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Utility of Geriatric Assessment in the Projection of Early Mortality Following Hip Fracture in the Elderly Patients

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Abstract

Hip fractures result in significant morbidity and mortality in elders. Indicators of frailty are associated with poor outcomes. Commonly used frailty tools rely on motor skills that cannot be performed by this population. We determined the association between the Charlson Comorbidity Score (CCS), intraoperative hypotension (IOH), and a geriatric medicine consult index (GCI) with short-term mortality in hip fracture patients. A retrospective cohort study was conducted at a single institution over a 2-year period. Patients aged 65 years and older who sustained a hip fracture following a low-energy mechanism were identified using billing records and our orthopedic fracture registry. Medical records were reviewed to collect demographic data, fracture classification and operative records, calculation of CCS, intraoperative details including hypotension, and assessments recorded in the geriatric consult notes. The GCI was calculated using 30 dichotomous variables contained within the geriatric consult note. The index, ranging from 0 to 1, included markers for physical and cognitive function, as well as medications. A higher GCI score indicated more markers for frailty. One hundred eight patients met inclusion criteria. Sixty-four (59%) were females and the average age was 77.3 years. Thirty-five (32%) patients sustained femoral neck fractures, and 73 (68%) patients sustained inter-/pertrochanteric hip fractures. The 30-day mortality was 6%; the 90-day mortality was 13%. The mean GCI was 0.30 in the 30-day survivor group as compared to 0.52 in those who died. The mean GCI was 0.28 in patients who were alive at 90 days as compared to 0.46 in those who died. In contrast, the CCS and IOH were not associated with 30- or 90-day mortality. In our older hip fracture patients, an index calculated from information routinely obtained in the geriatric consult evaluation was associated with 30- and 90-day mortality, whereas the CCS and measures of IOH were not.

Keywords

geriatric trauma, fragility fractures, geriatric medicine, trauma surgery, anesthesia

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Introduction

Hip fractures account for approximately 350 000 hospital admissions a year at an estimated cost of US$10 billion.[1] Increased life expectancy is predicted to increase the incidence of hip fractures to 650 000 new cases per year by 2050.[2] Hip fractures are associated with high mortality,[3] likely secondary to the high prevalence of medical comorbidities and frailty in this population. Early identification of older patients who are at increased risk of mortality in the perioperative period may lead to improved outcomes by better allocation of acute care resources and provision of specialty care,[4] but screening tools that account for the complexities inherent in an older population are needed.

The Charlson Comorbidity Score (CCS) evaluates specific medical diagnoses to generate a composite score and correlates with hospital readmission after surgery,[5] as well as 1-year and 5-year mortality.[6] However, CCS is not accurate in predicting 30- or 90-day mortality in hip fracture patients.[7,8] Intraoperative events, such as intraoperative hypotension (IOH) or

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hypothermia, are associated with adverse surgical outcomes. The incidence of IOH in injured geriatric patients is high after even minor trauma and reflects their tenuous hemodynamic response to stress.[9,10] Intraoperative hypotension has been linked to adverse cardiac events,[11,12] kidney dysfunction,[13] stroke,[14] and 30-day mortality,[15] but the variable definition of IOH in these studies makes generalizability difficult.[16] Intraoperative hypothermia is also common[17] and has been shown to increase the risk of several complications, including coagulopathy, adverse cardiac events,[18] and surgical site infection.[19]

Frailty is a decrease in physiological reserve and resistance to stressors that reflects declines in multiple physiologic systems.[20] The prevalence of frailty is estimated to be between 7% and 16% in community-dwelling older adults and has been shown to be an independent predictor of morbidity and mortality in community-dwelling adults and after surgery.[21,22] Most validated tools for frailty assessment require patient cooperation (answering questions or questionnaires) or participation (grip strength, walking speed),[21,23] which are generally not feasible in the injured population. Preoperative geriatric consultation and comanagement reduces complications in patients with hip fractures.[24] The geriatric consult contains information regarding independence, functional status, and medical complexities in a format that can generate an index of the patients' general medical and functional status.

The aim of this study was to compare information obtained in the traditional CCS with intraoperative measures, such as IOH and intraoperative hypothermia, and a geriatric consultation index to identify patients at higher risk of short-term mortality after low-energy hip fractures.

