Original Investigation

Gait Speed and Operative Mortality in Older Adults Following Cardiac Surgery

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IMPORTANCE Prediction of operative risk is a critical step in decision making for cardiac surgery. Existing risk models may be improved by integrating a measure of frailty, such as 5-m gait speed, to better capture the heterogeneity of the older adult population.

OBJECTIVE To determine the association of 5-m gait speed with operative mortality and morbidity in older adults undergoing cardiac surgery.

DESIGN, SETTING, AND PARTICIPANTS A prospective cohort study was conducted from July 1, 2011, to March 31, 2014, at 109 centers participating in the Society of Thoracic Surgeons Adult Cardiac Surgery Database. The 5-m gait speed test was performed in 15 171 patients aged 60 years or older undergoing coronary artery bypass graft, aortic valve surgery, mitral valve surgery, or combined procedures.

MAIN OUTCOMES AND MEASURES All-cause mortality during the first 30 days after surgery; secondarily, a composite outcome of mortality or major morbidity during the index hospitalization.

RESULTS Among the cohort of 15 171 patients undergoing cardiac surgery, the median age was 71 years and 4622 were female (30.5%). Compared with patients in the fastest gait speed tertile (>1.00 m/s), operative mortality was increased for those in the middle tertile (0.83-1.00 m/s; odds ratio [OR], 1.77; 95% CI, 1.34-2.34) and slowest tertile (<0.83 m/s; OR, 3.16; 95% CI, 2.31-4.33). After adjusting for the Society of Thoracic Surgeons predicted risk of mortality and the surgical procedure, gait speed remained independently predictive of operative mortality (OR, 1.11 per 0.1-m/s decrease in gait speed; 95% CI, 1.07-1.16). Gait speed was also predictive of the composite outcome of mortality or major morbidity (OR, 1.03 per 0.1-m/s decrease in gait speed; 95% CI, 1.00-1.05). Addition of gait speed to the Society of Thoracic Surgeons predicted risk resulted in a C statistic change of 0.005 and integrated discrimination improvement of 0.003.

CONCLUSIONS AND RELEVANCE Gait speed is an independent predictor of adverse outcomes after cardiac surgery, with each 0.1-m/s decrease conferring an 11% relative increase in mortality. Gait speed can be used to refine estimates of operative risk, to support decision-making and, since incremental value is modest when used as a sole criterion for frailty, to screen older adults who could benefit from further assessment.

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Frailty is a geriatric syndrome characterized by subclinical impairments in multiple organ systems that impede the body's ability to maintain physiological homeostasis in the face of stressors.[1] Gait speed, measured as the time required to walk a short distance (usually 5 m) at a comfortable pace, is one of the most commonly used tests to screen for frailty and identify high-risk older adults in need of further evaluation.[2] The gait speed test reflects impairments in lower-extremity muscle function and, to a lesser extent, neurosensory and cardiopulmonary function. In community-dwelling older adults, the prevalence of frailty is estimated to be 10%.[3] The prognostic implications of frailty are a 12% decrease in long-term survival for every 0.1-m/s slower gait speed.[4] The prevalence of frailty is higher among older adults with cardiovascular disease, ranging from 20% to 60%, depending on the population and assessment tool used.[5]

The utility of gait speed is especially promising in cardiac surgery, where an increasingly aged and complex geriatric population is subject to the inherent stress of surgery.[6] The Frailty Assessment Before Cardiac Surgery (Frailty ABCs) study measured gait speed in 131 patients undergoing cardiac surgery and found that slow gait speed (<0.83 m/s) was associated with an odds ratio (OR) of 3.05 (95% CI, 1.23-7.54) for in-hospital mortality or major morbidity.[7] The adoption of frailty and gait speed assessment has been substantial in the cardiovascular community, yet there remains a need to validate the results of small initial studies in a broader cohort before recommendations can be made. Therefore, we measured 5-m gait speed in the large population-based network of the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database, and then sought to determine its association with 30-day mortality and morbidity after cardiac surgery.

Key Points

Question What is the association of 5-m gait speed (a measure of frailty) with operative mortality and morbidity in older adults undergoing cardiac surgery?

Findings Gait speed was measured before cardiac surgery in a cohort study of 15 171 older adults and was found to be an independent predictor of adverse outcomes, with each 0.1-m/s slowing in gait speed conferring an 11% increase in mortality.

