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Association of Severity of Illness and Intensive Care Unit Readmission: A Systematic Review

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Abstract

Objectives—To determine whether ICU readmission is associated with higher severity of illness scores in adult patients.

Background—Readmissions to the intensive care unit (ICU) are associated with increased costs, morbidity, and mortality.

Methods—We performed searches of MEDLINE, EMBASE, and grey literature databases. We selected studies reporting data from adults who were hospitalized in an ICU, received severity of illness scores, and were discharged from the ICU. Characteristics of readmitted and non-readmitted patients were examined.

Results—We screened 4766 publications and included 31 studies in our analysis. In most studies, severity of illness scores were higher in patients readmitted to the ICU. Readmission was also associated with higher mortality and longer ICU and hospital stays. Excessive heterogeneity precluded the reporting of results in the form of a meta-analysis.

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Conclusions—ICU readmission is associated with higher severity of illness scores during the same hospitalization in adult patients.

Keywords

Intensive care unit; Readmission; Severity of illness; Systematic review

Introduction

Readmission to the intensive care unit (ICU) is a frequent adverse outcome in the critically ill population. [1] Approximately 10% of patients discharged from the ICU require readmission during the same hospital stay. [2] Readmission exposes patients to increased risks, as transfers between healthcare professionals have been linked to an increased rate of adverse events, higher mortality, and longer hospital stays. [2–5] Furthermore, the financial impact of ICU care is considerable, as up to 30% of total hospital costs and 1% of the US gross national product are directly linked to ICU expenses. [6] The management of critically ill patients therefore pose significant challenges to healthcare systems seeking to improve quality and reduce unplanned healthcare utilization. [7, 8]

Given the sizeable proportion of health care resources dedicated to critical care, reductions in ICU readmission rates could be an indicator of improved hospital performance. [9, 10] An important first step in reducing the number of ICU readmissions is identifying patients who are most likely to be readmitted. Therefore, there is substantial interest in examining risk factors associated with ICU readmission.

A 2009 systematic review and meta-analysis suggested that the Acute Physiology and Chronic Health (APACHE) score and the Simplified Acute Physiology Score (SAPS) may be useful in predicting ICU readmission. Both of these severity of illness scoring systems are routinely used in ICUs to predict mortality risk. [14–16] Prediction models for ICU readmission that incorporate severity of illness scores have been proposed, but are not routinely used in clinical practice. [17–20] The prospect of predicting ICU readmission risk using only APACHE or SAPS scores is an attractive one, as implementation of these systems would not require additional ICU resources.

Since the publication of the prior review, the delivery of healthcare services in the US has been changing to adjust to Affordable Care Act (ACA) priorities. Adopted by the US Congress in 2010, the primary aim of the ACA is to increase affordability of health insurance to Americans. The ACA has also introduced programs through which payment for health care services are linked to quality of care. ACA programs provide incentives for hospitals to improve value by reducing complicated care transitions and unplanned healthcare utilization, including hospital and ICU readmissions. This has led to an increased number of studies focusing on quality of care and predictors of readmission. Furthermore, novel interventions, such as critical care transition programs, may lower discharge thresholds and modify readmission rates. [21] The objective of this systematic review is to evaluate whether readmission to the ICU during the same hospitalization remains associated with the most commonly used severity of illness scores (APACHE and SAPS) in adult patients.

Methods

Data Sources

Our analysis was performed in accordance with methodology described in the Cochrane Handbook for Systematic Reviews of Interventions. [22] We searched the MEDLINE and EMBASE databases for literature published from inception to February 3 2014. Our search strategy included a combination of controlled vocabulary (MeSH and Emtree) and free-text keywords. Searches were developed in consultation with information specialists from the Johns Hopkins Welch Medical Library. We selected search terms related to three concepts: intensive care; severity of illness; and ICU readmission. We did not restrict the searches with regards to language, study type, or publication year. The full search strategy is presented in Supplementary Data Table 1. We searched the reference lists from our included articles to identify any additional relevant citations and completed forward citation searching through Web of Science. Using an abbreviated search strategy, we identified potentially relevant unpublished studies from the following databases: the NIH clinical trials registry (www.clinicaltrials.gov), WHO International Clinical Trials Registry Platform, Cochrane Register of Controlled Trials (CENTRAL), OpenSIGLE (System for Information on Grey Literature in Europe) and the New York Academy of Medicine Grey Literature Report and Database. We also searched conference proceedings of the American Thoracic Society and the European Respiratory Society.

