2016

Preoperative falls predict postoperative falls, functional decline, and surgical complications

Vanessa L. Kronzer
Washington University School of Medicine in St. Louis

Michelle R. Jerry
The University Of Michigan

Arbi Ben Abdallah
Washington University School of Medicine in St. Louis

Troy S. Wildes
Washington University School of Medicine in St. Louis

Susan L. Stark
Washington University School of Medicine in St. Louis

See next page for additional authors

Authors

Vanessa L. Kronzer, Michelle R. Jerry, Arbi Ben Abdallah, Troy S. Wildes, Susan L. Stark, Sherry L. McKinnon, Daniel L. Helsten, Anshuman Sharma, and Michael S. Avidan

EBioMedicine 12 (2016) 302–308

Contents lists available at ScienceDirect

EBioMedicine

journal homepage: www.ebiomedicine.com

Research Paper

Preoperative Falls Predict Postoperative Falls, Functional Decline, and Surgical Complications

Vanessa L. Kronzer BA [a], Michelle R. Jerry MS [b], Arbi Ben Abdallah PhD [a], Troy S. Wildes MD [a], Susan L. Stark PhD [c], Sherry L. McKinnon BS [a], Daniel L. Helsten MD [a], Anshuman Sharma MD [a], Michael S. Avidan MBBCh [a,*]

[a] Washington University School of Medicine, Department of Anesthesiology, 660 South Euclid Avenue, Campus Box 8054, Saint Louis, MO 63110, USA
[b] University of Michigan, Department of Biostatistics, 534 Canton Street, Canton, MI 48188, USA
[c] Washington University School of Medicine, Program in Occupational Therapy, 4444 Forest Park Avenue, CB 855, Saint Louis, MO 63108, USA

ARTICLE INFO

Article history:
Received 20 July 2016
Received in revised form 21 August 2016
Accepted 24 August 2016
Available online 26 August 2016

Keywords:
Accidental falls
Outcome assessment
Patient-reported outcomes
Preoperative period
Postoperative period
Elective surgical procedures

ABSTRACT

Background: Falls are common and linked to morbidity. Our objectives were to characterize postoperative falls, and determine whether preoperative falls independently predicted postoperative falls (primary outcome), functional dependence, quality of life, complications, and readmission.

Methods: This prospective cohort study included 7982 unselected patients undergoing elective surgery. Data were collected from the medical record, a baseline survey, and follow-up surveys approximately 30 days and one year after surgery.

Results: Fall rates (per 100 person-years) peaked at 175 (hospitalization), declined to 140 (30-day survey), and then to 97 (one-year survey). After controlling for confounders, a history of one, two, and ≥three preoperative falls predicted postoperative falls at 30 days (adjusted odds ratios [aOR] 2.3, 3.6, 5.5) and one year (aOR 2.3, 3.4, 6.9). One, two, and ≥three falls predicted functional decline at 30 days (aOR 1.2, 2.4, 2.4) and one year (aOR 1.3, 1.5, 3.2), along with in-hospital complications (aOR 1.2, 1.3, 2.0). Fall history predicted adverse outcomes better than commonly-used metrics, but did not predict quality of life deterioration or readmission.

Conclusions: Falls are common after surgery, and preoperative falls herald postoperative falls and other adverse outcomes. A history of preoperative falls should be routinely ascertained.

1. Introduction

In response to growing concern about the increasing incidence and morbidity of falls (Cigolle et al., 2015; WHO, 2012), the Joint Commission (United States) established fall prevention as one of its national patient safety goals in 2015 (The Joint Commission, 2015). Postoperative falls may occur more often than falls in the general population (O'loughlin et al., 1993; Berggren et al., 2008), yet their demographics and epidemiology have not been well-described. A few studies examine the characteristics and risk factors for postoperative falls, but most are retrospective, inpatient, orthopedic, or too small for risk factor assessment (Church et al., 2011; Clarke et al., 2012; Jorgensen et al., 2013).

In the general population, a history of falls is a strong predictor of falling again (Tinetti and Kumar, 2010; Deandrea et al., 2010), worse function (Skalska et al., 2014), and poor quality of life (Stenhagen et al., 2014). Falls are also associated with functional dependence and poor quality of life in the preoperative surgical population (Kronzer et al., 2016b). A link may therefore also exist between falls and outcomes in surgical populations. Indeed, in a restricted patient population, preoperative falls have been associated with postoperative complications, and on a crude basis, with readmission (Jones et al., 2013). However, the value of ascertaining fall history preoperatively has not been definitively established.

To address these limitations and provide the evidence needed to usher change in clinical practice, we conducted a large, prospective study of unselected surgical patients. Our objectives were twofold. First, we aimed to describe characteristics of postoperative falls, including their rate, timing, associated injuries, and risk factors. Second, we aimed to determine whether preoperative falls were associated with postoperative falls (primary outcome), functional dependence, quality

Abbreviations: ASA, American Society of Anesthesiologists; BRFSS, Behavior Risk Factor Surveillance System; METs, metabolic equivalents; MAR, missing at random; NMAR, not missing at random; ProFaNE, Prevention of Falls Network Europe; STROBE, STrengthening the Reporting of OBservational studies in Epidemiology; SATISFY-SOS, Systematic Assessment and Targeted Improvement of Services Following Yearlong Surgical Outcomes Surveys.

* Corresponding author at: Washington University School of Medicine in St. Louis, 660 South Euclid Avenue, Campus Box 8054, Saint Louis, MO 63110, USA.

E-mail addresses: vkronzer@wustl.edu (V.L. Kronzer), kleckner@umich.edu (M.R. Jerry), aba@anest.wustl.edu (A. Ben Abdallah), wildest@anest.wustl.edu (T.S. Wildes), sstark@wustl.edu (S.L. Stark), mckinnos@anest.wustl.edu (S.L. McKinnon), helstend@anest.wustl.edu (D.L. Helsten), sharmanu@anest.wustl.edu (A. Sharma), avidanm@anest.wustl.edu (M.S. Avidan).

http://dx.doi.org/10.1016/j.ebiom.2016.08.039

of life, complications, and readmission after controlling for routinely-collected potential confounders. We hypothesized that a history of preoperative falls would independently forecast poor postoperative outcomes.

