



SPECIAL ARTICLE

The future of intensive care medicine

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Abstract Intensive care medical training, whether as a primary specialty or as secondary add-on training, should include key competences to ensure a uniform standard of care, and the number of intensive care physicians needs to increase to keep pace with the growing and anticipated need. The organisation of intensive care in multiple specialty or central units is heterogeneous and evolving, but appropriate early treatment and access to a trained intensivist should be assured at all times, and intensivists should play a pivotal role in ensuring communication and high-quality care across hospital departments. Structures now exist to support clinical research in intensive care medicine, which should become part of routine patient management. However, more translational research is urgently needed to identify areas that show clinical promise and to apply research principles to the real-life clinical setting. Likewise, electronic networks can be used to share expertise and support research. Individuals, physicians and policy makers need to allow for individual choices and priorities in the management of critically ill patients while remaining within the limits of economic reality. Professional scientific societies play a pivotal role in supporting the establishment of a defined minimum level of intensive health care and in ensuring standardised levels of training and patient care

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PALABRAS CLAVE

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by promoting interaction between physicians and policy makers. The perception of intensive care medicine among the general public could be improved by concerted efforts to increase awareness of the services provided and of the successes achieved.

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El futuro de la medicina intensiva

Resumen La formación en medicina intensiva, ya sea como especialidad primaria o a partir de una troncalidad común para después convertirse en supra-especialidad, debería incluir competencias clave que garanticen un cuidado estándar y homogéneo del paciente crítico, así como proveer al sistema sanitario del número de especialistas en medicina intensiva (intensivistas) de forma ajustada y anticipada al ritmo de crecimiento de la necesidad asistencial.

La organización de los cuidados intensivos desde la visión de las distintas especialidades o en unidades centralizadas y jerarquizadas, es heterogénea y está en constante evolución. No obstante el acceso y tratamiento precoz del enfermo crítico por parte de un intensivista, debería estar siempre garantizado, no únicamente en los servicios de medicina intensiva, sino en todos los departamentos de un hospital, actuando el intensivista como elemento central en la comunicación y coordinación entre los diferentes servicios y especialistas, a fin de lograr la más alta calidad y eficacia en la asistencia.

La investigación clínica en medicina intensiva está sustentada por la excelencia de conocimiento de sus profesionales, pero son necesarias estructuras de apoyo: la integración de la investigación e innovación en la rutina diaria y un incremento de la investigación traslacional, a fin de identificar áreas que muestren elementos potenciales de avance en el aspecto clínico y la aplicación de los principios de la investigación básica y fisiológica en el entorno de la medicina intensiva. Las tecnologías de la comunicación y la información ofrecen un marco idóneo para compartir y poner en común el conocimiento y apoyar la formación, la investigación y la innovación en medicina intensiva.

Ciudadanía, profesionales de la salud y responsables políticos deben apoyar que aquellos profesionales con el mejor conocimiento científico tomen las decisiones sobre las prioridades en la gestión del cuidado del enfermo crítico, dentro de un modelo económico sostenible. Las sociedades científicas tienen un papel crucial en la definición de los niveles mínimos de atención médica intensiva y también en asegurar estándares de capacitación, formación de intensivistas y acreditación, promoviendo la interacción entre especialidades, familias, sociedad y responsables políticos. La percepción del valor de la medicina intensiva entre la ciudadanía y la Administración debe ser constantemente mejorada mediante esfuerzos coordinados y dirigidos a incrementar el conocimiento que la medicina intensiva pone a su disposición y de los éxitos alcanzados por esta especialidad.

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Introduction

Intensive care medicine is a heterogeneous, complex and evolving specialty. While the need for specialised around-the-clock medical care for a subset of acute patients is universal, the organisation of care and training of specialist physicians varies in different countries and regions of the world.¹⁻⁹ Intensive care medicine sets itself apart from many other areas of health care in that critically ill patients frequently have multiple interrelated issues that need to be managed rapidly and in a comprehensive manner to be effective. In addition, ethical considerations, which include personal, familial, cultural, religious and demographic values and expectations, influence patient management and outcome, the long-term consequences of which are borne by the individual patient, family and society as a whole.^{10,11} The demand for intensive care medicine is increasing as expectations for state-of-the-art

medical care rise, compounded by the ageing of the general population in many countries and medical advances that improve the survival of patients who then require specialised care to recover as many former faculties as possible.^{12,13}

Intensive care as a medical specialty lacks wide visibility among the general public and policy-making bodies, and yet both individuals and societies simultaneously expect that high quality care and the necessary resources are available when the need arises. The future of intensive care medicine requires advances in medical research and physician training as well as improvements in the organisation of patient management and public awareness.

