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Impact of Age on Perioperative Complications and Length of Stay in Patients Undergoing Noncardiac Surgery

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Background: **Major surgical procedures are performed with increasing frequency in elderly persons, but the impact of age on resource use and outcomes is uncertain.**

Objective: **To evaluate the influence of age on perioperative cardiac and noncardiac complications and length of stay in patients undergoing noncardiac surgery.**

Design: **Prospective cohort study.**

Setting: **Urban academic medical center.**

Patients: **Consecutive sample of 4315 patients 50 years of age or older who underwent nonemergent major noncardiac procedures.**

Measurements: **Major perioperative complications (cardiac and noncardiac), in-hospital mortality, and length of stay.**

Results: **Major perioperative complications occurred in 4.3% (44 of 1015) of patients 59 years of age or younger, 5.7% (93 of 1646) of patients 60 to 69 years of age, 9.6% (129 of 1341) of patients 70 to 79 years of age, and 12.5% (39 of 313) of patients 80 years of age or older ($P < 0.001$). In-hospital mortality was significantly higher in patients 80 years of age or older than in those younger than 80 years of age (0.7% vs. 2.6%, respectively). Multivariate analyses indicated an increased odds ratio for perioperative complications or in-hospital mortality in patients 70 to 79 years of age (1.8 [95% CI, 1.2 to 2.7]) and those 80 years of age or older (OR, 2.1 [CI, 1.2 to 3.6]) compared with patients 50 to 59 years of age. Patients 80 years of age or older stayed an average of 1 day more in the hospital, after adjustment for other clinical data ($P = 0.001$).**

Conclusions: **Elderly patients had a higher rate of major perioperative complications and mortality after noncardiac surgery and a longer length of stay, but even in patients 80 years of age or older, mortality was low.**

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As the U.S. population ages, major surgical procedures are being performed in elderly patients with increasing frequency (1), but few data are available to guide preoperative risk stratification. Several studies have described correlates of cardiac morbidity and mortality in patients undergoing noncardiac surgery (2–8), but the number of elderly patients in most series has been small. Furthermore, few data are available on noncardiac complications, the overall complication rate, and length of stay.

We describe the influence of age on perioperative complication and mortality rates in a large cohort of patients undergoing noncardiac surgery. As discussed elsewhere, age was not an independent correlate of major cardiac complications in this cohort (7). This analysis tests the hypothesis that advanced age is a correlate of the overall rate of complications, after adjustment for functional status.

METHODS

Patients

All patients 50 years of age or older who underwent major nonemergent noncardiac procedures at Brigham and Women's Hospital, Boston, Massachusetts, from 18 July 1989 to 28 February 1994 were eligible for the study. Major noncardiac procedures were defined as those with an expected length of stay of 2 or more days. Procedures were electively scheduled or were performed nonemergently during inpatient admissions. Eligibility criteria included the ability to speak English and adequate cognitive function to give informed consent. The enrollment and clinical data collection protocols were approved by the institutional review board of Brigham and Women's Hospital. The full study protocol included preoperative interviews by clinical study personnel (physicians or research nurses). Of the 4315 patients who provided informed consent to participate, 621 (14.4%) did not provide consent before surgery for the serial interview portion of the study, which included interviews 1 and 6 months after surgery. Patients who were not interviewed before surgery were not excluded on the basis of age or clinical status, but solely according to the availability of study personnel.

Data Collection

The data collection protocol is described elsewhere (7, 9, 10). In brief, patients who provided informed

