Journal of the Formosan Medical Association (2012) 111, 504—509

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.jfma-online.com

ORIGINAL ARTICLE

Readmission to the intensive care unit: A population-based approach

Jiun-I Lai [a,b,†], Hung-Yuan Lin [c,†], Yi-Chun Lai [a,b], Po-Chou Lin [a,b], Shih-Chieh Chang [a,b,*], Gau-Jun Tang [a,b]

[a] National Yang-Ming University School of Medicine, Taiwan, ROC
[b] Department of Medicine, National Yang-Ming University Hospital, Taiwan, ROC
[c] Shih-Hsin University, Department of Information Management, Taiwan, ROC

Received 8 June 2010; received in revised form 20 April 2011; accepted 16 June 2011

KEYWORDS
intensive care unit;
readmission

Background/Purpose: Readmission to the intensive care unit (ICU) results in increased consumption of medical resources and costs, and has been proposed as a marker for quality of care. ICU readmission rates have been estimated at 4—14% and different risk factors have been proposed by various studies.

Methods: Every admission event to the ICU was recorded and readmission episodes were analyzed using a population-based database from the Taiwan National Health Insurance Research Database (NHIRD) for the period from January 1, 2006 to December 31, 2006.

Results: The average follow-up time was 206.35 days. From the database of 192,201 patients admitted to the ICU, 25,263 patients were re-admitted, with a readmission rate of 13.13%. The leading etiologies for readmission were identified. Using multivariate analysis, age > 39 years old, female gender, ischemic heart disease, lung related disorders, pneumonia, cerebrovascular disease, sepsis, heart failure, chronic liver disease, diabetes mellitus, and chronic obstructive pulmonary disease were identified as significant risk factors for readmission to the ICU.

Conclusion: This study uses a novel approach to assess risk factors for readmission to the ICU. Higher risk patients should be assessed more carefully before discharge or transfer from the ICU to prevent readmission episodes.

Introduction

Hospitalizations in the intensive care unit (ICU) deal with the most critical illnesses and consume a significant portion of medical expenses. Readmission to the ICU, either due to

* Corresponding author. Department of Medicine, National Yang-Ming University Hospital, Number 152, Xin-Min Road, Yilan 26042, Taiwan, ROC.
E-mail address: dtsurga9@yahoo.com.tw (S.-C. Chang).
† Jiun-I. Lai and Hung-Yuan Lin contributed equally to this work.

0929-6646/$ - see front matter
doi:10.1016/j.jfma.2011.06.012

reoccurrence of a previous disease or an unrelated new illness, results in further consumption of cost and medical resources, and has been proposed as a marker for quality of care.[1] ICU readmission rates have been estimated from 4% to 14% in previous studies,[2] and have been shown to correlate with prolonged hospital stays and increased mortality rates in readmission patients.[2,3] Many studies have dealt with this issue by trying to identify risk factors for readmission patients[3,4,5] and have come up with a variety of results; however, consensus on common risk factors or high-risk patient profiles has not been achieved. The necessity for further information was highlighted by studies which pointed out that a significant number of readmission cases were potentially preventable[6] and that specific treatments aimed towards high-risk patients could decrease readmission rates.[3] Therefore, it is of clinical interest to further identify patients who are at higher risk for readmission to the ICU.

In Taiwan, the National Health Insurance (NHI) program was started in 1995 and has a near universal ($>$ 96%) coverage of the population. Because all claims data for inpatients are available to researchers in electronic form, it is possible to conduct a large series study to investigate ICU readmission events over a given period of time for the general population in Taiwan. Using this background information, we conducted a study using the population-based database of the NHI program in Taiwan, aiming to: (1) assess the prevalence and characteristics of ICU readmission episodes; (2) identify coexisting medical conditions that might represent risk factors; and (3) identify the common etiologies of readmission episodes. We then analyzed the statistical significance of the data distribution and proposed etiologies that could serve as risk factors. This population-based study method is a novel approach in identifying risk factors for ICU readmission. We hope that this study will provide solid data that will serve as information for further clinical judgment, discharge planning, and risk stratification for intensivists and physicians.

Methods

Database

Pooled data obtained from the Taiwan National Health Insurance Research Database (NHIRD) for the period of January 1, 2006 to December 31, 2006 were used for analysis in this study. The NHIRD is a nationwide database that includes all in-patient medical benefit claims for the Taiwanese population with an inclusion rate of over 96% of the population. The database includes registries of contracted medical facilities and board-certified physicians, monthly summaries of in-patient claims, and other in-patient hospitalization details. Individual operation procedure codes and diagnosis codes are included with compliance to the International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM).

