

UC San Diego

UC San Diego Previously Published Works

Title

Limited Preoperative Functionality Is Associated With Worse 30-D Mortality and Heart Failure After Carotid Artery Stenting

Permalink

<https://escholarship.org/uc/item/2kf3z2p1>

Journal

Journal of Surgical Research, 315

ISSN

0022-4804

Authors

Willie-Permor, Daniel
Moacdieh, Munir Paul
Herz Allah, Shatha
[et al.](#)

Publication Date

2025-11-01

DOI

10.1016/j.jss.2025.09.070

Peer reviewed

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofSurgicalResearch.com

Limited Preoperative Functionality Is Associated With Worse 30-D Mortality and Heart Failure After Carotid Artery Stenting

Daniel Willie-Permor, MD, MPH, CPH, Munir Paul Moacdieh, MD,
Shatha Herz Allah, MD, Sina Zarrintan, MD, MS, MPH,
Mohammed Hamouda, MD,
and Mahmoud B. Malas, MD, MHS, RPVI, FACS*

Center for Learning and Excellence in Vascular & Endovascular Research (CLEVER), Division of Vascular and Endovascular Surgery, Department of Surgery, University of California, San Diego (UCSD), La Jolla, California

ARTICLE INFO

Article history:

Received 25 August 2025

Accepted 20 September 2025

Available online 19 October 2025

Keywords:

Carotid artery stenting

Full functionality

Limited functionality

Trans carotid artery stenting (TCAR)

Trans-femoral carotid artery stenting (TFCAS)

ABSTRACT

Introduction: Carotid artery stenting is indicated in patients with significant carotid artery stenosis who are high risk for carotid endarterectomy. Patients who are nonambulatory before surgery are considered high risk for carotid revascularization. However, the effect of preoperative ambulatory status on outcomes has not been well established. We sought to use the Vascular Quality Initiative (VQI) multi-institutional database to evaluate the early outcomes of carotid artery stenting stratified by the preoperative ambulatory status.

Methods: Patients included were nonemergent cases performed in participating VQI centers from 2016 to 2021. The study cohort was divided into two groups: full-functionality patients with full, light work, or self-care, and limited-functionality (LF) patients with assisted care or bed-bound. We used propensity scores by stratification matching on 29 demographic and preoperative clinical characteristics to obtain similar patient characteristics across the two groups. Logistic regression analysis was performed to determine 30-d mortality and postoperative complications.

Results: We included 36,069 patients in the study, of which 1277 (3.54%) had LF. Patients in the LF group were older (mean age 74 y (SD 10.2) versus 71.9 (SD 9.4), had similar Preoperative medication exposure, similar Preoperative creatinine levels, and prior surgical intervention characteristics, but were more likely to have diabetes mellitus, hypertension, chronic obstructive pulmonary disease, prior congestive heart failure (CHF), and prior dialysis compared to full-functionality patients. After propensity stratification, both patient groups were not different across all strata on clinical and demographic characteristics. LF patients had a significantly increased odds of 30-d mortality (odds ratio (OR): 2.59, 95% confidence interval (CI): 1.77-3.78) and increased odds of post-op CHF (OR: 2.03, 95% CI: 1.09-3.77). They had similar odds of stroke (OR: 0.74, 95% CI: 0.50-1.08), transient ischemic attack (OR: 1.98, 95% CI: 0.81-4.86), myocardial infarction (OR: 1.31, 95% CI: 0.66-2.63), and any postoperative complication (OR: 1.20, 95% CI: 0.95-1.51).

Conclusions: Limited preoperative functional status is associated with a significant increase in the odds of 30-d mortality and postoperative CHF in patients undergoing CAS. However,

* Corresponding author. Vice Chair for Clinical Research, Division of Vascular and Endovascular Surgery, Department of Surgery, University of California, San Diego, 9452 Medical Center Drive, 3E 519, La Jolla, CA 92037.

E-mail address: mmalas@health.ucsd.edu (M.B. Malas).