Study Selection

All titles and abstracts were randomly assigned to be independently screened by two of five investigators (EGW, AMP, DGL, EPB and AIA). Observational studies (prospective or retrospective cohort studies, and case-control studies) that collected severity of illness measures and ICU readmission data were included in our systematic review. Abstracts as well as full-length publications were included in order to minimize potential publication bias. Reviews, case reports, randomized-controlled trials (RCTs), editorials, and case series were excluded. Studies were subsequently excluded during the selection process if they: 1) did not study adult ICU patients (≥18 years of age, predefined as “adults” by the manuscript authors, or admitted to an adult ICU); 2) did not categorize patients based on readmission status; 3) did not report a severity of illness score (SAPS, APACHE); 4) were not in English, Spanish, or French (languages spoken by the investigators); or 5) were not observational studies. The full texts of all studies selected based on titles and abstracts were also reviewed by two independent investigators, and the same exclusion criteria were applied. Any disagreements regarding inclusion of a specific article were adjudicated by discussion among investigators.

Data Extraction and Risk of Bias Assessment

Studies selected for analysis were randomly distributed across the five-investigator group. Data was independently extracted from each study by two investigators and subsequently verified between the dyad. Any discrepancies were resolved through discussion. Study design, participant, exposure, and outcome information was collected and entered into an electronic database. Risk of bias assessments were performed using the Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomized Studies in Meta-Analysis. [23]

Two investigators independently assessed each study for the following characteristics that would increase the risk of bias: selection of study subjects; comparability of exposure groups; and measurement of the exposure or outcome. Potential reporting and publication biases were examined graphically with a funnel plot.

Data Synthesis and Analysis

Our primary measure of association was the standardized mean difference (SMD) in severity of illness scores between readmitted and non-readmitted patients. This measure was selected so that different severity of illness indices could be compared. If studies reported both APACHE and SAPS scores, we used the APACHE scores in our combined analysis because this measure was the most frequently reported. When both ICU admission and discharge scores were available, admission scores were used to maximize comparability with the other included studies. For studies reporting severity of illness scores as medians and interquartile ranges (IQR), a normal distribution was assumed: medians were substituted for the mean, and IQRs were converted to standard deviations as recommended by the Cochrane Handbook. [22] Secondary outcomes included ICU length of stay (LOS), hospital LOS, and in-hospital mortality.

We assessed the degree of clinical heterogeneity between studies by comparing multiple types of study characteristics: study participants; type of ICU; type of severity of illness score; and timing of severity of illness measurement. In addition, we evaluated methodological heterogeneity by comparing study designs and risk of bias assessments. Forest plots were generated using Stata 12/IC software (StataCorp LP, College Station, TX) to assess for heterogeneity between studies. Poor overlap of the confidence intervals of SMD's would suggest significant heterogeneity. Quantitative assessment for heterogeneity was performed by calculating I^2 statistics. We considered an I^2 value above 50% as evidence of significant heterogeneity. We also calculated chi-squared statistics (Cochran's Q test) to assess for heterogeneity, with a p-value <0.05 suggesting significant heterogeneity.

Subgroup analyses were performed for the following pre-specified groups: type of severity score used (APACHE vs. SAPS); version of score used (APACHE I-IV, SAPS I-III); time of severity score assessment (ICU admission vs. ICU discharge); type of ICU (medical vs. surgical vs. mixed); risk of bias (low, moderate, high); type of study design (case-control vs. cohort); and continent in which the study was performed. We conducted sensitivity analyses to determine the impact of excluding studies with higher risk of bias, or studies reported in the grey literature. We also performed a sensitivity analysis to determine the impact of excluding studies that reported medians and inter-quartile ranges instead of means and standard deviations. Medians and inter-quartile ranges may have been used to report data that does not fall under a normal distribution, and this could influence the results of our analysis.

