Improving the ICU*
Part 2
Allan Garland, MD, MA

ICUs are a vital but troubled component of modern health-care systems. Improving ICU performance requires that we shift from a paradigm that concentrates on individual performance, to a systems-oriented approach that emphasizes the need to assess and improve the ICU systems and processes that hinder the ability of individuals to perform their jobs well. This second part of a two-part treatise establishes a practical framework for performance improvement and examines specific strategies to improve ICU performance, including the use of information systems.

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Key words: health services research; ICU; information systems; management quality circles; organization and administration; quality of health care; total quality management

Abbreviations: APACHE = acute physiology and chronic health evaluation; CADS = computer-aided decision support; CME = continuing medical education; EBBP = evidence-based best practice; PI = performance improvement; QA/QI = quality assurance/quality improvement; TQM = total quality management

Learning Objectives: 1. Improving ICU performance involves sequential steps of: (1) measuring relevant indices of ICU performance, (2) making interventions aimed at improving those measures, and then (3) remeasuring the indices to document the effect of the intervention. 2. Every ICU should have a systems-oriented Performance Improvement Program that is multidisciplinary and inclusive and has the support of the hospital and ICU leadership needed to succeed if ICU performance is to improve.

The previous part of this two-part review discussed methods for defining and measuring ICU performance. This second part of the review establishes the conceptual and practical features of an effective framework for performance improvement (PI), and examines specific strategies for improving ICU performance.

FRAMEWORK FOR IMPROVING ICU PERFORMANCE

Improving ICU performance involves the following sequential steps: (1) measuring indexes of ICU performance relevant to the topic or area of interest; (2) making interventions aimed at improving those measures; and then (3) remeasuring the indexes to document the effect of the intervention. This section will develop a framework for understanding the scope and nature of change.

There are two main domains of change for improving ICU performance. These are the technical components of ICU care and the organizational features of the ICU. Medical training and literature almost exclusively emphasize the technical. Thus, the attention of clinicians is dominated by choices such as ventilator settings, vasopressors, imaging modalities, and the angle of the bed during tube feeding. While these are important, changes to ICU structures and processes are given little attention but are at least as significant. Specifically, it requires making organizational changes to ensure that the appropriate technical choices are applied uniformly.

A simple but powerful framework for addressing technical interventions to improve care in individual ICUs has been adapted from Berwick. He tells us that we must (1) know what works, (2) use what works, and (3) do well what works.

Knowing what works amounts to reading, understanding, and appropriately interpreting the medical literature. Besides the time commitment this represents, we face three important barriers in this effort. First are the limits of current knowledge. With

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estimates that only 10 to 20% of medical practices are supported by rigorous studies, estimates that only 10 to 20% of medical practices are supported by rigorous studies, in most areas we simply do not know what works. A corollary is that many diagnostic and therapeutic interventions are used in the absence of clearly demonstrated efficacy. Second, many or most studies utilize surrogate or secondary end points instead of ones that are directly relevant. The value of such data is questionable, as it is unjustified to assume that a “beneficial” effect on a surrogate end point will improve relevant outcomes. Indeed, the literature is replete with counterexamples. For instance, inhaled nitric oxide improves arterial oxygenation in ARDS patients but does not reduce mortality. Third, understanding and correctly interpreting the literature are impeded because many physicians lack the statistical and logical skills needed for such critical evaluation.

As problematic as is our state of knowledge, the single most important deficiency in health care today is that we frequently fail to adhere to evidence-based best practices (EBBPs). Even simple, universally accepted practices such as therapy with aspirin and β-adrenergic blockers after acute myocardial infarction are often forgotten, leading to many unnecessary deaths. Seminal studies in the most widely read journals often do not change practice. To address this problem, to ensure that all patients uniformly receive every applicable EBBP requires a paradigm shift. The historical, physician-centered paradigm holds individual physicians entirely responsible and free to guide care as they will, regardless of whether their choices concur with best practices, and independent of outside oversight except for the risk of malpractice suits. Such a system, in which patients are entirely dependent on the knowledge, memory, and best intentions of their physicians, is not rational, and is not in the best interests of patients or clinicians. This is not an indictment of physicians. There are too many important things to know and remember to reasonably expect that individual physicians will always do all the right things. Instead, it is necessary to create structures and implement processes in the ICU that ensure that every patient, every time, receives every applicable EBBP. These efforts are commonly described as creating an environment of “patient safety.”

But ensuring the uniform application of EBBPs is not the only reason we need to reengineer ICU organization. ICUs are complex systems, and it has been known for many decades in industry that “the structure of a system significantly determines the performance of the system.” By emphasizing that most opportunities for improving performance derive from altering the system itself, Deming, Juran and Godfrey, and Walton created the most effective known method of improving the performance of complex systems. This methodology of PI, often called total quality management (TQM), applies equally well to service industries such as health care, and tells us that making changes in ICU organization offers opportunities to improve performance that are equal or greater than the gains from purely technical improvements. Although this systems engineering approach is largely alien to health care, it is the recommended method of PI. Six-Sigma, another version of systems-based PI, explicitly targets reducing errors and defects to < 3.4 per million.

