

# How Comorbidities and Preoperative Expenditures Correlate With Postoperative Adverse Outcomes

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**A**cute care for inpatient surgery is an effective indicator for assessing healthcare system quality because of clear postoperative outcomes such as complications and subsequent mortality.<sup>1-3</sup> Previous large-scale population studies on surgical care quality (eg, the National Veterans Affairs' Surgical Quality Improvement Program, the Surgical Care Improvement Project of the Centers for Medicare & Medicaid Services in the United States) mostly addressed specific populations under certain insurance systems, with important variations in follow-up regarding hospital performance and patient care.<sup>3,4</sup>

Among healthcare beneficiaries, elderly patients scheduled for major in-hospital surgery are at relatively higher risk for complications due to their complex preexisting comorbidities.<sup>5-7</sup> Although multidisciplinary approaches have significantly improved geriatric patient care in recent decades, and several specialized fields have documented associations between surgeries and patient outcomes,<sup>8-11</sup> assessment of outcomes specifically showing the overall quality of healthcare under universal coverage is lacking. The increasing need for medical therapies among the elderly also leads to increased medical costs.<sup>12-16</sup> Financial stresses have raised concerns among health policy makers and regulators of healthcare providers regarding costs and benefits for the elderly and their postoperative outcomes. However, studies are still lacking that comprehensively analyze (1) the impact of geriatric patients' characteristics (ie, preexisting comorbidities) on surgical complications or mortality and (2) the potential role of preoperative medical expenditures in predicting postoperative outcomes for geriatric inpatient surgery.

This was a large-scale, nationwide, and population-based study under a uniform and homogeneous healthcare system to verify the quality of acute care in terms of postoperative complication and mortality rates for elderly patients who underwent in-hospital surgery. We conducted a retrospective cohort analysis of beneficiaries aged  $\geq 65$  years under the universal coverage of Taiwan's National Health Insurance Program (NHIP).<sup>17</sup> Demographic and functional status, coexisting illnesses, and preoperative medical expenditures among different age groups of elderly

patients were analyzed for risk-adjusted 30-day postoperative complications and mortality rates after receiving inpatient surgery. After adjustment for

**Objectives:** To examine the correlation of preexisting illnesses and preoperative medical expenditures with postoperative major adverse outcomes among geriatric surgical patients.

**Study Design:** Retrospective cohort study using claims from Taiwan's National Health Insurance Research Database.

**Methods:** All geriatric patients aged  $\geq 65$  years receiving inpatient surgeries during 2004 to 2007 under universal healthcare coverage were included. Surgical patients aged 55 to 64 years were the reference group. Risk-adjusted 30-day postoperative complication and mortality rates among elderly patients in various age sectors were analyzed and correlated with the preexisting illnesses and preoperative medical expenditures quantitatively.

**Results:** Among 432,614 elderly surgical patients in specific age sectors and 238,802 controls, the prevalence of preexisting illnesses and the risk-adjusted postoperative adverse outcome rates were highly age dependent and illness related. When comparing patients aged  $\geq 85$  years with patients aged 55 to 64 years, the adjusted odds ratios were 2.74 (95% confidence interval [CI], 2.67-2.82) and 3.56 (95% CI 3.31-3.84) for incidence of major postoperative complications and mortality after major complications, respectively. Numbers of preexisting illnesses increased in an age-dependent pattern and the preoperative 24-month medical expenditures increased incrementally with the numbers of comorbidities. Postoperative major complications, but not mortality rates, were highly correlated with the numbers of comorbidities and increased parallel with preoperative 24-month comorbidity-related medical expenditures, especially in the younger age group.

**Conclusions:** Adjusting for preexisting covariates, geriatric patients had an age-dependent, illness-related, and expenditure-associated pattern of higher postoperative complication and mortality rates. The numbers of comorbidities and preoperative medical expenditures had high predictive value for postoperative adverse outcomes.

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## In this article

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**Take-Away Points**

Age range, number and types of preexisting illnesses, and preoperative 24-month medical expenditures were used preoperatively to predict postoperative complication and mortality rates for geriatric surgical patients who had universal healthcare coverage from the Taiwan National Health Insurance Program.

- Postoperative major complications, but not mortality rates, were highly correlated with the numbers of comorbidities.
- Complication rates increased parallel with preoperative 24-month comorbidity-related medical expenditures.

patients' preexisting medical conditions and preoperative medical expenditures, we validated the correlations of comorbidities and preoperative medical expenditures with postoperative adverse outcomes for elderly surgical patients. These correlations can serve as potential predictors of clinical outcomes and provide future guidance regarding resource allocation when considering healthcare policy reforms.<sup>18,19</sup>

**METHODS****Data Source and Study Population**

Medical claims identified from Taiwan's National Health Insurance Research Database were provided by the Department of Health's National Health Insurance Bureau.<sup>17,20</sup> The data set includes all claims from Taiwan's NHIP, a single-payer system begun in 1995, which finances care for all citizens and offers them unrestricted access to any healthcare provider.<sup>20</sup> Currently NHIP covers more than 22.6 million enrollees, representing 99% of the population.

