CHEST Recent Advances in Chest Medicine

Staffing in ICUs

Physicians and Alternative Staffing Models

Allan Garland, MD; and Hayley B. Gershengorn, MD

The evidence regarding physician staffing of ICUs does not yet provide a consistent view of the best model to use. Most studies have significant limitations, and this subject is complicated by the fact that optimal ICU staffing may depend on ICU characteristics. The topic with the most data regarding patient outcomes is the intensity of intensivist involvement in care, particularly the value of closed- vs open-model ICUs; however, the evidence is inconsistent here as well. Even if closed-model ICUs produce better outcomes, we do not know which specific elements of that multifaceted organizational paradigm are responsible for improvement. Also, studies of around-the-clock intensivist presence have not consistently shown that it is associated with superior outcomes. Increasingly, nonphysician providers are playing innovative roles in the ICU, and care provided by teams including nurse practitioners or physician assistants appears to be safe and comparable to that provided by other staffing models. Although we do not know the best way to staff ICUs, the conditions of ICU physician coverage will continue to change under the stresses of shortages of intensivists and increasing duty hour limitations for trainees. Nonphysician providers, innovative physician staffing models, telemedicine, and other technologies will be increasingly used to cope with these realities. This evolution makes it more important than ever to study how staffing affects outcomes. Only quantitative evaluation can tell us whether one staffing model is better than another. Accordingly, we need more research from multiple sites to develop a consistent and integrated understanding of this complex topic. ***CHEST 2013; 143(1):214–221***

Abbreviations: LOS = length of stay; NP = nurse practitioner; PA = physician assistant

Physician staffing of ICUs has always varied widely, and this has only increased with work hour limitations for physician trainees and the proliferation of staffing models including nonphysician extenders and telemedicine. Staffing options can be framed as a series of questions. Who does it? How many of them are there to do it? What do they do? How do they do it? These questions address the type, training, experience, and other characteristics of physicians, including details of work schedules (eg, workload, duty hours, shiftwork, and coverage for nights and weekends), details of assigned tasks, and interfaces with nonphysician health-care workers.

Manuscript received June 18, 2012; revision accepted July 31, 2012.

Affiliations: From the Section of Critical Care Medicine (Dr Garland), University of Manitoba, Winnipeg, MB, Canada; and the Department of Medicine (Dr Gershengorn), Albert Einstein College of Medicine, Beth Israel Medical Center, New York, NY.
Correspondence to: Allan Garland, MD, Winnipeg Health Sciences Centre, 820 Sherbrook St, Room GF-222, Winnipeg, MB, R3A 1R9, Canada; e-mail: agarland@hsc.mb.ca

Most of the opportunities to improve the performance of ICUs derive from improving the structures and processes of which they consist, including staffing models.[1] Staffing in most ICUs, however, reflects historical precedents and practical necessities rather than what works best based on formal assessment. In the absence of quantitative evaluation, there is no reason to believe that existing staffing models result in optimal outcomes.[2] Further, the optimal ICU staffing model may differ based on ICU type, size, case mix, and other factors.

Herein we review evidence related to intensivists, hospitalists, house officers, telemedicine, and physician extenders, with a focus on that which has appeared within the past 5 years. Although we concentrate on patient outcomes, we consider other outcomes that are important to physicians and society,

DOI: 10.1378/chest.12-1531

such as job satisfaction, length of stay (LOS), and costs.[3]

Intensivists

Many studies have assessed whether the outcomes of patients in the ICU are better if intensivists (attending physician specialists in critical care medicine) participate in their care or if patients experience greater exposure to intensivists. A coherent interpretation of this literature is challenging because of the myriad of differences between studies in ICU administration, team composition and function, physician practice, and other variables.[4] Nonetheless, we will review the available literature.

Open vs Closed ICUs

Most studies of intensivist staffing relate to open vs closed ICU structures. Typically, patients in an open ICU are cared for by multiple generalists with or without assistance of intensivists, whereas all patients in a closed ICU are cared for by a single intensivist. In the United States and some other countries, open ICUs are more common,[5-7] whereas closed ICUs are more common in other areas.[8,9] This classification of ICU structure does not adequately characterize the intensivist staffing model, as numerous variations and intermediate models exist for both types.[4,7] Furthermore, many other differences often exist between open and closed ICUs, making it difficult to infer that any benefits of closed-model ICUs are due to the contribution of intensivists; for example, closed ICUs are more common in academic hospitals that typically have residents and ICU fellows working in them.[5,7]

With these caveats in mind, > 30 studies have compared outcomes in open vs closed ICUs. Most were from single ICUs, and most evaluated outcomes after changing from open to closed units. Results have been mixed. A meta-analysis of 27 studies involving 27,000 patients addressed the organizational diversity of ICUs by classifying intensivist involvement into high vs low "intensity."[10,11] Closed-model ICUs and open ICUs in which consultation by an intensivist was mandatory were classified as high intensity. High-intensity intensivist involvement was associated with lower ICU and hospital mortality (unadjusted, pooled risk ratios of 0.61 and 0.71, respectively), shorter ICU and hospital LOS, and lower costs. However, a cross-sectional study using the Project IMPACT database, including 101,000 patients in 123 ICUs,[12] found that adjusted hospital mortality was higher for patients with intensivists involved in their care (OR, 1.42; $P < .001$). The reasons for these conflicting findings are unclear.[13]

