole (n = 105) | Sarcopenia (n = 38) | Non-sarcopenia (n = 67) |
|---|---|---|---|
| TAG | 6 (5.7) | 2 (5.3) | 4 (6.0) |
| Zenith TX2 | 47 (45) | 22 (58) | 25 (37) |
| Talent | 2 (1.9) | 0 (0.0) | 2 (3.0) |
| Relay Plus | 18 (17) | 6 (16) | 12 (18) |
| Valiant Captivia | 4 (3.8) | 1 (2.6) | 3 (4.5) |
| conformable TAG | 23 (22) | 6 (16) | 17 (25) |
| Zenith Alpha Thoracic | 5 (4.8) | 1 (2.6) | 4 (6.0) |

Values are presented as n (%). [a]The stent grafts used in the study population were TAG (W.L. Gore & Associates, Flagstaff, AZ), Zenith TX2 (Cook Medical, Bloomington, IN), Talent (Medtronic, Minneapolis, MN), Relay Plus (Bolton Medical, Sunrise, FL), Valiant Captivia (Medtronic, Minneapolis, MN), conformable TAG (W.L. Gore & Associates, Flagstaff, AZ), and Zenith Alpha Thoracic (Cook Medical, Bloomington, IN).

**Supplementary Table 2**

The first sensitivity analysis (Cox proportional-hazard model)

| | Univariate | | | Multivariate | | |
|---|---|---|---|---|---|---|
| Variables | Hazard ratio | 95% CI | *P* value | Hazard ratio | 95% CI | *P* value |
| Sarcopenia | 3.91 | 1.71–8.94 | .001 | 5.67 | 2.06–15.59 | < .001 |
| Propensity score | 2.69 | 0.69–10.43 | .15 | 0.44 | 0.09–2.26 | .33 |
| Debranching and bypass | 2.12 | 0.83–5.41 | .12 | 2.68 | 1.03–6.98 | .04 |

The multivariate model was significantly fitted to the data (likelihood ratio test, *P* = .002). CI, confidence interval.

**Supplementary Table 3**

The second sensitivity analysis (Cox proportional-hazard model)

| | Univariate | | | Multivariate | | |
|---|---|---|---|---|---|---|
| Variables | Hazard ratio | 95% CI | *P* value | Hazard ratio | 95% CI | *P* value |
| Sarcopenia | 3.08 | 1.33–7.15 | .009 | 2.53 | 1.03–6.24 | .04 |
| Age (per 1 year) | 1.10 | 0.99–1.21 | .07 | | | |
| Female (versus Male) | 0.47 | 0.17–1.27 | .14 | | | |
| Body surface area (per 1 $m^2$) | 1.41 | 0.11–18.62 | .79 | | | |
| Ever smoker | 1.35 | 0.57–3.19 | .49 | | | |
| Serum creatinine (per 1 mg/dL) | 1.09 | 0.70–1.71 | .71 | | | |
| Hemoglobin (per 1 g/dL) | 0.78 | 0.63–0.97 | .03 | 0.82 | 0.65–1.05 | .11 |
| Hypertension | 0.39 | 0.15–1.07 | .07 | | | |
| Diabetes mellitus | 0.90 | 0.30–2.64 | .84 | | | |
| Dyslipidemia | 0.33 | 0.11–0.96 | .04 | 0.21 | 0.07–0.65 | .007 |
| Chronic obstructive pulmonary disease | 0.69 | 0.24–2.05 | .51 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Congestive heart failure | 1.13 | 0.27–4.84 | .87 | | | |
| Coronary artery disease | 0.91 | 0.40–2.11 | .83 | | | |
| Atrial fibrillation | 1.65 | 0.49–5.58 | .42 | | | |
| Old cerebral infarction | 0.80 | 0.24–2.71 | .73 | | | |
| Prior thoracic aortic repair[a] | 1.15 | 0.43–3.11 | .78 | | | |
| Prior abdominal aortic repair[b] | 3.10 | 1.36–7.08 | .007 | 3.35 | 1.38–8.12 | .008 |
| Prior malignancy | 0.99 | 0.39–2.52 | .99 | | | |
| Post-dissection (versus Arteriosclerosis) | 1.19 | 0.35–4.02 | .78 | | | |
| Saccular (versus Fusiform) | 1.40 | 0.59–3.30 | .45 | | | |
| Maximum aneurysm diameter (per 1 mm) | 1.03 | 0.99–1.07 | .18 | 1.04 | 1.00–1.08 | .03 |
| Debranching and bypass | 2.12 | 0.83–5.41 | .12 | 2.32 | 0.83–6.52 | .11 |