2. Methods

2.1. Study Design and Population

This prospective cohort study received ethics committee approval at Washington University (Human Research Protection Office number 201505035), conforms to the standards of the Declaration of Helsinki, and was reported in compliance with the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines for observational studies (S2). It was a substudy of an ongoing registry at Barnes Jewish Hospital called the Systematic Assessment and Targeted Improvement of Services Following Yearlong Surgical Outcomes Surveys (SATISFY-SOS) study (Avidan, 2014).

For the present study, we included a subset of patients from the SATISFY-SOS registry. The data were collected prospectively prior to the design of the current study. The cohort comprised adult patients undergoing elective surgery who attended the preoperative assessment clinic and provided signed informed consent (S8) between January 16, 2014 and October 7, 2015. Approximately 19,400 out of 29,800 potentially eligible patients (65%) consented to participate in the study during this time window. Main reasons for non-participation included no invitation to participate, patient refusal, and lack of English literacy. Data were obtained from the electronic medical record, a presurgical baseline survey (S3), and 30-day and one-year postsurgical surveys (S4–S7). To maximize response rate, we used a multi-modal follow-up sequence involving email, two paper mailings, and up to five phone calls per participant.

In the time window for this substudy, 17,850 (92%) of participants completed the baseline survey. The main reason for not completing this survey was insufficient time. Of those completing the baseline survey, 9097 responded to the 30-day survey, of whom 2436 responded to the one-year survey. We estimated survey response percentages based on the fraction of participants whose follow-up windows had fully expired at the time of data retrieval. These response percentages were 8216 out of 14,313 (57%) for the 30-day survey and 1462 out of 2390 (61%) for one-year survey. Among the completed follow-up surveys, only those corresponding to the first surgery for each patient were included. We also excluded records with 30-day or one-year survey completion times outside our pre-specified time ranges (Kronzer et al., 2016a), resulting in intervals from surgery to 30-day survey of 20 to 120 days and surgery to one-year survey of 355 to 455 days. A total of 7982 unique patients were included in the analysis; 7902 met criteria for 30-day analysis, and 2320 for one-year analysis.

2.2. Measures

Following the Prevention of Falls Network Europe (ProFaNE) guidelines, we defined a fall as "an unexpected event where you come to rest on the ground, floor or lower level" (Lamb et al., 2005). Our primary explanatory variable was preoperative falls in the six months before surgery, categorized as zero, one, two, and three or greater. For sensitivity analyses, we re-ran each model replacing preoperative falls with a modified falls scale that incorporated the number of falls with the severity of fall-related injuries (Tinetti and Williams, 1997). Injuries were patient-reported. "Severe injury" included severe pain, seeking medical treatment, head injury, fracture, or change from independent to assisted living.

Other explanatory variables included Charlson index (≥3) (Charlson et al., 1987), American Society of Anesthesiologists (ASA) physical status score (≥3) (Cullen et al., 1994), and procedural cardiac risk (≥intermediate risk) (Lee et al., 1999). Although statistically it is not best practice to dichotomize variables, we pre-specified in our plan and specifically chose to dichotomize these variables because, in our institution and elsewhere, those are the thresholds commonly used to determine increased preoperative risk. Charlson index was scored using comorbidities identified from the medical record, while ASA physical status came from the anesthesia record. Procedural cardiac risk represents the procedure-specific, patient-independent, cardiac risk class. Preoperative clinicians estimated procedural cardiac risk based on planned procedures.

Obtained from the follow-up surveys, the five outcome variables of interest included (i) one or more falls, (ii) worse function, and (iii) physical and mental quality of life score (all at both 30 days and one year), along with (iv) one or more in-hospital complications and (v) 30-day readmission. Two versions of each survey were administered during the study period. The first version of each did not use the validated (ProFaNE) definition of falls, so we excluded these surveys from all postoperative falls analyses (Kronzer et al., 2016a). Since the other questions were identical, we used records from both versions for the other four outcomes. Functional dependence came from the Barthel Index, a ten-question index where "100" represents full function (Mahoney and Barthel, 1965). Physical and mental quality of life came from the Veterans Rand 12, a twelve-item questionnaire scored continuously from 0 to 100, where higher scores indicate greater quality of life (Kazis et al., 2006; Selim et al., 2009). Both in-hospital complications and readmission came from the 30-day survey. Complications included any of the following: heart problems, stroke, lung problems, blood clots, kidney or gastrointestinal problems, nerve injury, surgical wound infection, delirium, or other.

We selected demographic and confounder variables specific to each outcome that were both routinely collected and known at the time of surgical planning. Demographic and confounder variables, including those from the preoperative assessment visit, were obtained from the medical record using MetaVision® (iMDsoft, Needham, MA). The preoperative assessment clinician judged physical activity capability, with less than four metabolic equivalents (METs) considered "low" physical activity capability. "Mood Disorder" included depression or anxiety, while "Elimination Issue" included incontinence or toileting difficulty. When patients did not respond to "fill in all that apply" questions, we assumed that they did not experience the item of interest. These included fall-related injuries, in-hospital falls, and complications.

2.3. Statistical Analysis

We used chi square tests to compare proportions and either t-tests or Wilcoxon rank-sum tests to compare continuous variables. The general population fall rate was calculated from the Behavior Risk Factor Surveillance System (BRFSS) dataset, which contains data on the number of falls in the past year for over 200,000 United States adults (CDC, 2014). Because the in-hospital falls question was dichotomous (yes or no) rather than a number, we conservatively assumed one fall per person reporting a fall. We used length of stay for time. To estimate the 30-day and one-year fall rates, we used the reported number of falls, along with each participant's response time. We subtracted ten days for mailed surveys to account for processing time. For patients reporting "three or more falls," we estimated the true number of falls using the average number of falls among people reporting three or more falls in the BRFSS dataset, assuming similar counts in the surgical population (CDC, 2014).