These concepts originated with the seminal recognition that only 15% of errors and problems are a result of inadequate performance by individuals. Rather, 85% of the opportunities for PI relate to flaws in institutional systems and processes that hinder the ability of individuals to perform their jobs well. Thus, it is necessary to improve the systems that are used to deliver ICU care. This is effected by a continuous and relentless process of examining and improving structures and processes for the specific purpose of improving relevant outcomes. The process is driven by systemically collected and appropriately interpreted data on such outcomes.

Within this paradigm, every structure, process, activity, function, and relationship, clinical and nonclinical, that influences the ICU in any way is open to scrutiny and change. Table 1 contains a list of areas for consideration. Examples of altering the role of personnel include transferring lower level patient-care activities from highly trained nurses to less highly trained nurse extenders, and shifting some of the responsibilities of ventilator weaning from physicians to respiratory therapists.

Because they relate to the numerous complex interrelationships that comprise complex organizations, the mechanisms by which improving the organization improves performance will not always be easy to comprehend, but they go beyond simply increasing the use of EBBPs. Examples of improving outcomes via structural changes will aid in making these concepts more concrete. Evans and colleagues developed a computerized antibiotic consultant to assist physicians in the selection of appropriate empiric antibiotics. After making it available at every hospital workstation, the adequacy of the initial antibiotic choice rose from 77 to 94%, and the delay in ordering adequate antibiotics was reduced. Leape and coworkers altered the structure of morning work rounds in an ICU to include the participation...
of a senior pharmacist. This simple structural change reduced avoidable drug errors by 65%. Australian investigators reported that a variety of relevant outcomes were dramatically improved by having a team from the ICU go to evaluate ward patients who had experienced acute changes in status that did not yet warrant transfer to the ICU. Bernstein identified the fact that what appeared to be the ultimate in individual human error, surgery on the wrong side of the body, actually represented inadequacy of the system. What is needed instead is the evolution of new systems and processes that match the new environment. Obviously, the nature of ICU patients and ICU care, as well as the size of ICUs, has changed dramatically over the years. Projections show that this growth will continue as the population ages. But the organization of most ICUs is not the result of thoughtful planning driven by outcomes data, but rather reflects historical origins and subsequent growth by accretion. As a result, ICU organization is frequently inadequate to efficiently support the current demands, although this may not be evident to those who work there.

Systems-oriented PI is very different from the quality assurance/quality improvement (QA/QI) method that is still used in many ICUs. QA/QI responds to adverse events, errors, or other problems that are noted. Obviously, problems are noted only after they occur, and so QA/QI is reactive instead of proactive. Leadership then convenes a group, which usually is composed of supervisory-level personnel, to do “root cause analysis.” Most commonly, this takes the form of trying to identify the errors made by individuals that allowed the problem to occur. The Morbidity and Mortality Conference held regularly in most institutions is an example of this flawed approach to improving performance.

In fact, both components of QA/QI, the identification of problems/errors and the root cause analysis, are seriously deficient. QA/QI relies on occurrence screening to identify problems. This can take the form of medical record reviews, incident reporting, or the use of prospective “indicators.” An example of an indicator is a document that bedside nurses complete when a mechanically ventilated patient is inadvertently extubated. Retrospective occurrence screening using the medical record is limited by the many inadequacies of that document as a window.

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Table 1—TQM in the ICU: Some Potential Areas for Change

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
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<tbody>
<tr>
<td>The need for a function</td>
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<td>How a function is performed</td>
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<td>Which personnel perform a function</td>
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<td>The functional relationships among personnel</td>
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<tr>
<td>How personnel communicate with each other</td>
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<tr>
<td>The existence, frequency, and nature of ICU rounds</td>
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<tr>
<td>The role of equipment (including computers)</td>
<td></td>
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<tr>
<td>The interactions between personnel and equipment (including computers)</td>
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<tr>
<td>The administrative, medical, and functional structures of the ICU</td>
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</tr>
<tr>
<td>The administrative, medical and functional structures of ICU personnel</td>
<td></td>
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<tr>
<td>The rules governing, for example, responsibilities, and practice privileges</td>
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<tr>
<td>The training, skills, competence, knowledge, and experience of personnel</td>
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<tr>
<td>The scheduling of personnel, including shift coverage, night coverage, and weekend coverage</td>
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<tr>
<td>Workload per worker</td>
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<tr>
<td>The availability of supportive technology in the hospital (e.g., advanced imaging)</td>
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<td>The choice of products and services used in the ICU</td>
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<td>No. of ICU beds</td>
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<tr>
<td>Physical layout of the ICU</td>
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<td>Availability of intermediate care and ward beds</td>
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<td>Making outcomes data available to the ICU</td>
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<tr>
<td>Making outcomes data available to the public</td>
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into actual events. Incident reporting is also an inadequate method of identifying adverse events in hospitals. Only a small fraction of adverse drug events are identified by incident reports, and a study of direct observation in an ICU estimated that only half of the errors were reported. So-called audit filters, groups of prospectively defined and collected occurrence screens, are of low sensitivity. Even prospective occurrence screening can obscure the magnitude of a problem due to the changes individuals make in their behavior when they know that they are being watched, which is called the Hawthorne effect. In addition, medical care is so complex and variable that screening for even a large list of specific occurrences is unlikely to have much impact on overall performance.