The bureau reviews all reimbursement claims filed by contracted health organizations and screens the type, volume, quality, and appropriateness of medical services provided.<sup>17</sup> The research database's registration files include patient demographics, principal and secondary diagnostic codes, procedure and prescription codes, claim summaries, detailed orders, prescriptions and expenditures for inpatient and ambulatory care, and postoperative 30-day morbidity and mortality data.<sup>20</sup> The study contents (eg, diagnoses, procedures, medical utility parameters from the National Health Insurance Research Database) have been fully validated by the National Health Research Institutes and the Bureau of National Health Insurance, Taiwan. Besides the administrative and financial routine validation, the National Health Insurance Research Database was further validated in a recent study, suggesting that the research database is a valid resource for population-based research.<sup>21</sup> Patients enrolled in this study were those discharged from acute care hospitals between January 1, 2004, and December 31, 2007, with principal/secondary diagnoses and procedures based on *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* codes. All personal identifiers were decoded before the data were released

for research, and the National Health Insurance Research Database committee evaluated and approved the study.

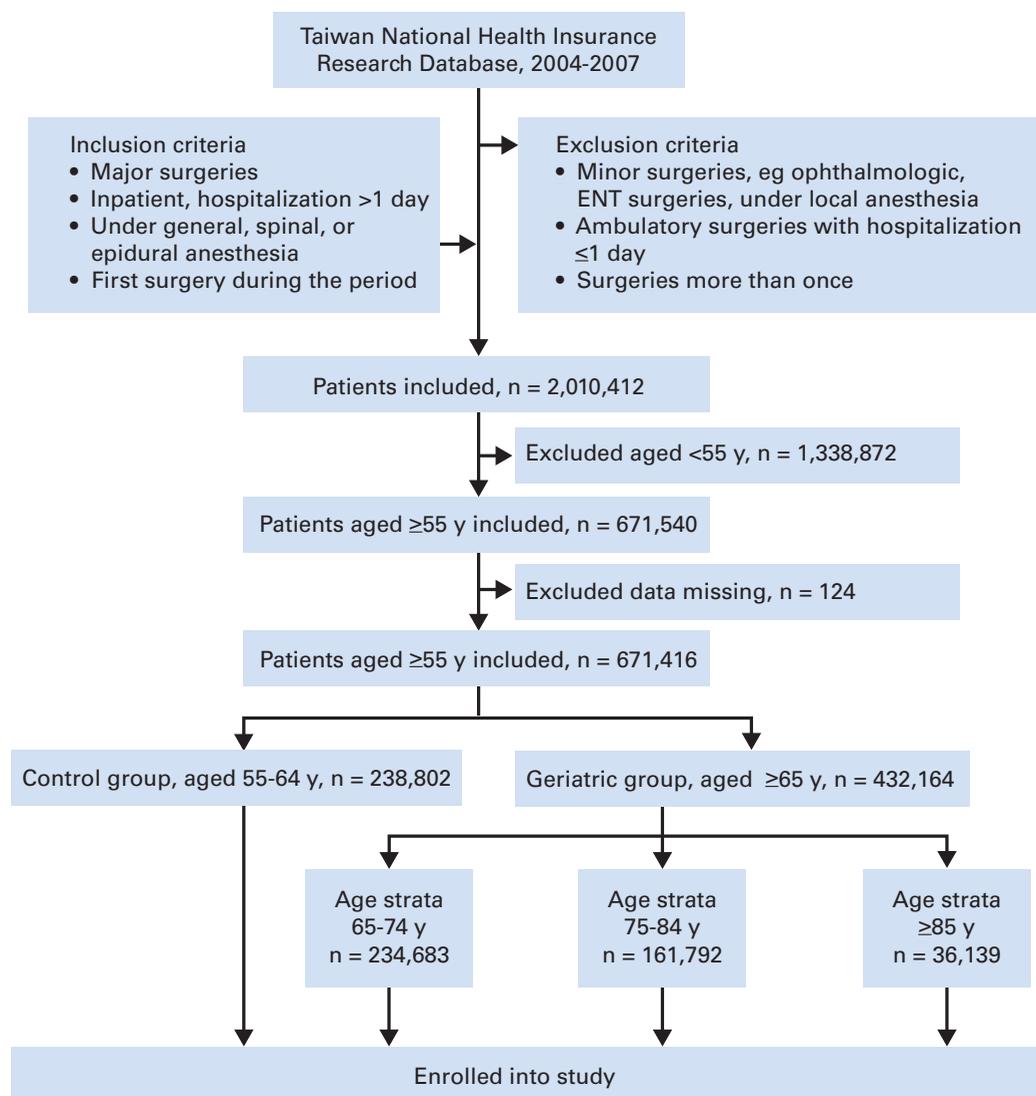
The initial 2004 to 2007 database included information on more than 2 million National Health Insurance beneficiaries who underwent inpatient surgery under anesthesia at contracted medical facilities. We limited the study

to patients who had procedures performed under general, spinal, or epidural anesthesia, and excluded surgeries with very low mortality rates such as ophthalmologic, auditory, nasal, and other minor procedures under regional or local anesthesia. Considering all the risk factors (primary variables) among the elderly, age difference and complex comorbidities were the major concerns and contributory factors for the outcomes of the study.<sup>5-7</sup> We selected geriatric patients (by definition aged  $\geq 65$  years) and categorized them into strata of ages 65 to 74, 75 to 84, and  $\geq 85$  years. These patients received inpatient surgeries in 2004 to 2007 under universal healthcare coverage from the Taiwan NHIP. Using the inclusion criteria identified in this paragraph, we selected surgical patients aged 55 to 64 years, the closest age group, as the reference group. We then segregated data on patients who received inpatient surgery and were admitted for more than 1 day in order to exclude outpatient surgeries and to take only an individual's first operation into consideration. In that way, we avoided the potential interference of surgeries derived from the postoperative complications per se if patients underwent more than 1 procedure during this period. As we restricted our analysis to patients aged  $>55$  years, 671,540 patients were identified. Excluding missing data in 124 claims left 671,416 patients. The 432,614 patients aged  $\geq 65$  years were classified into subgroups of 65 to 74, 75 to 84, and  $\geq 85$  years. The 238,802 patients aged 55 to 64 years served as the reference group (**Figure 1**).