This study was approved by the ethics committee of the authors' institution on the basis that no disclosure of any patient's private or individual data could be made public due to the unique encoding nature of the database.

Study sample

We included every ICU hospitalization episode from January 1, 2006 to December 30, 2006. The database included a total of 192,201 patients. Age, gender, and ICD-9 classification codes were recorded. A readmission event was recorded if the same patient ID was present in the same year; therefore, the follow-up period was different for each patient enrolled with the longest being 1 year. This study design was necessary due to the limitations of the database structure we could obtain, which only contained complete heath claims data for the time period studied. Each readmission episode was recorded for the main diagnosis ICD code using the International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM).

Laboratory information was not included in the claims database; therefore, only the admission date, discharge date, patient profile, and ICD-9 diagnosis codes were available and there was no way of knowing if the coding was correct for each patient. However, according to NHI program policy, peer review from other independent physicians served as an auditing system for these claims. If the diagnosis or claim influenced the treatment used, the claim would be invoked. As a result, we relied on this internal validation for the authenticity of our data.

Statistical analysis

In this study, MySQL 4.1 (1995-2008 MySQL AB, 2008-2009 Sun Microsystems, Inc.) was used as database software for data linkage and processing. Descriptive data was presented, including the number of patients and percentages. Multivariate logistic regression was used to assess hazard ratios and risk (SPSS software, version 14.0, SPSS Corp. Chicago, IL, USA). Results were displayed as coefficients, odds ratios and 95% confidence intervals. A p value ≤ 0.05 (two-tailed) was considered statistically significant.

Results

Statistics of ICU admissions in year 2006

From January 1, 2006 to December 31, 2006, there were a total of 192,201 valid ICU admissions. Patient gender was

Table 1 Age distribution of ICU admissions in 2006.

Age (y)	Number	Percentage (%)
$\leq$ 18	13150	6.8
19—28	8085	4.2
29—38	11266	5.9
39—48	16057	8.4
49—58	25052	13.0
59—68	27305	14.2
69—78	42253	22.0
$>$ 78	49033	25.5
Total	192201	100

ICU = Intensive Care Unit.

Table 2 Etiology of readmission episodes in 2006.

Rank	Diagnosis	ICD code	Episodes (no.)	Percentage (%)
1	Ischemic heart disease	410—414	1443	18.49
2	Lung-related disorders (including respiratory failure)	518	854	10.94
3	Pneumonia	486	723	9.26
4	Cerebrovascular disease (including hemorrhage and infarction of cerebral arteries)	430—434	444	5.69
5	Sepsis	038	425	5.45
6	Heart failure	428	386	4.95
7	Chronic liver disease and cirrhosis	571	342	4.38
8	Diabetes mellitus	250	241	3.09
9	COPD	491	200	2.56
10	Traumatic subarachnoid, subdural and extradural hemorrhage	852	174	2.23

COPD = chronic obstructive pulmonary disease, ICD = international classification of disease.

60.32% and 39.68% for males and females, respectively. The age distribution is summarized in Table 1.

Readmission rates and etiologies

The mean (± SD) follow-up time for each patient admitted to the ICU (defined as the period from the first ICU admission date to December 31, 2006) was 206.35 (± 112.35) days. A readmission episode was defined as when more than one admission episode was listed in the database for the same person. From the database of 192,201 patients admitted to ICUs in 2006, 25,263 patients were readmitted, with a readmission rate of 13.13%.

The most frequent diagnoses in readmission episodes according to ICD classification were: (1) ischemic heart disease (18.49%); (2) disease of the lung, including respiratory failure (10.94%); (3) pneumonia (9.26%); (4) cerebrovascular disease (5.69%); and (5) sepsis (5.45%) Table 2).

The most frequent etiologic organ systems, classified by category, were cardiovascular (35.38%), respiratory (26.96%), and digestive system (8.51%) (Table 3, Fig. 1).

On further analysis, we looked for readmission episodes due to the same etiology of the previous episode. The readmission episodes with the same ICD diagnosis (defined when the diagnosis code of the readmission episode shared the same integer number of the previous episode) accounted for 7401 counts, constituting 29.29% of the readmission episodes.

Female gender and age are independent risk factors for readmission to ICU

Using multivariate logistic regression, gender (female), and age (> 39 years) were shown as significantly predictive factors for ICU admissions. The analysis showed a trend of a higher odds ratio with increased age (Table 4).

Leading etiologies for ICU readmission are independent risk factors

Using data derived from our database (Table 2), we assessed each of the leading causes for an independent

Table 3 Etiology distribution classified by organs.

