ANESTHESIOLOGY

Days Alive and Out of Hospital

Validation of a Patient-centered Outcome for Perioperative Medicine

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ABSTRACT

Background: Days alive and out of hospital is a potentially useful patient-centered quality measure for perioperative care in adult surgical patients. However, there has been very limited prior validation of this endpoint with respect to its ability to capture differences in patient-level risk factor profiles and longer-term postoperative outcomes. The main objective of this study was assessment of the feasibility and validity of days alive and out of hospital as a patient-centered outcome for perioperative medicine.

Methods: The authors evaluated 540,072 adults undergoing 1 of 12 major elective noncardiac surgical procedures between 2006 to 2014. Primary outcome was days alive and out of hospital at 30 days, secondary outcomes were days alive and out of hospital at 90 days and 180 days. Unadjusted and risk-adjusted adjusted analyses were used to determine the association of days alive and out of hospital with patient-, surgery-, and hospital-level characteristics. Patients with days alive and out of hospital at 30 days values less than the tenth percentile were also classified as having poor days alive and out of hospital at 30 days. The authors then determined the association of poor days alive and out of hospital at 30 days with in-hospital complications, poor days alive and out of hospital at 90 days (less than the tenth percentile), and poor days alive and out of hospital at 180 days (less than the tenth percentile).

Results: Overall median (interquartile range) days alive and out of hospital at 30, 90, and 180 days were 26 (24 to 27), 86 (84 to 87), and 176 (173 to 177) days, respectively. Median days alive and out of hospital at 30 days was highest for hysterectomy and endovascular aortic aneurysm repair (27 days) and lowest for upper gastrointestinal surgery (22 days). Days alive and out of hospital at 30 days was associated with clinically sensible patient-level factors (comorbidities, advanced age, postoperative complications), but not measured hospital-level factors (academic status, bed size). Of patients with good days alive and out of hospital at 30 days, 477,163 of 486,087 (98%) and 470,093 of 486,087 (97%) remained within this group (greater than the tenth percentile) at days alive and out of hospital at 90 and 180 days.

Conclusions: Days alive and out of hospital is a feasibly measured patient-centered outcome that is associated with clinically sensible patient characteristics, surgical complexity, in-hospital complications, and longer-term outcomes. Days alive and out of hospital forms a novel patient-centered outcome for future clinical trials and observational studies for adult surgical patients.

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EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Days alive and out of hospital is an easily obtained patient-centered outcome

What This Article Tells Us That Is New

- Days alive and out of hospital was associated with patient-level factors including comorbidities, advanced age, and complications, but not less relevant hospital-level factors
- It appears to be a useful measure of surgical impact

Mortality among adults undergoing elective noncardiac surgical procedures in economically advanced countries is generally low (1 to 3%).[1] However, many patients experience postsurgical complications (16 to 44%) that are associated with prolonged hospital stays and reduced likelihood of returning to preoperative levels of functioning and independent living status.[1–5] Thus, when measuring the quality of perioperative care, it is important to capture this patient-centered aspect of postoperative recovery, using outcomes that are responsive to patient risk factor profiles and treatment efficacy. One such outcome that has been previously used in heart failure, atrial fibrillation, and stroke research is days alive and out of hospital.[6–10] This endpoint incorporates the patient treatment experience and treatment-related complications on the healthcare system. Days alive and out of hospital is a composite outcome that integrates several clinically important outcomes, including death, hospital length-of-stay, and hospital readmission.[11] Days alive and out of hospital after a surgical intervention can be used for both short- and long-term follow-up given it is calculated during a specified time frame (*e.g.*, 30 days, 6 months, 1 yr) after the procedure.

There has only been limited validation of days alive and out of hospital as an endpoint in perioperative medical and surgical research. This endpoint has several advantages for measuring patients' experience after surgical interventions. Days alive and out of hospital after different surgeries identifies relevant patient-centered postoperative information (*i.e.*, being alive, ability to return home, hospital readmission). It

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is often easier to measure for large groups of patients and is readily available from patient registries without adjudication.[6]

To help further assess the potential role of days alive and out of hospital as an endpoint for perioperative and surgical research, we conducted a population-based retrospective cohort study to determine its feasibility and validity as a patient-centered outcome for surgical patients. The study had an overarching goal of determining whether days alive and out of hospital forms a new patient-centric quality and safety metric that can be used by healthcare teams and policy makers conducting perioperative medical research, quality initiatives and interhospital outcomes, and performance comparisons. It had three more specific objectives. We aimed to characterize the distributional properties of days alive and out of hospital in elective surgical patients; describe its construct validity by assessing whether the distributions of days alive and out of hospital varied in expected directions across patients and surgeries with differing risk profiles; and assess criterion validity by determining whether days alive and out of hospital was associated with other postoperative outcomes in a manner that would be expected.