**Primary Outcomes**

Demographic characteristics included sex, preoperative functional status, and 15 other variables that identified additional major preoperative coexisting illnesses (ie, hypertension, diabetes, transient ischemic attack/stroke, chronic obstructive pulmonary disease, myocardial infarction/ischemia, dialysis, congestive heart failure, peripheral vascular disease, acute renal failure, ascites, bleeding disorder, emergent operation or not, and previous use of medications for or management of conditions such as preoperative transfusion of more than 4 units, use of vasopressors/inotropes, and albumin supplementation).<sup>3,22</sup> The coexisting illness variables were identified from all inpatient and outpatient administrative

■ **Figure 1.** Flow Chart of the Study Design



ENT indicates ear, nose, and throat.

health insurance claims of individual beneficiaries submitted since January 1, 2002, which provided data for 24 months prior to surgical admission date. Other potential variables included the number of medical illnesses and preoperative 24-month medical expenditures (all inpatient and outpatient medical services and medical resource consumption including prescription, laboratory, and radiologic examinations, preoperative evaluation and management, physician fees, etc) for patients enrolled. Individual healthcare expenses were collected and analyzed based on healthcare claims for comorbid conditions within 24 months preoperatively for the index surgery (Table 1A).

Complications and mortality after complications were categorized into 8 major groups, defined by the primary and sec-

ondary diagnoses according to the ICD-9-CM codes assigned at discharge and by subsequent inpatient or outpatient records within 30 days of surgery. Major postoperative complications included pneumonia (ICD-9-CM codes 480-486), acute renal failure (ICD-9-CM code 584), acute myocardial infarction (ICD-9-CM code 410), pulmonary embolism (ICD-9-CM code 415), postoperative bleeding (ICD-9-CM codes 998-999), deep wound infection (ICD-9-CM code 958), septicemia (ICD-9-CM codes 038; 998.0; 778.52), and stroke (ICD-9-CM codes 430-438) (Table 1A).<sup>3,22</sup>

### Statistical Analysis

Distributions of demographic characteristics, preoperative functional status, prevalence of coexisting conditions, ob-

■ **Table 1A.** Independent Variables and Outcome Variables

Independent Variables	Outcome Variables
<b>Age, y<sup>a</sup></b>	<b>Postoperative complications<sup>b</sup></b>
<b>Sex</b>	Pneumonia
<b>Preoperative functional status</b>	Acute renal failure
Totally dependent (ICU/RCC user)	Acute myocardial infarction
Partially dependent	Pulmonary embolism
Totally independent	Postoperative bleeding
<b>Preoperative medical conditions</b>	Deep wound infection
Hypertension	Septicemia
Diabetes	Stroke
Transient ischemic attack/stroke	Overall complications (any of the above) <sup>c,d</sup>
COPD	<b>Mortality due to postoperative complications<sup>b</sup></b>
Myocardial infarction/ischemia	Pneumonia
Dialysis	Acute renal failure
Congestive heart failure	Acute myocardial infarction
Preoperative transfusion	Pulmonary embolism
Emergency operation	Postoperative bleeding
Usage of vasopressors/inotropes	Deep wound infection
Albumin supplement	Septicemia
Peripheral vascular disease	Stroke
Acute renal failure	Overall complications (any of the above) <sup>c,d</sup>
Ascites	<b>Observed postoperative complication rate<sup>b</sup></b>
Bleeding disorder	<b>Adjusted postoperative complication rate<sup>b</sup></b>
<b>Number of coexisting medical conditions</b>	<b>Observed mortality rate after major complications<sup>b</sup></b>
<b>Preoperative medical expenditure</b>	<b>Adjusted mortality rate after major complications<sup>b</sup></b>

COPD indicates chronic obstructive pulmonary disease; ICU, intensive care unit; RCC, respiratory care center.  
<sup>a</sup>Patients were classified by age into 4 groups (55-64, 65-74, 75-84, and ≥85 years), using age 55 to 64 years as the reference group.  
<sup>b</sup>Analyses of variables shown in Table 2 using the multivariate logistic regression model.  
<sup>c</sup>Analyses of variables shown in Table 3 using the multivariate logistic regression model.  
<sup>d</sup>Analyses of variables shown in Table 4 using the multivariate logistic regression model.

served complication rates, and mortality rate after complications among the 4 age strata were compared using the  $\chi^2$  test. Multiple logistic regression models were used to estimate the odds ratio (OR) and 95% confidence interval (CI) of mortality associated with the postoperative complication status or numbers of coexisting medical conditions in different age groups. All models were adjusted for demographics, functional factors, and preexisting illnesses. In addition, the adjusted ORs of mortality related to different numbers of coexisting medical conditions were evaluated among the different age strata. Quartile values of preoperative medical expenditures were used as a cutoff for the trend test, and the rates of complications or mortality for 4 strata of preoperative medical expenditures were further evaluated after multivariate adjustment. Groups with low preoperative medical expenditures were used as a reference to estimate the adjusted ORs for other groups. All data analy-

ses were performed using SAS System for Windows, version 8.2 (SAS Institute, Inc, Cary, North Carolina). A 2-sided *P* value of less than .05 was considered significant.

