# Time of Day Is Associated With Postoperative Morbidity

## *An Analysis of the National Surgical Quality Improvement Program Data*

*Rachel R. Kelz, MD, MSCE,*† Kathryn M. Freeman, BA,† Patrick W. Hosokawa, MS,‡ David A. Asch, MD, MBA,§¶ Francis R. Spitz, MD,*† Miriam Moskowitz, RN, MSN,* William G. Henderson, MPH, PhD,‖ Marc E. Mitchell, MD,** and Kamal M. F. Itani, MD, FACS††*

**Objective:** To examine the association between surgical start time and morbidity and mortality for nonemergent procedures.

**Summary Background Data:** Patients require medical services 24 hours a day. Several studies have demonstrated a difference in outcomes over the course of the day for anesthetic adverse events, death in the ICU, and dialysis care. The relationship between operation start time and patient outcomes is yet undefined.

**Methods:** We performed a retrospective cohort study of 144,740 nonemergent general and vascular surgical procedures performed within the VA Medical System 2000–2004 and entered into the National Surgical Quality Improvement Program Database. Operation start time was the independent variable of interest. Logistic regression was used to adjust for patient and procedural characteristics and to determine the association between start time and, in 2 independent models, mortality and morbidity.

**Results:** Unadjusted later start time was significantly associated with higher surgical morbidity and mortality. After adjustment for patient and procedure characteristics, mortality was not significantly associated with start time. However, after appropriate adjustment, operations starting between 4 PM and 6 PM were associated with an elevated risk of morbidity (OR = 1.25, $P \leq 0.005$) over those starting between 7 AM and 4 PM as were operations starting between 6 PM and 11 PM (OR = 1.60, $P \leq 0.005$).

**Conclusions:** When considering a nonemergent procedure, surgeons must bear in mind that cases that start after routine "business" hours within the VA System may face an elevated risk of complications that warrants further evaluation.

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From the *Department of Surgery, Philadelphia VA Medical Center, Philadelphia, Pennsylvania; †Department of Surgery, Hospital of the University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania; ‡Eastern Colorado Health Care System, Department of Veterans Affairs, Aurora, Colorado; §Center for Health Equity Research and Promotion, Philadelphia VA Medical Center, Philadelphia, Pennsylvania; ¶Leonard Davis Institute of Health Economics, University of Pennsylvania, Philadelphia, Pennsylvania; ‖University of Colorado Health Outcomes Program, Aurora, Colorado; **Department of Surgery, University of Mississippi Medical Center, Jackson, Mississippi; ††Surgery, Boston VAHCS, Boston, Massachusetts; ‡‡Chief of Surgery, VA Boston Health Care System, Professor of Surgery, Boston University, and Associate Chief of Surgery, Boston Medical Center and Brigham and Women's Hospital, Boston, Massachusetts.

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Reprints: Rachel R. Kelz, MD, MSCE, 3400 Spruce Street, 4 Silverstein, Philadelphia, PA 19104-4283. E-mail: rapaporr@uphs.upenn.edu.



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Time of day variations have been associated with differences in vocational accident risks, changes in driving performance, and discrepancies in simulation-based performance studies.[1–4] Most of these findings have been attributed to worker fatigue; however, some suggest that technical skills may have a natural diurnal variation.[5,6] Along these lines, time of day differences have been described with respect to medical outcomes as well.[7–12]

Weekend admission is a risk factor for death for certain populations of acutely ill patients.[10,13] Additionally, evening and nighttime hours have been associated with an increased risk of death among ICU patients.[9] It has been suggested that these findings may be due to staffing differences on weekends when compared with weekdays. Alternatively, some have suggested that physician and staff fatigue and alterations in circadian rhythms might diminish mental acuity or technical ability at varying periods throughout the day.

As a technical skill, surgical ability is subject to the same vulnerabilities as driving or flying during which fatigue and circadian rhythm do influence performance. Studies have demonstrated that a near majority (44%–48%) of adverse events in the hospital setting is associated with an operation.[14–16] In an effort to identify a potentially controllable risk factor for adverse events, we explored the relationship between the start time of a nonemergent operation and the likelihood of both mortality and surgical complications following nonemergent general and vascular operations.

## METHODS

We performed a retrospective cohort study of all patients undergoing nonemergent general surgery and peripheral vascular surgeries within the Veteran's Affairs medical system and captured in the National Surgical Quality Improvement Program (NSQIP) Surgical Outcomes data set during fiscal years 2000–2004. The NSQIP is an active quality improvement program that has been described in great detail in multiple previous publications.[17–25] In brief, 123 VA Medical centers in which major surgeries are performed participate in the NSQIP. A fully trained nurse reviewer collects and verifies numerous patient and clinical care characteristics and the outcomes for each of the defined surgical cases. These data elements are then verified by the individual chiefs of surgery and transmitted to the Denver Data Analysis Center. The analysis for our study was conducted onsite at the Denver Data Analysis Center. IRB approval was granted through the Philadelphia VA Medical Center Institutional Review Board before commencing with our analysis.

