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MORTALITY EFFECTS OF TIMING ALTERNATIVES FOR HIP FRACTURE SURGERY

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CONTRIBUTORS STATEMENT

All authors contributed to the conception and design of the study. In addition, BS, PG, KJS, LK, JK contributed to the acquisition and the analysis of data. BS, PG, KJS, LK, JMS, AL, JB, EB, JK, EJH, SNM, LB, MD, SJ, and JW contributed to the interpretation of the analysis. BS and LK drafted the manuscript. All authors critically revised the manuscript. All authors approved the final version for submission.

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ABSTRACT

Background

Appropriate timing of hip fracture surgery remains debated. We sought to estimate the effect of changes in timing policy and the proportion of deaths attributable to surgical delay.

Methods

We obtained discharge abstracts from the Canadian Institute for Health Information for hip fracture surgery in Canada (excluding Quebec) between 2004 and 2012. We estimated the expected population-average risks of inpatient death within 30 days if patients were surgically-treated on admission day, inpatient day 2, day 3, or after day 3. We weighted observations with the inverse propensity score of surgical timing according to confounders selected from a causal diagram.

Results

Of 139,119 medically stable patients with hip fracture aged 65 years or older, 32,120 (23.1%) underwent surgery on admission day, 60,505 (43.5%) inpatient day 2, 29,336 (21.0%) day 3 and 17,258 (12.4%) after day 3. Cumulative 30-day in-hospital mortality was 4.9% among patients surgically-treated on admission day, increasing to 6.9% for surgery performed after day 3. We projected an additional 10.9 (95% confidence interval [CI] 6.8 to 15.1) deaths per 1000 surgeries if all surgeries were performed after inpatient day 3 instead of admission day. The attributable proportion of deaths for delays beyond inpatient day 2 was 16.5% (95% CI 12.0% to 21.0%).

Interpretation

Surgery on admission day or the following day was estimated to reduce postoperative mortality among medically stable patients with hip fracture. Hospitals should expedite operating room access for patients whose surgery has already been delayed for nonmedical reasons.

INTRODUCTION

In Canada, hospitals admit 30,000 older adults with hip fracture annually.[1] These patients face an increased risk of death, with up to 5% of women and 10% of men dying within 30 days.[2, 3] It is generally accepted that early operative intervention improves survival by reducing patients' exposure to immobilization and inflammation.[4] In 2005, the federal, provincial and territorial governments established a benchmark of 48 hours from admission for 90% of hip fracture surgeries to prevent potentially harmful delays.[5] However, delays to hip fracture surgery remain common.[6] Patients who are medically stable at presentation may have to wait until a surgeon or an operating room becomes available.[7, 8]

There has been considerable debate about the point at which delaying hip fracture surgery for nonmedical reasons worsens mortality.[9-25] This uncertainty leads to prioritization without benefit to the patient or underuse of expeditious surgery that could prevent deaths. Some argued understanding of the effects of policy change should guide reorganization of operating room resources[26] and prioritization in the presence of competing demand.[7, 27-29] In this paper, we offer 2 new estimates: the effect of possible changes in surgical timing policy in the same population of patients and the proportion of in-hospital deaths attributable to surgical delays.

METHODS

Study approach

Using population-based data, we contrasted the risk of in-hospital death that would be expected (i.e., marginal risk[30]) if all patients who are medically stable at presentation were to undergo surgery on the day of admission, on inpatient day 2, on inpatient day 3, or after inpatient day 3. We obtained these risks by stratifying observations on confounders identified from an evidence-informed causal diagram,[31, 32] and weighting observations with the inverse propensity score of surgical timing for their respective strata.[33] We then combined the weighted observations across strata to construct equal-sized samples, each representing the same patient population treated on a certain day (Appendix 1).

Study population

The Canadian Institute for Health Information (CIHI) provided discharge abstracts for all patients who underwent hip fracture surgery between January 1, 2004, and December 31, 2012, except for those in Quebec.[22] We combined multiple abstracts related to transfers to account for time spent at nonsurgical sites.[34] We excluded patients with: conditions that could delay hip fracture surgery;[35] preoperative intensive care unit admission; more than 9 preoperative days (inconsistent with urgent nature of the procedure); surgery in a hospital with an annual volume of fewer than 24 hip fracture surgeries; or invalid discharge date. We identified abstracts with medical reasons for delay using diagnosis and procedure codes for anemia, anticoagulation, volume depletion, electrolyte imbalance, uncontrolled diabetes, uncontrolled heart failure, acute cardiac arrhythmia or ischemia, acute chest infection or exacerbation of a chronic chest condition.[36]

Outcome

The outcome was any death within 30 inpatient days after surgery, reported per 1,000 surgeries.[37] The accuracy of in-hospital death data has been validated previously.[38] We focused on in-hospital deaths to isolate the acute phase of hip fracture care, because variation in quality and continuity of care after discharge from hospital may lead to exposure to risk factors not related to the timing of surgery. Stays after 30 days were deemed nonacute hospitalization.[39]

Exposure

The exposure was the timing of surgery, grouped as the day of admission (reference), inpatient day 2, inpatient day 3, and after inpatient day 3.[40] These groups represent natural timing alternatives, because group membership was governed by the process of booking time in the operating room. Following the decision to operate, surgeons add patients' names to the list of procedures to be performed within 48 hours, or earlier if the patient has already been delayed by admission late in the day or transfer.[7] Hospital managers book patients in the order of their addition to the list within the requested urgency category. Most hospitals do not offer evening surgery, and booking may not take place until the next morning if patients arrived after hours (Appendix 2). Therefore, booking practices suggest access to surgery is an event occurring on a daily scale, rather than an hourly scale.

Selection of confounders

We used a causal diagram to select confounders, conditioning on which would be sufficient to render timing and mortality independent.[32] Figure 1 shows known dependencies among factors that influence the timing of surgery and the occurrence of death, either directly or through a chain of dependencies.[41] Using Figure 1, we identified the following factors: treatment era, hospital type, procedure type, age at admission, prefracture health status, and surgical readiness (Appendix 1).[42, 43]

Stratification

We constructed 64 (=2×2×2×2×4×1) multifactor strata on the basis of treatment era (2004–2007, 2008–2012), hospital type (teaching, community), procedure type (fixation, arthroplasty), age at admission (65–84 yr, ≥85 yr) and prefracture health status (admitted from home without comorbidity, admitted from home with comorbidity or with home care services, admitted from a long-term care facility, or admitted from elsewhere) (Supplemental Table 1). We considered the following comorbidity: cardiac dysrhythmias, chronic obstructive pulmonary disease, diabetes mellitus, heart failure, hypertension, ischemic heart disease (acute and chronic), identified by diagnostic codes from all hospital discharge abstracts in the year before the index admission. Needham and associates[44] reported substantial agreement between comorbidities in CIHI discharge abstracts and hospital charts. Surgical readiness contributed 1 category because we excluded patients whose discharge abstracts showed medically appropriate reasons for delay.