Root cause analysis is a process in which medical professionals who are knowledgeable in the area under consideration perform a detailed review of an adverse event to identify its causes. As expressed by Berwick:

> Even when hospitals find ways to notice the injuries to their patients... they cling to unsound but deeply entrenched beliefs... [that] retrospection will allow them to find a single root cause, even though in fact the very idea of a “root cause” is misleading, since most system failures result from complex interactions between latent failures... and specific actions; conclusions about root causes are often illusions created by hindsight bias.

One reason for the ineffectiveness of root cause analysis is that there is very poor agreement among experts about the causes, and even the occurrence, of adverse events. The poorest agreement is for identifying management errors or negligence as the cause of adverse events.

Instead of identifying and improving structures and processes, the response of many institutions to a serious adverse event is to add additional layers aiming to eliminate the possibility for that particular problem. This frequently creates an even more complex and maladaptive system that becomes more prone to a variety of other mishaps.

QA/QI is about meeting minimum standards, detecting poor performance by individuals, and taking punitive actions. It is “at best inefficient, and at worst a formula for failure.” Despite prolonged and extensive use, there are almost no published data showing that health care is improved or behavior changed by PI methods that target individuals rather than structures and processes. Chassin concluded that there is a “paucity of evidence that, as a whole, previous quality-assurance programs actually did anything to improve outcomes for patients.”

The ICU is an opportune place to establish a comprehensive, systems-oriented PI environment. Although the details of implementing such a program are beyond the scope of this review, some key concepts should be mentioned. First, these efforts require substantial commitments of leadership, resources, training, and time. Investments often must be made in data gathering and analysis capabilities. Second, efforts must be made to ensure that personnel do not fear that discovery of problems, even of human error, will lead to retaliation. Third, the process must be inclusive of the full range of personnel who actually do the work. TQM is not controlled by management-level personnel. Its functional unit is the multidisciplinary “quality team” that replaces managerial authority with a participatory approach that emphasizes collective rather than individual responsibility.

The role of analyzing individual adverse events requires mention. As discussed in detail in Part 1 of this review, such analysis cannot serve as the primary method of PI. However, the discussion and analysis of individual events can effectively focus the attention of a quality team, and can assist in identifying the structures and processes that require alteration. For this reason, it is still important that ICUs work to identify individual errors and other problems.

There has been much discussion recently of improving error reporting in health care by creating a nonpunitive environment based on the principles of TQM. Such strategies have long been in place in the airline industry and elsewhere. This has created institutional and corporate cultures that successfully encourage the reporting of adverse events and “near misses,” and effectively respond to such events. These institutional cultures are successful precisely because they recognize that errors and adverse events are almost always a result of poorly designed systems that require modification rather than bad people who require punishment. Remarkable improvements in safety and performance have resulted. Within this framework, which is known in aviation as the crew resource management, it has been shown that more effective flight crews spend more time discussing threats and errors. Our efforts to improve ICU performance have much to learn from these models.
Teamwork in the ICU is problematic; there are large disparities between the perceptions of ICU physicians and nurses about the adequacy of teamwork and collaboration.64–67 A diametric opposite of aviation, medicine is an industry in which substantial pressures exist to cover up mistakes, thereby losing the opportunity to address their actual causes.64

There are a number of significant challenges to implementing systems-based PI in medicine. Among the largest impediments is resistance from physicians. Physicians receive little or no education in these concepts,14,68 frequently respond to objective results about performance by insisting that the data are inaccurate, and usually resist proposals that are perceived as abridging their professional autonomy.10 While there are a number of ways to try and change physicians’ habits and performance,69 the evidence amply demonstrates that this is difficult.70–72 Nonetheless, gaining physician acceptance and participation in these efforts is necessary. Various strategies to achieve this goal have been discussed.32,59 One particular experience of note was the effort of the Cleveland Health Quality Choice consortium to gain provider and purchaser confidence for its hospital quality efforts.73 Adapting its approach to the problem of gaining physician confidence in system-based PI would emphasize the following: (1) a large-scale effort to incorporate large numbers of physicians in the process from the start, especially those who are considered to be opinion leaders; and (2) sensitivity to physicians’ concerns about the presentation of data in ways that could be perceived as dangerous or threatening to their practices. The role of vigorous physician leadership in this regard cannot be underestimated.55 Despite all the difficulties, successful examples of implementing systems-based PI efforts in the ICU are there for emulation.25,37

Recently, collaborative groups of health-care organizations, academics, and businesses have formed to help fill the evidence-based policy-making void that exists in US health care. For example, the Leapfrog Group15 is attempting to improve hospital outcomes for its employees by making high-intensity involvement of intensivists in ICUs a requirement for any hospital to contract with their health plans. Beyond this however, Leapfrog, the Institute for Healthcare Improvement,17 and the National Quality Forum74 are all striving to encourage hospitals to effectively implement specific evidence-based and consensus-based best practices.