Material and Methods

Patients

Hospital surgical billing records and the hospital orthopedic fracture database were used to identify all patients treated for a hip fracture from January 1, 2015, through December 31, 2016, at Harborview Medical Center, a level 1 trauma center. All surgically treated patients age 65 or older at the time of injury who sustained either a femoral neck or intertrochanteric fracture resulting from a low-energy traumatic mechanism were included. To identify the patients, we used any of the surgical billing codes 27235, 27236, 27244, 27245, and 27130. The orthopedic fracture database was queried using AO/OTA codes 31-A and 31-B. Demographic data, race, ethnicity, age, gender, and CCS[6] were extracted from the electronic medical record (EMR). The operative reports were used to determine fracture type and surgical fixation.

Charlson Comorbidity Score

For each patient, the CCS was calculated through review of their chart and/or EMR. The score is based on a collection of diagnoses that were listed in their current problem list, past medical history, or derived from laboratory values.

Intraoperative Data

Intraoperative data were extracted from the Anesthesia Information Management System (AIMS). The AIMS system automatically collects hemodynamic, ventilation, and temperature parameters from the patient monitor and anesthesia machine every minute. Intraoperative medications, fluid input/output, and laboratory results are also documented in AIMS.[25] Additionally, AIMS records anesthesia management, such as intubation, emergence, and placement of lines and monitors (including location of the temperature probe). The AIMS database is copied, linked, and maintained in a data warehouse (PQRD—Perioperative Quality & Research Database). Database queries were constructed and executed to extract the needed data from PQRD.

Computation of derived parameters. Three thresholds for IOH were used: systolic blood pressure <90 mm Hg, <110 mm Hg, and a 25% drop from baseline systolic blood pressure measured prior to surgery.[16,26] Blood pressure was measured either by an automatic noninvasive blood pressure cuff every 3 minutes or continuously by an indwelling arterial line. In the cases where both measures of blood pressure were available, the data from the arterial line were used. Baseline blood pressure was chosen as the first measurement in the operating room prior to induction of anesthesia. The measures of IOH computed were the area under the curve (AUC) of the duration of systolic blood pressure below the threshold. The absolute thresholds for hypothermia were <36°C and <35°C. Hypothermia measures were computed as AUC of the duration of temperature below the hypothermia threshold.

Area under the curve calculation. A high incidence of IOH[27] and intraoperative hypothermia[28] is observed in elderly hip fracture patients. To estimate the severity of IOH and hypothermia, we calculated the AUC below the threshold because it takes into account the duration of time spent below the threshold and the magnitude of reduction below the threshold. The AIMS records blood pressure and body temperature every minute. To calculate AUC for IOH and hypothermia, we used a definite integral where the x-axis is time (in minutes) and the y-axis is the value of the parameter below the threshold (blood pressure in mm Hg or body temperature in °C). For example, if using a threshold of 90 mm Hg for systolic blood pressure and the systolic blood pressure was 85 for 5 minutes, the AUC would be 25 ($90 - 85 \times 5$). However, if the systolic blood pressure was 80 for 5 minutes, the AUC would be 50 ($90 - 80 \times 5$). The AUC calculation has been proposed as a measure of hypotension previously.[15]

Controlling for use of vasopressors and fluids. Anesthesiologists treat IOH by administering several types of vasopressor medications and intravenous fluids. To establish that the severity of IOH was not related to underutilization of vasopressors, we first adjusted the different vasopressors (vasopressin, phenylephrine, and ephedrine) into a unified standard dosage equivalence. Conversion factors for vasopressin, phenylephrine, and ephedrine were 0.01 U/kg, 0.5 mg/kg, and 5 mg/kg, respectively. We added all the doses of vasopressor used during the case into a dimensionless numerical value. To determine the effect of vasopressors and crystalloid fluid administration on IOH, we used linear correlations: The AUC for each threshold of IOH served as the dependent variable and the total dose of vasopressors or the total amount of crystalloid fluid were the independent variables.

