Derivation and Validation of a Simple Calculator to Predict Home Discharge after Surgery

Joseph A Hyder, MD, PhD, Elliot Wakeam, MD, Elizabeth B Habermann, PhD, Erik P Hess, MD, MSc, Robert R Cima, MD, MA, FACS, Louis L Nguyen, MD, MBA, MPH, FACS

BACKGROUND: Surgical patients and their physicians currently have tools to provide individualized prognostication for morbidity and mortality. For improved shared decision making, formal prediction of patient-centered outcomes is necessary. We derived and validated a simple, interview-based method to predict discharge home after surgery.

STUDY DESIGN: We used the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) Patient User File for 2011. Derivation in general and vascular surgery patients undergoing inpatient surgery was completed using serial multiple logistic regression. Validation was performed within multiple surgical specialties.

RESULTS: The derivation cohort included 88,068 patients, of whom 11,771 (13.4%) were not discharged home. The derived Home Calculator had excellent discrimination (c-statistic = 0.864) using 4 variables: age, American Society of Anesthesiologists' performance status, elective surgery, and preadmission residence. Validation cohorts had varying rates of home discharge as follows: general (63,826 of 71,591, 89.2%), vascular (12,319 of 16,102, 76.5%), gynecologic (16,603 of 17,005, 97.6%), urologic (13,662 of 14,435, 94.6%), orthopaedic (12,000 of 19,514, 61.5%), thoracic (4,467 of 5,092, 87.7%). The Home Calculator provided good to excellent discrimination in validation cohorts: general (c = 0.866), vascular (c = 0.800), gynecologic (c = 0.793), urologic (c = 0.814), orthopaedic (c = 0.876), and thoracic (c = 0.800). Comparable discrimination was demonstrated in sensitivity analyses in surgical patients admitted exclusively from home.

CONCLUSIONS: We derived and validated a simple Home Calculator that reliably predicts discharge to home after surgery and may be useful when counseling patients about postoperative course. Patient-centered tools such as this may allow physicians to better prepare patients and families for surgery and the recovery process. (J Am Coll Surg 2014;218:226−236. © 2014 by the American College of Surgeons)

One promise of patient-centered outcomes research is to describe the care experience in terms that patients not only understand but in terms that are meaningful to them.[1] Considerable effort has been expended to engage patients as partners in care, including shared decision making for surgery.[2-6] Comparable investments in large databases, predominantly from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) and the Society of Thoracic Surgeons, have enabled accurate, quantitative estimates of patient risk for morbidity and mortality after surgery, including individualized and detailed predictions for death and morbidity.[7-10]

Despite these dual efforts to engage patients and to provide reliable measures of surgical outcomes, there is very little patient-centered information describing or predicting patient-centered outcomes after surgical procedures, including destination after discharge.[11-13] Surgical patients and their families frequently want to know if they will return home immediately after a hospitalization, or if a less-desirable outcome or prolonged recuperation requiring rehabilitation or care at a nursing facility is anticipated before a return home.

We sought to derive a simple, interview-based tool that predicts home discharge in a general and vascular surgical population and validate it in diverse surgical populations

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From the Center for Surgery and Public Health (Hyder, Wakeam, Nguyen) and the Department of Surgery (Wakeam, Nguyen), Brigham and Women's Hospital, Boston, MA; the Departments of Anesthesiology (Hyder), Surgery (Habermann, Cima), and Emergency Medicine (Hess), and the Center for the Science of Health Care Delivery (Habermann, Cima), Mayo Clinic, Rochester, MN.
Correspondence address: Joseph A Hyder, MD, PhD, Department of Anesthesiology, Mayo Clinic, Rochester, MN. email: joseph.a.hyder@gmail.com

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including general, vascular, gynecologic, urologic, orthopaedic, and thoracic surgery. To assess the accuracy of the tool, we also benchmarked the Home Calculator with the performance of medically detailed, ACS NSQIP-provided predicted probabilities for mortality and morbidity.

METHODS

Patient data

Study data were taken from the ACS NSQIP 2011 Participant Use Data File (PUF).[14] The ACS NSQIP is a data registry developed by the American College of Surgeons using standardized variable definitions and trained abstractors collecting data from more than 400 hospitals. Data from ACS NSQIP are known to be of high quality and nearly complete, with minimal missing data.[15] The study year 2011 was the first year for which data were available to describe disposition destination after discharge. The study was determined to be exempt from review by the Institutional Review Board at Mayo Clinic, Rochester, MN.

