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SWEAT ICU – Study of Workload and the Association of Outcomes in the Intensive Care Unit

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ABSTRACT

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By Ankita Agarwal

Introduction: The optimal staffing model for physicians in the intensive care unit (ICU) is unknown. Patient-to-intensivist ratio may offer a simple measure of workload and be associated with an impact on patient and physician outcomes. The aim of this study was to evaluate the association of physician workload as measured by patient-to-intensivist ratio with burnout syndrome (BOS) and patient mortality in the ICU.

Methods: We conducted a cross-sectional observational study across 14 academic centers in the United States from August 2020 to July 2021. We enrolled ICU physicians and adult ICU patients under the participating physician's care on a single physician-selected study day. The primary exposure was workload, which was defined as the patient-to-intensivist ratio and measured by the number of patients the physician was taking care of on the study day. Workload was modeled as high (>14 patients per physician) or low (≤14 patients per physician). The primary outcome was BOS as measured by the Well-Being Index. A secondary outcome was 28-day patient mortality. We calculated odds ratios for BOS and patient death using a multivariable logistic regression model and a binomial mixed effects model, respectively.

Results: We enrolled 122 physicians from 62 ICUs with median workload of 12 patients per physician (IQR 10-14) on the study day, and the overall prevalence of BOS was 26.4% (n=32). There was a non-significant decrease in odds of BOS in physicians with high workload versus low when adjusted for patient illness severity factors, ICU team size, ICU strain, and number of new patients (adjusted odds ratio 0.74, 95% CI 0.24 – 2.23). Of 1,322 patients, 679 (51.4%) were discharged alive from the hospital, 257 (19.4%) remained hospitalized, 347 were deceased (26.2%) by day 28; with unknown 28-day outcome for 39 (3.0%) of patients. There was no significant difference in odds of death for patients cared for by physicians with high workload group versus low workload (adjusted odds ratio 1.33, 95% CI 0.92 – 1.91).

Conclusions: In our cohort, approximately 1 in 4 physicians experienced BOS on a single day. There was no relationship between workload as measured by patient-to-intensivist ratio and burnout. Factors other than the number of patients may be important drivers of burnout among ICU physicians.

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INTRODUCTION

More than 5 million patients are admitted to intensive care units (ICUs) across the United States each year, with about 30% of the adult patients dying in the ICU (1). Currently, there exists tremendous variation in ICU staffing models across ICU size, intensivist (physicians specially trained in critical care) presence, and patient-to-physician ratio in the ICU across the United States (2, 3). Most hospitals in the United States do not have resources to provide 24-hour physician coverage in the ICU or to employ intensivists in the ICU (4). Prior work examining ICU staffing models – nighttime staffing, use of telemedicine, and 24-hour intensivist presence, has shown mixed association with patient outcomes (5-8). A 2015 systematic review found that mortality rates are higher in ICUs with lower admission volumes (9). Two additional studies found contrasting relationships between patient-to-intensivist ratio and patient mortality in the United Kingdom and Australia/New Zealand (10, 11).

Studies mentioned above suggest a non-linear relationship between ICU workload and patient outcomes, but the impact of ICU workload on physicians is less well understood and there is limited evidence to support optimal workload. Consensus recommendations suggest that patient-to-intensivist ratios higher than 14:1 may be unfavorable for physicians well-being (12), but do not definitively recommend an optimal or maximal patient-to-physician ratio for ICU physicians (13). Burnout syndrome (BOS) is defined as a syndrome of depersonalization, emotional exhaustion and a sense of low accomplishment, and is associated with decreased work performance (14, 15). Burnout is not only independently associated with a desire to leave the ICU (16), but also related to reduction in work hours and with early retirement (17).

The primary aim of this study was to examine the association between physician workload and burnout syndrome (BOS) in ICU physicians. Our key secondary aim was the association between physician workload and 28-day patient mortality. We conducted a cross-sectional observational study of ICU physicians across multiple academic ICUs in the United States surveying the physicians regarding their workload, general clinical duties, and ICU structure and staffing in addition to the physician. We quantified workload as the patient-to-intensivist ratio, measured as the number of patients the physician was responsible on the study day. Workload was modeled as a dichotomous variable; high (>14 patients per physician) and low (≤ 14 patients per physician) based on the Society of Critical Care Medicine's (SCCM) consensus statement (13). We used the Well-Being Index (18), a validated measure, to assess presence or absence of BOS. For all patients under the participating physicians' care, we collected demographics, illness severity markers, and 28-day outcomes. For our primary aim, we constructed a multivariable logistic regression model to determine the association of workload with BOS. We constructed a binomial mixed effects model to determine the association of workload with patient mortality.

BACKGROUND

Critically ill patients clinically represent a heterogenous population with various co-morbidities, presenting illnesses, and treatment options. But all critically ill patients share a need for specialized medical care that results in high cost in terms of absolute dollars, mortality, and long-term morbidity. ICU care makes up 4.1% of the United States' overall healthcare costs (over $100 billion annually), and close to 1 in 3 ICU patients will die during their hospitalization (1, 19). The patients who survive to hospital discharge face an increased mortality risk compared to peers not requiring ICU hospitalization, as well as increased risk for long term medical and cognitive complications related to the ICU stay (20). Given the burden of ICU care and impact on healthcare, the need to understand how to protect and optimize ICU care is obvious.

ICU care is more common in high income countries, but most hospitals in the United States do not have the resources to provide 24-hr physician coverage in the ICU (4). For the nearly 100,000 ICU beds in the United States as of 2019, there were just 28,808 physicians trained as intensivists (physicians with specialized training in critical care). And close to half of acute care hospitals do not have a single intensivist to provide specialized care for critically ill patients (21). The coronavirus disease 2019 (COVID19) pandemic has further highlighted the realty that demand for ICU care can outpace the supply of specialized physicians to care for critically ill patients (1, 21-23). Recommendations on pandemic preparedness have included a call for expanding the workforce, protecting intensivists, and promoting resilience while ensuring adequate care for patients (21, 24). But it is not always possible to add more physicians to the system, and hospitals would benefit from developing staffing models that allow for the "just right" staffing intensity – that is neither understaffed nor underworked.

Currently, there is no consensus on the optimal ICU staffing model leading to much variation in models nationally. Examples of differences in ICU staffing models include the size of the ICU (or number beds available), use of advanced practice providers (non-physician clinicians, also called physician extenders), telemedicine, 24-hour intensivist coverage, and mandatory staffing of ICU patients by an intensivist (high-intensity ICU) (2). Most of the prior studies and systematic reviews have not shown a consistent benefit of these variations on staffing models (3, 5, 8, 25). One aspect of staffing models is the number of patients a physician cares for – also termed the patient-to-intensivist ratio. The patient-to-intensivist ratio has been used as a quantifiable and objective measure of workload and staffing in the ICU.

A retrospective cohort study of ICU patients in the United Kingdom found that there was substantial variation in patient-to-intensivist ratios across ICUs and the association with mortality was U-shaped (higher mortalities for the lowest and highest patient-to-intensivist ratios) (10). Another study by the same group, across ICUs in Australia and New Zealand, found no association between patient-to-intensivist ratio and mortality (11). Neuraz et al. found that risk of death doubled when the patient-to-physician ratio exceeded 14:1 in multiple ICUs (26). These studies suggest that the relationship between patient-to-intensivist ratio is not linear and mirror other studies that show a certain amount of work is needed for best patient outcomes (9, 27).

The impact of ICU work and staffing models on physician outcomes is less well understood but not less important. It may be even more important in the current landscape of ICU medicine to understand the relationship, if one exists, between physician work in the ICU and physician outcomes, as more physicians leave the profession due to increased moral distress and burnout (28-30). Burnout syndrome (BOS) – a triad of depersonalization, emotional exhaustion, and a sense of low accomplishment – is experienced by critical care physicians more often than other physicians and the general population (28). Burnout is associated with decreased work performance (14, 15), a desire to leave the ICU (16), and reduction in clinical hours and/or early retirement (17). In 2017, Shanafelt et al. described seven drivers of burnout: flexibility/control over work, efficiency and resources, degree of meaning in work, social and community support at work, alignment of individual and organizational values, work-life integration, and workload (31).

Small studies have suggested a relationship between physician workload in the ICU and well-being and burnout. Mikkelsen et al. looked at number of days worked continuously in the ICU and found that 14-day clinical workload (compared to 7-day) was associated with higher levels of burnout (61% vs 24%) in ICU physicians and that day of work cycle (i.e. day 2 of 7) was also associated with burnout (32). Ward et al. demonstrated that ICU physicians who perceived a higher clinical care burden (stratified as estimated patient to intensivist ratio > 14:1) self-reported a higher rate of stress and negative impact on teaching (12). But the question of the ideal staffing intensity for ICU physicians remains incompletely answered (33, 34). The most recent consensus statement on ICU staffing by the Society of Critical Care Medicine (SCCM), suggests, based on expert opinion, that patient-to-intensivist ratios greater than 14 to 1 may be unfavorable for the physician (13). But the guidelines do not offer strong evidence nor recommendations for measuring physician workload in the ICU, nor maximal patient-to-intensivist ratios for best physician well-being or patient outcomes (13, 34).

METHODS

Specific Aims and Hypothesis

Aim 1: Examine the association between physician workload and physician burnout in the ICU.

Hypothesis: We hypothesize that increased workload (defined as the patient-to-intensivist ratio) will be associated with increased physician burnout.

Aim 2: Examine the association between physician workload and 28-day patient outcomes in the ICU.

Hypothesis: We hypothesize that increased physician workload beyond a certain threshold will be associated with poorer 28-day patient outcomes.

Study Design

We conducted a cross-sectional study across 62 ICUs in 14 academic centers in the United States. Study sites were recruited through the Discovery Research Network of SCCM (35). A physician serving as the intensivist for an adult ICU was eligible for inclusion in the study. Participating sites were able to choose which ICUs to recruit and which study days based on ICU directors' guidance and feasibility of site investigators to collect data. A study day was defined as the 24-hour period starting at 7 am the day the ICU physician completed the study measures and could occur on any day during a participating physician's ICU rotation. Physicians were allowed to choose when, during the study day, to complete study measures. Up to 3 physicians working on separate days in the same ICU were eligible, and multiple ICUs within a site could be included. All adult patients under participating physicians' care were included in the study. If a patient was cared for by more than 1 physician enrolled in the study, the patient was only included in the study once. The study was approved by the institutional review boards of all sites.