Artifact removal. Boundary filters were applied to remove parameter values outside of the physiological range. The filters applied for blood pressures were systolic values beyond <40 or >300 mm Hg, diastolic values <30 or >150 mm Hg, and the presence of a pulse pressure <10 mm Hg.[15,29] For temperature, values <33°C or >42°C were removed. The AIMS records with <10 valid blood pressures or temperature values, due to failures in AIMS data acquisition or extended periods of artifacts, were excluded from the analysis.[26]

Geriatric Consult Index

In the emergency department, patients are assigned a primary service. About two-thirds of the patients are assigned to the orthopedics service and a third of the patients are assigned to the medicine service. Patients who are admitted to the orthopedics service are comanaged by a geriatric medicine service that is led by an attending geriatrician. The geriatricians complete an initial geriatric consult template and see the patient daily. The patients assigned to the medicine service as a primary service are cared for by an internist/hospitalist who consults the orthopedic team on surgical-related issues. Although the standardized geriatric consult template is not used, the data points that are used to calculate the geriatric consult index (GCI) are captured in the internist/hospitalist's note in conjunction with social work, physical therapy, and occupational therapy assessments. Every effort is made for evaluation of the patient before surgical intervention. The geriatric consult template includes a geriatric review of systems and functional status, medical problem list, confirmation of social habits, and medication list prior to admission. From the geriatric consultation template, 30 dichotomous variables were selected from 3 general categories of vulnerability: functional markers, medications, and mental status (Table 1). Geriatric consult index for any given patient was calculated as a ratio of the total number of positive markers of vulnerability to the total number of markers. The result is a dimensionless number between 0 and 1, similar to the method used to calculate the Rockwood frailty index.[30]

Main Outcomes: 30- and 90-Day Mortality

Survival at 30 days and at 90 days after discharge was calculated by identifying the last date of medical contact recorded in the EMR. For patients without documented follow-up at a time point greater than 90 days, an Internet search was conducted utilizing publicly available information to determine last known date of living or date of death.

Statistical Analysis

The study cohort was characterized using descriptive statistics. Age was analyzed as a continuous variable, observing mean, standard deviation, and skewness. Nominal and ordinal variables such as gender, race, and ethnicity were characterized with frequency tables. The differences between the CCS of survivors and nonsurvivors at 30 and 90 days were analyzed using the Student independent-samples t test. Intraoperative hypotension and hypothermia were measured as AUC for each of the defined thresholds. Pearson linear regression was used to analyze a linear association between AUC of each IOH threshold and adjusted vasopressor dosage. The Student independent samples t test was used to determine association between IOH or hypothermia and 30- or 90-day mortality. The differences between the GCI of survivors and nonsurvivors at 30 and 90 days were analyzed using the Student independent-samples t test. Each continuous variable was first visualized as a histogram to ensure normal distribution. If the data were skewed, it was transformed to a normal distribution before analysis. Descriptive plots comparing the mean with the 95% confidence intervals were examined. All statistical analysis was completed using Jamovi (version 0.7.3.5, The Jamovi Project) and box plots were constructed using Stata14 (StataCorp LLC, College Station, Texas).

Results

Demographics

One hundred fifty-two patients age 65 and older with a hip fracture were identified. Forty-four patients were excluded: high-energy mechanism and significant concomitant injuries (36 patients), significant head injuries (4 patients), inadequate follow-up data (2 patients), stroke (1 patient), and death prior to surgical intervention (1 patient). Therefore, 108 patients were appropriate for analysis and included in this study. The average age of the patients was 77.3 years (interquartile range: 69-83 years) and 64 (59%) were females (Table 2). Most patients lived independently (n = 75, 69%) before injury. The average length of time from admission to surgery was 1.5 days. Most patients were discharged to a skilled nursing facility (n = 82, 76%). Sixty-two percent (67 of 108) of the patients were admitted to the orthopedic service and evaluated by the geriatric medicine team. Patients seen by the geriatrics service were often seen postoperatively (36/67, 54%). All patients were seen within 24 hours of surgery. From the 108 patients evaluated, the average number of variables collected for the calculation of the GCI was 29.65 of a possible 30. The CCS was calculated for all 108 (100%) patients.

The hip fractures were classified as intertrochanteric/pertrochanteric fractures or femoral neck fractures. Most patients sustained a trochanteric fracture (n = 73, 7.6%). Of those cases, the majority were fixed with a medullary hip screw (61, 84%).

Table 1. Generating the geriatric consult index.