We constructed a derivation sample and multiple validation samples by surgical specialty. In the derivation sample, patients were included if undergoing inpatient surgery with complete data and potential predictor variables. We randomly divided a sample of general and vascular surgical patients in half to create 1 derivation (n = 88,068) cohort and 2 validation cohorts, one each for general surgery (n = 72,591) and vascular surgery (n = 16,102). Additional validation cohorts were created from the following surgical specialties: gynecology (n = 17,005), urology (n = 14,435), orthopaedics (n = 19,514), and thoracic (n = 5,092) surgery. Patients undergoing arthroplasty of the knee or hip were excluded from the orthopaedic sample because disposition location of these patients may be highly site dependent, and these patients may be discharged to rehabilitation even if in generally good health postoperatively to speed the rehabilitation process.[16]

Discharge destination (primary outcome)

The ACS NSQIP PUF records the discharge destination for each patient as follows: home; a skilled care facility that was not previously home (includes a transitional care unit, a subacute hospital, a chronic care facility accommodating ventilator beds, skilled nursing home); an unskilled facility that was not previously home (includes an unskilled nursing home or assisted facility); a facility that was home (includes a chronic care facility, an unskilled care facility, or and assisted living facility); or death.[14] These outcomes were reclassified as "home" or "other." Death was combined with nonmortality outcomes based on precedent and generalizability to the question, "Will I get to go home after my surgery?"[17]

Potential predictors of disposition location

Age was reclassified to simplify estimation of risk using ordered categories as follows: 18 to 39 years, 40 to 49, 50 to 59, 60 to 69, 70 to 79, and 80 years and older. A patient's location of residence before admission was coded using the following ACS NSQIP definitions: admitted directly from home, transfer acute care (acute care hospital inpatient, admitted from an outside emergency department or transferred from other acute care), or admitted from a nursing home (includes both chronic care and intermediate care facilities). A patient was noted to be undergoing elective surgery if the patient was "brought to the hospital or facility for a scheduled (elective) surgery from their home or normal living situation on the day that the procedure is performed."[14] Patients who were transferred from an emergency department or clinic or were admitted before a scheduled procedure "for any reason (eg, cardiac or pulmonary workup or 'tuning', bowel cleanout, TPN, hydration, anticoagulation reversal, etc.)" were classified as not undergoing elective surgery.[14] The ACS NSQIP reports that "The intent is to identify a relatively homogeneous group of patients who are well enough to come from home, to allow for more meaningful comparative analyses."[14] Patient functional status was defined by the ACS NSQIP to include activities of daily living such as bathing, feeding, dressing, toileting, and mobility, and the value reported is the patient's best functional status within the 30 days before surgery. Partially dependent patients would require some assistance from another person for any activities of daily living. Totally dependent patients would require "total assistance for all activities of daily living."[14] The American Society of Anesthesiology (ASA) Physical Status Classification of the patient's present physical condition was recorded according to ACS NSQIP definitions and recoded using a 4-level unordered categorical variable as follows: I or II, III, IV, V. Surgical priority, coded as emergency surgery or not, was determined in the PUF using documentation by surgeon and anesthesiologist, or when lacking or disparate, "best clinical judgment."[14] A patient's resuscitation status was recorded as "do not resuscitate (DNR)" if "a DNR order written in the physician's order sheet of the patient's chart and it has been signed or co-signed by an attending physician in the 30 days prior to surgery. If the DNR order as defined above was rescinded immediately prior to surgery in order to operate on the patient," the patient was reported as DNR per ACS methodology.[14]

Derivation of the Home Calculator

Candidate predictors of home discharge were selected a priori based on clinical experience and available literature describing risk adjustment and methodology and risk prediction among colorectal surgical patients.[18,19] Variables were selected based on 2 criteria: the variable data must be ascertainable in a simple, brief interview by a nurse or even a patient him- or herself, and these data must be known preoperatively (therefore excluding anesthesia type, wound classification, and Common Procedural Terminology [CPT] given that the planned and actual CPT may differ). This method excluded complex definitions of comorbidities such as COPD, and laboratory values. Serial simple models were evaluated with attention to Wald chi-square values for each variable as well as changes in c-statistics associated with variable addition and removal. These methods demonstrated that the variables describing DNR status and emergency status, although highly statistically significant, had comparably small Wald values and contributed minimally to changes in discrimination as assessed by the c-statistic.

Once a simple model was derived, the beta estimates for covariates were standardized and points were assigned to each level of each variable. Significant digits were limited to facilitate manual calculation by patients or nurses. Internal validation of the Home Calculator was performed by comparing the discrimination of the calculator to the ACS NSQIP-predicted mortality and predicted morbidity values by statistical comparison of c-statistics with the Wald chi-square test and by plotting the receiver operator characteristic curve within the derivation sample.