**Specific Strategies To Improve Performance**

As discussed, the template for improving ICU performance is to measure relevant outcomes, make changes aimed at improving those outcomes, and then remeasure the outcomes to confirm improvement. The remainder of this article addresses specific strategies for change.

All efforts to improve ICU performance require changing its structures and processes. A modest but growing body of research has studied strategies to improve performance via organizational changes in health-care systems. These strategies range from simple to complex and address widely differing aspects of change. They fall loosely into the following two categories: (1) changes in structures and processes that are not directly related to the technical aspects of medical care; and (2) strategies to increase or improve the use of specific EBPPs.

The former are a diverse group of interventions. The latter include education, audit with feedback, clinical practice guidelines, reminders, order sets, computerization, and combinations of these interventions. The current literature in this area is sparse; there is an urgent need for more high-quality research. This section reviews much of the existing literature as it is applicable to ICUs.

Strategies found to be effective in research studies are convenient, ready-made tools that individual ICUs can adopt and are likely to be effective within their own TQM efforts. Of course, interventions found to be effective in one setting may not be effective elsewhere.75 Thus, while it is best if the efficacy of each new strategy is demonstrated by local data comparing outcomes before vs after implementation, there should be no hesitation in making changes that have credible literature support even if you do not have the resources needed to carefully validate their local efficacy. I believe it is far more dangerous to assume, without data, that your ICU is already performing at the highest possible level in all areas and therefore requires no changes.

**Changes to ICU Structures and Processes Not Directly Related to Specific Technical Aspects of Care**

There is a broad range of processes and structures that comprise any given ICU. Many of these, such as how pharmacists participate in daily ICU rounds, are concrete and easy to comprehend. Others, relating to the underlying social-professional structure of complex organizations are much less obvious but nonetheless have important implications.64,76,77 Table 2 summarizes a substantial portion of the existing literature in this area. The interested reader who uses the listed references for further information will note that evidence-based information is sparse for many of these topics, with conflicting data for some.
Multiple investigations78–82 have shown that outcomes are superior in closed ICU systems. However, the many organizational differences exist-

Table 2—Published Studies Assessing Outcomes Related to Structures or Processes

<table>
<thead>
<tr>
<th>Structure or Process</th>
<th>References</th>
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<tbody>
<tr>
<td>Open vs closed ICU structure</td>
<td>84, 85</td>
</tr>
<tr>
<td>24-h intensivist presence</td>
<td>155</td>
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<td>Length of shifts for intensivists</td>
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<td>Weekend cross-coverage by intensivists</td>
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<tr>
<td>Remotely located intensivist (telemedicine)</td>
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<tr>
<td>Length of shifts for house officers</td>
<td>150, 160</td>
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<tr>
<td>Nighttime cross-coverage by house officers</td>
<td>161</td>
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<tr>
<td>Use of a daily goals sheet for each patient</td>
<td>115</td>
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<td>Mobile ICU team to assess unstable ward patients</td>
<td>35, 36</td>
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<tr>
<td>Formation of a ventilator team</td>
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<td>Computerized nighttime cross-coverage signouts</td>
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<tr>
<td>Role of the ICU medical director</td>
<td>164</td>
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<tr>
<td>Availability of an intermediate care unit</td>
<td>165–167</td>
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<tr>
<td>Pharmacist participation in ICU rounds</td>
<td>34</td>
</tr>
<tr>
<td>Role of advanced nurse practitioners</td>
<td>168–171</td>
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<tr>
<td>Nurse/patient ratio</td>
<td>172–178</td>
</tr>
<tr>
<td>Supplying cost information to ordering physicians</td>
<td>179–181</td>
</tr>
<tr>
<td>Disallowing standing orders for diagnostic testing</td>
<td>105, 181, 182</td>
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<td>Infection control processes</td>
<td>183–185</td>
</tr>
<tr>
<td>Automated early identification of clustered infections</td>
<td>116, 117, 186</td>
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<tr>
<td>Dissemination of clinical performance data</td>
<td>187–191</td>
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<tr>
<td>Family visiting hours</td>
<td>192–195</td>
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<tr>
<td>Palliative and end-of-life care</td>
<td>196–201</td>
</tr>
<tr>
<td>Nurse-physician communication and other aspects of ICU “culture”</td>
<td>64, 76, 77, 105, 178, 202–206</td>
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</table>

