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Operation Timing Does Not Affect Outcome after Coronary Artery Bypass Graft Surgery

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Background: **Human factors such as fatigue, circadian rhythms, scheduling, and staffing may have an impact on patient care over the course of a day across all medical specialties. Research by the transportation industry concludes that human performance is degraded by shift work, circadian rhythm disturbances, and prolonged duty. This study investigated whether the timing of coronary artery bypass graft surgery affects outcomes.**

Methods: **The outcomes of coronary artery bypass graft surgery patients were analyzed according to the hour of the day, day of the workweek, month, and moon phase in which the surgery started. All patients who underwent isolated coronary artery bypass graft surgery between January 1, 1993 and July 1, 2006 were considered for the study. The primary outcome measurement was a compound morbidity outcome of six variables defined by the Society of Thoracic Surgeons. These outcomes included (1) in-hospital death, (2) acute postoperative myocardial infarction, (3) neurologic morbidity, including focal or global neurologic deficits or death without awakening, (4) serious infection morbidity consisting of sepsis syndrome or septic shock, (5) new-onset renal failure requiring dialysis, and (6) postoperative ventilatory support exceeding 72 h.**

Results: **The composite morbidity and in-hospital mortality rates were 4.8% and 1.4%, respectively. The number of cases each weekday, each month of the year, and during each phase of the moon were consistent. None of the time factors significantly affected the composite morbidity outcome.**

Conclusions: **Elective coronary artery bypass graft surgery can be scheduled throughout the workday, any day of the work week and in any month of the year without compromising outcome.**

AVIATION and military research has convincingly documented that sleep deficits, circadian rhythm disturbances, and prolonged duty periods degrade human performance.[1,2] Industrial and motor vehicle accidents are similarly common at night.[2] Two newsworthy examples are the Chernobyl nuclear reactor disaster and Exxon Valdez grounding; both events occurred during circadian lows (2:00 to 5:00 AM). Fatigue contributes to 15–20% of all transportation accidents — a fraction that exceeds the combined contributions of drug and alcohol abuse.[2]

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Hospitals operate 24 h a day, every day of the year, and hospital-personnel performance may be affected by circadian rhythms. As might be expected, physicians are more likely to commit errors and to perform psychomotor tasks less proficiently at night rather than during the day.[3,4] When long periods of monitoring are required, as is often the case with anesthesia personnel, fatigue may reduce effectiveness by as much as 50%.[5]

Elective surgery is usually scheduled for weekdays during "normal" working hours. But even within the course of a standard working day, both circadian factors and fatigue may induce time-related performance impairment. For example, the probability of anesthetic-related adverse events reportedly increases from a low of 1.0% at 9:00 AM to 4.2% at 4:00 PM.[6] Increased fatigue and an accumulated sleep deficit are common among operating-room personnel, especially by Friday of a workweek.[7] And finally, during July and August, new residents enter the systems in teaching hospitals. Large learning curves associated with surgical procedures[8,9] may increase risks in the operating rooms during these months.

The well-established protocols for coronary artery bypass graft surgery (CABG) make this surgery a good model for studying the effects of timing on outcome. There is much less variability than with other procedures, and hospitals closely track morbidity and mortality for this operation. We therefore tested the hypotheses that perioperative risk associated with elective CABG (1) increases from morning to evening throughout the routine workday, (2) increases from Monday to Friday through the workweek, and (3) is greater in July and August than during other months of the year. In addition, as a (presumably) negative control, we evaluated perioperative complications as a function of the phase of the moon. The analysis was restricted to elective operations because emergency procedures inherently are higher risk and often performed in patients with greater comorbidities.

Materials and Methods

This investigation was approved by the Institutional Review Board, Cleveland Clinic, Cleveland, Ohio. Between January 1, 1993 and July 1, 2006, 19,150 patients underwent isolated CABG at our institution. Cardiac patients are cared for by a team of fellowship-trained anesthesiologists and intensivists at all times, including nights and weekends.