Around-the-Clock Intensivist Presence

Around-the-clock intensivist staffing, in which intensivists are present in the ICU 24/7, is common in some European countries.[9] It is usually operationalized via shiftwork, wherein different intensivists are present during days and nights. However, variations can include the following: (1) whether the intensivists are required to remain in the ICU, in the hospital, or within a short distance from the hospital; (2) whether they are responsible for a single, geographically restricted ICU, or for patients in the ICU in different locations within a hospital; and (3) the expectation for maximum time from being called to arriving in the ICU. Around-the-clock intensivist staffing is less common in North American ICUs[5,14-16] where even the much less rigorous staffing standards promulgated by the Leapfrog Group are rarely met.[14,17]

There are strong proponents of this staffing model,[18,19] and it is becoming increasingly common worldwide. The primary rationale for 24/7 intensivist presence is logical: that critically ill patients need expert care during the day and night. Other reasons include references to data suggesting that care and outcomes are worse at night; however, that literature is contradictory, with some studies showing such an effect[20-26] and others not.[27-33] Finally, 24/7 intensivist presence has also been proposed to provide better end-of-life care and to benefit trainees and nurses.[19]

Despite copious opinions, data on this topic are limited and largely based on observational studies and/or the use of before vs after designs that use potentially problematic historical controls.[34] Among 824 patients in an ICU in the United Kingdom, the standardized hospital mortality ratio declined from 1.11 to 0.81 after changing to the 24/7 staffing model.[35] A US study of 4,388 patients in a medical ICU found that such a change was not associated with improved ICU mortality (10.2% vs 10.4%, $P = .83$), hospital mortality (17% vs 19%, $P = .33$), ICU LOS (difference, −0.2 days; $P = .08$) or family satisfaction, although improvements occurred in ICU-acquired complications, processes of care, hospital LOS, and intensivist burnout.[36] Notably, in this latter study the standard staffing model had ICU fellows present overnight. The only interventional study that did not use historical control subjects[37] used an alternating crossover study design in two closed-model, intensivist-run ICUs, one academic and one in a community hospital without house staff. Including the community ICU was valuable because it is more comparable to most ICUs than are the large, academic units that

are the subject of most ICU research.[14,38] In this study, 24/7 intensivist presence did not improve patient outcomes or family satisfaction in either ICU. The main effect of the shiftwork model was on the intensivists, who reported reduced job and life stresses. The largest study thus far was a retrospective, cross-sectional analysis of 49 ICUs participating in the Acute Physiology and Chronic Health Evaluation (APACHE) database project.[39] Nocturnal intensivist presence was associated with lower hospital mortality in ICUs in which daytime involvement of intensivists was low intensity (OR, 0.62; $P = .04$) but not in ICUs in which daytime intensivist involvement was high intensity (OR, 1.08; $P = .78$).

These findings underscore that the impact of 24/7 intensivist coverage may depend on ICU type and preexisting staffing. Moreover, 24/7 staffing requires more intensivists, which will be difficult to supply given the worsening intensivist shortage.[40,41] An analysis limited to direct costs concluded that these were lower with 24/7 intensivists, although only for the sickest patients.[42]

Intensivist Workload

Staffing and workload are related. Aspects of intensivist workload include the number of hours worked per day, the details of nighttime coverage, the number of days worked per week and month, the details of weekend coverage, the number of patients cared for at a time, and the intensity of intellectual and physical effort while providing care. For the intensivists, staffing models must seek to ensure sustainable job satisfaction. This concern is highlighted by data showing that intensivists suffer from a high rate of job burnout.[43-45]

But intensivist workload is also relevant to society, as the shortage of intensivists[40,41] is exacerbated by the fact that trainees are discouraged from entering this subspecialty because they perceive the workload to be high.[46] And, of course, there is concern that patient outcomes may be adversely affected by overtired and overworked intensivists. Although the workload of physician trainees has been progressively limited because of concerns that overwork negatively influences patient and personal outcomes,[47] similar concerns for attending physicians have garnered little attention.[48] Few studies have addressed these issues.

In a preliminary study of 38 intensivists in four academic centers in the United States, hours worked per week and number of nights on call per year did not correlate with job burnout or job distress.[45] But three studies have found that the emotional consequences of being an intensivist are influenced by scheduling. In a cluster-randomized study in five medical ICUs, Ali et al[49] studied the effect of weekend cross-coverage for intensivists doing half-month rotations. Such weekend respite reduced intensivists' burnout and job distress without adversely affecting mortality or LOS. Two studies of intensivists doing 1-week rotations compared day/night shiftwork to enable around-the-clock intensivist presence, with staffing in which the intensivist was present during daytimes and took call at night from home.[36,37] Both studies observed lower burnout under shiftwork, without differences in patient outcomes.

