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A Vascular Quality Initiative Frailty Assessment Predicts Post-Discharge Mortality in Patients Undergoing Arterial Reconstruction

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Abstract

Introduction: Frailty assessment adds important prognostic information during pre-operative decision-making but can be cumbersome to implement into routine clinical care. We developed and tested an abbreviated method of frailty assessment using variables routinely collected by the Vascular Quality Initiative (VQI) registry.

Methods: An abbreviated frailty score (VQI-FS) was developed using eleven or fewer VQI variables (hypertension, congestive heart failure, coronary artery disease, peripheral vascular disease, diabetes, COPD, renal impairment, anemia, underweight, non-home residence, non-ambulatory status) that map to recognized frailty domains in the Comprehensive Geriatric Assessment and the literature. Non-emergent cases registered in the VQI from 2010–2017 (n=265,632) in seven registries (CEA, N=77,111; CAS, N=13,215; EVAR, N=29,607; OAAA, N=7442; INFRA, N=33,128; SUPRA, N=10,661; PVI, N=94,468) were analyzed using logistic regression models to determine the predictive power of the VQI-FS for perioperative and longer-term (9-month) mortality. Nomograms were created using weighted regression coefficients to assist in individualized frailty assessment and estimation of 9-month mortality.

Results: The VQI-FS using equal weighting of eleven VQI variables effectively predicted 9-month mortality with an area under the curve (AUC) of 0.724 by receiver operating characteristic (ROC) curve analysis. However, differential weighting of the variables allowed simplification of the model to only seven variables (CHF, renal impairment, COPD, not living at home, not

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ambulatory, anemia, underweight status) as hypertension, coronary artery disease, peripheral vascular disease and diabetes had relatively low predictive power. Adding procedure-specific risk further improved performance of the model with a final AUC on ROC analysis of 0.758. Model calibration was excellent with predicted/observed regression line slope of 0.991 and intercept of 5.449e-04.

Conclusions: A differentially weighted abbreviated VQI-FS using seven variables in addition to procedure-specific risk has strong correlation with 9-month mortality. Nomograms incorporating patient- and procedure-adjusted risk can effectively predict 9-month mortality. Reliable estimates of longer-term mortality should assist in pre-operative decision-making for vascular procedures that often carry substantial risk of mortality.

Table of Contents Summary

This retrospective analysis of arterial reconstructions recorded in VQI supported development of a simple frailty assessment tool (VQI-FS) that accurately predicted longer term (9-month) post-operative mortality. VQI users can use simple frailty assessment in clinic to assist in pre-operative counseling before arterial reconstruction.

INTRODUCTION

Frailty is a multidimensional syndrome of loss of reserves (energy, physical ability, cognition, health) that gives rise to vulnerability to adverse events [1]. In a surgical context, frailty implies loss of physiological resilience and increased susceptibility to catastrophic outcomes because of inability to sustain operative stress or withstand adverse post-operative events [2]. Frailty has become widely accepted within the surgical community as a pre-operative risk factor to take into account when contemplating a procedure [3]. In response, various methods of assessing frailty have been proposed although no single instrument has gained consensus acceptance and widespread use [4].

The Comprehensive Geriatric Assessment (CGA) used in the Canadian Study of Health & Aging is an exhaustive, validated evaluation that uses up to 70 domains to assess frailty which in turn predicts need for institutionalization or mortality in community-living older adults (Supplementary Table I) [1]. With the widespread adoption of surgical registries such as NSQIP that collect patient-specific clinical information, frailty instruments using registry data have been proposed. Velanovich et al [5] mapped various domains used in the CGA to data elements captured by the American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP). They showed that an instrument that measured only eleven variables (diabetes, dependent functional status, history of COPD/current pneumonia, CHF, MI/angina, prior cardiac intervention, hypertension requiring medication, delirium, history of TIA, CVA, history of critical limb ischemia/intervention for PAD) correlated strongly with post-operative outcomes in a mixed general surgical population. Subsequently, others have shown that the NSQIP-based frailty instrument applied specifically to vascular surgery procedures also correlates strongly with post-operative mortality and morbidity [6, 7]. More recently, the Risk Analysis Index (RAI) developed and validated in veterans [8] has been applied to the Vascular Quality Initiative (VQI) [9] but the original RAI includes some variables (cancer, cognitive function) not captured by VQI. The VQI also collects

information about other characteristics of frailty such as renal impairment, anemia and underweight status not included in the CGA.

A limitation of ACS-NSQIP is that it only assesses in-hospital or post-operative events that occur within 30 days of the index procedure. Given that the true clinical value of many vascular surgical procedures is not apparent within such a short post-operative time frame, the VQI was specifically designed to capture longer term outcomes around one year following surgery to better assess the enduring value of vascular surgical intervention [10]. Following the example of those who mapped various CGA domains to registry-based data elements, we sought to develop a similar frailty assessment instrument using VQI data elements. We hypothesized that a VQI-based frailty assessment tool would correlate with longer-term (~1 year) outcomes.

METHODS

The University of Utah Institutional Review Board reviewed the protocol and determined that it did not meet the definition of Human Subjects Research according to Federal regulations. IRB oversight was thus waived.

The domains that correlate with frailty as assessed in the CGA were compared to data elements captured by the VQI. Eleven VQI variables were identified that mapped to eight CGA domains (Table I). Three additional domains represented by VQI data elements commonly associated with frailty (renal impairment [11, 12], anemia [13, 14] and underweight status [14–16]) were also included. Similar to the method originally used by Rockwood et al [1], an equally weighted simple VQI-Frailty Score (sVQI-FS) was taken as the number of positive VQI data elements divided by the total number of data elements available for assessment:

$$\text{Simple VQI\!-\!FS} = \left(\text{ \# Variables Positive/ \# Variables Evaluated}\right).$$

A sVQI-FS was not calculated if information for fewer than five frailty domains was present. The sVQI-FS was then pilot-tested on a single institution's VQI cases registered from 2010–2015 (n=735) [17].