Rank	Etiology organs (ICD code)	Number	Percentage (%)
1	Diseases of the circulatory system (390—459)	2619	35.38
2	Diseases of the respiratory system (460—519)	1996	26.96
3	Diseases of the digestive system (520—579)	630	8.51
4	Neoplasms (140—239)	591	7.98
5	Infectious and parasitic diseases (001—139)	402	5.43
6	Injury and poisoning (800—999)	375	5.06
7	Endocrine, nutritional and metabolic diseases, and immunity disorders (240—279)	267	3.6
8	Diseases of the nervous system and sense organs (320—389)	143	1.93
9	Diseases of the genitourinary system (580—629)	122	1.64
10	Congenital anomalies (740—759)	102	1.37
11	Symptoms, signs, and ill-defined conditions (780—799)	74	0.99
12	Diseases of the musculoskeletal system and connective tissue (710—739)	40	0.54
13	Certain conditions originating in the perinatal period (760—779)	13	0.18
14	Diseases of the blood and blood-forming organs (280—289)	11	0.15
15	Diseases of the skin and subcutaneous tissue (680—709)	11	0.15
16	Twin birth mate live born in hospital delivered by cesarean section (v31.01)	2	0.00027

ICD = international classification of disease.

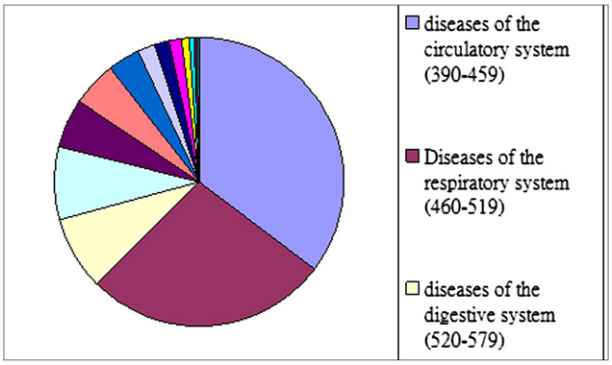

Figure 1 Pie figure of leading causes for readmission according to organ system (see Table 3 for details).

predictive value. Testing each etiology separately, we assessed the risk of readmission in patients with a given disease against risk of readmission in patients without the disease. The results were calculated using multivariate logistic regression. Ischemic heart disease, lung-related disorders (including respiratory failure), pneumonia, cerebrovascular disease, sepsis, heart failure, chronic liver disease, diabetes mellitus, and chronic obstructive pulmonary disease were identified as significant risk factors for readmission to the ICU (Table 5).

Discussion

Since the meta-analysis by Rosenberg[2] proposing a correlation between ICU readmission events and increased mortality rates, many studies have attempted to determine the risk factors and characteristics of ICU readmissions. In a prospective study in Australia, risk factors including age, colonization, weakness, co-morbidities of cardiac and/or respiratory disease, and depression were identified[7]; while in a study by Cambell et al,[4] age, male gender and disease severity upon admission to ICU (measured by the APACHE II scoring system) were identified. Another study proposed that age, male gender, the number of organ failures on admission, mechanical ventilation use, vasopressor use on the last day of admission, and active diuresis during the final days of admission were risk factors.[3] A recent meta-analysis pointed out that the severity of illness (measured by APACHE II, APACHE III, SAPS, or SAPS II), regardless of the time of measurement, could serve as a predictor for readmission.[8] The correlation between APACHE score and readmission was also demonstrated in a study consisting of surgery patients.[9] In other studies, C-reactive protein levels taken close to the time of admission were also shown to be predictors.[5,6]

Table 4 Risk analysis for readmission according to gender and age.

Characteristic	Correlation coefficient	OR (95% CI)	*p*
Sex			
Female		1 (reference)	
Male	−0.695	0.499 (0.419−0.594)	≤0.005
Age (y)			
19−28		1 (reference)	
29−38	0.145	1.157 (0.953−1.403)	0.140
39−48	0.565	1.759 (1.481−2.089)	≤0.005
49−58	0.638	1.893 (1.606−2.230)	≤0.005
59−68	0.683	1.980 (1.683−2.330)	≤0.005
69−78	0.766	2.152 (1.836−2.521)	≤0.005
≥79	0.842		≤0.005

CI = confidence interval, OR = odds ratio.