## RESULTS

The prevalence of the 15 major preexisting medical conditions listed above under “Primary Outcomes” increased with age, as well as preoperative medications such as transfusion of red blood cells and use of vasopressors/inotropes and albumin (*P* < .0001). Conditions showing age differences but not age dependence were ascites and bleeding disorders (*P* = .0037 and .0127, respectively). Among the illnesses, the incidences of hypertension, myocardial infarction/ischemia, and peripheral vascular disease were age dependent for patients aged 55 to 84 years, while they decreased in patients aged ≥85 years,

**Table 1B.** Distribution of Characteristics, Preoperative Functional Status, and Coexisting Conditions Among Controls and Geriatric Patient Groups Receiving Inpatient Surgeries<sup>a</sup>

Variable	Reference Group, 55-64 y	Geriatric Group			P <sup>b</sup>
		65-74 y	75-84 y	≥85 y	
<b>Number</b>	238,802	234,683	161,792	36,139	
<b>Male, %</b>	50.91	51.01	57.21	48.66	<.0001
<b>Preoperative functional status, %</b>					
Totally dependent (ICU/RCC user)	3.01	4.75	7.58	10.19	
Partially dependent	21.00	27.07	35.14	39.02	
Totally independent	75.99	68.18	57.28	50.79	
<b>Coexisting condition, %<sup>c</sup></b>					
Hypertension	32.02	44.92	50.54	46.94	<.0001
Diabetes	18.40	22.63	21.42	14.28	<.0001
Transient ischemic attack/stroke	16.91	27.44	36.01	36.46	<.0001
COPD	14.23	20.47	27.34	28.81	<.0001
Myocardial infarction/ischemia	7.87	12.77	16.11	14.91	<.0001
Dialysis	2.91	3.35	3.16	2.28	<.0001
Congestive heart failure	2.05	4.25	7.11	10.03	<.0001
Preoperative transfusion	0.74	0.98	1.48	2.25	<.0001
Emergency operation	1.12	1.21	1.47	1.84	<.0001
Usage of vasopressors/inotropes	1.19	1.81	3.11	4.37	<.0001
Albumin supplement	0.59	0.84	1.50	2.56	<.0001
Peripheral vascular disease	0.30	0.57	0.95	0.84	<.0001
Acute renal failure	0.22	0.38	0.59	0.75	<.0001
Ascites	0.14	0.15	0.12	0.08	0.0037
Bleeding disorder	0.11	0.13	0.12	0.07	0.0127

COPD indicates chronic obstructive pulmonary diseases; ICU, intensive care unit; RCC, respiratory care center.

<sup>a</sup>Demographic and clinical characteristics as well as coexisting medical conditions of patients in the geriatric and reference groups who received major surgeries between 2004 and 2007 under Taiwan's National Health Insurance Program.

<sup>b</sup>By  $\chi^2$  tests.

<sup>c</sup>Identified from all inpatient and outpatient administrative claims of individual beneficiaries for medical use of health insurance within the 24-month period before the index surgery.

an age greater than the population's average life expectancy (Table 1B).

In the reference group (aged 55-64 years), the overall postoperative complication rate for the 8 major postoperative complications listed above under "Primary Outcomes" was 11.94%, which increased to 18.05%, 26.63%, and 34.12% in the 65 to 74, 75 to 84, and ≥85 year age groups, respectively. The risk ratio of complications was 2.86 for the group aged ≥85 years versus the reference group. After adjusting for sex, preoperative functional status, and coexisting conditions, the risk-adjusted complication rates varied among the study groups, ranging from 15.52% in the reference group to 23.61% in group aged ≥85 years, with a risk ratio of 1.52 versus the reference group (Table 2). Although we focused mainly on 8 major postoperative complications, the mortality after these major complications in our cohort accounted for 66.70% of overall

deaths from all causes in the database. The crude mortality rate after major complications was 18.10% in the ≥85 year age group compared with 5.52% in the reference group, with a risk ratio of 3.28. After adjusting for sex and preexisting illnesses, the risk-adjusted mortality rate after complications increased from 8.64% in the reference group to 10.17% in the group aged ≥85 years, with a risk ratio of 1.18. For each variable, as age increased there were significant increases in the number of major postoperative complications such as pneumonia, acute renal failure, pulmonary embolism, septicemia, and stroke. Adjusted ORs ranged from 1.91 to 5.21 when comparing the 2 extreme age groups ( $P < .0001$ ). In contrast, the incidences of postoperative bleeding and deep wound infection significantly decreased with age ( $P < .0001$  and  $P = .0002$ ) (Table 2).