0022-4804/\$ – see front matter © 2025 Elsevier Inc. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

<https://doi.org/10.1016/j.jss.2025.09.070>

we found no significant differences in the odds of postoperative transient ischemic attack, stroke, and myocardial infarction. Outcomes did not differ when stratified by symptomatic status. We propose aggressive medical management for asymptomatic carotid artery stenosis in nonambulatory patients and optimization of symptomatic patients before stenting.

© 2025 Elsevier Inc. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

Introduction

Cerebrovascular disease has a significant mortality and morbidity burden in the United States, ranking as the fourth leading cause of death in the United States.¹ Carotid endarterectomy (CEA) remains the gold standard for treating carotid stenosis, with carotid artery stenting (CAS) deemed to be an effective alternative in high-risk patients.² To ensure the best outcomes, patient selection remains critical. Preoperative functional status may be used as a gauge for fitness for surgery, although an exact cause-and-effect relationship to outcomes is not yet clearly defined. Although the impact of preoperative nonambulatory status on surgical outcomes has been explored in various vascular pathologies^{3,4} a conspicuous dearth of literature exists regarding the influence of preoperative ambulatory or functional status specifically on CAS outcomes. Consequently, the selection of high-risk patients who may derive greater benefit from CAS *versus* CEA remains a subject of ongoing debate among vascular surgeons. In light of this knowledge gap, the present study aimed to assess the impact of limited preoperative ambulatory or functional status on CAS outcomes. Leveraging a multi-institutional database linked to Medicare, an analysis was conducted to tune out a hypothesized relationship between preoperative ambulatory or functional status and CAS outcomes. The study aimed to enhance the understanding of how preoperative ambulatory or functional status influences outcomes of CAS.

Methods

Database

The Vascular Quality Initiative (VQI) is a multi-institutional database that consists of prospectively collected eligible consecutive vascular and endovascular surgical cases performed at participating centers. In addition, 982 centers from both the United States and Canada currently participate in this registry, with a recent milestone of over one million procedures included. Routine audits comparing VQI registry data to hospital claims data are in place to ensure that all consecutive cases are captured in the database. The VQI database includes variables on demographics, comorbidities, anatomical characteristics, prior procedures, and preoperative medication. In addition, intraoperative details and postoperative outcomes are contained within the dataset. The rationale and design of the VQI have been previously

published.⁵ Current and detailed information about the VQI can be accessed at www.vqi.org. The necessary approval was obtained from the VQI Research Advisory Committee to use the data for this analysis, with RAC approval number 4919. Ethics review by the Institutional Review Board and individual informed consent were not required as the study did not use identifiable patient information.

Study participants

We reviewed all adult patients who underwent CAS, including transfemoral carotid artery stenting (TFCAS), transcarotid artery stenting (TCAR), from 2016 to 2021. Both asymptomatic and symptomatic carotid artery atherosclerosis were included in the study. The study cohort was divided into two groups by functional status before surgery: full-functionality (FF) patients with full, light work, or self-care, and limited-functionality (LF)-patients with assisted care or bed-bound.

Study outcomes and definitions

The primary outcome of the study is 30-d all-cause mortality. Secondary outcomes are as follows: post-op stroke, post-op transient ischemic attack (TIA), post-op myocardial infarction (MI) and post-op congestive heart failure (CHF), any post-op complication (defined as a composite variable in the VQI data collection process that denotes any postoperative complication, including but not limited to access site occlusion, MI, new dysrhythmia, CHF, surgical site infection, respiratory, cerebral symptoms, arm ischemia or emboli, leg ischemia or emboli, leg compartment syndrome, intestinal ischemia, renal ischemia, and spinal ischemia). Postoperative CHF was defined according to VQI criteria as a new diagnosis or significant aggravation of pre-existing CHF that required treatment, including pulmonary edema requiring monitoring or treatment in an intensive care unit or step-down unit.

Statistical methods

All statistical analyses were performed using Stata SE 17 (StataCorp LP, College Station, Texas), with statistical significance defined as $P \leq 0.05$. Continuous variables were presented as mean $\pm$ standard deviation (SD), and categorical variables as counts and percentages. For comparisons of categorical variables, we used Pearson's Chi-Square test, or Fisher's exact test when expected cell counts were small. For continuous variables, we used analysis of variance after

confirming assumptions of normality and homogeneity of variances. All variables had less than 5% missing data (and were treated as missing at random).