Dara and Afessa[50] studied patient outcomes as they related to intensivist workload among 2,492 patients admitted to a medical ICU over an 18-month period in which the ratio of beds per intensivist varied from 7.5 to 15. They found that ICU LOS was longer when the ratio was 15, whereas hospital LOS and mortality rates did not differ. Although it had methodologic limitations, an observational study suggested better patient outcomes when intensivists worked 12-h rather than 8-h shifts.[51] Despite limited data, the European Society of Intensive Care Medicine has stated that the optimal size of an ICU is 8 to 12 beds.[52]

Nonintensivist Attending Physicians

The shortage of intensivists assures us that nonintensivists will continue to act as primary attending physicians for most patients in the ICU in the United States.[14,41,53] Although this includes physicians trained in numerous areas, most attention has centered on emergency physicians or hospitalists, for whom pathways to formal certification as intensivists have been established or are under discussion, respectively.[54]

Hospitalists are attending physicians who specialize in the care of hospitalized patients.[55] Hospitalists already participate in ICU care in many US hospitals.[15,54] This can take a variety of forms, ranging from only responding to cardiopulmonary arrests and other emergencies, to routine off-hours coverage, to complete around-the-clock staffing. Two studies have assessed outcomes related to hospitalist participation. An observational study compared outcomes in two adult medical ICUs, one staffed by intensivists and the other by hospitalists supported by an intensivist-led consultation service.[56] After adjustment for large differences in case mix, the hospitalist-led ICU had similar hospital mortality (OR = 0.80, $P = .22$), ICU mortality (OR = 0.80, $P = .41$), and ICU LOS (mean difference, −0.3 days; $P = .32$). The second study compared outcomes when night coverage was provided by residents vs hospitalists in an intensivist-led pediatric ICU using a before vs after design.[57] ICU mortality (OR = 0.36, $P = .01$) and ICU LOS (mean difference, −21 h; $P = .01$) were lower when care was provided by hospitalists.

Emergency physicians already routinely provide initial care to critically ill patients. In many community hospitals in the United States they are also expected to leave their EDs and attend to unstable patients in the ICU.[58] We were unable to find any data on outcomes related to this latter role.

Telemedicine

ICU telemedicine has been implemented in several hundred hospitals in the United States.[59] In telemedicine, ICU physicians and/or nurses remotely provide real-time care; this may be nighttime only or around the clock. The remote clinicians can electronically access telemetry, diagnostic tests, information from ventilators and other devices, electronic medical records, and computer order entry.[60] Some telemedicine software continuously analyzes the data stream for early identification of worrisome trends. Telemedicine clinicians view patients via live video feeds and talk to ICU personnel by telephone or intercom; some have a robotic presence in the ICU.[61] The remote physicians may or may not have order-writing authority.

Several studies, most often assessing the Philips VISICU eICU system, have evaluated how ICU telemedicine affected mortality, LOS, and complications,[62-65] with conflicting results. A meta-analysis of 13 studies including 35 ICUs and >41,000 patients[59] identified the limitations of this literature: (1) before vs after study designs, (2) modest study quality, (3) large heterogeneity in baseline ICU structures and telemedicine implementation, and (4) potential for bias due to vendor involvement or support.[66] Based on the meta-analysis, ICU telemedicine was associated with lower ICU mortality (OR = 0.80, $P = .02$) and ICU LOS (difference, 1.3 days; $P = .01$), without concomitant changes in hospital mortality or LOS.

The initial and ongoing costs of ICU telemedicine systems are substantial, and there are conflicting data about the cost effectiveness of these systems.[67,68] In addition, ICU telemedicine requires the ability to hire and retain the necessary ICU clinicians in addition to on-site providers who are available, at the very least, to perform procedures such as intubations. Of possible relevance to the lives of eClinicians, the psychosocial aspects of doing ICU telemedicine work differ considerably from those of bedside work, including different types of relationships, interpersonal encounters, and physical and mental stressors.[69]

House Officers

Working under supervision as an extension of attending physicians, house officers have been an important component of ICU staffing in teaching hospitals, especially at night. Only a few studies have assessed how ICU staffing by residents or critical care fellows affects patient outcomes.

Peets et al[70] evaluated the impact of ICU fellows in two closed-model medical-surgical ICUs that always had junior house staff but only had fellows half the time. This study found no differences in mortality or LOS associated with the presence/absence of the fellows.

The level of training of ICU residents was associated with outcome in two studies. In Taiwan, a study of 2,274 patients in two open-model ICUs that were covered by a single surgical resident[71] found that hospital mortality of patients cared for by first-year residents was higher than those cared for by more advanced residents (25% vs 18%, $P = .002$). In another study of 16 pediatric ICUs, patients cared for by first- and second-year residents had higher mortality than those cared for by third-year residents, and higher mortality was seen earlier in the educational year for each resident level.[72]

Increasingly stringent limits in many countries on duty hours for house officers have had important consequences for ICU staffing in such hospitals, including lowering continuity of care.[47] The use of hospitalists and nonphysician providers has increased in teaching hospitals to fill these gaps.[47] Although a study in two ICUs found that first-year residents working reduced hours had a lower rate of serious errors in association with more weekly sleep and fewer attention failures during work,[73,74] in an evaluation of 104 ICUs, severity-adjusted mortality did not change after the 2003 duty hour limits were implemented in the United States.[75]

Nonphysician Providers

Acting as physician extenders, nurse practitioners (NPs) and physician assistants (PAs) are increasingly involved in the care of ICU patients.[15,76,77] These two types of providers differ with respect to their background and training[78] but often assume similar roles in the ICU.