Meaning The 5-m gait speed test can be used to refine estimates of operative risk, support decision making, and decide when a comprehensive geriatric assessment is warranted.

Methods

Study Design

A population-based cohort study within the STS Adult Cardiac Surgery Database was conducted from July 1, 2011, to March 31, 2014. This database houses more than 5.2 million surgical records, gathering information from more than 90% of the groups that perform cardiac surgery in the United States, as well as a growing number internationally. In July 2011, the 5-m gait speed test was added as a recommended parameter to the baseline preoperative assessment for patients undergoing cardiac surgery and became a standard variable on the data collection form. Gait speed data that accrued by July 2014 (36 months) was analyzed to determine its incremental value after adjusting for the STS predicted risk of mortality. The Duke Clinical Research Institute Institutional Review Board approved this study. All patient data were deidentified. This article was prepared in accordance with the standards set forth by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[8]

Population

Patients were included if they were 60 years or older; underwent coronary artery bypass graft (CABG) surgery, aortic valve surgery, mitral valve surgery, or CABG combined with aortic or mitral valve surgery; and had at least 1 record of 5-m gait speed in the STS Adult Cardiac Surgery Database. The age cutoff of 60 years or older was empirically chosen based on a reasonable lower age limit to obtain a useful yield from frailty testing in clinical practice, since prior studies have established that the prevalence of frailty is less than 4% in patients younger than 60 years vs more than 14% in those older than 60 years.[9,10] Patients were excluded if they were unable to safely walk or had a critical preoperative status before surgery (defined as emergency or emergency salvage surgery, cardiogenic shock, requirement for inotropic support, or an intra-aortic balloon pump). To set a minimum experience at the center level, centers were excluded if they had recorded gait speed in fewer than 10 patients during the study interval. A flow diagram of the study population is shown in **Figure 1**.

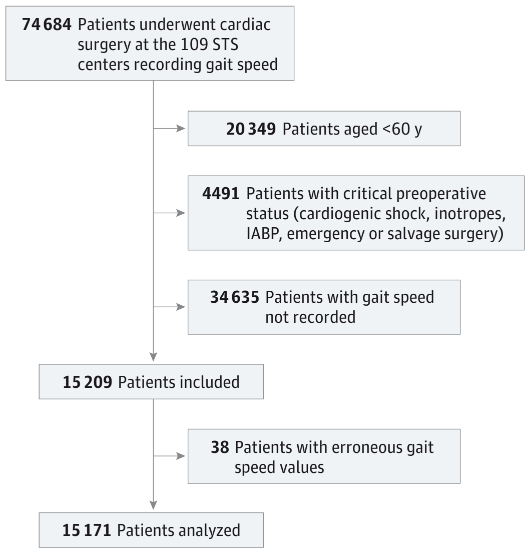
Predictor: 5-m Gait Speed Test

Before surgery, patients performed the 5-m gait speed test. The test was standardized according to the following instructions: position the patient with his or her feet behind and just touching the 0-m start line; instruct the patient to "walk at your comfortable pace" until a few steps past the 5-m mark (should not start to slow down before the 5-m mark); begin each trial on the word "go"; start the timer with the first footfall after the 0-m line; and stop the timer with the first footfall after the 5-m line. This test was repeated 3 times, allowing sufficient time for recuperation between trials. Most patients (13 654 of 15 171 [90.0%]) had 3 walking times recorded. Erroneous walking times of less than 2 seconds or more than 30 seconds were set to missing (n = 38). The time for each trial was then averaged to calculate the patient's gait speed (5 m per mean time in seconds).

Outcomes

The primary outcome was operative mortality, defined as death during the same hospitalization as the surgical procedure (regardless of timing) or within 30 days of the surgical procedure (regardless of venue). The secondary outcome was the STS composite of mortality or major morbidity, defined as[11] operative mortality, permanent stroke, reoperation (for bleeding, cardiac tamponade, valvular dysfunction, graft occlusion, or other cardiac or noncardiac reason), prolonged mechanical ventilation for more than 24 hours, deep sternal

Figure 1. Flow Diagram



The final cohort consisted of 15 171 patients 60 years or older whose 5-m gait speed was tested before undergoing nonemergent coronary artery bypass graft (CABG) surgery, surgical aortic valve replacement (AVR), mitral valve repair (MVR), CABG surgery plus AVR, or CABG surgery plus MVR. The study consisted of 109 centers that were participating in the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database and had recorded gait speed data in at least 10 patients. IABP indicates intra-aortic balloon pump.

wound infection, or acute kidney injury (risk, injury, failure, loss of kidney function, and end stage kidney disease [RIFLE] stage III: 3-fold increase in creatinine level, 75% decrease in glomerular filtration rate, or serum creatinine level of ≥4 mg/dL [to convert to micromoles per liter, multiply by 88.4] with an acute rise ≥0.5 mg/dL).