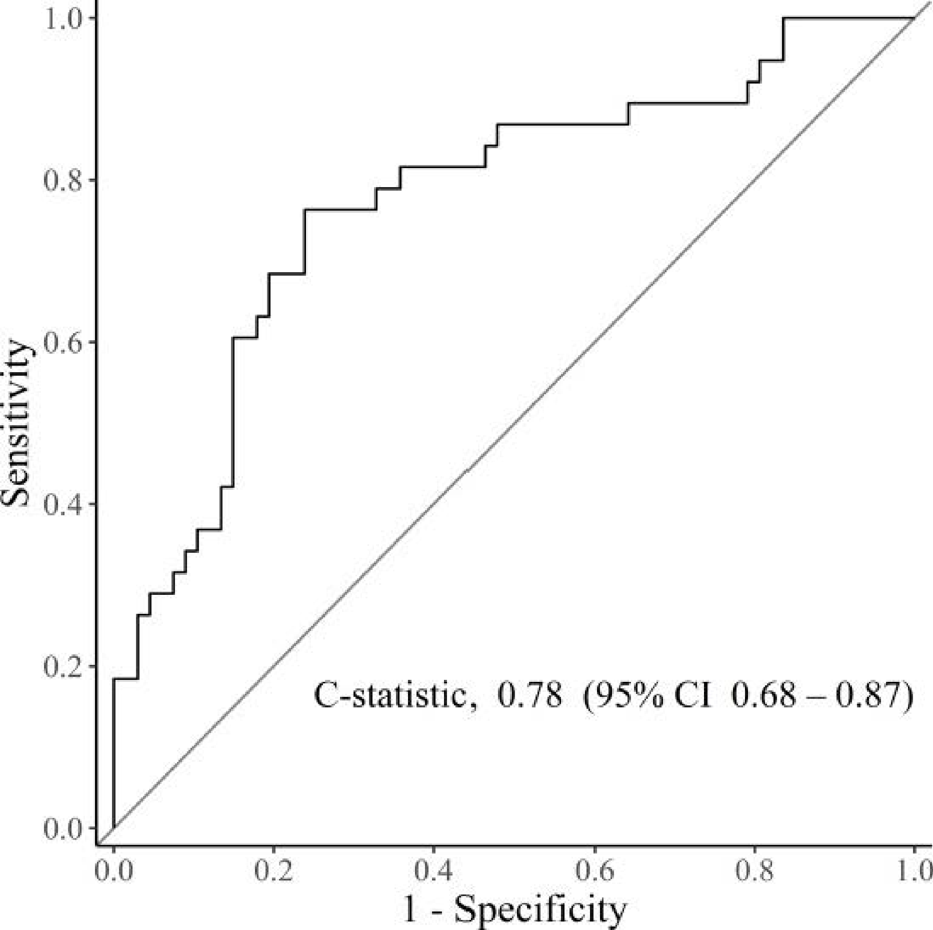
The multivariate model was significantly fitted to the data (likelihood ratio test, $P < .001$). [a]Prior thoracic aortic repair contained ascending aortic replacement and total arch replacement. [b]Prior abdominal aortic repair contained open surgical repair and endovascular aneurysm repair. CI, confidence interval.

**Supplementary Figure 1**

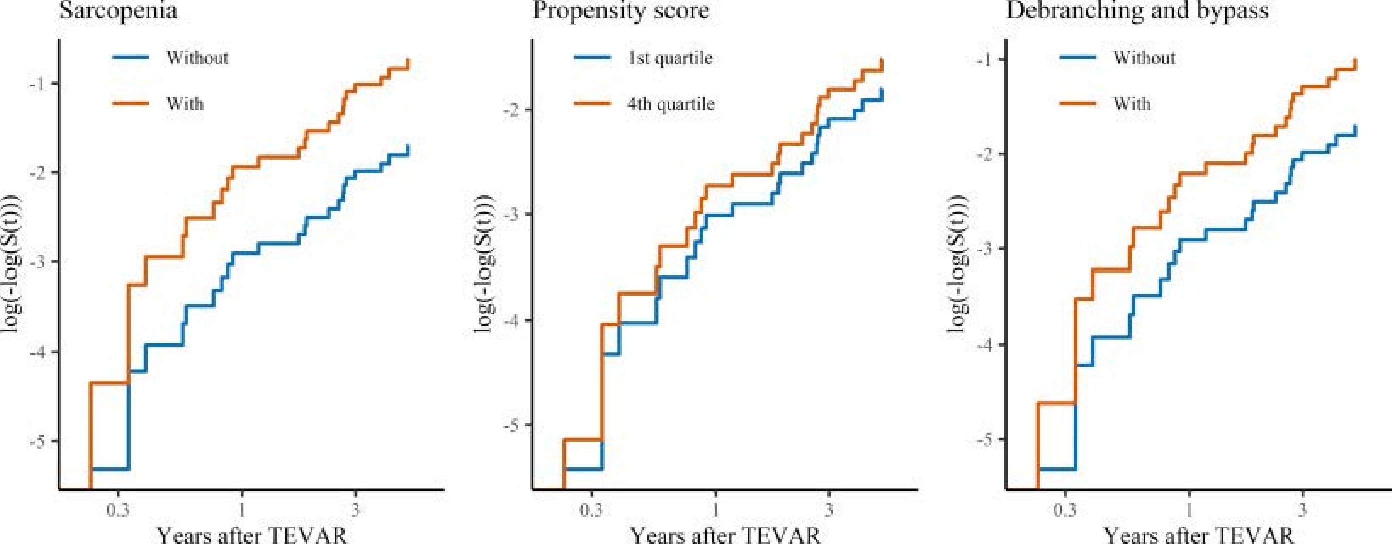
The receiver operating characteristic curve. The multivariate logistic regression model achieved a good discriminatory power. CI, confidence interval.

**Supplementary Figure 2**

The log-minus-log plots. All three variables met the proportional hazard assumption.



Sensitivity
1.0
0.8
0.6
0.4
0.2
0.0
C-statistic, 0.78 (95% CI 0.68 – 0.87)
0.0
0.2
0.4
0.6
0.8
1.0
1 - Specificity



Sarcopenia
Without
With
log(-log(S(t)))
-1
-2
-3
-4
-5
0.3
1
3
Years after TEVAR
Propensity score
1st quartile
4th quartile
log(-log(S(t)))
-2
-3
-4
-5
0.3
1
3
Years after TEVAR
Debranching and bypass
Without
With
log(-log(S(t)))
-1
-2
-3
-4
-5
0.3
1
3
Years after TEVAR