The VA-NSQIP database has been shown to be a reliable source of data. Davis et al recently demonstrated the reliability of the NSQIP database through a rigorous assessment of case selection bias, accuracy of postoperative mortality reporting, and interrater reliability of comorbidities. On case selection bias, the reviewers agreed with NSQIP decisions on 98% of the cases. Computer record matching identified 4 more deaths than the NSQIP total of 198, a difference of about 2%. For 52 of the categorical variables, agreement uncorrected for chance was 96%. For 48 of 52 categorical variables, kappas ranged from 0.61 to 1.0 (substantial to almost perfect agreement).[26]

For our study, patients were selected if they underwent a surgical procedure captured in the NSQIP database, which was performed by a general or vascular surgeon during the study time period. The specific procedure codes captured in our study cohort as defined by CPT codes can be found in Table 1. Patients were excluded from the study if the procedure was performed by a non general or vascular surgeon, was defined as emergent, or represented a repeat surgery within 30 days.

Because the effect of start time does not follow a clear linear or quadratic pattern, it was converted into a categorical variable for analysis. The categories were defined as: 7 AM to 3:59 PM, 4 PM to 5:59 PM, and 6 PM to 10:59 PM, 11 PM to 6:59 AM. The categories were suggested based on the Perioperative staffing practices of the Philadelphia VA Medical Center and then confirmed by the experts at the Denver Data Analysis Center as appropriate for the entire study cohort. The group of patients who underwent "nonemergent" procedures between 11 PM and 7 AM was so small (n = 61) that we eliminated them from further analysis.

For modeling purposes, all variables were considered categorical with the exception of age, length of the procedure, and work Relative Value Units (RVUs). Laboratory values were categorized by critical values, separating "Normal" values from either a single "Abnormal" range or 2 ranges ("Too High" and "Too Low"). Thirty-day postoperative morbidity and mortality was obtained for all cases as defined within the NSQIP.

The start time model included 49 variables for consideration. Laboratory values are often missing from records, so imputation was used to fill in those records with missing laboratory values to allow inclusion of laboratory variables in the model without discarding too many records.[27]

The models detailed below are logistic models performed on the 144,740 records. One model used mortality as the dichotomous outcome and the other used the presence or absence of a complication (19 complications are used and are listed at the end of this paper in Table 2) as the dichotomous outcome. The logistic regression used a forward stepwise

**TABLE 1.** CPT Codes for All General and Vascular Procedures Performed by General and Vascular Surgeons During the Study Time Frame

| | |
|---|---|
| Musculoskeletal system | 21555, 21556 |
| | 21930 |
| | 22900 |
| | 38100–38102 |
| | 24075, 25076 |
| | 24076, 25075 |
| | 27327, 27328 |
| | 27618, 27619 |
| | 27047, 27048 |
| Cardiothoracic system | 39502–39561 |
| Digestive system | 43107–49585 |
| Vascular system | 33877 |
| | 34800–34832 |
| | 35081–37181 |
| Lymph, heme system | 38724 |
| | 38740–38765 |
| Endocrine system | 60220–60605 |

**TABLE 2.** Thirty-day Complication Variables*

| Variable | Description |
|---|---|
| cdarrest | Cardiac arrest |
| cdmi | Myocardial infarction |
| cnscoma | Coma |
| cnscva | CVA/stroke |
| neurodef | Peripheral nerve injury |
| othbleed | Bleeding requiring >4 units PRBCs |
| othdvt | DVT/thrombophlebitis |
| othgrafl | Graft/prosthesis failure |
| othsysep | Systemic sepsis |
| oprenafl | Acute renal failure |
| renainsf | Renal insufficiency |
| urninfec | Urinary tract infection |
| failwean | Failure to wean >48 h postop |
| oupneumo | Pneumonia |
| pulembol | Pulmonary embolism |
| reintub | Reintubation |
| dehis | Dehiscent wound |
| supinfec | Superficial wound infection |
| wndinfd | Deep wound infection |

*The outcome variable for the morbidity model has a value of "1" if any of the following 19 complications occurred within 30 days postoperative. Otherwise it has a value of 0.