We used propensity score stratification to adjust for confounding.^{6,7} Using multivariable logistic regression and including patients' clinical and demographic characteristics, we obtained estimates of five mutually exclusive strata, with each stratum encompassing patient cohorts by functional status. Twenty-nine demographic and clinical variables were factored into the propensity score derivation. Anesthesia type was assessed and found to vary significantly across procedural approaches. However, due to a high degree of collinearity between anesthesia type and American Society of Anesthesiologists (ASA) class, we included only ASA class in the propensity score stratification model to avoid

multicollinearity. ASA class served as a comprehensive proxy for physiologic status and perioperative risk.

This method allowed us to obtain similar patient characteristics across the two patient cohorts, thereby controlling for confounding. We obtained estimates of 30-d mortality, stroke, TIA, MI, and CHF using these balanced strata as covariates.

Results

Baseline variables

We included 36,184 patients with FF and 1280 patients with LF in the study. Before propensity score stratification, FF group was younger (71.9 versus 74.0, $P < 0.01$), more likely to be White

Table 1 — Baseline characteristics before propensity stratification.

Variables	Full functionality (n = 36,184)	Restricted functionality (n = 1280)	P value
Demographics			
Age, mean $\pm$ SD, years	71.9 (9.4)	74.0 (4.2)	<0.01
Male	22,911 (63.3)	763 (59.6%)	<0.01
Race			
White	32,677 (90.4)	1097 (85.7)	<0.01
Black	1728 (4.7)	113 (8.8)	<0.01
Other	1779 (4.9)	70 (5.5)	<0.01
Non-Hispanic	34,756 (96.3)	1203 (94.3)	<0.01
Procedures			
TCAR	21,584 (61.3%)	735 (58.8%)	0.07
TFCAS	13,653 (38.7%)	516 (41.2%)	
Comorbidities			
BMI, mean $\pm$ SD	28.5 (19.3)	28.3 (9.0)	0.64
ASA >3	7679 (21.9)	468 (37.2)	<0.01
Symptomatic	846 (2.9%)	47 (4.6%)	<0.01
Prior stroke/TIA	17,730 (49.0)	990 (77.0)	<0.01
Hypertension	32,564 (90.4)	1182 (92.7)	<0.01
Diabetes mellitus	13,742 (38.1)	615 (48.3)	<0.01
COPD	9459 (26.2)	415 (32.5)	<0.01
CAD	18,097 (50.2)	666 (52.3)	<0.01
CHF	5939 (16.4)	344 (26.9)	<0.01
Dialysis	524 (1.4)	61 (4.8)	<0.01
Current/Former smoker	26,781 (74.0)	888 (69.5)	<0.01
History of CEA/CAS	11,091 (30.7)	201 (23.6)	<0.01
History of major amputation	705 (1.9)	112 (8.8)	<0.01
Preoperative medications			
Aspirin	32,240 (89.4)	1109 (86.8)	<0.01
P2Y ₁₂ inhibitor	31,283 (86.7)	1076 (84.4)	<0.01
Statin	31,937 (88.5)	1140 (89.3)	0.30
Beta blocker	19,388 (54.8)	696 (55.7)	0.02
ACEI	19,083 (52.9)	578 (45.3)	<0.01
Anticoagulants	5027 (13.9)	256 (20.1)	<0.01

ACEI = angiotensin-converting enzyme inhibitors; BMI = body mass index; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease.

