Do Intensivist Staffing Patterns Influence Hospital Mortality Following ICU Admission? A Systematic Review and Meta-Analyses*

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Objective: To determine the effect of different intensivist staffing models on clinical outcomes for critically ill patients.

Data Sources: A sensitive search of electronic databases and hand-search of major critical care journals and conference proceedings was completed in October 2012.

Study Selection: Comparative observational studies examining intensivist staffing patterns and reporting hospital or ICU mortality were included.

Data Extraction: Of 16,774 citations, 52 studies met the inclusion criteria. We used random-effects meta-analytic models unadjusted for case-mix or cluster effects and quantified between-study heterogeneity using I^2. Study quality was assessed using the Newcastle-Ottawa Score for cohort studies.

Data Synthesis: High-intensity staffing (i.e., transfer of care to an intensivist-led team or mandatory consultation of an intensivist), compared to low-intensity staffing, was associated with lower hospital mortality (risk ratio, 0.83; 95% CI, 0.70–0.99) and ICU mortality (pooled risk ratio, 0.81; 95% CI, 0.68–0.96). Significant reductions in hospital and ICU length of stay were seen (−0.17 d, 95% CI, −0.31 to −0.03 d and −0.38 d, 95% CI, −0.55 to −0.20 d, respectively). Within high-intensity staffing models, 24-hour in-hospital intensivist coverage, compared to daytime only coverage, did not improved hospital or ICU mortality (risk ratio, 0.97; 95% CI, 0.89–1.1 and risk ratio, 0.88; 95% CI, 0.70–1.1). The benefit of high-intensity staffing was concentrated in surgical (risk ratio, 0.84; 95% CI, 0.44–1.6) and combined medical-surgical (risk ratio, 0.76; 95% CI, 0.66–0.83) ICUs, as compared to medical (risk ratio, 1.1; 95% CI, 0.83–1.5) ICUs. The effect on hospital mortality varied throughout different decades; pooled risk ratios were 0.74 (95% CI, 0.63–0.87) from 1980 to 1989, 0.96 (95% CI, 0.69–1.3) from 1990 to 1999, 0.70 (95% CI, 0.54–0.90) from 2000 to 2009, and 1.2 (95% CI, 0.84–1.8) from 2010 to 2012. These findings were similar for ICU mortality.

Conclusions: High-intensity staffing is associated with reduced ICU and hospital mortality. Within a high-intensity model, 24-hour in-hospital intensivist coverage did not reduce hospital, or ICU, mortality. Benefits seen in mortality were dependent on the type of ICU and decade of publication. (*Crit Care Med* 2013; 41:2253–2274)

Key Words: critical care; intensivist; length of stay; meta-analysis; mortality; physician staffing pattern; systematic review

***See also p. 2433.**

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Dr. Wilcox conceived the study, searched the literature, selected studies for inclusion, abstracted data, analyzed data, wrote the first draft of the manuscript, and revised the manuscript. Drs. Chong and Fan selected studies for inclusion, abstracted data, verified analyses, and revised the manuscript. Drs. Niven and Wunsch abstracted data and revised the manuscript. Drs. Rubenfeld and Rowan provided feedback on study design and revised the manuscript. All authors approved the final manuscript.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (http://journals.lww.com/ccmjournal).

The authors have disclosed that they do not have any potential conflicts of interest.

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DOI: 10.1097/CCM.0b013e318292313a

The majority of ICUs in North America employ a low-intensity staffing model consisting of open units in which any physician can admit patients to the ICU and an intensivist may or may not be available for consultation (1, 2). Of these units, two thirds have intensivist consultation available and fewer than 5% have no intensivist coverage at all (1, 2). Many ICUs do not have dedicated 24-hour in-house physician coverage, and of those that do, most are staffed by physicians who have additional patient duties outside the ICU during their overnight shifts (1). However, both North American and European guidelines recommend that intensivists be the most responsible physicians for the care of ICU patients and ideally provide 24-hour in-hospital coverage (3–5). These guidelines imply that ICUs should be closed units with high-intensity staffing models in which there is transfer of primary care responsibility to a single intensivist team or at least mandatory intensivist consultation.

Two previous systematic reviews showed that intensivist-led care decreased mortality and length of stay (LOS) when compared to care without an intensivist or selective intensivist consultation (6, 7). Recently, however, a large, retrospective study by Levy et al (8) has contradicted the long-held belief that intensivist care is essential to improving ICU outcomes. Ongoing variability in patient outcomes has prompted attempts to standardize staffing resources and ICU organization to reliably evaluate the effects of select organizational factors. Given existing heterogeneity in practice, conflicting study conclusions, and increased efforts to better define organizational factors (9–12), we systematically reviewed and synthesized the available evidence for intensivist staffing. The objectives of this study were to evaluate the effect of high-intensity staffing on mortality and LOS and identify staffing structures associated with better outcomes for ICU patients.

METHODS

Data Sources and Searches

MEDLINE (1948 through October, Week 2 2012), EMBASE Classic and EMBASE (1947 through to Week 41 2012), Web of Science (1970 through October, Week 41 2012), and the Cochrane Central Register of Controlled Trials (third quarter, 2012) were searched for the following Medical Subject Heading terms and text words: intensive care, critical care, mortality, hospitalization, length of stay, LOS, reorganization, organization, staffing, open-unit, closed-unit, high-intensity, low-intensity, elective or mandatory consult, full-time, 24-hour, on-call, after-hours, night float, nighttime, intensivist, and specialist. Searches were performed with the aid of an experienced information specialist. We also hand-searched two major intensive care journals, *Critical Care Medicine* and *Intensive Care Medicine* (2001–2012); conference abstracts from the Society of Critical Care Medicine and the European Society of Intensive Care Medicine (2001–2012); and bibliographies of included studies and personal files. No language restrictions were imposed. Two reviewers (E.F. or C.C. and M.E.W.) independently reviewed all citations; disagreements were resolved by discussion. In cases of doubt, full-text articles were retrieved for review and discussion. The degree of interrater agreement (κ coefficient) was calculated using standard methods and published guidelines to determine level of agreement (13).

Study Selection

Full-text reports or abstracts, if a full-text report was not available, were reviewed and studies with the following criteria were included: 1) design: observational studies with a control group; randomized or quasi-randomized controlled trial; 2) population: patients requiring admission to an ICU; 3) intervention: different models of intensivist staffing (e.g., high-intensity compared to low-intensity staffing); and 4) outcomes: ICU or hospital mortality.

When authors reported in several publications on the same patient population, only the most recent or complete study was included in the analysis. Authors were contacted to clarify methodology and request additional data when a study was excluded because its data could not be used (14–16).

Data Extraction and Quality Assessment

Two reviewers (C.C., D.N. or H.W., M.E.W.) independently abstracted data, including patient population, intensivist staffing patterns, and patient outcomes (mortality [ICU, hospital] and LOS [ICU, hospital]), using standardized case report forms. Study quality was assessed using the Newcastle-Ottawa Score (NOS) for cohort studies (17).