With a bachelor's degree in nursing as a prerequisite, acute care NP programs in the United States last 1.5 to 5 years, culminating in a master's or doctorate-level degree, and usually include training in procedural skills. In most states, NPs have prescription-writing privileges and do not require physician supervision agreements. In contrast, starting with college-level coursework, PAs study for approximately 2 years to gain a bachelor's or master's degree. They have prescription-writing privileges but must obtain procedural skills on the job, and their practice requires physician supervisory agreements in all states.

NPs and PAs have been integrated into house staff-based ICU teams[79-81] or used to staff separate ICUs.[82,83] NPs have been used in specialty-based teams that remain involved in care of patients who enter the ICU[84-87] and as outcomes managers to provide unit-based care.[88-90]

A number of studies have assessed the impact of NPs and PAs. With an NP acting as outcomes manager, hospital mortality, hospital and ICU LOS, duration of mechanical ventilation, complications, and costs were reduced.[88,90] Adherence to clinical practice guidelines was greater when an NP was added to an open-model surgical ICU.[89]

Several studies attest to the comparability of nonphysician providers and house officers in adult ICUs. An older study using historical control subjects found that mortality rates were similar for medical ICU patients cared for by house officers as compared with PAs.[91] Two more recent studies each compared a medical ICU staffed by house officers to another staffed by NPs/PAs operating simultaneously in a single academic institution. These reported similar outcomes, including lengths-of-stay, mortality, and hospital discharge destination.[82,83] Finally, comparison between ICU fellows and NPs in a subacute ICU showed no differences in mortality, LOS, duration of mechanical ventilation, or ICU readmissions.[80,92]

The use of nonphysician providers in the ICU may lead to other benefits. First, unlike rotating house officers, these providers become a consistent workforce, which may reduce practice variation and improve communication between ICU staff members and, consequently, ICU culture and safety.[93,94] Second, since procedural proficiency increases with practice,[95-97] nonphysician providers have greater opportunity to hone these skills than do transient house officers. And third, over time these nonphysician providers can be expected to attain high-level expertise in ICU care by virtue of having repeated exposure to ICU-specific interventions and the nuances of diagnosis and management of critically ill patients.

The use of nonphysician providers in the ICU may have downsides, which should also be considered. First, NPs and PAs receive less formal in-school education on the pathophysiology, evaluation, synthesis, and presentation of complex medical cases than do medical school graduates. Thus, they often require a substantial investment of time and resources for on-the-job training.[79,81] Second, as permanent ICU staff members, nonphysician providers may be similar to intensivists and ICU nurses in being at high risk for job burnout.[98] Finally, employment of nonphysician providers is expensive, since their salaries are nearly twice that of residents,[99,100] although some of this increased cost may be offset by cost savings associated with nonphysician provider-based care.[85]

Discussion and Conclusions

Overall, the current evidence regarding physician staffing of ICUs does not yet provide a coherent view of the optimal model to use. Baseline differences between ICUs[4] and use of differing end points makes it hard to compare across studies and may explain some of the conflicting findings to date. Wide study heterogeneity and narrow focus hinders the ability to generalize and draw conclusions. Most existing studies suffer from serious limitations: single-center designs; use of historical controls; focus on large, academic ICUs, rather than community ICUs of more modest size where most critically ill patients receive care[14,38]; and evaluation limited to short-term patient outcomes, ignoring longer-term impact and outcomes relevant to the other stakeholders in ICU care.[3]

The topic with the most data relating to patient outcomes is the intensity of intensivist involvement in care. Despite persistent arguments for closed-model ICUs,[52] the evidence is inconsistent.[10,12] Even if closed-model ICUs ultimately produce better outcomes, we do not know which specific elements of that multifaceted organizational paradigm are responsible for improvement. Similarly, current evidence does not strongly support the superiority of models with around-the-clock intensivist presence.[35-37,39] The other topic with substantial (but still limited) data is use of nonphysician providers. This literature indicates that care provided by teams including NPs or PAs appears to be safe and comparable to that provided by other staffing models.

Although the best way to staff our ICUs is unknown, the landscape of ICU physician coverage will continue to change under the stresses of shortages of intensivists and increasing duty hour limitations for trainees. Nonphysician providers, innovative physician staffing models, telemedicine, and other technologies will be increasingly used to cope with these realities. This evolution makes it more important than ever to study how staffing affects outcomes.

As only quantitative evaluation can tell us whether one staffing model is better than another,[3] we need more research from multiple sites to develop a consistent and integrated understanding of this complex topic.[2] Research on this subject is complicated by several factors. First, optimal ICU staffing may depend on ICU characteristics such as type, size, and case mix. Second, designing and conducting studies on this topic is extremely challenging. Although interventional studies using cluster randomization or alternating crossover designs are feasible, it is difficult to obtain funding and buy-in from ICU physicians for this kind of research.[2] Investigators should be open to other study designs, such as comparative effectiveness approaches.[101] A third challenge is evaluating the

range of relevant outcomes for patients, health-care workers and society.[3]

A final comment derives from recognizing that all staffing models are composed of numerous elements that interact in complex ways with the other structures and processes involved in providing patient care. Accordingly, changing to a different staffing model is a complex intervention that results in numerous alterations in how an ICU functions. Finding superiority of one staffing model over another leaves unanswered the important question of whether this was due to the effects of a small number of essential elements or instead resulted from numerous elements of the better model and how they interacted with the specific structures existing in the ICU studied. Identifying such essential elements of ICU staffing, if they exist, might simplify the chance of replicating the intervention in other ICUs with full expectation of replicating the benefits. Although a worthy goal, identifying the essential or minimal elements of ICU staffing required to achieve superior outcomes adds an additional layer of difficulty to assessing the way we should be staffing our ICUs.