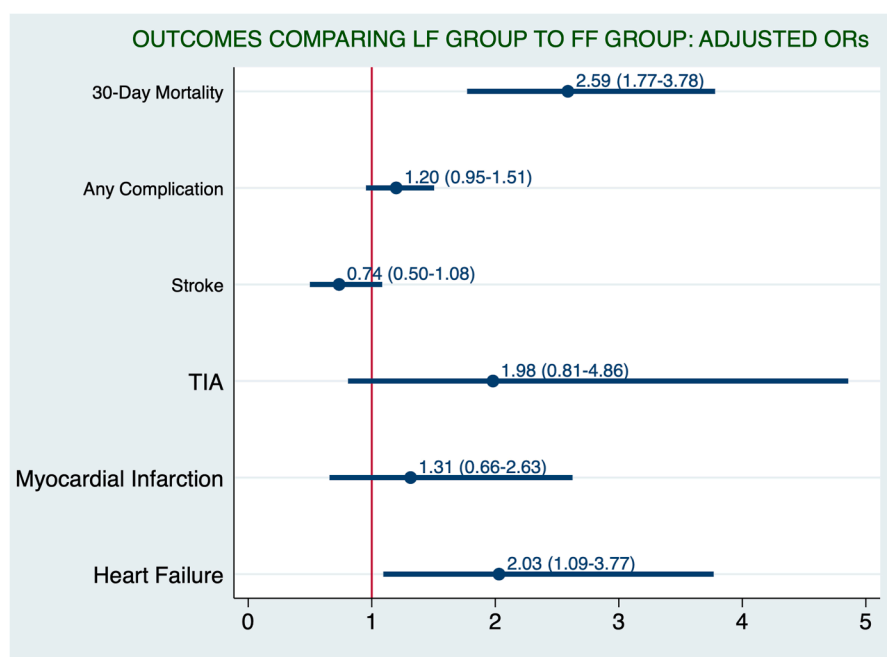


Fig. 1 – Adjusted odds ratios (95% CI) for 30-d outcomes comparing restricted or limited versus full functionality; models adjust for propensity-score strata; red line denotes OR = 1.

(90.4% versus 85.7%, $P < 0.01$), male (63.4% versus 59.7%, $P < 0.01$), less likely to be symptomatic (2.9% versus 4.6%, $P < 0.01$), less likely to have never smoked (25.9% versus 30.4%). FF group had similar prior coronary artery disease (50.2% versus 52.3%, $P = 0.7$), less CHF (16.5% versus 26.9%, $P < 0.01$), less chronic obstructive pulmonary disease (26.2% versus 36.5%, $P < 0.01$), less likely to be hypertensive (90.4% versus 92.7%, $P < 0.01$) and less likely to be diabetic (38.1% versus 48.3%, $P < 0.01$). Procedure choice among the two groups was similar: TCAR versus TFCAS (61.3% versus 58.8%, $P = 0.07$). Propensity score stratification created two well-balanced patient groups concerning preoperative clinical and demographic characteristics. Table 1 summarizes the demographic and clinical characteristics before propensity strata were created.

30-d mortality

The 30-d mortality rate was 0.9% among FF patients ($n = 252$) and 3.9% among LF patients ($n = 39$) ($P < 0.01$). After propensity

score stratification, there was more than a two-fold increase in the odds of mortality in the LF group compared to FF patients (adjusted odds ratio: 2.59, 95% confidence interval (CI): 1.77-3.78, $P < 0.001$) (Fig. 1).

Other adjusted outcomes

The raw rate of postoperative CHF was 1.02% (13 of 1275) in the LF group and 0.29% (106 of 36,065) in the FF group ($P < 0.01$). After propensity score stratification, LF patients had significantly higher odds of postoperative CHF compared to FF patients (adjusted odds ratio: 2.03, 95% CI: 1.09–3.77, $P = 0.025$), similar odds of post-op stroke (odds ratio (OR): 0.74, 95% CI: 0.50-1.08, $P = 0.12$), TIA (OR: 1.98, 95% CI: 0.81-4.86, $P = 0.14$), MI (OR: 1.31, 95% CI: 0.66-2.63, $P = 0.44$) and any post-op complication (OR: 1.20, 95% CI: 0.95-1.51, $P = 0.12$) (Table 2). In a subanalysis of TFCAS versus TCAR in the LF group, we found no differences in outcomes (Fig. 2). Outcomes were similar when stratified by symptomatic status. In a subanalysis of TFCAS versus TCAR in the FF group, patients offered TFCAS had worse 30-d mortality (OR: 1.50, 95% CI: 1.13-1.98, $P = 0.005$), worse post-op stroke (OR: 1.35, 95% CI: 1.09-1.64, $P < 0.001$) and worse post-op TIA (OR: 1.63, 95% CI: 1.20-2.17, $P < 0.001$).