Following promising initial results from our pilot, a VQI dataset including non-emergent procedures performed from 2010–2017 was obtained from the Society for Vascular Surgery Patient Safety Organization for analysis. We included procedures from seven registries within VQI: carotid artery stenting (CAS), carotid endarterectomy (CEA), open abdominal aortic aneurysm repair (OAAA), endovascular abdominal aortic aneurysm repair (EVAR), peripheral vascular intervention (PVI), infra- and supra-inguinal bypass (INFRA, SUPRA).

The primary outcome was mortality nine months after the procedure. VQI allows the "one-year long-term" follow-up assessment to occur anytime between 9 and 21 months after the index procedure which means that for some patients "one-year" follow-up could be more than twice as long as for others. To address this uncertainty, only patients known to have

died within 9 months of their index procedure were considered to have met the primary outcome.

Statistical Methods

Descriptive and regression analyses were performed in R 3.1.2 (https://cran.r-project.org/) [18]. Patient characteristics were summarized for the full cohort and stratified by survival at discharge and 9 months post-discharge. Categorical variables were summarized using count (percentage) and compared using chi-squared or chi-squared tests using Monte Carlo simulations.

Construction of weighted frailty measure—The differential frailty index weights were constructed by fitting a model for 9-month mortality that included procedure type and the 11 frailty domains as predictors. Weights (w_1, …, w_{11}) for each frailty domain and each procedure ($a_{Proc.}$) were constructed using a nomogram framework, as described by Yang [19]. The differentially weighted frailty index was created for each response, as follows:

$$Frailty\ index\ (Diff.) = \frac{\alpha_{Proc.} + \sum_i w_i \{Item\ i\ is\ `Yes'\ *\}}{\max \alpha + \sum_i w_i \{Item\ i\ is\ non\ missing\}}$$

*A few items have a weight for "No" instead. Thus, the weighted frailty measure is constrained between 0 and 1.

Construction of prediction models—Logistic regression models were developed comparing various expressions of frailty (see Results) with post-operative mortality measured nine months after the procedure. Odds ratios (OR), 95% confidence intervals (CIs) and p-values were reported for all predictors. The accuracy of each model was analyzed using a receiver operating characteristic curve (ROC) reporting the area under the curve (AUC) from 100 random iterations of 10-fold cross-validation. On each iteration, we fit a model to 90% of the data and tested it on the remaining 10% to estimate the AUC, and then we averaged the AUC results across the 100 iterations [20].

Nomograms were developed using regression coefficients of the association of each frailty element or procedure with the main outcome measure to allow estimation of 9-month mortality based on a mixture of frailty elements and the procedure performed. The point values for each variable in the nomogram were assigned using the methodology outlined by Yang [19].

RESULTS

The full VQI dataset included 265,632 arterial procedures registered in VQI from 2010–2017. Descriptive statistics for this cohort are shown in Supplementary Table II.

Sufficient information to calculate a VQI-FS (data pertaining to five or more of the eleven frailty domains, Table I) existed for 99.8% of patients with only 635 (0.2%) VQI records missing adequate data. Complete data regarding all eleven frailty domains were available for 208,785 (78.6%) records while 56,212 (21.2%) procedures contained information regarding

5–10 frailty items. The prevalence of the various frailty characteristics is also shown in Supplementary Table I. The most prevalent frailty characteristics were peripheral vascular disease (99%), hypertension (88%), coronary artery disease (45%), anemia (40%) diabetes (40%) and COPD (26%). All other frailty characteristics had a prevalence of < 20%. Figure 1A shows a histogram of sVQI-FS values for the entire cohort; the mean and median sVQI-FS is 0.3 (see also Supplementary Table I). However, there was poor correlation of sVQI-FS with age except for patients ≥ 80 years (Figure 1B)

For the entire cohort (N=265,632), inpatient mortality was 0.79% (N=2094). Vital status at 9 months was available for 239,776 patients or 91.2% of patients alive at discharge. Mortality at 9 months was 5.4% (N=14,316). Table II lists characteristics associated with both inpatient and 9-month mortality. Although statistically significant, age had a comparatively weak association with mortality, becoming most apparent for age ≥ 60 years. The relationship between sVQI-FS and 9-month mortality was stronger (Figures 2A and B).

An examination of the relationship of the various elements included in VQI-FS with 9-month mortality indicated that significant predictive information relative to mortality is lost by arbitrarily assigning equal weights to each frailty element (Table III). For instance, patients not living at home, or functionally dependent, were 3–4x more likely than the entire cohort (19.9% v 5.4%) to die within 9 months of the procedure.

Differential weighting also showed that three of the original frailty characteristics (hypertension, diabetes and peripheral vascular disease) were not significantly associated with 9-month mortality (Table III). Coronary artery disease was also removed from the model because of its relatively low odds ratio for 9-month mortality (OR=1.12) despite its statistical significance.

The procedure performed was also predictive of 9-month mortality with a nearly 3-fold increased risk for initial survivors of open infra-inguinal revascularization (INFRA, 8.4%) compared to CEA (2.9%, Table III).

A model incorporating only seven differentially weighted frailty characteristics along with procedure-specific risk improved the predictive power of the model for 9-month mortality (AUC = 0.758) compared to the original complete but equally weighted sVQI-FS frailty model (AUC = 0.724; Supplementary Figure 1A). Of note, the AUC for the differentially weighted model including all characteristics was also 0.758 so there was no loss of predictive power by deleting hypertension, diabetes, peripheral vascular and coronary artery disease from the model. The model also showed good calibration of observed to predicted events with a regression line slope of 0.991 and intercept of 5.449e-04 (Supplementary Figure 1B).