Materials and Methods

Settings and Data Sources

We conducted a retrospective cohort study using population-based administrative healthcare databases in Ontario, Canada. The use of data in this project was authorized under Section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a research ethics board. We used the Registered Persons Database, Vital Statistics, and Ontario Census data to extract demographics, socioeconomic status, and mortality. The Canadian Institute of Health Information Discharge Abstract Database was used to capture all hospital admissions. We used the Ontario Health Insurance Plan database to capture all physician service claim data. Specialized databases (Ontario Diabetes Database, Asthma Database, Chronic Obstructive Pulmonary Disease Database, Ontario Hypertension Database) were used to identify specific comorbidities. Data were linked through unique anonymized patient identifier numbers. Variables and codes used are summarized in Supplemental Digital Content tables 1 and 2, http://links.lww.com/ALN/B920.

Study Cohort

We identified adults greater than or equal to 40 yr who underwent selected high- and intermediate-risk elective noncardiac surgical procedures between 2006 and 2014 in Ontario hospitals. This cohort included 12 common procedure types: (1) open abdominal aortic aneurysm; (2) endovascular aortic aneurysm repair; (3) peripheral artery disease procedures (above/below knee amputation, lower limb revascularization); (4) open pneumonectomy or lobectomy; (5) video-assisted thoracoscopic lobectomy; (6) upper gastrointestinal procedures (partial liver resection, biliary bypass, Whipple's resection, gastrectomy, esophagectomy); (7) lower gastrointestinal colorectal resection; (8) nephrectomy; (9) hysterectomy; (10) neurosurgery (open craniotomy, posterior fossa surgery) procedures; (11) spine surgery; and (12) total joint (hip or knee) replacement surgery. In patients who underwent multiple eligible surgeries during the study period, only the first procedure was included. We excluded intraoperative deaths, interhospital transfers prior to surgery and hospitals undertaking low volumes of the aforementioned individual surgical procedures (fewer than 50 cases during the study period) in order to reduce variability of the data.

Outcome

The primary outcome was days alive and out of hospital at 30 days after surgery. It was calculated using mortality, hospital length of stay, and readmissions between the date of the index surgery and the 30th postoperative day using validated sources from Canadian Institute of Health Information Discharge Abstract Database.[12] Our approach for calculating days alive and out of hospital was consistent with previous work reported by Myles *et al.*[13] In this previously employed approach, patients who died during this 30-day period were assigned a days alive and out of hospital at 30 days of 0 days. For example, a patient who survived and was discharged 20 days after the indexed surgery had a days alive and out of hospital at 30 days of 10 days. If patients were readmitted to hospital during this time frame, the number of days spent in hospital were subtracted from the final days alive and out of hospital at 30 days. Thus, a patient discharged on postoperative day 20 who was subsequently readmitted for 2 days on postoperative day 21 has a days alive and out of hospital at 30 days of 8 days. The secondary outcomes were days alive and out of hospital at 90 days and 180 days, which were determined using similar calculations.

Covariates

Demographics (age, sex) were identified from the Registered Persons Database. Comorbidities (coronary artery disease, diabetes, hypertension, chronic obstructive pulmonary disease, asthma, stroke, chronic renal insufficiency, components of the Charlson Comorbidity Index score) were extracted from the Canadian Institute of Health Information Discharge Abstract Database (using International Classification of Disease, Tenth Revision codes from hospital admissions within 3 yr before the index surgery) and specialized validated Ontario databases.[14–17] Surgical information extracted included type and duration of the surgical procedure from Canadian Institute of Health Information Discharge Abstract Database, which shows high accuracy.[12] Hospital bed numbers and teaching status were obtained from the information about Ontario health care institutions database.

Statistical Analysis

The days alive and out of hospital at 30, 90, and 180 days were summarized for the entire cohort using the median and interquartile range, given that data were likely to be skewed. For individual surgeries, days alive and out of hospital at 30 days were described using median (interquartile range) and proportion of early deaths within 30 days postoperatively for each surgery were described using frequency (percentage).