Results

Study Selection

We identified 4766 citations using the search strategy described above (Figure 1). Screening of titles and abstracts yielded 473 articles for full-text review. Thirty-one publications on 30 unique study populations met the pre-defined eligibility criteria for inclusion in the final qualitative synthesis. Two publications that reported on the same study population were analyzed as one study. Ultimately, 24 studies presented enough information to calculate SMDs in severity of illness scores between readmitted and non-readmitted patients.

Characteristics of Included Studies

The 31 studies included in the qualitative review were highly variable in terms of their characteristics and outcome reporting (Tables 1–2). Most of the included studies were cohort studies (n=27), and 4 were case-control studies. There were 23 full-text articles and eight abstracts. Studies were conducted between 1987 and 2011 and included approximately 480,000 patients (one study did not report sample size at the patient level [24]). Of these, 32,537 were readmitted to the ICU. The most common severity of illness instrument used was APACHE II (11 studies). Nineteen studies reported ICU LOS, ten studies reported hospital LOS, and 19 studies reported inhospital mortality (Supplementary Data Table 2). Studies were published from five continents, including: North America (n= 11), South America (n=3), Europe (n=9), Asia (n=3), and Australia (n=3). Two studies were collaborations between European and North American countries. More studies were conducted in the United States (n=9) than in any other nation. The studies varied regarding the following characteristics: types of patients studied (subspecialty populations, such as tracheostomy patients, vs. general medical or surgical populations); type of ICU (medical vs. surgical vs. mixed); and hospital and ICU sizes.

Methodological Quality of Included Studies

We classified 22 studies as having low risk of bias, 4 as having moderate risk of bias, and 4 as having high risk of bias. We assigned high risk of bias for the following reasons: no description of how severity of illness was ascertained and verified; no statement of how cohorts were followed up; and concerns about comparability of cases and controls in case-control studies. The funnel plot showed high variability in the SMD, even in studies with low standard error (Figure 2). There was one clear outlier on the funnel plot, [25] but otherwise, we did not observe significant asymmetry that would raise concerns for publication bias.

The studies that were included in our systematic review had significant variation in the reporting of their methods of ascertainment. While most investigators identified readmission through hospital databases, many did not report methods of assessing severity scores. Some investigators provided differing case and control definitions. Not all studies included the secondary outcomes we included in our data extraction protocol. For instance, only 5 studies reported the time to readmission.

There were also several methodological factors contributing to the heterogeneity among studies. While all studies defined ICU readmission as a readmission occurring during the same hospitalization, several used time-based cut points (e.g., 48 hours) after ICU discharge to classify early vs. late readmissions. Other studies limited the time they followed patients during their hospitalization.

Outcomes

The overall readmission rate was 5.7% (27,517/482,338) in the cohort studies. There was substantial statistical heterogeneity across studies, with SMDs ranging from −0.39 (95%CI −1.03–0.24; Gerber 2009) to 0.77 (0.39–1.15; Lee 2010). The I^2 statistic was 94.1% ($p<0.001$) for cohort studies (Q statistic 356.40), and 67.2% ($p<0.001$) for case-control studies (Q statistic 3.05). The excessive heterogeneity precluded reporting of summary estimates in the form of a meta-analysis.

A majority of studies found that readmission was associated with higher APACHE and SAPS scores, with all but five studies demonstrating a statistically significant association between readmission and increased severity of illness (Figure 3). The remaining studies [25, 33, 41, 50, 53] had 95% CIs that overlapped the null value, suggesting that there was no statistically significant difference in severity of illness scores between readmitted and non-readmitted patients. Sensitivity analyses revealed similar results.

Subgroup analyses (stratifying by type and version of severity score, time of score assessment, type of ICU, risk of bias, study design, and continent of origin) did not rectify the significant heterogeneity and also precluded summary estimates. None of these analyses significantly modified the association between ICU readmission and severity scores.