consent to the full study protocol underwent preoperative evaluation by clinical investigators (physicians or research nurses) using a structured data form. These evaluations included detailed medical histories, physical examinations, and laboratory tests. For patients who did not undergo this evaluation because they could not be approached or because they declined participation in the interview portion of the study, we obtained clinical data from the structured evaluation by the anesthesiologist found in the medical record. This data source was also used to obtain American Society of Anesthesiologists classification for all patients. Hence, prospectively recorded clinical data were available for all patients. Consenting patients agreed to postoperative sampling of creatine kinase and, if total creatine kinase levels were elevated, measurement of creatine kinase–MB immediately after surgery, at 8 p.m. on the evening of surgery, and on the next two mornings. In all other enrolled patients, creatine kinase–MB was measured according to the physician's orders. Among all participants, the mean ($\pm$SD) number of cardiac enzyme samples obtained was 4.0 ± 2.2. Electrocardiography was performed in the recovery room and on the first, third, and fifth postoperative days if the patient remained hospitalized. The Charlson Comorbidity Index, a weighted comorbidity score based on the number and the severity of 16 selected medical diseases, was used to quantify the burden of medical comorbid conditions (11). The mean number of other common comorbid conditions in this population was calculated for all patients.

Preoperative functional status was assessed in 3890 patients by performing structured interviews using the Specific Activity Scale, an ordinally scaled, four-class instrument based on metabolic expenditure in various personal care, housework, occupational, and recreational activities (12, 13). This group included 196 patients who consented to preoperative interviews but did not consent to the full study protocol, including long-term follow-up.

Classification of Outcomes

The occurrence of major cardiac events postoperatively was classified by a single reviewer who was blinded to preoperative clinical data and who evaluated only postoperative clinical information, including cardiac enzyme measurements, electrocardiograms, and clinical events. Myocardial infarction was diagnosed on the basis of creatine kinase–MB levels and electrocardiographic findings (10). Major cardiac complications were unstable angina (postoperative typical chest pain associated with ischemic electrocardiographic changes), myocardial infarction, cardiogenic pulmonary edema, documented ventricular tachycardia, ventricular fibrillation or primary cardiac arrest, and sustained complete heart block requiring pacemaker.

Major noncardiac events were pulmonary embolism documented by autopsy, angiography, or a high-probability ventilation–perfusion scan; respiratory failure requiring intubation for more than 2 days or reintubation; noncardiogenic pulmonary edema; lobar pneumonia confirmed by chest radiography and requiring antibiotic therapy; acute renal failure requiring dialysis; or cerebrovascular accident with new neurologic deficit. In-hospital mortality was also recorded, and the combined end point of major cardiac or noncardiac complications or death was used in these analyses.

Statistical Analysis

To evaluate the impact of age on postoperative complications, we performed analyses in which age was considered as a continuous variable and as four categories (50 to 59 years, 60 to 69 years, 70 to 79 years, and $\geq$80 years). Because age was not linearly associated with the risk for outcomes, categorized age variables are used throughout this report.

Univariate correlations between clinical characteristics and age category were analyzed by using the chi-square test and the Fisher exact test for categorical variables and a *t*-test or Wilcoxon test for continuous variables. Because several clinical and laboratory variables are associated with age and because it is difficult to exclude the association of age with the event of interest, we included all relevant clinical variables in the multivariate analysis. Logistic regression analysis was used to determine the independent association of age with postoperative complications while controlling for the presence of comorbid conditions, sex, ethnicity, functional status as measured by Specific Activity Scale class, type of procedure, and preoperative laboratory data. Patients for whom data on selected variables were missing were excluded from the model. Clinically relevant variables from the regression model were analyzed for potential