Statistical analysis

We estimated cumulative incidence of mortality accounting for the rate of live discharge.[45] Postoperative stays were treated as right-censored observations if they exceeded 30 days or if they ended with transfer to another acute care facility or with live discharge within 1 day after the surgery.[46] We estimated the marginal risk of death as a population average of observations weighted by inverse propensity score of surgical timing, calculated as the proportion of patients with a certain timing of surgery within their respective strata (Appendix 1). We estimated risk differences and odds ratios relative to surgery on the day of admission using the respective marginal risks.[47] Using the risk estimates for surgery performed within 2 inpatient days and for surgery performed later, we calculated the proportion of deaths that could be attributed to delaying surgery until after inpatient day 2, assuming all other contributing factors were distributed as in the study population.[42] No outcome, exposure or confounder data were missing.

In sensitivity analyses, we compared stratification-based and model-based estimates.[48] The stratification used fewer categories than available in our data for age, treatment year, comorbidity and hospital type to ensure a sufficient number of events per stratum. The variables for each model were identical with those in the stratification, but the number of categories for each variable corresponded to the observed data. For example, we entered a separate indicator variable for each comorbid condition into regression models. We performed all model-based analyses using Stata "teffects" package allowing for intra-hospital correlation among observations.[49] We used the Vanderweele-Arah method to assess whether an unmeasured confounder could explain the risk difference between timing alternatives.[50]

Ethics approval

The University of British Columbia Behavioral Research Ethics Board approved this study.

RESULTS

Characteristics of the study population

A total of 195,253 discharge abstracts were available for 154,389 patients treated at 188 hospitals between 2004 and 2012. After exclusions, the study population consisted of 139,119 patients aged 65 years or older who underwent surgery for nonpathologic first-time hip fracture at 38 teaching hospitals and 106 community hospitals (Supplemental Figure 1). Most of these patients were women (103,405 [74.3%]), and almost half were 85 years or older (63,786 [45.8%]). Just over half of the surgeries (72,285 [52.0%]) were performed because of a transcervical fracture, and 83,643 (60.1%) involved fixation (Table 1).

Surgical timing was distributed unevenly: 32,120 (23.1%) underwent surgery on the day of admission, 60,505 (43.5%) on inpatient day 2, 29,336 (21.0%) on day 3 and 17,258 (12.4%) after day 3, and varied significantly within the strata ($p<0.001$, Figure 2). Patients who underwent surgery soon after admission were less likely to have been admitted from home with comorbidity, were less likely to have been transferred, and were more likely to undergo fixation, with the percentage of patients who were transferred increasing and the percentage of patients with fixation declining as the time to surgery increased (Table 1).

By day 30 after surgery, 6,371 (4.6%) of the patients had died, and 89,782 (64.5%) had been discharged alive. For 17,336 (12.5%) of the patients the postoperative stay was longer than 30 days, and for 25,630 (18.4%) there was another censoring event. The mortality varied across the strata from 11.2 to 138.7 deaths per 1,000 surgeries.

In-hospital death by timing of surgery

There were 3,903 deaths after 92,625 surgeries performed on the day of admission or inpatient day 2 (42.1 deaths per 1,000 surgeries, 95% CI 40.8 to 43.4), and 2,468 deaths after 46,494 surgeries performed on a later day (53.1 deaths per 1,000 surgeries, 95% CI 51.0 to 55.1). The cumulative 30-day mortality was 48.9 deaths per 1,000 surgeries performed on the day of admission and 48.0 deaths per 1,000 surgeries performed on inpatient day 2 (Figure 3). For surgery performed later, the mortality was substantially higher: 57.0 deaths per 1,000 surgeries performed on inpatient day 3 and 69.1 deaths per 1,000 surgeries performed after inpatient day 3.

Risk difference for timing alternatives

Weighting by the inverse propensity score resulted in 4 hypothetical samples of equal size, with identical distribution of the stratification factors but distinct timing of surgery (Figure 4). Table 2 shows the risks of in-hospital death that would be expected if all patients in the study were to undergo surgery on a certain day: 43.3 (95% CI 40.9 to 45.6) deaths per 1,000 surgeries if all were performed on the day of admission, 42.6 (95% CI 41.0 to 44.3) deaths per 1,000 surgeries if all were performed on inpatient day 2, 49.0 (95% CI 46.5 to 51.6) deaths per 1,000 surgeries if all were performed on inpatient day 3, and 54.2 (95% CI, 50.8 to 57.7) deaths per 1,000 surgeries if all were performed after inpatient day 3.

Undergoing the procedure on inpatient day 2 rather than the day of admission did not change the risk of death: risk difference −0.6 (95% CI, −3.5 to 2.2) deaths per 1,000 surgeries. However, if all surgeries were performed on inpatient day 3 rather than the day of admission, there would be an additional 5.8 (95% CI, 2.3 to 9.2) deaths for every 1,000 surgeries; and the number of deaths would increase further, to 10.9 (95% CI, 6.8 to 15.1) deaths for every 1,000 surgeries, if all surgeries were performed after inpatient day 3 (Table 2).

Relative to surgery on the day of admission, the marginal odds ratios were 0.98 (95% CI, 0.92 to 1.05) for surgery performed on inpatient day 2, 1.14 (95% CI 1.05 to 1.23) for surgery on inpatient day 3, and 1.27 (95% CI 1.16 to 1.38) for surgery after inpatient day 3 (Table 2). The estimates were similar for different specifications of the model-based analysis (Supplemental Table 3). Among the 7,183 patients who would be expected to die if all surgeries were delayed beyond inpatient day 2, 16.5% (95% CI, 12.0% to 21.0%), or 1,221 deaths, could be attributed to not undergoing surgery earlier.

Effect of unmeasured confounding

We also considered the effects of an unmeasured confounder. For example, evening surgery might be 20% more prevalent among surgeries performed on the day of admission than among those performed after inpatient day 3, and might increase mortality by, say, 54.2 deaths per 1,000 surgeries. The latter figure is artificially high because it equals to the mortality for surgery after inpatient day 3. This increase implies that mortality almost doubles for evening surgery, if mortality for patients with daytime surgery equals that for operations performed on the day of admission, that is 42 deaths per 1,000 surgeries. We calculate that such unmeasured confounding would introduce a bias of 10.8 (=54.2×0.2) deaths per 1,000 surgeries, and therefore our estimate for the risk difference should be reduced to 0 (95% CI -4.1 to 4.1) deaths per 1,000 surgeries.[50] Alternatively, if evening surgery were to increase the risk of death by 20.9 deaths per 1,000 surgeries, then a bias of 4.2 (=20.9×0.2) would reduce the estimate to 6.7 (95% CI 2.3 to 10.8) deaths per 1,000 surgeries. We therefore conclude that a single unmeasured confounder could produce the observed mortality differences only if it increased the risk of death by a factor of 2. It seems unlikely that a single *unknown* factor could have an effect sufficiently large to account, on its own, for the observed difference in mortality between the study groups.