A key objective of frailty assessment is to assist in pre-operative shared decision-making. To operationalize use of VQI elements to assess frailty, the regression coefficients were used to construct a nomogram allowing summation of the estimated risk represented by the concise (seven variables) differentially weighted frailty assessment (VQI-FS) as well as the proposed procedure (Figure 3).

DISCUSSION

Frailty assessment in surgery has gained wide acceptance as a valid method of estimating a patient's fitness for surgery [2, 3]. A major limitation to the routine use of frailty assessment instruments in the outpatient clinic is the burden of their implementation. A comprehensive evaluation such as the CGA (requiring up to 90 minutes) is clearly impractical in a surgical clinic. Shorter, abbreviated methods of frailty assessment using ACS-NSQIP variables have correlated well with 30-day morbidity and mortality [5–7]. The VQI-FS shares the advantage of these abbreviated methods but can also be correlated with outcomes longer than the perioperative period. However, methods that assign equal weighting to all frailty characteristics or do not include procedure-specific risk may lack sufficient granularity to add meaningful value to the pre-operative decision-making process. Our addition of differential weighting and procedure-specific risk to estimate 9-month mortality is another advantage in this regard. (The term VQI-FS refers to the differentially-weighted model. We do not recommend use of the equally-weighted sVQI-FS to estimate 9-month mortality.)

The RAI as applied to aneurysm procedures in VQI also uses differential weighting recognizing the particularly increased risk of poor nutritional status as reflected in the body mass index (BMI), CHF, renal insufficiency, COPD and functional independence [9]. A number of similarities and differences between our analysis and the RAI are worth noting. Similar to our findings, the RAI does not include diabetes, hypertension or coronary artery disease as predictors of longer-term mortality. The combination of dependent functional status and dependent ambulation were strong predictors of longer-term mortality in both the RAI and our analysis. We found anemia to be predictive of longer-term mortality but this variable is not included in the RAI. While RAI considers age as a risk, we did not include age in our frailty model given the notion that frailty and age do not automatically correlate and age is not specifically listed as a frailty element in the CGA. In the VQI, frailty did not measurably increase until age reached   80 years (Figure 1).

At first glance, it may be surprising that classic vascular risk factors such as hypertension, coronary artery disease, peripheral vascular disease or diabetes lacked predictive power for estimating 9-month mortality after an arterial reconstruction. There are probably at least three reasons for this finding. First, these risk factors are so prevalent in the vascular population that they may lose discriminating power. Second, the VQI is not immune to selection bias on the part of the surgeon; surgical decision-making in the VQI, representing real-world evidence, is not controlled. Third, while these are recognized as risk factors for cardiovascular death, nine months is still a relatively short period for a mortal event to occur and be strongly correlated to the presence of one of these risk factors.

A substantial number of elective vascular surgical procedures are performed for preventive (asymptomatic carotid, intact AAA) or lifestyle indications (claudication). For these procedures in particular, there is a need to estimate a patient's chances of survival outside of the typical perioperative period of 30 days. However, very few clinical registries offer insight into survival at these relevant time points. The VQI mandate of "one-year" follow-up is unique in general or vascular surgical registries (actual follow-up can occur between 9–21 months after the index procedure). While longer follow-up out to two years may be desirable

for procedures such as asymptomatic carotid stenosis [21] or lower extremity revascularization [22, 23], the VQI represents the longest clinically assessed follow-up available.

Patients whose frailty index measured by equal weighting is in the range of 0.3 are considered "frail" [1]. The mean and median sVQS-FI for the entire cohort in this analysis was 0.3 (Figure 1, Supplementary Table I) indicating that the average patient receiving arterial surgery in VQI is frail. This average level of frailty is greater than reported in other series using a modified frailty index [5–7] so special attention to longer-term prognosis in the vascular surgery clinic seems necessary and would likely be beneficial during pre-operative decision-making.

The pragmatic routine[i] use of differential weights in pre-operative risk assessment can be cumbersome if complicated polynomial equations must be solved. We have found nomograms to be relatively straightforward tools that obviate that problem. Consider a vascular patient with an AAA who has COPD, anemia and is underweight. According to Figure 3, if that patient requires open AAA to accomplish successful repair, the estimated 9-month mortality is 15–20%. With EVAR, the estimated mortality falls to ~10%. These risks can be compared in relative straightforward fashion for an aneurysm patient whose annual rupture risk can be estimated based on size [24]. It should be a relatively straightforward decision to defer repair in a patient whose operative risk for 9-month mortality exceeds their natural history risk by a considerable margin. Similar decision-making considerations apply to a patient with asymptomatic carotid stenosis whose natural history risk of stroke [21] at two or five years might be substantially lower than their estimated 9-month mortality after carotid endarterectomy or stenting. Notably, an analysis of CEA in VQI showed that frailty as measured by the RAI was associated with longer term mortality but not post-operative stroke [25]. Even in situations in which there are no randomized trials to confidently estimate natural history risk, some patients might hesitate to undergo a procedure if the estimated 9-month mortality exceeded a certain threshold, say 50%. According to our findings and the nomogram in Figure 3, any combination of frailty-based and procedural-specific risk that accumulates more than 440 points would carry a 50% risk of dying within nine months of the procedure.

The value of incorporating procedure-specific risk into the 9-month mortality estimate is illustrated by comparing the risk of open AAA repair with CEA. If this same underweight patient with COPD and anemia was being considered for carotid intervention for symptomatic stenosis, the estimated 9-month mortality is less than 10%. When compared with the two-year risk of stroke of 25–30% [26], the decision to offer intervention becomes relatively straightforward and data-driven.

In a very practical sense, nomograms can be used on a daily basis in clinic when laminated for repeated use with an erasable marker. The prediction equation could also be automatically solved by embedded calculators in the electronic medical record.