Validity is a measure of how well an instrument measures a specific construct.[18] Construct validity describes the degree days alive and out of hospital at 30 days behaves like a measure of patient-centered postoperative recovery. For example, we would expect days alive and out of hospital at 30 days to be worse among patients who had higher comorbidity burdens or undergone higher risk surgical procedures. To investigate construct validity, we assessed the association of various clinically sensible patient-, hospital-, and surgical-level characteristics with days alive and out of hospital at 30 days. For categorical characteristics, we determined the median (interquartile range) for alive and out of hospital at 30 days within strata defined by comorbidities (hypertension, coronary artery disease, diabetes mellitus, asthma, chronic obstructive airways disease, stroke, chronic kidney disease), Charlson Comorbidity Index score (0 to 1; greater than or equal to 2), sex, rural residence, and hospital academic status.[19] The distribution of continuous variables (*i.e.,* age, surgical volume, duration of surgery) were described less than and greater than the median days alive and out of hospital at 30 days. The correlation between these continuous variables and the days alive and out of hospital at 30 days were also assessed using Spearman correlation coefficient. When conducting adjusted comparisons using multivariable regression models, we chose to model the median quantile or fiftieth percentile, rather than the mean, because of the skewed nature of the data.[20,21] Accordingly, a hierarchical multivariable quantile regression model was used to assess the adjusted association of patient (age, sex, hypertension, coronary artery disease, diabetes mellitus, asthma, chronic obstructive airway disease, stroke, chronic kidney disease, Charlson Comorbidity Index score), surgery (procedure types, procedure duration), and hospital (academic status, total bed number, surgical volume at each institution) factors with the days alive and out of hospital at 30 days. The model incorporated hospital-specific random effects to account for within-hospital clustering.

To better understand the characteristics and prognostic implications associated with low number of days alive and out of hospital at 30 days, we classified patients as having "poor days alive and out of hospital at 30 days" and "good days alive and out of hospital at 30 days," after first removing all patients who died within 30 postoperative days. All patients in the lowest tenth percentile of days alive and out of hospital at 30 days were assigned to the poor days alive and out of hospital at 30 days category, while the remainder were assigned to the good days alive and out of hospital at 30 days category. Descriptive statistics using median (interquartile range) for continuous variables and frequency (percentages) for categorical variables were used to compare patients in the poor and good days alive and out of hospital at 30 days groups. The groups were also compared using standardized differences, Wilcoxon rank sum test (continuous variables), and chi-square test (categorical variables). The criterion validity of the poor *versus* good days alive and out of hospital at 30 days categories was assessed by separately calculating the frequency of late deaths (*i.e.*, after 30 days) occurring at 90 days and 180 days after surgery. We determined the proportion of individuals within the poor *versus* good days alive and out of hospital at 30 days categories who remained within the lower tenth percentile of days alive and out of hospital at 90 days (poor *vs.* good days alive and out of hospital at 90 days) and 180 days (poor *vs.* good days alive and out of hospital at 180 days) after surgery. In addition, we determined the proportion of patients in the poor and good days alive and out of hospital at 30 days groups who incurred serious postoperative complications (myocardial infarction, heart failure, stroke, pulmonary embolism, acute kidney dysfunction, new dialysis, respiratory failure, sepsis, surgical site infection, bleeding, wound dehiscence) within 30 days after surgery.[22]

To further understand the relative influence of mortality and postoperative length of stay on days alive and out of hospital at 30 days, a subanalysis was performed looking at patients undergoing elective lower gastrointestinal surgery. This procedure was chosen given it is commonly performed surgery by many acute care hospitals. This relationship was explored by initially calculating the risk-adjusted 30-day mortality and postoperative length of stay for each hospital using a multivariable regression model with the same above covariates (age, sex, hypertension, coronary artery disease, diabetes mellitus, asthma, chronic obstructive airways disease, stroke, chronic renal disease, Charlson Comorbidity Index score, duration of surgery, surgical volume, at academic status, total bed number). A logistic regression model was used for mortality and a Poisson regression model for length of stay.[23] Hospitals were subsequently ranked according to their risk-adjusted mortality and length of stay values separately. The median (interquartile range) days alive and out of hospital at 30 days across institutions was explored by dividing hospitals into three risk groups (low, medium, and high) based on their individual risk-adjusted mortality and length of stay values. Further, the relationship between the hospital-specific median postoperative length of stay, 30-day mortality and median days alive and out of hospital at 30 days was assessed using Spearman correlation coefficient.

All analyses were conducted using Microsoft Excel (v.2010; USA), SAS version 9.4 (SAS Institute, USA), and R statistical software (www.rstudio.org. Accessed June 2018).[20,21,24] Two-sided P values less than 0.05 were considered statistically significant.

No statistical power calculation was conducted prior to conducting this study and the sample size was based on the available data meeting the above eligibility requirements. This sample was based on our previous experience in conducting perioperative health services research using this patient population and research design.[25]

Results

The cohort included 540,072 patients. When considering the entire cohort, days alive and out of hospital at 30, 90, and 180 days all demonstrated a left-skewed distribution with a small secondary peak at 0 days (fig. 1). The median (interquartile range) values of days alive and out of hospital at 30, 90, and 180 days were 26 (24 to 27), 86 (84 to 87), and 176 (173 to 177) days, respectively. There were 2,735 (0.5%) deaths within 30 days after surgery, with a median postoperative length of stay of 4 (3 to 5) days. As would be expected, days alive and out of hospital at 30 days varied across different surgical procedures, with the lowest values in upper gastrointestinal surgery (median, 22 days) and highest values for hysterectomy and endovascular aortic aneurysm repair (median, 27 days) (table 1).