Physiological Markers		
ADLs	Bathing	+1 for each activity requiring assistance for maximum of 6 points for complete dependence or 0 points for completely independent
	Dressing	
	Feeding	
	Grooming	
	Toileting	
IADLs	Housework	+1 for each activity requiring assistance for maximum of 6 points for complete dependence or 0 points for completely independent
	Meals	
	Finances	
	Shopping	
	Telephone	
	Transportation	
Other	Ambulation status	+1 if requires a wheelchair or is bed bound
	Vision impairment	+1 if use of glasses or contacts
	Hearing impairment	+1 if uses hearing aids
	Incontinence	+1 if incontinent of bowl and/or bladder
	Nutrition	+1 concerns for malnutrition
Medication Score		
Cardiovascular medications	B-blockers	+1 for each category if currently taking a prescribed medication. i.e. a patient taking furosemide, lisinopril, and metoprolol would have a score of 3. Taking no medications in these categories would result in a score of 0. Maximum score is 6.
	ACE-inhibitor	
	Calcium channel blockers	
	Diuretics	
	Anticoagulation	
	Aspirin	
Social habits	Tobacco product use	+1 for past of current use of each. i.e. social drinking with a 10-pack year smoking history would have a score of 2
	Alcohol consumption	
	IV drug use	
Mental status		
	A&O in the emergency department	+1 for an A&O score equal to or less than 2
	Cognition	+1 if baseline dementia is present
	Mood	+1 if baseline depression on admission
	Anti-depressants	+1 for each category of currently taking prescribed medication in each category for a max of 2 points.
	Anti-psychotic	

The Geriatric consult index (GCI) is calculated by the ratio of the total of points scored divided by the number of data points scored. Maximum score is 30 points out of 30 which would equal to GCI of 1. Minimum score is 0 points (GCI = 0).

Of the 35 patients with femoral neck fractures (32% of total), 19 were fixed with arthroplasty (54%) and the remainder with independent screws or sliding hip screw. The incidence of femoral neck fractures in males was lower (n = 8, 18%), than in females (27, 42%). There was no difference between the mean GCI of those with trochanteric fractures (0.30 ± 0.19; 95% confidence interval [CI]: −0.26 to 0.34) and those with a femoral neck fracture (0.31 ± 0.17; 95% CI: −0.27 to 0.35; *P* = .87).

Thirty-Day Mortality

After 30 days, 6% of hip fracture patients died. There was no difference in the mean CCS (*P* = .8484) or age (*P* = .125) of those who survived and those who did not. The incidence of IOH and hypothermia in our cohort was high; 90% (n = 96) of the cohort had at least one reading with a systolic blood pressure below 90 mm Hg and 99% (n = 106) had at least one reading below 110 mm Hg. Similarly, 93% (n = 100) had a 25% drop from their baseline systolic blood pressure. The incidence of hypothermia below the threshold of 36°C was 38% (n = 41) and 16% (n = 17) below 35°C. In most cases, the IOH was transient and of limited duration. When the correlation between the AUC of IOH and hypothermia and 30-day mortality was analyzed, there was no difference in the mean AUC of IOH and hypothermia (regardless of the threshold used) of those who survived and those who did not (*P* values ranged from .48 to .93; Table 2).

In contrast, the mortality within 30 days was associated with a significantly higher GCI. The mean GCI of those who survived to 30-day past discharge was 0.30 (±0.18; 95% CI:

Table 2. Thirty-day and 90-day mortality.

	30 day mortality			90 day mortality		
	Alive (n = 102,94%)	Deceased (n = 6,6%)		Alive (n = 94, 87%)	Deceased (n = 14, 13%)	
	Mean ± SD[1] (95% CI)	Mean ± SD[1] (95% CI)	p =	Mean ± SD[1] (95% CI)	Mean ± SD[1] (95% CI)	p =
Age	77 ± 9 (75 to 79)	83 ± 13 (73 to 93)	p = 0.125	77 ±9 (75 to 79)	79 ±11 (73 to 85)	p = 0.579
Fracture type						
Femoral neck	n = 33	n = 2	p = 0.960	n = 32	n = 3	p = 0.347
Inter/pertrochateric	n = 69	n = 4		n = 62	n = 11	
CCS	1.86 ± 1.74 (1.52 to 2.2)	2 ± 0.89 (1.29 to 2.71)	p = 0.848	1.81 ±1.76 (-1.45 to 2.17)	2.29 ±1.14 (-1.69 to 2.89)	p = 0.329
IOH Threshold						
<90 mmHg AUC	86 ± 96 (67 to 105)	83 ± 114 (-8 to 174)	p = 0.939	88 ±98 (68 to 108)	72 ±88 (26 to 118)	p = 0.575
<110 mmHg AUC	425 ± 342 (359 to 491)	323 ± 294 (83 to 563)	p = 0.478	434 ±350 (363 to 505)	319 ±241 (189 to 449)	p = 0.236
<75% baseline AUC	311 ± 347 (244 to 378)	235 ± 328 (-25 to 495)	p = 0.598	313 ±346 (243 to 383)	271 ±347 (91 to 451)	p = 0.677
Hypothermia						
<35°C AUC	3.5 ± 15 (0.60 to 6.4)	4.5 ± 11 (-4.3 to 13)	p = 0.871	3.4 ±15 (0.4 to 6.4)	4.4 ±11 (-1.4 to 10.2)	p = 0.826
<36°C AUC	14 ± 32 (7.8 to 20.2)	9.8 ± 18 (-4.2 to 24)	p = 0.780	14 ±33 (7.3 to 20.7)	8 ±20 (-2 to 18)	p = 0.652
GCI	0.3 ± 0.18 (0.27 to 0.34)	0.52 ± 0.12 (0.42 to 0.62)	p = 0.002	0.28 ± 0.14 (-0.25 to 0.32)	0.46 ±0.17 (-0.39 to 0.53)	p < 0.001