Study Measures and Data Collection

Our primary exposure of interest was physician workload. As there are no validated measures or definition of ICU workload (2), we quantified workload as the patient-to-intensivist ratio, which was based on the number of ICU patients the physician was responsible for on the study day as reported by the participating physician (13). We surveyed physicians on the ICU's chosen study day (multiple days if an ICU had multiple physicians participating) and collected physician demographic information (age, gender, race/ethnicity, marital status, number of years in practice, and residency and fellowship(s) completed). Participating physicians answered questions about the number of new patients they had that morning, details regarding the structure of their clinical time in the ICU and non-clinical duties, and if their current clinical duties were impacted by COVID19. We also asked physicians if they experienced goals of care (GOC) conflict with patients or families and if they experienced ICU strain (a mismatch between supply and demand) by needing to make an ICU bed available urgently (full physician workload survey, Table 1).

Our primary outcome was physician BOS as measured by the Well-Being Index (WBI) (36). The WBI is a 9-item survey that evaluates symptoms in domains of burnout, depression, stress, fatigue, and mental and physical quality of life over the prior 30 days. BOS is defined at a score of 4 or above on the WBI for physicians (Well-Being Index, Table 2). Participating physicians completed the WBI as part of the physician survey on the study day.

We collected structural information from each ICU including type of ICU, size of ICU provider team, nighttime coverage, nurse to patient ratios, and summary ICU data such as average ICU mortality from the last complete calendar year (Full ICU survey, Table 3). For all adult patients under the participating physician's care on the study day, we collected patient data including, reason for ICU admission, code status at ICU admission, illness severity measured by the worst sequential organ failure assessment (SOFA) score (SOFA components, Table 4) and presence of certain life-sustaining measures (such as invasive mechanical ventilation and vasopressors) during the 24 hours preceding the study day (full patient survey, Table 5). We followed patients for 28 days from the study day and collected 28-day outcome – alive and discharged, deceased [including those discharged to hospice], or still hospitalized; and ICU length of stay.

De-identified study data were collected and managed using Research Electronic Data Capture (REDCap) either hosted at Emory University or individually at the participating institution and then sent securely to Emory University at completion (37, 38).

Statistical Analysis

Descriptive Analysis

Continuous and categorical variables were reported as medians with interquartile ranges (IQRs), and counts with percentages as appropriate. Workload was modeled as a dichotomous variable stratified into high (>14 patients per physician) or low (≤ 14 patients per physician) based on the SCCM ICU staffing statement (13). Physician and patient characteristics were compared using Wilcoxon Rank Sum test for medians, and Chi-square test (Fisher's exact test for counts ≤ 5) for proportions. For comparison of patient characteristics, patient variables were first aggregated by physician and then median values of continuous variables or median percentages of categorical variables were compared across physician workload groups (high vs low).

Primary Aim – Multivariable Logistic Regression Model

We used a univariate and multivariable logistic regression model to calculate the odds ratios (OR) and 95% confidence intervals (CI) quantifying the association of physician workload to burnout. Variables for the multivariable model were identified *a priori* using directed acyclic graph theory (DAG) (39) exploring the causal relationship between workload and burnout (13, 31) (Figure 1). Patient level variables included in the logistic regression model were aggregated by physician and included as median values of continuous variables or median percentages of categorical variables. Covariates in the multivariable model included the total number of new patients, number of non-intensivist ICU providers present, presence of GOC conflict, ICU strain, median aggregated patient SOFA score, aggregated median percentage on invasive mechanical ventilation (IMV), and aggregated median percentage on vasopressors. We also assessed for statistical interaction between workload and physician specific characteristics (physician gender, years in practice, ICU weeks worked per year) on the association of workload and burnout using the Breslow-Day test.

Secondary Aim – Logistic Regression Model with Mixed Effects

A multinomial nominal mixed effects logistic regression model was constructed to assess the relationship between workload and patient outcomes. When the multinomial model failed to converge, we used a binomial mixed effects logistic regression model restricted to patients with

28-day outcome of alive (including patients alive and discharged, and patients still hospitalized at day 28) or deceased, and excluding those patients with unknown 28-day outcome. Institution, ICU, and physician were set as random effects. Fixed effects were determined using directed acyclic graph theory (Figure 2) and included patient age, gender, body mass index, ICU admission diagnosis, presence of IMV, presence of vasopressors, SOFA score, ICU strain, presence of GOC conflict, number of new patients, and number of non-intensivist providers on the ICU team (3, 6, 26, 40-42).

Sample Size & Power Calculations, Post-Hoc Analyses, and Sensitivity Analyses

A type I error rate of 0.05 was defined *a priori*. We powered our study for 80% power to detect a 20% difference in the prevalence of BOS accounting for clustering by site.

We completed a sub-group analysis of physicians from Site 1 given the large number of participants from that site. An attempt to adjust for study site as a random effect in the multivariable logistic regression model for workload and burnout association was not feasible given the unequal number of physicians in each study site group. For sub-group analysis, we completed basic descriptive analyses, and logistic regression models for the primary and secondary aim as described above.

Post-hoc, a principal component analysis (PCA) was attempted to understand if different continuous variables regarding physician duties in the ICU would be more predictive, or strongly associated, with burnout as opposed to a single measure (number of patients per physician). Variables included in the PCA were number of patients on study day, number of new patients, years in practice, clinical weeks worked yearly, percentage of clinical time that is critical care time, day of the ICU cycle that study measures were completed on, number of non-intensivist providers on the ICU team, median SOFA score of patients, percentage of patients on IMV, and percentage of patients on vasopressors. Variables were mean standardized before inclusion in the PCA.

We conducted one pre-planned sensitivity analysis examining workload in quintiles of the number of patients the physicians had; and 3 post-hoc sensitivity analyses defining workload as 1: a linear variable of the number of patients physicians had on the study day, 2: a linear variable of the number of critical care weeks worked per year, and 3: the day of the ICU service cycle the survey was completed on.

Statistical analysis was completed using SAS 9.4 (SAS ® 9.4 Cary, NC: SAS Institute Inc) and openepi.org (Copyright (c) 2003, 2008 Andrew G. Dean and Kevin M. Sullivan, Atlanta, GA, USA).

RESULTS

Baseline Physician Characteristics

We enrolled 122 physicians (147 total invited, 83% response rate) across the 14 sites (Table 6, 7): 68.9% were men and 30.3% women with a median age of 40.0 years (interquartile range [IQR] 36.0-46.5 years). The majority of physicians identified as Caucasian (66.4%) or Asian (23.8%). Nearly all physicians (n=117 [95.9%]) completed a critical care fellowship as part of their training. Median years in practice was 6.0 (IQR 3.0-10.0).

Physician Workload Characteristics

The median number of patients the physicians cared for on the study day was 12 (IQR 10-14) (Figure 3), with a median of 2 new patients (IQR 0-3) (Table 7). Physicians worked a median of 22 weeks (IQR 13-30) annually on clinical service, with a median of 75% (IQR 50-100) of clinical time being critical care time. Fifty-two (42.6%) physicians reported having nighttime shifts in the ICU as part of their clinical time. Fifty-eight (48%) of the physicians reported having non-critical care related clinical responsibilities (e.g. clinic visits and issues related to outpatients, consults, non-ICU related procedures, acute care surgeries) during ICU time, and 39 (68.4%) of those physicians found the non-ICU duties to be burdensome. Forty-nine (40.2%) of physicians identified presence of ICU strain, and seventy-seven (63.1%) physicians reported ongoing GOC conflict with patients and/or families on the study day.

Physicians in the high workload group had more new patients compared to those in the low workload group (number of new patients 4 [IQR 1-4] vs 1 [IQR 0-3], p = 0.0001). While there was no difference in clinical weeks annually between the workload groups (high workload 22 weeks [IQR 19-36] vs low workload 20 weeks [IQR 13-33], p = 0.28), physicians in the high workload group had less critical care time than those in the low workload group (median % clinical time that is critical care 50.0% [IQR 35-75] vs 80.0% [IQR 50-100], p = 0.01). There were more physicians in the low workload group who worked night shifts in the ICU than the high workload group (45 [48.4%] vs 7 [24.1%], p = 0.03). Between the high and low workload groups there was no significant difference in presence of ICU strain (16 [55.2%] vs 33 [35.5%], p = 0.06), or in presence of GOC conflict (21 [72.4%] vs 56 [60.2%], p = 0.23).

ICU Characteristics

Of the 62 participating ICUs, 60 (96.8%) self-identified as academic ICUs and 2 (3.2%) as community ICUs (Table 8). Study ICUs were across the United States – Northeast (n=24, 38.7%), South (n=24, 38.7%), West (n=8, 13.3%) and Midwest (n=6, 9.6%). The majority of the included ICUs were medical ICUs (n=34, [54.8%]). Only 13 (21.0%) ICUs were open ICUs (patients are admitted by another attending with the intensivist providing consultative services only), and of those all but 3 required a mandatory critical care consult. In addition to the participating intensivist, ICU providers included advanced practice providers (APPs) in 46 (74.2%) ICUs, fellows in 42 (67.7%) ICUs, and residents in 39 (62.9%) ICUs. The median number of total providers during the day (excluding the intensivist) was 4 (IQR 3-6), and there was a median of 2 providers at night (IQR 1-3). There were more providers present at night in the high workload group (median 3 [IQR 2-3] vs 2 [IQR 1.1-3], p = 0.01), but no difference in number of providers present during the day (median 5 [IQR 4-6] vs 4 [IQR 3-6], p = 0.10).

Patient Characteristics

A total of 1,322 patients were enrolled in the study (Table 9). The median patient age was 61.0 years (IQR 50.0-70.0). The most common ICU admission diagnosis was respiratory failure (n=575, 43.5%) followed by sepsis/septic shock (n=173, 13.1%); with 693 patients (52.4%) on invasive mechanical ventilation (IMV) and 449 patients (34.0%) requiring vasopressors. The median SOFA score was 4 (IQR 2-8). There was no difference in presence of IMV (median percentage 53% [IQR 36-65] in high workload vs 55% [IQR 36.5-65] in low, p = 0.81), vasopressors (median percentage 29% [IQR 13-38] in high vs 31.5% [IQR 17.5-50] in low, p =0.19), or illness severity as measured by the SOFA score (median score 4.5 [IQR 2-7] in high vs 4 [IQR 2.75-6] in low, p = 0.87) between workload groups.

