An update on cost-effectiveness analysis in critical care
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Critical care providers are under increasing pressure to be attentive to cost concerns. The ICU consumes a significant amount of resources and, as such, is a frequently identified target of efforts to limit escalating healthcare costs. Attempts to reduce costs need not progress in a haphazard fashion. Rather, they can proceed in a logical, systematic manner with the assistance of formal economic studies. Cost-effectiveness analysis is one tool for these projects—it allows physicians to compare the financial consequences of different approaches to resource allocation. ICU physicians, therefore, must become familiar with the basic concepts that underlie cost-effectiveness analysis. Cost-effectiveness analyses that address many different aspects of critical care delivery are now commonly found in the critical care literature. With a framework for evaluating these studies, clinicians can better apply their findings to their own institutions. Curr Opin Crit Care 2002, 8:337–343 © 2002 Lippincott Williams & Wilkins, Inc.

The modern ICU represents a major economic burden to society. Although ICU beds account for fewer than 10% of all inpatient beds in the United States, nearly 1 in 3 dollars devoted to inpatient care are spent in the ICU [1]. In 1984, one estimate suggested that ICU care consumed 1% of the gross national product [2]. A more recent analysis implies that costs for sedation of ICU patients alone were nearly $1 billion in 1997 [3]. This trend of escalating costs for intensive care delivery has accelerated recently. Thus, the ICU has become a focus of efforts designed to limit rising healthcare costs.

The financial impact of the ICU is a result of several factors [4].

1. The ICU has significant fixed expenses.
2. Patients cared for in the ICU consume significant resources, because they are often treated with expensive pharmaceuticals and undergo many different types of imaging studies.
3. There is growing demand for ICU care.

The aging of the US population is expected to lead to a greater need for ICU beds and intensivists. Over the next 20 years, the incidence of severe sepsis and septic shock has been projected to rise by nearly 30% [5••].

Third-party payers are already demanding improvements in efficiency and optimization of resource use [6]. Potentially conflicting with pressure from payers are mounting calls for new therapies and better outcomes. Marginal changes in mortality may be achievable but may also be expensive. Thus, both policy makers and practicing physicians are faced with balancing these competing forces. One tool that can provide insight into the allocation of scarce resources and the determination of the relative value of different alternatives is economic analysis. Formal economic studies in critical care medicine have evolved significantly over the last several years. Specifically, financial studies in the areas of disease-specific outcomes, ICU organization, and prevention in the ICU merit attention. Before reviewing recent advances in these areas, it is important to provide a framework that describes economic analysis in healthcare.

Economic analysis: an overview
Types of analysis
By their very nature, resources are scarce. Decisions must be made regarding the allocation and utilization of money, personnel, and equipment. Formal economic
analysis represents a means to both qualitatively and quantitatively compare the financial implications of competing plans [7]. All economic analyses in healthcare have two basic facets. First, one must consider the costs and consequences of any action. Second, economic evaluations deal with choices. It will always be impossible to create all desired outcomes. Hence, as a policy guide, economic analysis aims to identify and make explicit a set of criteria that may be helpful in deciding between competing alternatives. Often the criteria used for resource allocation are implicit and, therefore, are not exposed to discussion regarding possible assumptions and bias. Readers should be aware that published guidelines exist for the conduct and reporting of cost-effectiveness analyses in medicine. The creation of such standards underscores the growing significance of economic studies in healthcare [8].

There are four basic types of economic evaluation: cost-minimization, cost-benefit, cost-effectiveness, and cost-utility analyses. The determination of the different costs and their valuation in dollar terms is similar across each of these types of analyses. These forms of analysis vary most importantly with respect to the consequences of the different approaches under study. Cost-minimization analysis is a tool for use when two alternatives achieve the endpoint of interest with similar effectiveness. In other words, the options are equivalent and the only question is which approach costs less. In most situations, however, the sequelae of different programs are not equivalent, and the impact of the alternatives may be multiple rather than single. For example, a program to screen for malignancy focuses on preventing early death, whereas rehabilitation following myocardial infarction is designed to limit disability and morbidity. Because the outcomes of interest differ, one must develop a common denominator through which it is possible to assign value to these distinct effects. When these outcomes are converted into dollar amounts, we can begin cost-benefit analysis. The findings from cost-benefit analysis can be expressed either as an absolute amount (eg, net savings or loss) or as a ratio of costs to benefits.

Cost-effectiveness analysis compares options with one common measure for effectiveness. The measure often used in medicine is years of life saved. Thus, cost-effectiveness analysis allows the comparison of many diverse health projects ranging from pneumococcal immunization to mandatory safety locks on handguns. Cost-effectiveness analysis also avoids the difficulty associated with determining the economic value of certain outcomes: because it may be ethically, if not technically, difficult to compute the financial “value” of a year of life, one can rely on cost-effectiveness analysis and avoid this conundrum [9••].