Most geriatric surgical patients had at least 1 comorbidity associated with complications and mortality (77.4% vs 57.4%

**Table 2.** Incidence and Adjusted Odds Ratios of Major Postoperative Complications and Mortality After Major Complications Among Reference and Geriatric Patient Groups

Complication	Reference Group, 55-64 y	Geriatric Group			Age >85 y vs 55-64 y		P
		65-74 y	75-84 y	≥85 y	OR <sup>a</sup>	95% CI	
<b>Number</b>	238,802	234,683	161,792	36,139			
<b>Incidence of major postoperative complications, %</b>							
Pneumonia	2.11	3.91	7.97	13.94	5.21	4.98-5.45	<.0001
Acute renal failure	0.63	1.13	2.00	3.46	4.38	4.03-4.77	<.0001
Acute myocardial infarction	0.36	0.61	0.86	1.01	1.91	1.67-2.19	<.0001
Pulmonary embolism	0.06	0.11	0.15	0.19	2.17	1.57-3.01	<.0001
Postoperative bleeding	3.08	3.24	3.21	2.74	0.80	0.75-0.86	<.0001
Deep wound infection	0.79	0.74	0.65	0.59	0.75	0.65-0.87	.0002
Septicemia	1.82	3.16	5.61	9.51	4.35	4.13-4.58	<.0001
Stroke	5.19	9.24	13.97	15.27	2.03	1.95-2.11	<.0001
Any of the above	11.94	18.05	26.63	34.12	2.74	2.67-2.82	<.0001
<b>Incidence of mortality after major complications, %</b>							
Pneumonia	11.10	13.17	19.40	22.95	2.38	2.12-2.67	<.0001
Acute renal failure	19.49	19.64	28.04	32.80	1.81	1.49-2.18	<.0001
Acute myocardial infarction	10.25	12.65	22.96	32.42	3.59	2.53-5.10	<.0001
Pulmonary embolism	5.19	9.52	10.61	19.40	7.10	2.08-24.19	.0017
Postoperative bleeding	1.75	2.97	5.46	11.30	5.34	4.01-7.12	<.0001
Deep wound infection	1.38	1.33	4.00	6.10	4.89	2.30-10.39	<.0001
Septicemia	17.76	19.43	28.40	34.13	2.34	2.09-2.63	<.0001
Stroke	2.65	2.76	4.52	7.94	3.13	3.12-3.14	<.0001
Any of the above	5.52	6.74	11.62	18.10	3.56	3.31-3.84	<.0001
<b>No. of complications</b>	28,509	42,358	43,088	12,332	RR, <sup>b</sup> ≥85 y vs 55-64 y		
<b>Observed complication rate, %</b>	11.94	18.05	26.63	34.12	2.86		
<b>Adjusted complication rate, %<sup>c</sup></b>	15.52	18.82	22.58	23.61	1.52		
<b>No. who died after major complications</b>	1575	2856	5008	2232	RR, <sup>b</sup> ≥85 y vs 55-64 y		
<b>Observed mortality rate after major complications, %</b>	5.52	6.74	11.62	18.10	3.28		
<b>Adjusted mortality rate after major complications, %<sup>c</sup></b>	8.64	8.93	9.68	10.17	1.18		

CI indicates confidence interval; OR, odds ratio; RR, relative risk.

<sup>a</sup>Adjusted for sex, preoperative functional status, and coexisting medical conditions.

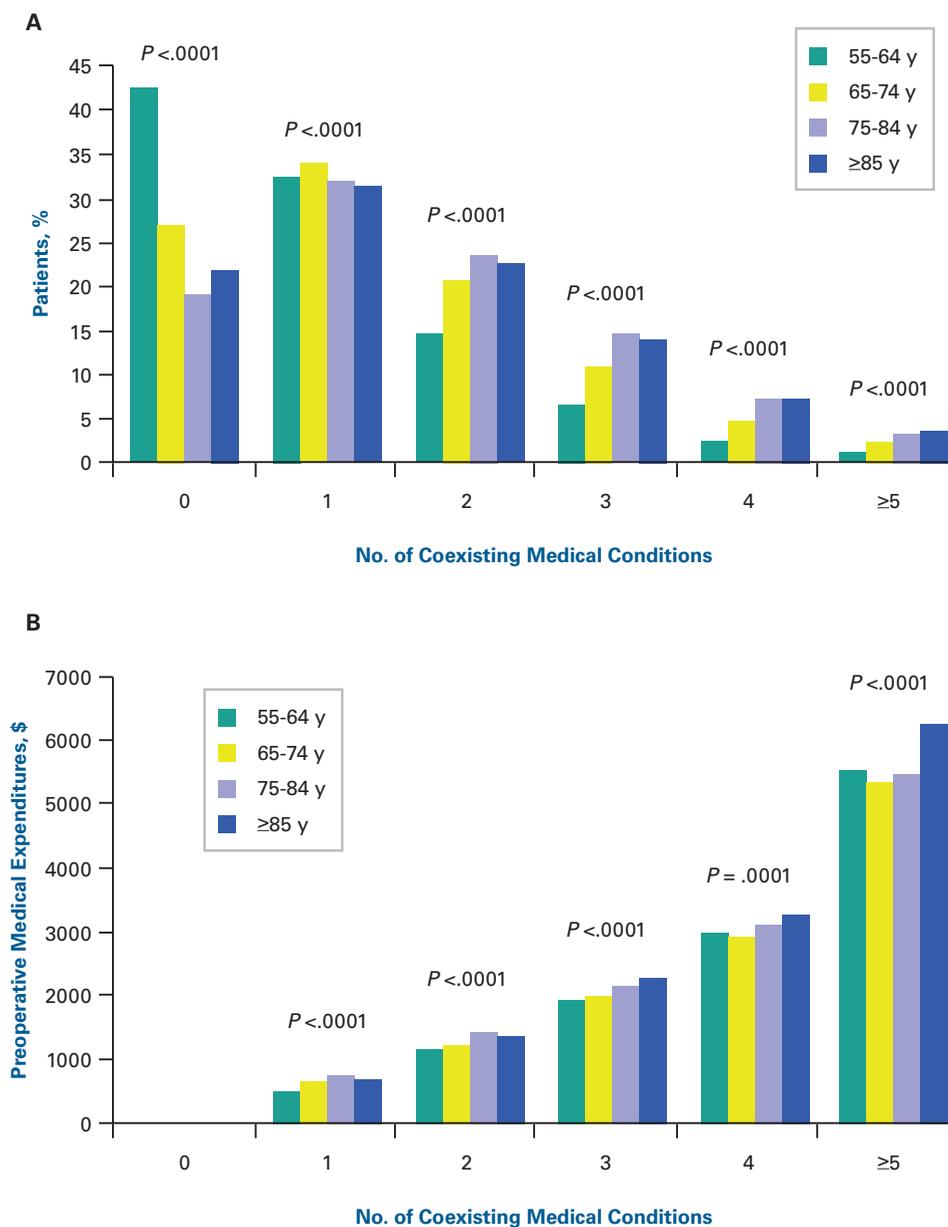
<sup>b</sup>Comparing the geriatric group age ≥85 years with the reference group, age 55 to 64 y.

