Factors Associated with Pneumonia Outcomes: A Nationwide Population-Based Study over the 1997–2008 Period

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BACKGROUND: Pneumonia is the most common infectious cause of death worldwide. Over the last decade, patient characteristics and health care factors have changed. However, little information is available regarding systematically and simultaneously exploring effects of these changes on pneumonia outcomes.

OBJECTIVES: We used nationwide longitudinal population-based data to examine which patient characteristics and health care factors were associated with changes in 30-day mortality rates for pneumonia patients.

DESIGN: Trend analysis using multilevel techniques.

SETTING: General acute care hospitals throughout Taiwan.

PARTICIPANTS: A total of 788,011 pneumonia admissions.

MEASUREMENTS: Thirty-day mortality rates. Taiwan's National Health Insurance claims data from 1997 to 2008 were used to identify the effects of patient characteristics and health care factors on 30-day mortality rates.

RESULTS: Male, older, or severely ill patients, patients with more comorbidities, weekend admissions, larger reimbursement cuts and lower physician volume were associated with increased 30-day mortality rates. Moreover, there were interactions between patient age and trend on mortality.

CONCLUSIONS: Male, older or severely ill patients with pneumonia have higher 30-day mortality rates. However, mortality gaps between elderly and young patients narrowed over time; namely, the decline rate of mortality among elderly patients was faster than that among young patients. Pneumonia patients admitted on weekends also have higher mortality rates than those admitted on weekdays. The mortality of pneumonia patients rises under increased financial strain from cuts in reimbursement such as the Balanced Budget Act in the United States or global budgeting. Higher physician volume is associated with lower mortality rates.

KEYWORDS: pneumonia; outcomes; mortality.

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INTRODUCTION

Pneumonia is the most common infectious cause of death and one of the top ten causes of death worldwide^{1,2}. The pneumonia mortality rate has been regarded as a proxy measure of hospital performance and quality of care to compare hospitals^{3–5}. For example, the 30-day mortality rate after pneumonia has been used by the Centers for Medicare & Medicaid Services (CMS) to compare outcomes among different hospitals. Finding the determinants that affect changes in pneumonia mortality rates is important for developing effective initiatives to improve pneumonia outcomes. Additionally, patient characteristics and health care factors have changed over the past years. As far as we know, there have been few studies using nationwide longitudinal population-based data to systematically and simultaneously explore effects of these changes on pneumonia mortality rates.

If the mortality rate is to be used as a key indicator of hospital performance for pneumonia care delivery, an understanding of the variables associated with pneumonia mortality rates is essential. One previous study has found that certain variables may influence pneumonia mortality rates, including patient characteristics (age, gender, illness severity and comorbid illness) and one health care factor (physician volume)⁶. However, so far, no research has examined the impact of weekend admissions or reimbursement cuts on pneumonia mortality. Prior studies have shown that weekend admissions for other different conditions or procedures are associated with increased mortality^{7,8}, and larger cuts in reimbursement from the Balanced Budget Act or global budgeting are associated with higher postoperative or stroke mortality^{9,10}.

This study, using nationwide population-based data from Taiwan from 1997 to 2008, applies a multilevel model to systematically and simultaneously examine the associations of patient characteristics and health care factors (weekend admissions, reimbursement cuts and physician volume) with

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changes in 30-day mortality rates among patients with pneumonia.

METHODS

Database

We used information from the National Health Insurance Research Database (NHIRD) for this study. The NHIRD, provided by the Bureau of National Health Insurance (BNHI) and managed by the National Health Research Institutes, is a de-identified secondary database that contains patient-level demographic, diagnostic and administrative information across Taiwan. It is released for public access for research purposes.

In Taiwan, the BNHI, which is the sole insurer, has implemented national health insurance (NHI) for almost the entire population since March 1995. Each enrollee pays a premium and then enjoys comprehensive benefits with a low coinsurance policy (10% for inpatient care with a yearly cap of about US\$1,500 in 2008). Every enrollee is free to go to any hospital or clinic because there is no gatekeeper system, and almost all providers have contracts with the BNHI. Pneumonia care is reimbursed on a fee-for-service basis.