Perioperative variables were prospectively collected concurrently with patient care and entered into the Cardiothoracic Anesthesia Patient Registry. Elective CABG operations are scheduled on weekdays at the Cleveland Clinic; weekend and emergency cases were thus excluded from our analysis.

A total of 18,597 cases were included in the analysis. The case start time for each patient was obtained and assigned a time block, day of the week, month of the year, and moon phase. Due to the lack of cases with start times in each hour from 5:00 PM to 05:00 AM, these patients were combined and analyzed as a single group. The data on the moon phase was obtained from the U.S. Naval Observatory, Washington, DC. Greenwich Mean Times were adjusted to local time in Cleveland, Ohio, taking into account adjustments for daylight savings time.

A composite of six major complications, defined by the Society of Thoracic Surgeons|| was used as the primary outcome. The outcome variables were (1) in-hospital death, (2) acute postoperative myocardial infarction, (3) neurologic morbidity, including focal or global neurologic deficits or death without awakening, (4) serious infection morbidity consisting of sepsis syndrome or septic shock, (5) new-onset renal failure requiring dialysis, and (6) postoperative ventilatory support exceeding 72 h. Data were obtained from the Cardiovascular Information Registry at our institution.

Statistical Analyses

Categorical variables are presented as frequency and percentage, and continuous variables are presented as means ± SD and median (25th percentile, 75th percentile).

Procedure type, gender, age, obstructive pulmonary disease or asthma, pulmonary hypertension, smoking, congestive heart failure, hypertension, myocardial infarction, diabetes, dialysis, creatinine, body mass index, intraoperative red cell transfusion, bypass duration, and year of operation were initially considered as covariates in the model. Operation hour, operation month, operation day, and moon phase were forced into the model during the variable selection procedure.

Backward-variable-selection procedure in logistic regression was used to assess the effect of operation timing on mortality and composite outcome. Operation timing variables were retained in the model during the variable selection procedure. *P* values and odds ratios were presented for the operation timing variables in the final model after adjusting for other significant factors. The significance level for each hypothesis was 0.05. SAS software, Carey, NC, was used for all analyses.

Results

Characteristics of patients included in the analysis are shown in table 1, along with the incidence of major outcomes, our composite of serious outcomes, and in-hospital mortality. The composite morbidity and in-hospital mortality rates were 4.8% and 1.4%, respectively.

Table 1. Patient Characteristics and Major Outcomes

Variable	Percent or Mean ± SD
Categorical	
Female	22.9%
COPD/asthma	7.2%
Pulmonary hypertension	1.7%
Congestive heart failure	16.9%
Hypertension	69.2%
Myocardial infarction	54.1%
Diabetes	35.0%
Continuous	
Age, yrs	64.5 ± 10.3
Creatinine, mg/dl	1.2 ± 0.8
Weight, kg	84.1 ± 17.1
Height, cm	170.8 ± 10.0
Intraoperative red cell transfusion	0.8 ± 1.5
Total bypass time, min	90.4 ± 46.0
Outcomes	
Hospital death	1.4%
Composite outcome	4.8%

Results are expressed as means ± SDs or percentages of 18,597 elective coronary bypass graft cases.

COPD = Chronic obstructive pulmonary disease.

Figure 1 shows the frequency of the isolated CABG surgery cases with respect to hour, day of the week, month of the year, and phase of the moon. As might be expected, surgery most often started at 7:00 or 8:00 AM, whereas cases starting after 5:00 PM were rare. However, there were only small differences in the number of cases as a function of the day of the week, month of the year, or phase of the moon.

Figure 2 shows the composite complication rate with respect to hour, day of the week, month of the year, and phase of the moon. None of these factors significantly influenced outcome. Tables 2 and 3 show the effect of operation timing factors on in-hospital mortality and composite morbidity outcome respectively. A number of coexisting diseases were associated with the outcomes on univariate analysis and are shown at the bottom of the tables. After considering those factors in a multivariate analysis, there was still no significant association between the various time factors and outcome.