Data Synthesis and Analysis

Hospital mortality was the primary outcome of this systematic review. Secondary outcomes included ICU mortality, ICU LOS, and hospital LOS. Review Manager version 5.0.22 (Cochrane Collaboration, Oxford, England) was used to calculate pooled risk ratios (RRs) and 95% CIs for dichotomous outcomes and pooled weighted mean differences (WMDs) and 95% CIs for continuous outcomes. Random-effects models using inverse-variance weights adjusted for between-trial heterogeneity were used. Due to variability in methods, including the reporting of adjustment for case-mix and cluster effects among included studies, we used unadjusted data for our meta-analyses. To test the hypothesis that the effect of high-intensity intensivist staffing could depend on patient severity of illness, we examined the relationship between each study's mean severity of illness (Acute Physiology and Chronic Health Evaluation [APACHE] II score) and the effect on hospital and ICU mortality (log RR) by simple linear regression models using Stata 11 (StataCorp LP, College Station, TX). Heterogeneity among trials was assessed using I^2, the percentage of total variability across studies attributable to heterogeneity rather than due to chance (18, 19) and interpreted using published guidelines for low (I^2 = 25–49%), moderate (I^2 = 50–74%), and high heterogeneity ($I^2 \geq 75\%$) (18). For the outcomes of ICU and hospital mortality, we inspected a funnel plot (scatterplot of standard error of log RR against RR for each study) for the presence of publication bias (18) and used Egger's regression test (20) to assess for the presence of publication bias. Continuous variables are expressed as mean (SD), unless otherwise indicated.

Sensitivity analyses were performed for ICU and hospital mortality stratified by study quality (high, defined as NOS ≥ 7, vs low). We performed several subgroup analyses including: 1) analysis by decade of publication, in an attempt to account for changes in care practices over time as well as possible unit-level characteristics, 2) ICU type (e.g., medical, surgical, vs medical-surgical; adult vs pediatric), and 3) geographical location of ICU (e.g., United States, United Kingdom, Canada, Asia-Pacific vs Other). To test for interaction, pooled RRs among subgroups in the random-effects model were compared using z tests (21). A second analysis evaluating high-intensity staffing included the duration of intensivist coverage (daytime coverage only as compared to 24-hr in-hospital coverage by an intensivist).

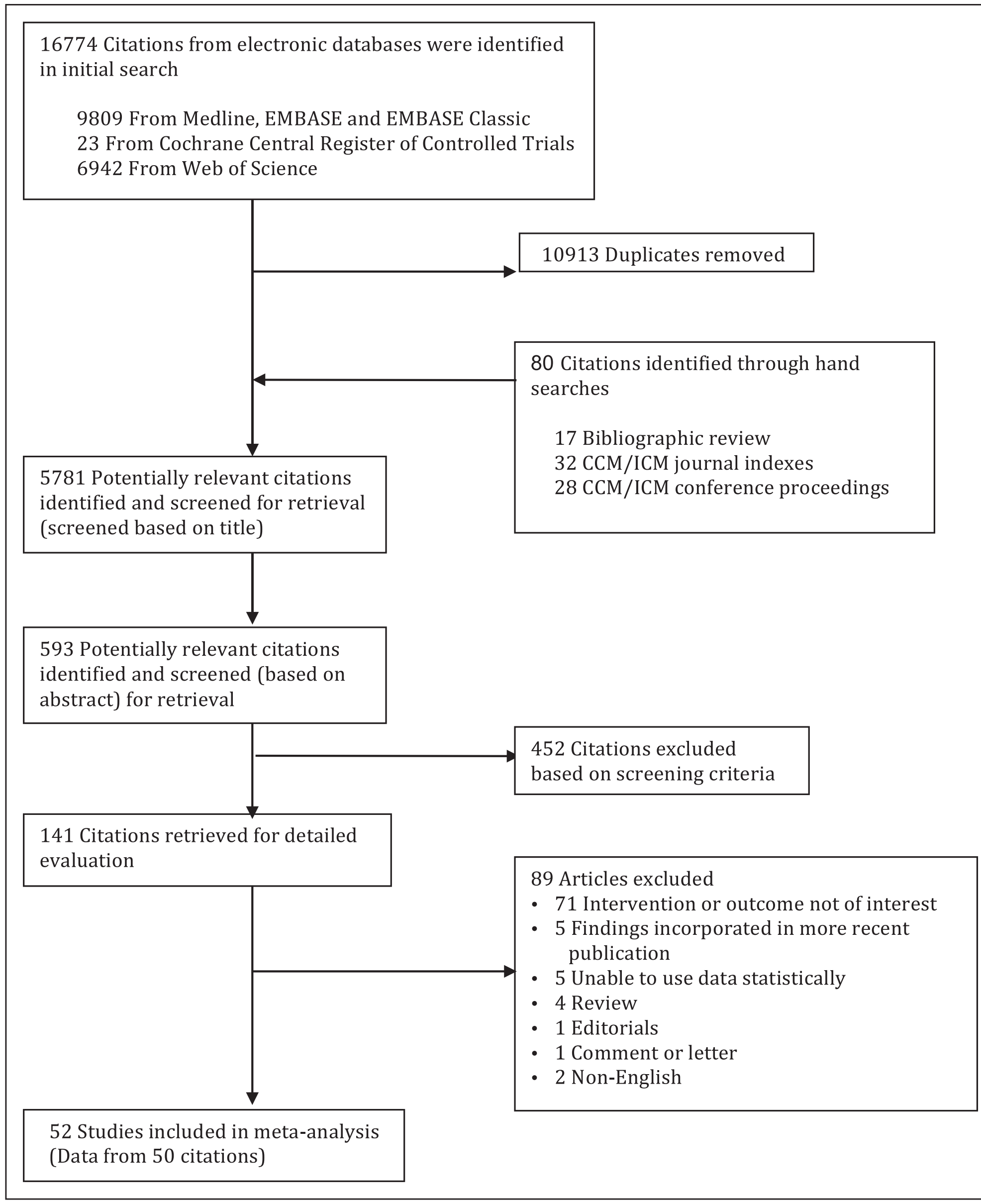

Figure 1. Flowchart of study selection for the systematic review. CCM = *Critical Care Medicine*, ICM = *Intensive Care Medicine*.

RESULTS

Study Flow

The search strategy yielded 16,774 citations (**Fig. 1**). One hundred forty-one were retrieved for detailed evaluation, of which 89 were excluded. Fifty-two studies with 331,222 patients met inclusion criteria (8, 22–71). No authors provided additional data (14–16).

Description of Included Studies

There were no randomized or quasi-randomized trials of intensivist staffing. All 52 included studies were observational: 6 were cross-sectional studies with concurrent controls; 44 were cohort studies, of which 32 used historical controls (before-after design) and 12 used concurrent controls. Two studies used both before-after and concurrent controls; these two articles were treated as four separate studies, as done previously (6). Therefore, 52 studies were included in the quantitative synthesis; 41 studies compared high-intensity to low-intensity staffing and 11 studies compared high-intensity staffing with either 24-hour in-hospital intensivist coverage or daytime only coverage.