Covariates

The main covariate was the STS predicted risk of mortality (STS-PROM) calculated with the full prediction model of the STS Adult Cardiac Surgery Database (http://riskcalc.sts.org/stswebriskcalc). The STS risk model integrates 30 to 35 demographic and clinical covariates to calculate a predicted risk of operative mortality for each patient. There are 3 variations of the STS risk model: 1 for isolated CABG surgery, 1 for isolated aortic or mitral valve surgery, and 1 for combined CABG plus aortic or mitral valve surgery. These 3 models have been extensively validated and found to have C statistics for operative mortality of 0.812,[12] 0.799,[13] and 0.750,[14] respectively. Given the expansive number of individual covariates, regression models were adjusted for the STS-PROM rather than for the individual covariates to prevent overfitting of the model.[15] However, as a sensitivity analysis, regression models were adjusted for the following 15 core covariates (and not the STS-PROM), defined by previous studies as those accounting for the bulk of the predictive effect: age (linear), sex, body surface area, diabetes mellitus, chronic lung disease, cerebrovascular disease, peripheral arterial disease, creatinine (linear), left ventricular ejection fraction (linear), heart failure within 2 weeks, myocardial infarction (within 24 hours, 1-21 days, >21 days, or none), left main or 3-vessel coronary artery disease, prior cardiac surgical procedures (0, 1, 2, or more), surgery status (urgent or elective), and prior cardiac surgery performed.

Statistical Analysis

Continuous variables were presented as medians with their first quartile (Q1) and third quartile (Q3), and categorical variables as number and proportion. Baseline characteristics and unadjusted outcomes were compared across tertiles of gait speed using the Kruskal-Wallis and χ^2 tests. Missing values for categorical covariates were handled by using simple imputation (common category), and for continuous covariates by using the conditional median. For binary covariates (yes or no), missing values were treated as an answer of no, according to STS analysis standards. To assess for selection bias, the baseline characteristics and observed outcomes were compared for patients with vs without gait speed captured in the STS Adult Cardiac Surgery Database during the study time frame. For included patients with gait speed captured, characteristics and outcomes were compared in a univariable fashion across stratified tertiles of gait speed.

Multivariable regression models were then built with the following 3 terms: the logit of STS-PROM as a fixed offset term (coefficient set to 1), gait speed, and intercept. Models were stratified by isolated CABG surgery, isolated aortic or mitral valve surgery, or combined surgery (corresponding to the 3 variations of the STS risk model) to generate 3 ORs, which were then pooled using a fixed-effects meta-analysis model to generate a pooled OR for the entire cohort. Gait speed was primarily represented as a continuous term and secondarily as a categorical tertile term. Model fit was compared using restricted cubic splines to treat gait speed as linear; since the use of splines did not improve the model's fit to the data, adjusted ORs were reported from models treating gait speed as linear. To test the model's incremental value, performance was evaluated using C statistics, integrated discrimination improvement (IDI), and relative IDI.[16]

Results

The study population consisted of 15 171 patients from 109 participating centers, with a median age of 71 years (Q1, 66 years; Q3, 77 years), including 2481 patients aged 80 to 89 years (16.4%) and 4622 women (30.5%). The surgery performed was isolated CABG in 9005 patients (59.4%), isolated aortic or mitral valve surgery in 3765 (24.8%), or combined CABG plus aortic or mitral valve surgery in 2401 (15.8%). The median overall gait speed was 0.94 m/s (Q1, 0.75 m/s; Q3, 1.15 m/s) in patients undergoing CABG surgery, 1.00 m/s (Q1, 0.79 m/s; Q3, 1.15 m/s) in those undergoing isolated valve surgery, and 0.94 m/s (Q1, 0.71 m/s; Q3, 1.07 m/s) in those undergoing combined CABG and valve surgery. The median overall STS-PROM was 1.70% (Q1, 0.92%; Q3, 3.18%); STS-PROM was lowest for isolated CABG surgery at 1.20% (Q1, 0.73%; Q3, 2.14%) and highest for combined CABG plus valve surgery at 3.66% (Q1, 2.38%; Q3, 5.83%).