In the raw dataset, missing data mostly came from functional dependence and quality of life on the 30-day (19%, 18%) and one-year (7%, 13%) surveys since they were each comprised of several items. Race, preoperative falls, Charlson index, ASA physical status, procedural cardiac risk, physical activity, smoking status, postoperative falls, and readmission also had minimal missingness (<5%). Missing data analysis revealed differences in characteristics between these participants with and without missing data. Therefore, to avoid systematic bias, imputing missing measurements was important. We assumed the missing data to be missing at random (MAR) given the 62 demographic, health, and outcome variables in the dataset. While not missing at random (NMAR) mechanisms were possible, they have minimal effects on the results of imputation (Graham et al., 1997).

We performed multiple imputation in SAS using fully conditional specification with 20 imputed datasets (Van Buuren, 2007). To improve imputation quality, we included all explanatory and outcome variables. Descriptive statistics used un-imputed data, while the main models used the imputed datasets. We did not use imputed outcomes in analysis, except for patients who lacked two or fewer items for functional dependence or quality of life indices (1% of the total data for each). Finally, for sensitivity analysis, we compared models estimated with the imputed data to those estimated with the un-imputed data.

To assess the relationship between falls and each outcome after controlling for confounders, we fit multivariable regression models. The 10% most clinically relevant interaction terms were tested in each model (Kronzer et al., 2016a). Using the un-imputed data and one of the imputed datasets, we identified no problems with collinearity; influential records; linearity of logit and goodness of fit; or independence, normality, and heteroscedasticity of residuals. We categorized or log-transformed variables that exhibited non-linear relationships with the outcomes (see Tables).

Analyses were performed using SAS/STAT® software, Version 9.4 (SAS Institute Inc., Cary, NC). Statistical significance was set at alpha = 0.01 (Kronzer et al., 2016a). We used two-sided tests and 99% confidence intervals (CI). We set a 20% clinical significance threshold for differences in proportions and odds ratios (Balk et al., 2014). For quality of life scores, the minimum important difference was five points (Norman et al., 2003). Except for the interaction between preoperative falls and age, all hypotheses and analyses were pre-specified in the protocol (Kronzer et al., 2016a).

2.4. Database Accession Number

Dryad: 10.5061/dryad.h3r45.

3. Results

A total of 7982 patients met criteria for inclusion. Non-responders were similar to responders except for younger age, lesser comorbidity and cardiac risk, and greater proportions of mood disorders and smoking (Appendix). In contrast, patients missing data were sicker than those not missing data on almost every characteristic (Appendix). Participants who had fallen preoperatively had more comorbidities and worse overall health than those who had not fallen (Table 1). In fact, patients' likelihood of falling in the year after surgery was directly proportional to the number of times they had fallen before surgery (Fig. 1).

3.1. Characteristics of Postoperative Falls

Based on the BRFSS dataset, we calculated a fall rate of 81 per 100 person-years in the general adult population (hereafter, fall rates in 100 person-years are assumed). In contrast, the fall rate reported in the cohort included in our study was 120 for the six month period prior to surgery. After surgery, 1.3% (20 out of 1549, 99% CI 0.7% to 2.3%) of patients reported a fall during hospitalization, 10% (149 out of 1494, 99% CI 8% to 12%) reported at least one fall between surgery and the 30-day survey (median 47 days), and 29% (510 out of 1792, 99% CI 26% to 31%) reported at least one fall between the 30-day and one-year surveys (median 323 days) (Table 2). The corresponding fall rates were 175 during postoperative hospitalization, 140 in the 30 days following surgery, and 97 between the 30-day and one-year surveys (Fig. 2).

Table 1
Study population characteristics by preoperative fall status.

Characteristic	[a]Number (%)		OR (99% CI)
	Non-faller (N = 5713)	Faller (N = 2019)	
Age, mean ± SD	59 ± 14	60 ± 14	–
Female sex	3295 (58)	1222 (61)	1.13 (0.98, 1.29)
White race	4998 (89)	1777 (89)	1.05 (0.85, 1.31)
BMI, mean ± SD	30 ± 13	31 ± 15	–
Charlson comorbidity index (≥3)	2865 (50)	1080 (53)	1.14 (1.00, 1.30)
ASA physical status (≥3)	2236 (39)	919 (46)	1.30 (1.14, 1.49)
Cardiac risk (≥intermediate)	2823 (51)	1055 (54)	1.11 (0.97, 1.28)
Low physical activity (<4 METS)	1394 (25)	784 (39)	1.96 (1.70, 2.26)
Elimination issue	107 (2)	85 (4)	2.28 (1.56, 3.34)
Mobility issue	278 (5)	221 (11)	2.38 (1.87, 3.04)
Dizziness	594 (10)	345 (17)	1.78 (1.47, 2.15)
Mood disorder	1023 (18)	534 (26)	1.65 (1.41, 1.93)
Ever smoked	2725 (48)	1019 (50)	1.11 (0.97, 1.27)
Neurological impairment	388 (7)	217 (11)	1.65 (1.31, 2.08)
Chronic pain	2324 (41)	1130 (56)	1.85 (1.62, 2.12)
Postoperative faller, 30 days	212 (4)	246 (13)	3.64 (1.83, 4.68)
Postoperative faller, 1 year	316 (19)	256 (47)	3.69 (2.81, 4.86)
Impaired baseline function (Barthel <100)	546 (10)	381 (20)	2.19 (1.81, 2.64)
Impaired postoperative function, 30 days	1181 (25)	606 (39)	1.88 (1.60, 2.21)
Impaired postoperative function, 1 year	368 (23)	184 (35)	1.77 (1.33, 2.34)
Physical QOL, baseline, median (IQR)	42 (31,53)	34 (26,45)	–
Physical QOL, 30 days, median (IQR)	42 (33,50)	36 (27,44)	–
Physical QOL, 1 year, median (IQR)	48 (38,55)	41 (29,52)	–
Mental QOL, baseline median (IQR)	57 (49,62)	54 (43,61)	–
Mental QOL, 30 days, median (IQR)	58 (49,62)	55 (44,61)	–
Mental QOL, 1 year, median (IQR)	59 (52,62)	56 (45,61)	–
In-hospital complication	1522 (27)	679 (34)	1.40 (1.21, 1.61)
Readmission within 30 days	285 (5)	127 (7)	1.28 (0.97, 1.70)

Abbreviations: OR = odds ratio, SD = standard deviation, QOL = quality of life, METS = metabolic equivalents, IQR = interquartile range.
[a] Due to different numbers of missing values for each variable, denominator may differ from the reported total.