The best studied of these topics addresses whether the ICU is “closed” or “open.” These terms refer to whether or not all of the patients in the ICU at a given time are under the care of a single attending physician. Multiple investigations78–82 have shown that outcomes are superior in closed ICU systems. However, the many organizational differences existing within the spectrum of closed (or open) ICUs,83 and the differences between the designs of these studies makes it difficult to clearly identify the origin of the observed differences in performance between open and closed ICUs. A systematic review84 on this topic avoided restrictive definitions by analyzing 26 studies according to whether intensivists were involved in a fashion rated as high intensity (defined as a closed ICU that was staffed by intensivists or in which a consultation by an intensivist was mandatory) or low intensity (defined as an ICU in which no intensivist was involved or in which intensivist consultation was elective). The high-intensity involvement of intensivists results in significantly lower mortality rates and shorter lengths of stay. After case-mix adjustment, none of the individual studies observed worse outcomes with more intensivist involvement in care. It is estimated that high-intensity involvement by intensivists for all ICU patients in the United States would save 54,000 lives per year.85

The kinds of changes listed in Table 2 are often challenging to implement. For many ICUs, the changes represent a radical paradigm shift. While some of them might be difficult for any given ICU to implement, many are not. As discussed extensively above, making progress in improving the performance of your ICU requires a genuine openness to new ideas and ways of doing things, and a commitment to beneficial change. These human factors must not keep us from doing what has been shown to work best. Within the limited scope of the current data, every ICU should evaluate this literature now and as it evolves, and should implement evidence-based structural changes that are feasible with available resources.

Strategies to Increase Use of EBBPs

Didactic educational interventions, such as conferences, rounds, meetings, and symposia, are the traditional method of teaching health-care practitioners how to optimally care for patients. Continuing medical education (CME) is a requirement for health professionals in most states in the United States and in industrialized countries. A systematic analysis86 of studies assessing the efficacy of traditional didactic CME found that the quality of these data are poor, with any benefit that is present being small and limited to CME interventions having interactive elements. Another analysis70 also concluded that passive educational methods did not improve physician performance or patient outcomes. Consistent with this, an interactive and participatory educational strategy is more effective at increasing physicians’ knowledge than is passive education.87 We must be careful in reading this literature, because the analyses88 that show more impressive gains from CME have, in fact, mixed didactic education with other modalities such as reminders or audit with feedback.

The term audit with feedback refers to a summary of the clinical performance of health care over a time interval that is then communicated back to practitioners. The feedback may be written, oral, or electronic, and can include recommendations for improvement or action. For example, the hospital could send to each staff physician a quarterly report identifying the number of patients that the physician cared for who had acute myocardial infarction, detailing the percentage of those who were promptly placed on β-blocking and antiplatelet drugs. The report could show these data from all the other physicians too,
which could be coded to be anonymous (or not). The conceptual basis for audit with feedback is the reasonable idea that professional performance will improve if well-meaning professionals know how well they are doing. Some systematic reviews98–103 have concluded that this body of literature is of poor quality, and that while audit with feedback appears to be useful, the effects are small. Isolated studies have, however, observed benefits from audit with feedback. In three medical ICUs, it led to economically relevant reductions in the length of stay for patients who were admitted to the hospital with chest pain, congestive heart failure, or syncope.91 A likely reason for the weak effects of audit with feedback is that it does not provide real-time information that is specific to the patient at hand. Indeed, a review70 of 26 studies found that audit with feedback was less effective than real-time reminders.

Practice guidelines represent attempts to increase the use of EBBPs by making available to clinicians a set of recommendations for care that incorporate them. Practice guidelines range from simple, to complex and comprehensive. They have been promulgated by professional organizations, governments, consulting firms, health maintenance organizations, hospitals, and other groups. The concept behind guidelines is the belief that EBBPs are omitted because clinicians are not aware of them. Many physicians harbor negative attitudes about practice guidelines,92 and numerous factors have been shown to influence their acceptance, utilization, and benefits. These include knowledge about their existence, complexity, manner of dissemination, local input into their construction, characteristics of the targeted practitioners, ease of accessibility, ease of use, and other factors.70,93–97 A systematic review97 found that “inertia” was a reason given by 45% of physicians for not using practice guidelines. While some studies98–103 of guidelines have demonstrated improvement in outcomes, most70,94 have found that simply developing guidelines and making them available, without the concomitant use of other strategies to ensure that they are actually used, is not very effective in changing physicians’ practice. In evaluating this body of literature, it is important to distinguish studies that assess clinically relevant outcomes from those that evaluate the surrogate measure of compliance with recommended care. This is especially important because many or most published guidelines fall short of the desirable features of good practice guidelines.94,96,104 Nonetheless, it is quite important that well-designed practice guidelines be used as adjunctive tools to improve ICU performance, with attention to these acceptance factors, and especially in conjunction with other strategies to improve their uniform use, as discussed below.

Because the number of EBBPs that clinicians are expected to implement is prohibitively large and constantly growing, it is not reasonable to expect that even the most knowledgeable and efficient doctor will remember to use each applicable EBP, each time, for each patient. This is why education, audit with feedback, and clinical practice guidelines are weak approaches to improving the use of EBBPs. A recurrent theme from studies to improve the use of best practices25,27,70,96,105 is that combining multiple strategies is more effective than the use of individual ones. However, combinations of weak strategies do not assure success.106 More effective strategies to improve the use of EBP in combination with practice guidelines include reminders, order sets, and computerization.