The most notable limitation to our study is that we only conducted an internal validation of our prediction model. Future studies will be needed, providing validation using external data sets, to more comprehensively assess the predictive performance of our models. In

particular, we plan to validate this model using more recent years of the VQI registry. While the VQI registry is the largest available data base with longer-term patient outcomes, it only contains procedures from contributing hospitals. Thus there may be some selection bias, and our findings may not perfectly represent national data that would include hospitals that do not participate in VQI. Further, additional selection bias is inherent in procedure-based registries such as VQI that include only patients in whom a surgical operation was performed. This is not unique to VQI but also afflicts registries such as ACS-NSQIP. However, there is value in large datasets that contain real-world data [27]. It should be emphasized that the VQI-FS assessment tool only applies to patients who are selected to undergo a vascular procedure; it is not a general frailty assessment tool and is inappropriate to use to estimate longer-term survival in patients deemed ineligible for surgery.

In summary, a concise differentially weighted VQI-FS using only seven routinely collected VQI data elements can be used to assess frailty in a clinically relevant and procedure-specific manner. Future studies are needed to provide validation on external data before our prediction models should be used to guide pre-operative shared decision-making.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

REFERENCES

1. Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I, et al. A global clinical measure of fitness and frailty in elderly people. CMAJ. 2005;173(5):489–95. [PubMed: 16129869]

2. Kraiss LW, Beckstrom JL, Brooke BS. Frailty assessment in vascular surgery and its utility in preoperative decision making. Semin Vasc Surg. 2015;28(2):141–7. [PubMed: 26655058]

3. Tjeertes EKM, van Fessem JMK, Mattace-Raso FUS, Hoofwijk AGM, Stolker RJ, Hoeks SE. Influence of Frailty on Outcome in Older Patients Undergoing Non-Cardiac Surgery - A Systematic Review and Meta-Analysis. Aging Dis. 2020;11(5):1276–90. [PubMed: 33014537]

4. Kraiss LW. Moving frailty assessment beyond knowing it when you see it. J Vasc Surg. 2020;71(1):307–8. [PubMed: 31864649]

5. Velanovich V, Antoine H, Swartz A, Peters D, Rubinfeld I. Accumulating deficits model of frailty and postoperative mortality and morbidity: its application to a national database. J Surg Res. 2013;183(1):104–10. [PubMed: 23415494]

6. Arya S, Kim SI, Duwayri Y, Brewster LP, Veeraswamy R, Salam A, et al. Frailty increases the risk of 30-day mortality, morbidity, and failure to rescue after elective abdominal aortic aneurysm repair independent of age and comorbidities. J Vasc Surg. 2015;61(2):324–31. [PubMed: 25312534]

7. Karam J, Tsiouris A, Shepard A, Velanovich V, Rubinfeld I. Simplified frailty index to predict adverse outcomes and mortality in vascular surgery patients. Ann Vasc Surg. 2013;27(7):904–8. [PubMed: 23711971]

8. Hall DE, Arya S, Schmid KK, Blaser C, Carlson MA, Bailey TL, et al. Development and Initial Validation of the Risk Analysis Index for Measuring Frailty in Surgical Populations. JAMA Surg. 2017;152(2):175–82. [PubMed: 27893030]

9. George EL, Chen R, Trickey AW, Brooke BS, Kraiss L, Mell MW, et al. Variation in center-level frailty burden and the impact of frailty on long-term survival in patients undergoing elective repair for abdominal aortic aneurysms. J Vasc Surg. 2020;71(1):46–55 e4. [PubMed: 31147116]

10. Cronenwett JL, Kraiss LW, Cambria RP. The Society for Vascular Surgery Vascular Quality Initiative. J Vasc Surg. 2012;55(5):1529–37. [PubMed: 22542349]

11. Shen Z, Ruan Q, Yu Z, Sun Z. Chronic kidney disease-related physical frailty and cognitive impairment: a systemic review. Geriatr Gerontol Int. 2017;17(4):529–44. [PubMed: 27240548]

12. Lorenz EC, Kennedy CC, Rule AD, LeBrasseur NK, Kirkland JL, Hickson LJ. Frailty in CKD and Transplantation. Kidney Int Rep. 2021;6(9):2270–80. [PubMed: 34514190]

13. Palmer K, Vetrano DL, Marengoni A, Tummolo AM, Villani ER, Acampora N, et al. The Relationship between Anaemia and Frailty: A Systematic Review and Meta-Analysis of Observational Studies. J Nutr Health Aging. 2018;22(8):965–74. [PubMed: 30272101]

14. van Mourik MS, Velu JF, Lanting VR, Limpens J, Bouma BJ, Piek JJ, et al. Preoperative frailty parameters as predictors for outcomes after transcatheter aortic valve implantation: a systematic review and meta-analysis. Neth Heart J. 2020;28(5):280–92. [PubMed: 32189208]

15. Picca A, Coelho-Junior HJ, Calvani R, Marzetti E, Vetrano DL. Biomarkers shared by frailty and sarcopenia in older adults: A systematic review and meta-analysis. Ageing Res Rev. 2022;73:101530. [PubMed: 34839041]

16. Shen Y, Hao Q, Zhou J, Dong B. The impact of frailty and sarcopenia on postoperative outcomes in older patients undergoing gastrectomy surgery: a systematic review and meta-analysis. BMC Geriatr. 2017;17(1):188. [PubMed: 28826406]

17. Kraiss LW, Al-Dulaimi R, Thelen J, Brooke BS. Postoperative Outcomes Correlate With Frailty Defined Using Vascular Quality Initiative Data. Journal of Vascular Surgery. 2015;62(2):532.

18. Team RC. A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2018.

19. Yang D Build prognostic nomograms for risk assessment using SAS. SAS Global Forum2013.

20. Kohavi R A study of cross-validation and bootstrap for accuracy estimation and model selection. International Joint Conference on Artificial Intelligence (IJCAI); Montreal: Morgan Kaufman; 1995.