Study Population

Mainly according to the Agency for Healthcare Research and Quality (AHRQ) technical specifications¹¹, all pneumonia discharges (excluding transfers) of patients aged 18 years and older admitted to acute care hospitals in Taiwan from 1997 to 2008 were identified by the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9 CM) code combinations as either: a principal diagnosis of pneumonia (codes 480.0 to 487.0) or a principal diagnosis of acute respiratory failure (code 518.81) or septicemia (code 038) with the 480 codes as a secondary diagnosis. Unaccredited hospitals were excluded because they were likely to receive only low-risk or rather few patients. The initial data set comprised 794,621 patients. Data cleanup entailed removing patients with missing data. The final data set consisted of 788,011 patients.

Study Variables

Dependent Variables. The outcome variable was all-cause 30-day mortality from the time of admission¹², which the CMS have suggested^{4,5}. The advantage of using 30-day mortality is that the variation in length of stay does not have an undue effect on mortality rates. Without a standardized period, hospitals would have an incentive to adopt strategies

that would shift deaths out of the hospital without improving quality of care. Hospital quality would be expected to influence patient outcomes in this timeframe¹³. The most important reason why the 30-day mortality rate is used by the CMS is because mortality within 30 days is pneumonia-related, while mortality after 30 days is primarily due to comorbid conditions¹⁴. The period of 30 days after admission is used in pneumonia outcome studies^{15–17}. Thirty-day mortality was calculated by linking inpatient admission records with withdrawal certificate records^{10,18,19}. Withdrawal dates are the same as death dates according to death certificate records. Taiwan's National Health Insurance is a compulsory single payer program, so the only reason for patients being withdrawn from NHI coverage within 30 days of hospital admission would be that they had died (the other two conditions for withdrawal, being jailed for over 2 months or disappearing for over 6 months, would not be possible reasons for withdrawal within 30 days of hospital admission).

Independent Variables. Patient characteristics included gender, age (<65, 65–74 and >74 years), illness severity and comorbid illness. Patient illness severity is captured in five variables, having an intensive care unit (ICU) admission, respiratory failure/arrest (ICD-9-CM 518.81, 799.1), or hypotension/shock (ICD-9-CM 458, 785.5), and receiving mechanical ventilation (ICD-9-CM 96.7) or in-hospital dialysis (ICD-9-CM 39.95, 54.98)^{6,20,21}. The Charlson-Deyo index was used to quantify the comorbidities of pneumonia patients^{6,22}. This index is the sum of weighted scores based on the presence or absence of 17 different medical conditions. The higher the scores are, the greater the comorbidity burden.

Health care factors included weekend admissions, cuts in reimbursement and physician volume. The weekend effect was defined by whether patients were admitted on Saturday or Sunday (yes/no)^{8,19}. For physician volume, each patient admission was linked with the number of pneumonia patients treated by that physician in the year of the patient's admission.

The degree of cuts in reimbursement was measured based on the quarterly monetary value of each point¹⁰. Since July 2002, a hospital global budgeting system (fixed budget) has been adopted to control the rapid growth in medical expenditures. The global budget for a certain year is determined at the end of the previous year. Reimbursement to providers is based on an existing fee-for-service schedule, which lists a relative value or number of points for each item of service. The monetary value of each point was fixed [NT \$1 (US \$0.03)] until the adoption of global budgeting. Since then, the monetary value of each point has been equal to the fixed budget divided by the number of points that all hospitals claim, so it fluctuates. For example, the value of NT \$0.8920 per point for the first quarter of 2005²³ meant that hospitals had an average decrease in reimbursement of

NT \$0.1080 per point, which corresponded to a 10.8% reduction in revenues. In other words, the monetary value per 100 points represents the percentage of reimbursement (with 100% indicating the full payment). Thus, the reimbursement cuts indicate discounted payment compared to full payment (100%).