Acknowledgments

Financial/nonfinancial disclosures: The authors have reported to *CHEST* that no potential conflicts of interest exist with any companies/organizations whose products or services may be discussed in this article.

References

1. Garland A. Improving the ICU: part 2. *Chest*. 2005;127(6):2165-2179.
2. Garland A. Figuring out what works: a need for more and better studies on the relationship between ICU organization and outcomes. *Crit Care*. 2010;14(1):108.
3. Garland A. Improving the ICU: part 1. *Chest*. 2005;127(6):2151-2164.
4. Rubenfeld GD. The structure of intensive care: if you've seen one ICU, you've seen one ICU. *Critical Care Alert* May 2000.
5. Brilli RJ, Spevetz A, Branson RD, et al; American College of Critical Care Medicine Task Force on Models of Critical Care Delivery. The American College of Critical Care Medicine Guidelines for the Defintion of an Intensivist and the Practice of Critical Care Medicine. Critical care delivery in the intensive care unit: defining clinical roles and the best practice model. *Crit Care Med*. 2001;29(10):2007-2019.
6. Scribante J, Bhagwanjee S. National audit of critical care resources in South Africa - open versus closed intensive and high care units. *S Afr Med J*. 2007;97(12 pt 3):1319-1322.
7. Bell R, Robinson L. *Final Report of the Ontario Critical Care Steering Committee March 2005*. Toronto, Canada: Ontario Ministry of Health and Long-term Care; 2005.
8. Bellomo R, Stow PJ, Hart GK. Why is there such a difference in outcome between Australian intensive care units and others? *Curr Opin Anaesthesiol*. 2007;20(2):100-105.
9. Graf J, Reinhold A, Brunkhorst FM, et al; German Competence Network Sepsis (SepNet). Variability of structures in German intensive care units—a representative, nationwide analysis. *Wien Klin Wochenschr*. 2010;122(19-20):572-578.
10. Pronovost PJ, Angus DC, Dorman T, Robinson KA, Dremsizov TT, Young TL. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. *JAMA*. 2002;288(17):2151-2162.
11. Pronovost PJ, Needham DM, Waters H, et al. Intensive care unit physician staffing: financial modeling of the Leapfrog standard. *Crit Care Med*. 2004;32(6):1247-1253.
12. Levy MM, Rapoport J, Lemeshow S, Chalfin DB, Phillips G, Danis M. Association between critical care physician management and patient mortality in the intensive care unit. *Ann Intern Med*. 2008;148(11):801-809.
13. Rubenfeld GD, Angus DC. Are intensivists safe? *Ann Intern Med*. 2008;148(11):877-879.
14. Angus DC, Shorr AF, White A, Dremsizov TT, Schmitz RJ, Kelley MA; Committee on Manpower for Pulmonary and Critical Care Societies (COMPACCS). Critical care delivery in the United States: distribution of services and compliance with Leapfrog recommendations. *Crit Care Med*. 2006;34(4):1016-1024.
15. Hyzy RC, Flanders SA, Pronovost PJ, et al. Characteristics of intensive care units in Michigan: not an open and closed case. *J Hosp Med*. 2010;5(1):4-9.
16. Parshuram CS, Kirpalani H, Mehta S, Granton J, Cook D; for the Canadian Critical Care Trials Group. In-house, overnight physician staffing: a cross-sectional survey of Canadian adult and pediatric intensive care units. *Crit Care Med*. 2006;34(6):1674-1678.
17. The Leapfrog Group. ICU physician staffing. Leapfrog website. http://www.leapfroggroup.org/media/file/Leapfrog-ICU_Physician_Staffing_Fact_Sheet.pdf. Accessed October 13, 2008.
18. Haupt MT, Bekes CE, Brilli RJ, et al; Task Force of the American College of Critical Care Medicine, Society of Critical Care Medicine. Guidelines on critical care services and personnel: Recommendations based on a system of categorization of three levels of care. *Crit Care Med*. 2003;31(11):2677-2683.
19. Azoulay E, Mancebo J, Brochard L. Surviving the night in the ICU: who needs senior intensivists? *Am J Respir Crit Care Med*. 2010;182(3):293-294.
20. Peberdy MA, Ornato JP, Larkin GL, et al; National Registry of Cardiopulmonary Resuscitation Investigators. Survival from in-hospital cardiac arrest during nights and weekends. *JAMA*. 2008;299(7):785-792.
21. Merrer J, DeJonghe B, Golliot F, et al. Complications of femoral and subclavian venous catherization in critically ill patients: a randomized controlled trial. *JAMA*. 2001;286(6):700-707.
22. Goldfrad C, Rowan K. Consequences of discharges from intensive care at night. *Lancet*. 2000;355(9210):1138-1142.
23. Beck DH, McQuillan P, Smith GB. Waiting for the break of dawn? The effects of discharge time, discharge TISS scores and discharge facility on hospital mortality after intensive care. *Intensive Care Med*. 2002;28(9):1287-1293.
24. Priestap FA, Martin CM. Impact of intensive care unit discharge time on patient outcome. *Crit Care Med*. 2006;34(12):2946-2951.
25. Duke GJ, Green JV, Briedis JH. Night-shift discharge from intensive care unit increases the mortality-risk of ICU survivors. *Anaesth Intensive Care*. 2004;32(5):697-701.
26. Singh MY, Nayyar V, Clark PT, Kim C. Does after-hours discharge of ICU patients influence outcome? *Crit Care Resusc*. 2010;12(3):156-161.
27. Wunsch H, Mapstone J, Brady T, Hanks R, Rowan K. Hospital mortality associated with day and time of admission to intensive care units. *Intensive Care Med*. 2004;30(5):895-901.