Discussion

The Institute of Medicine estimates as many as 98,000 preventable in-hospital deaths occur annually.[10] Healthcare thus appears to have a higher rate of preventable error than ultra-safe industries such as civil aviation and nuclear power.[11] A key feature of each industry is that they are protocol-driven and have established redundant safeguards. Implicit in this approach is the recognition that reliable protocols can prevent the vast majority of individual errors from becoming harmful events.

Outcome risk varies widely among different medical specialties and anesthesiology and blood banking are

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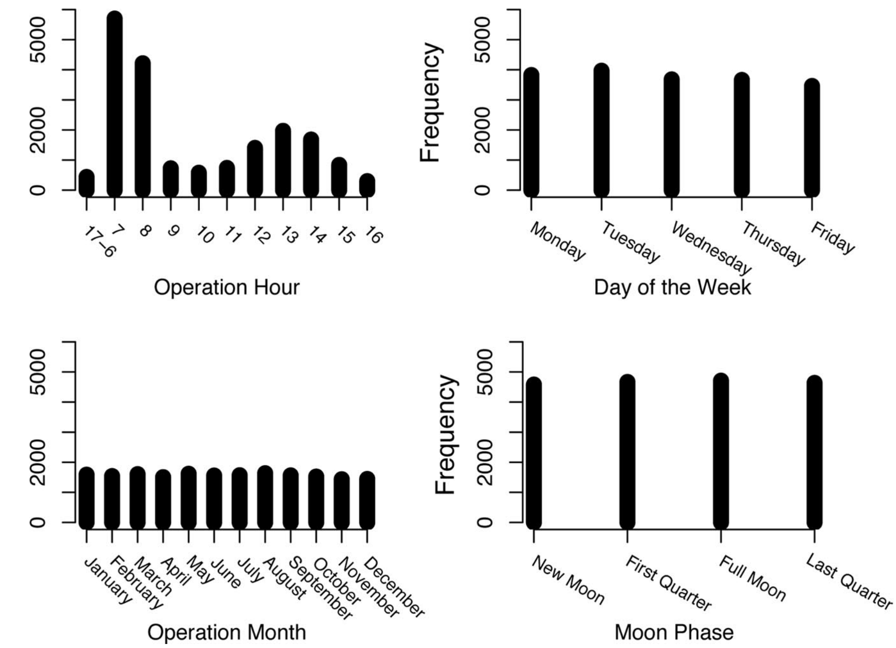

Fig. 1. The frequency of the isolated CABG surgery cases with respect to hour. CABG = coronary artery bypass graft.

recognized as being especially safe,[11] presumably because each specialty has established procedures and safety systems that prevent propagation of inevitable provider errors into patient injury. To the extent that these systems are effective, one might expect them to compensate for daily circadian effects, workweek fatigue, and training variability. Consistent with this theory, our principal finding is that surgical start time, day of the week, month of the year, and phase of the moon are not associated with outcome after isolated CABG surgery presumably because of well-established protocol-based practices that reduce variability.

Our results differ from those of Kelz *et al.*[12] who reported an increase in postoperative morbidity in patients having nonemergency surgery between 4:00 and 11:00 PM. It is notable that while Kelz's study excluded patients who underwent emergency surgery, in their investigation patients undergoing operations later in the day were more likely to have American Society of Anesthesiologists physical classifications of 4 or 5. It thus seems likely that worse outcomes later in the day actually resulted from higher acuity among the late patients.