Table 1. **Patient Characteristics**

Characteristic*	Age Group			
	50–59 Years (*n* = 1015)	60–69 Years (*n* = 1646)	70–79 Years (*n* = 1341)	≥80 Years (*n* = 313)
	← *n (%)* →			
Male sex	461 (45)	871 (53)	642 (48)	122 (39)
White ethnicity	892 (88)	1496 (91)	1220 (91)	295 (94)
Hypertension	322 (32)	756 (46)	690 (51)	144 (46)
Diabetes mellitus	100 (10)	228 (14)	220 (16)	42 (13)
Congestive heart failure	119 (12)	248 (15)	296 (22)	86 (27)
Ischemic heart disease	214 (21)	560 (34)	513 (38)	142 (45)
Cerebrovascular disease	30 (3)	63 (4)	112 (8)	28 (9)
Chronic lung disease	81 (8)	161 (10)	157 (12)	33 (11)
Chronic renal failure	23 (2)	32 (2)	40 (3)	11 (4)
Peptic ulcer disease	106 (10)	206 (13)	199 (15)	43 (14)
Arthritis	336 (33)	714 (43)	651 (49)	142 (45)
Cancer	393 (39)	579 (35)	389 (29)	79 (25)
Comorbid medical conditions†‡	1.7 (0–7)	2.2 (0–9)	2.4 (0–7)	2.4 (0–6)
Charlson Comorbidity Index score ≤ 2	791 (78)	1235 (75)	937 (70)	224 (72)
Specific Activity Scale score ≥ 3§	282 (31)	517 (39)	619 (52)	164 (61)
American Society of Anesthesiology class				
I	114 (11)	67 (4)	19 (1)	5 (2)
II	590 (58)	911 (55)	648 (48)	138 (44)
III	285 (28)	611 (37)	589 (44)	154 (49)
IV	16 (2)	37 (2)	58 (4)	13 (4)
Type of procedure				
Orthopedic	257 (25)	575 (35)	533 (40)	127 (41)
Intrathoracic	175 (17)	213 (13)	132 (10)	11 (4)
Abdominal aortic aneurysm repair	16 (2)	64 (4)	96 (7)	24 (8)
Abdominal	162 (16)	192 (12)	147 (11)	37 (12)
Vascular	125 (12)	247 (15)	274 (20)	78 (25)
Other	470 (46)	579 (35)	309 (23)	55 (18)

* $P < 0.05$ for trend for all characteristics except male sex and chronic renal failure.
† Conditions include hypertension, diabetes, congestive heart failure, ischemic heart disease, cerebrovascular disease, chronic lung disease, chronic renal failure, peptic ulcer disease, arthritis, and cancer.
‡ Data are given as the mean number of comorbid conditions (range).
§ 435 patients did not complete the Specific Activity Scale questionnaire (98 patients 50–59 years of age, 152 patients 60–69 years of age, 141 patients 70–79 years of age, and 44 patients ≥ 80 years of age).

interactions, and potentially significant interaction terms were considered in the regression models. A two-sided *P* value less than 0.05 was considered statistically significant in all analyses.

Linear regression models were used to estimate the independent variation in length of stay attributable to age, controlling for sex, ethnicity, preoperative clinical characteristics, American Society of Anesthesiologists classification, type of procedure, postoperative events, and in-hospital mortality. The logarithmic transformation of length of stay was used because of the non-normal distribution of this variable. The percentage change in the geometric mean of length of stay in the final model was used to estimate the numbers of adjusted hospital days attributable to age groups. All analyses were performed by using SAS statistical software for Windows, version 6.12 (SAS Institute, Inc., Cary, North Carolina).

Role of the Funding Source

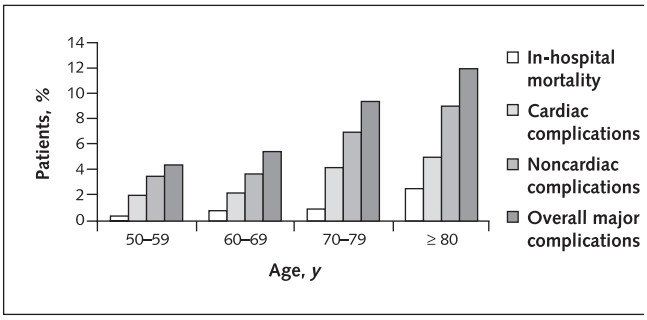
The funding source had no role in data collection and analysis or in subsequent decisions about publication of manuscripts.

RESULTS

Patients

The study sample constituted 4315 patients who had a mean age of 67 ± 9 years; 2096 patients (48%) were male and 3903 (90%) were white. Twenty-four percent (1015 patients) were younger than 59 years, 38% (1646 patients) were 60 to 69 years of age, 31%

Figure. **Major postoperative complications and in-hospital mortality in patients undergoing noncardiac surgery.**



(1341 patients) were 70 to 79 years of age, and 7% (313 patients) were older than 80 years of age. These patients undergoing elective surgery had a low prevalence of comorbid conditions, and 3187 (74%) patients had Charlson Comorbidity Index scores of 0 through 2. The types of procedures performed were orthopedic (35%), intrathoracic (12%), abdominal (12%), abdominal aortic aneurysm (5%), other vascular (17%), and other general surgical procedures (33%).