Survivors and non-survivors at 30 and 90 days.
(SD: standard deviation, AUC: Area under the curve)

0.27-0.34), whereas those who did not was 0.52 (±0.12; 95% CI: 0.42-0.62; Figure 1). Patients with a GCI ≥ 0.43 (the lowest GCI of the group of patients who died within 30 days) had a 20% chance of mortality at 30 days.

Ninety-Day Mortality

After 90 days, 13% of hip fracture patients died. There was no difference in the mean CCS ($P = .329$) or age ($P = .125$), IOH ($P = .24$-$.68$), and hypothermia ($P = .65$-$.83$) of those who survived and those who did not (Table 2). As was seen at 30 days, mortality within 90 days was also associated with a significantly higher GCI; mean GCI of those who survived to 90-day past discharge was 0.281(±0.174; 95% CI: 0.246-0.316), whereas those who did not had a mean GCI of 0.457 (±0.137; 95% CI: 0.385-0.529; Figure 2). Patients with a GCI ≥ 0.23 (the lowest GCI of the group of patients who died within 90 days) also had a 20% chance of mortality at 90 days.

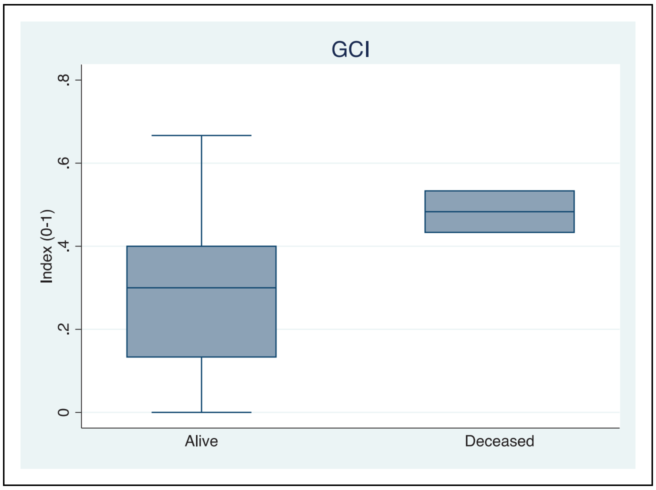

Figure 1. Geriatric consult index in survivors and nonsurvivors after 30 days.

Discussion

Hip fractures are a major public health concern due to rising costs, increasing prevalence, loss of independence, and high mortality.[31] Trends in short- and long-term mortality have been extensively studied,[32,33] and there is great interest in identifying patients who are at risk of early mortality after hip fracture surgery. Early identification can inform the patients, their families, and providers and lead to interventions that improve outcomes in this vulnerable population. In addition, the current health-care environment focuses on outcomes metrics including

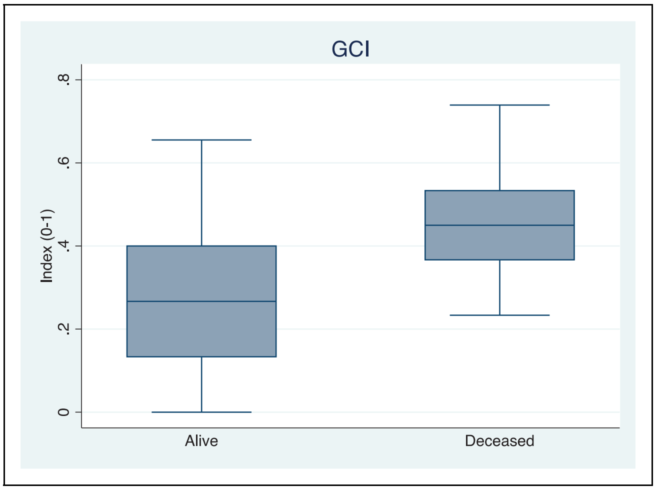

Figure 2. Geriatric consult index in survivors and nonsurvivors after 90 days.