The unadjusted associations of days alive and out of hospital at 30 days with perioperative characteristics are described in figure 2 and table 2. In general, advanced age and poor preoperative health state were associated with a lower median days alive and out of hospital at 30 days. A high preoperative Charlson score and particularly the presence of stroke, coronary artery disease, chronic obstructive airway disease, and chronic kidney disease were associated with significantly shorter median days alive and out of hospital at 30 days. Longer duration of surgical procedures was associated with lower days alive and out of hospital at 30 days.

Multilevel quantile regression was performed on 492,144 patients after excluding 47,928 patients' with missing data

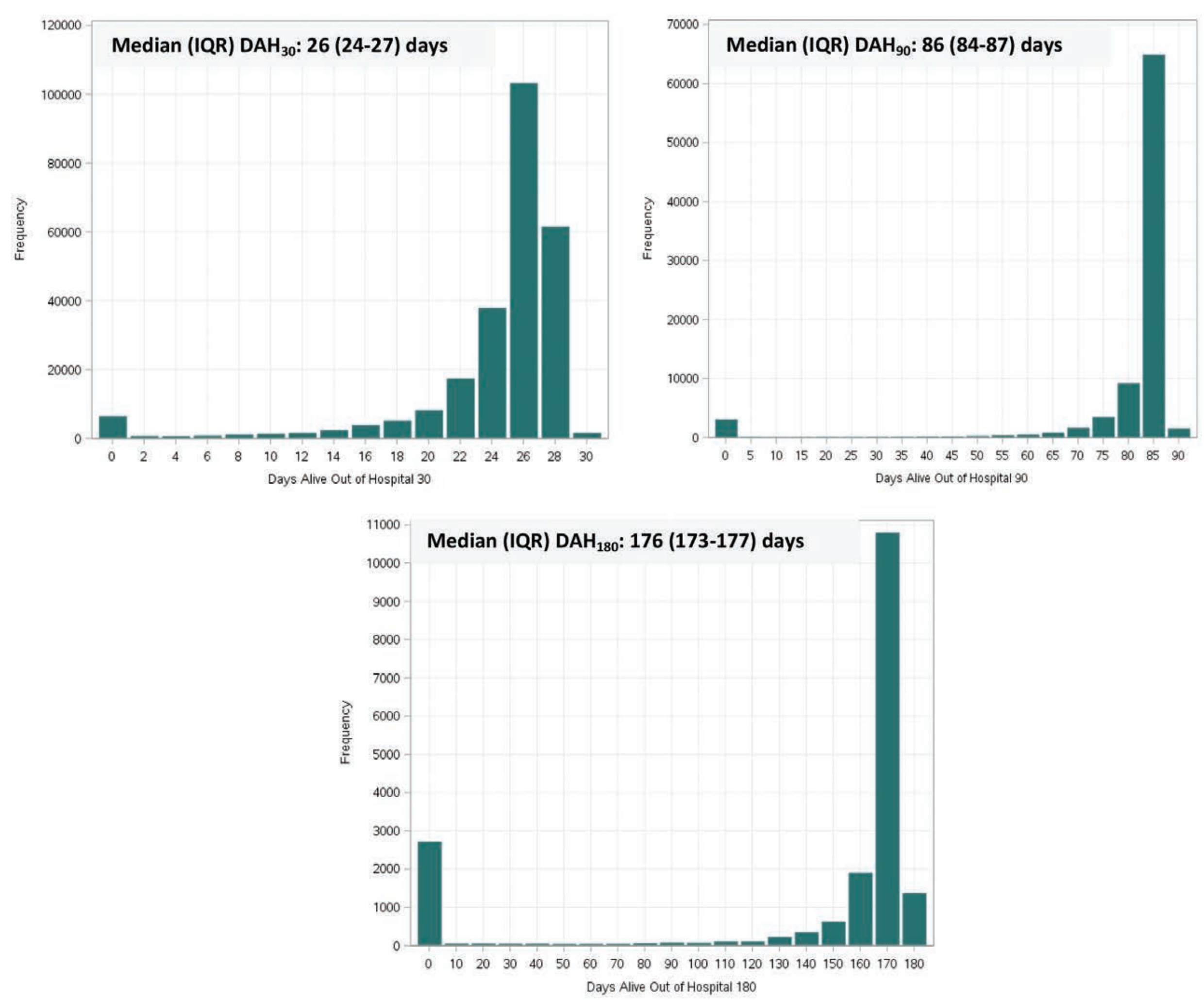

Fig. 1. Distribution of days alive out of hospital at 30, 90, and 180 days in entire cohort. DAH_{30}, days alive and out of hospital at 30 days; DAH_{90}, days alive and out of hospital at 90 days; DAH_{180}, days alive and out of hospital at 180 days; IQR, interquartile range.