21. Endarterectomy for asymptomatic carotid artery stenosis. Executive Committee for the Asymptomatic Carotid Atherosclerosis Study. JAMA. 1995;273(18):1421–8. [PubMed: 7723155]

22. Bradbury AW, Adam DJ, Bell J, Forbes JF, Fowkes FG, Gillespie I, et al. Bypass versus Angioplasty in Severe Ischaemia of the Leg (BASIL) trial: A survival prediction model to facilitate clinical decision making. J Vasc Surg. 2010;51(5 Suppl):52S–68S. [PubMed: 20435262]

23. Conte MS, Bradbury AW, Kolh P, White JV, Dick F, Fitridge R, et al. Global vascular guidelines on the management of chronic limb-threatening ischemia. J Vasc Surg. 2019;69(6S):3S–125S e40. [PubMed: 31159978]

24. Lederle FA, Johnson GR, Wilson SE, Ballard DJ, Jordan WD Jr., Blebea J, et al. Rupture rate of large abdominal aortic aneurysms in patients refusing or unfit for elective repair. JAMA. 2002;287(22):2968–72. [PubMed: 12052126]

25. Rothenberg KA, George EL, Barreto N, Chen R, Samson K, Johanning JM, et al. Frailty as measured by the Risk Analysis Index is associated with long-term death after carotid endarterectomy. J Vasc Surg. 2020;72(5):1735–42 e3. [PubMed: 32169359]

26. North American Symptomatic Carotid Endarterectomy Trial C, Barnett HJM, Taylor DW, Haynes RB, Sackett DL, Peerless SJ, et al. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. N Engl J Med. 1991;325(7):445–53. [PubMed: 1852179]

27. Rudrapatna VA, Butte AJ. Opportunities and challenges in using real-world data for health care. J Clin Invest. 2020;130(2):565–74. [PubMed: 32011317]

ARTICLE HIGHLIGHTS

Type of Research:

Multicenter, retrospective analysis of prospectively collected VQI registry data; non-randomized cohort

Key Findings:

An abbreviated frailty assessment instrument consisting of seven differentially weighted VQI variables along with procedure-weighted risk accurately predicted 9-month mortality following arterial reconstruction.

Take home Message:

A simple VQI frailty assessment tool allows pre-operative estimation of 9-month mortality risk after arterial reconstruction.

A

B
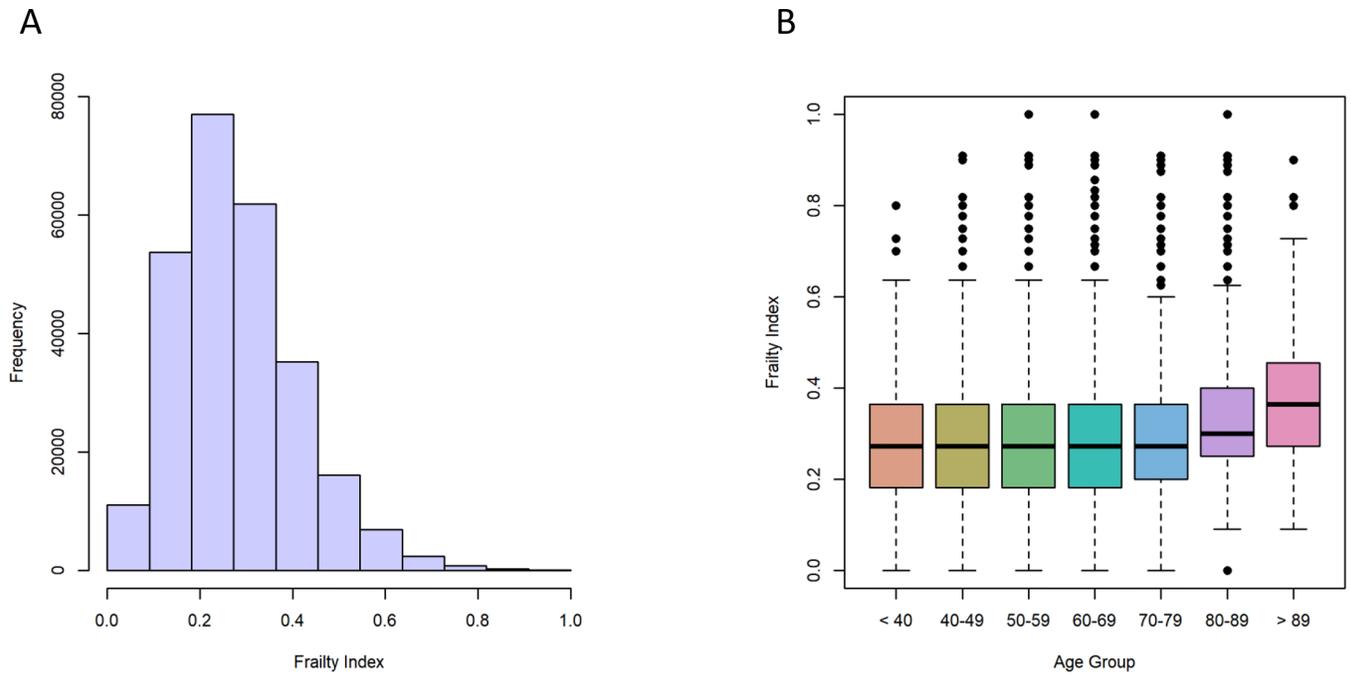
Figure 1.
Panel A. Histogram of equally-weighted frailty scores (sVQI-FS) among 265,632 procedures registered in VQI from 2010–2017.
Panel B. Box plots of equally-weighted frailty scores (sVQI-FS) among 265,632 VQI procedures stratified by age.

