Table 1. Results of the non-comparative observational studies

First author, year	Study design, Population Setting Country	Definition variable 'intensivist-patient ratio'	Analysis, confounders	Results
Dara, 2005	Retrospective cohort study, tertiary care medical center; all critically ill patients admitted to a medical ICU between December 8, 2001, and July 14, 2003; 2,492 patients.	Intensivist-to-bed ratio, divided into four periods: • The period between December 8, 2001, and March 31, 2002, was labeled period 1 (intensivist-to-bed ratio, 1:15). • The period between April 1, 2002, and August 6, 2002, was labeled period 2 (intensivist-to-bed ratio, 1:7.5). • Period 3 (intensivist-to-bed ratio, 1: 9.5) was from August 7, 2002, to December 17, 2002. • Period 4 (intensivist-to-bed ratio, 1:12) was from December 18, 2002, to July 14, 2003.	To determine if the intensivist-to-bed ratio is an independent variable associated with ICU or hospital mortality after controlling for other factors that impact on patient outcome, logistic regression analyses were performed with intensivist-to-bed ratio, APACHE III-predicted mortality, admission source, and intensity of treatment as independent variables.	Hospital mortality Period 1: 57/349 Period 2: 104/491 Period 3: 125/573 Period 4: 196/1,079 ICU mortality Period 1: 37/349 Period 2: 68/491 Period 3: 76/573 Period 4: 117/1,079 Mean weighted ICU LOS Period 1: 12.27 Period 2: 9.46 Period 3: 9.66 Period 4: 9.22 Mean weighted hospital LOS Period 1: 19.04 Period 2: 17.17 Period 3: 16.92 Period 4: 17.26 The ICU period with one intensivist for 15 beds (period 1) had a longer adjusted ICU LOS ratio than ICU periods with one intensivist for 7.5 beds ($p < 0.0001$), 9.5 beds ($p = 0.0003$), and 12 beds ($p < 0.0001$). Although the ICU period with an intensivist-to-bed ratio of 1:7.5 had the shortest ICU LOS ratio, the difference was not statistically significant

				compared to the periods with intensivist-to-ICU bed ratios of 1:9.5 (p =0.20) or 1:12 (p = 0.51). The observed hospital mortality, observed ICU mortality, and SMRs did not differ significantly across the four periods. Multiple logistic regression analysis did not show the intensivist-to-bed ratio to be independently associated with ICU or hospital mortality.
Neuraz, 2015	Multicenter longitudinal study using routinely collected hospital data, January to December 2013; 8 ICU's from 4 university hospitals in Lyon, France; 5,718 inpatient stays.	Patient-to-physician (P/P) ratios by shift. The following four categories for P/P were defined as follows: • less than or equal to 8:1 • greater than 8:1 to less than or equal to 10:1 • greater than 10:1 to less than or equal to 14:1 • greater than 14:1 (10:1 meaning 10 patients for one physician). Medical residents were included in the count of physicians. We calculated the resident-to-physician ratio (R/P) as the number of residents divided by the number of physicians.	To control for potential confounding variables, patients' characteristics were a priori selected as clinically important covariates. The proportion of surgical cases versus medical cases was used to adjust on the type of patient case-mix admitted to ICU. The final multivariate model included the following variables: P/N, P/P (patients/physician) and residents-to-physicians ratios, patient turnover, number of LSP, proportion of men, proportion of surgical cases, SAPSII, and number of comorbidities.	<u>Mortality:</u> The fully adjusted model, taking into account both staffing and workload levels, showed an increased risk of mortality, with the highest values for P/P and P/N. The ICU risk of death increased by a factor of 2.0 (1.3–3.2) when the number of patients was above 14 per physician. The presence of medical residents did not influence inpatient mortality ($p = 0.6$).
Ding, 2022	Retrospective study. A total of 1267 ICUs from 30 provinces in mainland China were included. Data were collected using the National Clinical Improvement System Data that report ICU information. A total of 1267 hospitals and 109,1878 ICU patients from 30 provinces were included.	Physician-to-bed ratio (calculated by the total number of ICU physicians divided by the number of beds in the ICU), patient-to-physician ratio (calculated by the total number of ICU patients divided by the number of ICU physicians).	Poisson regression analysis was used to identify the impact of factors on the incidence rate and mortality of VAP.	<u>VAP incidence rate</u> ICU VAP incidence rate was higher in hospitals with high physician-to-bed ratio ($\beta = 0.586$ (0.331,0.84), $p < 0.0001$) and patients-to-physician ratio ($\beta = 007$ (0.006,0.007), $p < 0.0001$). <u>VAP mortality</u> Physician-to-bed ratio and patients-to-physician ratio were not significantly associated with VAP mortality.

