Timing of Adverse Events Following Geriatric Hip Fracture Surgery: A Study of 19,873 Patients in the American College of Surgeons National Surgical Quality Improvement Program

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Take-Home Points

- The median postoperative day of diagnosis for myocardial infarction was 3, 3 for cardiac arrest requiring cardiopulmonary resuscitation, 3 for stroke, 4 for pneumonia, 4 for pulmonary embolism, 7 for urinary tract infection, 9 for deep vein thrombosis, 9 for sepsis, 11 for mortality, and 16 for surgical site infection.
- For the earliest diagnosed adverse events, the rate of adverse events had diminished by postoperative day 30; however, for the later diagnosed adverse events, the rate of adverse events remained high at postoperative day 30.
- The proportions of adverse events diagnosed prior to discharge were 81.0% for myocardial infarction, 77.8% for stroke, 76.1% for cardiac arrest requiring cardiopulmonary resuscitation, 71.9% for pulmonary embolism, 71.1% for pneumonia, 58.0% for urinary tract infection, 52.1% for sepsis, 46.9% for deep vein thrombosis, 44.3% for mortality, and 27.6% for surgical site infection.
These results facilitate targeted clinical surveillance, guide patient counseling, and inform the duration of follow-up required in research studies.

Clinicians should have the lowest threshold for testing for each adverse event during the time period of greatest risk.

Geriatric hip fracture surgery is associated with a higher rate of occurrence of postoperative adverse events than any other commonly performed orthopedic procedure. Indeed, the 90-day mortality rate following a geriatric hip fracture surgery may be as high as 15% and the 30-day morbidity rate as high as 30%. Furthermore, more than half of postoperative mortalities following orthopedic procedures occur after surgery for hip fracture. Therefore, extensive research has been conducted regarding interventions to reduce the rates of adverse events following a hip fracture surgery. For example, randomized trials have been conducted involving venous thromboembolism prophylaxis, nutritional supplementation, delirium prevention, anemia correction, geriatrics consultation, and anesthetic technique.

Despite these extensive research efforts, there is currently little information in the literature regarding when postoperative adverse events occur. A clear depiction of the timing of adverse events could help target clinical surveillance, inform patient counseling, and determine the duration of follow-up required for studies. The reason that the timing of adverse events has not been previously characterized may be that the sample sizes available through standard single- or multi-institutional studies may be insufficient to accurately characterize the timing of rare adverse events (eg, myocardial infarction, stroke, etc.). Moreover, although administrative datasets have become common data sources for investigation of rare postoperative adverse events, such data sources often do not contain data on the timing of diagnosis.

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) is a relatively new and growing surgical registry. The registry follows up patients undergoing surgical procedures at several hundred community and academic institutions nationwide. Unlike the administrative datasets discussed above, the ACS-NSQIP characterizes the postoperative day of diagnosis of well-defined adverse events during the first 30 postoperative days.

In this study, data collected by the ACS-NSQIP are used to characterize the timing of 10 specific postoperative adverse events following a geriatric hip fracture surgery.

**Methods**

A retrospective analysis of data collected prospectively through the ACS-NSQIP was conducted. Geriatric patients who underwent hip fracture surgery during 2010 to 2013 were identified. Specific inclusion criteria were (1) International Classification of Diseases, Ninth Revision, diagnosis code 820, (2) primary Current Procedural Terminology codes 27125, 27130, 27235, 27236, 27244, or 27245, and (3) age ≥70 years.

The ACS-NSQIP captures patient demographic, comorbidity, and procedural characteristics at baseline. At the end of the 30-day follow-up period, the ACS-NSQIP personnel review both inpatient and outpatient charts to characterize the occurrence vs nonoccurrence of specific postoperative adverse events. When an adverse event does occur, the postoperative day of diagnosis is recorded.

For this study, the following adverse event categories were investigated: myocardial infarction, cardiac arrest requiring cardiopulmonary resuscitation, stroke, pneumonia, pulmonary embolism, urinary tract infection, deep vein thrombosis, sepsis (either with or without shock), mortality, and surgical site infection (including superficial
surgical site infection, deep surgical site infection, and organ or space surgical site infection). Detailed definitions of each adverse event are provided in ACS-NSQIP materials.22

First, the 30-day incidence (and the associated 95% confidence interval) was determined for each adverse event. Second, the median postoperative day of diagnosis (and the associated interquartile range) was determined for each adverse event. Third, the postoperative length of stay was used to estimate the proportion of diagnoses occurring prior to vs following discharge for each adverse event. Finally, multivariate Cox proportional hazards models were used to identify independent risk factors for earlier occurrence of postoperative adverse events. The final models were selected using a backward stepwise process that sequentially eliminated variables with the weakest associations until all variables had \( P < .05 \).