Overall, mortality was greater in patients who were readmitted to the ICU vs. those who were not readmitted (Supplementary Data Table 2). Hospital mortality in non-readmitted patients varied widely (from 1% to 18%). Hospital mortality in the readmitted patients ranged from 10% to >50%, with the surgical ICUs showing overall lower mortality. ICU LOS was longer in the readmitted vs. non-readmitted patients. Most studies did not specify whether the LOS for readmitted patients included both the index and second admission, or whether the data referred only to the index admission. Hospital LOS was consistently longer in the readmitted vs. non-readmitted patients. In studies that reported hospital LOS, the readmitted patients spent approximately twice as much time in the hospital as the non-readmitted patients.

Discussion

The results of this systematic review found that ICU readmission is associated with higher severity of illness scores in patients discharged alive from the ICU. This association does not appear to be modified by type of severity score, timing of measurement, or type of ICU. Patients readmitted to the ICU were older, had longer hospital and ICU stays, and had higher mortality than non-readmitted patients.

Our findings were consistent with those of Frost et al., who reviewed studies published up until 2008. [14] Our review differed from that of Frost et al. in that we included searches of the grey literature, and we did not include a search of the CINAHL database. Our search strategy identified all of the articles that were used for the Frost systematic review, as well as 14 additional studies published after 2008. Given the interval of time that had passed since our original search, an updated literature search was performed in August 2015. This new search identified three additional publications that would likely have been included in the original systematic review. [26–28] Two of these studies found significantly higher APACHE II scores in readmitted ICU patients, while the third found a non-statistically significant increase in SAPS III scores among readmitted patients. Because these studies were not prospectively screened and analyzed, these findings have not been merged with those of the systematic review. However, we believe the inclusion of these studies would not alter our conclusions.

Unlike the previous systematic review, we decided that the significant heterogeneity among the selected studies precluded a meta-analysis, which would inappropriately combine widely disparate findings into a single summary measure. This heterogeneity persisted despite controlling for multiple characteristics (type of severity score, timing of measurement, type of ICU, risk of bias, study design, and continent of origin) through subgroup analyses. This finding suggests that the association between ICU readmission and severity of illness scores varies substantially across settings, and this variability is not explained by factors evaluated in our subgroup analyses. This heterogeneity may be related to unreported patient or hospital factors, such as source of admission, time of discharge, ICU staffing, and safety culture.

Numerous patient-level and hospital-level factors influence ICU readmission, and multiple complex prediction models for ICU readmission have been proposed. [5, 29–34] A 2013 systematic review of risk stratification tools identified eight models developed to predict ICU readmission and/or in-hospital mortality. [17] Although these prediction tools show promise, their complexity and lack of validation may limit their use. The widespread use and familiarity of APACHE and SAPS scores make them more likely to be clinically accepted and implemented. Although our analysis was not intended to assess the predictive value of severity of illness scores, it does provide evidence that severity of illness scores may have wider clinical use and could be considered for inclusion in future ICU readmission prediction models.

This systematic review has some notable limitations. Although our initial goal was to study severity of illness scores as the exposure of interest, the ways in which data were reported in the published studies made this analysis impossible. Instead, we used readmission as the exposure of interest, and this should be taken into account when extrapolating findings. Second, we limited our studies to those containing the two most commonly used severity of illness scores, APACHE and SAPS. Findings might differ if other severity of illness scores were included. Third, our selection criteria led to the exclusion of a few large cohort studies specifically evaluating severity of illness and ICU readmission; these studies did not permit a direct comparison of APACHE or SAPS scores between readmitted and non-readmitted patients. [4, 11] Fourth, a number of included studies were conference abstracts (8 of 31 studies), and these studies included limited information on their methods. Finally, there was limited information on hospital-level factors (such as characteristics of individual ICUs) that could be important sources of confounding and heterogeneity among studies.

Despite these limitations, the findings of our review contribute to current efforts to identify high-risk patients and to design interventions to reduced unplanned healthcare utilization. The study of ICU readmissions has important implications across the healthcare system. At the patient and caregiver level, unplanned ICU readmissions may become a publicly reported outcome used for benchmarking hospital performance, which could subsequently influence patients' choice of hospitals. At the health system level, identifying excessive numbers of unplanned readmissions may lead to the development of new service systems and interventions to improve quality of care and reduce readmissions. Ultimately, at the payer and policymaker level, payment strategies may be developed to incentivize readmission prevention and reduce health care costs.