Study populations were diverse. Thirty-three studies (66%) were from the United States and three (6%) were from the United Kingdom; the remaining 14 studies (28%) were from Australia, Canada, Taiwan, Korea, Turkey, Afghanistan, India, Gibraltar, Jordan, Malaysia, and Puerto Rico. Fifty-nine percent of studies were from university-affiliated or academic centers, three studies (6%) from community hospitals/non-university-affiliated centers and two (4%) from combat hospitals. Five studies (10%) were from PICUs, 15 studies (30%) were from medical ICUs, 8 studies (16%) were from surgical ICUs, and 15 studies (30%) were from mixed medical and surgical ICUs. Four studies (8%) were from specialized mixed medical and surgical ICUs,

TABLE 1. Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source	Study Design/Control	Type of Intervention[a]		
Study Periods	**Type of Hospital/ICU**	**Details of Pre- and Postintervention Staffing Models**	**Outcome Measures**	**Study Quality**
Al-Asadi et al (30)	Cohort study	Low-intensity staffing compared to high-intensity staffing	ICU mortality	5 (retrospective)
	Historical control	Open unit (general medicine attending) with elective intensivist consultation		7 (prospective)
Pre: August 1991 to 1993	356-bed Veterans' Administrative Hospital	Closed unit (critical care attending and fellow)		
Post: August 1993 to 1995	Medical ICU			
Baldock et al (32)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital and ICU mortality	8
	Historical control	Open unit (surgical or medical attending) with elective intensivist consultation		
Pre: January 1996 to 1997	440-bed teaching hospital; tertiary care referral center	Closed unit (daytime sessions covered by intensivist)		
Post: January 1998 to 1999[b]	Mixed medical/ surgical ICU			
Blunt and Burchett (27)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital and ICU LOS	7
	Historical control	Open unit (overnight coverage provided by intensivists 45% of time)		
	Community hospital	Closed unit (daytime sessions covered by intensivist)		
	Mixed medical/ surgical ICU			
Brown and Sullivan (22)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital and ICU mortality	7
	Historical control	Open unit (surgical or medical attending)		
Pre: July 1984 to June 1985	300-bed teaching hospital; tertiary care referral center	Closed unit (critical care specialist[c])[d]		
Post: July 1985 to June 1986	Mixed medical/ surgical ICU			

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TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source	Study Design/Control	Type of Intervention[a]		
Study Periods	Type of Hospital/ICU	Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Carson et al (28)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital and ICU LOS, hospital costs, duration of MV, nurses perceptions of ICU function, patient and family perceptions	8
	Historical control	Open unit (medical attending)		
Pre: October 1 to November 30, 1993	University-based tertiary care center	Closed unit (critical care specialist)		
Post: April 1 to May 31, 1994	Medical ICU			
DiCosmo (47)	Cohort study	Low-intensity staffing compared to high-intensity staffing	ICU mortality, ICU LOS, LOS with MV, MV-associated mortality	7
	Historical control	Open unit (primary physician) with elective intensivist consultation		
Pre: January 1, 1994–1996	250-bed nonteaching community hospital	Closed unit (critical care specialist)		
Post: January 1, 1996–1997	Medical ICU			
Dimick et al (48)	Outcomes study Cross-sectional	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital LOS, hospital costs, complications	7
January 1994 to December 1998	31 nonfederal acute care hospitals Surgical ICU[e]	Daily rounds performed by intensivist compared to other (prospective survey; completed by ICU directors or nurse managers)		
Dimick et al (49)	Outcomes study Cross-sectional	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital LOS, hospital costs	7
January 1994 to December 1998	25 nonfederal acute care hospitals Surgical ICU[f]	Daily rounds performed by intensivist compared to other (prospective survey; completed by ICU directors or nurse managers)		
Gajic et al (23)	Cohort study	High-intensity staffing compared to high-intensity staffing	Hospital and ICU mortality, hospital and ICU LOS, processes of care, complications, family/patient and staff satisfaction	8
	Historical control	Closed unit with critical care specialist available during daytime hours only		
Pre: 2005–2006	University-based tertiary care center	Closed unit with 24-hr intensivist cover		
Post: 2006–2007	Medical ICU			

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TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source / Study Periods	Study Design/Control / Type of Hospital/ICU	Type of Intervention[a] / Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Gannon et al (33) Pre: January 1, 2006 to April 1, 2007 Post: April 1, 2007 to December 31, 2008	Cohort study Historical control Surgical ICU	Low-intensity staffing compared to high-intensity staffing Open unit (surgical attending) with elective intensivist consultation Closed unit (critical care specialist)	ICU mortality, ICU LOS	6
Garland et al (50) January 1994–1995	Cohort study Concurrent control University-affiliated hospital Medical ICU	Low-intensity staffing compared to high-intensity staffing Primary care physician was either an intensivist or a nonintensivist (elective intensivist consultation)	Hospital and ICU mortality, hospital and ICU LOS, no. of intensivist consultations	8
Garland et al (71) October to December 2008	Cohort study Concurrent control University-affiliated hospital Medical and surgical ICUs	High-intensity staffing compared to high-intensity staffing Closed unit with critical care specialist available during daytime hours only Closed unit with 24-hr intensivist cover	Hospital and ICU mortality, hospital and ICU LOS, family/patient and staff satisfaction	8
Ghorra et al (29) Pre: January 1, 1995 to December 31, 1995 Post: January 1, 1996 to June 30, 1996	Cohort study Historical control 721-bed tertiary care hospital; university-affiliated Surgical ICU	Low-intensity staffing compared to high-intensity staffing Open unit (surgical or medical attending) with elective intensivist consultation Closed unit (critical care specialist)	ICU mortality, ICU LOS, 30-d mortality, no. of consultations, no. of interventions and medication use (antibiotics, feeding)	7
Goh et al (37) Pre: June 1996 to June 1997 Post: January 1999 to March 2000	Cohort study Historical control PICU	Low-intensity staffing compared to high-intensity staffing Open unit (general pediatricians) with elective intensivist consultation Closed unit (daytime sessions covered by intensivist)	Hospital mortality, hospital and ICU LOS	7

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TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source / Study Periods	Study Design/Control / Type of Hospital/ICU	Type of Intervention[a]: Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Hanson et al (31)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital LOS, duration of MV, no. of consultations	7
	Concurrent control	Open unit (surgical attending) with elective intensivist consultation		
July 1994 to June 1995	Academic medical center	Closed unit (critical care specialist)		
	Surgical ICU			
Hawari et al (42)	Cohort study	High-intensity staffing compared to high-intensity staffing	ICU mortality, 28-d mortality, bed turnover rate	7
	Historical control	Closed unit with critical care specialist available during daytime hours only		
Pre: 2004	120-bed oncology center; developing country	Closed unit with 24-hr intensivist cover		
Post: 2006–2007	Medical ICU[g]			
Kim et al (62)	Cohort study	Low-intensity staffing compared to high-intensity staffing	ICU mortality, ICU LOS, duration of MV	7
	Concurrent control	Open unit (surgical attending) with elective intensivist consultation		
March 2009 to February 2010	445-bed secondary referral hospital	Closed unit (critical care specialist)		
	Mixed medical/surgical ICU			
Kim et al (61)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital, ICU and 28-d mortality, hospital LOS, duration of MV, quality care metrics	8
	Concurrent control	Daily rounds performed by intensivist (care transferred to intensivist by turns of 24-hr duty) compared to other; data collected by prospective survey		
July 1 to 31, 2009	25 university hospitals; 28 ICUs			
	Mixed medical/surgical ICU[h]			

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TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source / Study Periods	Study Design/Control / Type of Hospital/ICU	Type of Intervention[a]: Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Kumar et al (26)	Cohort study	High-intensity staffing compared to high-intensity staffing	ICU mortality, ICU LOS, 30-d mortality	7
	Concurrent control	Closed unit with critical care specialist available during daytime hours only		
January 1, 2007–2008	University-based tertiary care center	Closed unit with 24-hr intensivist cover		
	Cardiac ICU			
Kuo et al (40)	Cohort study	Low-intensity staffing compared to high-intensity staffing	ICU mortality, ICU LOS	8
	Historical control	Open unit (surgical attending) with elective intensivist consultation		
Pre: 1986–1991	University-based tertiary care center	Closed unit (critical care specialist)		
Post: 1991–1996	Surgical ICU			
Lettieri et al (54)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital and ICU mortality, duration of MV, complications	7
	Historical control	Open unit (military surgical attending) with elective intensivist consultation		
March 2004 to January 2007	Combat support hospital	Closed unit (critical care specialist)		
	Mixed medical/surgical ICU			
Levy et al (8)	Outcomes study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, disposition location	5
	Cross-sectional with concurrent control	Open unit (< 5% of care provided by critical care specialist)		
2000–2004	123 ICUs in 100 hospitals across the United States; Project IMPACT database	Closed unit (> 95% of care provided by critical care specialist)[f]		
	Mixed medical/surgical ICU			