Table 1. DAH_{30}, 30-day Mortality and Postoperative Length of Stay for Patients Who Had 12 Selected Elective Surgical Procedures

Surgical Procedure	Total Volume of Surgical Procedures	DAH_{30}, Median (IQR)	Number (%) of Deaths	Postoperative LOS, Days Median (IQR)
Open AAA	7,426	23 (20–24)	180 (2.4)	7 (6–9)
Upper GI	11,340	22 (17–24)	225 (2.0)	8 (6–11)
Open lung	10,780	24 (21–26)	200 (1.9)	6 (4–8)
PAD	10,457	24 (20–26)	215 (2.1)	5 (3–8)
Neurosurgery	5,851	26 (22–28)	138 (2,4)	3 (2–6)
Lower GI	57,383	23 (20–25)	820 (1.4)	6 (4–9)
EVAR	4,685	27 (26–28)	48 (1.0)	2 (1–4)
Nephrectomy	12,770	25 (24–27)	92 (0.7)	4 (3–6)
VATS lung	8,177	26 (24–28)	60 (0.7)	3 (2–5)
Spine	27,333	26 (24–28)	86 (0.3)	3 (2–6)
Joint	280,173	26 (25–27)	563 (0.2)	4 (3–5)
Hysterectomy	103,697	27 (27–28)	108 (0.1)	3 (2–3)
All surgeries*	540,072	26 (24–27)	2735 (0.5)	4 (3–5)

*All 12 surgical procedures are combined in this row.

AAA, abdominal aortic aneurysm; DAH_{30}, days alive and out of hospital at 30 days; EVAR, endovascular aortic aneurysm repair; GI, gastrointestinal; IQR, interquartile range; LOS, length of stay; PAD, peripheral arterial disease; VATS, video-assisted thoracic surgery.

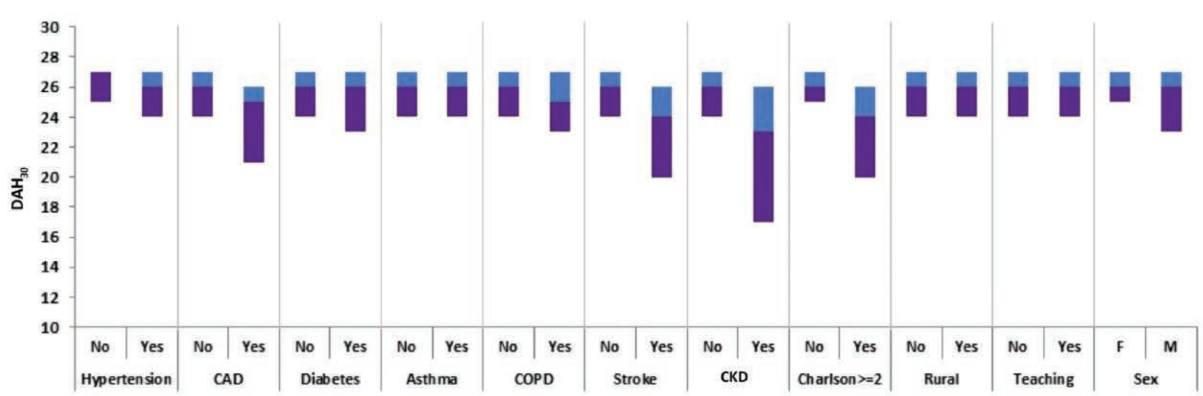

Fig. 2. Unadjusted differences in days alive and out of hospital at 30 days across strata defined by patient sex, comorbidities and hospital teaching status across entire study cohort. For each variable, intersection of purple and blue bars is the median DAH_{30}; lower and upper quartiles are represented by the purple and blue bars respectively. CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CKD, chronic kidney disease; DAH_{30}, days alive and out of hospital at 30 days; F, female; M, male.

regarding the duration of surgery; all other variables had no missing information. After risk adjustment using quantile regression modeling, increased age, male sex, increased comorbidity burden, and longer duration of surgical procedures were associated with lower days alive and out of hospital at 30 days (Supplemental Digital Content table 3, http://links.lww.com/ALN/B920). Lower-risk procedures such as hysterectomy and endovascular aortic aneurysm repair surgeries were associated with higher days alive and out of hospital at 30 days. Notably, measured hospital-level factors (teaching status, bed number, surgical volumes) were not associated with days alive and out of hospital at 30 days.