mortality and functional status. Physicians and hospitals are increasingly evaluated on these metrics, with publicly available data and reimbursement incentives. With increasing disincentives to care for patients at higher risk for poor outcomes, it is imperative that we identify appropriate tools to stratify patients in a meaningful way. If not, physicians and hospitals may be inappropriately penalized for worse outcomes and high-risk patients may have difficulty obtaining medical care.

Tools to predict mortality after hip fractures usually use multivariate regressions to generate complex formulas that take into account age, fracture type, hospital course, and comorbidities.[34,35] These tools are difficult to use in everyday clinical practice. Frailty assessment and other scales that evaluate vulnerability in injured older adults are being investigated to assist in decision-making. For example, who can be safely discharged after a fall[36] or to better triage individuals to specific provisions of acute hospital care and consultations that improve outcomes.[4] The American College of Surgeons and the American Geriatrics Society currently recommend preoperative evaluation of frailty or other measures of vulnerability in all aged patients.[37] Rapid and objective measures are needed in trauma patients, since few tools qualify as "objective, feasible, and useful" in injured older adults.[38] Our results suggest that the CCS and intraoperative measures are not useful to predict 30- and 90-day mortality in older hip fracture patients. In contrast, patients with a GCI $\geq$ 0.43 (the lowest GCI of the group of patients who died within 30 days) had a 20% chance of mortality at 30 days. Those with a GCI $\geq$ 0.23 (the lowest GCI of the group of patients who died within 90 days) also had a 20% chance of mortality at 90 days. These suggest that a simple GCI, calculated from data collected during routine patient care, is associated with 30- and 90-day mortality.

Based on previous observations in the literature, it is not surprising that CCS did not correlate with 30- or 90-day mortality.[7,8] These results likely reflect continuous improvement in managing comorbidities in the perioperative and rehabilitation environments. The lack of association of IOH and intraoperative hypothermia with 30- and 90-day mortality was more difficult to predict. In our cohort, we found that the incidence of hypothermia and hypotension was high. Prior studies had inconsistent definitions of IOH, but even with 3 different criteria, we found no relationship with short-term mortality. This was also the case for intraoperative hypothermia. Since longer duration of these intraoperative events is associated with worst outcomes,[39] we analyzed the AUC of these parameters (to account for the severity of hypotension and hypothermia) and still did not find a correlation between IOH or intraoperative hypothermia and short-term mortality. These results persisted after correcting for use of vasopressors and fluids and could reflect the common practice of triaging patients to a higher level of care after surgery based on intraoperative events. This approach is reasonable because intraoperative events, such as hypothermia and hypotension, are associated with adverse outcomes and are therefore a potential target for improved care.[40] We did not track different postoperative care interventions that could have impacted subsequent short-term mortality.

Geriatricians often participate in the care of hip fracture patients because multidisciplinary comanagement has been shown to improve outcomes.[24] To create the GCI, we selected 30 data points that were collected in every geriatric assessment and could be rapidly abstracted as dichotomous variables. The GCI can be broadly incorporated because it is extracted from a standardized note template. Although institutions may use different templates, the GCI is generalizable because the selected data points are those deemed by geriatricians as necessary for a complete perioperative assessment of an older adult. Moreover, the GCI is easy to calculate as the actual index represents positive values divided by the number of collected data points.

There are several limitations to this study. First, it is a retrospective analysis of a single academic tertiary referral center,[41] and routine clinical practice may be different in different institutions. In addition, although the choice of the 30 dichotomous parameters was based on a priori selection of data that can be universally collected, it is possible that a smaller number of parameters would have been sufficient to predict short-term mortality. Furthermore, the subcomponents of the GCI (functional markers, medications, and mental status) were not consistent for both 30 and 90 days. It is possible that in a larger cohort, a smaller number of parameters would have been sufficient to predict short-term mortality.