Benchmarking the Home Calculator

For general and vascular surgery patients, the ACS NSQIP PUF includes 2 variables calculated by ACS NSQIP. One, called "predicted mortality," is the patient's estimated risk of death within 30 days. Another variable, called "predicted morbidity," is the patient's estimated risk of morbidity within 30 days postoperatively. These estimated values are based on proprietary models that incorporate data describing the patient's surgical procedure, or CPT-specific data and patient data in a hierarchical model.[15]

These values are proprietary but are known to be estimated using upwards of 23 variable levels.[9] In estimates of performance for the morbidity predicted probability, morbidity was noted if any of the following events were reported "superficial incisional surgical site infection (SSI), deep incisional SSI, organ space SSI, wound disruption, pneumonia, unplanned intubation, pulmonary embolism, deep venous thrombosis, ventilator for greater than 48 hours, progressive renal insufficiency, acute renal failure, urinary tract infection, stroke, cardiac arrest, myocardial infarction, return to the operating room, or systemic sepsis."[9] This estimate was among a random subsample of inpatients and was presumed to contain some variation, but not enough to invalidate it for benchmarking purposes.

Validation of the Home Calculator

We established 6 diverse samples to validate the Home Calculator. These were patients who underwent general surgery, vascular surgery, gynecologic surgery, urologic surgery, orthopaedic surgery, and thoracic surgery. Risk scores were calculated for each patient using the fixed intercept from the derivation cohort, and predicted probabilities of nonhome discharge were calculated. The utility of the Home Calculator was assessed with the c-statistic as well as sensitivity, specificity, and accuracy, using an arbitrary cut-point of 10% risk of nonhome discharge as a "positive" test. Given the large sample sizes and absence of formal hypotheses for these values, confidence intervals were not constructed.

Additional statistical methods and benchmarking

Differences between groups were tested using chi-square tests and generalized linear models for categorical and continuous variables. Predictive models were evaluated for discrimination, calibration and clinical calibration using the c-statistic, and the Hosmer-Lemeshow goodness-of-fit test. Sensitivity analyses were conducted to examine predictive performance for elective surgery only, for emergency surgery only, when patients who died were excluded, when only patients admitted from home were included, and using alternative risk cut-points for a "positive" test for home discharge.

As a reference, we compared the clinical utility of the Home Calculator to the performance of the ACS-NSQIP-predicted mortality and predicted morbidity values for their respective outcomes, calculating the c-statistic, sensitivity, specificity, predictive values, and accuracy. These calculations were undertaken without estimation of 95% confidence intervals because the sample sizes were large and no formal hypothesis testing was planned. In addition, the values we calculated contain some error because they were obtained from a random sample of patients. They are not meant to represent the exact performance of the ACS-NSQIP prediction variables, but to serve as a coarse guide for general benchmarking.[15]

RESULTS

Demographic descriptions of patients in the derivation cohort are presented in Table 1. This cohort included 88,068 patients, 71,831 of whom were general surgery patients and 16,237 who were vascular surgery patients. Compared with patients who were discharged home, those who were not were significantly older, more likely to be male, have a higher American Society of Anesthesiologists classification, have a lower independent functional status, were more likely to be listed as "do not resuscitate," and were less likely to have been admitted from home initially. Patients who were discharged home had statistically lower mean and median values for predicted morbidity and predicted mortality, as estimated by the ACS-NSQIP.

Patient morbidity and mortality in the derivation cohort are presented in Table 2. In all, 2.7% of patients died, and patients who were discharged home had statistically lower 30-day death rates than those who were not discharged home (0.3% vs 15.7%, $p < 0.0001$). Patients who were discharged home had significantly lower 30-day morbidity rates.

Table 1. Characteristics of Derivation Sample by Location before Admission

	Location after discharge		
Characteristic	**Home**	**Other***	**p Value**
Total, n (%)	76,297 (86.6)	11,771 (13.4)	
Patient			
Age, y (SD)	55.8 (16.7)	70.3 (14.3)	<0.0001
Sex, male, n (%)	33,453 (43.9)	5,791 (49.2)	<0.0001
ASA classification, n (%)			<0.0001
I or II	34,564 (45.3)	1,109 (9.4)	
III	36,643 (48.0)	6,180 (52.5)	
IV	9,157 (6.6)	4,148 (35.2)	
V	81 (0.1)	334 (2.8)	
Functional status, n (%)			<0.0001
Independent	74,357 (97.5)	8,425 (71.6)	
Some assistance	1,631 (2.1)	2,343 (19.9)	
Full assistance	309 (0.4)	1,003 (8.5)	
Do not resuscitate, n (%)	91 (0.1)	257 (2.2)	<0.0001
Location before admission, n (%)			<0.0001
Home	72,794 (95.4)	8,228 (69.9)	
Nursing home	139 (0.2)	1,449 (12.3)	
Outside acute care hospital	1,800 (2.5)	1,404 (11.9)	
Emergency department	1,464 (1.9)	690 (5.9)	
Sepsis, n (%)	3,067 (4.0)	2,284 (19.4)	<0.0001
COPD, n (%)	4,021 (5.3)	1,740 (14.8)	<0.0001
Surgery			
Elective surgery, yes, n (%)	50,136 (65.7)	4,199 (35.7)	<0.0001
Emergency surgery, yes, n (%)	13,568 (17.8)	3,931 (33.4)	<0.0001
Surgical type, n (%)			<0.0001
General (n = 71,831)	63,970 (89.1)	7,861 (10.9)	
Vascular (n = 16,237)	12,327 (75.9)	3,910 (24.1)	
Outcomes			
Predicted risk of death, %			
Mean (SD)	1.1 (3.2)	10.5 (15.9)	<0.0001
Median (IQR)	0.3 (0–0.9)	3.9 (1.4–11.7)	<0.0001
Predicted risk of morbidity, %			
Mean (SD)	11.8 (10.1)	29.0 (17.7)	<0.0001
Median (IQR)	8.2 (4.4–16.0)	25.5 (15.5–39.8)	<0.0001