After excluding 2,735 early deaths, 51,250 of 537,337 (9.5%) patients were in the lowest tenth percentile and defined as "poor days alive and out of hospital at 30 days." Poor and good groups had median (interquartile range) days alive and out of hospital at 30 days values of 16 (11 to 19) and 26 (25 to 27) days, respectively (table 3). Relative to patients in the good days alive and out of hospital at 30 days category, patients within the poor days alive and out of hospital at 30 days group were older individuals who had a greater burden of chronic illness and had undergone longer and higher-risk procedures (*i.e.*, open abdominal aortic aneurysm, open lung resection, peripheral artery disease procedures, upper and lower gastrointestinal procedures). The number of late deaths (*i.e.*, after 30 days) at 90 and 180 days were 2,513 and 3,490, respectively. Of patients who died between 31 and 90 days after surgery, 60% were

Table 2. Association of Age, Total Number of Hospital Beds, Surgical Volume, and Duration of Surgical Procedures above and below the Median Days Alive and Out of Hospital at 30 Days

	Less than Median DAH_{30}*	Greater than or Equal to Median DAH_{30}**	Spearman Correlation Coefficient with DAH_{30} (*P* Value)
Age (yr)	69 (60–77)	63 (53–71)	−0.29 (< 0.0001)
Surgical volume	2,271 (878–5,208)	3,276 (1,613–5,828)	0.10 (< 0.0001)
Duration surgery (min)	152 (110–228)	118 (95–151)	−0.27 (< 0.0001)

*<25 days; ** ≥26 days.

DAH_{30}, days alive and out of hospital at 30 days.

Table 3. Patient, Hospital, and Surgical Characteristics of Poor *versus* Good Days Alive at 30 Days

Variable	Good DAH_{30} (N = 486,087)	Poor DAH_{30} (N = 51,250)	Total (N = 537,337)	Absolute Standardized Difference
Patient				
Age (yr)	64 (55–73)	71 (61–79)	65 (55–74)	0.48
Male	174,913 (36.0%)	25,517 (49.8%)	200,430 (37.3%)	0.28
Asthma	74,673 (15.4%)	8,388 (16.4%)	83,061 (15.5%)	0.03
CAD	17,415 (3.6%)	4,920 (9.6%)	22,335 (4.2%)	0.24
COPD	86,869 (17.9%)	15,034 (29.3%)	101,903 (19.0%)	0.27
Stroke	4,142 (0.9%)	1,282 (2.5%)	5,424 (1.0%)	0.13
Diabetes	107,617 (22.1%)	16,193 (31.6%)	123,810 (23.0%)	0.21
Hypertension	296,069 (60.9%)	37,032 (72.3%)	333,101 (62.0%)	0.24
Chronic kidney disease	3,688 (0.8%)	1,718 (3.4%)	5,406 (1.0%)	0.18
Charlson ≥2	49,447 (10.2%)	16,707 (32.6%)	66,154 (12.3%)	0.57
Hospital				
Teaching hospital	175,189 (36.0%)	23,734 (46.3%)	198,923 (37.0%)	0.21
Total beds	279 (189–358)	304 (215–409)	282 (196–360)	0.2
Surgical volume	3,104 (1,361–5,633)	1,304 (698–3,556)	2,988 (1,243–5,383)	0.52
Surgery				
Open AAA	5,199 (1.1%)	2,018 (3.9%)	7,217 (1.3%)	0.18
Lower GI	40,767 (8.4%)	15,796 (30.8%)	56,563 (10.5%)	0.59
Hysterectomy	101,062 (20.8%)	2,527 (4.9%)	103,589 (19.3%)	0.49
Joint	264,045 (54.3%)	15,565 (30.4%)	279,610 (52.0%)	0.5
Nephrectomy	11,509 (2.4%)	1,169 (2.3%)	12,678 (2.4%)	0.01
Upper GI	6,721 (1.4%)	4,394 (8.6%)	11,115 (2.1%)	0.34
EVAR	4,314 (0.9%)	328 (0.6%)	4,642 (0.9%)	0.03
Neurosurgery	4,635 (1.0%)	1,078 (2.1%)	5,713 (1.1%)	0.09
Open lung	8,353 (1.7%)	2,178 (4.2%)	10,531 (2.0%)	0.15
PAD	7,777 (1.6%)	2,465 (4.8%)	10,242 (1.9%)	0.18
Spine	24,490 (5.0%)	2,757 (5.4%)	27,247 (5.1%)	0.02
VATS lung	7,218 (1.5%)	907 (1.8%)	8,125 (1.5%)	0.02
Duration surgery (min)	124 (99–167)	194 (128–285)	127 (100–178)	0.76
Outcomes				
DAH_{30}	26 (25–27)	16 (11–19)	26 (24–27)	2.74
DAH_{90}	86 (85–87)	75 (66–78)	86 (84–87)	2.64
DAH_{180}	176 (174–177)	163 (152–168)	176 (173–177)	2.52

Continuous and categorical variables are reported using median (inter-quartile range) and frequency (percentage) respectively.