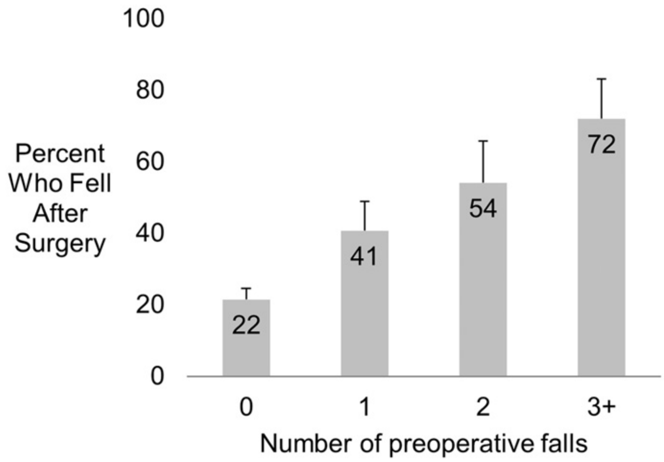

Fig. 1. Percent of patients who reported falling in the year after surgery, stratified by number of preoperative falls. Legend: Error bars represent 99% confidence intervals.

Fall rates varied substantially by surgical specialty (Fig. 3, Appendix for sample sizes). Patients receiving neurosurgery had the highest fall rate at baseline (273), 30-days (255), and one year (162). Notably, patients receiving gastrointestinal/hepatobiliary or ophthalmological surgery had relative spikes in fall rates reported on the 30-day survey compared to their preoperative and one-year fall rates (Fig. 3).

Many of the patients who fell postoperatively reported a fall-related injury, for both the 30-day (45%) and one-year (66%) surveys (Table 2). Among those who reported one or more falls on the 30-day survey, 18% (27 out of 149, 99% CI 11% to 28%) reported a severe injury. For patients who reported falling on the one-year survey, 27% (140 out of 510, 99% CI 23% to 33%) reported a severe injury. The only risk factors associated with postoperative falls—out of the thirteen studied—were low physical activity capability and preoperative falls (Table 3).

3.2. Preoperative Falls and Postoperative Outcomes

One, two, and three or more preoperative falls exhibited a strong relationship with postoperative falls for both the 30-day survey (adjusted OR 2.3, 3.6, and 5.5, $p < 0.001$ for each) and the one-year survey (adjusted OR 2.3, 3.4, and 6.9, $p < 0.001$ for each) (Table 3). Charlson index, ASA physical status, and the procedural cardiac risk were not associated with postoperative falls at either time point.

A strong relationship also existed between falls and postoperative functional deterioration (Table 4). One, two, and three or more preoperative falls were associated with a decline in function on the 30-day survey (adjusted OR 1.2, 2.4, 2.4, $p < 0.001$ for each), and three preoperative falls were strongly associated with worse function on the one-year survey (adjusted OR 3.2, 99% CI 1.8 to 5.6). Higher scores on the Charlson index and procedural cardiac risk were associated with functional decline on the 30-day survey (adjusted OR 1.3, 99% CI 1.1 to 1.6; adjusted OR 1.4, 99% CI 1.2 to 1.6), while higher ASA physical status was associated with functional decline on the one-year survey (adjusted OR 1.4, 99% CI 1.0 to 1.8).

Preoperative falls, low physical activity capability, and baseline quality of life were associated with 4.0 to 4.9 point changes in postoperative quality of life after adjusting for confounders, but none of these differences met the pre-specified five-point threshold for clinical significance (Table 4, Appendix).

Preoperative falls were associated with increased odds of in-hospital complications, especially for three or more preoperative falls (adjusted OR 2.0, 99% CI 1.5 to 2.7) (Table 4). Higher Charlson index, ASA physical status, and procedural cardiac risk were also associated with increased odds of complications (adjusted OR 1.3, 1.6, and 1.3, respectively, $p < 0.001$ for each). On a crude basis, a history of one or more falls was associated with many of the complication sub-types, especially delirium (OR 2.0, 99% CI 1.5 to 2.7) and surgical wound infection (OR 1.7, 99% CI 1.1 to 2.8) (Table 5).

Finally, preoperative falls were not associated with 30-day readmission (Table 4). Interaction terms, including the post-hoc interaction between falls and age, were also nonsignificant in all models. The postoperative falls models did not have sufficient outcomes to test any further interactions.

In general, sensitivity analyses using the Tinetti fall scale produced lower odds ratio estimates compared to those for the number of preoperative falls (Table 3, Appendix). Regression models fit to the un-imputed datasets showed minimal differences compared to the main analyses (Appendix).

4. Discussion

Using a large population of unselected surgical patients, this study characterized postoperative falls and showed that a history of preoperative falls predicted postoperative falls, functional decline, and in-hospital complications. The postoperative fall rate spiked during postoperative hospitalization and remained elevated for several weeks after surgery. This finding suggests surgery-related falls occur not just during hospitalization, but also after discharge. Thus, post-discharge falls should become a target for further research and prevention efforts.

Surprisingly, patients who underwent gastrointestinal/hepatobiliary, ophthalmologic, cardiac, and gynecologic surgery had greater 30-day fall rates compared to their baseline and one-year fall rates. These results may represent chance findings since they were unexpected and based on small sample sizes. Alternatively, these surgeries might for various reasons (e.g., impaired vision following ophthalmologic surgery) lead to higher postoperative fall rates. If fall rates truly were higher following these surgeries, this would indicate potentially high-yield opportunities for targeted fall prevention interventions.