Because the ACS-NSQIP reports timing data in calendar days, when the postoperative length of stay was equivalent to the postoperative day of diagnosis, it was not possible to ascertain whether the diagnosis occurred prior to or following discharge. For this study, when the postoperative length of stay was equivalent to the postoperative day of diagnosis, the adverse event was considered to have been diagnosed following discharge. The rationale for this is that for most of the adverse events, it was thought to be unlikely that an inpatient would be discharged before the end of the same day as an inpatient diagnosis. However, there was one exception to this rule; when the postoperative day of discharge, the postoperative length of stay, and the postoperative day of death were all equivalent, the adverse event was considered to have occurred prior to discharge. This is because when a patient dies during the initial inpatient stay, the ACS-NSQIP considers the postoperative length of stay to be equivalent to the postoperative day of death. This makes it much more likely that a diagnosis on the final hospital day had occurred in a patient who had not been discharged.

The mandatory ACS-NSQIP statement is “The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS-NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.”26

**Results**

In total, 19,873 geriatric patients undergoing a hip fracture surgery were identified (Table 1). The rates of adverse events ranged from 6.7% for urinary tract infection to 0.6% for pulmonary embolism (Table 2).

**Figure 1** depicts the timing of postoperative adverse events in detail in histograms and timing curves. For the earliest diagnosed adverse events, the rate of adverse events had diminished by postoperative day 30. For the later diagnosed adverse events, the rate of adverse events remained high at postoperative day 30.

**Figure 2** provides the summary statistics for adverse events diagnosed in the first 30 postoperative days. The median postoperative day of diagnosis (and the interquartile range) was 3 (1-5) for myocardial infarction, 3 (0-8) for cardiac arrest requiring cardiopulmonary resuscitation, 3 (1-10) for stroke, 4 (2-10) for pneumonia, 4 (2-11) for pulmonary embolism, 7 (2-13) for urinary tract infection, 9 (4-16) for deep vein thrombosis, 9 (4-18) for sepsis, 11 (6-19) for mortality, and 16 (11-22) for surgical site infection.

**Figure 3** depicts the timing of adverse events relative to discharge. The proportions of adverse events diagnosed prior to discharge were 81.0% for myocardial infarction, 77.8% for stroke, 76.1% for cardiac arrest requiring cardiopulmonary resuscitation, 71.9% for pulmonary embolism, 71.1% for pneumonia, 58.0% for urinary tract infection, 52.1% for sepsis, 46.9% for deep vein thrombosis, 44.3% for mortality, and 27.6% for surgical site infection.
Table 3 shows the independent risk factors for earlier occurrence of adverse events. Following multivariate stepwise selection of final models, at least 1 patient characteristic was independently associated with the timing of cardiac arrest, stroke, urinary tract infection, deep vein thrombosis, and death. In contrast, no patient characteristics were independently associated with the timing of myocardial infarction, pneumonia, pulmonary embolism, sepsis, and surgical site infection.

**Discussion**

Adverse events are extremely common following a geriatric hip fracture surgery.\(^1\)\(^-\)\(^4\) Despite extensive investigation regarding methods to prevent these events,\(^5\)\(^-\)\(^12\) there is limited published description of the timing at which such events occur. This study used a large prospectively followed up cohort of geriatric patients undergoing a hip fracture surgery to deliver a better description of the timing of adverse events than was previously available. The findings of this study should enable more targeted clinical surveillance, inform patient counseling, and help determine the duration of follow-up required for studies on adverse events.

There was wide variability in the timing at which the different postoperative adverse events were diagnosed (Figures 1, 2). Myocardial infarction was diagnosed the earliest, with more than three-fourth of diagnoses in the first postoperative week. Other relatively early-diagnosed adverse events included cardiac arrest requiring cardiopulmonary resuscitation, stroke, pneumonia, and pulmonary embolism.

The latest-diagnosed adverse event was surgical site infection (Figures 1, 2). Surgical site infection was actually the only adverse event with a rate of diagnosis during the first week that was lower than the rate of diagnosis later in the month (as can be seen by the inflection in the timing curve for surgical site infection in Figure 1). Mortality showed a relatively consistent rate of diagnosis throughout the entire first postoperative month. Other relatively late-diagnosed postoperative events, including sepsis, deep vein thrombosis, and urinary tract infection, showed varying degrees of decreased rate of diagnosis near the end of the first postoperative month. Of note, for the later-diagnosed adverse events, the estimated median and interquartile ranges (Figure 2) were presumably quite biased toward earlier diagnosis, as the 30-day follow-up period clearly failed to capture a large proportion of later-occurring adverse events (Figure 1).