<sup>c</sup>The observed adverse event rates were adjusted for sex, preoperative functional status, and coexisting medical conditions by using the multivariate logistic regression model.

of the reference group;  $P < .0001$ ) (Figure 2A). Numbers of medical conditions increased with age. The reference group had the highest percentage of patients without preoperative medical conditions, and the group aged 75 to 84 years had the lowest percentage (42.56% vs 19.18%,  $P < .0001$ ). The incidence of patients with 5 or more preexisting conditions

was much greater in those aged ≥85 years than in the reference group (3.65% vs 1.09%;  $P < .0001$ ). The proportions of patients with 2 or more medical conditions were similar in the groups aged 75 to 84 and ≥85 years; the groups aged 55 to 64 and 65 to 74 years had significantly lower proportions of those patients ( $P < .0001$ ) (Figure 2A). Considering the num-

**Figure 2.** Distribution of Patients (A) and Average Comorbidity-Related Expenditures (B) in Reference Group and Age-Specific Elderly Surgical Groups With Various Numbers of Coexisting Medical Conditions 24 Months Preoperatively<sup>a</sup>



<sup>a</sup> $P < .0001$  or  $P = .0001$  versus reference group.

ber of medical conditions and postoperative outcomes in geriatric surgical patients, the complication and mortality rates increased with an incremental number of coexisting conditions among all age groups, and the incidence was highest in patients with 5 or more comorbidities (Table 3). After adjusting for preoperative status, the OR of complication rates in patients with 5 or more medical conditions compared with patients who had none was 7.23 (95% CI 6.63-7.89) in the

reference group and 4.04 (95% CI 3.56-4.59) in patients aged ≥85 years.

The correlation between mortality rates after major complications and numbers of coexisting conditions displayed a different and relatively unaffected pattern in elderly surgical patients when they had fewer than 3 comorbidities. The adjusted OR was significant at 1.65 (95% CI 1.34-2.03) and 1.97 (95% CI 1.53-2.53) in the reference group and at 1.44

**Table 3.** Incidence and Risks of Postoperative Major Complications and Mortality Associated With Number of Coexisting Medical Conditions in Geriatric Surgical Patients and the Reference Group

No. of Coexisting Medical Conditions	Reference Group, 55-64 y (n = 238,802)			Geriatric Group								
				65-74 y (n = 234,683)			75-84 y (n = 161,792)			≥85 y (n = 36,139)		
	Complications, %	OR <sup>a</sup>	95% CI	Complications, %	OR <sup>a</sup>	95% CI	Complications, %	OR <sup>a</sup>	95% CI	Complications, %	OR <sup>a</sup>	95% CI
None	6.75	1.00	Reference	9.24	1.00	Reference	14.68	1.00	Reference	21.24	1.00	Reference
1	11.32	1.76	1.71-1.82	14.89	1.72	1.66-1.78	22.26	1.66	1.60-1.73	30.11	1.60	1.49-1.71
2	18.95	3.23	3.12-3.35	23.98	3.10	2.99-3.20	31.27	2.64	2.55-2.75	40.55	2.53	2.36-2.71
3	23.55	4.26	4.07-4.45	28.56	3.93	3.78-4.08	35.74	3.23	3.10-3.37	44.21	2.94	2.72-3.18
4	26.55	4.99	4.69-5.32	30.52	4.31	4.11-4.53	37.73	3.52	3.35-3.70	44.55	2.98	2.71-3.28
≥5	34.36	7.23	6.63-7.89	37.94	6.00	5.63-6.40	42.59	4.31	4.04-4.60	52.13	4.04	3.56-4.59
No. of Coexisting Medical Conditions	Mortality, %	OR <sup>a</sup>	95% CI	Mortality, %	OR <sup>a</sup>	95% CI	Mortality, %	OR <sup>a</sup>	95% CI	Mortality, %	OR <sup>a</sup>	95% CI
None	5.23	1.00	Reference	6.29	1.00	Reference	11.68	1.00	Reference	16.05	1.00	Reference
1	5.16	0.99	0.86-1.14	6.07	0.96	0.85-1.10	10.52	0.89	0.80-0.99	16.38	1.02	0.88-1.20
2	5.00	0.95	0.82-1.11	6.07	0.96	0.84-1.10	10.10	0.85	0.76-0.95	17.32	1.10	0.94-1.28
3	5.72	1.10	0.92-1.31	7.07	1.13	0.99-1.30	11.78	1.01	0.90-1.13	19.76	1.29	1.09-1.52
4	8.34	1.65	1.34-2.03	8.15	1.32	1.13-1.55	6.34	1.28	1.14-1.45	21.59	1.44	1.19-1.75
≥5	9.81	1.97	1.53-2.53	12.92	2.21	1.86-2.63	11.64	1.88	1.63-2.16	25.54	1.79	1.43-2.25

CI indicates confidence interval; OR, odds ratio.