Primary Aim: Physician Burnout and Association with Workload

Thirty-two of the physicians (26.4%) met the threshold for BOS. The median WBI score was 2 (IQR 0-4) (Table 7, Figure 4). There was a significant difference in presence of ICU strain in those physicians with BOS compared to those without BOS (59.4% vs 33.7%, p = 0.04) (Figure 5). Additionally, median aggregated SOFA score of patients was higher for physicians with BOS compared to those without BOS (median aggregated SOFA 5 [IQR 3-7] vs 4 [IQR 2-6], p = 0.02) (Figure 6). In the unadjusted logistic model, there was no difference in odds of BOS in the high workload group compared to the low workload group (unadjusted OR 1.08, 95% CI 0.42-2.76). In the multivariable model, there was a non-significant decrease in the odds of BOS in the high workload group (adjusted OR 0.74, 95% CI 0.25-2.24) (Table 10, Figure 7). There was no interaction between workload and physician gender, years worked, or total clinical time on the association for workload and BOS (Table 11).

Secondary Aim: Patient Outcomes and Association with Workload

At 28-days, 679 (51.4%) patients were alive and discharged from the hospital, 347 (26.2%) patients were deceased. Two hundred and fifty-seven (19.4%) patients remained hospitalized at day 28 with 113 (8.5%) still in the ICU and 144 (10.9%) on a non-ICU hospital ward. Thirty-nine (3.0%) patients' 28-day outcome was unknown. Median ICU length of stay was 9 days (IQR 4-20). A binomial mixed effects model restricted to the patients alive or deceased, showed a significant decrease in odds of death in the high workload group compared to low workload group in a model adjusted only for random effects of site, ICU, and physician (OR 0.69, 95% CI 0.49–0.98). However, this association was non-significant and in the opposite direction when the model included fixed effects in addition to random effects (OR 1.33, 95% CI 0.92–1.91) (Table 12).

Subgroup, Principal Component, and Sensitivity Analyses

In the subgroup analysis of physicians enrolled from Site 1, 16 physicians (38.1%) were in the high workload group and 26 physicians (61.9%) in the low workload group. The median number of patients physicians cared for on the study day was 14 (IQR 12-17), with a median of 2 new patients (IQR 1-4). Eleven physicians (26.8%) met threshold for BOS on the WBI (5 [31.3%] in the high workload group, and 6 [24%] in the low workload group). An unadjusted logistic regression model did not show a significant association between workload category and BOS in the subgroup of physicians (unadjusted odds ratio 1.44, 95% CI 0.36-5.84). There were 492 patients from Site 1. At day 28, 251 (51.0%) were alive and discharged, 123 (25%) deceased, and 118 (24.0%) still hospitalized. A binomial logistic regression model restricted to patients deceased or alive with random effects set to study site, ICU, and physician showed no difference in odds of death in the high workload group compared to low workload group (OR 0.91, 95% CI 0.60 – 1.39). There was no difference in our primary results of full cohort compared to results of our subgroup analysis.

The principal component analysis showed that 94% of the variation in the variables chosen was explained by the first four principal components (Figure 8). Scatter plots of each of the 4 principal components against one another did not show a clear separation of the outcome of BOS. In addition, due to the nature of principal component analysis we were not able to include categorical variables, such as presence of ICU strain, in the analysis.

All 4 sensitivity analyses assessing varying definitions of workload and burnout showed no association between workload and burnout (Table 13).

DISCUSSION

Our study captured intensivist workload as quantified by the patient-to-intensivist ratio in ICUs across the United States. The overall prevalence of BOS in our cohort of ICU physicians was 26.4%. There was a non-significant decrease in the odds of BOS in physicians with high workload (> 14 patients per physician) compared to physicians with low workload (≤ 14 patients per physician) in an adjusted model, but with a wide confidence interval that overlapped 1. There was no association between workload and burnout using alternative definitions of workload (number of critical care weeks worked, or day of ICU service cycle). At 28-days, there was non-significant increase in odds of patient death in the high workload group compared to the low workload group when adjusted for patient factors, illness severity, and ICU factors.

Present society guidelines, based on expert opinion, do not offer an optimal or maximal patient-to-intensivist ratio (13). Ward et al. showed that in a cohort of critical care fellowship program directors, those physicians who perceived a higher clinical care burden (stratified as estimated patient-to-intensivist ratio > 14:1) self-reported a higher rate of stress and negative impact on teaching (12). Our study differed, as we included any ICU physician (not only fellowship program directors) and defined workload objectively as the self-reported number of patients under the physician's care on the study day. However, despite evidence that workload and job demands are perceived as drivers of burnout (43), we saw a non-significant decrease in presence of BOS in those physicians with greater than 14 patients. It is possible the physicians in our study did experience greater stress related to workload, but not in the manner, or time, that we assessed.

Current literature cites the prevalence of burnout syndrome among ICU physicians to range from 25-70% (2, 29, 44). Our results fall on the lower end of this range. This may be related to selection bias. Physicians with an interest in the topic of physician burnout and with time available to complete study measures are more likely to have participated in the study, which may have led to a lower prevalence of burnout. Another reason for the prevalence of BOS captured may be the timing of our burnout assessments. Mikkelsen et al. looked at the length of ICU service time and measures of physician burnout and wellness; and showed that intensivists finishing a two-week continuous clinical cycle (compared to one-week) experienced higher levels of burnout (76% vs 35%) (32). Our study did not show an association between the day of the service cycle and BOS (sensitivity analysis, Table 13). This may, in part, be due to shorter clinical blocks as the majority of physicians (n=114, 93%) already worked in 7-day service blocks and 105 physicians (86%) completed survey measures on days 1 through 4 of a 7-day (or longer) cycle.

While our study did not identify the number of patients as a driver of BOS, our results can support hypotheses of other potential drivers of BOS. The majority of intensivists indicated that non-ICU responsibilities and ICU strain contributed to their burden of work; and there was a significant difference in presence of ICU strain in physicians experiencing BOS versus not ($p = 0.04$, Figure 5). While some studies have examined the relationship between ICU strain and patient outcomes (45, 46), greater understanding of the relationship between ICU strain and physician outcomes could add to understanding what aspects of ICU work are associated with burnout. Patient illness severity measured by the SOFA score was also significantly higher for patients of those physicians experiencing BOS versus not ($p = 0.02$, Figure 6). Though these results are not adjusted for multiple comparisons and must be interpreted with caution, they may potentially generate hypothesis of other drivers of BOS.

Our study has limitations: first, there is high likelihood of selection bias. We gave sites flexibility in choosing ICUs/physicians and study day for participation and captured a fairly homogenous group of younger physicians working primarily in medical ICUs in academic institutions. It is possible that the physicians who participated in the study represented a less distressed sample of ICU physicians (analogous to the "healthy worker" effect) (47). Younger physicians may experience less burnout simply because they have spent less time in practice, and though our interaction analysis did not show a difference in BOS based on years in practice, we may not have had a large enough sample of older physicians to see a difference. The academic medical ICU setting may differ from community practice ICUs, as well as different subspecialty ICUs (such as surgical, cardiothoracic, trauma) and physicians working in those ICUs may experience workload and BOS differently.

We chose the WBI for its shorter format and accessibility and the WBI is included as a recommended assessment by the National Academy of Medicine (48). It has been validated against the Maslach Burnout Inventory (15) in healthcare workers (18), and several studies of ICU physicians have used the WBI (32, 43, 49). But it is possible that use of another instrument may have given different results. Our study also limited by our chosen definition of workload – the patient-to-intensivist ratio; this is, an objective, easily calculable definition, but it may not accurately or sufficiently capture ICU physician workload. Cognitive load, or the amount of working memory used for a specific task (or work), has been used in the healthcare environment (50) and shown to be associated with higher volume of clinical responsibility (51) and physician burnout and fatigue (50, 51); and may more accurately capture physician workload in the ICU. Our sensitivity analyses attempted to evaluate the limitations of the workload definition and categorization and showed results similar to our primary analysis. Additionally, factors we did not measure in this study, such as support outside of other ICU team members (lab support, completion of non-physician duties), time spent on the documentation, and or personal duties (such as childcare or elder care) may contribute to perceived workload. These unmeasured, and thus, unaccounted for, factors may also explain the non-significant decrease in BOS presence in those physicians with high workload as it is possible those physicians have access to greater support for non-physician duties or personal duties. Finally, our study may have been underpowered for our primary outcome, given the unequal distribution across sites as our power calculations assumed equal site-by-site enrollment.

Conclusions:

Our study showed that 1 in 4 ICU physicians in mostly academic ICUs working for 7 consecutive days experience burnout. We did not demonstrate a significant association between physician workload, as measured by the patient-to-intensivist ratio, and burnout in the ICU. Physician workload was not significantly associated with 28-day patient mortality. Future studies are needed to better understand how physicians define their workload, and if and how a more nuanced quantification of workload may be associated with physiological wellbeing. Whether workload drives BOS or not, future studies are urgently needed to understand interventions and resources ICU physicians would find helpful as more than a quarter experiencing burnout is too high.

REFERENCES

1. Society of Critical Care Medicine: Critical Care Statistics. (http://www.sccm.org/Communications/Critical-Care-Statistics). (Accessed February 4, 2020).
2. Pastores SM, Kvetan V, Coopersmith CM, et al. Workforce, Workload, and Burnout Among Intensivists and Advanced Practice Providers: A Narrative Review. *Critical care medicine* 2019;47(4):550-7.
3. Pronovost PJ, Angus DC, Dorman T, et al. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. *Jama* 2002;288(17):2151-62.
4. Angus DC, Shorr AF, White A, et al. Critical care delivery in the United States: distribution of services and compliance with Leapfrog recommendations. *Critical care medicine* 2006;34(4):1016-24.
5. Venkataraman R, Ramakrishnan N. Outcomes related to telemedicine in the intensive care unit: what we know and would like to know. *Critical care clinics* 2015;31(2):225-37.
6. Kerlin MP, Harhay MO, Kahn JM, et al. Nighttime intensivist staffing, mortality, and limits on life support: a retrospective cohort study. *Chest* 2015;147(4):951-8.
7. Kerlin MP, Small DS, Cooney E, et al. A Randomized Trial of Nighttime Physician Staffing in an Intensive Care Unit. *New England Journal of Medicine* 2013;368(23):2201-9.
8. Wilcox ME, Chong CA, Niven DJ, et al. Do intensivist staffing patterns influence hospital mortality following ICU admission? A systematic review and meta-analyses. *Critical care medicine* 2013;41(10):2253-74.

9. Nguyen YL, Wallace DJ, Yordanov Y, et al. The Volume-Outcome Relationship in Critical Care: A Systematic Review and Meta-analysis. *Chest* 2015;148(1):79-92.

10. Gershengorn HB, Harrison DA, Garland A, et al. Association of Intensive Care Unit Patient-to-Intensivist Ratios With Hospital Mortality. *JAMA internal medicine* 2017;177(3):388-96.