Table 2 – Multivariable logistic regression analysis for 30-d mortality and postoperative complications using propensity score strata.

Variables	aOR (95% CI)	P value
30-d mortality	2.59 (1.77, 3.78)	<0.01
Any complication	1.20 (0.95, 1.51)	0.12
Myocardial infarction	1.31 (0.66, 2.63)	0.44
CHF	2.03 (1.09, 3.77)	0.03
Stroke	0.74 (0.50, 1.08)	0.12
TIA	1.98 (0.81, 4.86)	0.81

aOR = adjusted odds ratio.

Discussion

We have shown in this analysis that preoperative functionality is significantly associated with the odds of survival and CHF after CAS. We have also shown that within the LF sub-cohort, post-op outcomes did not differ with stenting approach, across symptomatic status, and within the FF

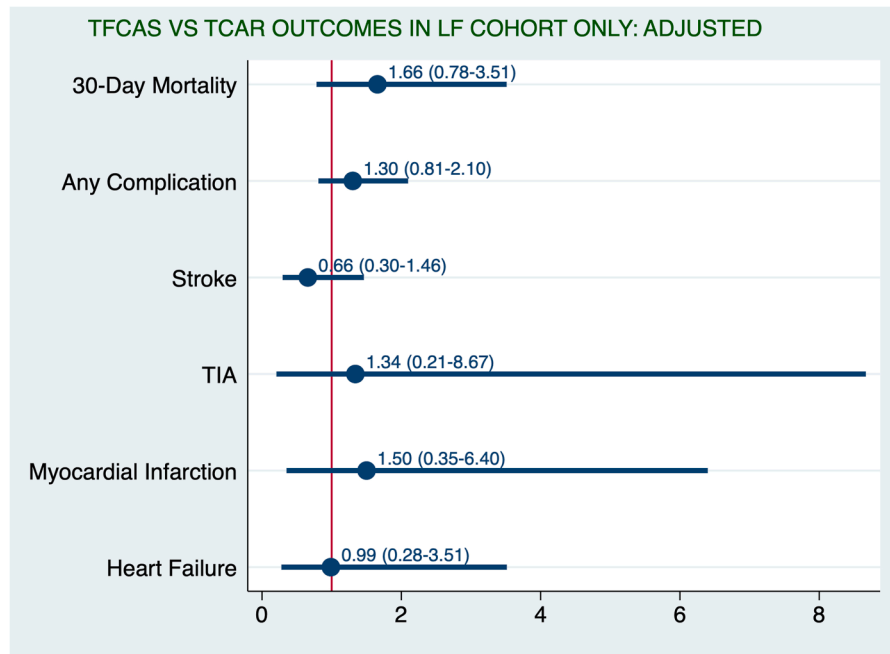


Fig. 2 – Adjusted odds ratios (95% CI) for 30-d outcomes comparing TFCAS versus TCAR within the limited-functionality cohort; models adjust for propensity-score strata; red line denotes OR = 1. aOR = adjusted odds ratio.

group, patients offered TCAR had lower odds of 30-d mortality and post-op stroke or TIA compared to patients offered TFCAS.

The LF group in our study was older, and considering age as a strong independent predictor of daily functioning,⁸ we adjusted for age and other demographic and clinical variables to determine outcomes, through the construction of propensity score strata, which provided the usefulness of ensuring that patient characteristics were similar across the comparison groups.⁹

Patients selected for CAS are likely to be high-risk, having been selected for the procedure likely due to their unsuitability for CEA, though in recent times, TCAR has been emerging as a strong alternative in standard-risk patients. Despite the significant morbidities of patients selected for CAS, the procedure offers good outcomes in well-selected patients. However, we have demonstrated in our study that patients with LF had higher odds of 30-d mortality and post-operative CHF compared to patients with FF. Our findings showing worse outcomes of CAS in the LF group are similar to previous conclusions in other vascular surgery outcomes.^{4,5,10-12} In another study, preoperative functional status predicted return to function after surgery.¹³ This association has also been observed in several nonvascular surgical studies.¹⁴⁻²¹