<sup>a</sup>Adjusted for sex and preoperative functional status in the multivariate logistic regression models.

(95% CI 1.19-1.75) and 1.79 (95% CI 1.43-2.25) in the group aged ≥85 years when comparing patients who had 4 or more than 5 coexisting conditions with patients who did not have medical conditions (Table 3).

The preoperative 24-month medical expenditures increased significantly with the incremental number of major preexisting medical conditions among all age groups, and differences among various age groups who had the same number of conditions were relatively minute, although still statistically significant ( $P < .0001$ ) (Figure 2B). There was a linear increase in average preoperative 24-month expenditures among all age groups: US dollars =  $n \times 600 \times \text{constant}$ , where  $n$  is the number of coexisting conditions, and the constant is equal to 1.0 to 1.2 (Figure 2B).

After stratifying the preoperative comorbidity-related medical expenditures into low, median, high, and very high levels with equal numbers of patients, there was a consistent positive correlation between the observed postoperative complication rates and the preoperative expenditures for patients' preexisting illnesses. After adjusting for the preexisting conditions and preoperative medical expenses in each age group, the adjusted ORs for postoperative major complications in the medium, high, and very high medical expenditure sub-

groups increased from 1.03 (95% CI 0.98-1.08) to 2.01 (95% CI 1.90-2.12) in the group aged 55 to 64 years and increased from 1.17 (95% CI 1.08-1.27) to 1.99 (95% CI 1.81-2.20) in patients aged ≥85 years when using the low medical expenditure group as the reference (Table 4). There was overt homogeneity in mortality rates after major complications with adjusted ORs of 1.03 (95% CI 0.85-1.25) to 0.90 (95% CI 0.73-1.11) among different expenditure groups aged 55 to 64 years and adjusted ORs of 0.95 (95% CI 0.80-1.14) to 1.13 (95% CI 0.92-1.37) in the subgroup aged ≥85 years compared with the low medical expenditure subgroup, after adjusting for preoperative expenditures in addition to coexisting illnesses (Table 4).

## DISCUSSION

In this large population-based cohort study of elderly surgical patients under a healthcare system with universal coverage, we first verified that the adverse outcomes of inpatient surgery for the elderly were age dependent, related to comorbidities, and associated with preoperative medical expenditures. After adjusting for patients' covariates, the risk ratios for postoperative major complications, but not for

**Table 4.** Incidence and Risks of Postoperative Complications and Mortality Associated With Preoperative Medical Expenditure in Geriatric Surgical Patients and the Reference Group

Medical Expenditures <sup>a</sup>	Geriatric Group											
	Reference Group, 55-64 y (n = 238,802)			65-74 y (n = 234,683)			75-84 y (n = 161,792)			≥85 y (n = 36,139)		
	Compli-cations, %	OR <sup>b</sup>	95% CI	Compli-cations, %	OR <sup>b</sup>	95% CI	Compli-cations, %	OR <sup>b</sup>	95% CI	Compli-cations, %	OR <sup>b</sup>	95% CI
Low	6.85	1.00	Reference	9.39	1.00	Reference	15.39	1.00	Reference	21.77	1.00	Reference
Medium	8.81	1.03	0.98-1.08	12.39	1.09	1.04-1.13	20.76	1.17	1.12-1.22	28.31	1.17	1.08-1.27
High	13.90	1.47	1.35-1.49	18.74	1.48	1.42-1.55	27.12	1.48	1.41-1.54	35.05	1.42	1.30-1.55
Very high	24.57	2.01	1.90-2.12	32.77	2.18	2.07-2.28	43.26	2.17	2.07-2.28	51.37	1.99	1.81-2.20
Medical Expenditures <sup>a</sup>	Mortal-ity, %	OR <sup>b</sup>	95% CI	Mortal-ity, %	OR <sup>b</sup>	95% CI	Mortal-ity, %	OR <sup>b</sup>	95% CI	Mortal-ity, %	OR <sup>b</sup>	95% CI
Low	5.41	1.00	Reference	6.53	1.00	Reference	11.66	1.00	Reference	15.96	1.00	Reference
Medium	5.14	1.03	0.85-1.25	6.46	1.01	0.86-1.81	10.22	0.90	0.80-1.01	15.44	0.95	0.80-1.14
High	4.83	1.03	0.85-1.25	5.90	0.98	0.84-1.14	10.26	0.91	0.81-1.02	17.56	1.13	0.94-1.36
Very high	6.13	0.90	0.73-1.11	7.40	0.93	0.79-1.10	13.14	0.93	0.82-1.05	20.84	1.13	0.92-1.37

CI indicates confidence interval; OR, odds ratio.

<sup>a</sup>Average preoperative medical expenditures included all inpatient, outpatient, and emergency services of individual beneficiaries for coexisting medical conditions within 24 months before index surgery. These expenditures were divided into quartiles: the 1st quartile represented low, the 2nd quartile represented medium, the 3rd quartile represented high, and the 4th quartile represented very high expenditures.