AAA, abdominal aortic aneurysm; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; DAH_{30}, days alive and out of hospital at 30 days; DAH_{90}, days alive and out of hospital at 90 days; DAH_{180}, days alive and out of hospital at 180 days; EVAR, endovascular aortic aneurysm repair; GI, gastrointestinal; PAD, peripheral arterial disease; VATS, video-assisted thoracic surgery.

assigned to the poor days alive and out of hospital at 30 days group. Of patients who died between 31 and 180 days after surgery, 41.5% were assigned to the poor days alive and out of hospital at 30 days group. Of 51,250 individuals in the poor days alive and out of hospital at 30 days group, 77% (39,572 of 51,250) remained in the poor days alive and out of hospital group at 90 days after surgery, and 66% (33,933 of 51,250) remained in the poor group at 180 days (table 4). Conversely, of the 486,087 individuals in the good days alive and out of hospital at 30 days group, only

Table 4. Criterion Validity of Poor and Good Days Alive and Out of Hospital at 30 Days Assessed at 90 and 180 Days*

	Good DAH_{30}	Poor DAH_{30}	Total
DAH_{90}			
Good DAH_{90}	477,163 (98.2%)	11,678 (22.8%)	488,841
Poor DAH_{90}	8,924 (1.8%)	39,572 (77.2%)	48,496
Total	486,087	51,250	537,337
DAH_{180}			
Good DAH_{180}	470,093 (96.7%)	17,317 (33.8%)	487,410
Poor DAH_{180}	15,994 (3.3%)	33,933 (68.0%)	49,927
Total	486,087	51,250	537,337

*Frequency and column percentages presented within the table.

DAH_{30}, days alive and out of hospital at 30 days; DAH_{90}, days alive and out of hospital at 90 days; DAH_{180}, days alive and out of hospital at 180 days.

2% (8,924 of 486,087) transitioned to the poor group by 90 days after surgery, and only 3% (15,994 of 486,087) transitioned to the poor group by 180 days after surgery (table 4). A total of 23,154 (4.3%) patients incurred one or more postoperative complications. There was significantly higher proportion of individuals who experienced postoperative complications in the poor (12,635 of 51,250 [24.7%]) *versus* the good (10,519 of 486,087 [2.2%]) days alive and out of hospital at 30 days group. A summary of various complications is provided in Supplemental Digital Content table 4, http://links.lww.com/ALN/B920.

A subset analysis was performed on 57,383 patients who underwent lower gastrointestinal surgery across 87 Ontario hospitals. The risk-adjusted 30-day mortality and postoperative length of stay for each hospital is displayed in Supplemental Digital Content figure 1, http://links.lww.com/ALN/B920. Hospitals were divided into low, medium, and high risk based on the risk-adjusted values to examine the relationship with days alive and out of hospital at 30 days. In this patient subgroup, the median days alive and out of hospital at 30 days was more influenced by length of stay (days alive and out of hospital at 30 days varying from 24 to 22 days between low- and high-risk hospitals) than mortality (days alive and out of hospital at 30 days of 24 days across all hospital risk groups). This was further supported by a strong negative correlation between the median postoperative length of stay and days alive and out of hospital at 30 days ($r = -0.84$; $P < 0.0001$) compared to a weaker relationship between mortality and days alive and out of hospital at 30 days ($r = -0.12$; $P = 0.269$).

Discussion

Validation of measurement tools is important in order to understand whether they measure what they are supposed to measure in a specific populations and clinical setting.[18] This large population-based cohort study showed that days alive and out of hospital at 30 days has convergent construct validity with respect to common patient-level risk factors (*i.e.,* comorbidities and advanced age are associated with expected reductions in days alive and out of hospital at 30 days). Surgeries of longer duration also had shortened days alive and out of hospital at 30 days. Surgeries included in the study cohort varied in complexity and mortality and showed sensible differences in the days alive and out of hospital at 30 days. These findings make good clinical sense given older patients with greater burden of comorbidities undergoing complex surgery are at greater risk of postoperative death and complications (as seen within the poor days alive and out of hospital at 30 days group), which prolongs hospital stay.[26,27] Importantly, days alive and out of hospital is a patient-centered outcome which demonstrated greater sensitivity to patient- and surgery-level characteristics than differences in hospital characteristics (*i.e.*, academic status, bed number).