*Other includes dead, still in-hospital, discharged to nursing facility, long-term acute care hospital, or rehabilitation.
ASA, American Society of Anesthesiologists; IQR, interquartile range.

Table 2. Hierarchy of Outcomes in Derivation Cohort

Variable	Total, n (%)	Discharge location: Home, n (%)	Other	p Value
Total patients	88,068	76,297 (86.6)	11,771 (13.4)	
Death	2,093 (2.4)	245 (0.3)	1,848 (15.7)	<0.0001
Morbidity*	13,301 (15.1)	7,936 (10.4)	5,365 (45.6)	<0.00001

*Morbidity includes superficial, deep or organ space surgical site infection, wound disruption, pneumonia, unplanned intubation, pulmonary embolism, deep venous thrombosis, ventilator greater than 48 hours, progressive renal insufficiency, acute renal failure, urinary tract infection, stroke, cardiac arrest, myocardial infarction, return to the operating room, systemic sepsis.

The results of the logistic regression model used to predict discharge to home including the relative contributions of each variable, as assessed by the Wald chi-square, demonstrated that age (Wald 2660.4) and American Society of Anesthesiologists classification (Wald 2769.3) were powerful variables in the model (Table 3).

Benchmarking for discrimination

The Home Calculator was referenced to ACS NSQIP-predicted mortality and predicted morbidity as potential predictors of home discharge. Three approaches exhibited similar abilities to discriminate, assessed by the c-statistic, between patients who were discharged home vs not (Table 3). The ACS-NSQIP-predicted mortality score (c = 0.8719), and ACS-NSQIP-predicted morbidity score (c = 0.8220) demonstrated excellent discrimination, as did the simple model (c = 0.8642). All values were significantly different ($p < 0.05$) from each other. The receiver-operator characteristic curves for the 3 approaches demonstrated performance over a range (Fig. 1).

How to use the Home Calculator

An example Home Calculator for patients or their care providers to estimate a risk score using the appropriate patient descriptions is presented (Fig. 2A) along with a companion graphic to translate the relationship between risk score and probability of nonhome discharge (Fig. 2B).

Validation

In Table 4, descriptions and validation characteristics are presented for 6 validation cohorts. The cohorts were diverse. For example, the fractions of functionally independent patients varied widely across the cohorts

Table 3. Derivation of Home Calculator Predicting Discharge to Home

Simple model	Odds ratio (95% CI)	Wald chi-square	df
Age (decade past age 40 y)	1.61 (1.58–1.64)	2660.4	1
Elective surgery		1291.2	1
Yes	1 (ref)		
No	2.50 (2.38–2.63)		
ASA performance status		2769.3	3
I or II	1 (ref)		
III	2.72 (2.54–2.93)		
IV	7.55 (6.96–8.20)		
V	31.85		
Functional status		1437.5	1
Independent	1 (ref)		
Partially dependent	3.78 (3.48–4.10)		
Totally dependent	5.77 (4.97–6.72)		
Preadmission location		1441.5	1
Home	1 (ref)		
Acute care setting	2.22 (2.06–2.39)		
Nursing home	24.95 (20.57–30.27)		
Model discrimination c-statistic (95% CI)*			
Simple model	0.8642 (0.8605–0.8679)		
ACS NSQIP predictors			
Predicted mortality	0.8719 (0.8685–0.8754)		
Predicted morbidity	0.8220 (0.8180–0.8259)		

*All c-statistics are significantly different from each other.
ASA, American Society of Anesthesiologists.