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Education, training and organisation of the specialty

Intensive care medicine as a medical specialty

The national commission on medical specialties in Spain defines intensive care as the medical specialty that manages severely ill patients with one or more dysfunctional organs and at high risk of death or permanent disability, but with the possibility of a complete recovery⁷. Specialists in intensive care medicine often serve as general physicians for severely ill patients, who may have been referred or are primarily managed by a variety of other medical departments. Intensive care therefore represents a medical specialty that must maintain horizontal relationships with a variety of other specialties within a medical institution.

Medical training and education

Intensive care medicine has existed as a primary medical specialty in Spain for approximately the past 35 years, as is the case in some countries in Latin America. In many other countries, however, including most of the rest of Europe, the United States and other parts of Latin America, training in intensive care medicine comprises secondary specialty education following primary training in internal medicine, anaesthesiology, surgery or emergency medicine.^{14,15} Parts of Western Europe, Africa and Southeast Asia are now initiating efforts to introduce and harmonise intensive care as a primary medical specialty. The international Competency Based Training programme in Intensive Care Medicine for Europe (CoBaTrICE; www.cobatrice.org) has identified key competencies that should be included as part of intensive care training and aims to serve as a basis for high-quality global training programmes, independent of the current system of training, to ensure a uniform standard of care.¹⁶⁻²⁶

Unfortunately, the supply of physicians trained to provide intensive medical care has not kept pace with increasing demand, leaving many intensive care units (ICUs) understaffed with qualified personnel.^{13,27-29} Educational institutions and programmes need to implement measures to ensure that an adequate number of physicians are trained to provide intensive care to the population that may require these services.³⁰⁻³³ One potential strategy may be the exposure of medical students to intensive care departments at an early stage in the medical education curriculum, thereby increasing the chances that young physicians choose intensive care as a specialty.

Organisation

Organisation within a medical institution may comprise so-called open ICUs that manage patients under the primary care of and physically located within other medical departments. In contrast, closed ICUs care for severely ill patients with a variety of medical indications under the primary care of intensive care physicians and physically located in a common facility with the necessary means, materials and expertise readily available. Key to the success of either model is the rapid detection and treatment of patients at

risk of severe complications, thereby reducing or avoiding lengthy ICU stays.^{7,34-36}

Another key component of optimal intensive patient care is the availability of a specialist trained in intensive care medicine at all times.³⁷ Institutions with limited resources or located in remote areas may need to rely on consultation with trained specialists using virtual means, but ultimately an intensive care specialist should be available at every ICU bedside and at all hours of the day and night.^{7,27,38-44}

Research and innovation: challenges and business

Research

After more than 60 years of research in intensive care medicine, notable progress has been made in areas such as ventilation and renal replacement, changing clinical practice and improving patient outcomes. In parallel, the necessary infrastructure has been created to support the execution of randomised controlled trials (RCTs) in the intensive care setting now and in the future.^{45,46} While more well-designed RCTs that provide clear clinical guidance are required, the adaptation of RCT results to real-life clinical scenarios remains a challenge, and innovations in research design may be necessary to ease this transition.⁴⁷

One notable failure, after three decades of research, has been the search for a universal treatment solution for septic patients.⁴⁸ Future efforts will need to focus on successful translational research to address this and other remaining clinical needs. Important will be the training and recruitment of young physicians with an interest in performing translational research. The European Board of Intensive Care Medicine has prepared a set of recommendations for modifications to the European Commission's Clinical Trials Directive (2001/20/EC) that aim to streamline both the costs and time required for new treatment or management concepts to reach the clinic (<http://ebicm.esicm.org/eu-activities/clinical-trial-directive>). Coordinated changes in the way in which intensive care research is regulated, for example the use of centralised institutional review boards to approve larger multi-centre trials, may also serve to improve efficiency.