INTERPRETATION

Main findings

We estimated the extent to which in-hospital mortality might change if the timing of hip fracture surgery had been different for a given patient population. We projected an additional 11 deaths for every 1,000 surgeries if all patients considered in this study had undergone the operation after waiting 3 days or more, relative to surgery on the day of admission. The proportion of in-hospital deaths attributable to surgical delays beyond inpatient day 2 was estimated at 16.5%.

Comparison with previous literature

Lewis and Waddell[12] concluded that considerable variation in practice and inconsistent evidence leave uncertainty about the optimal timing of hip fracture surgery. Lizaur-Utrilla and associates[13] argued that there is no single timing of hip fracture repair that can be considered optimal for all, because of heterogeneity among patients, their injuries, and their care needs. In the current study, we were concerned with the effect of changes in the timing policy rather than with the etiological question of whether delays worsen mortality. We compared expected mortality for timing alternatives if they had been implemented for the same patient population. Our projections refer to the total effect of the timing alternatives; whether postoperative complications might explain the differences in mortality across these timing alternatives requires further investigation.[9]

Several authors have acknowledged their failure to address imbalance between timing groups in terms of baseline variables that might influence outcomes.[31, 51-53] Therefore, inconsistent findings may result from differences between various surgical timing groups.[54] We used an evidence-informed causal diagram to justify the selection of variables that would be sufficient to control for a spurious association between timing of surgery and mortality. However, there is still potential for unmeasured confounding, because the causal diagram includes only known factors and dependencies. Although our sensitivity analysis suggested that a single confounding factor could conceivably account for the between-group difference in mortality, such a factor would need to double the risk of postoperative death.

Limitations

We used administrative data, which might have led to misclassification of medical delays[36] and underreporting of comorbidity.[55] In particular, our data omit renal disease, cerebrovascular accident, and dementia, which may influence in-hospital mortality through increased risk of complications. Therefore, some observations in the group "admitted from home without comorbidity" might have been misclassified. However, the percentage of observations in this group was similar across the timing groups, while the percentage of "admitted from home with comorbidity" increased with time to surgery. The study population included only patients who underwent surgery; therefore, our analysis does not account for deaths that occurred before the surgery could be performed.[56] We studied delays occurring after admission to hospital; time between injury and arrival at the hospital and in the emergency department was not available.[57] It is possible the overall time from injury to surgery, and therefore exposure to immobilization and inflammation, was similar for inpatient day 1 and 2. We were unable to differentiate between surgeries performed during and after working hours, because the timing of surgery was not available on an hourly basis. Booking surgery to occur after hours would reduce time to surgery, but it might also worsen mortality, because of reduced staffing and surgical team fatigue. Given strategies to address surgical delays include increasing after-hours surgery, it will be important to study whether this approach produces better outcomes than waiting until the next day. We did not differentiate teaching hospitals of various sizes or rural and urban community hospitals; therefore, unobserved variation in care delivery across hospital types might have influenced both the timing of surgery and mortality. Finally, prefracture health status was characterized by a combination of comorbidity and preadmission residence.[58] Although preadmission residence reflects health care needs, local supply may also influence admission to a long-term care facility.[59]

Conclusion

Our findings allow to infer a critical point for the timing of hip fracture repair. We suggest that all medically stable older adults with hip fracture undergo surgery on the day of their admission to hospital or the following day. This approach places the emphasis of managerial efforts on expediting operating room access for patients whose surgery might be delayed for nonmedical reasons.

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TABLES

Table 1. Baseline characteristics of patients by timing of surgery

			Timing of surgery; no (%) of patients							
Characteristic	All patients (n = 139,119)‡‡		Admission day (n = 32,120)		Inpatient day 2 (n = 60,505)		Inpatient day 3 (n = 29,236)		After three days (n = 17,258)	
Age, yr										
65–74	20,827	(15.0)	5,112	(15.9)	8,997	(14.9)	4,223	(14.4)	2,495	(14.5)
75–84	54,506	(39.2)	12,499	(38.9)	23,701	(39.2)	11,475	(39.2)	6,831	(39.6)
85–94	56,353	(40.5)	12,743	(39.7)	24,514	(40.5)	12,032	(41.2)	7,064	(40.9)
≥ 95	7,433	(5.3)	1,766	(5.5)	3,293	(5.4)	1,506	(5.2)	868	(5.0)
Sex*										
Women	103,405	(74.3)	24,245	(75.5)	45,393	(75.0)	21,480	(73.5)	12,287	(71.2)
Men	35,699	(25.7)	7,873	(24.5)	15,106	(25.0)	7,754	(26.5)	4,966	(28.8)
Prefracture health status										
Home without comorbidity	62,291	(44.8)	14,534	(45.2)	27,655	(45.7)	13,024	(44.5)	7,078	(41.0)
Home with comorbidity†	18,275	(13.1)	3,247	(10.1)	7,048	(11.6)	4,475	(15.3)	3,505	(20.3)
Home care	3,295	(2.4)	680	(2.1)	1,521	(2.5)	711	(2.4)	383	(2.2)
Long-term care facility	29,258	(21.0)	6,755	(21.0)	12,816	(21.2)	6,164	(21.1)	3,523	(20.4)
Elsewhere	26,000	(18.7)	6,904	(21.5)	11,465	(18.9)	4,862	(16.6)	2,769	(16.0)
Comorbidity‡										
Cardiac dysrhythmias	11,220	(8.1)	1,823	(5.7)	4,190	(6.9)	2,941	(10.1)	2,266	(13.1)
COPD	4,765	(3.4)	993	(3.1)	1,937	(3.2)	1,020	(3.5)	815	(4.7)
Diabetes mellitus	4,738	(3.4)	875	(2.7)	1,892	(3.1)	1,092	(3.7)	879	(5.1)
Heart failure	9,198	(6.6)	1,585	(4.9)	3,359	(5.6)	2,244	(7.7)	2,010	(11.6)
Hypertension	7,267	(5.2)	1,442	(4.5)	2,976	(4.9)	1,677	(5.7)	1,172	(6.8)
IHD, acute	6,664	(4.8)	1,267	(3.9)	2,702	(4.5)	1,453	(5.0)	1,242	(7.2)
IHD, chronic	1,912	(1.4)	361	(1.1)	695	(1.1)	443	(1.5)	413	(2.4)
Hospital type§										
Teaching	54,212	(39.0)	8,189	(25.5)	23,335	(38.6)	14,182	(48.5)	8,506	(49.3)
Community large	63,975	(46.0)	17,078	(53.2)	28,322	(46.8)	11,925	(40.8)	6,650	(38.5)
Community medium	19,513	(14.0)	6,541	(20.4)	8,221	(13.6)	2,875	(9.8)	1,876	(10.9)
Annual hospital volume¶										
Lower for its type	34,231	(24.6)	9,044	(28.2)	14,697	(24.3)	6,712	(23.0)	3,778	(21.9)
Higher for its type	104,888	(75.4)	23,076	(71.8)	45,808	(75.7)	22,524	(77.0)	13,480	(78.1)
Timing of admission**										
Weekday 12 am to 06:59 am	15,020	(10.8)	6,763	(21.1)	4,969	(8.2)	2,074	(7.1)	1,214	(7.0)
Weekday 7 am to 3:59 pm	32,217	(23.2)	10,486	(32.6)	12,681	(21.0)	5,602	(19.2)	3,448	(20.0)
Weekday 4 pm to 11:59 pm	53,039	(38.1)	4,785	(14.9)	25,245	(41.7)	14,864	(50.8)	8,145	(47.2)
Weekend	38,777	(27.9)	10,073	(31.4)	17,591	(29.1)	6,669	(22.8)	4,444	(25.8)
Admission status										
Urgent or emergent	136,586	(98.2)	31,294	(97.4)	59,440	(98.2)	28,834	(98.6)	17,018	(98.6)
Otherwise	2,533	(1.8)	826	(2.6)	1,065	(1.8)	402	(1.4)	240	(1.4)
Surgical demand††										
Excess demand	96,834	(69.6)	22,326	(69.5)	41,724	(69.0)	20,518	(70.2)	12,266	(71.1)
Otherwise	42,285	(30.4)	9,794	(30.5)	18,781	(31.0)	8,718	(29.8)	4,992	(28.9)
Transfer history										
No	127,812	(91.9)	31,679	(98.6)	57,352	(94.8)	25,660	(87.8)	13,121	(76.0)
Yes	11,307	(8.1)	441	(1.4)	3,153	(5.2)	3,576	(12.2)	4,137	(24.0)
Preoperative procedures										