Conclusions

Based on our systematic review of data from over 480,000 ICU patients and more than 32,000 readmissions, we conclude that ICU readmission is associated with increased severity of illness scores. The APACHE and SAPS severity of illness measures are routinely measured in clinical practice, are easily retrievable from health system databases, and can be used as part of a larger effort to understand ICU readmissions. Because a broad range of factors contribute to readmission risk, future studies examining ICU readmission should include ICU and health-system characteristics in addition to patient-level variables. These studies would provide useful information for health systems aiming to reduce the risk of ICU readmission—an important goal for patients, caregivers, providers, health systems, payers, and policymakers.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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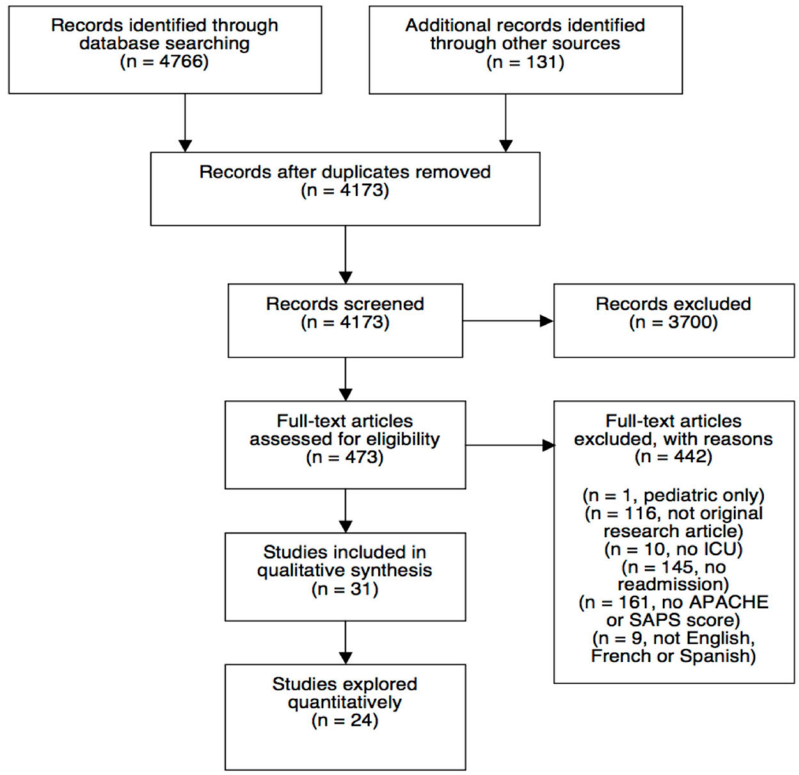

Figure 1.

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flow Diagram

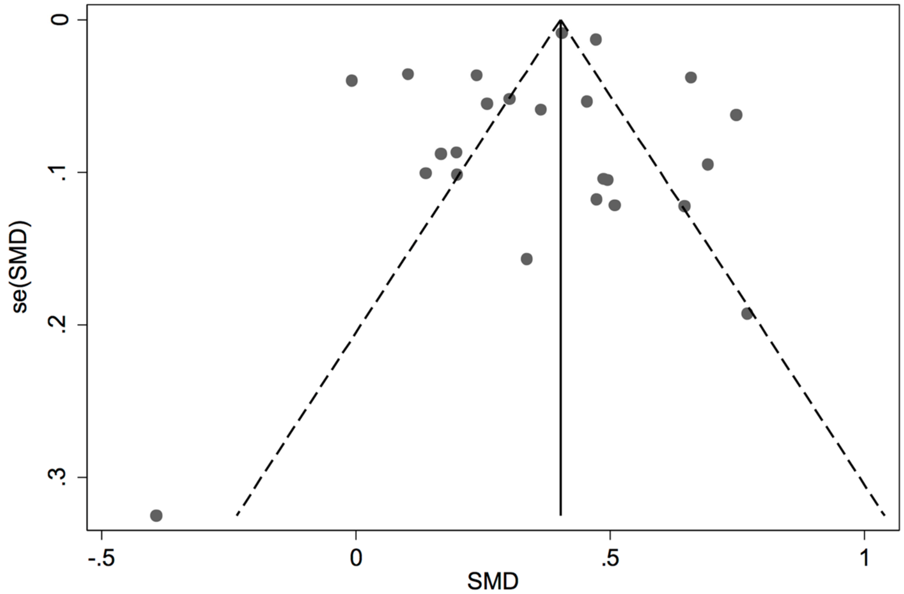

Figure 2.