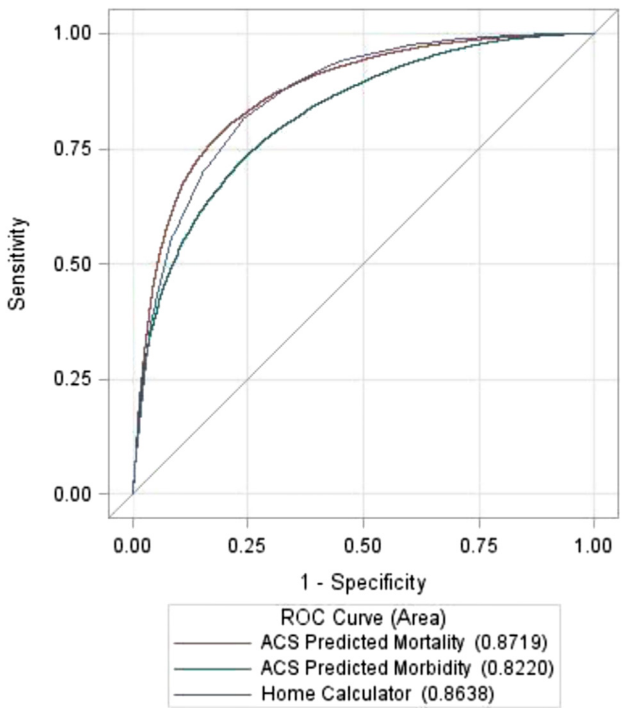

Figure 1. Comparison of receiver-operator characteristic (ROC) curves for 3 methods to predict home discharge.

(86.5% of orthopaedic patients vs 95.3% of general surgery patients, no p value applicable), as did the mortality rates (0.2% for gynecologic surgery patients vs 3.4% for vascular surgery patients) and rates of home discharge (97.6% for gynecologic surgery patients vs 61.5% for orthopaedic surgery patients). The discriminatory ability of the Home Calculator was good to excellent for all surgical subspecialties, with the lowest value for gynecologic surgery ($c = 0.793$) and the best discrimination among orthopaedic surgery patients ($c = 0.876$).

We calculated traditional measures of test performance for the Home Calculator. Assuming that a 10% or greater risk of nonhome discharge was a "positive" test, the Home Calculator's performance varied across surgical specialties. The range of performance corresponded to fluctuations by underlying mortality and morbidity in the populations. For example sensitivity was lower for gynecologic surgery than vascular surgery (48.0% vs 91.7%, no p value calculated), but specificity was greater in gynecologic surgery compared with vascular surgery (92.8% vs 64.1%). In sensitivity analyses excluding elective surgical patients or excluding patients who died in-hospital after surgery or were admitted from home, performance assessed by the c-statistic was similar. For example, when only patients admitted from home were included, the c-statistics were as follows: gynecologic surgery (0.771), general surgery (0.836), vascular surgery (0.748), urologic surgery (0.777), orthopaedic surgery (0.855), and thoracic surgery (0.761).

Benchmarking for sensitivity, specificity, predictive value, and accuracy

Given the limited positive predictive values for the Home Calculator mentioned previously, we performed further benchmarking by comparing the Home Calculator with ACS NSQIP-generated predicted probabilities for death and morbidity. With the derivation cohort, we considered a 10% or greater risk of death based in the "predicted mortality" variable as a positive test, and we considered a 10% or greater risk of morbidity based on the "predicted morbidity" variable as a positive test. The ACS-NSQIP variable "predicted mortality" was evaluated as a predictor of mortality and the following performance values were calculated: sensitivity (1,243 of 2,093, 59.4%), specificity (82,653 of 85,975, 96.1%), positive predictive value (1,243 of 4,565, 27.2%), negative predictive value (82,653 of 83,503, 99.0%), and accuracy (83,896 of 88,068, 95.3%). The c-statistic for "predicted mortality" as a predictor of death was 0.904 in this sample. For the ACS NSQIP variable predicted morbidity, the following performance values were calculated: sensitivity (10,655 of 13,301, 80.1%), specificity (42,547 of 74,767, 56.9%), positive predictive value (10,655 of 42,875, 24.9%), negative predictive value (42,547 of 45,193, 94.2%), and accuracy (53,202 of 88,068, 60.4%). The c-statistic for the outcome of morbidity for this model in this subsample of inpatients was 0.762.

DISCUSSION

The aim of this study was to derive and validate a simple tool to help patients begin discharge planning with their care team including surgeons, mid-level providers, nurses, and discharge coordinators. The result was a 4-variable Home Calculator that achieved excellent discrimination assessed by the c-statistic and predictive utility assessed by conventional measures, even when compared with sophisticated risk prediction tools available for general and vascular surgical patients. This simple tool was validated in diverse surgical samples, including general, vascular, gynecologic, urologic, and thoracic surgical patients. In these samples, the Home Calculator demonstrated comparably good results. This tool may be a useful starting point for discussions of postoperative discharge planning among patients, their families, and physicians.

This study attempted to create a tool that patients could use to predict a patient-centered outcome. Home

A

Scoring Your Discharge Destination

							Your Score
How old are you?	20-39	40-49	50-59	60-69	70-79	80 or older	
(POINTS)	0	4	8	12	16	20	
Is your surgery elective surgery or not?	Elective		Not elective				
(POINTS)	0		8				
How independent are you for daily activities?	Independent		Partially dependent			Totally dependent	
(POINTS)	0		11			15	
Where were you living or being treated before surgery?	Home		Acute care facility			Nursing home	
(POINTS)	0		7			27	
What is your ASA Performance Status?	I or II		III		IV	V	
(POINTS)	0		9		17	30	

Circle the points that apply to you. Add them up to determine your score. Find your score on the figure.