No	125,297	(90.1)	29,655	(92.3)	55,225	(91.3)	25,997	(88.9)	14,420	(83.6)
Yes	13,822	(9.9)	2,465	(7.7)	5,280	(8.7)	3,239	(11.1)	2,838	(16.4)
Fracture type										
Transcervical	72,285	(52.0)	16,075	(50.0)	31,101	(51.4)	15,607	(53.4)	9,502	(55.1)
Inter- or sub-trochanteric	66,834	(48.0)	16,045	(50.0)	29,404	(48.6)	13,629	(46.6)	7,756	(44.9)
Procedure type										
Fixation	83,643	(60.1)	20,208	(62.9)	36,908	(61.0)	16,869	(57.7)	9,658	(56.0)
Arthroplasty	55,476	(39.9)	11,912	(37.1)	23,597	(39.0)	12,367	(42.3)	7,600	(44.0)
Year of surgery										
2004–2006	46,563	(33.5)	11,476	(35.7)	20,047	(33.1)	9,088	(31.1)	5,952	(34.5)
2007–2009	45,746	(32.9)	10,593	(33.0)	19,168	(31.7)	9,713	(33.2)	6,272	(36.3)
2010–2012	46,810	(33.6)	10,051	(31.3)	21,290	(35.2)	10,435	(35.7)	5,034	(29.2)
Province										
Alberta	15,281	(11.0)	3,076	(9.6)	7,008	(11.6)	3,415	(11.7)	1,782	(10.3)
British Columbia	26,774	(19.2)	5,813	(18.1)	12,375	(20.5)	5,830	(19.9)	2,756	(16.0)
Manitoba	7,636	(5.5)	1,315	(4.1)	3,673	(6.1)	1,540	(5.3)	1,108	(6.4)
New Brunswick	4,774	(3.4)	1,663	(5.2)	1,877	(3.1)	732	(2.5)	502	(2.9)
Newfoundland and Labrador	3,155	(2.3)	748	(2.3)	1,341	(2.2)	717	(2.5)	349	(2.0)
Nova Scotia	5,985	(4.3)	1,917	(6.0)	2,174	(3.6)	1,022	(3.5)	872	(5.1)
Ontario	67,119	(48.2)	16,260	(50.6)	28,390	(46.9)	14,030	(48.0)	8,439	(48.9)
Prince Edward Island	1,028	(0.7)	366	(1.1)	363	(0.6)	184	(0.6)	115	(0.7)
Saskatchewan	7,367	(5.3)	962	(3.0)	3,304	(5.5)	1,766	(6.0)	1,335	(7.7)

Note: COPD = chronic obstructive pulmonary disease; IHD = ischemic heart disease.

*For 15 patients, sex was unknown.

†The level of care of the facility from which the patient was transferred was identified by "the institution from type" field in the hospital discharge abstracts. Comorbidity is represented by an indicator variable for any of the coexisting conditions listed in the "Comorbidity" section of this table.

‡Based on diagnostic codes from all hospital discharge abstracts in the year before the index admission.

§For 1,419 patients, hospital type was unavailable.

¶We dichotomized hospitals into higher and lower volume categories by comparing their annual volumes in the year of index surgery with the median of average annual volumes among hospitals of the same type (174 surgeries for teaching hospitals, 141 for community large hospitals, 37 for community medium hospitals) [60, 61]

**For 66 patients, admission time was unknown.

††The number of admissions in the week of the index admission compared with the hospital's weekly capacity.

‡‡Based on codes for hip fracture surgery from either the Canadian Classification of Interventions (1VA74^^, 1VA53^^, 1VC74^^, 1SQ53^^), or the Canadian Classification of Procedures (9054, 9114, 9134, 9351, 9359, 9361, 9362, 9363, 9364, 9369).

Table 2: Marginal risks, risk differences and odds ratios for timing alternatives

	Timing alternatives, estimate (95% CI)			
Measure	Admission day	Inpatient day 2	Inpatient day 3	After 3 days
Risk per 1000 surgeries*	43.3 (40.9 to 45.6)	42.6 (41.0 to 44.3)	49.0 (46.5 to 51.6)	54.2 (50.8 to 57.7)
Risk difference per 1000 surgeries	–	−0.6 (−3.5 to 2.2)	5.8 (2.3 to 9.2)	10.9 (6.8 to 15.1)
Odds ratio	1.00	0.98 (0.92 to 1.05)	1.14 (1.05 to 1.23)	1.27 (1.16 to 1.38)

Note: CI = confidence interval.