Funnel plot of included studies with standardized mean differences (SMD) and associated standard error (se(SMD))

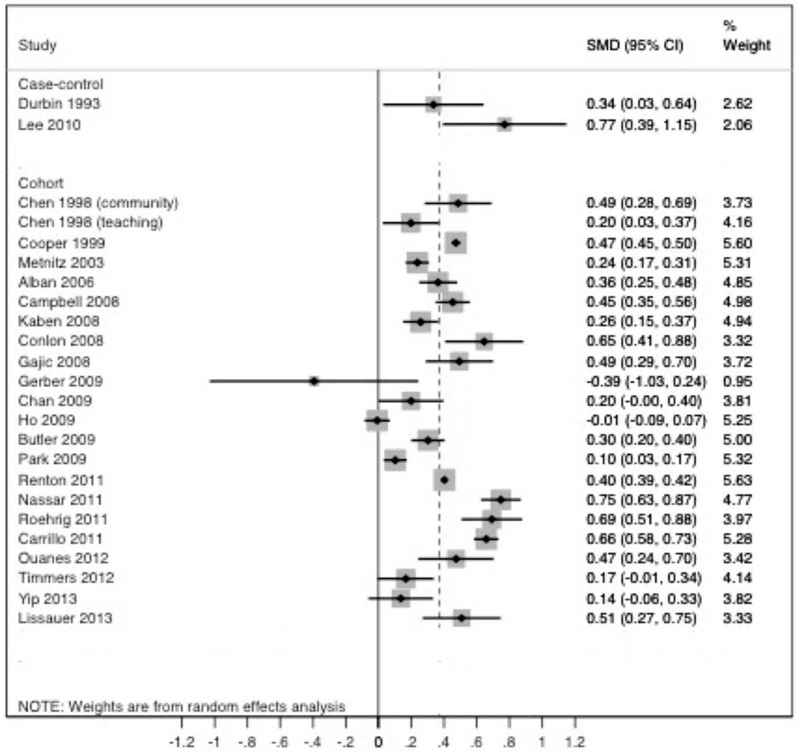

Figure 3.

Forest plot depicting standardized mean differences (SMD) and 95% confidence intervals (95% CI) of severity of illness scores between re-admitted and non re-admitted patients