Elective surgery means you came into the hospital for surgery on the same day and were not admitted beforehand to get "tuned up."
Independent means you require no assistance for bathing, feeding, toileting, dressing or transfer. Totally depdendent means that you require assistance with each of these tasks. Partially depdendent patients are neither totally independent nor totally dependent.
An acute care facility includes another hospital or emergency department or similar place where sick patients are diagnosed and treated.
Your ASA Performance Status would correspond to the following examples. If you have questions, ask your surgeon or anesthesiologist.

I or II Patients with no or only mild systemic disease. The majority of patients fall into this category.
-You have hypertension, which is well controlled
-You have diabetes which is controlled with oral medications only

III Patients with severe systemic disease. Some patients will be included in this category.
-You have asthma that requires daily medications including occasional symptomatic treatments
-You have diabetes which is poorly controlled or requires insulin therapy

IV Patients with severe systemic disease that is a constant threat to life. Few patients fall into this category.
-You have asthma requiring daily medications including frequent symptomatic treatments or a recent hospitalization
-You have diabetes which is poorly controlled, requires insulin therapy or for which you have had a complication such as vision loss or amputation
-You have had heart disease that severely limits your ability to perform regular activities.

V Patients who are moribund, or near death, for whom death is almost certain without surgery. Very few patients fit this category.

B

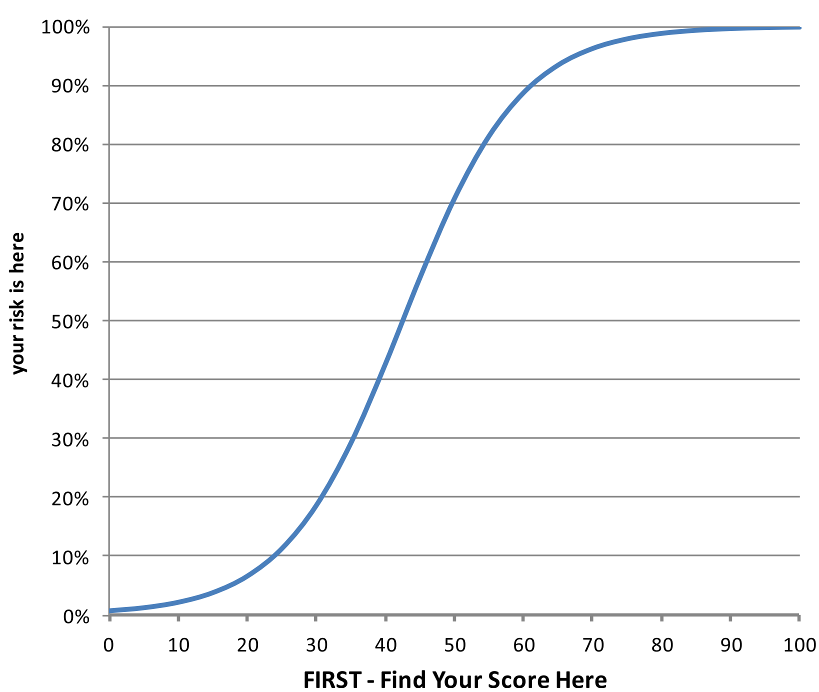

Figure 2. (A) Example of the home calculator to predict home discharge. ASA, American Society of Anesthesiologists. (B) Your risk of not going straight home: comparison of risk score and risk of not being discharged to home.

discharge is one possible postoperative outcome along with numerous postoperative outcomes that currently define surgical quality.[20] Surgical quality is frequently defined by the absence of complications postoperatively. Despite this, surgical teams are increasingly concerned with achieving patient-centered outcomes and patient