Zare *et al.*[13] studied patients having nonemergency surgery, who were admitted to a regular nursing floor,

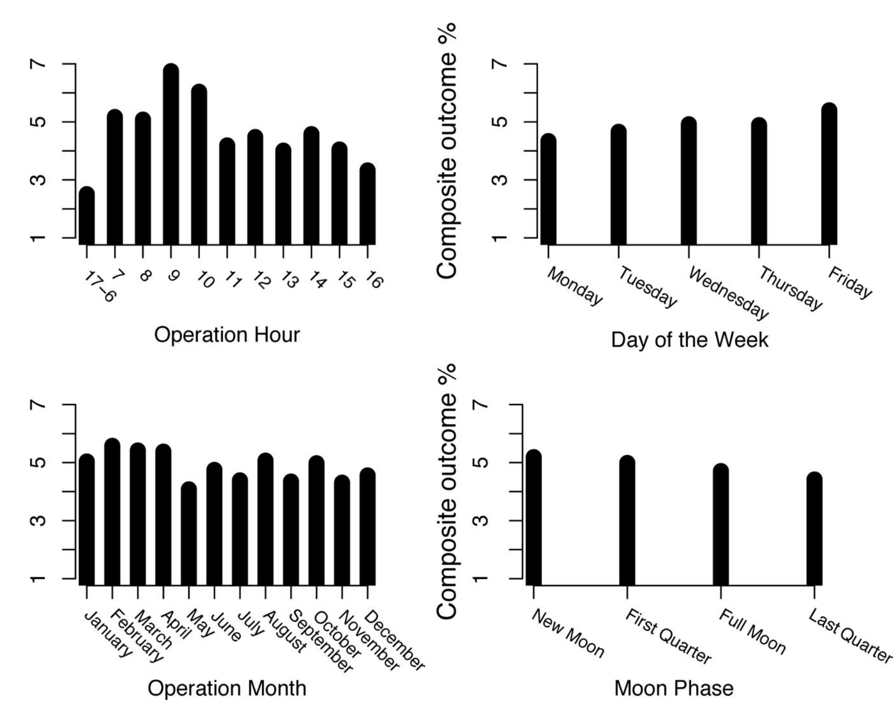

Fig. 2. The composite complication rate with respect to hour, day of the week, month of the year, and phase of the moon. None of these factors significantly influenced outcome.

Table 2. Effect of Operation Time on Hospital Mortality after Adjusting for Other Significant Factors

Variable	Odds Ratio	*P* Value
Hour of surgery		0.28
5:00 PM–5:00 AM *vs.* 7:00 AM	2.40 (0.60, 9.63)	
6:00 AM *vs.* 7:00 AM	0.49 (0.12, 2.06)	
8:00 AM *vs.* 7:00 AM	0.99 (0.66, 1.47)	
9:00 AM *vs.* 7:00 AM	1.58 (0.86, 2.92)	
10:00 AM *vs.* 7:00 AM	1.56 (0.82, 2.97)	
11:00 AM *vs.* 7:00 AM	0.83 (0.39, 1.78)	
12:00 AM *vs.* 7:00 AM	0.96 (0.55, 1.69)	
1:00 PM *vs.* 7:00 AM	0.79 (0.48, 1.30)	
2:00 PM *vs.* 7:00 AM	1.44 (0.92, 2.25)	
3:00 PM *vs.* 7:00 AM	1.06 (0.53, 2.09)	
4:00 PM *vs.* 7 AM	1.76 (0.77, 4.05)	
Month of surgery		0.27
Jan *vs.* Dec	0.67 (0.35, 1.27)	
Feb *vs.* Dec	0.90 (0.49, 1.65)	
March *vs.* Dec	0.83 (0.44, 1.54)	
April *vs.* Dec	0.99 (0.54, 1.84)	
May *vs.* Dec	1.16 (0.66, 2.06)	
June *vs.* Dec	1.04 (0.57, 1.89)	
July *vs.* Dec	0.89 (0.48, 1.65)	
Aug *vs.* Dec	1.17 (0.65, 2.10)	
Sept *vs.* Dec	0.52 (0.25, 1.04)	
Oct *vs.* Dec	0.76 (0.41, 1.44)	
Nov *vs.* Dec	0.54 (0.26, 1.11)	
Day of the week		0.72
Monday *vs.* Friday	0.80 (0.53, 1.23)	
Tuesday *vs.* Friday	0.77 (0.51, 1.115)	
Wednesday *vs.* Friday	0.83 (0.56, 1.24)	
Thursday *vs.* Friday	0.81 (0.53, 1.23)	
Phase of the moon		0.86
New moon *vs.* last qtr	1.14 (0.79, 1.64)	
First qtr *vs.* last qtr	1.16 (0.81, 1.68)	
Full moon *vs.* last qtr	1.09 (0.75, 1.58)	
Age, yrs	1.04 (1.03, 1.06)	< 0.001
COPD/asthma	1.65 (1.12, 2.43)	0.011
CHF	2.16 (1.64, 2.84)	< 0.001
MI	1.53 (1.115, 2.03)	0.003
Creatinine, mg/dl	1.19 (1.09, 1.31)	< 0.001
Intraoperative red cell transfusion	1.40 (1.34, 1.47)	< 0.001
Total bypass time, min	1.004 (1.002, 1.007)	< 0.001

CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; MI = Myocardial infarction.

Table 3. Effect of Operation Time on Composite Morbidity Outcome after Adjusting for Other Significant Factors

Variable	Odds Ratio	*P* Value
Hour of surgery	1.51 (0.59, 3.89)	0.12
5:00 PM–5:00 AM *vs.* 7:00 AM		
6:00 AM *vs.* 7:00 AM	0.40 (0.16, 0.99)	
8:00 AM *vs.* 7:00 AM	0.98 (0.80, 1.21)	
9:00 AM *vs.* 7:00 AM	1.42 (1.02, 1.98)	
10:00 AM *vs.* 7:00 AM	1.17 (0.80, 1.72)	
11:00 AM *vs.* 7:00 AM	0.88 (0.0.59, 1.31)	
12:00 AM *vs.* 7:00 AM	0.95 (0.71, 1.27)	
1:00 PM *vs.* 7:00 AM	0.79 (0.60, 1.03)	
2:00 PM *vs.* 7:00 AM	0.89 (0.68, 1.17)	
3:00 PM *vs.* 7:00 AM	0.95 (0.65, 1.38)	
4:00 PM *vs.* 7:00 AM	0.72 (0.37, 1.40)	
Month of the surgery		0.62
Jan *vs.* Dec.	0.99 (0.70, 1.40)	
Feb *vs.* Dec	1.14 (0.81, 1.61)	
March *vs.* Dec	1.17 (0.83, 1.65)	
April *vs.* Dec	1.23 (0.87, 1.74)	
May *vs.* Dec	0.86 (0.60, 1.23)	
June *vs.* Dec	1.09 (0.77, 1.55)	
July *vs.* Dec	0.97 (0.67, 1.39)	
Aug *vs.* Dec	1.19 (0.84, 1.68)	
Sept *vs.* Dec	0.93 (0.65, 1.33)	
Oct *vs.* Dec	1.08 (0.76, 1.54)	
Nov *vs.* Dec	0.97 (0.67, 1.40)	
Day of the week		0.42
Monday *vs.* Friday	0.80 (0.63, 1.01)	
Tuesday *vs.* Friday	0.88 (0.71, 1.09)	
Wednesday *vs.* Friday	0.89 (0.71, 1.11)	
Thursday *vs.* Friday	0.94 (0.75, 1.17)	
Moon phase		0.45
New moon *vs.* last qtr	1.18 (0.96, 1.44)	
First qtr *vs.* last qtr	1.12 (0.92, 1.37)	
Full moon *vs.* last qtr	1.11 (0.90, 1.35)	
Age, yrs	1.02 (1.01, 1.36)	< 0.001
COPD/asthma	1.28 (1.02, 1.61)	0.037
Pulmonary hypertension	1.63 (1.14, 2.34)	0.008
Smoking	1.18 (1.01, 1.36)	0.034
Congestive heart failure	1.76 (1.50, 2.06)	< 0.001
Myocardial infarction	1.18 (1.02, 1.36)	0.029
Diabetes	0.46 (0.23, 0.93)	0.031
Creatinine, mg/dl	1.32 (1.21, 1.44)	< 0.001
BMI	1.02 (1.006, 1.03)	0.004
Intraoperative red cell transfusion	1.32 (1.27, 1.36)	< 0.001
Total bypass time, min	1.003 (1.002, 1.005)	< 0.001
Operation year		< 0.001
1993 *vs.* 2006	0.44 (0.24, 0.80)	
1994 *vs.* 2006	0.27 (0.14, 0.50)	
1995 *vs.* 2006	0.35 (0.19, 0.64)	
1996 *vs.* 2006	0.33 (0.18, 0.60)	
1997 *vs.* 2006	0.35 (0.19, 0.65)	
1998 *vs.* 2006	0.28 (0.15, 0.53)	
1999 *vs.* 2006	0.42 (0.23, 0.77)	
2000 *vs.* 2006	0.28 (0.15, 0.54)	
2001 *vs.* 2006	0.28 (0.15, 0.54)	
2002 *vs.* 2006	0.88 (0.48, 1.59)	
2003 *vs.* 2006	0.99 (0.54, 1.81)	
2004 *vs.* 2006	1.08 (0.59, 1.97)	
2005 *vs.* 2006	0.96 (0.52, 1.77)	