The above studies have all come to different conclusions, given that each study was conducted at a different ICU with different patient populations and physician decision-making philosophies, which could result in varied results. The variety of conclusions drawn from these different studies may originate from: regional differences related to where the study was performed; differences in study design (retrospective or prospective) and study methods or inclusion criteria; and healthcare policy differences, which may indirectly alter physician decision-making for discharge or readmission of patients. Increasing the number of ICUs and patients enrolled may increase the variance of hospitalization profiles and ultimately increase statistical power. Previous studies involved sample sizes that were smaller compared to our study, with the largest study being led by Cooper et al,[10] including 103,984 patients. The strength of our study lies in the number of patients enrolled and the non-selective patient profile due to near universal healthcare coverage.

In our study, the top five etiologies were ischemic heart disease, lung-related disorders (including respiratory failure), pneumonia, cerebrovascular disease, and sepsis. The top five etiologies may not seem uncommon since these are common ICU admission diseases, but our study provides robust statistical evidence to support the conclusion. The leading etiology is ischemic heart disease, which may partially reflect the wide use of the coronary care unit (CCU) in Taiwan per the results from the Survival and Ventricular Enlargement (SAVE) trial.[11] Thus, any patient who received a second cardiac intervention would be readmitted to the CCU, which would be reflected in our results and is a possible overestimation. The next two etiologies for readmission are related to respiratory problems, which are difficult to completely heal and dissipate the need for readmission. The fourth etiology is cerebrovascular disease, which has a high recurrence rate.[12] The fifth etiology, sepsis, is a relatively novel finding for readmission, which may imply that a person who was critically ill with sepsis might be prone to repeated critical bacteremia. This may be due to a predisposing chronic debilitating disease or poor immune function, which is a common observation in our daily practice: that patients with multiple chronic diseases tend to acquire sepsis more often than others. We searched the literature for previous studies that could correlate with our findings above. Relatively rare data were found, as few studies implicitly categorized readmission events by ICD coding or etiologies. For data that existed, the studies were quite small. In a study by Chan et al,[9] the most common etiology for readmission was respiratory disease (43.6%), followed by neurological (20.9%) and cardiovascular disease (16.4%). Their study was in a surgical ICU, which may skew the data. However, in

Table 5 Risk analysis for readmission according to disease etiology.

Diagnosis	Correlation coefficient	OR (95% CI)	*p*
Ischemic heart disease	1.077	2.935 (2.758–3.124)	≤0.001
Lung-related disorders (including respiratory failure)	1.233	3.430 (3.207–3.669)	≤0.001
Pneumonia	1.124	3.078 (2.862–3.310)	≤0.001
Cerebrovascular disease (including hemorrhage and infarction of cerebral arteries)	0.444	1.560 (1.423–1.709)	≤0.001
Sepsis	0.739	2.094 (1.924–2.279)	≤0.001
Heart failure	1.214	3.365 (3.047–3.717)	≤0.001
Chronic liver disease and cirrhosis	1.748	5.745 (5.133–6.431)	≤0.001
Diabetes mellitus	1.062	2.892 (2.554–3.274)	≤0.001
COPD	1.316	3.728 (3.282–4.234)	≤0.001
Traumatic Subarachnoid, subdural and extradural hemorrhage	0.103	1.109 (0.955–1.287)	0.173

CI = confidence interval, COPD = chronic obstructive pulmonary disease, OR = odds ratio.

Table 6 Comparison of readmission etiologies with Chan et al.[15]

Leading etiology (rank)	Chan et al[15] (%)	Our study (%)
1	Respiratory disease (43.6)	Ischemic heart disease (18.5)
2	Neurological diseases (20.9)	Lung-related disorders, including respiratory failure (10.9)
3	Cardiovascular diseases (16.4)	Pneumonia (9.3)
4	Sepsis (N/A)[a]	Cerebrovascular disease (5.7)
5	Gastrointestinal (N/A)[a]	Sepsis (5.5)

N/A = not applicable.
[a] Actual numbers not reported in original paper.

general their study correlated with our findings as cardiovascular, respiratory, and neurological disease being leading etiologies, although our study provided more specific etiologic classifications and details, as well as a significantly larger sample size. We implemented a simple comparison table listing some data from the Chan study (Table 6).

Comorbidities or coexisting medical illness are proven risk factors for readmission[13] and different studies have identified somewhat different results regarding significant risk factors.[13,14] We investigated the 10 leading causes for readmission to the ICU in our database and identified 9 causes with significance using multivariable analysis. Our data demonstrate that patients admitted to the ICU with these diagnoses have a higher risk of readmission to the ICU after discharge, and physician awareness of this is paramount in determining the appropriate time for discharge or transfer to an ordinary ward.