28. Uusaro A, Kari A, Ruokonen E. The effects of ICU admission and discharge times on mortality in Finland. *Intensive Care Med*. 2003;29(12):2144-2148.
29. Morales IJ, Peters SG, Afessa B. Hospital mortality rate and length of stay in patients admitted at night to the intensive care unit. *Crit Care Med*. 2003;31(3):858-863.
30. Arabi Y, Alshimemeri A, Taher S. Weekend and weeknight admissions have the same outcome of weekday admissions to an intensive care unit with onsite intensivist coverage. *Crit Care Med*. 2006;34(3):605-611.
31. Luyt CE, Combes A, Aegerter P, et al. Mortality among patients admitted to intensive care units during weekday day shifts compared with "off" hours. *Crit Care Med*. 2007; 35(1):3-11.
32. Giraud T, Dhainaut JF, Vaxelaire JF, et al. Iatrogenic complications in adult intensive care units: a prospective two-center study. *Crit Care Med*. 1993;21(1):40-51.
33. Sheu CC, Tsai JR, Hung JY, et al. Admission time and outcomes of patients in a medical intensive care unit. *Kaohsiung J Med Sci*. 2007;23(8):395-404.
34. Friedman LM, Furberg CD, DeMets DL. *Historical Controls/Data Bases. Fundamentals of Clinical Trials*. New York, NY: Springer-Verlag; 1998:47-51.
35. Blunt MC, Burchett KR. Out-of-hours consultant cover and case-mix-adjusted mortality in intensive care. *Lancet*. 2000; 356(9231):735-736.
36. Gajic O, Afessa B, Hanson AC, et al. Effect of 24-hour mandatory versus on-demand critical care specialist presence on quality of care and family and provider satisfaction in the intensive care unit of a teaching hospital. *Crit Care Med*. 2008;36(1):36-44.
37. Garland A, Roberts D, Graff L. Twenty-four-hour intensivist presence: a pilot study of effects on ICU patients, families, doctors, and nurses. *Am J Respir Crit Care Med*. 2012; 185(7):738-743.
38. Depasse B, Pauwels D, Somers Y, Vincent JL. A profile of European ICU nursing. *Intensive Care Med*. 1998;24(9): 939-945.
39. Wallace DJ, Angus DC, Barnato AE, Kramer AA, Kahn JM. Nighttime intensivist staffing and mortality among critically ill patients. *N Engl J Med*. 2012;366(22):2093-2101.
40. Ewart GW, Marcus L, Gaba MM, Bradner RH, Medina JL, Chandler EB. The critical care medicine crisis: a call for federal action: a white paper from the critical care professional societies. *Chest*. 2004;125(4):1518-1521.
41. Angus DC, Kelley MA, Schmitz RJ, White A, Popovich J Jr; Committee on Manpower for Pulmonary and Critical Care Societies (COMPACCS). 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):2762-2770.
42. Banerjee R, Naessens JM, Seferian EG, et al. Economic implications of nighttime attending intensivist coverage in a medical intensive care unit. *Crit Care Med*. 2011;39(6): 1257-1262.
43. Embriaco N, Azoulay E, Barrau K, et al. High level of burnout in intensivists: prevalence and associated factors. *Am J Respir Crit Care Med*. 2007;175(7):686-692.
44. Guntupalli KK, Fromm RE Jr. Burnout in the internist—intensivist. *Intensive Care Med*. 1996;22(7):625-630.
45. Shaman Z, Roach MJ, Marik P, et al. Job stress and workload among intensivists [abstract]. *Proc Am Thorac Soc*. 2005;2(abstracts issue):A597.
46. Lorin S, Heffner J, Carson S. Attitudes and perceptions of internal medicine residents regarding pulmonary and critical care subspecialty training. *Chest*. 2005;127(2):630-636.
47. Pastores SM, O'Connor MF, Kleinpell RM, et al. The Accreditation Council for Graduate Medical Education resident duty hour new standards: history, changes, and impact on staffing of intensive care units. *Crit Care Med*. 2011;39(11):2540-2549.
48. Mercurio MR, Peterec SM. Attending physician work hours: ethical considerations and the last doctor standing. *Pediatrics*. 2009;124(2):758-762.
49. Ali NA, Hammersley J, Hoffmann SP, et al; Midwest Critical Care Consortium. Continuity of care in intensive care units: a cluster-randomized trial of intensivist staffing. *Am J Respir Crit Care Med*. 2011;184(7):803-808.
50. Dara SI, Afessa B. Intensivist-to-bed ratio: association with outcomes in the medical ICU. *Chest*. 2005;128(2):567-572.
51. Bollschweiler E, Krings A, Fuchs KH, et al. Alternative shift models and the quality of patient care. An empirical study in surgical intensive care units. *Langenbecks Arch Surg*. 2001;386(2):104-109.
52. Valentin A, Ferdinande P; ESICM Working Group on Quality Improvement. Recommendations on basic requirements for intensive care units: structural and organizational aspects. *Intensive Care Med*. 2011;37(10):1575-1587.
53. The Critical Care Workforce. *A Study of the Supply and Demand for Critical Care Physicians*. Washington, DC: Health Resources and Services Administration; 2006. Senate Rep No. 108-81.
54. Siegal EM, Dressler DD, Dichter JR, Gorman MJ, Lipsett PA. Training a hospitalist workforce to address the intensivist shortage in American hospitals: a position paper from the Society of Hospital Medicine and the Society of Critical Care Medicine. *Crit Care Med*. 2012;40(6):1952-1956.
55. Wachter RM, Goldman L. The hospitalist movement 5 years later. *JAMA*. 2002;287(4):487-494.
56. Wise KR, Akopov VA, Williams BR Jr, Ido MS, Leeper KV Jr, Dressler DD. Hospitalists and intensivists in the medical ICU: a prospective observational study comparing mortality and length of stay between two staffing models. *J Hosp Med*. 2012;7(3):183-189.
57. Tenner PA, Dibrell H, Taylor RP. Improved survival with hospitalists in a pediatric intensive care unit. *Crit Care Med*. 2003;31(3):847-852.
58. Sherwin RL, Garcia AJ, Bilkovski R. Quantifying off-hour emergency physician coverage of in-hospital codes: a survey of community emergency departments. *J Emerg Med*. 2011;41(4):381-385.
59. Young LB, Chan PS, Lu X, Nallamothu BK, Sasson C, Cram PM. Impact of telemedicine intensive care unit coverage on patient outcomes: a systematic review and meta-analysis. *Arch Intern Med*. 2011;171(6):498-506.
60. Breslow MJ. Remote ICU care programs: current status. *J Crit Care*. 2007;22(1):66-76.
61. Sucher JF, Todd SR, Jones SL, Throckmorton T, Turner KL, Moore FA. Robotic telepresence: a helpful adjunct that is viewed favorably by critically ill surgical patients. *Am J Surg*. 2011;202(6):843-847.
62. Breslow MJ, Rosenfeld BA, Doerfler M, et al. Effect of a multiple-site intensive care unit telemedicine program on clinical and economic outcomes: an alternative paradigm for intensivist staffing. *Crit Care Med*. 2004;32(1):31-38.
63. Rosenfeld BA, Dorman T, Breslow MJ, et al. Intensive care unit telemedicine: alternate paradigm for providing continuous intensivist care. *Crit Care Med*. 2000;28(12): 3925-3931.
64. Thomas EJ, Lucke JF, Wueste L, Weavind L, Patel B. Association of telemedicine for remote monitoring of intensive care patients with mortality, complications, and length of stay. *JAMA*. 2009;302(24):2671-2678.