11. Gershengorn HB, Pilcher DV, Litton E, et al. Association of patient-to-intensivist ratio with hospital mortality in Australia and New Zealand. *Intensive care medicine* 2021:1-11.

12. Ward NS, Read R, Afessa B, et al. Perceived effects of attending physician workload in academic medical intensive care units: a national survey of training program directors. *Critical care medicine* 2012;40(2):400-5.

13. Ward NS, Afessa B, Kleinpell R, et al. Intensivist/patient ratios in closed ICUs: a statement from the Society of Critical Care Medicine Taskforce on ICU Staffing. *Critical care medicine* 2013;41(2):638-45.

14. West CP, Dyrbye LN, Sloan JA, et al. Single item measures of emotional exhaustion and depersonalization are useful for assessing burnout in medical professionals. *Journal of general internal medicine* 2009;24(12):1318-21.

15. C M, SE J, MP L. *Maslach Burnout Inventory Manual*. Fourth ed.: Mind Garden Inc.; 1996.

16. Burghi G, Lambert J, Chaize M, et al. Prevalence, risk factors and consequences of severe burnout syndrome in ICU. *Intensive care medicine* 2014;40(11):1785-6.

17. Dewa CS, Jacobs P, Thanh NX, et al. An estimate of the cost of burnout on early retirement and reduction in clinical hours of practicing physicians in Canada. *BMC health services research* 2014;14:254.

18. Dyrbye LN, Satele D, Shanafelt T. Ability of a 9-Item Well-Being Index to Identify Distress and Stratify Quality of Life in US Workers. *Journal of occupational and environmental medicine* 2016;58(8):810-7.

19. Zimmerman JE, Kramer AA, Knaus WA. Changes in hospital mortality for United States intensive care unit admissions from 1988 to 2012. *Critical care (London, England)* 2013;17(2):R81.

20. Wunsch H, Guerra C, Barnato AE, et al. Three-year outcomes for Medicare beneficiaries who survive intensive care. *Jama* 2010;303(9):849-56.

21. Halpern N, Tan K. United States Resource Availability for COVID-19. 2020. (https://www.sccm.org/Blog/March-2020/United-States-Resource-Availability-for-COVID-19). (Accessed November 23, 2021).

22. Angus DC, Kelley MA, Schmitz RJ, et al. Caring for the critically ill patient. Current and projected workforce requirements for care of the critically ill and patients with pulmonary disease: can we meet the requirements of an aging population? *Jama* 2000;284(21):2762-70.

23. Halpern NA, Pastores SM, Oropello JM, et al. Critical care medicine in the United States: addressing the intensivist shortage and image of the specialty. *Critical care medicine* 2013;41(12):2754-61.

24. Aziz S, Arabi YM, Alhazzani W, et al. Managing ICU surge during the COVID-19 crisis: rapid guidelines. *Intensive care medicine* 2020;46(7):1303-25.

25. Kerlin MP, Adhikari NK, Rose L, et al. An Official American Thoracic Society Systematic Review: The Effect of Nighttime Intensivist Staffing on Mortality and Length

of Stay among Intensive Care Unit Patients. *American journal of respiratory and critical care medicine* 2017;195(3):383-93.

26. Neuraz A, Guerin C, Payet C, et al. Patient Mortality Is Associated With Staff Resources and Workload in the ICU: A Multicenter Observational Study. *Critical care medicine* 2015;43(8):1587-94.

27. Kahn JM, Goss CH, Heagerty PJ, et al. Hospital volume and the outcomes of mechanical ventilation. *The New England journal of medicine* 2006;355(1):41-50.

28. Kane L. 'Death by 1000 cuts': Medscape National Physician Burnout & Suicide Report 2021. Medscape; 2021. (https://www.medscape.com/slideshow/2021-lifestyle-burnout-6013456?src=wnl_physrep_210123_burnout2021&uac=186615BG&impID=3148805&faf=1#2). (Accessed January 27, 2021).

29. Moll V, Meissen H, Pappas S, et al. The Coronavirus Disease 2019 Pandemic Impacts Burnout Syndrome Differently Among Multiprofessional Critical Care Clinicians-A Longitudinal Survey Study. *Critical care medicine* 2021.

30. Moreno-Mulet C, Sansó N, Carrero-Planells A, et al. The Impact of the COVID-19 Pandemic on ICU Healthcare Professionals: A Mixed Methods Study. *International journal of environmental research and public health* 2021;18(17).

31. Shanafelt TD, Noseworthy JH. Executive Leadership and Physician Well-being: Nine Organizational Strategies to Promote Engagement and Reduce Burnout. *Mayo Clinic proceedings* 2017;92(1):129-46.

32. Mikkelsen ME, Anderson BJ, Bellini L, et al. Burnout, and Fulfillment, in the Profession of Critical Care Medicine. *American journal of respiratory and critical care medicine* 2019;200(7):931-3.

33. Gershengorn HB. The Goldilocks Dilemma. How Much Work is "Just Right" for the Intensivist? *Annals of the American Thoracic Society* 2016;13(5):598-9.

34. Ward NS, Howell MD. Intensivist-to-patient ratios in ICUs: is there a number? *Current opinion in anaesthesiology* 2015;28(2):172-9.

35. Discovery, the Critical Care Research Network. (https://www.sccm.org/Research/Research/Discovery-Research-Network). (Accessed February 5, 2020).

36. Dyrbye LN, Satele D, Sloan J, et al. Utility of a brief screening tool to identify physicians in distress. *Journal of general internal medicine* 2013;28(3):421-7.

37. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: Building an international community of software platform partners. *J Biomed Inform* 2019;95:103208.

38. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;42(2):377-81.

39. Greenland S, Pearl J, Robins JM. Causal diagrams for epidemiologic research. *Epidemiology* 1999;10(1):37-48.

40. Granholm A, Moller MH, Krag M, et al. Predictive Performance of the Simplified Acute Physiology Score (SAPS) II and the Initial Sequential Organ Failure Assessment (SOFA) Score in Acutely Ill Intensive Care Patients: Post-Hoc Analyses of the SUP-ICU Inception Cohort Study. *PloS one* 2016;11(12):e0168948.

41. Namendys-Silva SA, Texcocano-Becerra J, Herrera-Gomez A. Application of the Sequential Organ Failure Assessment (SOFA) score to patients with cancer admitted to

the intensive care unit. *The American journal of hospice & palliative care* 2009;26(5):341-6.

42. Wagner J, Gabler NB, Ratcliffe SJ, et al. Outcomes among patients discharged from busy intensive care units. *Annals of internal medicine* 2013;159(7):447-55.

43. Gomez S, Anderson BJ, Yu H, et al. Benchmarking Critical Care Well-Being: Before and After the Coronavirus Disease 2019 Pandemic. *Crit Care Explor* 2020;2(10):e0233.

44. Embriaco N, Azoulay E, Barrau K, et al. High level of burnout in intensivists: prevalence and associated factors. *American journal of respiratory and critical care medicine* 2007;175(7):686-92.

45. Hua M, Halpern SD, Gabler NB, et al. Effect of ICU strain on timing of limitations in life-sustaining therapy and on death. *Intensive care medicine* 2016;42(6):987-94.

46. Vranas KC, Jopling JK, Scott JY, et al. The Association of ICU Acuity With Outcomes of Patients at Low Risk of Dying. *Critical care medicine* 2018;46(3):347-53.

47. Shrank WH, Patrick AR, Brookhart MA. Healthy user and related biases in observational studies of preventive interventions: a primer for physicians. *Journal of general internal medicine* 2011;26(5):546-50.

48. Valid and Reliable Survey Instruments to Measure Burnout, Well-Being, and Other Work-Related Dimensions. National Academy of Sciences. (https://nam.edu/valid-reliable-survey-instruments-measure-burnout-well-work-related-dimensions/). (Accessed February 28, 2022).

49. Kerlin MP, Silvestri JA, Klaiman T, et al. Critical Care Clinician Wellness during the COVID-19 Pandemic: A Longitudinal Analysis. *Annals of the American Thoracic Society* 2022;19(2):329-31.

50. Harry E, Sinsky C, Dyrbye LN, et al. Physician Task Load and the Risk of Burnout Among US Physicians in a National Survey. *Joint Commission journal on quality and patient safety* 2021;47(2):76-85.

51. Lund S, Yan M, D'Angelo J, et al. NASA-TLX assessment of workload in resident physicians and faculty surgeons covering trauma, surgical intensive care unit, and emergency general surgery services. *American journal of surgery* 2021;222(6):1158-62.

TABLES/FIGURES

<table>
<tr><th colspan="2">Table 1: Full Physician Workload Survey</th></tr>
<tr><td>How many weeks in a year do you spend, total, on clinical service</td><td>Today, (as of 7 am), how many patients are you responsible for as the ICU physician</td></tr>
<tr><td>What percent of your clinical time is critical care time</td><td>How many of these patients are “new patients” (i.e. staffed in the last 24 hours)</td></tr>
<tr><td>Do you work nights and if so, how many continuously and what percent of your critical care time is nights</td><td>How many days is this service block for you What day in the cycle is today (i.e. day 4 of 7)</td></tr>
<tr><td>During your critical care weeks, do you have other clinical responsibilities outside the ICU? Do these add a significant burden to your clinical duties?</td><td>During this clinical block, were there any times you were asked to admit a patient urgently you did not have space for in the ICU</td></tr>
<tr><td rowspan="3">Do you have other duties that add to your workload (non-physician ICU duties, non-ICU clinical duties, research, administrative, teaching)?