BMI = body mass index; COPD = chronic obstructive pulmonary disease.

and reported higher 30-day mortality when surgery was performed on Friday than when surgery was on a Monday, Tuesday, or Wednesday. However, they did not observe an increase in 30-day mortality for either outpatients or patients who were admitted to the Intensive Care Unit. The results of Zare *et al.* cannot be directly compared to our results since they evaluated 30-day mortality whereas we report in-hospital mortality. But their observation that 30-day mortality in patients admitted to an intensive care unit is not affected by weekday of operation is consistent with our results, which also show no effect of the day of the week on serious complications or in-hospital mortality. Our findings differ from those reported in noncardiac surgery patients. An explanation might be that cardiac surgery is more protocolized than many other types of surgery and that protocol-based practice reduces individual error, or outcomes independent of timing factors could be related specifically to protocols specific to our institution.

The relationship between moon phase and medical events and outcomes is a well-established "urban legend." It has been reported that an increased number of canine and feline emergency room visits occur on fuller moon days,[14] and that a new moon is associated with an increased risk of aneurysmal subarachnoid hemorrhage.[15] However, most investigations of moon phase and medical outcomes do not find any association. For example, conception after assisted reproductive techniques, suicide, psychiatric admissions, and postoperative nausea and vomiting all seem to be unrelated to moon phase.[16,17–19] Consistent with these studies, Holzheimer *et al.* reported no association between moon phase and outcome after ambulatory surgery.[20] We similarly found no association between moon phase and morbidity or mortality.

It would be difficult to prospectively randomize enough patients to operation time, day, month, and moon phase to provide sufficient power to analyze relatively rare events. Our study was therefore observational. An unavoidable limitation of observational trials is poor protection against selection bias, measurement bias, and confounding. While it remains possible that sicker patients were systematically scheduled earlier or later in the day, there was no statistical evidence to support this theory. Similarly, morbidity in our registry is objectively defined and carefully recorded during hospitalization (data acquisition for the registry is thus prospective, even though our analysis was retrospective). And finally, confounding seems unlikely in the context of this study, especially as the results were negative.

Emergency surgery is inherently risky and often performed in patients with substantial comorbidities whose medical conditions may not be optimally controlled. We thus restricted our analysis to patients having elective surgery. A consequent limitation of our study is that nearly all cases we evaluated started during routine work hours and none were performed on weekends. It remains possible that outcomes would have been worse, even for elective CABG, had we analyzed weekend procedures.

In summary, the risk of major morbidity after elective isolated CABG surgery was not associated with the time of surgery, day of the work week, month of the year, or phase of the moon in an analysis of more than 18,000 cases that had adequate power to detect even small differences. We thus conclude that elective CABG surgery can be safely scheduled for any time in the day, any day of the workweek and in any month of the year without affecting outcome.

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