The low number of risk factors for postoperative falls is surprising since the thirteen variables we tested are strongly associated with falls in the general population (Tinetti and Kumar, 2010; Deandrea et al., 2010) and in our preoperative population (Kronzer et al., 2016b). In spite of this finding, the association between preoperative falls and postoperative falls was quite strong. That is, patients with one, two, and three or more preoperative falls had approximately two, three, and six times greater odds of postoperative falls compared to those who had not fallen. Thus, knowledge of preoperative falls is likely essential for predicting and preventing postoperative falls.

We also found that a history of preoperative falls independently predicted poor postoperative outcomes. The association between preoperative falls and functional decline is not surprising given the relationship between falls and function in the general and preoperative populations (Skalska et al., 2014; Kronzer et al., 2016b). Nevertheless, the observed associations were stronger than expected. The association between preoperative falls and postoperative complications has been found

Table 2
Occurrence and injuries of postoperative falls.

Outcome	Number (%)	
	30-days (N = 1494)	1-year (N = 1792)
Any fall	149 (10)	510 (29)
One fall	90 (6)	231 (13)
Two falls	36 (2)	139 (8)
Three or more falls	23 (2)	140 (8)
Any fall-related injury	67 (45)	329 (66)
Bruising	50 (34)	259 (51)
Sought medical treatment	11 (8)	83 (16)
Severe pain	19 (13)	60 (12)
Loss of mobility	18 (12)	61 (12)
Fracture	5 (3)	40 (8)
Head injury	5 (3)	22 (4)
Assisted living	0 (0)	6 (1)

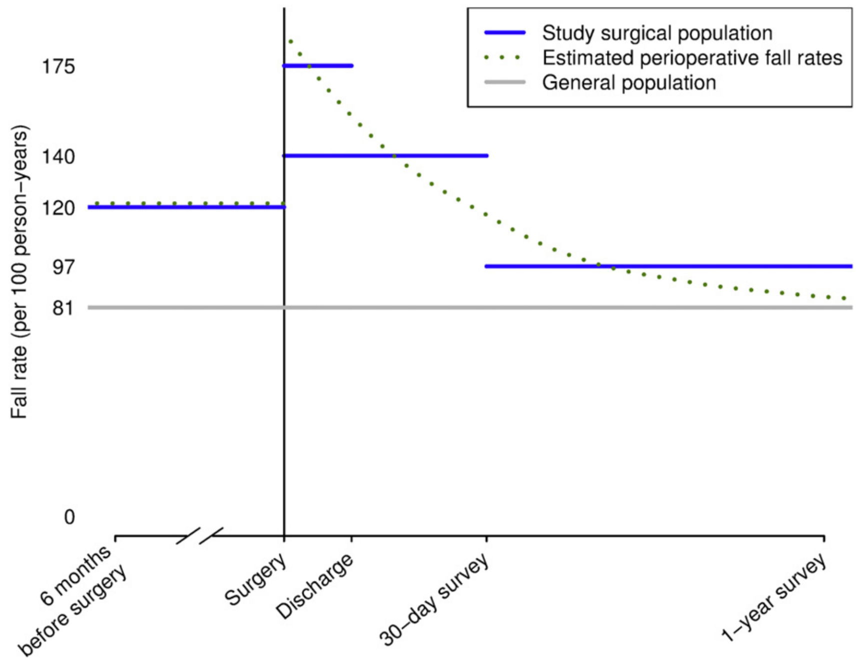

Fig. 2. Actual and estimated perioperative fall rates.

previously, but in a small, specialized population (Jones et al., 2013). Our study replicated and generalized those findings in a large population of unselected surgical patients. Moreover, we discovered that on a crude basis, preoperative falls were associated with many different types of surgical complications such as delirium and surgical wound infections. Unlike the previous study, which found a crude association between preoperative falls and readmission (Jones et al., 2013), our study did not find a significant association after taking into account potential confounders.

Whereas one preoperative fall conferred a similar risk for poor outcomes compared to currently-used measures of surgical risk (Charlson index, ASA physical status, and procedural cardiac risk), the observed associations between multiple preoperative falls and poor postoperative outcomes were stronger than, and independent of those measures. The stronger associations were striking, even with the conservative 99% confidence intervals. Approximately 5% of patients report falling three or more times before surgery (Kronzer et al., 2016b). This group is sufficiently small and the risk sufficiently high to justify interventions, which could change their postoperative health trajectories. In addition, compared to a widely-accepted falls scale that incorporates fall injuries, the Tinetti falls scale (Tinetti and Williams, 1997), the simple number of preoperative falls was more predictive of poor surgical outcomes.

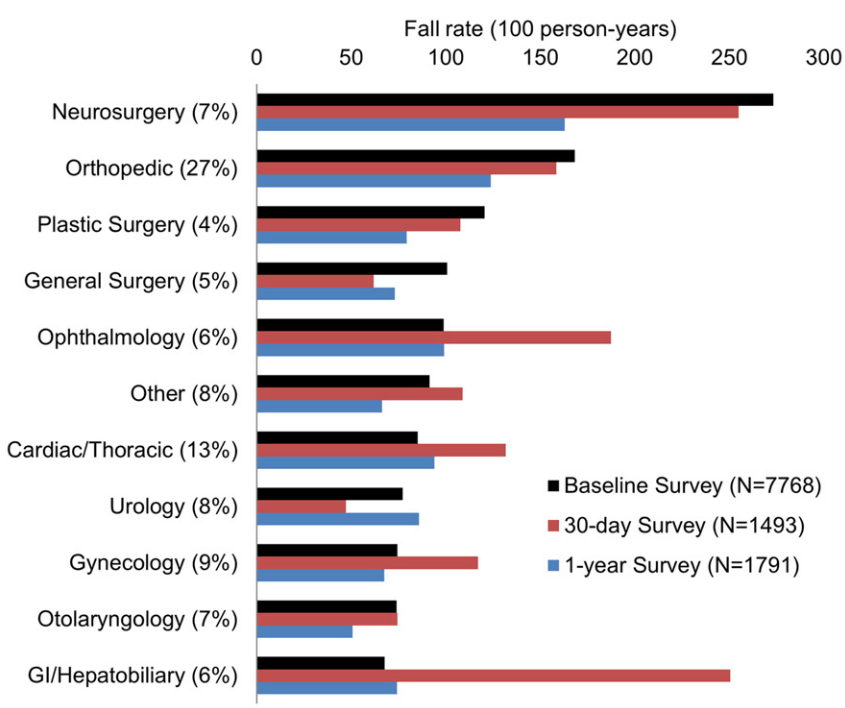

Fig. 3. Fall rate at baseline, 30 days, and one year, by surgical specialty. Legend: GI = Gastrointestinal.