*For each timing alternative, the population-average risk of in-hospital death was estimated by weighting observations with the inverse propensity score of surgical timing within the strata that were defined according to confounders selected from a causal diagram, see Supplemental Table 2.

FIGURES

Figure 1: Dependencies among factors involved in producing the association between timing of surgery and in-hospital death after hip fracture.

Orange nodes represent the following factors that influence both timing of surgery and occurrence of death through chains of dependencies (orange arrows): treatment era, hospital type, procedure type, age at admission, prefracture health status, and surgical readiness. Conditioning on these factors was sufficient to block all influences that might have produced the putative association between time to surgery and occurrence of death (green dashed arrow).[43] The dependency graph was adapted from Sheehan and associates[62] to reflect recent publications, adding new nodes (patient preference[63] and prefracture health status[58]) and the following dependencies: between hospital type and socioeconomic status (SES),[64] between prefracture health and SES,[65] between resource availability and patient preference,[63] and between complications and surgeon skills.[66] LOS = length of stay.

Figure 2: Distribution of surgical timing within strata.

Shown are the observed proportions of surgeries by inpatient day (day 1 is dark blue, after inpatient day 3 is light blue) within the 64 strata. These proportions were used to calculate non-parametrically the propensity of being sampled with a certain timing of surgery within respective strata.

Figure 3: Cumulative incidence of in-hospital death, by observed timing of surgery.

Figure 4. Application of inverse propensity scores of surgical timing to the number observations in various strata.

Shown are bars representing the weighted number of surgeries across the 64 multifactor strata. Within each bar, dots show the weighted number of deaths for each timing of surgery. Data are shown on a logarithmic scale to accommodate the range of values. The right panel shows the number of deaths in all strata combined representing postoperative in-hospital mortality that would be expected if all patients in the study were to undergo surgery on the day of admission, on inpatient day 2, on inpatient day 3, or after inpatient day 3.