A

B
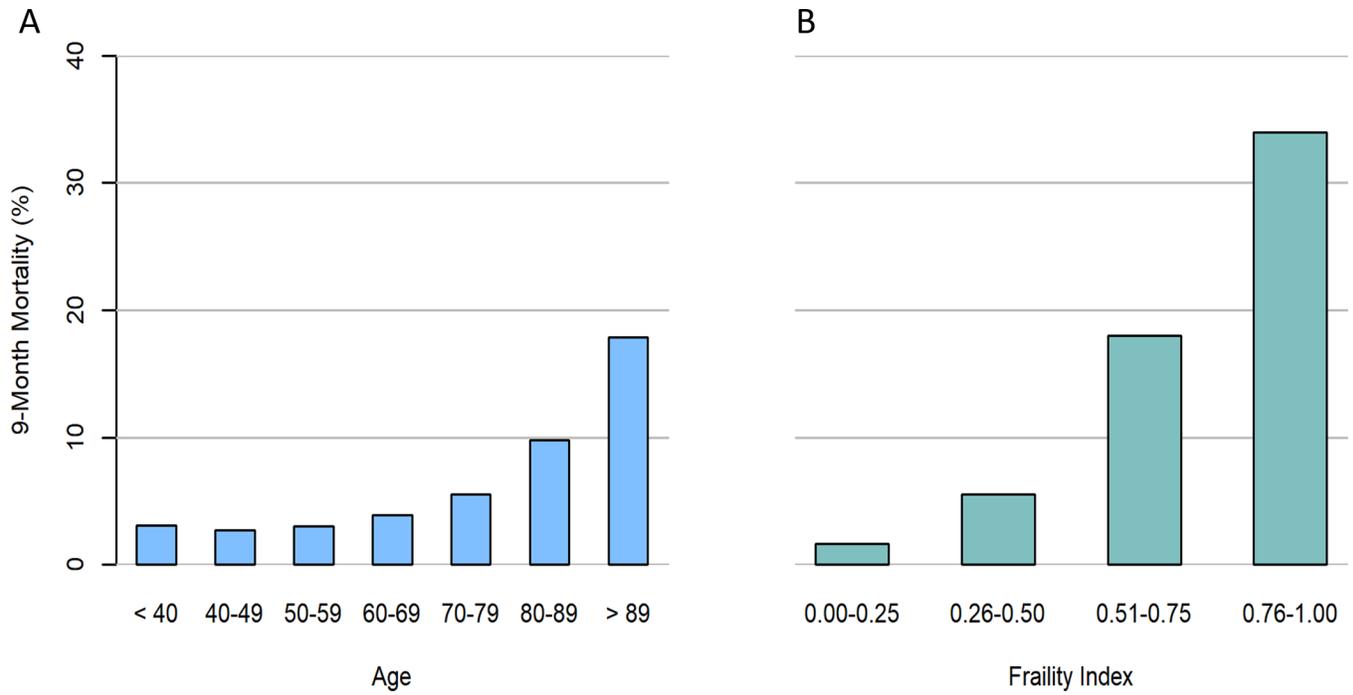
Figure 2.
Panel A. Mortality at 9-months stratified by age group. Panel B. Mortality at 9-months stratified by equally-weighted frailty score (sVQI-FS).
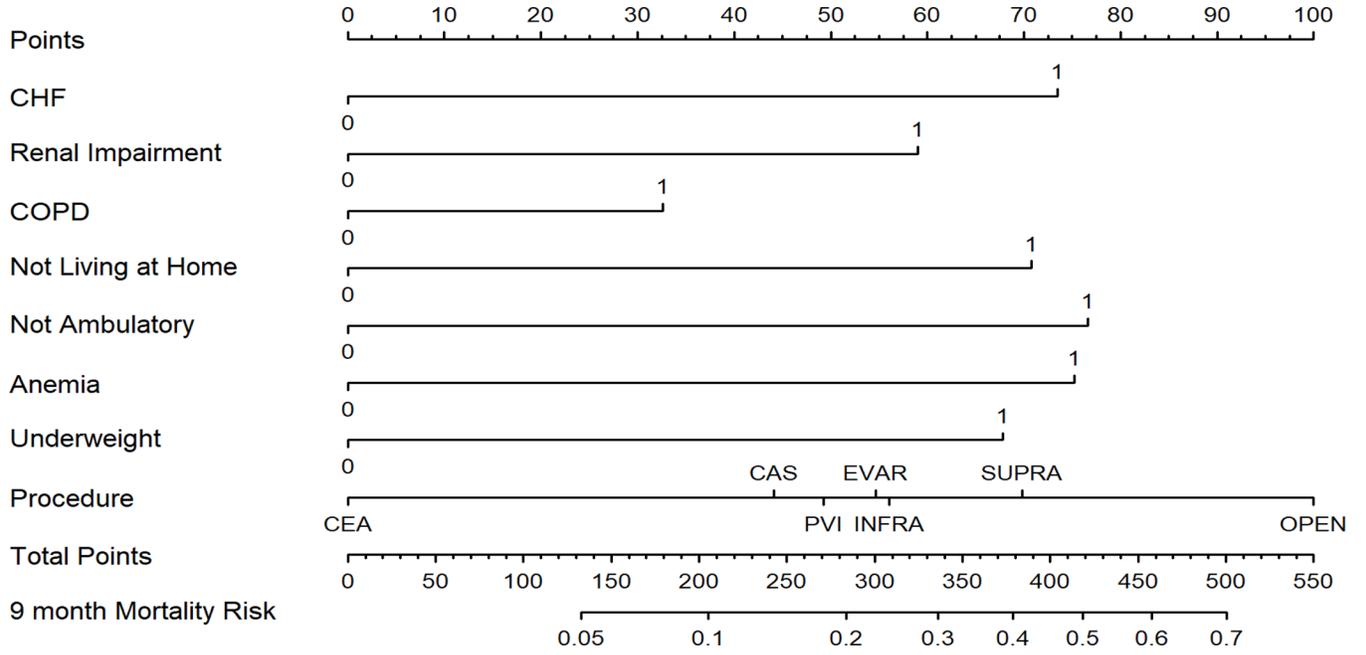
Figure 3.
Nomogram predicting 9-month mortality incorporating seven differentially-weighted frailty characteristics and procedure. Each frailty characteristic and proposed procedure are assigned a point value (top line, Points) based on regression coefficients. Points are then summed and plotted on Total Points line (second from bottom) which can then be mapped to estimated risk of 9-month mortality (bottom line).