It could be argued that patients who are bedridden or moribund likely have multiple co-morbidities, which increase their risk of inferior outcomes after surgery, including after CAS. The patient characteristics in this study, indeed, seem to augment this reasoning, with the LF group more likely to be older, having a higher percentage of diabetes mellitus, hypertension, chronic obstructive pulmonary disease, prior CHF,

and prior stroke. These comorbidities are, however, adjusted for, and therefore any effect differences seen should be attributable to the state of functionality on the larger part, and residual or unmeasured confounding.

It is noteworthy that, in this study, when considering patients in the LF group alone, outcomes did not differ between TCAR and TFCAS, nor between symptomatic and asymptomatic patients. However, when we considered patients in the FF group alone, TCAR had better outcomes than TFCAS. This could suggest that in patients with better preoperative functionality, TCAR may offer better outcomes than TFCAS.

In patients with impaired or LF and carotid artery stenosis, it is prudent for the care team and the patient or family to consider the risks of performing CAS versus medical care, especially if the procedure would likely lead to equal or worse outcomes than if only medical care were considered. We are therefore more confident in prescribing an aggressive medical management instead of CAS for patients who have very limited preoperative ambulatory status, especially if asymptomatic. Such patients, in the face of the current evidence, would most likely benefit from nonsurgical care approaches, at least until their mobility or ambulatory status improves before surgery.

Limitations

This study was based on a retrospective analysis of data collected prospectively and is subject to coding errors during data collection and selection bias due to the nonrandomized nature. However, the VQI data collection process is robust, and its granularity means input is done by qualified personnel, reducing the incidence of errors to the highest

extent possible. As a secondary analysis of registry data, our sample size was determined by available cases rather than prospective planning. Therefore, a formal power analysis was not conducted. Although this limits our ability to define the minimal detectable effect size, we used propensity score stratification based on 29 important clinical variables to control for confounding and improve comparability between groups despite differences in cohort sizes. Nonetheless, unmeasured and residual confounding remain possible. In addition, although anesthesia type may influence perioperative outcomes, it was not included in the propensity score model due to its collinearity with ASA class. As the ASA class was incorporated as a summary measure of perioperative risk, we believe this approach appropriately accounts for underlying risk, though residual confounding by anesthesia technique may remain.

Conclusions

Limited preoperative functional status is associated with a significant increase in the odds of 30-d mortality and CHF following CAS. There are no significant differences in the odds of postoperative TIA, stroke, and MI compared to normal functional status patients. Outcomes are similar when we stratify by symptomatic status and by type of stenting procedure in the LF group only, but when we consider FF patients only, TCAR offers better outcomes than TFCAS. We propose medical management for asymptomatic nonambulatory patients and optimization of symptomatic patients before stenting.

Disclosure

None declared.

Funding

None.

Meeting Presentation

E-poster presented at 2023 SCVS Annual Symposium.

CRedit authorship contribution statement

Daniel Willie-Permor: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Software, Writing – original draft, Writing – review & editing, Validation. **Munir Paul Moacdieh:** Validation, Writing – review & editing. **Shatha Herz Allah:** Validation, Writing – original draft, Writing – review & editing. **Sina Zarrintan:** Conceptualization, Methodology, Validation, Writing – review & editing. **Mohammed Hamouda:** Project administration, Validation, Writing – review & editing. **Mahmoud B. Malas:**

Conceptualization, Methodology, Resources, Supervision, Validation, Writing – review & editing.