In the oldest age group, significantly fewer patients were male and nonwhite compared with the younger age groups (**Table 1**). The number of comorbid conditions and the average Charlson Comorbidity Index scores increased with increasing age. The distribution of Specific Activity Scale class and American Society of Anesthesiology class was also significantly worse in the older age groups; a greater proportion of patients 70 to 79 years of age and ≥80 years of age was classified as class 3 or 4. As expected, the type of surgical procedure performed varied among age groups. Higher percentages of older patients underwent orthopedic procedures, aortic aneurysm repair, and other vascular surgeries (**Table 1**).

Perioperative Complications

Major or fatal perioperative complications occurred in 44 (4.3%) patients younger than 59 years of age, 93 (5.7%) patients 60 to 69 years of age, 129 (9.6%) patients 70 to 79 years of age, and 39 (12.5%) patients 80 years of age or older ($P < 0.001$) (**Figure**). Age was significantly associated with a higher risk for cardiogenic pulmonary edema, myocardial infarction, ventricular arrhythmias, bacterial pneumonia, respiratory failure requiring intubation, and in-hospital mortality. All other major complications evaluated were more prevalent in elderly patients, but these trends were not statistically significant (**Table 2**). Compared with patients younger than 60 years of age, those 70 to 79 years of age and those 80 years of age or older had a higher risk for major cardiac and noncardiac complications. In-hospital mortality was significantly higher in patients 80 years of age or older than in those younger than 80 years of age (odds ratio, 3.5 [95% CI, 1.7 to 7.5]).

Table 2. **Postoperative Complications and Mortality**

Postoperative Complication	Age Group				*P* Value
	50–59 Years (*n* = 1015)	60–69 Years (*n* = 1646)	70–79 Years (*n* = 1341)	≥80 Years (*n* = 313)	
	← *n (%)* →				
Acute cardiac event					
Cardiogenic pulmonary edema	9 (0.9)	9 (0.5)	17 (1.3)	7 (2.2)	0.03
Myocardial infarction	8 (0.8)	14 (0.9)	18 (1.3)	6 (1.9)	0.05
Unstable angina	15 (1.5)	26 (1.6)	33 (2.5)	7 (2.2)	0.07
Ventricular tachycardia	13 (1.3)	23 (1.4)	36 (2.7)	13 (4.2)	<0.001
Ventricular fibrillation or cardiac arrest	1 (0.1)	3 (0.2)	9 (0.7)	3 (1.0)	0.003
Noncardiac event					
Bacterial pneumonia	11 (1.1)	10 (0.6)	23 (1.7)	7 (2.2)	0.02
Noncardiogenic pulmonary edema	0	5 (0.3)	6 (0.5)	1 (0.3)	0.08
Respiratory failure requiring intubation	9 (0.9)	19 (1.2)	31 (2.3)	12 (3.8)	<0.001
Renal failure requiring dialysis	1 (0.1)	7 (0.4)	7 (0.5)	0	>0.2
Cerebrovascular accident	4 (0.4)	6 (0.4)	10 (0.7)	2 (0.6)	0.2
Pulmonary embolism	1 (0.1)	5 (0.3)	4 (0.3)	2 (0.6)	0.16
In-hospital mortality	3 (0.3)	14 (0.8)	12 (0.9)	8 (2.6)	0.002
One or more postoperative complications or death	44 (4.3)	93 (5.7)	129 (9.6)	39 (12.5)	<0.001

With patients 50 to 59 years of age serving as the reference group, the unadjusted relative risks for the combined outcome of postoperative complications or death were 2.3 (CI, 1.7 to 3.3) for patients 70 to 79 years of age and 3.1 (CI, 2.0 to 4.9) for patients 80 years of age or older. Functional status as measured by using the Specific Activity Scale was also a correlate of the combined outcome of postoperative complications or in-hospital mortality. In Specific Activity Scale classes I to IV, rates of this outcome were 3.2% (43 of 1332 patients), 7.4% (68 of 916 patients), 8.0% (113 of 1404 patients), and 9.2% (22 of 238 patients), respectively ($P < 0.01$ for trend).