Table I.

Frailty Domains Mapped to VQI Variables.

Frailty Domain	VQI Variable
Hypertension (CGA)	• Hypertension
Congestive Heart Failure - CHF (CGA)	• Congestive Heart Failure (CHF)
Myocardial Infarction (CGA)	• History of Angina/MI • Prior coronary artery bypass/percutaneous coronary intervention • Positive cardiac stress test
Peripheral vascular disease (CGA)	• Any ABI <0.7 • History of arterial intervention/amputation
Diabetes mellitus (CGA)	• Diabetes mellitus
Lung or Respiratory Problems (CGA)	• Chronic obstructive pulmonary disease (COPD)
Functional Independence (CGA)	• Pre-admission living (home v care facility)
Ambulation (CGA)	• Pre-admission ambulation status
Renal Impairment (VQI)	• Cr > 1.8 mg/dl • Dialysis
Anemia (VQI)	• Hemoglobin <13 g/dl (male); <12 g/dl (female)
Underweight (VQI)	• BMI < 19

TABLE II.

Summary by Mortality (In-Hospital & 9-Month)

Variable	Type/Level	Died in Hospital (N=2094)	Alive on Discharge (N=262,951)	P-value	Died within 9 months (N=14,316)	Alive after 9 months (N=231,394)	P-value	Test
Sex	Female	871 (42%)	95,095 (36%)	<0.001	5317 (39%)	81,724 (36%)	<0.001	2
	Male	1223 (58%)	167,833 (64%)		8799 (61%)	143,714 (64%)		
Age	[mean (SD)]	73.1 (10.3)	69.0 (10.6)	<0.001	73.8 (10.6)	68.7 (10.6)	<0.001	1
	[median (IQR)]	74 (67, 81)	69 (62, 77)		75 (67, 82)	69 (62, 76)		
Age Category	<40	7 (0%)	1282 (0%)	<0.001	40 (0%)	1094 (0%)	<0.001	2
	40–49	26 (1%)	7721 (3%)		210 (1%)	6963 (3%)		
	50–59	167 (8%)	40,573 (15%)		1231 (9%)	35,949 (16%)		
	60–69	512 (24%)	83,227 (32%)		3253 (23%)	72,185 (32%)		
	70–79	751 (36%)	84,925 (32%)		4726 (33%)	72,424 (32%)		
	80–89	561 (27%)	40870 (16%)		4058 (28%)	33,542 (15%)		
	> 89	70 (3%)	4393 (2%)		798 (6%)	3303 (1%)		
Smoking Status	Never	450 (22%)	51,515 (20%)	<0.001	3414 (24%)	43,948 (19%)	<0.001	2
	Prior	1025 (49%)	121,034 (46%)		7032 (49%)	102,651 (46%)		
	Current	606 (29%)	89,845 (34%)		3812 (27%)	78,481 (35%)		
Dialysis	No	1738 (83%)	251,100 (96%)	<0.001	11,818 (83%)	216,356 (96%)	<0.001	2
	Functioning Transplant	10 (0%)	1480 (1%)		97 (1%)	1262 (1%)		
	On Dialysis	337 (16%)	10,057 (4%)		2368 (17%)	7226 (3%)		
Hemoglobin	[mean (SD)]	11.4 (2.2)	12.9 (2.1)	<0.001	11.4 (2.1)	13.0 (2)	<0.001	1
	[median (IQR)]	11.2 (9.7, 12.9)	13.1 (11.6, 14.3)		11.3 (9.9, 12.9)	13.1 (11.6, 14.4)		
Creatinine	[mean (SD)]	1.3 (0.8)	1.1 (0.5)	<0.001	1.3 (0.7)	1.1 (0.5)	<0.001	1
	[median (IQR)]	1.1 (0.8, 1.5)	1 (0.8, 1.2)		1.1 (0.8, 1.5)	1 (1.0, 1.2)		
Pre-op Living Status	Home	1945 (94%)	255,677 (97%)	<0.001	12,935 (91%)	219,647 (98%)	<0.001	3, 2
	Nursing Home	129 (6%)	6176 (2%)		1304 (9%)	4475 (2%)		
	Homeless	6 (0%)	342 (0%)		19 (0%)	293 (0%)		
Pre-op Ambulatory Status	Ambulatory	1063 (59%)	184,564 (82%)	<0.001	7374 (57%)	160,001 (84%)	<0.001	2
	Ambulatory w/ Assistance	523 (24%)	31,378 (14%)		3844 (30%)	24,798 (13%)		