REFERENCES

1. Meschia JF, Bushnell C, Boden-Albala B, Braun LT, Bravata DM, Chaturvedi S, et al. Guidelines for the primary prevention of stroke: a statement for healthcare professionals from the American heart Association/American Stroke Association. *Stroke*. 2014;45:3754–3832.
2. Ricotta JJ, Aburahma A, Ascher E, et al. Updated Society for Vascular Surgery guidelines for management of extracranial carotid disease. *J Vasc Surg*. 2011;54:e1–e31.
3. Naazie IN, Arhuidese I, Zil-E-Ali A, Siracuse JJ, Malas MB. Impact of impaired ambulatory capacity on the outcomes of peripheral vascular interventions among patients with chronic limb-threatening ischemia. *J Vasc Surg*. 2021;74:489–498.e1.
4. Lu K, Farber A, Schermerhorn ML, et al. The effect of ambulatory status on outcomes of percutaneous vascular interventions and lower extremity bypass for critical limb ischemia in the vascular quality initiative. *J Vasc Surg*. 2017;65:1706–1712.
5. Cronenwett JL, Kraiss LW, Cambria RP. The society for vascular surgery vascular quality initiative. *J Vasc Surg*. 2012;55:1529–1537.
6. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behav Res*. 2011;46:399–424.
7. Desai RJ, Rothman KJ, Bateman BT, Hernandez-Diaz S, Huybrechts KF. A propensity-score-based fine stratification approach for confounding adjustment when exposure is infrequent. *Epidemiology (Cambridge, Mass.)*. 2017;28:249–257.
8. Hébert R. Functional decline in old age. *CMAJ*. 1997;157:1037–1045.
9. Rubin DB. Estimating causal effects from large data sets using propensity scores. *Ann Intern Med*. 1997;127:757–763.
10. Crawford RS, Cambria RP, Abularrage CJ, et al. Preoperative functional status predicts perioperative outcomes after infrainguinal bypass surgery. *J Vasc Surg*. 2010;51:351–359.
11. Dinga MI, Slade MD, Orion KC, Sarac T, Ochoa Chaar CI. The impact of functional status on the outcomes of endovascular lower extremity revascularization for critical limb ischemia in the elderly. *Ann Vasc Surg*. 2017;45:42–48.
12. Obeid T, Hicks CW, Yin K, et al. Contemporary outcomes of open thoracoabdominal aneurysm repair: functional status is the strongest predictor of perioperative mortality. *J Surg Res*. 2016;206:9–15.
13. Gibbons GW, Burgess AM, Guadagnoli E, et al. Return to well-being and function after infrainguinal revascularization. *J Vasc Surg*. 1995;21:35–45.
14. Johansson HR, Bergschmidt P, Skripitz R, Finze S, Bader R, Mittelmeier W. Impact of preoperative function on early postoperative outcome after total hip arthroplasty. *J Orthop Surg (Hong Kong)*. 2010;18:6–10.
15. Röder C, Staub LP, Egli S, Dietrich D, Busato A, Müller U. Influence of preoperative functional status on outcome after total hip arthroplasty. *J Bone Joint Surg Am*. 2007;89:11–17.
16. Albright EL, Davenport DL, Roth JS. Preoperative functional health status impacts outcomes after ventral hernia repair. *Am Surg*. 2012;78:230–234.

17. Solano QP, Howard R, Mullens CL, et al. The impact of frailty on ventral hernia repair outcomes in a statewide database. *Surg Endosc*. 2022;7:1–9.
18. Shehadeh AA, McLaren GW, Collins JT, Munene G, Sawyer RG, Shebrain SA. Frailty as a predictor of surgical outcomes following femoral hernia repair. *Am Surg*. 2022;15:31348221084085.
19. Farhat JS, Velanovich V, Falvo AJ, et al. Are the frail destined to fail? Frailty index as predictor of surgical morbidity and mortality in the elderly. *J Trauma Acute Care Surg*. 2012;72:1526–1530. discussion 1530-1.
20. Yu J, Lee J, Ha S, et al. Impact of chart-derived frailty index on 1-Year mortality after radical cystectomy in 1004 patients with bladder cancer. *Ann Surg Oncol*. 2023;30:5295–5303.
21. Burg ML, Daneshmand S. Frailty and preoperative risk assessment before radical cystectomy. *Curr Opin Urol*. 2019;29:216–219.