Table 3
Risk factors for postoperative falls at 30-days and one-year.

Explanatory variable	Odds ratio (99% CI)	
	Postop falls, 30 days (N = 1494)	Postop falls, 1 year (N = 1792)
Age, by decade	0.9 (0.8, 1.1)	
Age, by age group[a]		
18–45 years (reference)		–
46–64 years		1.0 (0.6, 1.7)
65 + years		0.8 (0.5, 1.3)
Female sex	1.3 (0.8, 2.2)	0.9 (0.7, 1.2)
White race	0.7 (0.4, 1.5)	1.3 (0.7, 2.3)
BMI, by 10 units	1.0 (0.9, 1.0)	1.1 (0.9, 1.4)
1 preoperative fall	**2.3** (**1.2**, **4.3**)	**2.3** (**1.6**, **3.4**)
2 preoperative falls	**3.6** (**1.8**, **7.5**)	**3.4** (**2.0**, **5.9**)
≥3 preoperative falls	**5.5** (**2.4**, **12.5**)	**6.9** (**3.4**, **13.9**)
Charlson comorbidity index (≥3)	1.0 (0.6, 1.9)	1.1 (0.8, 1.7)
ASA physical status (≥3)	1.4 (0.8, 2.5)	1.2 (0.9, 1.7)
Cardiac risk (≥intermediate)	0.8 (0.5, 1.3)	0.9 (0.7, 1.2)
Low physical activity (<4 METS)	**1.8** (**1.0**, **3.2**)	**1.5** (**1.0**, **2.1**)
Elimination issue	1.2 (0.3, 4.7)	1.9 (0.8, 4.5)
Mobility issue	1.2 (0.5, 2.6)	1.5 (0.9, 2.7)
Dizziness	1.4 (0.8, 2.7)	1.3 (0.9, 2.1)
Mood disorder	1.2 (0.7, 2.1)	1.5 (1.0, 2.2)
Tinetti fall scale comparison		
One Fall, No Severe Injury	2.0 (1.0, 4.2)	**2.4** (**1.6**, **3.7**)
Two or More Falls, No Severe Injury	**4.2** (**2.2**, **8.0**)	**4.4** (**2.7**, **7.2**)
Any Number of Falls, Severe Injury	**3.8** (**1.8**, **8.2**)	**3.0** (**1.7**, **5.1**)

Abbreviations: OR = odds ratio, QOL = quality of life, METS = metabolic equivalents.
Bold values indicate statistical significance ($p < 0.01$).
[a] Categorized in the one-year fall model due to nonlinearity.

Therefore, a history of multiple falls should be seen as an ominous predictor and a valuable tool for preoperative assessment—especially when considering its simplicity.

Finally, we found that age was not a significant predictor of any outcome. Furthermore, post-hoc testing showed that the interaction between age and preoperative falls was not significant in any model. In other words, the effect of preoperative falls on poor postoperative outcomes appears to be similar across all ages. Our previous work shows that preoperative falls are common and result in severe injuries for adults of all ages, especially in middle age (Kronzer et al., 2016b), Together, these findings suggest that perioperative fall interventions should be geared towards patients of all ages.

This study has important limitations. First, participants came from one academic medical center with its own patterns of clinic attendance, which may limit generalizability. The results may also differ by surgical specialty, which would be an interesting avenue for future investigation. Second, the enrollment process and survey nonresponse may have introduced selection bias for reasons such as poor health or low English literacy. Fortunately, enrolled patients did not differ in clinically important ways from those who are not enrolled (Helsten et al., 2016), and the characteristics of survey responders closely resembled those of non-responders (Appendix). Third, patient-reported falls are prone to recall bias, especially in older adults and for time periods longer than one month (Cummings et al., 1988). Such bias might have affected all of the patient-reported outcomes in this study, attenuating the observed associations among preoperative falls, postoperative outcomes, and age. Fourth, the true proportions of in-hospital falls, fall-related injuries, and complications may be higher than reported since these questions were phrased as “fill in all that apply”, with the assumption that no response signified absence of the outcome. Finally, although the multivariable models controlled for known confounders for each outcome, the possibility of unknown confounders cannot be excluded.

In conclusion, postoperative falls are common both during and after hospitalization, and preoperative falls are a main indicator for these events. Preoperative falls also predict functional dependence and in-hospital complications better than commonly-used measures. Therefore, a history of preoperative falls is a valuable and pragmatic tool, and should become part of routine preoperative assessment.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ebiom.2016.08.039.

Role of the Funding Source

This study was supported by the Institute of Clinical and Translational Sciences grant UL1TR000448 (sub award TL1 TR000449) from the National Center for Advancing Translational Sciences, along with grant 1UH2AG050312-01 from the National Institute on Aging, of the National Institutes of Health (NIH, Bethesda, MD, USA). The content is solely the responsibility of the authors and does not necessarily represent the official view of the NIH. It was also supported by grant BJHF#7937-77 from the Barnes-Jewish Hospital Foundation and the Washington University in St. Louis Department of Anesthesiology (Saint Louis, MO, USA). The funding sources had no role in the design or conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication.

Conflicts of Interest

None.

Table 4
Adjusted relationships between explanatory variables and other poor postoperative outcomes.