Table 4. Validation of the Home Calculator by Surgical Specialty

Variable	General	Vascular	Gynecologic	Urologic	Orthopaedic	Thoracic
Total, n	71,591	16,102	17,005	14,435	19,514	5,092
Patients						
Age, y (SD)	55.4 (17.1)	68.4 (12.5)	51.2 (13.6)	63.4 (12.6)	64.2 (17.8)	61.6 (14.8)
ASA classification, n (%)						
I or II	34,737 (48.5)	1,187 (7.4)	12,551 (73.9)	7,322 (50.8)	8,874 (45.5)	1,157 (22.7)
III	31,478 (44.0)	10,774 (66.9)	4,194 (24.7)	6,559 (45.5)	9,070 (45.5)	3,186 (62.6)
IV	5,108 (7.1)	4,000 (24.8)	241 (1.4)	539 (3.7)	1,539 (7.9)	736 (14.5)
V	268 (0.4)	141 (0.9)	4 (0.0)	4 (0.0)	14 (0.1)	9 (0.2)
Functional status, n (%)						
Independent	68,200 (95.3)	14,271 (88.6)	16,813 (99.1)	13,950 (97.4)	16,615 (86.5)	4,838 (95.3)
Some assistance	2423 (3.4)	1,453 (9.0)	139 (0.8)	291 (2.0)	2,187 (11.4)	177 (3.5)
Full assistance	968 (1.4)	378 (2.4)	16 (0.1)	76 (0.5)	408 (2.1)	61 (1.2)
Preadmission location, n (%)						
Home	66,705 (93.2)	14,043 (87.2)	16,757 (98.6)	14,083 (97.6)	17,009 (87.2)	4,751 (93.3)
Nursing home	976 (1.4)	1,470 (9.1)	216 (1.3)	129 (1.5)	990 (5.1)	51 (1.0)
Acute care setting	3,910 (5.5)	589 (3.7)	22 (0.1)	218 (0.9)	1,506 (7.7)	288 (5.7)
Elective surgery, n (%)	43,577 (60.9)	10,414 (64.7)	15,369 (91.5)	12,806 (90.1)	11,049 (57.7)	3,754 (76.0)
Outcomes						
Death, n (%)	1,564 (2.2)	552 (3.4)	38 (0.2)	99 (0.7)	412 (2.1)	173 (3.4)
Home discharge, n (%)	63,826 (89.2)	12,319 (76.5)	16,603 (97.6)	13,662 (94.6)	12,000 (61.5)	4,467 (87.7)
Performance						
Sensitivity	6,290/7,765 (81.0)	3,469/3,783 (91.7)	193/402 (48.0)	531/773 (68.7)	6,003/7,514 (79.9)	479/625 (76.6)
Specificity	48,935/63,826 (89.2)	7,890/12,319 (64.1)	15,411/16,603 (92.8)	10,617/13,662 (77.7)	9,323/12,000 (77.7)	2,758/4,467 (61.7)
Positive predictive value	6,290/21,181 (29.7)	3,469/11,359 (30.5)	193/1,385 (13.9)	531/3,576 (14.9)	6,003/8,680 (69.2)	479/2,188 (21.9)
Negative predictive value	48,935/50,410 (97.1)	4,429/4,743 (93.4)	15,411/15,620 (98.7)	10,617/10,859 (97.8)	9,323/10,834 (86.1)	2,758/2,904 (95.0)
Accuracy	51,670/7,1591 (72.2)	12,319/16,102 (76.5)	15,604/17,005 (91.8)	11,148/14,435 (77.2)	15,326/19,514 (78.5)	3,237/5,092 (63.6)
c-statistic	0.866	0.800	0.793	0.814	0.876	0.800

ASA, American Society of Anesthesiologists.

satisfaction rather than simply avoiding complications.[20] Discharge to home postoperatively is an attractive patient-centered outcome because patients generally aim to live at home, and data describing this outcome may be simpler and easier to acquire than alternative, more individualized patient-centered outcomes. Moreover, measuring home discharge captures new information not included in assessments of morbidity and mortality, and absence of an in-hospital ACS NSQIP complication does not equate with home discharge. The suitability of home discharge as a surgical performance measure is unknown, and such a measure is not advocated here. Home discharge is also highly relevant to physicians and hospitals. Early or anticipatory discharge planning may potentially allow hospitals to improve efficiency in staffing and more reliably discharge patients in terms of location and timing. It is unknown, however, what specific staffing, workflow, or financial implications may be from anticipatory discharge planning for home. Regardless, home discharge will remain highly relevant to patients.

A few other investigations have attempted to predict home discharge postoperatively. These studies have typically included variables that require laboratory testing and/or postoperative data and have addressed only narrow surgical samples such as joint arthroplasty, necrotizing soft tissue infections, gynecologic cancer surgery, or colectomy.[11,21-24] These features limit the broad applicability of these methods for anticipatory discharge planning, regardless of the model successes. The discriminatory power of the calculator presented here was excellent, and the validation within and across diverse surgical samples marks a divergence from results of previous studies. In no studies, including the ACS NSQIP risk calculators, have the clinical calibration of models been demonstrated with sensitivity and specificity.

The Home Calculator derived in this study may be attractive as a clinical and patient education tool due to its excellent predictive performance, wide generalizability to diverse surgical samples, and the simplicity of calculation. In terms of predictive performance, the Home Calculator demonstrated very good to excellent discrimination. For clinical applications, however, estimated probabilities of home discharge would ideally demonstrate a consistent relationship with the probability of outcome, or "clinical calibration." Even the best risk predictors, those for mortality and morbidity in the ACS NSQIP, have limited "clinical calibration." For example, the ACS NSQIP-predicted mortality and morbidity estimates had sensitivities of approximately 59.4% and 80.1%, respectively, for their intended outcomes when the same cut-point of 10% risk was used among the inpatients sampled. The Home Calculator presented here demonstrated sensitivity, specificity, predictive values, and accuracy within the range set out by the ACS-NSQIP-predicted morbidity and mortality values for their respective outcomes. These performance values are subject to cut-point determination in the setting of underlying event rates, which explains, for example, the poor positive predictive values for all predictors, but knowing that the Home Calculator performs within the range of the ACS-NSQIP predictors for their respective outcomes is reassuring given the excellent utility of these predictors, which are the gold standard in surgery.[15]