Compared with patients who were included, those excluded on the basis of not having had an assessment of gait speed were similar in terms of median age, female sex, and median STS-PROM (eTable 1 in the Supplement). A major reason for not assessing gait speed was short time between hospital admission and surgery (nonelective status, surgery within 24 hours of admission), during which time the gait test was usually performed. Gait speed was more likely to be assessed in patients requiring valve surgery and less likely to be assessed in patients classified as New York Heart Association classes III or IV, although the proportion of recently decompensated heart failure was similar between patients who were included and those excluded.

Gait speed was less than 0.83 m/s in the slowest tertile, 0.83 to 1.00 m/s in the middle tertile, and more than 1.00 m/s in the fastest tertile (eFigure in the Supplement). Compared with those in the fastest tertile, patients in the slowest tertile were older (median, 74 vs 69 years) and had higher STS-PROM (median, 2.50% vs 1.22%), body mass index (calculated as weight in kilograms divided by height in meters squared) (median, 29.0 vs 27.9), proportions of women (43.3% vs 20.2%), and rates of diabetes mellitus (49.5% vs 32.2%), chronic lung disease (36.3% vs 22.9%), peripheral arterial disease (18.1% vs 11.4%), prior stroke (11.6% vs 4.5%), prior myocardial infarction (40.0% vs 27.7%), recent heart failure (34.4% vs 21.9%), New York Heart Association classes III or IV (63.4% vs 42.6%), and urgent surgery (47.6% vs 25.8%) (**Table 1**).

In unadjusted models, slower gait speed was associated with higher operative mortality (**Figure 2** and **Table 2**). Compared with those in the fastest tertile, there was a graded increase in the risk of operative mortality among patients in the middle tertile (OR, 1.77; 95% CI, 1.34-2.34) and the slowest tertile (OR, 3.16; 95% CI, 2.31-4.33). Compared with those in the fastest tertile, there was a modest nonlinear increase in the risk of composite mortality or major morbidity among patients in the middle tertile (OR, 1.26; 95% CI, 1.09-1.46) and the slowest tertile (OR, 1.86; 95% CI, 1.60-2.16).

After adjusting for STS-PROM and stratifying by type of surgery, gait speed as a continuous variable remained predictive of operative mortality (pooled OR, 1.11 per 0.1-m/s decrease in gait speed; 95%, CI 1.07-1.16) (**Figure 3**). Compared with those in the fastest tertile, there was a graded increase in risk among patients in the middle tertile (OR, 1.58; 95% CI, 1.19-2.09) and the slowest tertile (OR, 2.10; 95% CI, 1.52-2.89). Gait speed was also a predictor of composite mortality or major morbidity in the adjusted models (pooled OR, 1.03 per 0.1-m/s decrease in gait speed; 95% CI, 1.00-1.05). Compared with those in the fastest tertile, there was a graded increase in risk among patients in the middle tertile (OR, 1.08; 95% CI, 0.93-1.26) and the slowest tertile (OR, 1.20; 95% CI, 1.01-1.43). In particular, patients in the slowest tertile had a 2-fold increase in risk of reoperation for noncardiac causes, acute kidney injury, and prolonged mechanical ventilation.

For operative mortality, the C statistic of the baseline STS model was 0.772 in isolated CABG surgery, 0.738 in isolated valve surgery, and 0.725 in combined surgery; after adding gait speed, the C statistic was 0.776, 0.744, and 0.728, respectively, and the IDI was 0.003, 0.004, and 0.003, respectively. For composite mortality or major morbidity, the C statistic of the baseline STS model was 0.671 in isolated CABG surgery, 0.663 in isolated valve surgery, and 0.678 in combined surgery; after adding gait speed, the C statistic was 0.672, 0.665, and 0.677, respectively, and the IDI was 0.001, 0.004, and 0.002, respectively (eTable 2 in the Supplement).

Sensitivity analysis adjusting for 15 individual covariates rather than STS-PROM yielded similar results (adjusted OR for operative mortality, 1.09 per 0.1-m/s decrease in gait speed; 95% CI, 1.04-1.14; adjusted OR for composite mortality or major morbidity, 1.04 per 0.1-m/s decrease in gait speed; 95% CI, 1.02-1.07). An exploratory post hoc subgroup analysis did not demonstrate any statistically significant interactions using a Bonferroni-corrected threshold of $P < .01$ (eTable 3 in the Supplement).