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TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source / Study Periods	Study Design/Control / Type of Hospital/ICU	Type of Intervention[a] / Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Lin et al (53)	Outcomes study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, mortality by case volume	7
	Cross-sectional with concurrent control	Open unit (specialty other than pulmonary/critical care)		
2002–2004	Teaching and nonteaching hospitals	Closed unit (critical care specialist)		
	Mixed medical/surgical ICU[i]			
Marini et al (34)	Cohort study	Low-intensity staffing compared to high-intensity staffing	ICU mortality, ICU LOS, duration of MV, no. of consultations	7
Pre: August 1 to September 30, 1993	Historical control	Open unit (surgical attending) with elective intensivist consultation		
Post: October 1 to December 31, 1993	Surgical ICU	Closed unit (critical care specialist)		
Post: January 1 to March 31, 1994				
McMillen et al (60)	Cohort study	High-intensity staffing compared to high-intensity staffing	ICU mortality, LOS (> 7 d), duration of MV	8
	Historical control	Closed unit with critical care specialist available during daytime hours only		
Pre: 2001–2006	800-bed teaching hospital; university-based tertiary care center	Closed unit with 24-hr intensivist cover		
Post: 2007–2010	Surgical ICU			
Multz et al (prospective) (35)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital and ICU LOS, non-ICU LOS, procedure use, duration of MV	8
	Concurrent control	Open unit (medical attending) with elective intensivist consultation		
May 1, 1993 to August 15, 1993	581-bed acute care hospital (control); 800-bed acute care hospital (intervention) university-affiliated	Closed unit (critical care specialist)		
	Medical ICUs			

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TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source / Study Periods	Study Design/Control / Type of Hospital/ICU	Type of Intervention[a] / Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Multz et al (retrospective) (35)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital and ICU LOS, procedure use, duration of MV	7
	Historical control	Open unit (medical attending) with elective intensivist consultation		
Pre: February 1, 1993 to April 30, 1993	581-bed acute care hospital; university-affiliated	Closed unit (critical care specialist)		
Post: May 1, 1993 to August 15, 1993	Medical ICU[j]			
Nathens et al (46)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality	8
	Concurrent control	Daily rounds performed by intensivist (care transferred to intensivist or comanagement) compared to other; data collected by prospective survey		
July 2001 to November 2002	69 ICUs across the United States; National Study on the Costs and Outcomes of Trauma			
	Mixed medical/surgical ICU			
Netzer et al (24)	Cohort study	High-intensity staffing compared to high-intensity staffing	Hospital and ICU mortality, hospital and ICU LOS, 28-d ICU-free days	7
	Historical control	Closed unit with critical care specialist available during daytime hours only		
Pre: April 19, 2004 to April 18, 2006	705-bed teaching hospital; university-affiliated hospital	Closed unit with 24-hr intensivist cover		
Post: September 5, 2006 to September 4, 2008	Medical ICU			
Nishisaki et al (63)	Cohort study	High-intensity staffing compared to high-intensity staffing	ICU mortality, MV-free days	7
	Historical control	Closed unit with critical care specialist available during daytime hours only		
Pre: January 1, 2000 to December 31, 2003	University-based tertiary pediatric care center	Closed unit with 24-hr intensivist cover		
Post: January 1, 2004 to December 31, 2006	PICU			

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TABLE 1 **(*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes**

Source / Study Periods	Study Design/Control / Type of Hospital/ICU	Type of Intervention[a] / Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Petitti et al (64)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality	8
	Historical control	Open unit (surgical attending)		
Pre: January 1, 2002 to September 1, 2005	334-bed acute care hospital; tertiary trauma referral center	Closed unit (critical care specialist)		
Post: January 1, 2008 to December 31, 2008[k]	Surgical ICU			
Pollack et al (55)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital and ICU mortality, ICU LOS, no. of days monitored	7
	Historical control	Open unit (general pediatrician)		
Pre: October 1, 1983 to December 31, 1983	275-bed university-affiliated general hospital	Closed unit (PICU team; critical care specialist or pediatric cardiologist)		
Post: March 26 to June 26, 1984	PICU			
Pollack et al (56)	Outcomes study	Low-intensity staffing compared to high-intensity staffing	Hospital and ICU mortality, no. of readmission, no. of transfers	7
	Cross-sectional with concurrent control	Daily rounds performed by intensivist compared to other (general pediatrician); data collected by prospective survey		
December 1989 to January 1992	16 hospitals (range: 20–173 beds); teaching and nonteaching hospitals			
	PICUs			
Pronovost et al (51)	Outcomes study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital and ICU LOS, complications	7
	Cross-sectional with concurrent control	Daily rounds performed by intensivist compared to other (prospective survey; completed by ICU directors or nurse managers)		
1994–1996	46 nonfederal acute care hospitals			
	Surgical ICU[l]			

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TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source / Study Periods	Study Design/Control / Type of Hospital/ICU	Type of Intervention[a] / Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Reich et al (43)	Cohort study	Low-intensity staffing compared to high-intensity staffing	ICU mortality, no. of patients receiving MV, PAC use	6
	Historical control	Open unit (medical or surgical attending) with no intensivist consultation		
	Community hospital	Closed unit (critical care specialist)		
	Mixed medical/surgical ICU			
Reriani et al (65)	Cohort study	High-intensity staffing compared to high-intensity staffing	Hospital mortality, quality of life at 6 mo post-ICU discharge (SF-36)	7
	Historical control	Closed unit with critical care specialist available during daytime hours only		
Pre: January 1, 2005 to January 2, 2006	University-based tertiary care center	Closed unit with 24-hr intensivist cover		
Post: January 3, 2006 to December 31, 2006	Medical ICU			
Resnick et al (70)	Cohort study	High-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital LOS, duration of MV, quality of care metrics	7
	Historical control	Closed unit with critical care specialist available during daytime hours only		
Pre: February 1, 2002 to January 31, 2003	Tertiary neonatal referral center	Closed unit with 24-hr intensivist cover		
Post: April 1, 2003 to March 31, 2004	Neonatal ICU			
Reynolds et al (44)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, ICU and hospital LOS, duration of MV, PAC use, costs	8
	Historical control	Open unit (medical or surgical attending) with no intensivist consultation		
Pre: July 1, 1982 to June 30, 1983	330-bed teaching hospital; tertiary care referral center	Closed unit (critical care specialist)		
Post: July 1, 1983 to June 30, 1984	Medical ICU			