The covariates included physician, hospital characteristics and time trend. The physician covariates were: age and specialty (internal medicine, family medicine, others). The hospital covariates were: teaching status (yes/no), geographic location (Taipei, northern, central, southern, Kao-Ping, eastern) and competition. Hospital competition was measured by the Herfindahl–Hirschman Index (HHI). The HHI is the sum of squared market shares of each hospital in the market, and the market share is the ratio of bed counts in each hospital divided by the total beds in the market¹⁸. We calculated the HHI for the 17 medical area networks (markets) demarcated by Taiwan's Department of Health. The higher the HHI is, the more concentrated (less competitive) the market. The linear time trend was included to capture all omitted trending variables such as increases in vaccination coverage or advances in medical treatment and to separate them from the impact of hospital global budgeting^{10,24–26}.

Statistical Analysis. Multilevel logistic regression (also known as the hierarchical generalized linear model, HGLM) was applied to inpatient admissions data over the 1997–2008 period to analyze trends in 30-day mortality^{10,24}. Patients (level 1) were considered to be nested within physicians at level 2 and then nested within hospitals at level 3. Multilevel modeling is appropriate for hierarchically structured data comprising patients treated by physicians who practice in hospitals because it provides more accurate results regarding precise estimates than conventional regression modeling, which basically ignores the possible correlation of outcomes within a given physician or hospital^{27,28}. Multilevel modeling also avoids the problem of atomistic fallacy, where inferences about the groups are incorrectly drawn from individual-level information^{29,30}.

Multilevel logistic regression was applied to explore the effects of patient characteristics (gender, age, illness severity and comorbidities) and health care factors (weekend admissions, cuts in reimbursement and physician volume) on 30-day mortality, adjusted for physician characteristics (age and specialty), hospital characteristics (teaching status, geographic location and competition) and time trend. Moreover, to examine questions about differences in the intercept that can be predicted by higher level variables, multilevel models are also used to examine differences in slopes for a dependent variable (i.e., interaction terms)³¹. Thus, potential interactions selected a priori between patient characteristic/health care factors and

time trend, and health care factors and hospital characteristics were explored. The SAS statistical software (version 9.1) and HLM (version 6.02) were used for the analysis. A two-sided P value of less than 0.05 was considered statistically significant.

RESULTS

Descriptive Trends

In Table 1, information is presented on patient characteristics, health care factors and patient outcomes over the study period, 1997–2008. The percentage of male patients increased from 59.6% to 63.9%. The percentage of patients age 75 and over rose from 30.7% to 51.4%. The percentage of patients who had at least one ICU stay increased from 12.4% to 16.3%. The percentage of patients with complications of respiratory failure/arrest increased from 8.1% to 13.8%. The mean Charlson-Deyo index rose from 0.81 to 1.23. The proportion of weekend admissions was almost constant (approximately 24.0%). The mean quarterly monetary value of each point under global budgeting decreased steadily from 0.9805 in 2002 to 0.8999 in 2004, and then rebounded to 0.9429 in 2008. In other words, the mean magnitude of payment reduction on hospital revenues was highest (10.01%) in 2004. Mean physician volume increased from 62 cases in 1997 to 121 cases in 2002, but then decreased to 106 cases in 2008. The 30-day mortality rate decreased from 11.2% to 10.2%.

Furthermore, Figure 1 exhibits the 30-day mortality rate by patient age group, 1997–2008. Older age groups had higher mortality rates than younger groups, and the age gap in mortality decreased over time.

Multilevel Analysis

Table 2 presents the results of the multilevel logistic regression analysis examining the associations of patient characteristics and health care factors with 30-day mortality. After adjusting for physician, hospital characteristics and time trend, there were significant associations of patient gender and age, severity, comorbidities, weekend admissions, cuts in reimbursement and physician volume with 30-day mortality rates. There were also significant interactions between patient age and time trend.