In terms of generalizability, the Home Calculator performed similarly across diverse surgical samples, which varied by specialty, patient health status, and baseline rates of home discharge (62% for orthopaedics and 98% for gynecologic surgery). In addition, the calculator performed well even when applied only to patients coming from home. Although dozens of separate, unique home calculators for unique age and surgical groupings may result in incremental predictive improvement, the aim of this tool was to achieve good discrimination in diverse samples using patient-accessible methods.[25]

Finally, the calculator achieved these results using a very simple approach. Only 4 variables make up the calculator, and the calculator requires no data describing laboratory tests, refined medical diagnoses, or the patients' surgical anesthetics or procedures. We hope that this simplicity will make the calculator accessible to patients themselves or, more likely, with minimal assistance from a nurse or physician. There is potential for patients to misclassify their conditions, and this would lead to error in prediction. The Home Calculator would ideally be used along with patients, whether by a nurse or physician, rather than by the patient alone, which would improve the utility of the tool. The limited inputs and general simplicity of calculation would allow the time saved to be used in consultation and discussion rather than calculation. It is unknown how the Home Calculator performs compared with physician judgment, and such an assessment would require prospective evaluation or simulation study using physician subjects. Given the excellent discrimination, it is unclear which single approach would have better discrimination or calibration. Regardless, the tool is not intended to replace a preoperative consultation by the surgeon and/or anesthesiologist, but the tool could serve as a starting point for discussion of postdischarge planning. Such a discussion would allow refinement based on a patient's surgical details, such as CPT or surgical extent, and the process of incorporating the tool into everyday practice with patients may encourage patient engagement with anticipatory discharge planning.

There are several potential limitations in this study. Conclusions, particularly regarding clinical application of this calculator, are limited by the context of the retrospective design and specific features of participating patients and hospitals. The relationship between risk score and probability of home discharge may vary by hospital, or institution-level variation, independent of patient mix and surgical case mix. Institution-level data were not available in the ACS-NSQIP, so the relative importance of institution-level variation is not known.[16] Discharge destination may be subject to insurance status, wealth, or family structure.[26,27] We intentionally excluded sociodemographic variables such as sex or race/ethnicity when creating the tool. Eliciting patients' family circumstances may assist with discharge planning, but was unlikely to improve model discrimination given the excellent discrimination already present. The derivation of the tool was limited by the data available in the ACS-NSQIP, and the validation of the tool was restricted to surgical samples included in the ACS-NSQIP. Currently, patient outcomes within other datasets including the Centers for Medicare and Medicaid, the Nationwide Inpatient Sample, and regional datasets lack descriptions of key variables for this calculator. These variables, such as functional status, residence before admission, or elective nature of an operation, are easily ascertainable from a brief patient interview. How the accuracy of this calculator compares to that which can be achieved by clinicians' unstructured estimate of the likelihood of nonhome discharge is unknown. We plan to assess this in future prospective studies.

Conclusions are further limited if home is assumed to be an ideal discharge destination. Although the tool demonstrated excellent discrimination when predicting which patients would be discharged home vs not, the tool predicts only that. It does not provide information as to whether home is an appropriate or safe discharge location for a patient. Moreover, discharge location is not a gold standard for surgical quality given the heterogeneity of home placements. Some patients who are discharged home may be better served by stays in rehabilitation or a nursing home, but these patients lack the resources to gain admission to these settings. Some patients are discharged home as part of a palliative, or end-of -life care plan and not because they are healthy enough to recuperate and thrive in a home setting. In our study sample, no data were present regarding palliative status at the time of hospital discharge or insurance status, and too few patients were admitted to rehabilitation facilities to make a meaningful comparison or to model outcomes across these groups. Many patients discharged to home are known to receive services at home.[11] For these patients, even a "false positive" screen for nonhome discharge may serve to alert physicians, nurses, and discharge planners of a patient who may benefit from additional planning despite a home discharge.

CONCLUSIONS

This study aimed to derive and validate a Home Calculator to predict home discharge for surgical patients. The resultant tool demonstrated excellent predictive ability across diverse surgical samples, and its simplicity may encourage use by patients themselves or with assistance from nurses before as part of a surgical consultation with anticipatory discharge planning.

Author Contributions

Study conception and design: Hyder, Wakeam, Nguyen
Acquisition of data: Hyder, Wakeam, Habermann, Cima, Nguyen
Analysis and interpretation of data: Hyder, Wakeam, Habermann, Hess, Cima, Nguyen
Drafting of manuscript: Hyder
Critical revision: Wakeam, Habermann, Hess, Cima, Nguyen

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