Research of any kind requires financial resources, and a disproportionate amount of money is spent on patient care in the ICU relative to research to support advances in the field.⁴⁹ With a history of disappointing results in some areas of intensive care medicine,⁵⁰⁻⁵² the pharmaceutical industry may be increasingly hesitant to support large RCTs without some reassurance of a successful outcome. Therefore, the aim of translational research should be to identify areas in which an investment in large RCTs is likely to be worthwhile.¹¹ In the meantime, professional societies with an interest in this area may need to play a larger role in supporting translational research studies.

Clinical research efforts in both oncology and haematology over the past two decades have been successful in part because participation in clinical trials has become a routine component of clinical management. To ensure further progress in intensive care medicine, physicians should aim to include every ICU patient in at least one clinical trial.

Innovation

Future research will need to develop models that can accommodate both the clinical complexity and the multimodal interventions that are often required to treat critically ill patients. Electronic simulation of some conditions provides the opportunity to experiment with innovative treatment or management strategies without putting patients at risk. The use of biomarkers in the clinic is rapidly changing patient management in many areas of medicine and is likely to do so in the ICU setting, such as septic patients,⁵³⁻⁵⁷ as well.

The use of so-called electronic or tele-ICUs has gained in popularity, particularly in the United States, and is likely to continue to support patient care for units in remote areas, rapid response teams in the field and institutions that do not maintain around-the-clock intensive care staff.⁵⁸⁻⁶¹ Institutions and countries with limited resources have also begun to develop means by which to perform collaborative research using electronic networks such as registry databases and surveys, which facilitate the collection and comparison of larger numbers of intensive care units and patients. This type of research will contribute to a global picture of ICU management and support efforts to establish a uniform standard of care. Collaborative projects between individual national or regional professional societies can also be enhanced using electronic networks.

Health economic implications

Medical need

The conflict between rising health care costs, the availability of complex medical procedures, increasing demand created by ageing populations and limited resources may require changes in the allocation as well as the management of health care. While extreme medical measures may be applied to any patient, independent of the cost or likely benefit, a rational balance must be achieved between the level of care that is possible and that which is appropriate to the individual situation. Such ethical considerations are delicate to approach, awkward to discuss and preferentially avoided by both individuals and policy makers. Unfortunately, intensive care patients, their families and medical caregivers are often confronted with end-of-life decisions that require a rapid consensus.

Some of the awkwardness and insecurity associated with health care decisions for critically ill patients could be alleviated by increasing awareness of the necessity for individuals to contemplate and discuss the options and consequences of intensive medical care and clearly document their preferences before the medical need arises.⁶² One consideration for both individuals and societies is the personal and economic costs compared to the likely benefits to be achieved by a particular intervention. Age, life situation, the type of likely disability to be expected and longer-term quality of life issues all factor into treatment decisions that look beyond simple mortality.

Economic reality

Because a large proportion of societal resources in many countries are spent on critical care medicine,^{13,63,64}

physicians and institutions often find themselves faced with pressure to reduce costs by any means.⁶⁵ Research advances in intensive care medicine reflect progress in medical care as a whole; therefore more, rather than less, investment to support innovation, increase efficiency and improve patient outcomes is needed and might well achieve the same economic goals in the long run.⁶⁶ Unfortunately, the bodies that generally support research are not necessarily the same communities that may benefit if a patient can be fully rehabilitated, however, carefully designed health-economic research can lend support to these arguments by showing the relationships between the risk of mortality and morbidity, cost of care in the ICU, cost of long-term care if the patient survives with sequelae, negative cost if the patient is partially or fully rehabilitated and quality of life measures.^{39,67,68}

Medical advances require the synergistic efforts of physicians, patients, regulatory bodies and industrial partners. Without economic incentives to develop new products and cooperation in bringing these products into clinical use, industrial interests may focus on other areas of medicine that present lower thresholds to be overcome.