Male patients had 11% higher odds of 30-day death compared with female patients [odds ratio (OR)=1.11; 95% confidence interval (CI)=1.09 to 1.13]. Patients aged 75 and older had 3.14 times higher odds of death compared with patients aged 64 and younger (OR=3.14; 95% CI=2.97 to 3.31), but there was a significant difference in the degree of mortality rate improvements for older patients compared with younger patients (OR=0.98 with each

Table 1. Characteristics of Patients, Physicians and Hospitals (N=788,011)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
No. of patients	35,241	41,991	50,496	49,744	62,991	71,565	67,225	74,601	86,389	73,015	83,645	91,108
Patient characteristics												
Gender, male, %	59.6	58.9	59.6	60.0	62.6	63.5	63.4	63.9	62.1	65.0	63.7	63.9
Patient age, %												
65–74	27.0	26.4	26.0	25.2	21.7	21.2	21.2	21.0	19.4	19.5	18.7	18.4
75+	30.7	33.1	33.7	36.0	34.3	36.0	39.2	43.4	43.6	48.7	50.4	51.4
Intensive care unit, %	12.4	12.6	13.8	14.7	14.7	15.1	16.3	16.7	16.2	18.3	17.2	16.3
Respiratory failure/arrest, %	8.1	9.5	11.1	12.4	12.2	12.6	14.4	13.8	13.3	14.7	13.9	13.8
Hypotension/shock, %	4.1	4.1	4.5	4.7	4.6	4.4	5.0	4.9	4.7	5.3	4.9	5.3
Mechanical ventilation, %	3.5	3.8	5.2	6.1	6.8	8.4	11.4	13.2	12.9	14.0	13.2	12.4
Dialysis, %	1.1	1.2	1.5	1.7	1.8	2.1	2.6	2.7	3.1	3.4	3.6	3.9
Mean Charlson score	0.81	0.86	0.91	0.96	0.93	0.97	1.05	1.11	1.08	1.22	1.22	1.23
Weekend admissions, %	23.9	23.4	23.5	24.3	23.3	23.4	23.7	23.7	23.5	23.5	23.9	24.3
Mean quarterly monetary value of each point	1.0000	1.0000	1.0000	1.0000	1.0000	0.9805	0.9559	0.8999	0.9002	0.9336	0.9478	0.9429
Cuts in reimbursement ^a , %	0.00	0.00	0.00	0.00	0.00	-1.95	-4.41	-10.01	-9.98	-6.64	-5.22	-5.71
Physician characteristics												
Mean physician volume	61.8	71.6	86.4	79.7	108.4	121.1	105.2	106.9	116.3	92.7	100.5	105.8
Mean physician age, years	42.3	42.0	42.2	42.0	41.8	42.2	42.4	42.4	42.6	42.4	42.7	42.8
Specialty, %												
Internal medicine	77.1	78.7	77.6	79.4	79.3	78.3	79.2	85.3	84.9	83.5	87.3	87.6
Family medicine	16.4	15.1	14.1	12.7	11.5	11.9	10.8	10.2	8.7	7.2	7.3	6.8
Hospital characteristics												
Teaching, %	62.9	65.8	66.6	70.1	73.0	74.5	75.0	72.4	75.9	77.6	76.7	74.7
Location, %												
Taipei	25.9	26.1	27.9	29.0	26.7	26.7	25.8	25.0	25.1	28.2	29.0	28.7
Northern	15.8	16.2	15.2	17.4	17.6	16.0	16.1	15.4	13.7	13.8	13.6	13.9
Central	15.1	16.8	14.2	16.7	17.3	19.0	20.6	20.5	20.4	17.4	16.4	16.8
Southern	15.1	14.7	15.3	14.3	14.7	14.6	15.3	16.0	16.8	17.8	17.6	17.8
Kao-Ping	24.0	22.2	23.2	18.9	20.1	20.2	18.4	19.1	19.5	18.2	19.3	18.7
Mean HHI	0.088	0.091	0.094	0.097	0.096	0.093	0.099	0.098	0.099	0.099	0.099	0.102
Patient mortality												
30-day mortality, %	11.2	11.4	10.8	11.1	10.0	9.5	10.0	9.7	9.5	10.4	10.0	10.2

HHI indicates Herfindahl-Hirschman Index

^aThe reimbursement cuts represent discounted payment compared to full payment (100%). Percentage of reimbursement cuts = [(monetary value of each point-1)/1] × 100% = monetary value of each point × 100% - 100%

additional year; 95% CI=0.97 to 0.98). Patients admitted to the ICU had 2.56 times higher odds of death compared with patients not admitted (OR=2.56; 95% CI=2.50 to 2.63). Patients with complications of respiratory failure/arrest had 3.54 times higher odds of death compared with patients without respiratory failure/arrest (OR=3.54; 95% CI=3.46 to 3.63). A one-point increase in the Charlson-Deyo Comorbidity Index score resulted in a 26% increase in the risk of death (OR=1.26; 95% CI=1.26 to 1.27).