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TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source / Study Periods	Study Design/Control / Type of Hospital/ICU	Type of Intervention[a] / Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Rivera et al (58)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital and ICU mortality, ICU LOS, 30-d mortality	6
	Historical control	Open unit (medical or surgical attending) with no intensivist consultation		
Pre: June–November 2000	Veterans' Administrative Hospital	Closed unit (critical care specialist)		
Post: June–November 2001	Surgical ICU			
Roberts et al (25)	Cohort study	High-intensity staffing compared to high-intensity staffing	ICU mortality	7
	Historical control	Closed unit with critical care specialist available during daytime hours only		
Pre: October 1, 2003 to September 30, 2006	212-bed university-affiliated hospital	Closed unit with 24-hr intensivist cover		
Post: October 1, 2006 to October 1, 2007	Mixed medical/surgical ICU			
Sales et al (66)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality	8
	Concurrent control	Daily rounds performed by intensivist (care transferred to intensivist or comanagement) compared to other; data collected by prospective survey		
February to June 2003	125 Veterans Health Administration hospitals; 213 ICUs			
	Mixed medical/surgical ICUs			
Samuels et al (67)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, disposition location	7
	Historical control	Open unit (neurology and neurologic surgery attending) with elective intensivist consultation		
Pre: January 1, 1995 to August 31, 1998	University-based tertiary care center	Closed unit (critical care specialist)		
Post: September 1, 1998 to December 31, 2002	Mixed medical/surgical ICU[m]			

(*Continued*)

TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source / Study Periods	Study Design/Control / Type of Hospital/ICU	Type of Intervention[a]: Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Singh et al (38)	Cohort study	Low-intensity staffing compared to high-intensity staffing	ICU mortality, ICU LOS, days of MV	9
	Historical control	Open unit (surgical attending) with elective intensivist consultation		
Pre: 1991–2000	University-based tertiary care center	Closed unit (critical care specialist)		
Post: 2002–2007	Medical ICU[n]			
Suarez et al (52)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital and ICU LOS, readmit rates, disposition location	6
	Historical control	Open unit (neurology and neurologic surgery attending) with elective intensivist consultation		
Pre: January 1997 to August 1998	University-based tertiary care center	Closed unit (critical care specialist)		
Post: September 1998 to March 2000	Mixed medical/surgical ICU[h]			
Thurlby et al (57)	Cohort study	Low-intensity staffing compared to high-intensity staffing	ICU mortality, ICU LOS	8
	Concurrent control	Open unit with no intensivist consultation		
	Combat support hospital	Closed unit (critical care specialist)		
	Mixed medical/surgical ICU[o]			
Topeli et al (45)	Cohort study	Low-intensity staffing compared to high-intensity staffing	ICU and hospital mortality, ICU and hospital LOS, no. of invasive procedures	8
Pre: June 1, 1996 to October 31, 1996	Historical control	Open unit (medical attendings) with no intensivist consultation		
Post: November 1, 1998 to April 30, 1999	1,000-bed university hospital; tertiary care referral center	Closed unit (critical care specialist)		
Post: March 1, 2000 to February 28, 2001	Medical ICU			

(*Continued*)

TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source / Study Periods	Study Design/Control / Type of Hospital/ICU	Type of Intervention[a]: Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Treggiari et al (69)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital mortality, hospital and ICU LOS	8
	Concurrent control	Open unit with elective intensivist consultation		
April 1999 to July 2000	16 hospitals participating in the King County Lung Injury Project; 24 ICUs	Closed unit (critical care specialist)		
	Mixed medical/ surgical ICUs			
Varelas et al (36)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital and ICU mortality, hospital and ICU LOS, disposition location, 30-d readmission	9
	Historical control	Open unit (neurology and neurologic surgery attending) with elective intensivist consultation		
Pre: February 1999 to August 2000	University-based tertiary care center	Closed unit (critical care specialist)		
Post: September 2000 to March 2002	Mixed medical/ surgical ICU[n]			
Wallace et al (59)	Cohort study	High-intensity staffing compared to high-intensity staffing	Hospital mortality	7
	Concurrent control	Closed unit with critical care specialist available during daytime hours only; data collected by prospective survey		
2009–2010	25 hospitals (49 ICUs); participating in Acute Physiology and Chronic Health Evaluation clinical information system	Closed unit with 24-hr intensivist cover		
	Mixed medical/ surgical ICUs			
Wise et al (68)	Cohort study	Low-intensity staffing compared to high-intensity staffing	Hospital and ICU mortality, hospital and ICU LOS	8
	Concurrent study	Open unit (medical attending) with elective intensivist consultation		
October 2007 to September 2008	University-based tertiary care center	Closed unit (critical care specialist)		
	Medical ICU			

(*Continued*)

TABLE 1 (*Continued*). Studies of Low- and High-Intensity Physician Staffing and Measured Outcomes

Source	Study Design/Control	Type of Intervention[a]		
Study Periods	Type of Hospital/ICU	Details of Pre- and Postintervention Staffing Models	Outcome Measures	Study Quality
Zwaal and Baba (39)	Cohort study	Low-intensity staffing compared to high-intensity staffing	ICU mortality, ICU LOS	8
	Historical control	Open unit (medical attendings) with no intensivist consultation		
2 yr	Mixed medical/surgical ICU	Closed unit (critical care specialist)		

LOS = length of stay, MV = mechanical ventilation, PAC = pulmonary artery catheter.
[a]Low-intensity, high-intensity (daytime), high-intensity (24-hr).
[b]Data from 1997 to 1998 during changes were not included in meta-analysis.
[c]Defined as individual who, in addition to board certification, have completed further fellowship-level training in critical care.
[d]Night cover provided by medical and surgical residents on ICU rotation.
[e]Patients who underwent an esophagectomy resection.
[f]Patients who underwent hepatic resection (patients cared for 5%-95% of time by critical care specialist excluded).
[g]Patients admitted with an oncologic diagnosis.
[h]Battlefield/trauma facilities.
[i]Patients admitted with severe pneumonia.
[j]Critical care area shared jointly between medical ICU and the coronary care unit.
[k]Data collected from October 1, 2005, to December 31, 2007, during the “partial” intensivist period, were not included in meta-analysis.
[l]Patients who underwent abdominal aortic aneurysm repair.
[m]Patients admitted to neurosciences critical care unit.
[n]Patients admitted with severe acute pancreatitis.
[o]Patients admitted with severe sepsis.

including three neuroscience ICUs and a cardiac critical care unit (Table 1).

Studies included a median of 358 patients (interquartile range [IQR], 150–1,383 patients). The median of the mean ages of patients was 60 years (IQR, 53–65 yr) in the standard group and 61 years (IQR, 53–65 yr) in the intervention group (**eTable 1**, Supplemental Digital Content 1, http://links.lww.com/CCM/A680). Twenty-nine studies (58%) provided data on gender: in both the standard and intervention groups 58% of patients were men (range, 45–94% and 45–91%, respectively).

Study Quality

Overall study quality was good with a mean NOS score of 7 out of a possible 9 (range, 5–9) and with 46 studies (92%) receiving a NOS greater than or equal to 7 (**eTable 2**, Supplemental Digital Content 1, http://links.lww.com/CCM/A680). Twenty-nine studies (58%) had low risk of bias from temporal trends, whereas 14 studies had medium risk and seven had high risk. Thirty-five studies (70%) had low risk of bias from confounding, whereas 11 studies had medium risk and four studies had high risk. Five studies did not report any form of risk adjustment. All studies had complete follow-up (**eTable 3**, Supplemental Digital Content 1, http://links.lww.com/CCM/A680).