We divided the cohort into a poor and good days alive and out of hospital groups at the tenth percentile to identify a high risk subgroup of patients. This appeared to be a sensible approach given the skewed nature of the data and previous studies have identified that approximately 10% of surgical patients are responsible for the majority of postoperative deaths.[28,29] Dividing days alive and out of hospital at 30 days at the tenth percentile demonstrated good construct validity with patients in the poor days alive and out of hospital at 30 days presenting for surgery at an older age with greater levels of chronic disease and incurred more postoperative complications. In our dataset, days alive and out of hospital at 30 days demonstrated good criterion validity with 98% and 97% of patients in the good days alive and out of hospital at 30 days group remaining in this category at days alive and out of hospital at 90 and 180 days, respectively. This indicates that measurement of days alive and out of hospital at 30 days is an excellent marker for both short- and longer-term patient outcomes, and these patients are more likely to suffer late deaths. Our subset analysis of elective lower gastrointestinal surgery revealed that days alive and out of hospital at 30 days is more heavily influenced by postoperative length of stay than mortality. This was not surprising given there was greater variation in this outcome *versus* mortality and there were relatively few deaths in this surgical subgroup. Further investigation is needed of factors influencing this interhospital variation in days alive and out of hospital at 30 days—which might include differences in timely intervention of postoperative complications, hospital efficiency, and access to continuing care facilities and home supports.

Days alive and out of hospital also demonstrate several features of being a highly sensible measurement tool when applied to a large and well-defined surgical population.[30] The components making up days alive and out of hospital are relevant to surgical patients, thereby providing good content validity. The measure is transparent and can be simply applied to surgical patients, thus indicating good face validity. It is also a highly feasible outcome given many components are recorded in population databases and prospective clinical studies. These data sources are readily available and easier methods for collecting data than conducting surveys, which may contain missing information.

Our findings are largely consistent with a previous cohort study of 2,109 cardiac and noncardiac surgical patients, where the study data were obtained from clinical trial registries.[13] This previous study also demonstrated similar reductions in days alive and out of hospital after adjusting for patient factors, duration of surgery, and specific postoperative complications—albeit in a smaller and less generalizable sample. Our current study has several important methodologic strengths over previous work. Specifically, we used a large population-based sample from well-validated datasets, assessed many common patient-level risk factors within 12 defined elective surgical groups, analyzed the highly skewed data using a quantile regression approach, and evaluated the association of days alive and out of hospital at 30 days with subsequent longer-term outcomes.

This study is not without limitations. First, we did not look at time spent in postrehabilitation facilities, which has been previously included as part of the hospital stay.[13] Second, population databases capture postsurgical morbidities with variable accuracy, hence the true incidence of complications is likely to be underestimated. Third, further work at the local hospital-level would be required to assess the impact of social factors on days alive and out of hospital, which may also vary across different healthcare systems. However, within this multicenter study set in a single publicly funded healthcare system, days alive and out of hospital was relatively insensitive to measured hospital factors and primarily influenced by typical patient level risk factors and surgical complexity. Fourth, the complex distributional properties of days alive and out of hospital should always be considered when using this outcome. This outcome is negatively skewed with a secondary peak at 0 days. Thus consideration of the number of patients with 0 days alive and out of hospital should always be given, particularly in perioperative settings associated with a high mortality. Further, these distributional properties are best analyzed using nonparametric techniques or quantile regression as performed within this study. Fifth, we were unable to assess the association of days alive and out of hospital with more qualitative metrics that measures function of independent living, quality of life, or other functional outcomes secondary to this information not being captured by healthcare databases.

Patient-centric outcomes are pivotal to better understanding the "value" of an intervention based on either improved patient outcomes or cost savings.[31] Increasingly, healthcare jurisdictions are incorporating these outcomes as part of value-based bundle payments.[32] Identifying simple and relevant measurement tools is imperative for widespread usability in clinical trial or healthcare delivery settings. Days alive and out of hospital forms a feasible, valid, and sensitive instrument for this purpose. Future work exploring relationships between important patient-reported outcomes and functional qualitative metrics associated with individual surgeries, and days alive and out of hospital would provide valuable information for clinicians, patients, and government organizations in guiding clinical decision-making, effects of treatments, and healthcare funding. Additional further work in this area will include assessment of days alive and out of hospital in other clinical settings and international comparisons of days alive and out of hospital for specific interventions will provide insights into difference in healthcare structures.

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Competing Interests

The authors declare no competing interests.

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