While medical advances may ultimately reduce the direct and indirect costs of critical care medicine, structural changes may contribute more immediately to savings. By identifying patients likely to require intensive care and initiating treatment early, ICU stays may be shortened or avoided entirely.⁶⁷⁻⁶⁹ Particularly in countries or regions with limited resources, the definition of a minimum level of care that should be available to all who require it would provide the basis on which policy makers can base allocation of the resources that are available. Medicare, the health care reimbursement system for the elderly in the United States, plans to withhold reimbursement from hospitals that do not implement, assess and adhere to minimum quality standards.⁷⁰ Government agencies and contributors of economic support could use similar tools to ensure the implementation of a minimum level of critical care.

Professional societies and institutions: leadership roles at the macro and micro levels

Professional scientific societies

One of the major functions of professional medical or scientific societies is to provide a link between physicians and the society at large, represented by its political bodies. Individual physicians are affiliated with institutional and national organisations, which can in turn cooperate with regional, continental and global organisations, the collaborative efforts of which are more likely to produce results at the level of public policy than individual smaller organisations. Aside from patient advocacy organisations, scientific societies also indirectly represent patient interests, thereby providing a voice for the patient community.

Scientific societies also serve as a structure within which physicians and industry can meet to exchange knowledge and research advances and ensure a standardised level of high-quality care. The Declaration of Vienna, generated by the European Society of Intensive Care Medicine (ESICM)

and signed by a long list of national and international intensive care organisations, outlines the principles that should support patient safety and quality of care, including measures to avoid human error, optimisation of existing treatment modalities, processes and careful monitoring of new medications and technologies.¹⁰ Professional societies also have an important function in defining and promoting a universal minimum standard of care that should be implemented with the support of government policy makers.

Professional scientific societies can play a leading role in working to achieve recognition of intensive care medicine as a primary medical specialty as discussed above at the European level and beyond. Leadership will also be required in the definition and standardisation of intensive care training, ensuring both efficiency and quality.⁷¹

Medical institutions

Leadership by scientific societies begins with an active collaboration between intensive care specialists and other medical specialties within each institution. Intensivists are ideally situated to coordinate activities from different specialties and encourage an atmosphere of open cooperation, especially in crisis situations.^{36,72}

Medical institutions have an important role to play in the establishment of collaborations to ensure a high level of patient care, reduced costs and improved patient outcomes (www.ihl.org).⁶⁶ These cooperative efforts may include quality assurance monitoring, scientific exchange or the sharing of expertise using electronic networks. One tool that may be required to achieve this goal is a common language which defines an ICU, an ICU patient, and a patient who should be admitted to the ICU; these definitions can then be universally applied to both outcome and quality assessment research. The application of scientific principles of peer review to quality assurance assessments may be beneficial and could be coordinated by institutional, governmental or scientific bodies.

The social role and visibility of intensive care medicine

Support for the maintenance and further development of intensive care medicine may be improved by increasing public awareness of the need for high-quality critical care services. Critical illness is an integral part of everyday life for society as a whole but one that most individuals prefer not to think about until confronted with a need⁶²; it is therefore often ignored by the population at large and its political representatives.

The perception of intensive care medicine among the general public is often negative, with critical care regarded in close association with death. This image reflects the fact that few members of society at large have a detailed awareness of the services provided by an ICU, the contributions of the medical personnel and especially the high rates of treatment success.⁷³ The highly technical nature of many interventions may also exert an intimidating effect. Public relations campaigns using simple messages that aim to create a more realistic image of post-ICU survival with and

without disabilities may improve the way in which critical care medicine is viewed and valued.^{74,75} Efforts to educate political representatives about the contributions high-quality intensive care medicine can make to society as a whole may also be required. We can show these efforts in the next websites:

<http://www.semicyuc.org/ciudadanos>
<http://www.life-priority.com/>
<http://www.fepimcti.org/>
<http://www.esicm.org/>
<http://www.semicyuc.org/sites/default/files/santanderstatement.english.pdf>
<http://www.world-critical-care.org/>
<http://www.world-sepsis-day.org/>

Different sorts of mass media may be effectively used to increase awareness and improve the prestige of intensive care medicine. Prominent persons with a high level of social impact and who require critical care services can be engaged after recovery from their critical illness to serve as positive examples or spokespersons for the cause. Intensive care physicians and other medical personnel can play an important role in providing the public with information about their work, for example, an ongoing effort aims to establish a worldwide "Sepsis Day" (www.world-sepsis-day.org). Continued efforts to encourage lay persons to learn CPR may provide further opportunities for interaction and create advocacy. Social media and patient "survivor" organisations might also contribute to greater awareness of the service to individuals and societies provided by critical care medicine.