**TABLE 3.** Patient Preoperative Conditions, Comorbidities, and Laboratory Values

| Variable | 7 AM to 4 PM | 4 PM to 6 PM | 6 PM to 11 PM | *P** |
|---|---|---|---|---|
| Sample size | 142,771 | 1513 | 456 | |
| Sex | | | | <0.0001 |
| Male | 96.93% | 95.90% | 92.76% | |
| Female | 3.07% | 4.10% | 7.24% | |
| Age (±SD) | 63.23 (12.16) | 63.41 (12.45) | 63.27 (13.21) | <0.0001 |
| ASA class | | | | <0.0001 |
| 1–2 | 34.02% | 26.57% | 27.41% | |
| 3 | 57.41% | 58.63% | 51.97% | |
| 4–5 | 8.57% | 14.81% | 20.61% | |
| DNR status | 0.66% | 1.47% | 1.54% | <0.0001 |
| Alcohol >2 drinks/d | 9.67% | 9.83% | 10.84% | 0.6893 |
| Dependent functional | | | | |
| Status | 5.85% | 11.04% | 11.40% | <0.0001 |
| Smoker | 36.31% | 38.47% | 34.87% | 0.1806 |
| Cardiac | | | | |
| History of CHF | 1.79% | 3.64% | 3.73% | <0.0001 |
| Central nervous system | | | | |
| Impaired sensorium | 0.81% | 2.12% | 2.41% | <0.0001 |
| Coma | 0.02% | 0.00% | 0.00% | 0.8019 |
| CVA with neurological deficit | 5.06% | 6.21% | 5.48% | 0.1178 |
| CVA without neurological deficit | 3.42% | 3.64% | 3.95% | 0.7451 |
| Hemiplegia | 2.83% | 3.90% | 3.51% | 0.0311 |
| History of TIA | 5.24% | 4.96% | 4.61% | 0.7414 |
| CNS tumor | 0.11% | 0.13% | 0.00% | 0.7513 |
| Hepatobiliary | | | | |
| Ascites | 0.78% | 2.12% | 2.63% | <0.0001 |
| Nutritional/immune/other | | | | |
| Diabetes | 17.54% | 20.49% | 19.30% | 0.0069 |
| Disseminated cancer | 2.00% | 2.78% | 5.04% | <0.0001 |
| Open wound or infection | 3.87% | 7.07% | 5.92% | <0.0001 |
| Steroid use | 2.00% | 3.17% | 3.29% | 0.0009 |
| Weight loss >10% | 4.13% | 6.68% | 7.89% | <0.0001 |
| Bleeding disorder | 2.20% | 4.03% | 4.82% | <0.0001 |
| Transfusion >4 units | 0.40% | 0.79% | 1.10% | 0.0032 |
| Chemotherapy | 0.77% | 1.85% | 3.29% | <0.0001 |
| Radiotherapy | 0.81% | 0.86% | 0.66% | 0.9150 |
| Sepsis | 0.53% | 3.77% | 5.92% | <0.0001 |
| Pulmonary | | | | |
| Dyspnea | 14.23% | 16.09% | 15.74% | 0.0817 |
| Ventilator dependent >48 h | 0.12% | 1.12% | 1.54% | <0.0001 |
| Current pneumonia | 0.28% | 1.19% | 3.07% | <0.0001 |
| History of COPD | 13.37% | 15.40% | 15.57% | 0.0280 |
| Renal | | | | |
| Acute renal failure | 0.26% | 1.12% | 2.19% | <0.0001 |
| On dialysis | 0.71% | 1.78% | 1.54% | <0.0001 |
| Wound classification | <.0001 | | | |
| Clean | 71.48% | 57.30% | 44.52% | |
| Clean/contaminated | 25.64% | 34.10% | 44.30% | |
| Contaminated | 2.16% | 5.55% | 8.55% | |
| Infected | 0.72% | 3.04% | 2.63% | |
| Laboratory | | | | |
| Albumin ≤3.5 | 19.76% | 35.96% | 45.39% | <0.0001 |
| Alkaline phosphatase >125 | 9.24% | 16.33% | 18.42% | <0.0001 |

(*Continued*)

**TABLE 3.** (*Continued*)

| Variable | 7 AM to 4 PM | 4 PM to 6 PM | 6 PM to 11 PM | P* |
|---|---|---|---|---|
| Bilirubin >1.0 | 8.51% | 16.92% | 20.61% | <0.0001 |
| BUN >40 | 1.87% | 5.49% | 7.24% | <0.0001 |
| Creatinine >1.2 | 21.74% | 26.57% | 25.22% | <0.0001 |
| HCT ≤38 | 24.87% | 37.08% | 43.42% | <0.0001 |
| HCT >45 | 22.35% | 16.19% | 16.67% | <0.0001 |
| Platelets ≤150 | 7.07% | 9.65% | 7.89% | 0.0004 |
| Platelets >400 | 4.51% | 6.54% | 10.53% | <0.0001 |
| SGOT >40 | 8.42% | 14.54% | 18.42% | <0.0001 |
| Sodium ≤135 | 10.81% | 15.99% | 22.15% | <0.0001 |
| Sodium >145 | 1.29% | 1.19% | 3.29% | 0.0008 |
| WBC ≤4.5 | 6.08% | 5.88% | 7.02% | 0.6692 |
| WBC >11.0 | 8.05% | 18.04% | 32.46% | <0.0001 |

*$\chi^2$ test was used for categorical variables and *t* test was used for continuous variable.

regression (with an inclusion alpha of 0.05). The 49 candidate variables for inclusion in the model are listed as either included or not in each model. In each model, the primary variable of interest (start time) was forced into the model. Because of a large number of missing values due to changes in collection of the race variable in 2000–2004, patient race was excluded from consideration in the model. A value indicating ventilator dependence prevented the model from converging, and so was also removed.