Discussion

To our knowledge, this is the largest study to evaluate the prognostic value of gait speed, an indicator of frailty, in a representative national sample of patients undergoing cardiac surgery. The 5-m gait speed test was successfully implemented at 109 centers in more than 15 000 patients during a 3-year time frame. Slow gait speed was independently predictive of operative mortality and, to a lesser extent, of composite mortality or major morbidity. This result was observed across a spectrum of the most commonly performed cardiac surgical procedures used to treat ischemic and valvular heart disease. Overall, for each 0.1-m/s decrease in gait speed (eg, taking 6 seconds as opposed to 7 seconds to walk the 5-m course at a comfortable pace), there was an 11% relative increase in operative mortality after adjusting for STS-PROM.

The effect size is clinically significant and consistent with a meta-analysis of 9 cohort studies, which reported that each 0.1-m/s increase in gait speed was associated with a 10% decrease in mortality after adjusting for sociodemographic and comorbid covariates (hazard ratio, 0.90; 95% CI, 0.89-0.91).[4] This meta-analysis differs from our study in that the population was community-dwelling older adults with a relatively low burden of heart disease (8%-24%). The mean gait speed in community-dwelling older adults (0.92 m/s) was similar to that in our cohort of cardiac surgery patients (0.94 m/s). Moreover, the 10% effect on mortality was incurred after a follow-up period of more than 5 years in community-dwelling older adults as compared with a follow-up period of 30 days in our population undergoing cardiac surgery.

Associations between clinical and demographic characteristics and slow gait speed have been described.[7] Slow walkers frequently have the profile of being an older obese woman with diabetes and multiple comorbid conditions. This profile is contrary to the popular belief that low body mass index and thin body habitus are indicative of frailty. The same profile was noted in the Frailty ABCs study, which similarly reported a 3-fold increase in mortality for patients whose gait speed was less than 0.83 m/s.[7] Compared with the findings of the Frailty ABCs study, our study found a greater correlation between STS-PROM and gait speed, such that the effect of gait speed

Table 1. Baseline Characteristics Stratified by Gait Speed Tertiles

Characteristic	Value[a] Slow Tertile (<0.83 m/s) (n = 4588)	Middle Tertile (0.83-1.00 m/s) (n = 5717)	Fast Tertile (>1.00 m/s) (n = 4866)	*P* Value
Demographics				
Age, median, y (Q1-Q3)	74 (67-79)	71 (66-77)	69 (65-74)	<.001
Female sex	1988 (43.3)	1652 (28.9)	982 (20.2)	<.001
Race				<.001
White	3964 (86.4)	5081 (88.9)	4205 (86.4)	
Black or African American	258 (5.6)	236 (4.1)	122 (2.5)	
Asian	98 (2.1)	134 (2.3)	275 (5.7)	
Other	254 (5.5)	242 (4.2)	241 (5.0)	
Clinical				
BMI, median (Q1-Q3)	29.0 (25.4-33.4)	28.7 (25.6-32.7)	27.9 (25.1-31.3)	<.001
Diabetes mellitus	2272 (49.5)	2280 (39.9)	1567 (32.2)	<.001
Hypertension	4215 (91.9)	5066 (88.6)	4108 (84.4)	<.001
Dyslipidemia	3949 (86.1)	4935 (86.3)	4137 (85.0)	.13
Cigarette smoker	981 (21.4)	1254 (21.9)	1056 (21.7)	.80
Previous MI	1836 (40.0)	1772 (31.0)	1347 (27.7)	<.001
Three-vessel or left main CAD	2796 (60.9)	3259 (57.0)	2748 (56.5)	<.001
Heart failure within 2 wk	1576 (34.4)	1495 (26.2)	1063 (21.9)	<.001
NYHA class III-IV	999 (63.4)	761 (50.9)	453 (42.6)	<.001
LVEF, median, % (Q1-Q3)	55 (46-60)	58 (50-62)	60 (50-63)	<.001
Prior stroke	533 (11.6)	416 (7.3)	219 (4.5)	<.001
Cerebrovascular disease	1031 (22.5)	953 (16.7)	585 (12.0)	<.001
Peripheral arterial disease	831 (18.1)	827 (14.5)	553 (11.4)	<.001
Chronic lung disease	1663 (36.3)	1600 (28.0)	1112 (22.9)	<.001
Chronic kidney disease	1623 (35.4)	1524 (26.7)	1068 (22.0)	<.001
Creatinine, median, mg/dL (Q1-Q3)	1.0 (0.8-1.3)	1.0 (0.8-1.2)	1.0 (0.8-1.2)	.002
Procedural				
Prior cardiac surgery	354 (7.7)	460 (8.1)	393 (8.1)	.77
Urgent surgery	2184 (47.6)	1670 (29.2)	1257 (25.8)	<.001
Surgery performed				<.001
Isolated CABG	2786 (60.7)	3347 (58.5)	2872 (59.0)	
Isolated aortic or mitral valve	1015 (22.1)	1468 (25.7)	1282 (26.4)	
CABG plus valve	787 (17.2)	902 (15.8)	712 (14.6)	
STS-PROM, median, % (Q1-Q3)	2.5 (1.3-4.6)	1.6 (0.9-3.0)	1.2 (0.7-2.2)	<.001
STS-PROM <2%	1845 (40.2)	3379 (59.1)	3444 (70.8)	<.001
STS-PROM 2%-3.9%	1344 (29.3)	1450 (25.4)	970 (19.9)	
STS-PROM 4%-7.9%	961 (21.0)	682 (11.9)	373 (7.7)	
STS-PROM ≥8%	438 (9.6)	206 (3.6)	79 (1.6)	
STS-PROMM, median, % (Q1-Q3)	18.1 (12.3-26.5)	14.0 (9.8-20.4)	11.8 (8.5-17.3)	<.001