Table 1

Descriptive characteristics of included studies

First author	Study design	Location	Number of patients	ICU type	Year(s)	ICU beds	Hospital beds	Age Mean (S.D.) or *median (interquartile range)*	
								Readmitted	Non-Readmitted
Durbin et al.[35]	case-control	US	1803	Mixed		24	650	59.5 (15.2)	59.1 (15.8)
Chen et al.[31]	prospective cohort	Canada	236		1995–1996				
Cooper et al.[9]	prospective cohort	US	121161	Mixed	1991–1995			65.4 (29.0)	63.4 (18.1)
Bracco et al. [36]	prospective cohort	Germany & Canada	44	Mixed	1995–1996	14	280		
Chung et al.[32]	case-control	UK	65	SICU	1998	17			
Metnitz et al.[34]	prospective cohort	Austria	15180	Mixed	1998–2000			64.8 (14.9)	62.6 (17.0)
Alban et al.[29,37] Nishi et al.	retrospective cohort	US	10840	SICU	1996–2001	20	850	60.6 (18.8)	58.7 (30.3)
Gajic et al.[19]	prospective cohort	US & Netherlands	1131	MICU	2004–2005			64 (18)	66 (18)
Conlon et al. [38]	prospective cohort	Ireland	73	Mixed	2004	18	570	66.9 (14.8)	61.7 (15.2)
Kaben et al. [39]	prospective cohort	Germany	381	SICU	2004–2006			64 (14)	62 (15)
Campbell et al.[30]	retrospective cohort	Scotland	385	Mixed	1995–2005			*66 (54–73)*	*60 (43–71)*
Park et al.[40]	retrospective cohort	UK	873	Mixed	1995–2007			65.6 (9.7)	64.2 (9.9)
Chan et al.[41]	retrospective cohort	Taiwan	110	SICU	2003–2003			64.10 (16.98)	58.66 (17.42)
Gerber et al. [25]	retrospective cohort	US	15	Mixed	2004–2006	24	500	59.4 (17.8)	67.5 (15.0)
Butler et al. [42]	prospective cohort	US	390		2002–2008				
Ho et al. [33]	prospective cohort	Australia	16926	Mixed	1987–2002	22		56.3 (17.0)	53.8 (19.4)
Arsenault et al.[43]	case-control	Canada		Mixed		10–15			
Park et al.[44]	prospective cohort	South Korea	4257	SICU	2007–2010	32			
Lee et al.[45]	case-control	Taiwan	116	Neurologic	2003–2005	92		60.9 (19.4)	50.6 (16.9)
Silva et al.[46]	prospective cohort	Brazil	600	Mixed	2006–2007				
Carrillo Alcaraz et al.[47]	prospective cohort	Spain	12934						
Roehrig et al.[48]	prospective cohort	Brazil	1277		2008–2009			72 (17)	66 (17)
Khaja et al. [24]	prospective cohort	US	3724	MICU	2008–2009				

First author	Study design	Location	Number of patients	ICU type	Year(s)	ICU beds	Hospital beds	Age Mean (S.D.) or *median (interquartile range)*	
								Readmitted	Non-Readmitted
Nassar et al.[49]	prospective cohort	Brazil	3993		2010–2011			*73 (56–82)*	*63 (47–77)*
Renton et al. [12]	retrospective cohort	Australia	247103		2000–2007			62.5 (16.8)	59.9 (18.3)
Timmers et al.[50]	prospective cohort	Netherlands	1682	SICU	1995–2000	32	673	65 (15)	58 (18)
Ouanes et al. [20]	prospective cohort	France	3462	Mixed	1998–2010	10–18	460–1500		
Willsie et al.[51]	prospective cohort	US	10324	Mixed	2003–2009			63	59
Lissauer et al.[52]	prospective cohort	US	703	SICU	2011	19	570	59.8 (13.5)	56.6 (15.1)
Yip et al. [53]	prospective cohort	Australia	1599		2009–2010	23	800	*53 (34–67)*	*50 (32–65)*