Rated on a Likert Scale 1-5 (1 = very little, less than 25%; 5 = a lot, greater than 75%), how much do they add to your workload</td><td>Currently, are you taking care of any patients for whom the patient and/or family and the team have differences about the direction of goals of care</td></tr>
<tr><td>Are you currently taking care of patients with COVID19? If yes, are you taking care of more, less, or the same number of patients as before the pandemic?</td></tr>
<tr><td>Has the length of your service block changed with the COVID19 pandemic? If yes, is it longer or shorter?</td></tr>
</table>

<table>
<tr><th colspan="2">Table 2: The Well-Being Index[18]</th></tr>
<tr><td>For items 1-7: During the past month, have you …
(answered as yes/no)</td><td>For items 8,9: Rate level of agreement with following statement on a Likert Scale</td></tr>
<tr><td>1. Felt burned out from your work
2. Worried that your work is hardening you emotionally
3. Been bothered by feeling down, depressed, or hopeless
4. Fallen asleep while sitting inactive in a public place
5. Felt that all the things you had to do were piling up so high that you could not overcome them
6. Been bothered by emotional problems
7. [Has] your physical health interfered with your ability to do your daily work at home or away from home</td><td>8. The work I do is meaningful to me (Scale 1-7, with 1 = “very strongly disagree” and 7 = “very strongly agree”)
9. My work schedule leaves me enough time for my personal and family life (Scale 1-5, with 1 = “strongly disagree” and 5 = “strongly agree”)</td></tr>
</table>

<table>
<tr><th colspan="2">Table 3: Full ICU Structure/Summary Survey</th></tr>
<tr><td>Indicate the type of hospital (academic, community, other)</td><td>Is this a closed unit? If no, is there a mandatory critical care consult?</td></tr>
<tr><td>What region of the United States is the hospital located (northeast, Midwest, south, west)</td><td>Is there an electronic-ICU or tele-ICU available</td></tr>
<tr><td>Select the type of ICU (medical, surgical, combined medical/surgical, cardiac [medical], cardiothoracic surgery, neurointensive care, trauma, other – specify)</td><td>For each provider type, indicate if they work in the ICU during the day and/or night, and on average how many. Provider types – advanced practice providers (nurse practitioner, physicians’ assistants), fellows, and residents</td></tr>
<tr><td>How many ICU beds are in the unit</td><td rowspan="3">For the following staff, indicate if there is someone dedicated to the ICU and if they participate in daily rounds (charge nurse, pharmacist, social worker, respiratory therapist, physical therapist, occupational therapist)</td></tr>
<tr><td>On average, how many patients does each nurse have</td></tr>
<tr><td rowspan="2">For the last calendar year, indicate the following
-annual admissions
-mean ICU length of stay
-average ICU mortality</td></tr>
<tr><td>Are there patients with diagnosed or suspected COVID19 in the unit?</td></tr>
</table>

Table 4: Sequential Organ Failure Assessment (SOFA) Score					
	0	1	2	3	4
PaO_2/ FiO_2 mm Hg	≥ 400	< 400	< 300	< 200	< 100
Platelets ($10^3/mm^3$)	≥150	<150	<100	<50	<20
Bilirubin (mg/dl)	≤1.2	1.2-1.9	2.0-5.9	6.0-11.9	>12.0
Hypotension (Mean Arterial Pressure mmHg)	MAP ≥70 + NO pressor	MAP < 70 + NO Pressor	Dopamine ≤ 5, dobutamine any dose	Norepinephrine (or equivalent) ≤ 0.1, dopamine > 5	Norepinephrine (or equivalent) > 0.1
Glasgow Coma Score	15	13-14	10-12	6-9	< 6
Creatinine mg/dl OR Urine Output ml/day	≤1.2	1.2-1.9	2.0-3.4	3.5-4.9, or UOP < 500	≥ 5.0 or UOP < 200, or active dialysis

Table 5: Full Patient Survey	
Demographics Age, height, weight, gender, race, ethnicity	For the following, indicate if present either on or 24 hours prior to the study day COVID19 diagnosis Invasive mechanical ventilation Vasopressors Extra Corporeal Membranous Oxygenation Left heart circulatory support devices Continuous renal replacement therapy
Code status (on ICU admission)	
ICU admission diagnosis	
Worst SOFA score (*see table 4)* on study day or 24 hours prior to study day	
At 28 days (from study day), what was the patient status – alive & discharged, alive and still hospitalized, deceased (or discharged to hospice), unknown	What was the ICU length of stay (if still in ICU at 28 days indicate 0 days)

Table 6: Enrollment Summary by Site			
Site Total n = 14	**#Physicians enrolled** total n=122	**#ICUs enrolled** total n=62	**#Patients enrolled** total n=1,322
1	42	16	492
2	3	2	18
3	3	2	25
4	2	2	17
5	3	2	40
6	12	5	91
7	2	2	29
8	9	4	77
9	12	5	127
10	9	4	86
11	8	8	81
12	4	4	46
13	11	4	171
14	2	2	22

Table 7: Physician Characteristics by Workload category			
	All Physicians n=122	**High Workload**[a] n=29	**Low Workload**[b] n=93
DEMOGRAPHICS			
Age (years)[c], median [IQR]	40 [36-46.5]	40 [36-47.5]	40 [36-46]
Gender, n (%)			
Female	37 (30.3)	8 (27.6)	29 (31.2)
Male	84 (68.9)	20 (69.0)	64 (68.8)
Marital Status, n (%)			
Single	17 (13.9)	4 (13.8)	13 (14.0)
Partnered	104 (85.3)	25 (86.2)	79 (84.9)
Other/Unknown	1 (0.8)	0 (0)	1 (1.1)
Race, n (%)			
White	81 (66.4)	17 (58.6)	64 (68.8)
Black	4 (3.3)	3 (10.3)	1 (1.1)
Asian	29 (23.8)	7 (24.1)	22 (23.7)
Other	6 (4.9)	2 (6.9)	4 (4.3)
Completed Critical Care Fellowship, n (%)	117 (95.9)	27 (93.1)	90 (96.8)
Residency Completed, n (%)			
Anesthesia	11 (9.0)	4 (13.8)	7 (7.5)
Emergency Medicine	8 (6.6)	2 (6.9)	6 (6.5)
Internal Medicine	89 (73.0)	16 (55.2)	73 (78.5)
Combined Medicine & Pediatrics	2 (1.6)	2 (6.9)	0 (0.0)
Neurology	7 (5.7)	2 (6.9)	5 (5.4)
Surgery	4 (3.3)	3 (10.3)	1 (1.1)
GENERAL CLINICAL WORK CHARACTERISTICS			
Years in Practice, median [IQR]	6 [3, 10]	8 [3.75, 12]	5 [3, 9]
Weeks on Clinical Service (per year), median [IQR]	22 [13-30]	22 [19-36]	20 [13-30]
% Clinical Time on Critical Care Service, median [IQR]	75 [50-100]	50 [35-75]	80 [50-100]
Length of service blocks (days), median [IQR]	7 [7-7]	7 [7-7]	7 [6-7]
Work nights in-house, n (%)	52 (42.6)	7 (24.1)	45 (48.4)
ICU time has non-ICU clinical work, n (%)	58 (47.5)	13 (44.8)	45 (48.4)
Duties are burdensome (yes) , n (%)	39 (68.4)	10 (76.9)	29 (65.9)
WORKLOAD CHARACTERISTICS ON STUDY DAY			
# Patients on Study Day, median [IQR]	12 [10-14]	18 [17-20]	11 [8-13]
# NEW Patients on Study Day, median [IQR]	2 [0-3]	4 [1-4]	1 [0-3]

COVID19 Patients in Unit, n (%)	92 (75.4)	25 (86.2)	67 (72.0)
ICU Strain Present, n (%)	49 (40.2)	16 (55.2)	33 (35.5)
GOC Conflict with Patients/Family, n (%)	77 (63.1)	21 (72.4)	56 (60.2)
BURNOUT SYNDROME ON STUDY DAY			
Well-Being Index Score, median [IQR]	2 [0-4]	2 [0-4]	2 [0-4]
Burnout Syndrome present[d], n (%)	32 (26.4)	8 (27.6)	24 (26.1)

[a]High Workload: > 14 patients per physician
[b]Low Workload: ≤ 14 patients per physician
[c]N missing 10, all other variables with N missing <5
[d]Burnout Syndrome is defined as a score ≥4 on Well-Being Index
GOC = goals of care
ICU = intensive care unit
IQR = interquartile range

Table 8: ICU Characteristics by Physician Workload

	All ICUs n = 62	ICUs for High Workload Physicians[a], n=29	ICUs for Low Workload Physicians[a], n=93
GENERAL ICU CLASSIFICATION			
Academic ICU, n (%)	60 (96.8)	28 (96.6)	91 (97.8)
U.S. Region[b], n (%)			
North	24 (38.7)	4 (13.8)	39 (41.9)
South	24 (38.7)	17 (58.6)	34 (36.6)
West	8 (12.9)	4 (13.8)	16 (17.2)
Midwest	6 (9.7)	3 (10.3)	4 (4.3)
Type of ICU, n (%)			
Medical ICU	34 (54.8)	12 (41.4)	52 (55.9)
Surgical	5 (8.1)	4 (13.8)	3 (3.2)
Combined Medical/Surgical	6 (9.7)	2 (6.9)	9 (9.7)
Cardiac Care Unit	5 (8.1)	1 (3.5)	12 (12.9)
Cardiothoracic Surgery	4 (6.4)	3 (10.3)	6 (6.5)
Neurointensive care unit	5 (8.1)	3 (10.3)	9 (9.7)
Other	3 (4.8)	4 (13.8)	2 (2.1)
ICU STRUCTURE AND STAFF			
Tele-ICU present, n (%)	23 (37.1)	13 (44.8)	37 (39.8)
Closed ICU, n (%)	49 (79.0)	25 (86.2)	67 (72.0)
If open ICU, requires mandatory consult, n (%)	10/13 (76.9)	3/4 (75)	19/26 (73.1)
COVID19 patients present, n (%)	49 (79)	17 (58.6)	74 (79.6)
Day Team Members, n (%)			
APPs	46 (74.2)	25 (86.2)	73 (78.5)
Fellows	42 (67.7)	23 (79.3)	59 (63.4)
Residents	39 (63.9)	21 (72.4)	51 (54.8)
# Providers during day[c], median [IQR]	4 [3-6]	5 [4-6]	4 [3-6]
Night Team Members, n (%)			
APPs	36 (58.1)	25 (86.2)	53 (57.0)
Fellows	25 (40.3)	14 (48.3)	33 (35.5)
Residents	32 (53.3)	15 (51.7)	44 (47.3)
# Providers during night[c], median [IQR]	2 [1-3]	3 [2-3]	2 [1.1-3]
Intensivist Present at night, n (%)	32 (51.6)	7 (24.1)	45 (48.4)

Ancillary Staff Presence, n (%)			
Occupational Therapist	23 (37.1)	8 (27.6)	33 (35.5)
Pharmacist	47 (75.8)	25 (86.2)	69 (74.2)
Physical Therapist	30 (48.4)	12 (41.4)	42 (45.2)
Respiratory Therapist	55 (88.7)	26 (89.7)	82 (88.2)
Social Worker	46 (74.2)	20 (69.0)	69 (74.2)
SUMMARY ICU DATA[d,e]			
# Beds available, median [IQR]	16 [12-20]	20 [16.5-20]	16 [12-22]
Average PT:RN ratio, median [IQR]	2 [2-2]	2 [2-2]	2 [2-2]
Annual admissions, median [IQR]	1192 [750-1800]	1450 [1279-1541]	1300 [750-2501]
Average LOS (days), median [IQR]	4.61 [3.37-5.57]	5.1 [3.93-5.75]	4 [3.02-5]
Annual average mortality (%), median [IQR]	11.7 [6.02-19.4]	5.04 [3.57-7.66]	11.7 [6.07-19]