Abbreviations: BMI, body mass, index (calculated as weight in kilograms divided by height in meters squared); CABG, coronary artery bypass graft surgery; CAD, coronary artery disease; LVEF, left ventricular ejection fraction; MI, myocardial infarction; NYHA, New York Heart Association; Q1, quartile 1; Q3, quartile 3; STS-PROM, Society of Thoracic Surgeons predicted risk of mortality; STS-PROMM, Society of Thoracic Surgeons predicted risk of mortality or major morbidity.

SI conversion factor: To convert creatinine to micromoles per liter, multiply by 88.4.

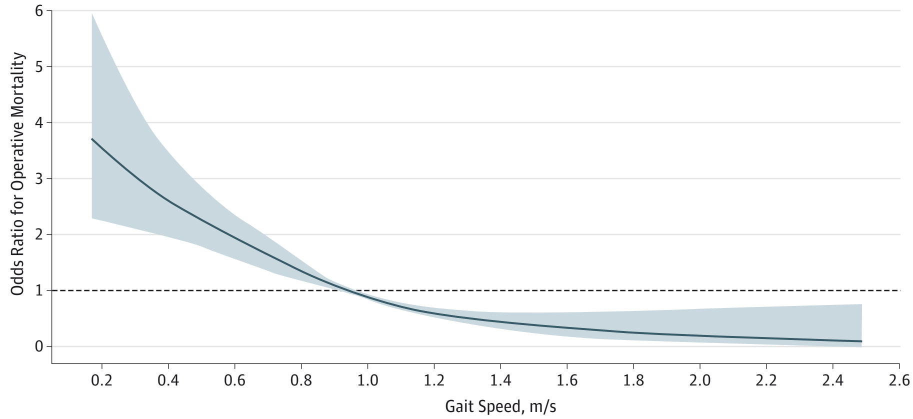
[a] Data are presented as number (percentage) of patients unless otherwise indicated.

after adjusting for STS-PROM was slightly attenuated. Gait speed was similar across types of cardiac surgery, despite a higher STS-PROM in valve procedures than in isolated CABG surgery. This finding illustrates the distinct information provided by gait speed beyond clinical variables in the STS-PROM calculation.

Gait speed was an independent predictor of mortality after adjusting for STS-PROM, but its incremental value to discriminate between older adults who had a positive or negative postoperative outcome, as measured by the change in C statistic and IDI, was modest. Improvements in discrimination were previously reported in higher-risk oldest old patients in the Frailty ABCs study (enrolled age, 70 years or older; 30-day mortality, 5%)[7] and the Frailty Predicts Death One Year After Cardiac Surgery Test (FORECAST) study (enrolled age, 74 years or older; 30-day mortality, 8%),[17] whereas our cohort consisted predominantly of low- to moderate-risk patients in their seventh or eighth decade of life (enrolled age, 60 years or older; 30-day mortality, 2%). Furthermore, the FORECAST study used a multidomain frailty assessment, which may be incremental to the single domain of gait speed to capture the heterogeneity of this complex population.