## RESULTS

A total of 145,718 operations were analyzed. Because of incomplete records, 917 cases were discarded. Sixty-one cases were discarded due to start times between 11 PM and 7 AM. Therefore, the final cohort was 144,740 cases. Of these, 3312 operations were discarded because of missing values in the response or explanatory variables, leaving 141,428 cases to determine the model parameters.

The mean age for patients enrolled in the study was 63 years. The majority of patients were male, 95.6%. Eight-five percent of the cases were general surgical cases, whereas 15% were vascular in nature. Whereas the number of comorbid conditions was only slightly greater in the later groups than the 7 AM to 4 PM group, patients operated on later in the day were more likely to have an ASA Classification of 4 to 5 than those operated on between 7 AM and 4 PM. Patients whose surgeries began after 4 PM were more likely to have a history of heart failure, an impaired sensorium, a dependent functional status, and nutritional/immune compromise than the 7 AM to 4 PM group. The late group was also more likely to have renal or severe pulmonary compromise; however, these disorders only affected a small percentage of the cohort overall. The specific preoperative conditions, comorbid conditions, and laboratory values can be seen in Table 3.

The mean length of the surgical procedure was longer for the 7 AM to 4 PM group than the late groups. The mean RVUs were the same for the 7 AM to 4 PM start time group as the 6 PM to 11 PM group, whereas the mean RVU for the 4 PM to 6 PM group was slightly less than the other 2 groups. General anesthesia was more likely to be used for cases entering the operating room after 4 PM than local or regional anesthetics. Operative characteristics can be seen in Table 4.

An initial (unadjusted) look at the relative rates of mortality and morbidity showed marked differences among the 3 categories of start time. Unadjusted complications by type of event that were more likely to occur following a case that began after 4 PM included: systemic sepsis, deep venous thrombosis, cardiac arrest, myocardial infarction, serious respiratory events, urinary tract infection, dehiscence, and superficial and deep wound infection (Table 5).

### Mortality

Start time of operation was not significantly related to mortality, after adjustment for patient and procedural characteristics. The model performed well, the calculated *c*-index was 0.876. The Hosmer-Lemeshow goodness-of-fit test produced a $\chi^2$ value of 19.7395 ($df = 8$, $P$ value $= 0.0114$). In the final mortality model, many preoperative comorbid conditions, operative conditions, and laboratory abnormalities remained significantly associated with postoperative mortality despite the insignificance of surgery start time further

**TABLE 4.** Operative Characteristics

| Variable | 7 AM to 4 PM | 4 PM to 6 PM | 6 PM to 11 PM | P* |
|---|---|---|---|---|
| Sample size | 142,771 | 1513 | 456 | |
| Mean work RVU (±SD) | 14.04 (7.56) | 13.82 (6.66) | 14.86 (6.01) | <0.0001 |
| Anesthesia | | | | <0.0001 |
| General | 79.19% | 86.19% | 92.11% | |
| Spinal | 1.52% | 1.59% | 0.22% | |
| Epidural | 10.62% | 8.00% | 6.36% | |
| Monitored | 1.43% | 0.86% | 0.00% | |
| Local | 0.49% | 0.59% | 0.44% | |
| Other | 6.75% | 2.78% | 0.88% | |
| Length of procedure (±SD) | 2.28 (1.67) | 2.01 (1.33) | 2.12 (1.60) | <0.0001 |

*$\chi^2$ test was used for categorical variables and *t* test was used for continuous variable.

**TABLE 5.** Postoperative Unadjusted Outcomes

| Variable | 7 AM to 4 PM | 4 PM to 6 PM | 6 PM to 11 PM | P* |
|---|---|---|---|---|
| Sample size | 142,771 | 1513 | 456 | |
| 30-d mortality rate | 1.62% | 3.30% | 4.17% | <0.0001 |
| 30-d morbidity rate | 11.22% | 16.39% | 23.46% | <0.0001 |
| Postop other complications | | | | |
| Graft prosthetic failure | 0.35% | 0.53% | 0.66% | 0.2715 |
| Bleeding requiring >4 units PRBCs | 0.36% | 0.46% | 0.44% | 0.7637 |
| Systemic sepsis | 1.03% | 1.59% | 2.19% | 0.0054 |
| DVT/thrombophlebitis | 0.29% | 0.40% | 1.32% | 0.0007 |
| Postop cardiac events | | | | |
| Cardiac arrest | 0.62% | 0.99% | 1.54% | 0.0086 |
| Myocardial infarction | 0.55% | 0.86% | 1.32% | 0.0242 |
| Postop CNS events | | | | |
| Coma | 0.07% | 0.07% | 0.00% | 0.9463 |
| CVA | 0.33% | 0.40% | 0.22% | 0.9009 |
| Peripheral nerve injury | 0.07% | 0.13% | 0.00% | 0.7561 |
| Postop respiratory events | | | | |
| Pneumonia | 1.95% | 2.51% | 4.61% | <0.0001 |
| Unplanned intubation | 1.67% | 2.91% | 3.51% | <0.0001 |
| Pulmonary embolism | 0.16% | 0.33% | 0.00% | 0.0074 |
| Failure to wean >48 h | 1.55% | 3.24% | 7.02% | <0.0001 |
| Postop urinary tract events | | | | |
| Acute renal failure | 0.36% | 0.46% | 0.44% | 0.7830 |
| Progressive renal | | | | |
| Insufficiency | 0.43% | 0.59% | 0.66% | 0.4567 |
| Urinary tract infection | 1.71% | 2.18% | 3.29% | 0.0130 |
| Postop wound events | | | | |
| Dehiscence | 0.99% | 1.59% | 2.41% | 0.0007 |
| Superficial infection | 2.92% | 3.64% | 4.39% | 0.0463 |
| Deep wound infection | 1.26% | 1.26% | 3.29% | 0.0006 |