Clinical Outcomes

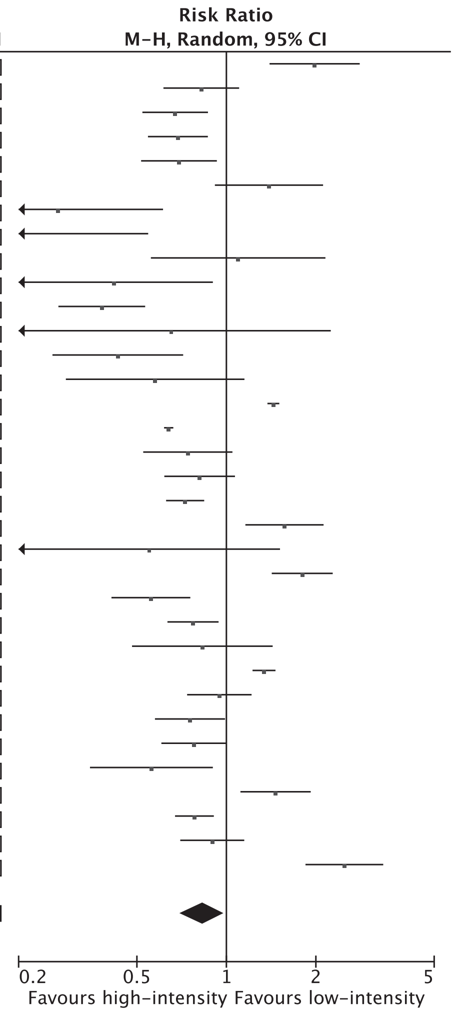
Hospital mortality was reported in 34 studies (67%), showing significantly lower hospital mortality with high-intensity staffing compared to low-intensity staffing (pooled RR, 0.83; 95% CI, 0.70–0.99; **Fig. 2**). Although visual inspection of the funnel plot did not suggest publication bias, Egger's test was of borderline statistical significance ($p = 0.05$). Eighteen studies (35%) reported ICU mortality, demonstrating significantly lower ICU mortality with high-intensity staffing compared to low-intensity staffing (pooled RR, 0.81; 95% CI, 0.68–0.96). There was no suggestion of publication bias with either visual inspection of the funnel plot or Egger's test ($p = 0.44$). Both analyses showed high between-study heterogeneity ($I^2 > 75\%$).

A second analysis was performed based on intensivist staffing differences within a closed ICU model (e.g., 24-hr in-hospital intensivist coverage compared to daytime only coverage). Pooled RRs were 0.97 (95% CI, 0.89–1.1; $I^2 = 48\%$) for 24-hour in-hospital intensivist coverage, as compared to daytime only cover by an intensivist (**Fig. 3**). The effects on ICU mortality were also similar between 24-hour in-hospital intensivist coverage and daytime only cover by an intensivist (RR, 0.88; 95% CI, 0.70–1.1; $I^2 = 89\%$).

A

Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio M–H, Random, 95% CI
Al-Asadi et al 1996 (pro)	66	1005	55	1659	3.1%	1.98 [1.40, 2.81]
Al-Asadi et al 1996 (ret)	66	1005	112	1404	3.2%	0.82 [0.61, 1.10]
Baldock et al 2001	78	387	107	357	3.3%	0.67 [0.52, 0.87]
Blunt et al 2001	93	393	113	328	3.3%	0.69 [0.54, 0.87]
Brown et al 1989	53	216	79	223	3.2%	0.69 [0.52, 0.93]
Carson et al 1996	38	121	28	124	2.9%	1.39 [0.91, 2.11]
Dimick et al 2001	7	182	24	169	2.0%	0.27 [0.12, 0.61]
Dimick et al 2002	4	276	21	275	1.5%	0.19 [0.07, 0.55]
Garland et al 1996	9	32	19	74	2.3%	1.10 [0.56, 2.15]
Ghorra et al 1999	9	149	18	125	2.1%	0.42 [0.20, 0.90]
Goh et al 2001	42	355	82	264	3.1%	0.38 [0.27, 0.53]
Hansen et al 1999	4	100	6	98	1.2%	0.65 [0.19, 2.24]
Kim JH et al 2012	14	78	72	173	2.7%	0.43 [0.26, 0.72]
Lettieri et al 2009	9	223	52	742	2.2%	0.58 [0.29, 1.15]
Levy et al 2008	3349	18618	2859	22870	3.6%	1.44 [1.37, 1.51]
Lin et al 2008	4884	50064	5707	37415	3.6%	0.64 [0.62, 0.66]
Multz et al 1998 (pro)	52	185	36	95	3.1%	0.74 [0.53, 1.05]
Multz et al 1998 (ret)	56	154	68	152	3.3%	0.81 [0.62, 1.07]
Nathens et al 2006	528	5228	217	1561	3.5%	0.73 [0.63, 0.84]
Petitti et al 2012	52	1979	191	11399	3.2%	1.57 [1.16, 2.12]
Pollack et al 1988	5	113	12	149	1.6%	0.55 [0.20, 1.51]
Pollack et al 1994	150	2036	115	2809	3.3%	1.80 [1.42, 2.28]
Pronovost et al 1999	131	2134	52	472	3.2%	0.56 [0.41, 0.76]
Reynolds et al 1988	64	112	74	100	3.4%	0.77 [0.63, 0.94]
Rivera et al 2009	20	115	22	105	2.6%	0.83 [0.48, 1.43]
Sales et al 2011	1477	21287	664	12806	3.5%	1.34 [1.22, 1.46]
Samuels et al 2011	98	386	85	317	3.3%	0.95 [0.74, 1.22]
Singh et al 2008	30	50	35	44	3.3%	0.75 [0.57, 0.99]
Suarez et al 2004	97	1180	127	1201	3.3%	0.78 [0.60, 1.00]
Thurlby et al 2005	68	471	16	62	2.8%	0.56 [0.35, 0.90]
Topeli et al 2005	134	359	51	200	3.3%	1.46 [1.11, 1.92]
Treggiari et al 2007	239	684	175	391	3.5%	0.78 [0.67, 0.91]
Varelas et al 2004	116	1279	110	1087	3.3%	0.90 [0.70, 1.15]
Wise et al 2012	97	528	61	828	3.2%	2.49 [1.85, 3.37]
Total (95% CI)		**111484**		**100078**	**100.0%**	**0.83 [0.70, 0.99]**
Total events	12139		11465			

Heterogeneity: $Tau^2 = 0.21$; $Chi^2 = 1054.70$, df = 33 ($P < 0.00001$); $I^2 = 97\%$
Test for overall effect: Z = 2.11 (P = 0.03)



B

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Blunt et al 2001	13	11.9	393	14	11.3	328	8.2%	−0.09 [−0.23, 0.06]
Carson et al 1996	15.9	14.2	121	16.7	19.4	124	7.2%	−0.05 [−0.30, 0.20]
Dimick et al 2001	9	2.2	182	15	10.4	169	7.6%	−0.81 [−1.03, −0.59]
Dimick et al 2002	8	3.7	276	7	3	275	8.0%	0.30 [0.13, 0.46]
Garland et al 1996	21.3	31.4	32	28.4	38.8	74	5.5%	−0.19 [−0.61, 0.22]
Goh et al 2001	4	5.6	355	6.8	10.3	264	8.1%	−0.35 [−0.51, −0.19]
Hansen et al 1999	20.3	2	100	23.6	2.3	98	6.5%	−1.53 [−1.84, −1.21]
Pronovost et al 1999	10.8	10.5	2134	12.5	11.5	472	8.5%	−0.16 [−0.26, −0.06]
Reynolds et al 1988	24	23	112	21	22	100	7.0%	0.13 [−0.14, 0.40]
Suarez et al 2004	8.4	6.9	1180	9.9	8	1201	8.6%	−0.20 [−0.28, −0.12]
Topeli et al 2005	12.2	12	359	9	7.4	200	7.9%	0.30 [0.13, 0.48]
Treggiari et al 2007	15	13.3	684	14	10.4	391	8.3%	0.08 [−0.04, 0.21]
Varelas et al 2004	7.32	7.4	1279	7.9	7.7	1087	8.6%	−0.08 [−0.16, 0.00]
Total (95% CI)			**7207**			**4783**	**100.0%**	**−0.18 [−0.34, −0.02]**