Explanatory variable	Odds ratio (99% CI)		Estimate (99% CI)				Odds ratio (99% CI)	
	Function worse, 30 days [a](N = 7534)	Function worse, 1 year (N = 2230)	Physical QOL, 30 days (N = 7618)	Physical QOL, 1 year (N = 2236)	Mental QOL, 30 days (N = 7618)	Mental QOL, 1 year (N = 2236)	In-hospital complication (N = 7901)	30-day readmission (N = 7640)
1 Preoperative fall	1.2 (1.0, 1.5)	1.3 (0.9, 1.9)	−0.9 (−1.7, −0.2)	−1.3 (−2.8, 0.2)	−0.5 (−1.3, 0.3)	−1.0 (−2.4, 0.3)	1.2 (1.0, 1.5)	1.2 (0.8, 1.6)
2 Preoperative falls	2.4 (1.9, 3.1)	1.5 (0.9, 2.6)	−1.0 (−2.1, 0.1)	−1.5 (−3.7, 0.6)	−0.8 (−1.9, 0.3)	−2.4 (−4.2, −0.5)	1.3 (1.0, 1.7)	1.2 (0.7, 2.0)
≥3 Preoperative falls	2.4 (1.8, 3.3)	3.2 (1.8, 5.6)	−0.6 (−2.0, 0.7)	−3.2 (−5.6, -0.7)	−2.1 (−3.4, −0.8)	−4.9 (−7.1, −2.7)	2.0 (1.5, 2.7)	1.1 (0.6, 1.9)
Charlson index (≥3)	1.3 (1.1, 1.6)	1.3 (0.9, 1.8)	−2.3 (−3.0, −1.6)	−2.5 (−4.0, −1.0)	−1.0 (−1.7, −0.3)	−0.4 (−1.7, 0.9)	1.3 (1.1, 1.5)	1.5 (1.1, 2.1)
ASA physical status (≥3)	1.1 (1.0, 1.3)	1.4 (1.0, 1.8)	−0.9 (−1.5, −0.3)	−2.2 (−3.4, −1.0)	−1.2 (−1.8, −0.3)	−0.9 (−1.9, 0.1)	1.6 (1.4, 1.9)	1.3 (0.9, 1.7)
Cardiac risk (≥intermed.)	1.4 (1.2, 1.6)	1.2 (0.9, 1.6)	−1.2 (−1.7, −0.7)	1.6 (0.6, 2.7)	0.4 (−0.2, 0.9)	0.6 (−0.4, 1.5)	1.3 (1.2, 1.5)	1.8 (1.3, 2.3)

Abbreviations: OR = odds ratio, QOL = quality of life, METS = metabolic equivalents.
[a] Note: Ns differ in this table since outcome variables were not imputed. Each outcome had a different number of missing records.

Table 5
Crude relationship between preoperative falls and postoperative complications.

Complication type	Number (%)		OR (99% CI)
	Non-fallers (N = 5657)	Fallers (N = 1995)	
Delirium	196 (3)	132 (7)	2.0 (1.5, 2.7)
Surgical Wound Infection	78 (1)	47 (2)	1.7 (1.1, 2.8)
Clotting Complication	70 (1)	39 (2)	1.6 (0.9, 2.7)
Pulmonary Complication	120 (2)	61 (3)	1.5 (1.0, 2.2)
Nerve Injury or Paralysis	125 (2)	63 (3)	1.4 (1.0, 2.2)
Other Complication	986 (17)	443 (22)	1.4 (1.2, 1.6)
Cardiovascular Complication	261 (5)	94 (5)	1.0 (0.7, 1.4)
Kidney or Intestinal Complication	53 (0.9)	18 (0.9)	1.0 (0.5, 2.0)

Author Contributions

VLK: literature search, study design, data acquisition, data analysis, data interpretation, figures, manuscript writing; MRJ: study design, data analysis, data interpretation, figures, manuscript revision; ABA: study design, data analysis, data interpretation, manuscript revision; TSW: study design, data interpretation, manuscript revision; SLS: data interpretation, manuscript revision; SLM: study design, manuscript revision; DLH: data acquisition, manuscript revision; AS: data interpretation, manuscript revision; MSA: study design, data acquisition, data analysis, data interpretation, figures, manuscript revision.

Acknowledgements

We thank James VandenBerg for assistance in manuscript revision; Randy Wright for assistance in data acquisition; and Dawn Anderson, Marsha Fizette, Mark Foesterling, Stacey Hellman, Michelle Hieger, Mary Kehrer, Jill Lafata, Jessica McGowan, Angelika Nagele, Keryn Padgett, Mary Scherer, Tina Thomlison, Bonnie Vemmer, Linda Wiemer, Pathena Williams, Tammy Murphy, and Amy Campbell for their hard work in consenting patients for SATISFY-SOS.

References

Avidan, M.S., 2014. Systematic Assessment and Targeted Improvement of Services Following Yearlong Surgical Outcomes Surveys (SATISFY-SOS). In: ClinicalTrials.gov. (Available: https://clinicaltrials.gov/ct2/show/NCT02032030) ([cited 2016 Feb 10]).

Balk, E.M., Earley, A., Hadar, N., Shah, N., Trikalinos, T.A., 2014. AHRQ Comparative Effectiveness Reviews. Benefits and Harms of Routine Preoperative Testing: Comparative Effectiveness. Agency for Healthcare Research and Quality (US), Rockville (MD) (Available: https://www.effectivehealthcare.ahrq.gov/ehc/products/480/1846/preoperative-testing-report-140130.pdf).

Berggren, M., Stenvall, M., Olofsson, B., Gustafson, Y., 2008. Evaluation of a fall-prevention program in older people after femoral neck fracture: a one-year follow-up. Osteoporos. Int. 19, 801–809.

CDC, 2014. BRFSS 2012 Survey Data and Documentation. Centers for Disease Control and Prevention. (Available: http://www.cdc.gov/brfss/annual_data/annual_2012.html).

Charlson, M.E., Pompei, P., Ales, K.L., Mackenzie, C.R., 1987. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J. Chronic Dis. 40, 373–383.

Church, S., Robinson, T.N., Angles, E.M., Tran, Z.V., Wallace, J.I., 2011. Postoperative falls in the acute hospital setting: characteristics, risk factors, and outcomes in males. Am. J. Surg. 201, 197–202.

Cigolle, C.T., Ha, J., Min, L.C., Lee, P.G., Gure, T.R., Alexander, N.B., Blaum, C.S., 2015. The epidemiologic data on falls, 1998–2010: more older Americans report falling. JAMA Intern. Med. 175, 443–445.