<sup>b</sup>Adjusted for sex, preoperative functional status, and coexisting conditions in the multivariate logistic regression models.

the mortality rates, increased incrementally with numbers of comorbidities and preoperative comorbidity-related medical expenditures among elderly surgical patients. Considering the study scale and patient populations, we validated use of preexisting comorbidities and preoperative medical expenditures to predict the potential surgical adverse outcomes of elderly surgical patients, providing a new way to explore correlations between preconditioned costs (preoperative medical expenditures) and effectiveness (comorbidities or adverse outcomes) in acute care services for the elderly.<sup>3,23</sup>

Previous studies have primarily focused on either the prognostic impacts of comorbidities or their correlations with medical costs of chronic illnesses in the elderly, without verifying potential correlations between preoperative costs and postoperative outcomes in geriatric surgical patients.<sup>24-26</sup> Theoretically, the prevalence of coexisting medical conditions increases with age, and medical expenses associated with healthcare increase with additional chronic conditions. In this study, we first correlated the number of preexisting medical conditions with major postoperative adverse outcomes and validated their impact in an age-specific pattern. Among various age groups, patients aged 55 to 64 and 65 to 74 years with more than 5 illnesses had higher adjusted ORs (7.23 [95% CI 6.63-7.89] and 6.00 [95% CI 5.63-6.40]) than the patients aged 75 to 84 and ≥85 years (4.31 [95% CI 4.04-4.60] and 4.04 [95% CI 3.56-4.49]) for postoperative rates of com-

plications after risk adjustment when using patients without preexisting illnesses as a reference. This result indicates that the complexity of preoperative comorbidities is more influential in younger groups than in older groups in determining the incidence of postoperative adverse outcomes.<sup>25</sup> Further analyses (Figure 1B) also confirmed a linear correlation, with complexity (number of illnesses) rather than age differences playing a major role in determining average preoperative expenditures.<sup>27,28</sup> Accordingly, we could estimate potential risk for surgical adverse outcomes based on the number of major comorbidities that elderly surgical patients in different age groups had preoperatively.

Although it might be clinically intuitive to expect patients with more comorbidities to consume more medical resources, analyses among different levels of preoperative medical expenditures exhibited specific correlation patterns. Preoperative medical expenditures showed a positive correlation with the adjusted risk ratio of major postoperative complications, but were irrelevant to the adjusted mortality rate, which was nearly consistent among patients with various levels of cost. Basically, preoperative medical expenditures were for preexisting medical conditions, and healthcare spending was mainly for prescriptions (medications), laboratory examinations, and to a lesser extent, management or procedures related to systemic diseases. Major perioperative complications resulted from major preexisting comorbidities, which also caused

subsequent postoperative adverse outcomes. Therefore, co-existing medical conditions, preoperative expenses, and postoperative complication rates were all closely correlated. In contrast, the mortality rate was the final result derived from the combination of patient factors, surgical outcomes, and the quality of postoperative care throughout the period of hospitalization. Influences on the mortality rate were not confined only to patient factors (preoperative comorbidities and associated expenses).

Our data show that after adjusting for medical expenditures, elderly patients had surgical outcomes that were of consistent and acceptable quality under universal coverage in this single-payer healthcare system. Several factors contributed to the relatively uniform healthcare outcomes in this study. Enhanced governmental expense controls and continuous quality improvements in healthcare service management at the local level are the 2 major ways in which healthcare cost and effectiveness are regulated.<sup>29</sup> Government control of both budgets and expenditures is always necessary for health programs with universal coverage. Through regulating the payment system, such as with a global budget for regional health providers (carrot) and an accreditation system for quality control of healthcare (stick), healthcare spending can be restrained at the supply end. Another important strategy at the demand end is that the Taiwan NHIP uses disease-management programs for complex health needs such as diabetes and actively monitors for potential overuse by beneficiaries due to ease of availability.<sup>16,30</sup> In addition, it is extremely important to negotiate with and engage healthcare professionals and organizations to improve the quality and efficiency of services and to avoid resistance or overuse behaviors when revising regulations.

This study had several limitations. First, we used a data set of an administrative nature without definitive laboratory data, so hospital discharge codes' accuracy should be verified. However, we complemented the data by linking to a governmental catastrophic illness registry system to strengthen the accuracy of the comorbidities and clinical adverse events.<sup>17</sup> Second, we might have oversimplified the assumption of equivalence of the severity and importance of each preexisting medical condition to analyze the impact of comorbidity numbers on outcomes and expenditures. Third, different surgical or anesthesia features were not taken into consideration for detailed analyses in this study; those factors might have influenced postoperative outcomes. Finally, the extreme outliers of patients with very high levels of medical expenditures and adverse outcomes among all age groups might represent a category of beneficiaries with potentially ineffective care, and this needs further analysis.<sup>31</sup>

## CONCLUSIONS

In summary, the numbers of preoperative major medical illnesses and preoperative comorbidity-related medical expenditures in geriatric surgical patients closely correlate with the postoperative major complication rates, although they are relatively irrelevant to mortality. Our findings suggest that pre-existing comorbidities and related preoperative expenses are potential predictors of postoperative adverse outcomes. To reduce postoperative adverse outcomes for elderly surgical patients, increased integrated healthcare for the comorbidities of elderly patients before surgery and prevention/management of potential complications postoperatively are crucial and mandatory.

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