Heterogeneity: $Tau^2 = 0.08$; $Chi^2 = 187.89$, df = 12 ($P < 0.00001$); $I^2 = 94\%$
Test for overall effect: Z = 2.24 (P = 0.03)

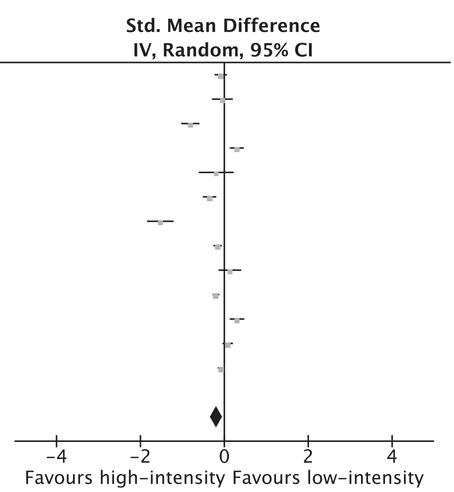


Figure 2. Effect of high-intensity intensivist staffing compared to low-intensity staffing on hospital mortality (**A**) and length of stay (**B**). The pooled risk ratio and weighted mean difference with 95% CI were calculated using random-effects models. Weight refers to the contribution of each study to the overall estimate of treatment effect. M–H = Mantel-Haenszel.

Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Risk Ratio M–H, Random, 95% CI
Gajic et al 2008	251	1321	221	1301	16.6%	1.12 [0.95, 1.32]
Garland et al 2012	53	244	62	257	6.1%	0.90 [0.65, 1.24]
Netzer et al 2011	525	2424	326	1263	22.9%	0.84 [0.74, 0.95]
Reriani et al 2012	255	1697	228	1584	16.5%	1.04 [0.89, 1.23]
Resnick et al 2010	17	245	13	225	1.5%	1.20 [0.60, 2.42]
Wallace et al 2012	1842	14424	6872	51328	36.4%	0.95 [0.91, 1.00]
Total (95% CI)		**20355**		**55958**	**100.0%**	**0.97 [0.89, 1.05]**
Total events	2943		7722			

Heterogeneity: Tau^2 = 0.00; Chi^2 = 9.69, df = 5 (P = 0.08); I^2 = 48%
Test for overall effect: Z = 0.80 (P = 0.42)

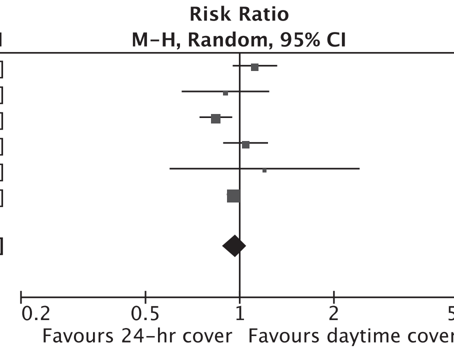


Figure 3. Effect of high-intensity during daytime only intensivist staffing compared to high-intensity 24-hr (daytime and nighttime) intensivist staffing on hospital mortality. The pooled risk ratio and 95% CI were calculated using random-effects models. Weight refers to the contribution of each study to the overall estimate of treatment effect. M–H = Mantel-Haenszel.

Secondary Outcomes

Pooled data from 14 studies showed a significantly reduced hospital LOS in the high-intensity staffing group (WMD, –0.17 d; 95% CI, –0.31 to –0.03 d; Fig. 2). In addition, the reduction in ICU LOS was also statistically significant (WMD, –0.38 d; 95% CI, –0.55 to –0.20 d). Both analyses showed high between-study heterogeneity ($I^2 > 90\%$).

Sensitivity Analysis

The effect of intensivist staffing on hospital mortality was sensitive to study quality, with the benefit concentrated among the high-quality studies (RR, 0.84 [95% CI, 0.72–0.98; I^2 = 93%]) versus low-quality studies (RR, 0.89 [95% CI, 0.43–1.87; I^2 = 95%]). The interaction test for difference in RRs was not statistically significant (p = 0.88). ICU mortality was insensitive to study quality (high-quality studies, pooled RR, 0.81; 95% CI, 0.65–1.0; I^2 = 84% vs low-quality studies, pooled RR, 0.99; 95% CI, 0.69–1.4; I^2 = 0%). These RRs were not statistically different from each other (p = 0.34 for test for interaction). For studies providing APACHE II data, linear regression showed no significant relationship between illness severity and high-intensity staffing on mortality (ICU mortality: seven studies; 1,124 events; p = 0.64 and hospital mortality: nine studies; 1,031 events; p = 0.89).

Subgroup Analyses

Further analyses were performed based on decade of publication as well as ICU type (e.g., medical, surgical, medical-surgical vs pediatric) and geographical location (e.g., United States, United Kingdom, Canada, Asia-Pacific vs Other; **eTable 4**, Supplemental Digital Content 1, http://links.lww.com/CCM/A680). For hospital mortality, pooled RRs were 0.74 (95% CI, 0.63–0.87; I^2 = 0%), 0.96 (95% CI, 0.69–1.3; I^2 = 87%), 0.70 (95% CI, 0.54–0.90; I^2 = 98%), and 1.2 (95% CI, 0.84–1.8; I^2 = 91%) from 1980 to 1989, 1990 to 1999, 2000 to 2009, and 2010 to 2012, respectively. The RRs from 1980 to 1989 were statistically different from 2010 to 2012 but not from 1990 to 1999 and 2000 to 2009 (p = 0.02, 0.16, and 0.72, respectively). The effects on ICU mortality were similar; pooled RRs were 0.49 for 1980–1989 (95% CI, 0.33–0.71; I^2 = 0%), 0.74 for 1990–1999 (95% CI, 0.46–1.20; I^2 = 85%), 0.84 for 2000–2009 (95% CI, 0.70–1.0; I^2 = 61%), and 1.0 for 2010–2012 (95% CI, 0.53–2.1; I^2 = 91%). Tests for interaction were statistically significant between 1980–1989 and 2000–2009, but not between 1980–1989 and 1990–1999 or 2010–2012 (p = 0.01, 0.19, and 0.06, respectively).

When analyses were undertaken by unit type, pooled RRs for hospital mortality were 1.1 for medical ICUs (95% CI, 0.83–1.5; I^2 = 89%), 0.84 for surgical ICUs (95% CI, 0.44–1.6; I^2 = 77%), and 0.76 for combined medical-surgical ICUs (95% CI, 0.66–0.83; I^2 = 35%). The test for interaction was significant between medical and combined medical-surgical ICUs (p = 0.02) but not between medical and surgical ICUs (p = 0.42). Pooled RR for PICUs was 0.74 (95% CI, 0.22–2.5; I^2 = 96%) as compared to 0.84 (0.70–1.0; I^2 = 97%) for adult ICUs. The interaction test for difference in RRs was not statistically significant (p = 0.84). Similar statistical trends were seen in ICU mortality; however, a statistically significant benefit of high-intensity staffing was seen in both surgical (RR, 0.75; 95% CI, 0.57–0.98; I^2 = 40%) and combined medical-surgical ICUs (RR, 0.74; 95% CI, 0.62–0.89; I^2 = 50%). No statistically significant benefit of high-intensity staffing was seen in medical ICUs (RR, 1.2; 95% CI, 0.61–2.4; I^2 = 93%) or PICUs (RR, 0.61; 95% CI, 0.42–2.4; I^2 = 61%). The RRs were not statistically different (p = 0.19 and 0.16, surgical and combined medical-surgical as compared to medical ICUs).