Variable	Type/Level	Died in Hospital (N=2094)	Alive on Discharge (N=262,951)	P-value	Died within 9 months (N=14,316)	Alive after 9 months (N=231,394)	P-value	Test
	Wheelchair	169 (7%)	7954 (4%)		1377 (11%)	6081 (3%)		
	Bedridden	56 (3%)	892 (0%)		280 (2%)	611 (0%)		
ASA Class	1	5 (0%)	2532 (1%)	<0.001	81 (1%)	2210 (1%)	<0.001	3, 2
	2	79 (3%)	28,731 (12%)		995 (8%)	26,006 (13%)		
	3	879 (42%)	163,452 (70%)		7750 (60%)	141,029 (70%)		
	4	860 (41%)	38,124 (16%)		4017 (31%)	30,873 (15%)		
	5	30 (1%)	171 (0%)		51 (3%)	140 (0%)		
Urgency	Elective	1304 (63%)	224818 (86%)	<0.001	10491 (74%)	193491 (86%)	<0.001	2
	Urgent	771 (37%)	36972 (14%)		3731 (26%)	30579 (14%)		
Procedure	CAS	68 (4%)	13,131 (5%)	<0.001	583 (4%)	11,169 (5%)	<0.001	2
	CEA	239 (11%)	76,787 (29%)		1946 (14%)	65,281 (29%)		
	EVAR	214 (10%)	29,332 (11%)		1257 (9%)	24,951 (11%)		
	OPEN	254 (12%)	7182 (3%)		452 (3%)	6272 (3%)		
	PVI	681 (33%)	93,467 (36%)		6906 (48%)	81,841 (36%)		
	SUPRA	240 (11%)	10,391 (4%)		709 (5%)	8978 (4%)		
	INFRA	398 (19%)	32,661 (12%)		2463 (17%)	26968 (12%)		
BMI	[mean (SD)]	26.8 (6.6)	28 (6)	<0.001	26.5 (6.3)		<0.001	1
	[median (IQR)]	26.1 (22.5, 30.4)	27.3 (24.0, 31.2)		25.8 (22.2, 30)	27.4 (24.1, 31.2)		
Frailty Item - Hypertension	No	177 (8%)	32,878 (13%)	<0.001	1302 (9%)	28,639 (13%)	<0.001	2
	Yes	1906 (92%)	229,730 (87%)		12,978 (91%)	196,180 (87%)		
Frailty Item - CHF	No	1360 (65%)	225,771 (86%)	<0.001	9413 (66%)	195,682 (87%)	<0.001	2
	Yes	718 (35%)	36,767 (14%)		4857 (34%)	29,070 (13%)		
Frailty Item - CAD	No	718 (42%)	119,170 (55%)	<0.001	5129 (45%)	100,504 (56%)	<0.001	2
	Yes	965 (58%)	96,623 (45%)		6273 (55%)	80,011 (44%)		
Frailty Item - PVD	No	57 (3%)	2985 (1%)	<0.001	173 (2%)	2514 (1%)	<0.001	2
	Yes	2019 (97%)	259,255 (99%)		14,076 (99%)	221,949 (99%)		
Frailty Item - Renal Impairment	No	1470 (85%)	235,816 (94%)	<0.001	10,186 (86%)	203,705 (95%)	<0.001	2
	Yes	265 (15%)	14,494 (6%)		1679 (14%)	11800 (5%)		
Frailty Item - Diabetes	No	1138 (55%)	157,363 (60%)	<0.001	6770 (47%)	135,937 (60%)	<0.001	2

Variable	Type/Level	Died in Hospital (N=2094)	Alive on Discharge (N=262,951)	P-value	Died within 9 months (N=14,316)	Alive after 9 months (N=231,394)	P-value	Test
	Yes	941 (36%)	105,157 (40%)		7504 (53%)	88,799 (40%)		
Frailty Item - COPD	No	1299 (62%)	194,780 (74%)	<0.001	9204 (65%)	168,200 (75%)	<0.001	2
	Yes	780 (38%)	67,695 (26%)		5062 (35%)	56,488 (25%)		
Frailty Item - Not Living at Home	No	1945 (94%)	255,677 (98%)	<0.001	12,935 (91%)	219,647 (98%)	<0.001	2
	Yes	135 (6%)	6518 (2%)		1323 (9%)	4768 (2%)		
Frailty Item - Not Ambulatory	No	1063 (59%)	184,564 (82%)	<0.001	7374 (57%)	160,001 (84%)	<0.001	2
	Yes	748 (41%)	40,224 (18%)		5501 (43%)	31,490 (16%)		
Frailty Item - Anemia	No	626 (31%)	149,849 (60%)	<0.001	4180 (31%)	130,603 (61%)	<0.001	2
	Yes	1365 (69%)	100,306 (40%)		9499 (69%)	82,487 (39%)		
Frailty Item - Underweight	No	1889 (92%)	250,639 (96%)	<0.001	12,946 (91%)	214,952 (96%)	<0.001	2
	Yes	174 (8%)	10,421 (4%)		1205 (9%)	8490 (4%)		
sVQI-FS (Equal Weight)	[mean (SD)]	0.4 (0.1)	0.3 (0.1)	<0.001	0.4 (0.2)	0.3 (0.1)	<0.001	1
	[median (IQR)]	0.4 (0.3, 0.5)	0.3 (0.2, 0.4)		0.4 (0.3, 0.5)	0.3 (0.2, 0.4)		

Test: 1=t test, 2=Chi square, 3=Fisher's exact test with simulation

Table III

Logistic Regression Analysis of Mortality at 9-Months

Variable	9-Month Mortality (%)	OR (95% CI)	P-value
Total Sample	5.4	REFERENCE	
Hypertension	5.6	1.06 (0.98, 1.14)	0.17
CHF	12.9	2.02 (1.91, 2.13)	<0.001
CAD	6.4	1.12 (1.07, 1.18)	<0.001
PVD	5.4	0.83 (0.68, 1.02)	0.071
Renal Impairment	11.4	1.76 (1.31, 1.88)	<0.001
Diabetes	7.1	1.04 (0.99, 1.09)	0.085
COPD	7.4	1.38 (1.32, 1.45)	<0.001
Not Living at Home	19.9	2.09 (1.92, 2.28)	<0.001
Not Ambulatory	13.4	2.21 (2.10, 2.32)	<0.001
Anemia	9.3	2.15 (2.05, 2.26)	<0.001
Underweight	11.4	2.07 (1.91, 2.25)	<0.001
Procedure			
CAS	5.0	REFERENCE	
CEA	2.9	0.63 (0.57, 0.71)	<0.001
EVAR	4.8	1.14 (1.00, 1.30)	0.054
Open AAA	6.7	1.78 (1.52, 2.08)	<0.001
INFRA	8.4	1.10 (0.98, 1.23)	0..095
SUPRA	7.3	1.31 (1.15, 1.50)	<0.001
PVI	7.8	1.04 (0.94, 1.15)	0.44