An inherent value conflict frequently arises between the formal aim of critical care medicine to preserve life and the personal and societal consequences of survival with sequelae. Hospital administrators, payors and governmental bodies often require justification for the high cost of intensive care medicine in terms of morbidity and quality measures. The criteria applied and priorities defined by the patient community that legitimise the existence of ICU services, however, may be entirely different. For the individual patient, the 28-day survival that is used as a standard for many assessments may be less important than measures of long-term quality of life. Future research needs to examine the quality of life and (health) economic consequences that arise when patients survive with disabilities, and societies as a whole will need to develop policies and mechanisms with which to better manage this value conflict.

Conclusions

Access to high-quality intensive care medicine should be ensured by establishing a uniform standard of care, key competencies for physician training and the availability of an adequate number of qualified physicians to meet demand. Physicians, professional scientific societies and policy makers will need to work together to ensure advances in patient care and to find a balance between evolving medical and economic demands.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.medin.2012.12.004>.

References

- Ali NA, Hammersley J, Hoffmann SP, O'Brien Jr JM, Phillips GS, Rashkin M, et al. Continuity of care in intensive care units: a cluster-randomized trial of intensivist staffing. *Am J Respir Crit Care Med*. 2011;184:803–8.
- Azoulay E, Mancebo J, Brochard L. Surviving the night in the ICU: who needs senior intensivists? *Am J Respir Crit Care Med*. 2010;182:293–4.
- Barrett H, Bion JF. An international survey of training in adult intensive care medicine. *Intensive Care Med*. 2005;31:553–61.
- Garland A, Roberts D, Graff L. Twenty-four-hour intensivist presence: a pilot study of effects on intensive care unit patients, families, doctors, and nurses. *Am J Respir Crit Care Med*. 2012;185:738–43.
- Mancebo J, Hall J. Is the doctor in? Views on the deployment of intensivists from both sides of the Atlantic. *Am J Respir Crit Care Med*. 2012;185:696–7.
- Lindell KO, Chlan LL, Hoffman LA. Nursing perspectives on 24/7 intensivist coverage. *Am J Respir Crit Care Med*. 2010;182:1338–40.
- Valentin A, Ferdinande P. Improvement EWGoQ. Recommendations on basic requirements for intensive care units: structural and organizational aspects. *Intensive Care Med*. 2011;37:1575–87.
- Vincent JL, Suter P, Bihari D, Bruining H. Organization of intensive care units in Europe: lessons from the EPIC study. *Intensive Care Med*. 1997;23:1181–4.
- Rothen HU, Stricker K, Einfalt J, Bauer P, Metnitz PG, Moreno RP, et al. Variability in outcome and resource use in intensive care units. *Intensive Care Med*. 2007;33:1329–36.
- Moreno RP, Rhodes A, Donchin Y. European Society of Intensive Care, patient safety in intensive care medicine: the Declaration of Vienna. *Intensive Care Med*. 2009;35:1667–72.
- Murthy S, Wunsch H. Clinical review: International comparisons in critical care – lessons learned. *Crit Care*. 2012;16:218.
- Vincent JL. Need for intensivists in intensive-care units. *Lancet*. 2000;356:695–6.
- Poalillo FE, Jimenez EJ, Falk J. Critical care in the United States of America. *Crit Care Clin*. 2006;22:447–55, ix.
- Cox CE, Carson SS, Ely EW, Govert JA, Garrett JM, Brower RG, et al. Effectiveness of medical resident education in mechanical ventilation. *Am J Respir Crit Care Med*. 2003;167:32–8.