*$\chi^2$ test was used for categorical variables and *t* test was used for continuous variable.

**TABLE 6.** Mortality Model With Start Time Effect

| Variable | Odds Ratio | 95% Confidence Interval | P |
|---|---|---|---|
| Start time (4 PM to 6 PM vs. 7 AM to 4 PM) | 1.037 | 0.749, 1.435 | 0.8288 |
| Start time (6 PM to 11 PM vs. 7 AM to 4 PM) | 1.040 | 0.630, 1.717 | 0.8782 |
| Disseminated cancer | 3.034 | 2.633, 3.497 | <0.0001 |
| ASA class (3 vs. 1–2) | 2.011 | 1.678, 2.411 | <0.0001 |
| ASA class (4–5 vs. 1–2) | 3.345 | 2.738, 4.085 | <0.0001 |
| Integumentary versus hernia | 1.723 | 0.696, 4.264 | 0.2391 |
| Respiratory and hemic versus hernia | 6.492 | 4.419, 9.537 | <0.0001 |
| Heart versus hernia | 3.901 | 2.691, 5.654 | <0.0001 |
| Aneurysm versus hernia | 2.774 | 2.208, 3.484 | <0.0001 |
| Mouth, palate versus hernia | 6.817 | 4.394, 0.575 | <0.0001 |
| Stomach, intestines versus hernia | 4.732 | 3.774, 5.934 | <0.0001 |
| Urinary, nervous system versus hernia | 2.297 | 1.320, 3.997 | 0.0032 |
| Ascites | 4.016 | 3.293, 4.898 | <0.0001 |
| Dependent functional status | 1.627 | 1.445, 1.833 | <0.0001 |
| Preoperative albumin (≤3.5 vs. >3.5) | 1.449 | 1.301, 1.614 | <0.0001 |
| Age | 1.031 | 1.026, 1.035 | <0.0001 |
| Operation time | 1.139 | 1.111, 1.167 | <0.0001 |
| Do not resuscitate order | 3.034 | 2.432, 3.786 | <0.0001 |
| Preoperative BUN >40 | 1.638 | 1.370, 1.960 | <0.0001 |
| Weight loss | 1.761 | 1.556, 1.993 | <0.0001 |
| Preoperative white blood count >11.0 | 1.533 | 1.359, 1.729 | <0.0001 |
| Preoperative platelet count ≤150 | 1.506 | 1.318, 1.720 | <0.0001 |
| Dyspnea | 1.382 | 1.250, 1.528 | <0.0001 |
| Impaired sensorium | 1.663 | 1.331, 2.077 | <0.0001 |
| Work RVU | 1.021 | 1.013, 1.028 | <0.0001 |
| Preoperative creatinine >1.2 | 1.304 | 1.179, 1.442 | <0.0001 |
| Preoperative serum sodium <135 | 1.392 | 1.249, 1.551 | <0.0001 |
| Preoperative sepsis | 1.523 | 1.188, 1.952 | 0.0009 |
| Preoperative SGOT >40 | 1.215 | 1.067, 1.383 | 0.0033 |
| Preoperative serum sodium >145 | 1.670 | 1.272, 2.191 | 0.0002 |
| Congestive heart failure <30 d before surgery | 1.400 | 1.171, 1.672 | 0.0002 |
| CVA with neurological deficit | 1.314 | 1.134, 1.523 | 0.0003 |
| Ventilator dependent | 1.778 | 1.194, 2.647 | 0.0046 |
| Preoperative wound infection | 0.776 | 0.653, 0.921 | 0.0038 |
| Preoperative hematocrit ≤38 | 1.171 | 1.057, 1.298 | 0.0025 |
| Transfusion >4 units | 1.440 | 1.091, 1.900 | 0.0100 |
| Wound class (clean/contaminated vs. clean) | 0.896 | 0.792, 1.015 | 0.0842 |
| Wound class (contaminated vs. clean) | 1.212 | 0.982, 1.495 | 0.0731 |
| Wound class (infected vs. clean) | 0.965 | 0.698, 1.334 | 0.8290 |
| CNS tumor | 2.231 | 1.147, 4.339 | 0.0180 |
| Preoperative platelet count >400 | 0.821 | 0.697, 0.968 | 0.0187 |
| Preoperative alkaline phosphatase >125 | 1.140 | 1.015, 1.281 | 0.0276 |

supporting the strength of the model. Additionally, CPT and work RVU were significantly associated with postoperative mortality (Table 6).