Certain risk factors were independently associated with earlier occurrence of adverse events. Perhaps most strikingly, body mass index in the obese range was associated with substantially earlier occurrence of deep vein thrombosis (median of 5 vs 10 days). This finding suggests that clinical monitoring for deep vein thrombosis should be performed earlier in patients with greater body mass index. Also notable is the earlier occurrence of cardiac arrest and death among patients with end-stage renal disease than among those without. Patients with end-stage renal disease may have a greater risk for these adverse events immediately following the cardiac stresses of surgery.\(^27\) Similarly, such patients may be more prone to early electrolyte abnormalities and arrhythmia.

In addition to its clinical implications, this study informs about the interpretation of the many studies of adverse events following hip fracture procedures that have been conducted using retrospective data. Several such studies have relied on inpatient-only administrative databases.\(^1\)\(^3\)\(^,\)\(^14\)\(^-\)\(^35\) As clearly demonstrated in Figure 3, for most of the commonly studied adverse events, inpatient-only databases failed to capture a large proportion of adverse events occurring in the first postoperative month. This highlights a substantial limitation of this commonly published type of study that is often not emphasized in the literature.

There has also been an increase in the publication of studies of adverse events following a hip fracture surgery
As discussed, the ACS-NSQIP provides data on 30-days of follow-up. This relatively extended follow-up is often touted as a distinct advantage. However, this study demonstrates that even the 30-day follow-up afforded by the ACS-NSQIP is limited in its ability to enable investigation of the later-occurring adverse events (Figure 1). In particular, the rate of surgical site infection shows little sign of slowing by postoperative day 30. Similarly, the rates of mortality, sepsis, deep vein thrombosis, and urinary tract infection remain substantial.

This study does have limitations. First, as discussed, the duration of follow-up is a limitation of any ACS-NSQIP-based investigation, including this study. Second, the ACS-NSQIP does not capture relevant orthopedic-specific outcomes (eg, screw cutout). In addition, it could not be determined with certainty whether adverse events occurring on the final hospital day occurred prior to or following discharge. However, only a small proportion of most of the adverse events was diagnosed on the final hospital day. Finally, the ACS-NSQIP reports on days from the operation until diagnosis of the adverse event. Although some adverse events are probably diagnosed quickly after they have occurred (eg, myocardial infarction and cardiac arrest), other adverse events may have a delayed diagnosis (eg, surgical site infection may be identified days after its initial occurrence during a follow-up examination). Therefore, it is important to note the subtle distinction between occurrence and diagnosis throughout the article. This article reports on the timing of diagnosis, not actual occurrence.

**Conclusion**

The timing of postoperative adverse events has been understudied in the past. This may be due to an inability of standard single- or multi-institutional investigations to achieve sample sizes adequate to study the less commonly occurring adverse events. Using a relatively new prospective surgical registry, this study provides a far more detailed description of the timing of adverse events following surgery than was previously available. The authors anticipate that these data can be used to inform patient counseling, target clinical surveillance, and direct clinical research. The authors chose to study the timing of postoperative adverse events following geriatric hip fracture surgery because of the high rate of adverse events associated with the procedure. However, future ACS-NSQIP studies may involve characterization of the timing of adverse events following other orthopedic and non-orthopedic procedures.

*This paper will be judged for the Resident Writer's Award.*

**Key Info**

**Figures/Tables**

Figures / Tables:

[grauer0918_f1.jpg](graue0918_f1.jpg)
Figure 1. Histograms and timing curves for the timing of diagnosis of adverse events. The figure is sorted by increasing median postoperative day of diagnosis.
Abbreviation: CPR, cardiopulmonary resuscitation.
Figure 2. Medians and interquartile ranges for the timing of diagnosis of adverse events during the first 30 postoperative days. The figure is sorted by increasing median postoperative day of diagnosis.