- Rubulotta F, Moreno R, Rhodes A. Intensive care medicine: finding its way in the "European labyrinth". *Intensive Care Med*. 2011;37:1907–12.
- CoBaTr ICEC. The educational environment for training in intensive care medicine: structures, processes, outcomes and challenges in the European region. *Intensive Care Med*. 2009;35:1575–83.
- CoBaTr ICEC. International standards for programmes of training in intensive care medicine in Europe. *Intensive Care Med*. 2011;37:385–93.
- CoBaTr ICEC, Bion JF, Barrett H. Development of core competencies for an international training programme in intensive care medicine. *Intensive Care Med*. 2006;32:1371–83.
- Harper A, Van Eaton E, Payne T. Information Scientists in the ICU: a Key to Improved Adherence to Clinical Guidelines. *AMIA Annual Symposium*. 2010:1075.
- Conditions techniques de fonctionnement des activités de soins en réanimation Code de la Santé publique. Livre 1er, titre II, chapitre IV, section 1, Art D6124-27 à 34–35.
- Décret no 2006-72 du 24 janvier 2006 relatif à la réanimation dans les établissements de santé et modifiant le code de la santé publique (dispositions réglementaires).
- Décret no 2006-74 du 24 janvier 2006 relatif aux conditions techniques de fonctionnement auxquelles doivent satisfaire les établissements de santé pour pratiquer les activités de réanimation pédiatrique et de surveillance continue pédiatrique.
- Direction Générale de la Santé. Circulaire DGS/DH/4B/N°280 du 7 Février. Annexe 2: programme technique d'une unité de réanimation et plateau technique d'un service de réanimation; 1989.
- Comité de Coordination de la Réanimation, Référentiels de compétences et d'aptitudes du médecin réanimateur. *Réanimation*. 2011;20:S705–24.
- van Mook WN, de Grave WS, Gorter SL, Muijtjens AM, Zwaveling JH, Schuwirth LW, et al. Fellows' in intensive care medicine views on professionalism and how they learn it. *Intensive Care Med*. 2010;36:296–303.
- CoBaTr ICEC. The views of patients and relatives of what makes a good intensivist: a European survey. *Intensive Care Med*. 2007;33:1913–20.
- Pastores SM, O'Connor MF, Kleinpell RM, Napolitano L, Ward N, Bailey H, 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;39:2540–9.
- Ward NS, Read R, Afessa B, Kahn JM. Perceived effects of attending physician workload in academic medical intensive care units: a national survey of training program directors. *Crit Care Med*. 2012;40:400–5.
- Needleman J, Buerhaus P, Pankratz VS, Leibson CL, Stevens SR, Harris M. Nurse staffing and inpatient hospital mortality. *N Engl J Med*. 2011;364:1037–45.
- Chudgar SM, Cox CE, Que LG, Andolsek K, Knudsen NW, Clay AS. Current teaching and evaluation methods in critical care medicine: has the Accreditation Council for Graduate Medical Education affected how we practice and teach in the intensive care unit? *Crit Care Med*. 2009;37:49–60.
- Van Eaton EG, Horvath KD, Pellegrini CA. Professionalism and the shift mentality: how to reconcile patient ownership with limited work hours. *Arch Surg*. 2005;140:230–5.
- Kaplan LJ, Shaw AD. Standards for education and credentialing in critical care medicine. *JAMA*. 2011;305:296–7.
- Besso J, Bhagwanjee S, Takezawa J, Prayag S, Moreno R. A global view of education and training in critical care medicine. *Crit Care Clin*. 2006;22:539–46 x–xi.
- Carson SS, Stocking C, Podsadecki T, Christenson J, Pohlman A, MacRae S, et al. Effects of organizational change in the medical intensive care unit of a teaching hospital: a comparison of 'open' and 'closed' formats. *JAMA*. 1996;276:322–8.
- Multz AS, Chalfin DB, Samson IM, Dantzker DR, Fein AM, Steinberg HN, et al. A "closed" medical intensive care unit (MICU) improves resource utilization when compared with an "open" MICU. *Am J Respir Crit Care Med*. 1998;157:1468–73.