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MORTALITY EFFECTS OF TIMING ALTERNATIVES

FOR HIP FRACTURE SURGERY

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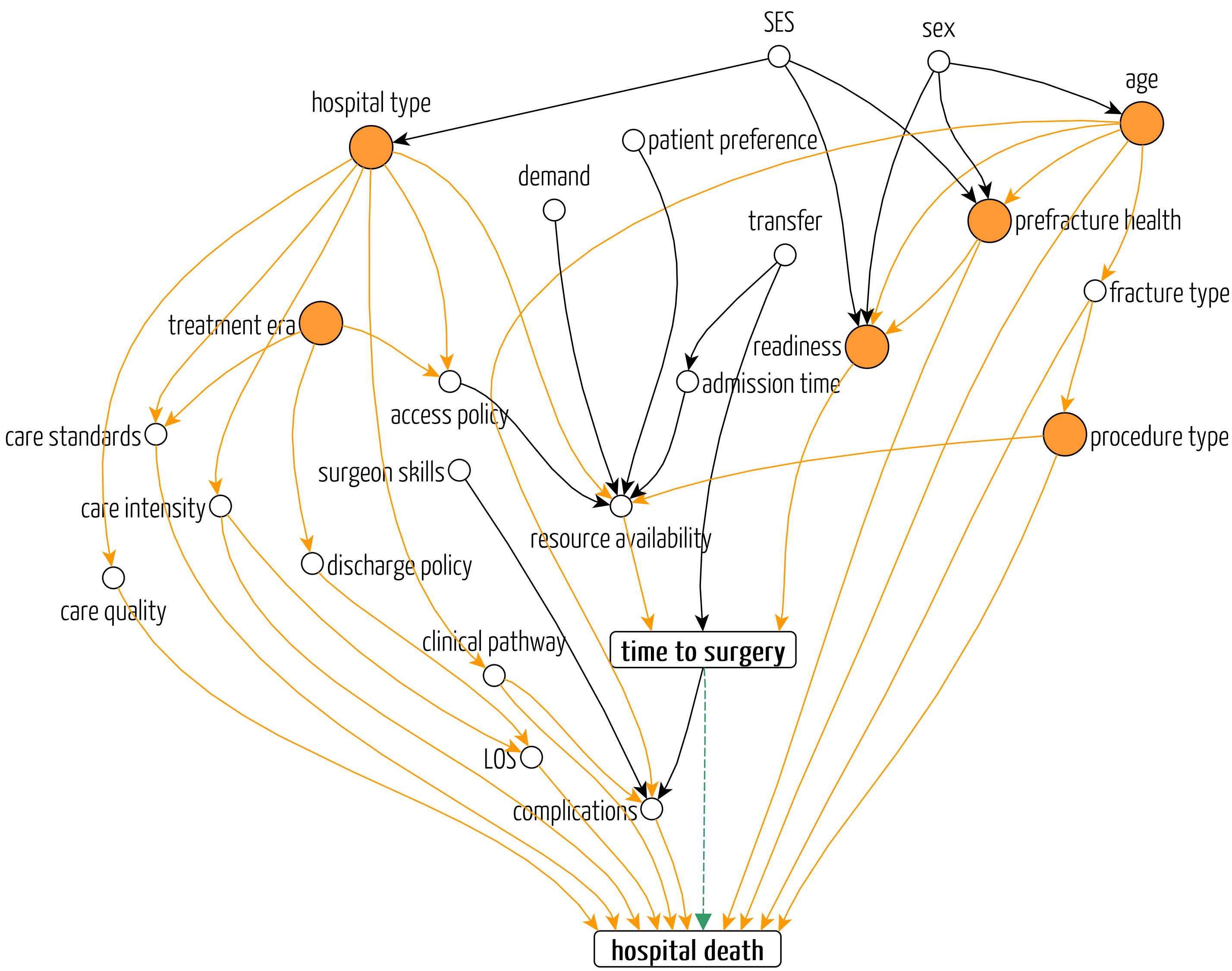
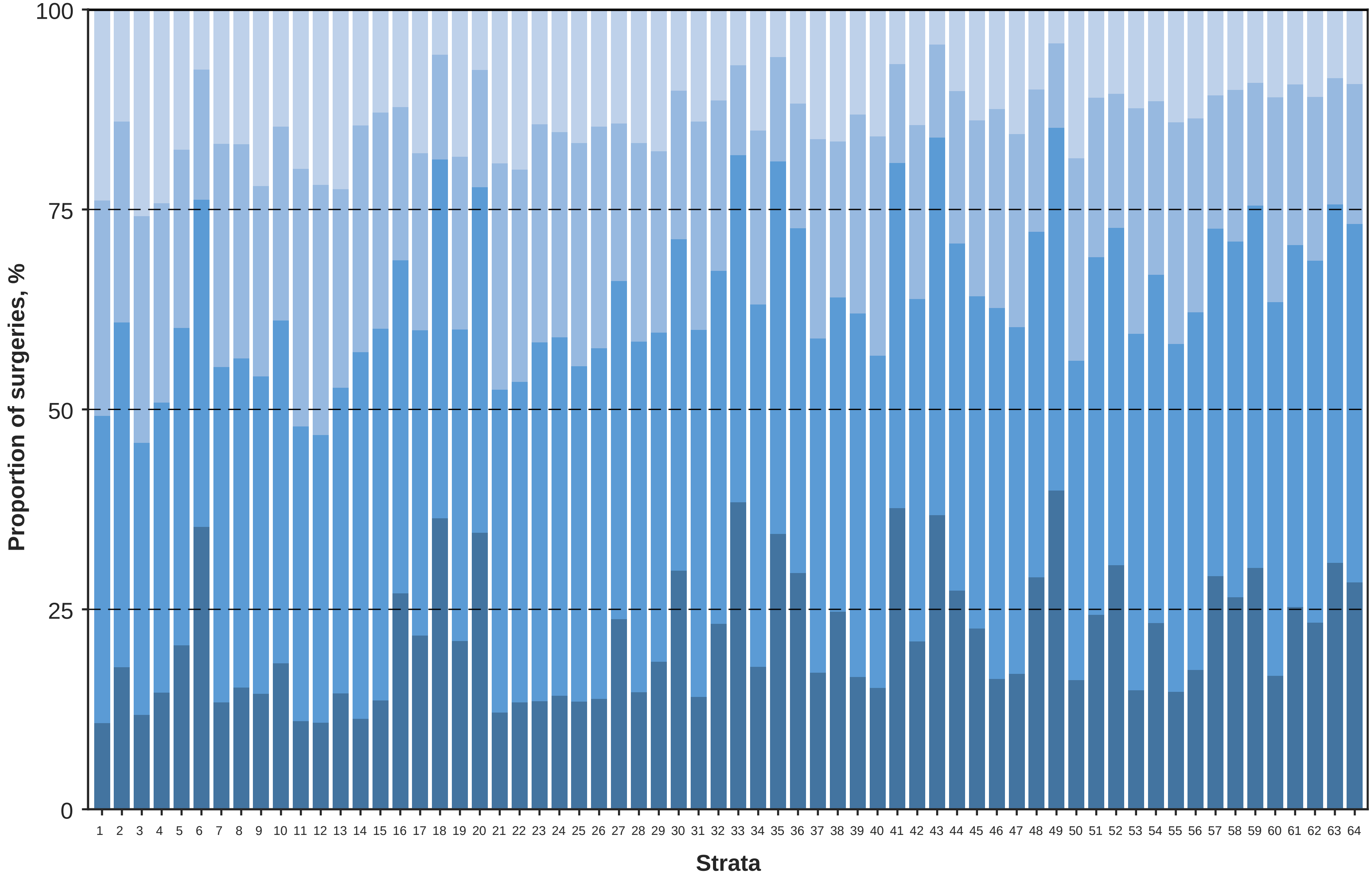
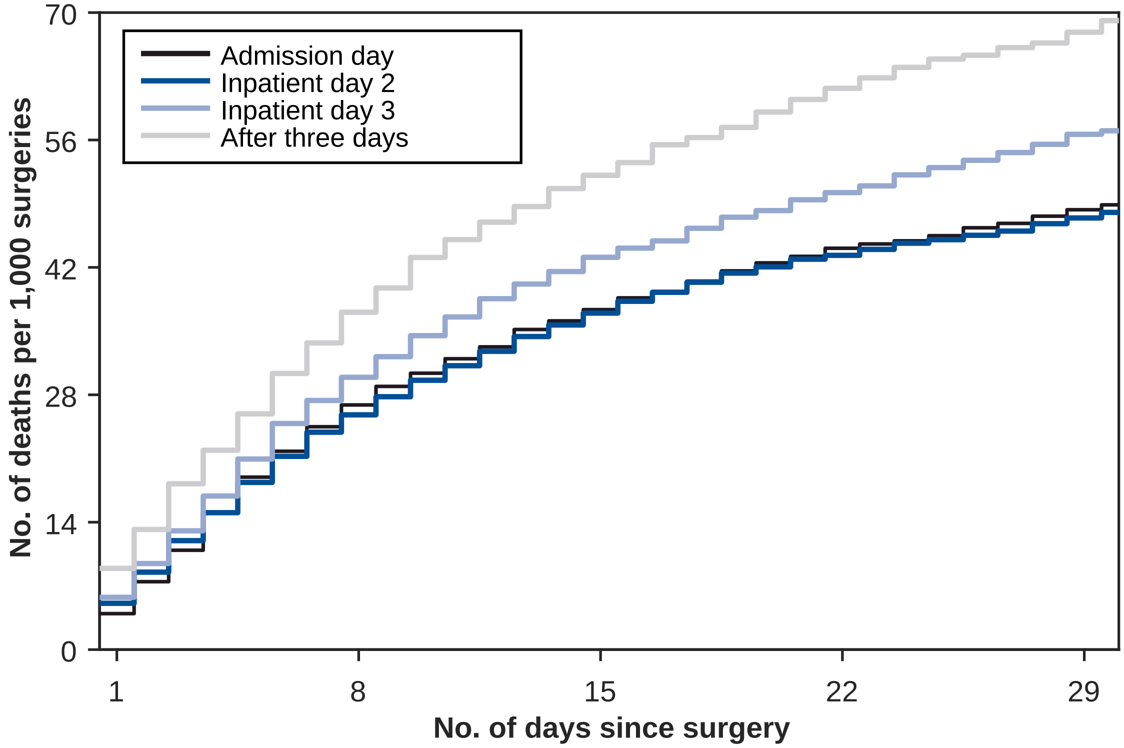

SES
sex
age
hospital type
patient preference
demand
transfer
prefracture health
fracture type
treatment era
readiness
admission time
access policy
care standards
procedure type
surgeon skills
care intensity
resource availability
discharge policy
care quality
clinical pathway
time to surgery
LOS
complications
hospital death



100
75
50
25
0
Proportion of surgeries, %
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
Strata


Admission day
Inpatient day 2
Inpatient day 3
After three days
No. of deaths per 1,000 surgeries
70
56
42
28
14
0
1
8
15
22
29
No. of days since surgery