Abbreviation: CPR, cardiopulmonary resuscitation.
Table 1. Patient Population

<table>
<thead>
<tr>
<th>Total Age</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>70-74 years</td>
<td>1852</td>
<td>9.3%</td>
</tr>
<tr>
<td>75-79 years</td>
<td>2764</td>
<td>13.9%</td>
</tr>
<tr>
<td>80-84 years</td>
<td>4328</td>
<td>21.8%</td>
</tr>
<tr>
<td>85-89 years</td>
<td>5525</td>
<td>27.8%</td>
</tr>
<tr>
<td>≥90 years</td>
<td>5404</td>
<td>27.2%</td>
</tr>
<tr>
<td>Total Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>5359</td>
<td>27.0%</td>
</tr>
<tr>
<td>Female</td>
<td>14,514</td>
<td>73.0%</td>
</tr>
<tr>
<td>Total Body mass index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;30 kg/m²</td>
<td>17,733</td>
<td>89.2%</td>
</tr>
<tr>
<td>≥30 kg/m²</td>
<td>2140</td>
<td>10.8%</td>
</tr>
<tr>
<td>Total Functional status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Independent</td>
<td>14,348</td>
<td>72.2%</td>
</tr>
<tr>
<td>Dependent</td>
<td>5525</td>
<td>27.8%</td>
</tr>
<tr>
<td>Total Diabetes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3321</td>
<td>16.7%</td>
<td></td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>738</td>
<td>3.7%</td>
</tr>
<tr>
<td>Dyspnea on exertion</td>
<td>1542</td>
<td>7.8%</td>
</tr>
<tr>
<td>Hypertension</td>
<td>14,265</td>
<td>71.8%</td>
</tr>
<tr>
<td>End-stage renal disease</td>
<td>322</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

Figure 3. Timing of adverse events relative to discharge. The figure is sorted by decreasing percentage diagnosed prior to discharge.

Abbreviation: CPR, cardiopulmonary resuscitation.
COPD 2239 11.3%
Current smoker 1506 7.6%

Abbreviation: COPD, chronic obstructive pulmonary disease.

Table 2. Patients with Adverse Events Diagnosed During the First 30 postoperative days (N = 19,873)

<table>
<thead>
<tr>
<th>Adverse Event</th>
<th>Number</th>
<th>Percent</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urinary tract infection</td>
<td>1321</td>
<td>6.7%</td>
<td>6.3%-7.0%</td>
</tr>
<tr>
<td>Mortality</td>
<td>1240</td>
<td>6.2%</td>
<td>5.9%-6.6%</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>771</td>
<td>3.9%</td>
<td>3.6%-4.2%</td>
</tr>
<tr>
<td>Sepsis</td>
<td>428</td>
<td>2.2%</td>
<td>2.0%-2.4%</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>347</td>
<td>1.8%</td>
<td>1.6%-1.9%</td>
</tr>
<tr>
<td>Surgical site infection</td>
<td>247</td>
<td>1.2%</td>
<td>1.1%-1.4%</td>
</tr>
<tr>
<td>Deep vein thrombosis</td>
<td>199</td>
<td>1.0%</td>
<td>0.9%-1.1%</td>
</tr>
<tr>
<td>Stroke</td>
<td>144</td>
<td>0.7%</td>
<td>0.6%-0.8%</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>136</td>
<td>0.7%</td>
<td>0.6%-0.8%</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>126</td>
<td>0.6%</td>
<td>0.5%-0.7%</td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.

Table 3. Timing of Diagnosis of Adverse Events

<table>
<thead>
<tr>
<th>Adverse events and associated baseline characteristic(s)</th>
<th>Median postoperative day of diagnosis with vs without baseline characteristic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac arrest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>End-stage renal disease</td>
<td>1 vs 3</td>
<td>.005</td>
</tr>
<tr>
<td>Stroke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>4 vs 2</td>
<td>.025</td>
</tr>
<tr>
<td>Dependent functional status</td>
<td>2 vs 4</td>
<td>.027</td>
</tr>
<tr>
<td>Urinary tract infection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female sex</td>
<td>6 vs 8</td>
<td>.009</td>
</tr>
<tr>
<td>Deep vein thrombosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index $\geq 30$ kg/m$^2$</td>
<td>5 vs 10</td>
<td>.015</td>
</tr>
<tr>
<td>Death</td>
<td></td>
<td></td>
</tr>
<tr>
<td>End-stage renal disease</td>
<td>10 vs 11</td>
<td>.031</td>
</tr>
</tbody>
</table>

*a*Baseline characteristics that were independently associated with the timing of each adverse event were identified through a backwards stepwise selection process initially including all characteristics listed in Table 1, and sequentially excluding characteristics with the weakest associations until only characteristics with $P < .05$ remained. Independent associations with the timing of cardiac arrest, stroke, urinary tract infection, deep vein thrombosis, and death are shown. There were no characteristics independently associated with timing of myocardial infarction, pneumonia, pulmonary embolism, sepsis, or surgical site infection; hence, these adverse events are not listed in the table.

*b*From final Cox proportional hazards models identified through multivariate stepwise selection.
References


24. Ingraham AM, Richards KE, Hall BL, Ko CY. Quality improvement in surgery: the American College of


**Multimedia**
Product Guide

BioComposite SwiveLock Anchor
BioComposite SwiveLock C, with White/Black TigerTape™ Loop
BioComposite SwiveLock Anchor, With Blue FiberTape Loop
Knotless SutureTak® Anchor

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