Conclusion

In summary, a structured routine geriatric evaluation contains information that is associated with short-term mortality following surgical fixation of low-energy hip fractures in elderly patients. This information can be obtained preoperatively and used to inform decision-making and institute early interventions such as multidisciplinary consultation.

Declaration of Conflicting Interests

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References

1. Gill TM, Allore H, Guo Z. Restricted activity and functional decline among community-living older persons. *Arch Intern Med*. 2003;163(11):1317-1322.
2. Gullberg B, Johnell O, Kanis JA. World-wide projections for hip fracture. *Osteoporos Int*. 1997;7(5):407-413.
3. Brauer CA, Coca-Perraillon M, Cutler DM, Rosen AB. Incidence and mortality of hip fractures in the united states. *JAMA*. 2009; 302(14):1573-1579.
4. Landefeld CS, Palmer RM, Kresevic DM, et al. A randomized trial of care in a hospital medical unit especially designed to improve the functional outcomes of acutely ill older patients. *N Engl J Med*. 1995;332(20):1338-1344.
5. Voskuijl T, Hageman M, Ring D. Higher Charlson Comorbidity Index Scores are associated with readmission after orthopaedic surgery. *Clin Orthop Relat Res*. 2014;472(5):1638-1644.
6. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373-383.
7. Karres J, Heesakkers NA, Ultee JM, Vrouenraets BC. Predicting 30-day mortality following hip fracture surgery: evaluation of six risk prediction models. *Injury*. 2015;46(2):371-377.
8. Neuhaus V, King J, Hageman MG, Ring DC. Charlson comorbidity indices and in-hospital deaths in patients with hip fractures. *Clin Orthop Relat Res*. 2013;471(5):1712-1719.
9. Sheffy N, Bentov I, Mills B, et al. Perioperative hypotension and discharge outcomes in non-critically injured trauma patients, a single centre retrospective cohort study. *Injury*. 48(9):1956-1963.
10. McGarry SA, Engemann JJ, Schmader K, Sexton DJ, Kaye KS. Surgical-site infection due to Staphylococcus aureus among elderly patients: mortality, duration of hospitalization, and cost. *Infect Control Hosp Epidemiol*. 2004;25(6):461-467.
11. Kheterpal S, O'Reilly M, Englesbe MJ, et al. Preoperative and intraoperative predictors of cardiac adverse events after general, vascular, and urological surgery. *Anesthesiology*. 2009;110(1): 58-66.
12. van Waes JA, van Klei WA, Wijeysundera DN, van Wolfswinkel L, Lindsay TF, Beattie WS. Association between intraoperative hypotension and myocardial injury after vascular surgery. *Anesthesiology*. 2016;124(1):35-44.
13. Walsh M, Devereaux PJ, Garg AX, et al. Relationship between intraoperative mean arterial pressure and clinical outcomes after noncardiac surgery: toward an empirical definition of hypotension. *Anesthesiology*. 2013;119(3):507-515.
14. Bijker JB, Persoon S, Peelen LM, et al. Intraoperative hypotension and perioperative ischemic stroke after general surgery: a nested case-control study. *Anesthesiology*. 2012;116(3):658-664.
15. Monk TG, Bronsert MR, Henderson WG, et al. Association between intraoperative hypotension and hypertension and 30-day postoperative mortality in noncardiac surgery. *Anesthesiology*. 2015;123(2):307-319.
16. Bijker JB, van Klei WA, Kappen TH, van Wolfswinkel L, Moons KG, Kalkman CJ. Incidence of intraoperative hypotension as a function of the chosen definition: literature definitions applied to a retrospective cohort using automated data collection. *Anesthesiology*. 2007;107(2):213-220.
17. Yi J, Xiang Z, Deng X, et al. Incidence of inadvertent intraoperative hypothermia and its risk factors in patients undergoing general anesthesia in Beijing: a prospective regional survey. *PLoS One*. 2015;10(9):e0136136.
18. Sessler DI. Mild perioperative hypothermia. *N Engl J Med*. 1997; 336(24):1730-1737.
19. Melling AC, Ali B, Scott EM, Leaper DJ. Effects of preoperative warming on the incidence of wound infection after clean surgery: a randomised controlled trial. *Lancet*. 2001;358(9285):876-880.
20. Rodriguez-Manas L, Feart C, Mann G, et al. Searching for an operational definition of frailty: a Delphi method based consensus statement: the frailty operative definition-consensus conference project. *J Gerontol A Biol Sci Med Sci*. 2013;68(1):62-67.
21. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci*. 2001; 56(3):M146-M156.
22. Beggs T, Sepehri A, Szwajcer A, Tangri N, Arora RC. Frailty and perioperative outcomes: a narrative review. *Can J Anaesth*. 2015; 62(2):143-157.
23. Rockwood K, Mitnitski A. Frailty in relation to the accumulation of deficits. *J Gerontol A Biol Sci Med Sci*. 2007;62(7): 722-727.
24. Friedman SM, Mendelson DA, Bingham KW, Kates SL. Impact of a comanaged Geriatric Fracture Center on short-term hip fracture outcomes. *Arch Intern Med*. 2009;169(18):1712-1717.
25. Nair BG, Horibe M, Newman SF, Wu WY, Peterson GN, Schwid HA. Anesthesia Information Management System-based near real-time decision support to manage intraoperative hypotension and hypertension. *Anesth Analg*. 2014;118(1):206-214.
26. Cheung CC, Martyn A, Campbell N, et al. Predictors of intraoperative hypotension and bradycardia. *Am J Med*. 2015;128(5): 532-538.
27. Moller JT, Cluitmans P, Rasmussen LS, et al. Long-term postoperative cognitive dysfunction in the elderly ISPOCD1 study. ISPOCD investigators. International Study of Post-Operative Cognitive Dysfunction. *Lancet*. 1998;351(9106):857-861.
28. Gurunathan U, Stonell C, Fulbrook P. Perioperative hypothermia during hip fracture surgery: an observational study. *J Eval Clin Pract*. 2017;23(4):762-766.
29. Hirsch J, DePalma G, Tsai TT, Sands LP, Leung JM. Impact of intraoperative hypotension and blood pressure fluctuations on early postoperative delirium after non-cardiac surgery. *Br J Anaesth*. 2015;115(3):418-426.
30. Rockwood K, Song X, MacKnight C, et al. A global clinical measure of fitness and frailty in elderly people. *CMAJ*. 2005; 173(5):489-495.