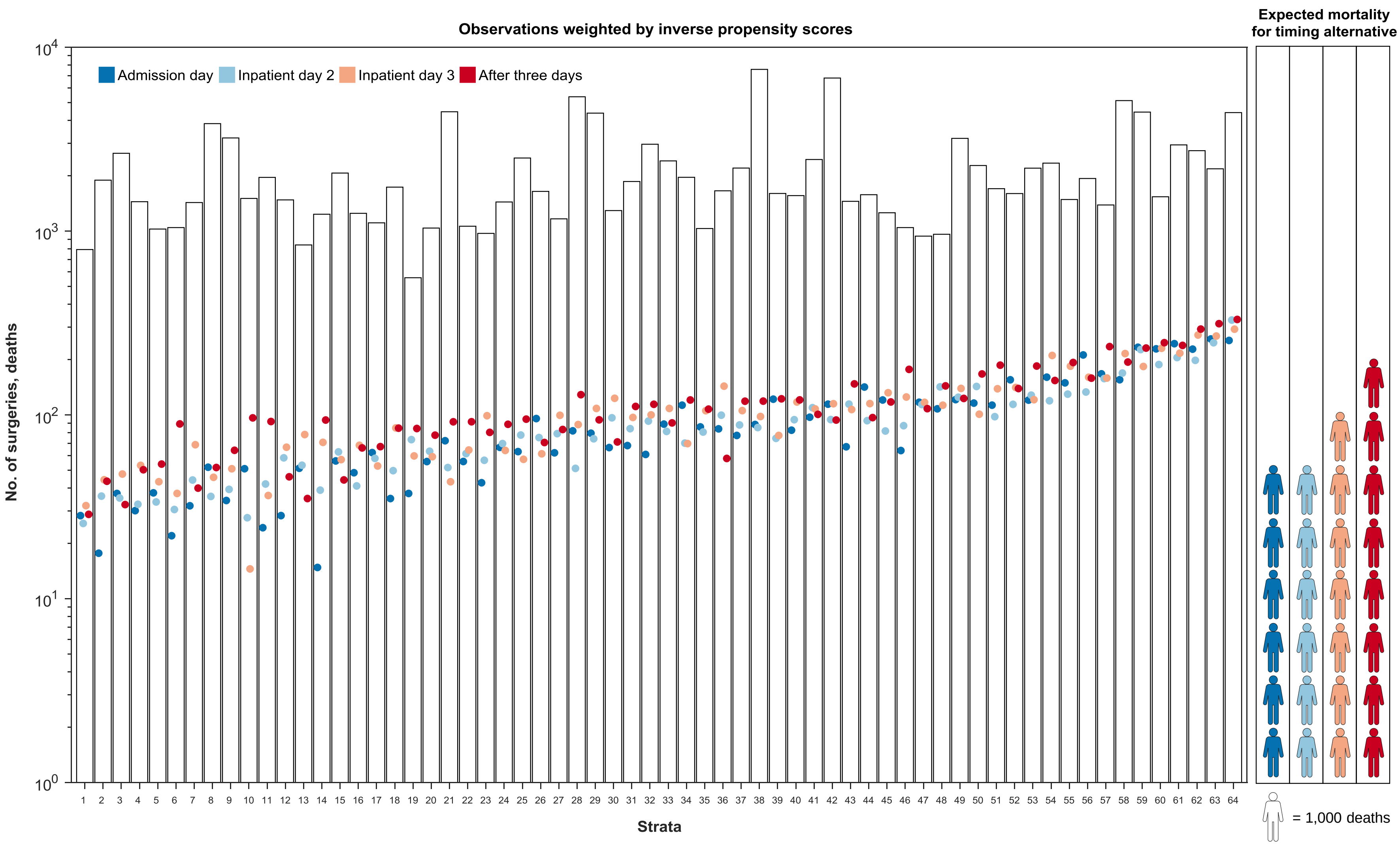

Observations weighted by inverse propensity scores
Expected mortality for timing alternative
Admission day
Inpatient day 2
Inpatient day 3
After three days
No. of surgeries, deaths
10^4
10^3
10^2
10^1
10^0
Strata
= 1,000 deaths