Patient-specific reminders are a powerful tool to improve the use of EBBPs. Provided at the point of care and at the time of care in relation to a specific patient, reminders relieve the clinician of needing a perfect memory to provide optimal care. Available evidence identifies reminders as one of the most effective methods of improving adherence to EBBPs.70,96 The main limitation is in effecting the reliable and timely delivery of reminders to clinicians. Hay et al107 showed that reminders given to physicians by study nurses led to effective compliance with an evidence-based guideline for upper GI bleeding and to impressive reductions in both ICU and hospital lengths of stay. However, hiring an army of outcomes managers to perform this function is not practical. Computer-generated reminders, discussed in the following section, are a much more workable solution to this problem.

Another potential method of improving the use of EBBPs is to use prefabricated orders that have those practices built into them. For example, an order set could be used for all newly intubated patients that includes, by default, prophylaxis against stress gastritis bleeding,108 and EBBPs that have been shown to decrease the rate of ventilator-associated pneumonia.109 Initial ICU admission orders could help to increase the use of EBBPs of wide applicability. For example, universal admission orders could give automatic authority for nurses to start an insulin infusion protocol (a form of clinical practice guideline) for any ICU patient whose blood sugar is persistently above a predefined threshold.110 Examples from the small amount of published data using the prefabricated order strategy show improvements in diverse measures such as semierect positioning among mechanically ventilated patients,111 the rate of enteral feeding,112 and trauma procedures.113 It is quite important to note that some
prior assessments of this approach have been unsuccessful because they were written in a way that required the orders for EBBPs to be actively chosen for them to be implemented. In most cases, the reverse of this strategy is better (ie, they be the default), so that EBBPs are implemented unless explicitly “switched off.” An impressive illustration of this principal is provided by Dexter et al.,114 who studied the administration of appropriate vaccines to inpatients. This study found that a computerized system that automatically generated a reminder and then made it easy for physicians to submit the required order led to lower rates of appropriate care than did a system that bypassed the physicians by having the nurses implement a computer-generated order for eligible patients. Just as for reminders, and as discussed in the following section, computerization offers the best and most efficient way to create and use prefabricated order sets to improve the use of EBBPs.

An implied message of this material is that a major responsibility for ensuring that EBBPs are uniformly used has passed from the individual clinicians to the institution. This necessitates the following: (1) that the PI leadership and/or quality teams regularly review relevant literature for new practices with sufficiently strong evidence to merit installing them as standard practice; (2) the creation of clinical practice guidelines that are unequivocally understood to be the expected standard of care for all practitioners; and (3) the installation of practicable strategies, such as those discussed above and in the next section, to ensure effective implementation of EBBPs. A set of 30 recommended “safe practices” from the National Quality Forum16 has been endorsed by the Leapfrog Group15; many of these are applicable to the ICU setting and are an excellent starting point for a list of EBBPs to help “create a healthcare culture of safety.” In the ideal ICU, all of these steps for change would be Sandwiched between outcomes data collection efforts, and each clinician would get regular statistical feedback about their performance. This latter point may be of minimal incremental value in improving outcomes, but it is important for professionals to be aware of their performance.

Last, efforts to improve the use of EBBPs must attend to the ever-present human component. Cook and coworkers67 found that poor communication and a lack of clear discussion about goals between ICU physicians and nurses thwarted the implementation of a simple EBBP. However, even such problems are amenable to systems-based solutions.115

**Information Systems in ICU PI**

Computers and other information technologies are powerful tools for improving ICU performance. Unlike people, computers can keep track of almost limitless amounts of information, never forget, and are essentially flawless in doing their assigned tasks. Their information-processing capacity dwarfs that of the smartest of us and can identify important patterns long before they are obvious.116,117

Table 3 lists some ways that computers can advance PI efforts in the ICU. Although there are, as yet, few studies118 evaluating whether such technologies improve ICU outcomes, many believe10 that their further development and widespread diffusion will be necessary for improving health care.

Computers have facilitated access to clinical data for several decades. In most hospitals, clinicians can obtain laboratory and other test results on terminals throughout the hospital. More recently, many hospitals have bought a picture archiving communications systems, making it possible to view radiologic images without leaving the ICU. Although there is conflicting evidence about whether picture archiving communications systems lead to more timely viewing of images by clinicians,119,120 they do make viewing more convenient and save time.121

Keeping track of patient-related information is an ever-increasing challenge. Data about ICU patients originates from observations and manual measurements made by numerous health-care workers, bedside monitors, laboratories, radiology instruments, devices such as infusion pumps and ventilators, progress notes, clinical flowsheets, the hospital information system, and other sources. In most ICUs, collecting this mass of diverse information requires