Furthermore, the change in C statistic is a function of the effect size, prevalence of the added predictor, and the C statistic

Figure 2. Unadjusted Association Between Gait Speed and Operative Mortality



Decreasing gait speed was associated with increasing odds of operative mortality. The blue area indicates the 95% CI. The dashed line indicates the reference odds ratio of 1.0.

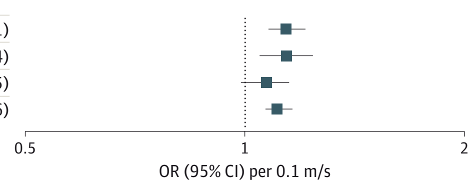
Table 2. Thirty-Day Outcomes Stratified by Gait Speed Tertiles

Outcome	No. (%) Slow Tertile (<0.83 m/s) (n = 4588)	No. (%) Middle Tertile (0.83-1.00 m/s) (n = 5717)	No. (%) Fast Tertile (>1.00 m/s) (n = 4866)	*P* Value
Primary end point				
Operative mortality	154 (3.4)	108 (1.9)	52 (1.1)	<.001
Secondary end point and components[a]				
Composite mortality and morbidity	767 (16.7)	685 (12.0)	474 (9.7)	<.001
Reoperation for bleeding	109 (2.4)	144 (2.5)	117 (2.4)	.88
Reoperation for graft occlusion	8 (0.2)	7 (0.1)	9 (0.2)	.68
Reoperation for valve dysfunction	0 (0.0)	2 (0.03)	3 (0.06)	.26
Reoperation for other cardiac cause	26 (0.6)	21 (0.4)	15 (0.3)	.18
Reoperation for noncardiac cause	104 (2.3)	82 (1.4)	51 (1.1)	<.001
Permanent stroke	83 (1.8)	92 (1.6)	74 (1.5)	.52
Acute kidney injury	156 (3.4)	156 (2.7)	79 (1.6)	<.001
Deep sternal wound infection	23 (0.5)	7 (0.1)	8 (0.2)	<.001
Prolonged mechanical ventilation	496 (10.8)	406 (7.1)	246 (5.1)	<.001

[a] The secondary outcome was a composite of in-hospital all-cause death, stroke, prolonged mechanical ventilation, acute kidney injury, deep sternal wound infection, or need for reoperation.

Figure 3. Effect of Gait Speed After Adjusting for Society of Thoracic Surgeons (STS) Predicted Risk

Surgery	No.	OR (95% CI) per 0.1 m/s	*P* Value
CABG	9005	1.14 (1.08-1.21)	<.001
Valve	3765	1.14 (1.05-1.24)	.002
CABG plus valve	2401	1.07 (0.99-1.15)	.07
All pooled	15 171	1.11 (1.07-1.16)	<.001



A logistic regression model was stratified for the 3 cardiac surgical procedures, and adjusted for the STS predicted risk of mortality as a fixed offset term (from the surgery-specific STS model). The pooled odds ratio (OR) for gait speed to predict operative mortality was 1.11 (95% CI, 1.07-1.16) per 0.1-m/s decrease in gait speed. CABG indicates coronary artery bypass graft.

of the baseline model. In considering factors that may have mitigated our observed change in C statistic, the effect size (adjusted OR, 2.10 for slowest tertile) and prevalence of slow gait speed were not low, yet the C statistic of the baseline STS model was high, at 0.77. Given a baseline C statistic greater than 0.75, simulation studies have shown that the expected change in C statistic will be trivial unless the effect size exceeds an OR of 5.[18] As a result, the lack of improvement in C statistic may partially reflect the insensitive properties of this statistic in the context of a good baseline STS model. Gait speed remains a valid predictor of operative mortality and morbidity, and as an independent screening tool, may facilitate testing or other triage of those at higher risk of short-term adverse outcomes (the C statistic of gait speed alone was 0.62-0.66 in our study).

Although it is clear that frailty portends adverse outcomes, its subjective nature has inhibited the application of this knowledge. This study supports the use of the 5-m gait speed test as an objective measure of frailty and should help overcome this barrier. Gait speed can play an influential role in defining the appropriate treatment plan for the older patient. In addition to signaling for further evaluation and support at the slow end of gait speed, it can be reassuring at the high end of gait speed despite a patient's advanced chronological age. Prediction of operative risk, particularly in the complex clinical case of a patient with multiple chronic conditions, can help the care team and patient arrive at the most informed decision aligned with values and goals for both survival and quality of life. This shared decision may on occasion be for a less-invasive option, such as percutaneous intervention, medical management, or comfort care.