Our study is prone to several intrinsic weaknesses that are limited by the database itself. The study design is purely retrospective; therefore, prospective studies are needed to further validate the conclusions. The claims database does not contain information on laboratory data and, as a result, correlation with common ICU scoring systems such as the APACHE II score could not be done. It was impossible to perform the same follow-up period for every patient enrolled according to this database, and we therefore used an alternative approach that counted readmission episodes in the study period. In other words, each patient had a different enrollment time but the same finishing time. Our data, therefore, should be interpreted as the description of ICU readmission episodes and etiologies in a given period of time. We believe that due to the number of enrolled participants, and the comprehensive enrollment of every ICU in Taiwan, the database is of normal distribution and the results are of statistical significance.

Although clinical validation and laboratory data are lacking, we believe that this nationwide study with a large case number (192,201 patients) demonstrates the scope and power of the NHIRD database of Taiwan for population-based studies. Recently, a study utilizing the NHIRD database validated the results using clinical data,[15] which showed good agreement between clinical observation and retrospective conclusions from the database. We believe the NHIRD provides a unique angle for approaching clinical problems and is of great value.

In conclusion, we performed a population-based analysis on ICU readmission rates in Taiwan. Using multivariate analysis, we identified age, gender, and other risk factors for predicting ICU readmissions. In order to prevent higher readmission rates, patients with the aforementioned risk factors should be assessed carefully before discharge or transfer.

References

1. Kiefe C. Predicting rehospitalization after bypass surgery: can we do it? Should we care? *Med Care* 1999;**37**:625–36.
2. Rosenberg AL, Watts C. Patients readmitted to ICUs: a systematic review of risk factors and outcomes. *Chest* 2000; **118**:492–502.

3. Metnitz PG, Fieux F, Jordan B, Lang T, Moreno R, Le Gall JR. Critically ill patients readmitted to intensive care units—lessons to learn? *Intensive Care Med* 2003;**29**:241—8.
4. Campbell AJ, Cook JA, Adey G, Cuthbertson BH. Predicting death and readmission after intensive care discharge. *Br J Anaesth* 2008;**100**:656—62.
5. Rosenberg AL, Hofer TP, Hayward RA, Strachan C, Watts CM. Who bounces back? Physiologic and other predictors of intensive care unit readmission. *Crit Care Med* 2001;**29**:511—8.
6. Angus DC. Grappling with intensive care unit quality—does the readmission rate tell us anything? *Crit Care Med* 1998;**26**: 1779—80.
7. Paratz J, Thomas P, Adsett J. Re-admission to intensive care: identification of risk factors. *Physiother Res Int* 2005;**10**:154—63.
8. Frost SA, Alexandrou E, Bogdanovski T, Salamonson Y, Davidson PM, Parr MJ, et al. Severity of illness and risk of readmission to intensive care: a meta-analysis. *Resuscitation* 2009;**80**:505—10.
9. Chan KS, Tan CK, Fang CS, Tsai CL, Hou CC, Cheng KC, et al. Readmission to the intensive care unit: an indicator that reflects the potential risks of morbidity and mortality of surgical patients in the intensive care unit. *Surg Today* 2009; **39**:295—9.
10. Cooper GS, Sirio CA, Rotondi AJ, Shepardson LB, Rosenthal GE. Are readmissions to the intensive care unit a useful measure of hospital performance? *Med Care* 1999; **37**:399—408.
11. Rouleau JL, Moyé LA, Pfeffer MA, Arnold JM, Bernstein V, Cuddy TE, et al. A comparison of management patterns after acute myocardial infarction in Canada and the United States. *N Engl J Med* 1993;**328**:779—84.
12. Kernan WN, Launer LJ, Goldstein LB. What is the future of stroke prevention?: debate: polypill versus personalized risk factor modification. *Stroke* 2010;**41**(Suppl. 10):S35—8.
13. Ho KM, Dobb GJ, Lee KY, Finn J, Knuiman M, Webb SA. The effect of comorbidities on risk of intensive care readmission during the same hospitalization: a linked data cohort study. *J Crit Care* 2009;**24**:101—7.
14. Chen LM, Martin CM, Keenan SP, Sibbald WJ. Patients readmitted to the intensive care unit during the same hospitalization: clinical features and outcomes. *Crit Care Med* 1998;**26**: 1834—41.
15. Cheng CL, Kao YH, Lin SJ, Lee CH, Lai ML. Validation of the National Health Insurance Research Database with ischemic stroke cases in Taiwan. *Pharmacoepidemiol Drug Saf* 2011;**20**: 236—42.