65. Morrison JL, Cai Q, Davis N, et al. Clinical and economic outcomes of the electronic intensive care unit: results from two community hospitals. *Crit Care Med*. 2010;38(1):2-8.
66. Friedman LS, Richter ED. Relationship between conflicts of interest and research results. *J Gen Intern Med*. 2004; 19(1):51-56.
67. Kumar G, Falk DM, Bonello RS, Kahn JM, Perencevich E, Cram P. The costs of critical care telemedicine programs: a systematic review and analysis. *Chest*. 2013;143(1): 19-29.
68. Franzini L, Sail KR, Thomas EJ, Wueste L. Costs and cost-effectiveness of a telemedicine intensive care unit program in 6 intensive care units in a large health care system. *J Crit Care*. 2011;26(3):329.e1-6.
69. Stafford TB, Myers MA, Young A, Foster JG, Huber JT. Working in an eICU unit: life in the box. *Crit Care Nurs Clin North Am*. 2008;20(4):441-450.
70. Peets AD, Boiteau PJ, Doig CJ. Effect of critical care medicine fellows on patient outcome in the intensive care unit. *Acad Med*. 2006;81(10)(suppl):S1-S4.
71. Lee M-T, Hu P, Hsi S-C, Liu KY, Chao HM, Chen YQ. Mortality rates under the care of junior and senior surgery residents in a surgical intensive care unit/neurologic intensive care unit: a 5-year retrospective cohort study at Taoyuan Armed Forces General Hospital. *J Crit Care*. 2008;23(4): 550-555.
72. Pollack MM, Cuerdon TT, Patel KM, Ruttimann UE, Getson PR, Levetown M. Impact of quality-of-care factors on pediatric intensive care unit mortality. *JAMA*. 1994; 272(12):941-946.
73. Lockley SW, Cronin JW, Evans EE, et al; Harvard Work Hours, Health and Safety Group. Effect of reducing interns' weekly work hours on sleep and attentional failures. *N Engl J Med*. 2004;351(18):1829-1837.
74. Landrigan CP, Rothschild JM, Cronin JW, et al. Effect of reducing interns' work hours on serious medical errors in intensive care units. *N Engl J Med*. 2004;351(18):1838-1848.
75. Prasad M, Iwashyna TJ, Christie JD, et al. Effect of work-hours regulations on intensive care unit mortality in United States teaching hospitals. *Crit Care Med*. 2009;37(9):2564-2569.
76. Moote M, Krsek C, Kleinpell R, Todd B. Physician assistant and nurse practitioner utilization in academic medical centers. *Am J Med Qual*. 2011;26(6):452-460.
77. Riportella-Muller R, Libby D, Kindig D. The substitution of physician assistants and nurse practitioners for physician residents in teaching hospitals. *Health Aff (Millwood)*. 1995;14(2):181-191.
78. Gershengorn HB, Johnson MP, Factor P. The use of nonphysician providers in adult intensive care units. *Am J Respir Crit Care Med*. 2012;185(6):600-605.
79. D'Agostino R, Halpern NA. Acute care nurse practitioners in oncologic critical care: the memorial Sloan-Kettering cancer center experience. *Crit Care Clin*. 2010;26(1):207-217.
80. Hoffman LA, Tasota FJ, Zullo TG, Scharfenberg C, Donahoe MP. Outcomes of care managed by an acute care nurse practitioner/attending physician team in a subacute medical intensive care unit. *Am J Crit Care*. 2005;14(2): 121-130.
81. Landsperger JS, Williams KJ, Hellervik SM, et al. Implementation of a medical intensive care unit acute-care nurse practitioner service. *Hosp Pract (Minneap)*. 2011;39(2): 32-39.
82. Gershengorn HB, Wunsch H, Wahab R, et al. Impact of nonphysician staffing on outcomes in a medical ICU. *Chest*. 2011;139(6):1347-1353.