Patients admitted on weekends had 3% higher odds of 30-day death compared with those admitted on weekdays (OR=1.03; 95% CI=1.01 to 1.05). Larger reimbursement cuts from hospital global budgeting were associated with higher 30-day mortality rates. An increase in reimbursement of NT\$1 per 100 points was associated with 1% lower odds of 30-day mortality (OR=0.99; 95% CI=0.99–0.99). In other words, for every NT\$1 decrease per 100 points, which corresponded to every 1% reduction in average hospital revenues, the odds of 30-day mortality were 1.0% higher. There was a significant inverse association between

physician volume and 30-day mortality (OR=0.78 with a 100-patient increase in annual physician volume, 95% CI=0.76 to 0.79); namely, patients had 22% lower odds of 30-day mortality per additional 100 patients treated annually by a physician.

Figure 1. Thirty-day mortality rates by patient age.

Table 2. Multilevel Logistic Regression Analysis of 30-Day Mortality (N=788,011)

	OR	95% CI	
Patient level			
Male (ref: female)	1.11	1.09	1.13
Age (ref: <65 years)			
65–74 years	1.88	1.77	2.00
In trend	0.98	0.97	0.98
>74 years	3.14	2.97	3.31
In trend	0.98	0.97	0.98
Intensive care unit (ref: no)	2.56	2.50	2.63
Respiratory failure/arrest (ref: no)	3.54	3.46	3.63
Hypotension/shock (ref: no)	6.82	6.64	7.00
Mechanical ventilation (ref: no)	1.37	1.33	1.41
Dialysis (ref: no)	1.11	1.06	1.16
Charlson score	1.26	1.26	1.27
Weekend admission (ref: no)	1.03	1.01	1.05
Quarterly monetary value per 100 points	0.99	0.99	0.99
Physician level			
Physician volume/100	0.78	0.76	0.79
Physician age, years	1.00	1.00	1.00
Specialty (ref: others)			
Internal medicine	0.97	0.94	1.00
Family medicine	1.01	0.97	1.05
Hospital level			
Teaching (ref: non-teaching)	0.92	0.88	0.96
Location (ref: eastern)			
Taipei	0.79	0.71	0.88
Northern	0.83	0.75	0.92
Central	1.06	0.96	1.18
Southern	1.05	0.95	1.17
Kao-Ping	0.99	0.89	1.10
HHI	1.18	0.89	1.57
Trend	0.96	0.95	0.97

Ref indicates reference group; OR, odds ratio; CI, confidence interval; HHI, Herfindahl-Hirschman Index

DISCUSSION

This study was the first using nationwide longitudinal population-based data to systematically and simultaneously examine the associations of patient characteristics and health-care factors with 30-day mortality. We found that male patients, older patients, severely ill patients, patients with more comorbidities, weekend admissions, larger cuts in reimbursement and lower physician volume were associated with increased 30-day mortality. Additionally, there was an interaction between patient age and trend on mortality.

The findings of the effects of patient gender, age, severity and comorbidities on pneumonia mortality are consistent with the results of Marrie et al.⁶. Patients with these characteristics were considered to be at higher risk for mortality. Furthermore, we found that mortality gaps between elderly and young patients narrowed over time; namely, the decline in the mortality rate among elderly patients was faster than that among young patients. It is probable that influenza and pneumococcal vaccination rates among elderly patients increased over time because of gradual implementation of government-sponsored vaccination programs for the elderly^{17,32–34}. In 1998, a national government-sponsored influenza vaccination program for

the elderly (age 65 and older) was introduced in Taiwan. In 1998 and 1999, the free vaccinations were offered to all elderly people who had been hospitalized because of cardiovascular and pulmonary illnesses or diabetes mellitus, and who resided in a health care institution. In 2000, free coverage was extended to elderly people who had been hospitalized because of stroke, pulmonary tuberculosis or pneumosilicosis. Since 2001, free vaccinations have been offered to all elderly people. The pneumococcal vaccine has been offered for individual purchase in Taiwan since 1999³². Additionally, several county governments have provided free influenza vaccines to all the county's elderly population and pneumococcal vaccinations to all the county's older elderly (age 75 and older) since 2000^{33,34}. Other studies have also shown declining mortality rates among patients with pneumonia over the past 10–20 years^{17,35}.