Table 1. Baseline characteristics of patients by timing of surgery

			Timing of surgery; no (%) of patients							
Characteristic	All patients (n = 139,119)		Admission day (n = 32,120)		Inpatient day 2 (n = 60,505)		Inpatient day 3 (n = 29,236)		After three days (n = 17,258)	
Age, yr										
65–74	20,827	(15.0)	5,112	(15.9)	8,997	(14.9)	4,223	(14.4)	2,495	(14.5)
75–84	54,506	(39.2)	12,499	(38.9)	23,701	(39.2)	11,475	(39.2)	6,831	(39.6)
85–94	56,353	(40.5)	12,743	(39.7)	24,514	(40.5)	12,032	(41.2)	7,064	(40.9)
≥ 95	7,433	(5.3)	1,766	(5.5)	3,293	(5.4)	1,506	(5.2)	868	(5.0)
Sex*										
Women	103,405	(74.3)	24,245	(75.5)	45,393	(75.0)	21,480	(73.5)	12,287	(71.2)
Men	35,699	(25.7)	7,873	(24.5)	15,106	(25.0)	7,754	(26.5)	4,966	(28.8)
Prefracture health status										
Home without comorbidity	62,291	(44.8)	14,534	(45.2)	27,655	(45.7)	13,024	(44.5)	7,078	(41.0)
Home with comorbidity†	18,275	(13.1)	3,247	(10.1)	7,048	(11.6)	4,475	(15.3)	3,505	(20.3)
Home care	3,295	(2.4)	680	(2.1)	1,521	(2.5)	711	(2.4)	383	(2.2)
Long-term care facility	29,258	(21.0)	6,755	(21.0)	12,816	(21.2)	6,164	(21.1)	3,523	(20.4)
Elsewhere	26,000	(18.7)	6,904	(21.5)	11,465	(18.9)	4,862	(16.6)	2,769	(16.0)
Comorbidity‡										
Cardiac dysrhythmias	11,220	(8.1)	1,823	(5.7)	4,190	(6.9)	2,941	(10.1)	2,266	(13.1)
COPD	4,765	(3.4)	993	(3.1)	1,937	(3.2)	1,020	(3.5)	815	(4.7)
Diabetes mellitus	4,738	(3.4)	875	(2.7)	1,892	(3.1)	1,092	(3.7)	879	(5.1)
Heart failure	9,198	(6.6)	1,585	(4.9)	3,359	(5.6)	2,244	(7.7)	2,010	(11.6)
Hypertension	7,267	(5.2)	1,442	(4.5)	2,976	(4.9)	1,677	(5.7)	1,172	(6.8)
IHD, acute	6,664	(4.8)	1,267	(3.9)	2,702	(4.5)	1,453	(5.0)	1,242	(7.2)
IHD, chronic	1,912	(1.4)	361	(1.1)	695	(1.1)	443	(1.5)	413	(2.4)
Hospital type§										
Teaching	54,212	(39.0)	8,189	(25.5)	23,335	(38.6)	14,182	(48.5)	8,506	(49.3)
Community large	63,975	(46.0)	17,078	(53.2)	28,322	(46.8)	11,925	(40.8)	6,650	(38.5)
Community medium	19,513	(14.0)	6,541	(20.4)	8,221	(13.6)	2,875	(9.8)	1,876	(10.9)
Annual hospital volume										
Lower for its type¶	34,231	(24.6)	9,044	(28.2)	14,697	(24.3)	6,712	(23.0)	3,778	(21.9)
Higher for its type	104,888	(75.4)	23,076	(71.8)	45,808	(75.7)	22,524	(77.0)	13,480	(78.1)
Timing of admission††										
Weekday 12 am to 06:59 am	15,020	(10.8)	6,763	(21.1)	4,969	(8.2)	2,074	(7.1)	1,214	(7.0)
Weekday 7 am to 3:59 pm	32,217	(23.2)	10,486	(32.6)	12,681	(21.0)	5,602	(19.2)	3,448	(20.0)
Weekday 4 pm to 11:59 pm	53,039	(38.1)	4,785	(14.9)	25,245	(41.7)	14,864	(50.8)	8,145	(47.2)
Weekend	38,777	(27.9)	10,073	(31.4)	17,591	(29.1)	6,669	(22.8)	4,444	(25.8)
Admission status										
Urgent or emergent	136,586	(98.2)	31,294	(97.4)	59,440	(98.2)	28,834	(98.6)	17,018	(98.6)
Otherwise	2,533	(1.8)	826	(2.6)	1,065	(1.8)	402	(1.4)	240	(1.4)
Surgical demand**										
Excess demand	96,834	(69.6)	22,326	(69.5)	41,724	(69.0)	20,518	(70.2)	12,266	(71.1)
Otherwise	42,285	(30.4)	9,794	(30.5)	18,781	(31.0)	8,718	(29.8)	4,992	(28.9)
Transfer history										
No	127,812	(91.9)	31,679	(98.6)	57,352	(94.8)	25,660	(87.8)	13,121	(76.0)
Yes	11,307	(8.1)	441	(1.4)	3,153	(5.2)	3,576	(12.2)	4,137	(24.0)
Preoperative procedures										
No	125,297	(90.1)	29,655	(92.3)	55,225	(91.3)	25,997	(88.9)	14,420	(83.6)
Yes	13,822	(9.9)	2,465	(7.7)	5,280	(8.7)	3,239	(11.1)	2,838	(16.4)
Fracture type										

Transcervical	72,285	(52.0)	16,075	(50.0)	31,101	(51.4)	15,607	(53.4)	9,502	(55.1)
Inter- or sub-trochanteric	66,834	(48.0)	16,045	(50.0)	29,404	(48.6)	13,629	(46.6)	7,756	(44.9)
Procedure type										
Fixation	83,643	(60.1)	20,208	(62.9)	36,908	(61.0)	16,869	(57.7)	9,658	(56.0)
Arthroplasty	55,476	(39.9)	11,912	(37.1)	23,597	(39.0)	12,367	(42.3)	7,600	(44.0)
Year of surgery										
2004–2006	46,563	(33.5)	11,476	(35.7)	20,047	(33.1)	9,088	(31.1)	5,952	(34.5)
2007–2009	45,746	(32.9)	10,593	(33.0)	19,168	(31.7)	9,713	(33.2)	6,272	(36.3)
2010–2012	46,810	(33.6)	10,051	(31.3)	21,290	(35.2)	10,435	(35.7)	5,034	(29.2)
Province										
Alberta	15,281	(11.0)	3,076	(9.6)	7,008	(11.6)	3,415	(11.7)	1,782	(10.3)
British Columbia	26,774	(19.2)	5,813	(18.1)	12,375	(20.5)	5,830	(19.9)	2,756	(16.0)
Manitoba	7,636	(5.5)	1,315	(4.1)	3,673	(6.1)	1,540	(5.3)	1,108	(6.4)
New Brunswick	4,774	(3.4)	1,663	(5.2)	1,877	(3.1)	732	(2.5)	502	(2.9)
Newfoundland and Labrador	3,155	(2.3)	748	(2.3)	1,341	(2.2)	717	(2.5)	349	(2.0)
Nova Scotia	5,985	(4.3)	1,917	(6.0)	2,174	(3.6)	1,022	(3.5)	872	(5.1)
Ontario	67,119	(48.2)	16,260	(50.6)	28,390	(46.9)	14,030	(48.0)	8,439	(48.9)
Prince Edward Island	1,028	(0.7)	366	(1.1)	363	(0.6)	184	(0.6)	115	(0.7)
Saskatchewan	7,367	(5.3)	962	(3.0)	3,304	(5.5)	1,766	(6.0)	1,335	(7.7)

Note: COPD = chronic obstructive pulmonary disease; IHD = ischemic heart disease.

*For 15 patients, sex was unknown.

†The level of care of the facility from which the patient was transferred was identified by “the institution from type” field in the hospital discharge abstracts. Comorbidity is represented by an indicator variable for any of the coexisting conditions listed in the “Comorbidity” section of this table.

‡Based on diagnostic codes from all hospital discharge abstracts in the year before the index admission.

§For 1,419 patients, hospital type was unavailable.

¶‖Lower surgical volume was defined as fewer than 174 surgeries per year for teaching hospitals, fewer than 141 surgeries per year for large community hospitals, and fewer than 37 surgeries per year for medium-size community hospitals.

**For 66 patients, admission time was unknown.

††The number of admissions in the week of the index admission compared with the hospital’s weekly capacity.

Table 2: Marginal risks, risk differences and odds ratios for timing alternatives

	Timing alternatives, estimate (95% CI)			
Measure	Admission day	Inpatient day 2	Inpatient day 3	After 3 days
Risk per 1000 surgeries*	43.3 (40.9 to 45.6)	42.6 (41.0 to 44.3)	49.0 (46.5 to 51.6)	54.2 (50.8 to 57.7)
Risk difference per 1000 surgeries	–	−0.6 (−3.5 to 2.2)	5.8 (2.3 to 9.2)	10.9 (6.8 to 15.1)
Odds ratio	1.00	0.98 (0.92 to 1.05)	1.14 (1.05 to 1.23)	1.27 (1.16 to 1.38)

Note: CI = confidence interval.

*For each timing alternative, the population-average risk of in-hospital death was estimated by weighting observations with the inverse propensity score of surgical timing within strata that were defined according to confounders selected from a causal diagram.