ICU=Intensive care unit; MICU=Medical ICU; SICU=Surgical ICU

Table 2

Summary of exposure by primary outcome

First author	N	# Readmitted	#Non-readmitted	Cutoff for readmission	Severity scale	Severity of illness score timing[a]	Score Mean (S.D.) or *median (interquartile range)* [absolute range]	
							Readmitted	Non-Readmitted
Durbin et al.[35]	1803	83	82	same hospitalization	APACHE II	discharge	10.6 (5.5)	8.8 (5.2)
Chen et al.[31]	2250	140	2110	same hospitalization	APACHE II	admission	21.4 (8.1)[b]	19.8 (8.1)[b]
	2878	95	2782			admission	16.8 (6.8)[c]	13.3 (7.2)[c]
Cooper et al.[9]	121161	6371	97613	same hospitalization	APACHE III	admission	54.3 (24.3)	43.7 (22.3)
Bracco et al.[36]	1024	44			SAPS II	admission	22[d]	16[d]
Chung et al.[32]		65	65	same hospitalization	APACHE III	admission	63.3[e]	57.4[e]
Metnitz et al[34]	15180	780	14400	same hospitalization	SAPS II		*28 (21–38)*	*25 (18–35)*
Alban et al.[29], Nishi et al.[37]	10840	296	10544	same hospitalization	APACHE II	admission	18.4 (8.9)	15.3 (8.5)
						discharge	15.7 (6.7)	13.8 (7.1)
					SAPS	admission	13.7 (5.8)	11.5 (5.5)
						discharge	12.2 (4.8)	10.7 (4.9)
Gajic et al.[19]	1131	100	1026	<7 days after ICU discharge	APACHE III	admission	58.1 (22.9)	69.6 (26.8)
						discharge	49.4 (18.2)	56.8 (18.8)
Conlon et al.[38]	1061	73	988	same hospitalization	APACHE II	admission	14.4 (5.1)	10.2 (6.6)
Kaben et al.[39]	2852	381	2471	same hospitalization	SAPS II		37.1 (16.4)	32.9 (16.3)
Campbell et al.[30]	4376	385	3981	same hospitalization	APACHE II	admission	*20 (16–24)*	*17 (13–22)*
					SAPS II	admission	*37 (28–48)*	*33 (23–43)*
Park et al.[40]	7227	873	6354	same hospitalization	APACHE II	admission	14.3 (4.5)	13.8 (4.9)
					SAPS II	admission	25.8 (10.1)	25.0 (10.6)
Chan et al.[41]	945	110	835	same hospitalization	APACHE II		12.80 (6.69)	11.36 (7.31)
Gerber et al.[25]	42	15	27	same hospitalization	APACHE II		18.7 (7.0)	21.4 (6.8)
Butler et al.[42]	6511	390	6121	same hospitalization	APACHE II	admission	*16 (12–20)*	*14 (10–19)*
					SAPS II	admission	31 (23–42)	29 (20–39)
Ho et al.[33]	16926	654	16272	same hospitalization	APACHE II		*14* (13)[f]	*14.1*(13)[f]

First author	N	# Readmitted	#Non-readmitted	Cutoff for readmission	Severity scale	Severity of illness score timing[a]	Score Mean (S.D.) or *median (interquartile range)* [absolute range]	
							Readmitted	Non-Readmitted
Arsenault et al.[43]		85[g]		≤ 72 hours after ICU discharge	APACHE II	admission		
					SAPS	discharge		
Park et al. [44]	4257	271	3986	same hospitalization	APACHE II	admission and discharge		
Lee et al. [45]	116	58	58	same hospitalization	APACHE II	admission	15 (6.8)	10.1 (5.9)
						discharge	12.1 (5.4)	7.3 (4.8)
Silva et al.[46]	600	44	556	same hospitalization	SAPS II	admission		
						discharge		
Carrillo Alcaraz et al.[47]	12934	730	12204	same hospitalization	SAPS II		40 (18)	30 (15)
Roehrig et al. [48]	1277	126	1151	same hospitalization	APACHE II		18 (9)	13 (7)
Khaja et al.[24]	3724[h]	163	3495	same hospitalization	APACHE IV		67.5 (30.7)	88.5 (31.2)
Nassar et al.[49]	3993	283	3354	same hospitalization	APACHE II	admission	37 [23–51]	26 [18–36]
Renton et al.[12]	247103	13598	223505	same hospitalization	APACHE III		*56 (42–73)*	*47 (34–64)*
					SAPS II		*31 (23–41)*	*26 (19–36)*
Timmers et al.[50]	1682	141	1541	<30 days after ICU discharge	APACHE II	admission	12 (6)	11 (6)
					SAPS III	admission	46 (12)	42 (13)
Ouanes et al.[20]	3462	74	3360	<7days after ICU discharge	SAPS II	admission	*40 (19)*	*33 (20)*
Willsie et al.[51]	10324	1197	9127	<48 hrs, 48 hrs-30 days, >30 days after ICU discharge	APACHE II	admission	7.4	6.0
Lissauer et al.[52]	703	77	610	same hospitalization	APACHE III	admission	69.5 (54.9)	54.9 (23.5)
Yip et al.[53]	1599	106	1340	same hospitalization	APACHE II	discharge	*20 (16–24)*	*19 (14–24)*

[a] Admission = index admission unless otherwise specified;

[b] Academic hospital;

[c] Community hospital;

[d] p=0.001;

[e] p=0.05;

[f] Reported as median and SD;

[g] Total N – number in each group not reported;

[h] Unit of analysis is number of readmissions