[a]8 out 62 ICUs had physicians in both high and low workload groups. ICU characteristics reported for high and low workload groups by each physician
[b]Region of United States based on U.S. Census Bureau of Regions and Divisions
[c]Number of providers during day and night are *excluding* ICU physician
[d]Summary ICU data based on last complete calendar year of data available (for most ICUs data is from 2019)
[e]N with missing Summary ICU data = 10, all other variables with N missing < 2
APP = advanced practice provider
ICU = intensive care unit
IQR = interquartile range
LOS = length of stay
PT:RN ratio = # patients per nurse in ICU
U.S. = United States

Table 9: Patient Characteristics for Full Patient Cohort	
	All Patients n = 1,322
Patient age (years), median [IQR]	61 [50-70]
Patient BMI[a], median [IQR]	28.60 [23.82-34.74]
Gender, n (%)	
Male	765 (57.9)
Female	556 (42.1)
Race, n (%)	
White	654 (49.5)
Black	476 (36.0)
Asian	26 (2.0)
Unknown	158 (11.9)
Other	8 (0.6)
Hispanic, n (%)	107 (8.1)
Full Code on ICU admission, n (%)	1232 (93.2)
ICU Admission Diagnosis, n (%)	
Respiratory Failure	575 (43.5)
Sepsis/Septic Shock	173 (13.1)
Post-Operative State	121 (9.1)
Other[b]	453 (34.3)
COVID19 present, n (%)	275 (20.8)
Life Sustaining Treatment, n (%)	
IMV	693 (52.4)
Vasopressors[a]	449 (34.0)
CRRT	150 (11.3)
ECMO	39 (3.0)
Left Heart Support	37 (2.8)
SOFA Score, median [IQR]	4 [2-8]
28-day outcome	
Discharged alive	679 (51.4)
Hospitalized – non-ICU floor	144 (10.9)
Hospitalized - ICU	113 (8.5)
Deceased	347 (26.2)
Unknown	39 (3.0)
Length of ICU Stay (days), median [IQR]	9 [4-20]

[a]N missing , BMI = 18, vasopressors = 15, all other variables with N missing < 5

[b]Other diagnosis includes: myocardial infarction, arrhythmias, stroke, gastrointestinal bleed, heart failure, renal failure, toxic ingestion, pulmonary embolism, trauma, undifferentiated shock, cardiac arrest, diabetic ketoacidosis, cardiogenic shock, seizure, altered mental status;

CRRT = continuous renal replacement therapy
ECMO = extra corporeal membranous oxygenation
ICU = intensive care unit
IMV = invasive mechanical ventilation
IQR = interquartile range
SOFA = sequential organ failure assessment score

Table 10: Logistic Regression for Presence of Burnout Syndrome				
Workload Category	**% Burnout[a]**	**Odds Ratio for Burnout Syndrome**	**95% CI**	**p value**
Low Workload (≤ 14 pts)	26.1	Ref	Ref	Ref
High Workload (>14 pts) (unadjusted)	27.6	1.08	0.42 – 2.76	0.87
High workload (>14 pts)[b] (adjusted[c])	n/a	0.74	0.24 – 2.23	0.60

[a]Burnout is defined as a score of ≥4 on the Well-Being Index
[b]Multivariable model with 4 missing observations, n used = 118
[c]adjusted for median SOFA score, % patients on invasive mechanical ventilation, % patient on vasopressors, #new patients, total # ICU people during day, goals of care conflict, ICU strain presence
CI = confidence interval

Table 11: Interaction analysis with risk of burnout syndrome stratified by physician characteristics					
PHYSICIAN GENDER					
	Female Physicians, n = 37		Male Physicians, n = 83		
	BOS present, n (%)	BOS absent, n (%)	BOS present, n (%)	BOS absent, n (%)	
High Workload	3 (8.1)	5 (13.5)	5 (6.0)	15 (18.1)	
Low Workload	13 (35.1)	16 (43.3)	11 (13.2)	52 (62.7)	
Risk Ratio (95% CI)	0.84 (0.3 – 2.2)		1.43 (0.6 – 3.6)		p = 0.44
Risk Difference (95% CI)	-7.33% (-45.4 – 30.8)		7.54% (-13.6 – 28.7)		p = 0.51
NUMBER OF YEARS IN PRACTICE					
	≤ 10 years in practice, n = 91		> 10 years in practice, n = 29		
	BOS present, n (%)	BOS absent, n (%)	BOS present, n (%)	BOS absent, n (%)	
High Workload	6 (6.6)	13 (14.3)	2 (6.9)	7 (24.1)	
Low Workload	20 (22.0)	52 (57.1)	4 (13.8)	16 (55.2)	
Risk Ratio (95% CI)	1.14 (0.5 – 2.4)		1.14 (0.5 – 2.4)		p = 0.98
Risk Difference (95% CI)	3.8% (-19.5 – 27.1)		2.2% (-30.1 – 34.6)		p = 0.94
NUMBER OF CLINICAL WEEKS WORKED YEARLY					
	≤ 22 clinical weeks/year, n = 64		> 22 clinical weeks/year, n = 56		
	BOS present, n (%)	BOS absent, n (%)	BOS present, n (%)	BOS absent, n (%)	
High Workload	2 (3.1)	13 (20.3)	6 (10.7)	7 (12.5)	
Low Workload	13 (20.3)	36 (56.3)	11 (19.6)	32 (57.1)	
Risk Ratio (95% CI)	0.50 (0.1 – 2.0)		1.8 (0.8 – 3.9)		p = 0.11
Risk Difference (95% CI)	-13.2% (-34.4 – 8.0)		20.57% (-9.5 – 50.6)		p = 0.07

p-values generated with Breslow-Day Test for interaction of risk (ratio & difference) over strata
BOS = burnout syndrome
CI = confidence interval

Table 12: Logistic Regression for 28-day Patient Mortality			
Workload Category	**Odds Ratio for outcome of death**	**95% CI**	**p value**
Low Workload (≤ 14 pts)	Ref	Ref	Ref
High Workload (>14 pts) (adjusted for random effects only)	0.69	0.49 – 0.98	0.04
High workload (>14 pts)[a] (adjusted for random + fixed effects)	1.33	0.92 – 1.91	0.13

Analysis restricted to cohort of patients alive (includes patient alive & discharged, and still hospitalized at day 28) or deceased, total n = 1283, alive n = 936, deceased n = 347
[a]Observations used in model = 1251 due to missing data (alive n = 909, deceased n = 342)
Random effects – site, ICU, and physician
Fixed effects – patient age, patient body mass index, patient gender, presence of mechanical ventilation, presence of vasopressors, SOFA score, #new patients, #providers on ICU team, presence of ICU conflict, presence of ICU strain
CI = confidence interval

Table 13: Sensitivity Analysis for alternative definitions of workload and odds of burnout syndrome

Workload Definition	**Odds Ratio for Burnout Syndrome**	**95% CI**	**P value**
# Patients per physician per day (linear variable)	1.035	0.94 – 1.14	0.46
# Critical care weeks per year	1.01	0.97 – 1.05	0.66
Quintiles of Workload (patients/physician/day)			0.66*for model
Quintile 1: ≤ 9 pts, n=28	REF	REF	
Quintile 2: 10 to ≤ 11 pts, n=25	0.83	0.24 – 2.87	
Quintile 3: 12 to ≤ 13 pts, n=23	0.88	0.26 – 3.05	
Quintile 4: 14 to ≤ 16 pts, n=24	0.50	0.13 – 1.93	
Quintile 4: >16 pts, n=22	1.43	0.43 – 4.72	
Day of the continuous ICU work cycle	1.07	0.28 – 4.11	0.92

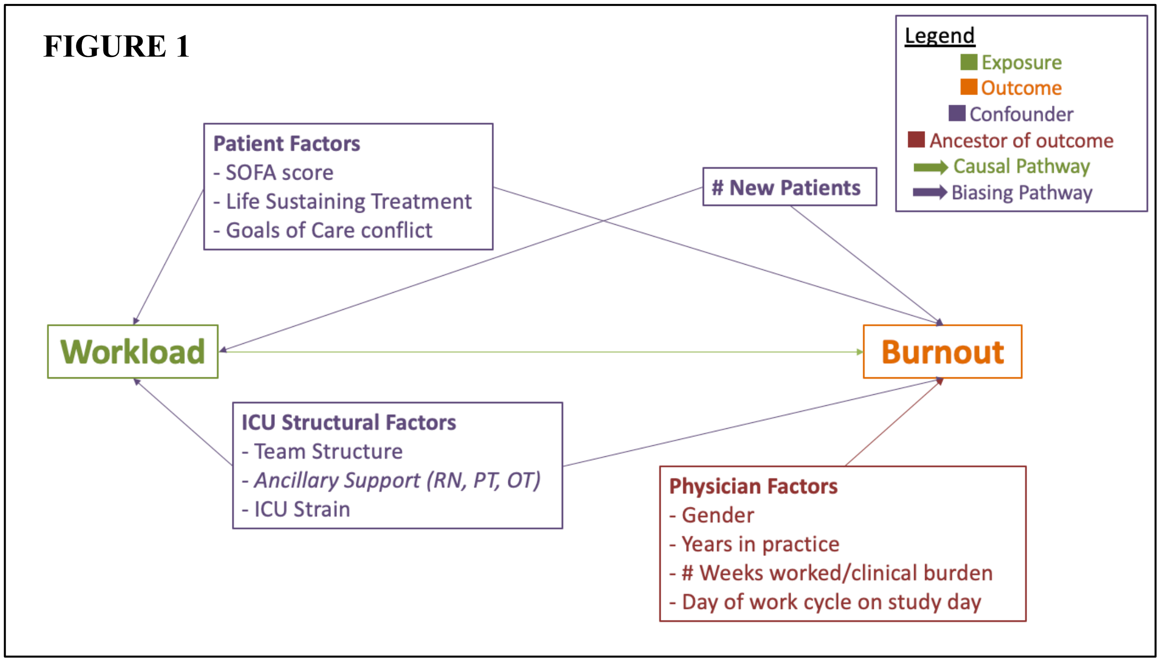

FIGURE 1: Directed acyclic graph (DAG) exploring exposure-outcome relationship for physician workload (exposure, green), and burnout syndrome (outcome, orange).