36. Rhodes A, Moreno RP, Chiche JD. ICU structures and organization: putting together all the pieces of a very complex puzzle. *Intensive Care Med.* 2011;37:1569–71.
37. Wallace DJ, Angus DC, Barnato AE, Kramer AA, Kahn JM. Nighttime intensivist staffing and mortality among critically ill patients. *N Engl J Med.* 2012;366:2093–101.
38. Pronovost PJ, Jenckes MW, Dorman T, Garrett E, Breslow MJ, Rosenfeld BA, et al. Organizational characteristics of intensive care units related to outcomes of abdominal aortic surgery. *JAMA.* 1999;281:1310–7.
39. Hanson 3rd CW, Deutschman CS, Anderson 3rd HL, Reilly PM, Behringer EC, Schwab CW, et al. Effects of an organized critical care service on outcomes and resource utilization: a cohort study. *Crit Care Med.* 1999;27:270–4.
40. Blunt MC, Burchett KR. Out-of-hours consultant cover and case-mix-adjusted mortality in intensive care. *Lancet.* 2000;356:735–6.
41. Reynolds HN, Haupt MT, Thill-Baharozian MC, Carlson RW. Impact of critical care physician staffing on patients with septic shock in a university hospital medical intensive care unit. *JAMA.* 1988;260:3446–50.
42. Kumar K, Zarychanski R, Bell DD, Manji R, Zivot J, Menkis AH, et al. Cardiovascular Health Research in Manitoba Investigator G, Impact of 24-hour in-house intensivists on a dedicated cardiac surgery intensive care unit. *Ann Thorac Surg.* 2009;88:1153–61.
43. 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;288:2151–62.
44. Gajic O, Afessa B, Hanson AC, Krpata T, Yilmaz M, Mohamed SF, 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;36:36–44.
45. Kahn JM, Goss CH, Heagerty PJ, Kramer AA, O'Brien CR, Rubenfeld GD. Hospital volume and the outcomes of mechanical ventilation. *N Engl J Med.* 2006;355:41–50.
46. Cook DA, Fleming J. Understanding the shared responsibility in assessing the benefits and risks of research for the vulnerable critical care patient. *Crit Care Med.* 2009;37:1169–70.
47. Tonelli MR, Curtis JR, Guntupalli KK, Rubenfeld GD, Arroliga AC, Brochard L, et al. Group AASW, An official multi-society statement: the role of clinical research results in the practice of critical care medicine. *Am J Respir Crit Care Med.* 2012;185:1117–24.
48. Ranieri VM, Thompson BT, Barie PS, Dhainaut JF, Douglas IS, Finfer S, et al. Group P-SS, Drotrecogin alfa (activated) in adults with septic shock. *N Engl J Med.* 2012;366:2055–64.
49. Coopersmith CM, Wunsch H, Fink MP, Linde-Zwirble WT, Olsen KM, Sommers MS, et al. A comparison of critical care research funding and the financial burden of critical illness in the United States. *Crit Care Med.* 2012;40:1072–9.
50. Valentin A, Capuzzo M, Guidet B, Moreno RP, Dolanski L, Bauer P, et al. Research Group on Quality Improvement of European Society of Intensive Care M, Sentinel Events Evaluation Study I, Patient safety in intensive care: results from the multinational Sentinel Events Evaluation (SEE) study. *Intensive Care Med.* 2006;32:1591–8.
51. Wright D, Mackenzie SJ, Buchan I, Cairns CS, Price LE. Critical incidents in the intensive therapy unit. *Lancet.* 1991;338:676–8.
52. Donchin Y, Gopher D, Olin M, Badihi Y, Biesky M, Sprung CL, et al. A look into the nature and causes of human errors in the intensive care unit. *Crit Care Med.* 1995;23:294–300.
53. Foushee JA, Hope NH, Grace EE. Applying biomarkers to clinical practice: a guide for utilizing procalcitonin assays. *J Antimicrob Chemother.* 2012.
54. Jolivet P, Christen G, Seematter G, Que YA, Eggimann P. Usefulness of biomarkers of sepsis in the ICU. *Rev Med Suisse.* 2011;7:2430–4.