## Morbidity

The morbidity model demonstrated a significant relationship between start time and postoperative complications. Operations starting between 4 PM and 6 PM were significantly more likely to be associated with complications than those starting between 7 AM and 4 PM (odds ratio = 1.26, $P$ = 0.004). Operations starting between 6 PM and 11 PM were significantly more likely to be associated with complications than those starting between 7 AM and 4 PM (odds ratio = 1.60, $P$ = 0.0002). The *c*-index for this model was 0.800. The Hosmer-Lemeshow goodness-of-fit test produced a $\chi^2$ value of 182.6800 ($df$ = 8, $P$ value ≤0.0001). The model also demonstrated significant associations between multiple preoperative comorbid conditions and operative conditions and postoperative morbidity (Table 7).

## DISCUSSION

Our results demonstrate that the time at which a patient enters the operating room for a nonemergent procedure in the VA Medical system is associated with perioperative morbidity. Patients whose nonemergent operation began after 4 PM were at an elevated risk of perioperative morbidity after

**TABLE 7.** Morbidity Model With Start Time Effect

| Variable | Odds Ratio | 95% Confidence Interval | P |
|---|---|---|---|
| Start time (4 PM to 6 PM vs. 7 AM to 4 PM) | 1.256 | 1.077, 1.464 | 0.0037 |
| Start time (6 PM to 11 PM vs. 7 AM to 4 PM) | 1.596 | 1.250, 2.038 | 0.0002 |
| Work RVU | 1.048 | 1.044, 1.052 | <0.0001 |
| Integumentary versus hernia | 2.075 | 1.620, 2.656 | <0.0001 |
| Respiratory and hemic versus hernia | 2.714 | 2.267, 3.248 | <0.0001 |
| Heart versus hernia | 1.202 | 1.025, 1.410 | 0.0239 |
| Aneurysm versus hernia | 1.193 | 1.105, 1.290 | <0.0001 |
| Mouth, palate versus hernia | 1.999 | 1.632, 2.447 | <0.0001 |
| Stomach, intestines versus hernia | 2.070 | 1.921, 2.231 | <0.0001 |
| Urinary, nervous system versus hernia | 0.808 | 0.653, 1.001 | 0.0508 |
| Operation time | 1.238 | 1.224, 1.252 | <0.0001 |
| ASA class (3 vs. 1–2) | 1.428 | 1.355, 1.505 | <0.0001 |
| ASA class (4–5 vs. 1–2) | 1.833 | 1.706, 1.969 | <0.0001 |
| Dependent functional status | 1.450 | 1.361, 1.543 | <0.0001 |
| History of COPD | 1.334 | 1.269, 1.402 | <0.0001 |
| Preoperative albumin (≤3.5 vs. >3.5) | 1.140 | 1.090, 1.192 | <0.0001 |
| Wound class (clean/contaminated vs. clean) | 1.297 | 1.228, 1.371 | <0.0001 |
| Wound class (contaminated vs. clean) | 1.505 | 1.360, 1.667 | <0.0001 |
| Wound class (infected vs. clean) | 1.372 | 1.169, 1.610 | 0.0001 |
| Dyspnea | 1.243 | 1.184, 1.305 | <0.0001 |
| Preoperative BUN >40 | 1.345 | 1.209, 1.497 | <0.0001 |
| Age | 1.009 | 1.007, 1.011 | <0.0001 |
| Bleeding disorders | 1.344 | 1.224, 1.476 | <0.0001 |
| Preoperative white blood count >11.0 | 1.228 | 1.160, 1.300 | <0.0001 |
| Transfusion >4 units PRBCs in 72 h before surgery | 1.726 | 1.429, 2.084 | <0.0001 |
| Congestive heart failure <30 d before surgery | 1.349 | 1.220, 1.491 | <0.0001 |
| Preoperative wound infection | 1.205 | 1.119, 1.298 | <0.0001 |
| Preoperative acute renal failure | 1.644 | 1.299, 2.081 | <0.0001 |
| Preoperative serum sodium <135 | 1.120 | 1.064, 1.178 | <0.0001 |
| Preoperative creatinine >1.2 | 1.122 | 1.074, 1.173 | <0.0001 |
| Weight loss | 1.130 | 1.053, 1.212 | 0.0007 |
| Smoker | 1.090 | 1.047, 1.136 | <0.0001 |
| Impaired sensorium | 1.286 | 1.108, 1.492 | 0.0009 |
| Preoperative hematocrit ≤38 | 1.079 | 1.034, 1.126 | 0.0005 |
| Ascites | 1.296 | 1.108, 1.517 | 0.0012 |
| Preoperative serum sodium >145 | 1.292 | 1.122, 1.487 | 0.0004 |
| Currently on dialysis | 0.729 | 0.611, 0.869 | 0.0004 |
| Steroid use | 1.186 | 1.068, 1.316 | 0.0014 |
| CVA with neurological deficit | 1.135 | 1.057, 1.219 | 0.0005 |
| Preoperative platelet count ≤150 | 1.111 | 1.041, 1.186 | 0.0016 |
| Current pneumonia | 1.369 | 1.098, 1.708 | 0.0054 |
| Disseminated cancer | 1.157 | 1.051, 1.273 | 0.0028 |
| Preoperative sepsis | 1.252 | 1.058, 1.482 | 0.0089 |
| Diabetes (oral or insulin vs. none) | 1.063 | 1.018, 1.111 | 0.0062 |
| Alcohol >2 drinks/d | 1.077 | 1.014, 1.143 | 0.0157 |
| History of TIA | 0.914 | 0.845, 0.988 | 0.0243 |