Variables in purple (Patient factors, # new patients, ICU structural factors) represent confounders (with a causal relationship with both exposure and outcome). Physician factors in red (gender, years in practice, # weeks worked, day of work cycle) represent ancestors of burnout and analyzed as potential interaction variables.

FIGURE 2

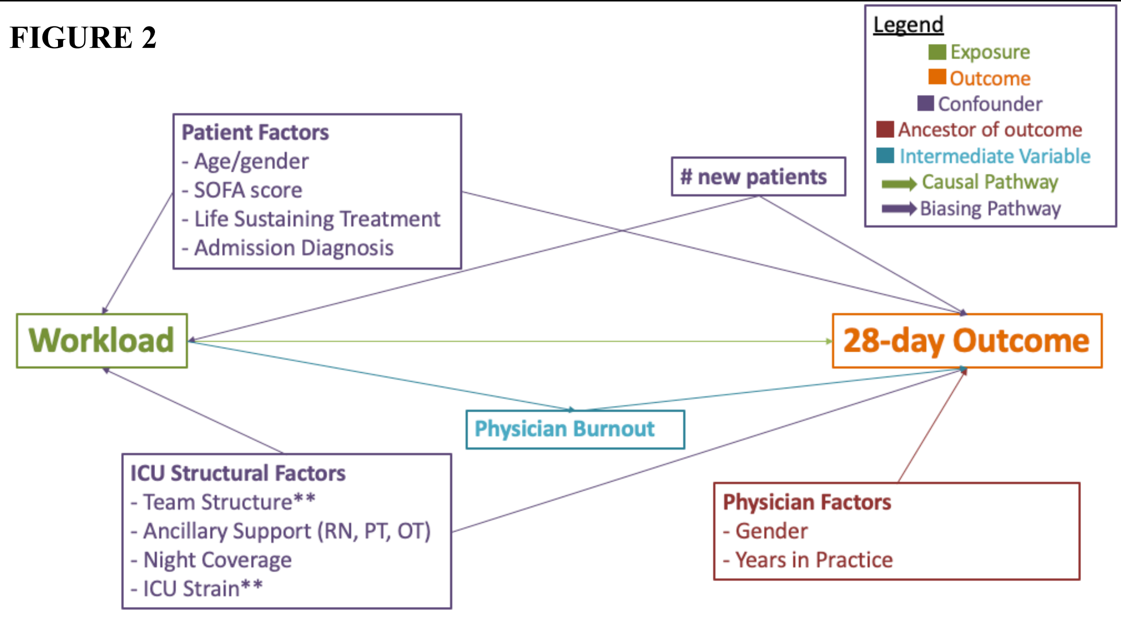

FIGURE 2: Directed acyclic graph (DAG) exploring exposure-outcome relationship for physician workload (exposure, green), and 28-day patient outcome (outcome, orange).

Variables in purple (Patient factors, # new patients, ICU structural factors) represent confounders (with a causal relationship with both exposure and outcome). Physician Burnout represents and intermediate variable (light blue). Physician factors (red) represent ancestors of 28-day outcomes

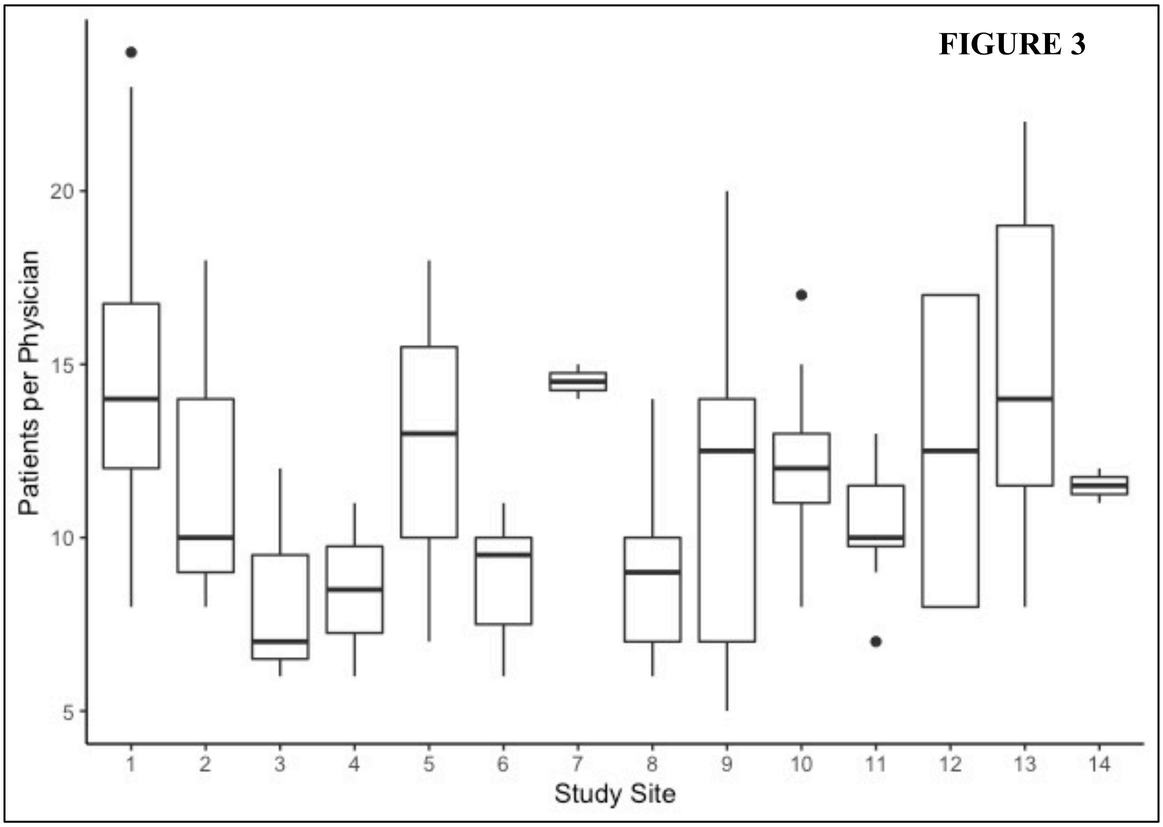

FIGURE 3: Box-Whisker Plot of Number of Patients per Physician by Study Site

Solid horizontal line indicates median, box indicates quartile 1 and quartile 3, and vertical lines full range. Dots identify outliers

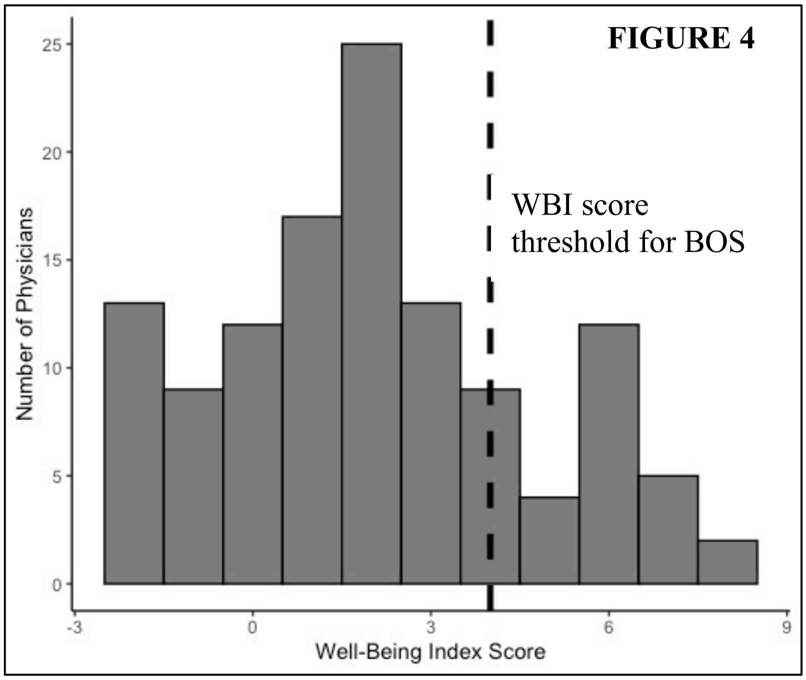

FIGURE 4: Histogram of Well-Being Index Score Frequencies.

Dashed line = threshold WBI score for burnout syndrome (BOS), values above 4 indicate presence of burnout syndrome

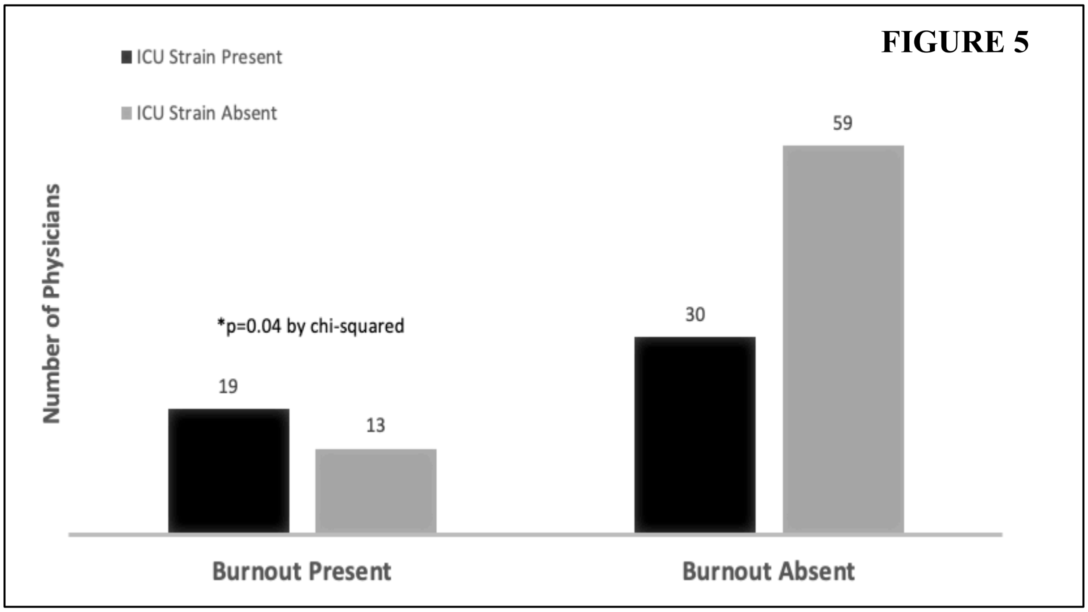

FIGURE 5: Presence of ICU strain by burnout syndrome presence

Bar graph showing number of physicians who did and who did not experience ICU strain stratified by presence of burnout syndrome