**Table 3—Uses of Information Technology in ICU Performance Improvement**

<table>
<thead>
<tr>
<th>Uses of Information Technology in ICU Performance Improvement</th>
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<tbody>
<tr>
<td>Acquire, integrate, store, analyze, and display information</td>
</tr>
<tr>
<td>More efficient and less error prone entry of orders</td>
</tr>
<tr>
<td>More efficient, available, and legible entry of progress notes and other patient information</td>
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<tr>
<td>Make clinical data more readily available</td>
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<tr>
<td>Make knowledge more readily accessible</td>
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<tr>
<td>Facilitate availability and use of EBBPs, including clinical practice guidelines</td>
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<tr>
<td>Provide clinical reminders</td>
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<tr>
<td>Facilitate use of order sets</td>
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<tr>
<td>Facilitate communication</td>
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<tr>
<td>Assist with calculations</td>
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<tr>
<td>Assist with clinical monitoring</td>
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<tr>
<td>Continuous, real-time monitoring of, for example, complications and adverse events</td>
</tr>
<tr>
<td>Provide decision support</td>
</tr>
<tr>
<td>Examine large amounts of data for meaningful patterns</td>
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<tr>
<td>Automated assistance with technical aspects of care</td>
</tr>
<tr>
<td>Verify correct administration of, for example, medications and blood products (eg, via bar coding with bedside scanning)</td>
</tr>
<tr>
<td>Facilitate data collection and case-mix adjustment for TQM purposes</td>
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physicians to read paper records, use several different computer systems, and leave the ICU to obtain information residing elsewhere. This situation makes it difficult and inefficient for clinicians to acquire and integrate all of the necessary data, and is prone to oversight and error. Only a highly competent computer system can solve all of these problems. Via various interfaces, such systems can automatically acquire data from bedside devices and other computer systems in the hospital, and can acquire manual input via bedside workstations. They can display the data as customizable tables and graphs that people can understand and use at any enabled workstation, including those at remote locations that are connected via the Internet. Because of these advantages, electronic, paperless medical records should become increasingly common. The future likely will include the use of hand-held devices for wireless remote access to clinical data and more rapid communication of problems to clinicians.

Computer technologies have vastly improved access to sources of medical knowledge. Textbooks, databases such as MEDLINE, full-text journals, and other authoritative sources are widely available around-the-clock from Internet-ready terminals in ICUs. It no longer requires a trip to the hospital library to find state-of-the-art answers to clinical questions about the patient who just arrived in the ICU. An increasing amount of medical knowledge is even more conveniently accessible via hand-held devices.

Errors in order writing are the most common sort of medical error. Hand written orders suffer from illegibility, mistakes in transcription, erroneous dosing, and other ills. Computer order entry dramatically reduces such errors and can reduce costs. Computer order entry, already relatively common and increasing in prevalence, is being driven by the safety concerns of organizations such as the Leapfrog Group.

As discussed above, reminders or prefabricated orders are potent strategies to increase the use of EBBPs. However, both are limited by practical difficulties in making the information available to clinicians in a reliable, convenient, and timely way. Information systems can solve these problems. Computer-based order entry renders it simple to present clusters of orders that are relevant to the situation. Each time a caregiver logs into the computer for any purpose there is an opportunity to deliver a reminder message or offer up a relevant practice guideline. Having these occur during order entry makes it especially easy for the clinician to execute orders to act on the reminder or to initiate a protocol from a guideline. While writing an order, the computer could be programmed to remind us to write an appropriate related order. For example, a computer-generated reminder could be displayed to order elevation of the head of the bed every time a clinician orders tube feedings. Intelligent computer systems with access to other patient data residing in the electronic medical record are required to allow this concept to achieve its fuller potential. An integrated ICU information system that is linked to both the ventilator and the electronic medication administration record could identify that a patient is mechanically ventilated and is not receiving prophylaxis for stress gastritis, and could automatically generate a reminder or the order itself. If the patient was receiving sedatives, the computer could suggest the use of the sedation protocol of the ICU and could automatically generate the necessary orders for the clinician to implement. Even higher compliance with EBBPs may result if an indicated order were, by default, generated in the appropriate setting by the computer, with the clinician having the option to cancel it if appropriate. Currently, sparse evidence exists about the effect of such systems. Computerized reminders have demonstrated benefit in most studies, but not all. Studies of complex interventions that included computer-aided practice guidelines have observed improvements in care or reduced costs. Including an order to keep the head of the bed elevated at 45° among the standard, computerized ICU admission order set for mechanically ventilated patients led to a higher use of this beneficial practice.

Extending these uses of information systems is computer-aided decision support (CADS). CADS systems with electronic access to patient data provide clinicians with “expert” medical advice. Take the example of a physician doing computer entry of an order for gentamicin. Combining the latest creatinine value from the laboratory, the patient’s weight from the paperless daily nursing notes, and age from the computer in the admitting department, the expert system would estimate pharmacokinetic parameters and recommend a dosing regimen. When peak and trough levels become available, it would include those in the calculations, and the next time the clinician accessed that patient’s electronic medical record it would suggest a revised dosing regimen. These smart systems can help to avoid incorrect dosing and can proactively identify drug interactions. Indeed, most studies of CADS systems have evaluated the effects on the choice and dosing of pharmaceuticals. These studies have found an impressive variety of improvements including better empiric antibiotic choices, better dosing, reduced drug costs, reductions in adverse drug events, and other improvements in clinically relevant outcomes.