55. Peres Wingeyer SD, Cunto ER, Nogueras CM, San Juan JA, Gomez N, De Larranaga GF. Biomarkers in sepsis at time zero: intensive care unit scores, plasma measurements and polymorphisms in Argentina. *J Infect Dev Ctries.* 2012;6:555–62.
56. Reinhart K, Meisner M. Biomarkers in the critically ill patient: procalcitonin. *Crit Care Clin.* 2011;27:253–63.
57. Venet F, Lepape A, Monneret G. Clinical review: flow cytometry perspectives in the ICU - from diagnosis of infection to monitoring of injury-induced immune dysfunctions. *Crit Care.* 2011;15:231.
58. Lilly CM, Cody S, Zhao H, Landry K, Baker SP, McIlwaine J, et al. University of Massachusetts Memorial Critical Care Operations G, Hospital mortality, length of stay, and preventable complications among critically ill patients before and after tele-ICU reengineering of critical care processes. *JAMA.* 2011;305:2175–83.
59. Lilly CM, Thomas EJ. Tele-ICU: experience to date. *J Intensive Care Med.* 2010;25:16–22.
60. 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, 329 e321-326.
61. Wilcox ME, Adhikari NK. The effect of telemedicine in critically ill patients: systematic review and meta-analysis. *Crit Care.* 2012;16:R127.
62. Fried TR, Bradley EH, Towle VR, Allore H. Understanding the treatment preferences of seriously ill patients. *N Engl J Med.* 2002;346:1061–6.
63. Edbrooke DL, Minelli C, Mills GH, Iapichino G, Pezzi A, Corbella D, et al. Implications of ICU triage decisions on patient mortality: a cost-effectiveness analysis. *Crit Care.* 2011;15:R56.
64. Carrasco G, Pallares A, Cabre L. Cost of quality in Intensive Medicine. Guidelines for clinical management. *Med Intensiva.* 2006;30:167–79.
65. Angus DC, Kelley MA, Schmitz RJ, White A, Popovich Jr J. Committee on Manpower for P, Critical Care S, 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;284:2762–70.
66. Pronovost PJ, Needham DM, Waters H, Birkmeyer CM, Calinawan JR, Birkmeyer JD, et al. Intensive care unit physician staffing: financial modeling of the Leapfrog standard. *Crit Care Med.* 2004;32:1247–53.
67. Wunsch H, Angus DC, Harrison DA, Linde-Zwirble WT, Rowan KM. Comparison of medical admissions to intensive care units in the United States and United Kingdom. *Am J Respir Crit Care Med.* 2011;183:1666–73.
68. Banerjee R, Naessens JM, Seferian EG, Gajic O, Moriarty JP, Johnson MG, et al. Economic implications of nighttime attending intensivist coverage in a medical intensive care unit. *Crit Care Med.* 2011;39:1257–62.
69. Kastrup M, Seeling M, Barthel S, Bloch A, le Claire M, Spies C, et al. Effects of intensivist coverage in a post-anaesthesia care unit on surgical patients' case mix and characteristics of the intensive care unit. *Crit Care.* 2012;16:R126.
70. Patient Protection and Affordable Care Act: Title III—Improving the Quality and Efficiency of Health Care; Subtitle A—Transforming the Health Care Delivery System; Part 1—Linking Payment to Quality Outcomes Under the Medicare Program (2010).
71. Bion J, Evans T. The influence of health care reform on intensive care: a UK perspective. *Am J Respir Crit Care Med.* 2011;184:1093–4.

72. Rhodes A, Chiche JD, Moreno R. Improving the quality of training programs in intensive care: a view from the ESICM. *Intensive Care Med.* 2011;37:377-9.
73. Palencia Herrejon E, Gonzalez Diaz G, Mancebo Cortes J. The future of intensive medicine. *Med Intensiva.* 2011;35:232-5.
74. Iwashyna TJ. Survivorship will be the defining challenge of critical care in the 21st century. *Ann Intern Med.* 2010;153:204-5.
75. Angood PB. Right care, right now – you can make a difference. *Crit Care Med.* 2005;33:2729-32.