adjustment for both patient and procedure related risk factors. The NSQIP data set makes a clear distinction between preoperative risk factors and postoperative conditions; therefore, we were able to adjust for a large portion of patient disease unlike adjustments performed using administrative discharge data. Results were controlled for operative complexity utilizing CPT codes, length of the procedure, and work RVUs.

Our results are consistent with other healthcare studies that have demonstrated an association between time of treatment and outcome. Studies of pediatric emergency department admissions showed an increased risk of medication prescribing errors in between 4 AM and 8 AM when compared with 8 AM to 12 PM.[8] Anesthesiologists administering epidural anesthesia between midnight and 8 AM have an increased risk of dural puncture.[12] Similarly, a recent finding out of Duke University Medical Center demonstrated a clear association between start time of a case and anesthetic adverse events with a peak event likelihood occurring for cases that began at 4 PM.[28] As in the present study, these studies did not demonstrate any difference with respect to time of day and mortality. The only groups that have seen mortality effects by time of day in the ICU and general wards studied inpatient populations and were not able to demonstrate an increase in mortality rate for new "after hours" admissions.[9,13]

A few studies of surgical outcomes after late night trauma and transplantation procedures outside of the VA system have been analyzed for an association between after-hours procedures and rates of mortality. Their findings did not demonstrate any differences between time of procedure and perioperative morbidity and mortality.[11,29] It is possible, however, that within the private sector, particularly within institutions that are staffed to accommodate 24-hour emergency care like transplant centers and level 1 trauma centers, we would not see such a striking difference in outcomes for our nonemergent population either. However, this does not apply to the VA system on the whole where there is a clear distinction between regular "block time" and "off hour" care. Additionally, the procedures that trauma centers and transplant groups perform are often not able to be safely delayed until regular work hours. They must be performed within a timely fashion dependent only upon the availability of the organs or the random occurrence of a traumatic event. Therefore, like emergent procedures, these patients would not even qualify for limited start times designed to reduce perioperative events.

Our finding that a start time after 4 PM of an operation is associated with a higher risk of perioperative morbidity may be explained in several ways including: (1) Provider factors like staff number, seniority, and fatigue may compromise care as operative times extend into evening; (2) System issues related to care of the hospitalized patient may fluctuate during the day and leave patients at an increased risk of poor outcome late in the day; or (3) Biologic patient-related factors may contribute to poor outcomes.

Recently, the contribution of physician fatigue to human error has been paramount, leading to the enactment of the Accreditation Council for Graduate Medical Education work-hours limitations.[30,31] It is well known that sleep deprivation is associated with decreased cognitive performance and motor coordination.[12] However, studies of fatigue and quality of patient care have less clear conclusions. Studies are fraught with design limitations where randomization is impossible and individual fatigue must be weighed against problems of continuity of care.[30,32–34] Perhaps most relevant to our data are virtual reality simulations that suggest that sleep-deprived surgeons made more errors and had longer procedures than their well-rested controls.[35] Also, in survey analysis of surgical error at 3 teaching hospitals, 33% of incidents were at least partially attributed to fatigue or excessive workload.[36] These findings are particularly interesting given our data demonstrating elevated rates of deep wound infection and wound dehiscence following late start times, as both of these are technical complications.