The potential of computers to assist in the man-
agement of ICU patients extends beyond providing technical advice. A computer linked to real-time monitoring can be programmed to automatically adjust devices such as ventilators and infusion pumps to maintain optimal parameters in a way that is impossible for humans. In a study of pressure-support mechanical ventilation, a computer controlling the ventilator via ordinary closed-loop linear programming while continuously monitoring respiratory rate, tidal volume, and end-tidal P\textsubscript{CO\textsubscript{2}} simultaneously maintained all three parameters within desired limits 93\% of the time, while humans did so only 66\% of the time. The use of fuzzy logic controllers may have even wider ICU applications. The ability of computers to tirelessly monitor and analyze the entire ICU data stream in real time makes them ideal, and superior to people, for performing tasks such as the early detection of physiologic instability, adverse events, and surveillance for care practices outside of established practice guidelines. The future promises an automated ICU environment in which many EBBPs are put into effect without the need for humans to remember to order them. For example, the computer will automatically elevate the head of the computer-controlled bed for patients it senses are receiving computer-regulated mechanical ventilation and have enteral feedings being delivered by a computer-controlled infusion pump.

In addition to assisting in the care of individual patients, computer applications greatly facilitate the implementation of a systems-based PI program. Acquisition, analysis, and presentation of the information necessary for such efforts is labor-intensive and expensive. Creating a comprehensive ICU patient database is an important step that will considerably ease the personnel demand for such PI programs. Likewise, the collection of case-mix variables, and even adjustment for case-mix, can be automated. The manual calculation of scores for APACHE (acute physiology and chronic health evaluation), simplified acute physiology score (SAPS), Pediatric Risk of Mortality (PRISM), or other prognostic systems is cumbersome and time-consuming. Computers linked to hospital information systems can compile, organize, calculate, and store these parameters automatically. Such databases are themselves potent tools for systems-based PI. They can be queried to identify subtle relationships between variables that suggest opportunities for improving performance that are not obvious even to those intimately involved in day-to-day operations. For example, an evaluation of database information identified laboratory test-ordering patterns in an ICU that led to policy changes and subsequent cost savings.

Unfortunately, there are a number of barriers to the widespread use of information technologies to improve ICU performance. These include a paucity of commercially available user-friendly systems, the high cost for those that exist, a lack of interfacing standards again leading to high costs, and opposition from clinicians. Nonetheless, such highly capable systems do exist and a few forward-looking institutions have invested in them, to their benefit.

**Summary and Conclusions**

Improving ICU performance requires a shift of paradigm away from the discredited notion that most omissions, adverse events, errors, and other problems are the fault of individuals, and can be fixed by remediation that is aimed at individuals. Instead, meaningful and sustained improvement of ICU performance requires a systems-oriented approach via a relentless process of studying and changing the ICU structures and processes, which make it easy for people to make mistakes and hard for people to do their jobs well, in order to transform them into the opposite. Even the smallest ICU should have an appropriately constituted, multidisciplinary, systems-oriented PI team that meets at least monthly.

While PI is much easier in an ICU having the resources to hire personnel and purchase information systems, even an ICU with few resources can improve its performance. The most difficult, labor-intensive, and expensive component of PI is data collection, and there are ways to make this less burdensome. The outcomes studied could be those for which data are already being collected as part of regulatory requirements, or new ones that can be gathered relatively easily on paper reporting sheets by clinical personnel in the ICU. If resources are insufficient to perform a case-mix adjustment of outcomes data, then unadjusted data should be used without apology. Conclusions based on raw data cannot be worse than conclusions based on no data at all. Although it is not preferred, in place of the large effort needed to identify and collect data on an outcome of primary relevance (Table 1), you could substitute the lesser effort needed to collect information about an associated process-related variable. For example, it takes a great amount of work to identify the rate of ventilator-associated pneumonia, but it is much easier to measure the utilization rate of a bedside intervention such as semirecumbent positioning, which has been demonstrated to reduce the rate of that complication. A continuous program of such small-scale efforts (ie, plan-do-study-act cycles) can add up to major improvements in performance over time. Even an ICU with literally no
extra resources can use systems principles to ensure the effective application of EBBPs from the medical literature without actually assessing the local benefits of those practices. Of course, such humble versions of PI should be accompanied by ongoing efforts to convince the hospital’s administration that applying resources to improving ICU performance is money that is well-spent.

Therefore, every ICU should have a systems-oriented PI program that is multidisciplinary and inclusive, has the vigorous support of hospital and ICU leadership, and has sufficient personnel and economic support to succeed. These ideas must become an integral part of the routine activities of the ICU; its concepts and methods must be incorporated into the culture of the ICU. Movement toward these goals should begin now.

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