Gershengorn, 2017	Retrospective cohort study using data on admissions to adult general critical care units in the United Kingdom participating in the Intensive Care National Audit and Research Centre (ICNARC) Case Mix Programme (CMP), linked with data from 2 staffing surveys. The cohort included participating ICUs from January 1, 2010, through December 31, 2013; 49,686 adults in 94 ICUs.	Patient-intenvisist-ratio (PIR): For the primary analysis, we calculated the PIR for a given patient as the total number of patients cared for by the intensivist for all or any portion of daytime hours, averaged over the patient's ICU stay. For example, if 10 patients were in the ICU at 8:00 AM, of whom 2were discharged prior to 3:59 PM and 3 new patients were admitted during the daytime (8:00 AM-3:59 PM), the PIR would be 13 (the initial 10 plus the 3 admitted) for that day. All patients, including readmissions, were included for this calculation. This definition aimed to reflect the average overall patient workload for the intensivist, during daytime hours, over the duration of stay for a given patient.	We used multivariable, mixed-effect logistic regression to assess the association of patient-level PIR and mortality. All listed patient, ICU, and hospital variables were included as covariates with clustering within ICUs, except ICU bed number owing to collinearity with PIR.	<u>Ultimate hospital mortality</u> After multivariable adjustment, the PIR for each patient was significantly associated with ultimate hospital mortality (P = .003). This relationship was U-shaped with the lowest mortality at a nadir PIR of 7.5 and significantly higher mortality when the PIR was lower or higher than this value. <u>Ultimate ICU mortality</u> nadir PIR of 7.8; P < .001 <u>Original ICU mortality</u> nadir PIR of 7.8; P < .001 <u>Original hospital mortality (from original acute hospital housing original ICU)</u> nadir PIR of 7.6; P = .006
Gershengorn, 2022	Retrospective study of adult admissions to ICUs (August 2016–June 2018) in Australia and New Zealand, using two cohorts: "narrow", based on previously used criteria including restriction to ICUs with a single daytime intensivist (27,380 complete cases in 67 ICUs); and "broad", refined by individual ICU daytime staffing information	Patient-to-intensivist ratio (PIR): daytime average PIR, calculated as the number of all patients (including the index patient and any patients excluded due to cohort restrictions) in the ICU during daytime hours divided by the number of daytime intensivists. For the narrow cohort, daytime hours were defined as 8 a.m.–4 p.m. For the broad cohort, each	Multilevel multivariable logistic regression models were used to assess the association of PIR with mortality. In each, PIR was modeled using restricted cubic splines to allow for non-linear associations. The broad cohort model included non-PIR physician and non-physician staffing covariables	<u>Mortality:</u> *Narrow cohort* Median average PIR (the median value of PIR averaged over all days) was 10.1 (IQR 7–14, full range of 0–53.5). Hospital mortality was 6.1%. There was no association of average PIR with hospital mortality in this cohort using mixed effects logistic regression modeling (PIR 1st spline term odds ratio [95% CI]: 1 [0.94, 1.06], Wald testing of all spline terms p=0.61.

	(91,206 complete cases in 73 ICUs).	ICU's daytime hours were assigned as the interval during which at least one intensivist was continuously present onsite (up to 24 h for ICUs with continuous 24 h onsite coverage). Daily values were averaged over each patient's ICU stay to determine their exposure.		*Broad cohort* Median average PIR was 7.8 (IQR 5.8–10.2, full range 0–56. Hospital mortality was 8.5%. Model 3 differed significantly from Models 1 and 2 (likelihood ratio Model 1 nested in Model 2, p=0.28; Model 2 in Model 3, p=0.001; Model 1 in Model 3, p=0.004). However, we found no association between average PIR and hospitality mortality in any of the models (Wald testing for association of average PIR with mortality—Model 1, p=0.91; Model 2, p=0.58; Model 3, p=0.4). Given the null association, we did not assess whether PIR coefficients changed significantly from Models 1 to 3. Tere was a significant interaction between the 23 staffing covariables and average PIR (p<0.001); however, no association was found between average PIR and hospital mortality in any staffing subgroup where models converged. Similarly, no association was found between average PIR and mortality across patient and ICU subgroups. Finally, no association was found in any of the sensitivity analyses.
Kahn, 2023	Retrospective cohort study of intensivist-to-patient ratios in 29 ICUs in 10 hospitals in the United States from 2018 to 2020. Data were obtained from an ongoing EHR-based registry of ICU patients; The final analysis included 51,656 patients, 210,698 patient days, and 248 intensivist physicians.	The primary exposure variable was the daily intensivist caseload expressed as a count. This variable was created at the level of the patient day and reflected the total number of patients seen by that intensivist (including the index patient) on that day, prior to all patient exclusions.	A multivariable proportional hazards model with time varying covariates was fitted to estimate the relationship between the daily intensivist-to-patient ratio and ICU mortality at 28 days. To control for potential confounding, we defined several additional variables at the level of either the patient or the patient day. Variables defined at the patient level included age, gender, ICU admission source (emergency department, operating room, procedure unit, intermediate care unit, ward, or other), and comorbidities derived from ICD-10 diagnosis codes in the manner of Elixhauser. Variables defined at the level of the patient day included severity of illness (using the highest SOFA score on that day), an indicator for	ICU mortality (28 days): There was no association between the intensivist-to-patient ratio and mortality (hazard ratio for each additional patient: 0.987, 95% confidence interval: 0.968–1.007, p=0.2). This relationship persisted when we defined the ratio as caseload over the sample-wide average (hazard ratio: 0.907, 95% confidence interval: 0.763–1.077, p=0.26) and cumulative days with a caseload over the sample-wide average (hazard ratio: 0.991, 95% confidence interval: 0.966–1.018, p=0.52). The relationship was not modified by the presence of physicians-in-training, nurse practitioners, and physician assistants (p value for interaction term: 0.14).

			whether or not the patient received mechanical ventilation on that day, a count of new admissions on that day, and an indicator for whether a physician-in-training, a physician assistant, or a nurse practitioner was involved in the patient's care on that day, determined from meta-data in the clinical notes.	