In multivariate analysis, after adjustment for baseline characteristics (including associated comorbid conditions, Specific Activity Scale class, and type of procedure), age older than 70 years was independently associated with a higher risk for postoperative complications and in-hospital mortality (**Table 3**). In addition, significant interactions between age and ischemic heart disease ($P < 0.01$) and between age and history of chronic renal failure ($P < 0.05$) were observed. The interactions suggested that the adverse effects of age on risk for perioperative complications was most pronounced among patients without ischemic heart disease. In patients with ischemic heart disease, only those 80 years of age or older showed an increase in risk for the combined end point. Similar findings were observed for history of chronic renal failure.

Table 3. **Multivariate Analysis of Preoperative Clinical Correlates of Major Postoperative Complications***

Predictor	Odds Ratio (95% CI)	*P* Value
Age		
50–59 y	1.0 (referent)	
60–69 y	1.1 (0.8–1.8)	>0.2
70–79 y	1.8 (1.2–2.7)	0.007
≥80 y	2.1 (1.2–3.6)	0.01
Male sex	1.2 (0.9–1.6)	>0.2
Nonwhite ethnicity	1.8 (1.1–2.8)	0.01
Hypertension	1.2 (0.9–1.6)	0.17
Diabetes mellitus	1.0 (0.7–1.5)	>0.2
Congestive heart failure†	1.4 (1.0–1.9)	0.05
Ischemic heart disease‡	1.3 (0.9–1.7)	0.11
Cerebrovascular disease	1.8 (1.2–2.6)	0.003
Chronic lung disease	1.0 (0.7–2.8)	>0.2
Chronic renal failure	1.5 (0.8–2.8)	>0.2
Peptic ulcer disease	0.8 (0.5–1.2)	>0.2
Cancer	0.7 (0.5–1.0)	0.05
Specific Activity Scale score ≥ 3	1.3 (1.0–1.8)	0.05
American Society of Anesthesiology class		
I/II	1.0 (referent)	
III	2.3 (1.6–3.2)	<0.001
IV	2.7 (1.4–5.1)	0.003
Type of procedure		
Orthopedic	0.8 (0.5–1.3)	>0.2
Intrathoracic	2.6 (1.7–4.4)	<0.001
Abdominal aortic aneurysm repair	3.3 (2.0–5.6)	<0.001
Abdominal	1.4 (0.8–2.3)	>0.2
Vascular	1.3 (0.8–2.0)	>0.2

* Major postoperative complications were major cardiac complications, major noncardiac complications, and death. See Methods section for further detail.
† History of congestive heart failure, pulmonary edema, or paroxysmal nocturnal dyspnea; physical examination showing bilateral rales or S_3 gallop, or chest radiograph showing congestive heart failure.
‡ History of myocardial infarction, positive exercise test, current ischemic chest pain, use of nitrate therapy, or electrocardiogram with Q waves.

Impact on Length of Stay and Hospital Discharge Disposition

The overall mean hospital length of stay was 8.2 ± 8.0 days (median, 7 days). Length of stay increased in a stepwise manner by age group. Mean length of stay was 7.4 ± 0.3 days among patients 50 to 59 years of age, 7.8 ± 0.2 among those 60 to 69 years of age, 9.2 ± 0.3 days among those 70 to 79 years of age, and 9.2 ± 0.5 days among those 80 years of age or older; the respective median values were 6, 7, 7, and 8 days. In multivariate analysis, after adjustment for sex, preoperative clinical variables, American Society of Anesthesiologists classification, type of procedure, and postoperative events, age remained an independent predictor of increased length of stay. After controlling for these confounders, patients 80 years of age or older had an increase in length of stay of more than 1 day in the hospital (9.3 days compared with 7.6, 8.3, and 8.8 days among patients 50 to 59 years of age, 60 to 69 years of age, and 70 to 79 years of age). In addition, patients 80 years of age or older were less likely than younger patients to be discharged to their preoperative residence (61% [143 of 236 patients] vs. 84% [2556 of 3028 patients]).