83. Kawar E, DiGiovine B. MICU care delivered by PAs versus residents: do PAs measure up? *JAAPA*. 2011;24(1):36-41.
84. McNatt GE, Easom A. The role of the advanced practice nurse in the care of organ transplant recipients. *Adv Ren Replace Ther*. 2000;7(2):172-176.
85. Dahle KL, Smith JS, Ingersoll GL, Wilson JR. Impact of a nurse practitioner on the cost of managing inpatients with heart failure. *Am J Cardiol*. 1998;82(5):686-688.
86. Haan JM, Dutton RP, Willis M, Leone S, Kramer ME, Scalea TM. Discharge rounds in the 80-hour workweek: importance of the trauma nurse practitioner. *J Trauma*. 2007;63(2):339-343.
87. Jarrett LA, Emmett M. Utilizing trauma nurse practitioners to decrease length of stay. *J Trauma Nurs*. 2009;16(2): 68-72.
88. Burns S, Earven SF, C, Lewis R, et al. Implementation of an institutional program to improve clinical and financial outcomes of mechanically ventilated patients: one-year outcomes and lessons learned. *Crit Care Med*. 2003;31(12): 2752-2763.
89. Gracias VH, Sicoutris CP, Stawicki SP, et al. Critical care nurse practitioners improve compliance with clinical practice guidelines in "semiclosed" surgical intensive care unit. *J Nurs Care Qual*. 2008;23(4):338-344.
90. Russell D, VorderBruegge M, Burns SM. Effect of an outcomes-managed approach to care of neuroscience patients by acute care nurse practitioners. *Am J Crit Care*. 2002; 11(4):353-362.
91. Dubaybo BA, Samson MK, Carlson RW. The role of physician-assistants in critical care units. *Chest*. 1991;99(1):89-91.
92. Hoffman LA, Miller TH, Zullo TG, Donahoe MP. Comparison of 2 models for managing tracheotomized patients in a subacute medical intensive care unit. *Respir Care*. 2006;51(11):1230-1236.
93. Petersen LA, Brennan TA, O'Neil AC, Cook EF, Lee TH. Does housestaff discontinuity of care increase the risk for preventable adverse events? *Ann Intern Med*. 1994; 121(11):866-872.
94. Huang DT, Clermont G, Kong L, et al. Intensive care unit safety culture and outcomes: a US multicenter study. *Int J Qual Health Care*. 2010;22(3):151-161.
95. Dong Y, Suri HS, Cook DA, et al. Simulation-based objective assessment discerns clinical proficiency in central line placement: a construct validation. *Chest*. 2010;137(5): 1050-1056.
96. Loukas C, Nikiteas N, Kanakis M, Moutsatsos A, Leandros E, Georgiou E. A virtual reality simulation curriculum for intravenous cannulation training. *Acad Emerg Med*. 2010; 17(10):1142-1145.
97. Mulcaster JT, Mills J, Hung OR, et al. Laryngoscopic intubation: learning and performance. *Anesthesiology*. 2003; 98(1):23-27.
98. Embriaco N, Papazian L, Kentish-Barnes N, Pochard F, Azoulay E. Burnout syndrome among critical care healthcare workers. *Curr Opin Crit Care*. 2007;13(5):482-488.
99. American Medical Association. FREIDA Online specialty training search. https://freida.ama-assn.org/Freida/user/specStatisticsSearch.do?method=viewSpecialty&pageNumber=2. Accessed June 27, 2011.
100. Pronsati M, Gerchufsky M. National salary report 2010: inching forward with mixed results. http://nurse-practitioners-and-physician-assistants.advanceweb.com/Features/Articles/National-Salary-Report-2010.aspx. Accessed July 20, 2012.
101. Sox HC, Goodman SN. The methods of comparative effectiveness research. *Annu Rev Public Health*. 2012;33:425-445.