The effect of ICU staffing on hospital mortality appeared to be associated with geographic location of the study, with the United Kingdom (pooled RR, 0.68; 95% CI, 0.57–0.81; I^2 = 0%), Canada (pooled RR, 0.69; 95% CI, 0.52–0.93; I^2 = 0%), and Asia-Pacific (pooled RR, 0.40; 95% CI, 0.30–0.52; I^2 = 0%) sites showing significant effects, as compared to the United States (pooled RR, 0.87; 95% CI, 0.70–1.1; I^2 = 98%). The interaction test for difference in RRs was statistically significant between studies performed in Asia-Pacific and the United States (p < 0.001), but not between studies performed in the United Kingdom or Canada as compared to the United States (p = 0.09 and 0.21, respectively). Similar statistical trends were seen in ICU mortality with pooled RR of 0.81 (95% CI, 0.70–0.95; I^2 = 16%) for the United Kingdom, 0.48 (95% CI, 0.32–0.72; single study) for Canada, 0.65 (95% CI, 0.43–0.99; I^2 = 72%) for Asia-Pacific, and 0.96 (95% CI, 0.65–1.4; I^2 = 88%) for the United States, respectively.

DISCUSSION

Our systematic review and meta-analysis of 52 studies demonstrate that high-intensity intensivist staffing reduces ICU and hospital mortality in critically ill patients. Within high-intensity staffing models, a further reduction in mortality was not seen with 24-hour in-hospital coverage as compared to daytime only intensivist coverage. Our results are consistent with the findings of a recently published retrospective cohort study showing no benefit of 24-hour in-hospital intensivist coverage in ICUs with high-intensity staffing models (59). Further, we found reductions in ICU and hospital LOS with high-intensity staffing when compared to low-intensity staffing models.

A decade of new published literature, including a large study that did not find a benefit to intensivist-led care (8), made it unclear whether our results would be similar to previous reviews (6, 7). New to this review, however, is the lack of benefit seen in mortality with a 24-hour in-hospital intensivist. This analysis highlights the need for further research to determine whether outcomes could be improved by physicians with specific critical care training and expertise, and whether benefit is achieved by increased availability (e.g., reduced response time) or through changes in ICU culture. Further, the impact of other organizational factors, such as nursing staffing patterns (e.g., care practices, nurse-led quality initiatives, and nurse-to-patient ratios), on different aspects of inpatient care needs to be better explored.

Surgical and combined medical-surgical, as compared to medical, ICUs showed the greatest benefit from high-intensity staffing, assuming that patients were admitted to a diagnosis-appropriate unit (72). Why surgical patients might benefit more from mandatory intensivist involvement is unclear and may warrant further investigation. When mortality was analyzed over time, there was initially benefit to high-intensity staffing models in the 1980s but this did not persist in the 1990s. The lack of benefit during the 1990s may have been secondary to universal changes in care practices such as with the ARDSnet low tidal volume ventilation trial (73). A trend to benefit in more recent decades may be secondary to the rise of ICU bundles and a focus on quality initiatives, interventions largely driven by intensivists most likely to staff high-intensity units (74–76). Our geographic subgroup analysis suggests that our main findings may not apply to all geographic locations, particularly the United States. Critical care services in terms of absolute number of beds and volume of admissions have been shown to vary substantially between countries (77). Whether differing models of national care delivery truly influence staffing efficacy, however, is unclear.

Current shortages in intensivist workforce may limit universal implementation of a high-intensity staffing model (1, 78). Studies to better understand the mechanisms through which intensivist staffing improves patient outcomes are needed. If these mechanisms can be easily replicated in a less human resource intense manner (e.g., daytime only coverage by an intensivist with 24-hr in-hospital nonintensivist physician providers), we might achieve similar improvements while allowing sufficient time for workforce growth to meet current and future demands. Alternative strategies to high-intensity intensivist staffing include telemedicine (79) and employment of hospitalists and nonphysician providers (physician assistants and nurse practitioners) (80). In a review by Gershengorn et al (80), patients cared for by nonphysician providers had similar mortality compared to those cared by intensivist-led teaching teams, possibly as a result of their increased adherence to clinical practice guidelines.

Strengths of this review include its methods to minimize bias, a comprehensive literature search, duplicate outcomes abstraction, consideration of important clinical outcomes, and use of an established method to assess study quality specific to nonrandomized studies (17). Our review also has weaknesses. In the absence of any randomized trials of intensivist staffing, we included before-after observational studies, which can overestimate the effect of an intervention due to secular trends (81–83). We used unadjusted estimates of effect in our meta-analyses because of between-study differences in methods used for and reporting of adjustment. A large randomized controlled trial on intensivist staffing would be technically difficult to implement. As a result, the best evidence for ICU staffing is likely to remain grounded in observational research. Although the possibility of publication bias influencing our effect estimates cannot be completely eliminated, our systematic review was rigorously conducted and transparently reported and followed recommendations of the Meta-analysis of Observational Studies in Epidemiology Group (84).

Although we believe the studied interventions to be sufficiently similar in concept and execution to permit statistical aggregation, there are still differences. These differences reflect the myriad of staffing patterns currently in practice. Our findings are further challenged by the possibility of unmeasured confounding factors influencing care delivery, such as the presence of nonintensivist physician providers, type of bedside nursing care, specialty teams, regionalization of medical care, and a lack of standard definitions for ICU administration and management (85–91). Subgroup analysis was performed to explore possible reasons for heterogeneity. Our subgroup analyses included few studies; for example, the subgroup with data on geographical location, ICUs in the United Kingdom had only two studies (outcome: ICU mortality), one of which contributed greater than 70% of the weighting to the meta-analysis. The power to detect clinically important subgroup effects was therefore limited. However, we included such categorizations to identify the aspects of high-intensity staffing that might translate into improved outcomes. Severity of illness (e.g., requirement for mechanical ventilation) has been shown to impact whether an intensivist would best provide care. Our analysis exploring the relationship between the effect of high-intensity intensivist staffing on mortality and patient severity of illness had few studies (nine of 24 studies were included in the regression for hospital mortality) and is therefore likely also underpowered to detect significant differences. As severity of illness was the only confounder reliably described in the majority of studies, we were limited to this single confounder as a predictor in our regression model.

In conclusion, there is a consistent trend indicating that high-intensity intensivist staffing is associated with improved patient outcomes. High-intensity staffing is associated with reduced ICU and hospital mortality. Within a high-intensity model, a mortality benefit was not furthered by 24-hour in-house intensivist coverage. Since widespread implementation of a high-intensity model of care will not be practical for many years, further research should determine which features of high-intensity intensivist staffing are associated with patient benefit and whether these can be replicated without the presence of intensivists.

ACKNOWLEDGMENTS

We thank Hannah Wood, Assistant Librarian, London School of Hygiene and Tropical Medicine, University College London, for her assistance in the literature search. We also thank Neill K. J. Adhikari for his valuable comments on previous drafts of this manuscript.

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