FIGURE 6

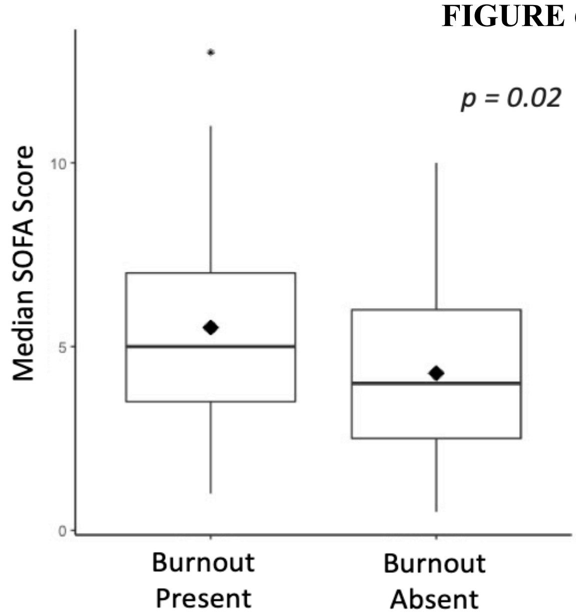

FIGURE 6: Distribution of median SOFA score by burnout syndrome

Box plots showing median SOFA score (solid horizontal line) by presence of burnout syndrome. Median SOFA score was obtained by the median of all SOFA scores for patients for each physician. Box indicates the first and third quartile. Diamond indicates mean, and bars the full range of median SOFA score

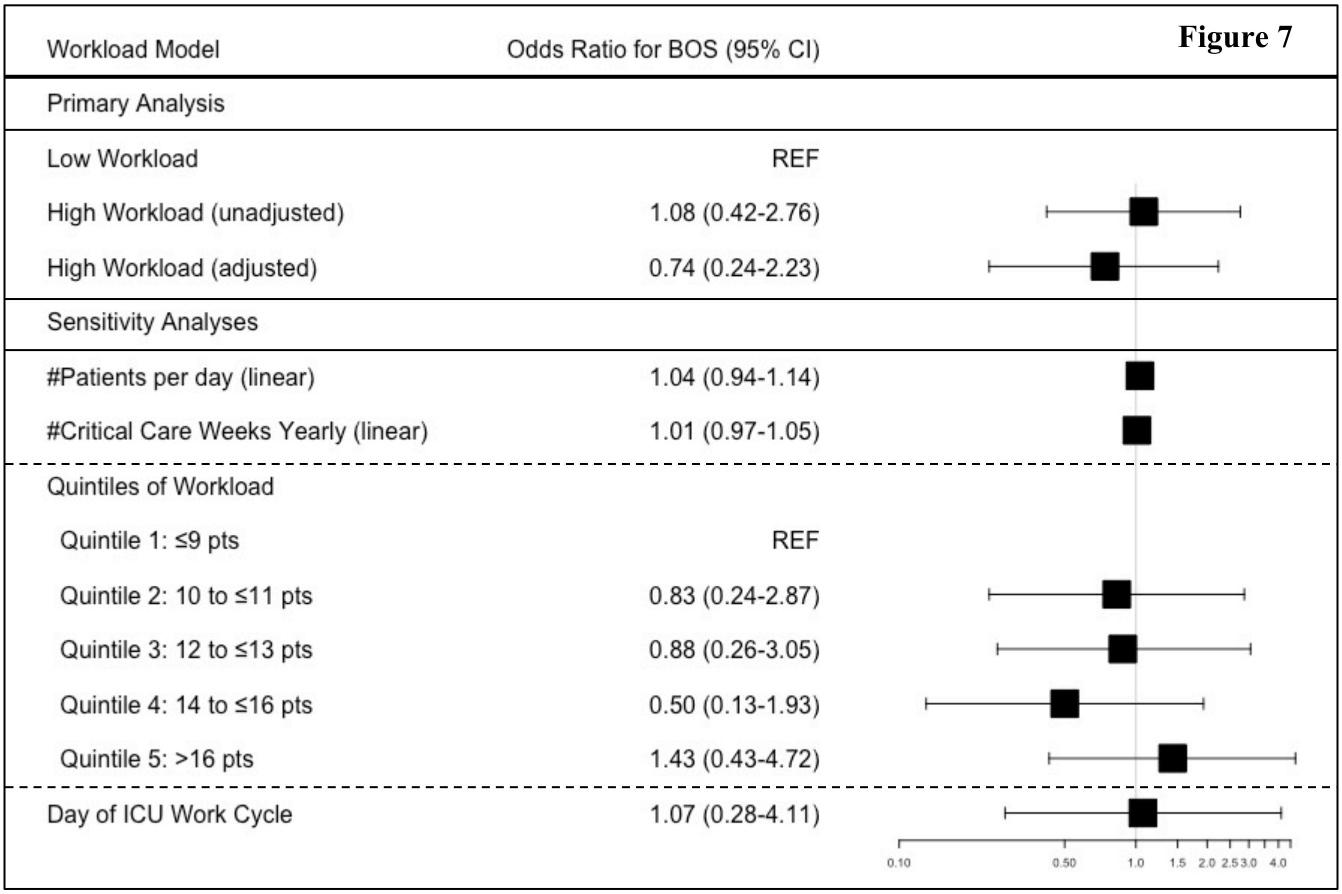

Figure 7: Forest Plot of odds ratios for burnout syndrome (BOS) by workload models.

All odds ratios and CI generated by logistic regression.

BOS defined at WBI score ≥ 4

Low Workload ≤ 14 patients per physician; high workload > 14 patients per physician

Unadjusted analysis – univariate logistic regression model

Adjusted analysis – multivariable logistic regression model, n = 118, adjusted for median SOFA score, %on invasive mechanical ventilation, %on vasopressors, #new patients, total # ICU people during day, Goals of care conflict, ICU strain.

Sensitivity analyses – unadjusted logistic regression models for alternative definitions of workload

patients per day per physician as a linear variable

Critical care weeks worked yearly as a linear variable

Quintiles of workload refers to patients per physician

Day of continuous ICU work cycle (i.e. day 2 of 7), as a linear variable

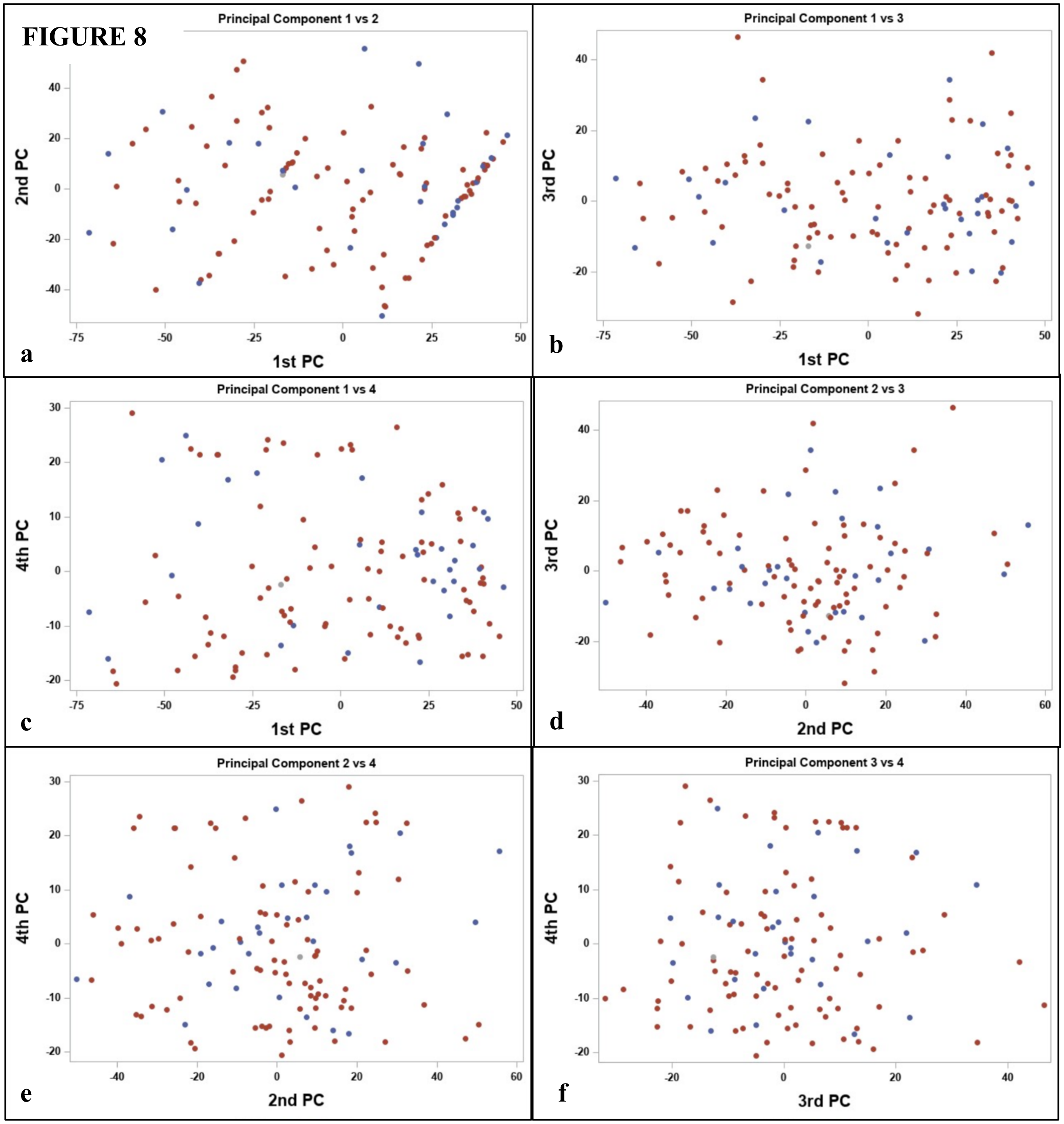

FIGURE 8: Scatter plots of principal components (PC) 1 through 4 by presence of burnout syndrome.

A: 2^{nd} PC vs 1^{st} PC, b: 3^{rd} PC vs 1^{st} PC, c: 4^{th} PC vs 1^{st} PC, d: 3^{rd} PC vs 2^{nd} PC,

e: 4^{th} PC vs 2^{nd} PC, f: 4^{th} PC vs 3^{rd} PC

Legend: blue circles = burnout present, red circles = burnout absent

Each scatter plot shows observations by two principal components graphed against one another with blue circles identifying those observations where burnout was present and red circles those observations where burnout was not present. There is no clear separation in any PC component graph of burnout syndrome.