DISCUSSION

We found that elderly patients (those 70 years of age or older) who underwent nonemergent major surgery were at higher risk for perioperative complications and death after adjustment for clinical data, including functional status and type of surgery. Age was also an independent predictor of longer hospital length of stay after adjustment for sex, ethnicity, preoperative clinical

characteristics, American Society of Anesthesiologists classification, and type of procedure.

These data are consistent with and extend findings from previous investigations of the impact of age in perioperative complications, most of which have focused on major cardiac complications (2, 3, 5, 7, 14, 15). The incidence of major perioperative complications in patients older than 80 years of age in our cohort was similar to rates reported in two previous studies in geriatric patients (16, 17). In addition, increased in-hospital mortality (1.3%) has been described in geriatric patients undergoing abdominal surgery (1). Our own recent analysis in a subset of the current population failed to demonstrate an independent association of age with major cardiac complications (7), presumably because we had less statistical power than in the current analysis, which focused on more prevalent adverse outcomes.

An important finding for clinicians is the high prevalence of noncardiac perioperative complications, which is also consistent with results of other investigations. In data from Veterans Affairs hospitals after elective laparotomy, for example, the incidence of pulmonary complications was higher than the incidence of cardiac complications (9.6% vs. 5.7%) (18). Thus, evaluations that focus solely on the risk for cardiac complications may overlook important clinical issues for elderly patients undergoing noncardiac surgery.

Few data are available on the impact of age on length of stay after noncardiac surgery. Previous studies have demonstrated that variance in length of stay correlates with age after some elective procedures (19), coronary artery bypass surgery (20) and trauma (21). We observed that elderly patients stayed in the hospital an average of 1 day longer than younger patients after adjustment for clinical data and type of procedure. Part of this longer hospital stay may result from incomplete adjustment in the analysis for the severity of complications and comorbid medical conditions among elderly patients. These findings, however, raise the question of whether length of stay could be shortened in elderly patients by proactive discharge planning.

These data must be interpreted in the context of the study design. Our study is the largest recent cohort of patients described in the literature, but it was restricted to a single institution and to a heterogeneous group of selected patients undergoing different types of elective procedures for different surgical conditions. Many of the patients underwent procedures more than a decade ago, and technical advances during that time may have altered reported associations. Certain types of high-risk patients made up only a fraction of the total cohort (for example, those undergoing neurosurgery), and patients undergoing emergent surgical procedures were not included in our study sample. Elderly patients with more comorbid conditions may have been excluded from our sample because they were considered poor candidates for procedures. Therefore, our findings should be evaluated and confirmed in other populations before the rates of complications described in this report are assumed to be generalizable to those settings. In addition, 14% of the study sample was evaluated not by research clinicians but by the anesthesiologist caring for the patient. One would expect, however, that the use of different clinicians to collect data would bias analyses toward the null hypothesis.

The effects attributed to age in our report could be due to other factors. When we adjusted for sex, ethnicity, functional status, number of comorbid conditions, and type of surgery, the magnitude of the age effect was somewhat reduced but remained statistically significant. Other unmeasured functional and cognitive factors may be associated with age and affect outcomes after surgery.

In conclusion, our data demonstrate that age significantly affects the risk for perioperative cardiac and noncardiac complications after noncardiac surgery. In general, elderly patients (those older than 70 years of age) were at higher risk for most major cardiac and noncardiac complications. However, even among patients 80 years of age or older, the rate of complications was not prohibitive. Our data suggest the need for further research to develop strategies aimed at reducing perioperative complications in elderly patients and improving physical recovery after surgery.

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