When cardiac surgery is the treatment of choice, this real-world study reaffirms that older adults have the potential for excellent outcomes with low overall rates of mortality and major morbidity. To further improve outcomes, comparative effectiveness studies are needed to determine whether the risks of cardiac surgery are modulated by patient frailty, as are randomized clinical trials to determine whether the benefits of cardiac surgery are maximized by concomitant interventions, such as exercise training, nutritional supplementation, multidimensional programs, home-based services, and drug therapies.[19,20] According to the 2011 American College of Cardiology Foundation/American Heart Association Guideline for Coronary Artery Bypass Graft Surgery, exercise training in the setting of a supervised cardiac rehabilitation program is a class I recommendation for all eligible patients after cardiac surgery,[21] although referral rates remain below achievable benchmarks. The Pre-operative Rehabilitation for reduction of Hospitalization After coronary Bypass and valvular surgery trial (NCT02219815)[22] is currently investigating the functional benefits of cardiac rehabilitation for patients with objective evidence of frailty before cardiac surgery.

There are a number of limitations to this study. First, the 5-m gait speed test was not performed in all STS centers. Compared with nonparticipating centers, participating centers had a slightly higher number of hospital beds (439 vs 423; $P < .001$) and higher rates of residency training (53% vs 50%; $P < .001$) and white patients (85% vs 82%; $P < .001$); however, patients served had a similar median age (67 vs 67 years; $P = .84$) and percentage of women (30% vs 30%; $P = .05$). In addition, the test was not performed in 34 675 patients who were excluded. Baseline characteristics and postoperative outcomes were compared between included and excluded patients and suggested logistical barriers rather than systematic bias. Second, given the real-world implementation across more than 100 centers, training for the gait speed test was limited to a written protocol and variable education sessions at the local centers. To minimize measurement error, centrally coordinated on-site training would have been preferable along with verification of observer reliability. Finally, the cohort included a minority of high-risk patients between the ages of 80 and 89 years and did not include any patients with transcatheter aortic valve replacements; frailty assessment in these types of individuals would be valuable. Large-scale initiatives, such as the Frailty Assessment Before Cardiac Surgery & Transcatheter Interventions study (NCT01845207) and the STS/American College of Cardiology Transcatheter Valve Therapy Registry[23] are under way to assess the prognostic value of frailty in high-risk patients between the ages of 80 and 89 years and those undergoing transcatheter aortic valve replacement.

Conclusions

Gait speed is an independent predictor of operative mortality and major morbidity, and a useful screening test for frailty in older adults being considered for cardiac surgery. The adverse impact of slow gait speed in our study is comparable with that reported in community-dwelling frail older adults (11% per 0.1-m/s decrease), yet the time lag to observe fatal and nonfatal adverse events is considerably shorter (within 30 days after cardiac surgery as compared with many years). When used as the sole criterion for frailty, gait speed adds modestly to the STS risk model and should ideally be followed by a multidomain frailty test or a comprehensive geriatric assessment to discriminate risk (2-tiered approach).[24] Additional research is needed to examine the effect of gait speed on long-term hazards and patient-centered outcomes, and to develop targeted interventions that can offset the negative impact of frailty.

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Invited Commentary

Using Gait Speed to Refine Risk Assessment in Older Patients Undergoing Cardiac Surgery

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When cardiac surgery is considered to treat diseases of the valves or coronary arteries, an assessment and discussion of the operative risk of mortality or major morbidity is routine. Beyond simply providing the patient with a rough probability of success, this risk assessment is critical for 2 primary reasons. First, it addresses the question of whether the anticipated risks of the procedure are outweighed by the anticipated benefits in terms of survival and quality of life; that is, should an intervention be performed at all? Second, in the age of expanding transcatheter and percutaneous approaches to coronary and valve disease, risk stratification has important implications for selecting the approach taken to treat the cardiovascular condition. In the United States, the primary instruments used for the assessment of cardiac surgical risk are the Society of Thoracic Surgeons (STS) predicted risk of mortality score and the predicted risk of mortality or major morbidity score. However, the STS scores do not include factors that reflect aging-

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