31. Salkeld G, Cameron ID, Cumming RG, et al. Quality of life related to fear of falling and hip fracture in older women: a time trade off study. *BMJ*. 2000;320(7231):341-346.
32. Roberts SE, Goldacre MJ. Time trends and demography of mortality after fractured neck of femur in an English population, 1968-98: database study. *BMJ*. 2003;327(7418):771-775.
33. Vestergaard P, Rejnmark L, Mosekilde L. Increased mortality in patients with a hip fracture-effect of pre-morbid conditions and post-fracture complications. *Osteoporos Int*. 2007;18(12):1583-1593.
34. Jiang HX, Majumdar SR, Dick DA, et al. Development and initial validation of a risk score for predicting in-hospital and 1-year mortality in patients with hip fractures. *J Bone Miner Res*. 2005;20(3):494-500.
35. Aharonoff GB, Koval KJ, Skovron ML, Zuckerman JD. Hip fractures in the elderly: predictors of one year mortality. *J Orthop Trauma*. 1997;11(3):162-165.
36. Robinson TN, Finlayson E. How to best forecast adverse outcomes following geriatric trauma: an ageless question? *JAMA Surg*. 2014;149(8):773.
37. Chow WB, Rosenthal RA, Merkow RP, et al. Optimal preoperative assessment of the geriatric surgical patient: a best practices guideline from the American College of Surgeons National Surgical Quality Improvement Program and the American Geriatrics Society. *J Am Coll Surg*. 2012;215(4):453-466.
38. McDonald VS, Thompson KA, Lewis PR, Sise CB, Sise MJ, Shackford SR. Frailty in trauma: a systematic review of the surgical literature for clinical assessment tools. *J Trauma Acute Care Surg*. 2016;80(5):824-834.
39. Sessler DI, Sigl JC, Kelley SD, et al. Hospital stay and mortality are increased in patients having a "triple low" of low blood pressure, low bispectral index, and low minimum alveolar concentration of volatile anesthesia. *Anesthesiology*. 2012; 116(6):1195-1203.
40. Kheterpal S, Avidan MS. "Triple Low" murderer, mediator, or mirror. *Anesthesiology*. 2012;116(6):1176-1178.
41. Bulger EM, Kastl JG, Maier RV. The history of Harborview Medical Center and the Washington State Trauma System. *Trauma Surg Acute Care Open*. 2017;2(1):e000091.