Clarke, H.D., Timm, V.L., Goldberg, B.R., Hattrup, S.J., 2012. Preoperative patient education reduces in-hospital falls after total knee arthroplasty. Clin. Orthop. Relat. Res. 470, 244–249.

Cullen, D.J., Apolone, G., Greenfield, S., Guadagnoli, E., Cleary, P., 1994. ASA physical status and age predict morbidity after three surgical procedures. Ann. Surg. 220, 3–9.

Cummings, S.R., Nevitt, M.C., Kidd, S., 1988. Forgetting falls. The limited accuracy of recall of falls in the elderly. J. Am. Geriatr. Soc. 36, 613–616.

Deandrea, S., Lucenteforte, E., Bravi, F., Foschi, R., La Vecchia, C., Negri, E., 2010. Risk factors for falls in community-dwelling older people: a systematic review and meta-analysis. Epidemiology 21, 658–668.

Graham, J., Hofer, S., Donaldson, S., Mackinnon, D., Shafer, J., 1997. Analysis with missing data in prevention research. The Science of Prevention: Methodological Advances from Alcohol and Substance Abuse Research. American Psychological Association, Washington D.C.

Helsten, D.L., Abdallah, A.B., Avidan, M.S., Wildes, T.S., Winter, A., Mckinnon, S.L., Bollini, M., Candelario, P., Burnside, B.A., Sharma, A., 2016. Methodological considerations for collecting patient reported outcomes from unselected surgical patients. Anesthesiology http://dx.doi.org/10.1097/ALN.0000000000001217.

Jones, T.S., Dunn, C.L., Wu, D.S., Cleveland Jr., J.C., Kile, D., Robinson, T.N., 2013. Relationship between asking an older adult about falls and surgical outcomes. JAMA Surg. 148, 1132–1138.

Jorgensen, C.C., Kehlet, H., Lundbeck Foundation Centre For Fast-Track, H. & Knee Replacement Collaborative, G., 2013. Fall-related admissions after fast-track total hip and knee arthroplasty - cause of concern or consequence of success? Clin. Interv. Aging 8, 1569–1577.

Kazis, L.E., Miller, D.R., Skinner, K.M., Lee, A., Ren, X.S., Clark, J.A., Rogers, W.H., S. III, A., Selim, A., Linzer, M., Payne, S.M., Mansell, D., Fincke, B.G., 2006. Applications of methodologies of the Veterans Health Study in the VA healthcare system: conclusions and summary. J. Ambul. Care Manage. 29, 182–188.

Kronzer, V.L., Abdallah, A.B., Mckinnon, S.L., Wildes, T.S., Avidan, M.S., 2016a. Ability of preoperative falls to predict postsurgical outcomes in non-selected patients undergoing elective surgery at an academic medical center: protocol for a prospective cohort study. BMJ Open (In Press).

Kronzer, V.L., Tang, R.D., Schelble, A.P., Abdallah, A.B., Wildes, T.S., Mckinnon, S.L., Sadiq, F., Lin, N., Helsten, D.L., Sharma, A., Stark, S.L., Avidan, M.S., 2016b. Preoperative falls and their association with functional dependence and quality of life. Anesthesiology 125, 322–332.

Lamb, S.E., Jorstad-Stein, E.C., Hauer, K., Becker, C., 2005. Development of a common outcome data set for fall injury prevention trials: the Prevention of Falls Network Europe consensus. J. Am. Geriatr. Soc. 53, 1618–1622.

Lee, T.H., Marcantonio, E.R., Mangione, C.M., Thomas, E.J., Polanczyk, C.A., Cook, E.F., Sugarbaker, D.J., Donaldson, M.C., Poss, R., Ho, K.K., Ludwig, L.E., Pedan, A., Goldman, L., 1999. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 100, 1043–1049.

Mahoney, F.I., Barthel, D.W., 1965. Functional evaluation: the Barthel index. Md. State Med. J. 14, 61–65.

Norman, G.R., Sloan, J.A., Wyrwich, K.W., 2003. Interpretation of changes in health-related quality of life: the remarkable universality of half a standard deviation. Med. Care 41, 582–592.

O'loughlin, J.L., Robitaille, Y., Boivin, J.F., Suissa, S., 1993. Incidence of and risk factors for falls and injurious falls among the community-dwelling elderly. Am. J. Epidemiol. 137, 342–354.

Selim, A.J., Rogers, W., Fleishman, J.A., Qian, S.X., Fincke, B.G., Rothendler, J.A., Kazis, L.E., 2009. Updated U.S. population standard for the Veterans RAND 12-item Health Survey (VR-12). Qual. Life Res. 18, 43–52.

Skalska, A., Wizner, B., Wiecek, A., Zdrojewski, T., Chudek, J., Klich-Raczka, A., Piotrowicz, K., Bledowski, P., Mossakowska, M., Michel, J.P., Grodzicki, T., 2014. Reduced functionality in everyday activities of patients with self-reported heart failure hospitalization–population-based study results. Int. J. Cardiol. 176, 423–429.

Stenhagen, M., Ekstrom, H., Nordell, E., Elmstahl, S., 2014. Accidental falls, health-related quality of life and life satisfaction: a prospective study of the general elderly population. Arch. Gerontol. Geriatr. 58, 95–100.

The Joint Commission, 2015. National Patient Safety Goals. The Joint Commission, United States (Available: http://www.jointcommission.org/assets/1/6/2015_NPSG_OME.pdf).

Tinetti, M.E., Kumar, C., 2010. The patient who falls: "It's always a trade-off". JAMA 303, 258–266.

Tinetti, M.E., Williams, C.S., 1997. Falls, injuries due to falls, and the risk of admission to a nursing home. N. Engl. J. Med. 337, 1279–1284.

Van Buuren, S., 2007. Multiple imputation of discrete and continuous data by fully conditional specification. Stat. Methods Med. Res. 16, 219–242.

WHO, 2012. Falls Fact Sheet [Online]. World Health Organization (Available: http://www.who.int/mediacentre/factsheets/fs344/en/ Accessed 27 April 2016).