Nurses and other ancillary staff are equally affected by extended working hours, fatigue, and circadian rhythm status; increased length of nursing shifts have been associated with an increased risk of errors, near errors, and decreased vigilance.[37,38] This reality becomes particularly worrisome when considering that up to 38.7% of nursing shifts may be 12.5 hours of longer.[37] Scott et al suggests that the risk of a nursing error is 2 times greater when shifts exceed 12 hours, putting surgeries that end after 7 PM at risk, as the typical nursing daily shift begins at 7 AM.[38]

Clearly, perioperative morbidity depends on a complex set of system factors outside the skill of the surgeon during an operation or the alertness of the other healthcare providers. After-hours hospital wide services may be less available than during regular duty hours and this certainly can contribute to the elevated risk of postoperative morbidity. Radiographic examinations are not uniformly available after hours, pharmacy staffing is often reduced, and certainly nurse to patient ratios and physician availability fluctuate during "off hours." The effects of decreasing seniority for later shifts may also contribute to our findings. Decreased numbers of registered nurses, and nurse to patient ratios have been associated with increasing rates of complications.[39,40] If surgeries at VA hospitals ending after 4 PM are associated with a decrease in the proportion of registered nurses and a decline in nurse-to-patient ratios, this could be contributing to the differences seen in our data. Similarly, it is not uncommon for junior residents to provide in-hospital coverage for the surgical services within the VA System at nights and on weekends, whereas staff surgeons and senior residents reside in the hospital during regular duty hours only. Our finding that cases beginning between 4 PM and 11 PM are at an elevated risk of perioperative complications when compared with cases starting between 7 AM and 4 PM suggests that the "change of shift" may play a role in adverse events related to the timing of surgical procedures.

Biologic patient factors may contribute to the increased risk of postoperative complications later in the day. Historically, it has been practice to have operative patients fast after midnight on the morning of their scheduled surgery to reduce the risk of aspiration. Recently, the accepted practice of keeping preoperative patients NPO has been challenged.[41,42] It has been found to be associated with increased preoperative hunger and anxiety, and postoperative nausea and vomiting.[41] More concerning is the link between NPO status and hypovolemia.[42] The risk is compounded for patients who are starting late in the day and require longer than expected fasting times.

This retrospective cohort study can only describe an association between start time and outcomes and cannot prove causality. Many factors not controlled for in this analysis may have contributed to the observed differences in perioperative morbidity. Different start times might reflect different surgeon, staff, or hospital characteristics that also might be determining operative morbidity or mortality. Although we excluded emergent operations, 1 significant limitation of the NSQIP data is there is no differentiation between elective and urgent cases. It is possible that more urgent cases were performed during later hours and these cases had an inherent higher risk. The observation that the increased risk of perioperative morbidity was significant even after adjusting for perioperative comorbidities and risk factors while perioperative mortality was not significantly different would diminish the likelihood that our late cases were "misclassified" urgent cases as other studies have routinely shown an increase risk of postoperative death with urgent cases that we did not observe in our "late" start group.[43–46] Additionally, several VA Medical Centers routinely use overtime after hours to finish the daily elective schedule due to long waiting lists and limited physical resources which would explain these after-hours elective cases. However, it is possible that unmeasured differences in these populations accounted for the results. Although we did not adjust for the volume-outcome relationship described throughout the literature,[47] it has already been demonstrated that this relationship is not observed within the VA health system.[48]

The analysis did not discriminate within the morbidity model between major events, eg, myocardial infarction, and minor events, eg, UTI. However, our bivariate analysis does imply that the majority of the difference in complications can be attributed to major events. Additionally, one could also argue that based on modern literature, even minor complications are associated with significant patient dissatisfaction and expense[49–55] and often lead to the cascade of complications[24,50] that can often follow 1 bad event. Finally, because of the differences between healthcare delivery within and outside of the VA system, one must be careful when generalizing these results to other populations and settings. It is quite possible that results may vary from type of institution and staffing profiles.

The National Confidential Enquiry into Perioperative Deaths is a surgical quality assessment program in Great Britain that has found that surgeons often consider work outside of 8 AM to 6 PM as part of their standard work day.[56] This may explain why a surgeon's practice may not routinely call for the cancellation of a case when circumstances call for it to start after hours. Consequently, the standard work day for surgeons often extends beyond 8 AM to 6 PM.[56] However, it may be time to re-examine the long standing surgical custom that mandates that one continues to work until the work is done.

Additionally, it is important to note that if late start time is associated with increased perioperative morbidity purely because of the urgent nature of these cases that is important as well. In that case, we need to re-examine OR block allocation to assure that the schedule can always accommodate the unexpected urgent case in a more timely fashion to reduce perioperative morbidity in this population. This might result in longer wait times for elective cases which would need to be considered before making these changes. Unfortunately, we were not able to evaluate the relationship between start time and emergent cases because the sample size was too small to perform risk adjustment. However, this population is important to study, and overcrowding in an elective schedule often results in delays to the operating room for emergent and urgent cases.

An association between time of delivery of health care and outcome has been observed by others. The observation in this study of a significant increase in patient morbidity and later operative start times in this VA population would indicate that timing of procedures may contribute to poor outcomes for surgical patients and warrants further evaluation. If this observation were to be confirmed it would indicate the need for new approaches to surgical scheduling. A reevaluation of the decision making processes for OR scheduling including consideration of physician and staff work hours may be appropriate.

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