Our study confirms the weekend-outcome relationship for pneumonia care. The finding of the relationship between weekend admissions and higher mortality is similar to the results of Foss and Kehlet regarding hip fracture³⁶, Kostis et al. concerning acute myocardial infarction⁸, and Saposnik et al. and Tung et al. regarding stroke^{19,37}. Disparities in medical resources, expertise or staffing levels for nurses as well as for physicians during weekends may exist in Taiwan¹⁹. These disparities can lead to higher mortality on weekends.

The finding of the relationship between larger reimbursement cuts and higher pneumonia mortality is consistent with Seshamani et al.'s findings regarding eight postoperative complications⁹, as well as Tung and Chang's findings concerning stroke¹⁰. In Taiwan, as hospitals have come under financial strain from global budgeting, leading to a reduction in revenue, they may be compelled to reduce operating expenses to preserve profit¹⁰. Approaches to reducing operating expenses may include reducing the quantity or quality of nursing staff, decreasing efforts to train and improve staff performance, curtailing investment in infrastructure, and lowering the levels and availability of care.^{9,10,38} Cutting operating expenses may lead to deficiencies in the quality of care, which patients with more severe diseases, including pneumonia, may be less able to withstand, so they will have higher mortality rates^{3,9,10}. Previous studies showed that decreased nursing staff, lower educational levels of nurses or higher proportions of casual/temporary nurses were associated with higher mortality^{39–43}.

Our study also confirms the volume-outcome relationship for pneumonia care^{6,21}. One possible explanation for the relationship between higher physician volume and better pneumonia outcomes is the “practice makes perfect” hypothesis or a learning effect. Besides, there were marked differences in mortality among geographic regions. It is possible that regions with higher mortality are more rural or poorer.

There are some limitations of our study that deserve comment. First, similar to prior studies using administrative databases^{6,12,21}, we have no information on clinical details for risk adjustment such as results according to the Pneumonia Severity Index, CURB-65 (confusion, uremia, respiratory rate, low blood pressure, age 65 years or older) or American Thoracic Society/Infectious Disease Society of America (ATS/IDSA) 2007 criteria. However, we adjusted for patient gender, age, case severity and comorbid conditions, which are also important for adjustment of pneumonia complexity. Second, we have limited information on the structure/processes of pneumonia care delivery, influenza/pneumococcal vaccination and treatment adherence. Although we showed the impacts of weekend admissions, reimbursement cuts and physician volume on pneumonia mortality rates, this observational study could not identify the mechanisms through which these health care factors affect pneumonia outcome. It is possible that other unavailable variables such as the nurse staffing, medication use or timing of medication use may explain these relationships.

Our national longitudinal population-based study showed that male, older or severely ill patients with pneumonia have higher 30-day mortality rates, but there have been significant improvements in mortality among elderly patients over time. Pneumonia patients admitted on weekends have higher mortality than those admitted on weekdays. The mortality of pneumonia patients rises under increased financial strain from cuts in reimbursement. Higher physician volume is associated with lower mortality. Based on these findings, there is still opportunity for improvement regarding pneumonia care delivery. Health care policy-makers should determine what services and processes explain the differences in mortality between low-volume and high-volume physicians, between weekend and weekday admissions, and before and after the adoption of reimbursement cuts. Additional efforts to urge all providers to improve these services and processes might reduce the mortality rates from pneumonia even further. Quality improvement efforts may include establishing national protocols and guidelines, monitoring services and processes of care, increasing fees for deficient services and processes associated with outcomes and implementing a pay-for-performance initiative under cuts in reimbursement. Our study encourages further research identifying potentially remediable factors in reducing mortality among patients with pneumonia.

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Conflict of Interest: None disclosed.

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