One can also use cost-effectiveness analysis in situations in which the interventions do not directly produce health benefits but achieve other important clinical goals (eg, prevention of central line infections). In cost-utility analysis, one adjusts the primary outcome for the impact of interventions based on the quality of that endpoint. Two different interventions may each result in 5 additional years of life for two patients, but as a result of one plan, those years may be spent in perfect health, whereas in the other, the patient may be confined to a nursing home. These results are clearly not equivalent, and, thus, a rubric is required to adjusting for such supervening factors. In medicine, researchers have developed the concept of the quality-adjusted life year (QALY).

**Costs**

One of the important limitations of all economic analyses in healthcare is the difficulty of determining the actual costs associated with various interventions. Healthcare does not behave as a perfect market, and the prices charged for services do not reflect their cost. Additionally, many interventions have both direct and indirect costs. Direct costs (eg, the cost for a new drug) are often computed with relative ease. Indirect or hidden costs are more difficult to ascertain but are nonetheless important. Readers should therefore be attentive when reviewing cost-effectiveness studies to the methods used to compute costs. The most precise method of calculating costs in healthcare is microcosting. With this approach, each component of resources use is identified and included in the final cost estimate. Similarly, because prospective studies are more reliable than retrospective ones, readers should also note if the cost data are derived from the actual patient charges incurred and calculated in a prospective fashion or if the estimated costs simply reflect retrospective data extrapolated from a diverse group of patients cared for in the ICU. Costs calculated based on average per-day charges (eg, the cost of a day in the ICU) may be readily accessible but often do not reflect the costs for specific types of patients with distinct diagnoses. For example, the daily ICU costs for treating a patient with a gastrointestinal hemorrhage are lower than those for an individual receiving mechanical ventilation. Any analysis that does not acknowledge such limitations should be read with skepticism. Finally, cost analysis raises the central question, “Cost to whom?” In other words, the perspective from which economic analysis is undertaken invariably affects its conclusions. A certain strategy may seem cost-effective to an individual hospital, but the same approach may prove exceedingly costly to a third-party payer. For most studies, researchers should assume a societal perspective. Viewing economic issues from such a vantage point helps to guarantee a more precise ascertainment of costs.

**Uncertainty**

The component pieces of cost-effectiveness analysis are shrouded by uncertainty, and some effort must be made to ascertain the importance of this uncertainty. This is
best accomplished by sensitivity analysis. Critical assumptions are routinely made for the completion of economic studies. Sensitivity analysis represents an evaluation mechanism for use in cases in which uncertainty in these assumptions alters an analyst’s conclusions. If extensive variation in basic inputs does not modify the results, one can have more confidence in a study’s conclusions. Sensitivity analysis is an instrument for establishing the robustness of a study’s findings.

**Disease-specific outcomes**

Two expensive technologies often used in the ICU are mechanical ventilation and renal replacement therapy (RRT). Outcomes for patients who require mechanical ventilation for acute respiratory failure have improved, but the mortality rate remains approximately 30% [10]. In-hospital mortality rates for individuals in the ICU who develop acute renal failure range from 40 to 80% [11]. Because the majority of the costs of treating patients with either acute respiratory or renal failure are spent on those who eventually die, considerable concern exists as to the cost-effectiveness of mechanical ventilation for acute respiratory failure or renal failure in the ICU.

To address the cost-effectiveness of mechanical ventilation for acute respiratory failure, Hamel et al. [12••] used data from the Study to Understand the Prognoses and Preferences for Outcomes and Risks of Treatments (SUPPORT) to estimate the relative value of this intervention. They examined a cohort of 1005 patients with either pneumonia or adult respiratory distress syndrome to determine not only mortality but also functional status and quality of life after index hospitalization. The investigators estimated that the incremental cost-effectiveness of mechanical ventilation for patients with acute respiratory failure varied from $29,000 per QALY to $110,000 per QALY depending on the patient’s initial risk of death [12••].

One strength of this project is that the researchers endeavored for a complete accounting of patient costs by linking outcome data with Medicare charge data not only for the initial ICU stay but also for physician and other charges incurred after hospital discharge. The investigators assumed, however, that the healthcare costs for persons aged 65 years and older were the same as those under 65 years of age. Both hospital costs for the index ICU admission and costs incurred after discharge varied by the patient’s estimated probability of survival (computed at time of ICU admission). Sensitivity analysis revealed that the researchers’ findings were relatively insensitive to their model’s input variables. Under any number of assumptions unfavorable to the use of mechanical ventilation, the cost-effectiveness of mechanical ventilation for the most gravely ill persons never fell below $50,000 per QALY. In an effort to address whether aggressive strategies were less cost-effective in older persons, the same investigators conducted an expanded cost-effectiveness analysis focusing on the impact of patient age on outcome [13••]. In particular, they hoped to address the often assumed but rarely investigated premise that aggressive care in older patients is not cost-effective per se. They concluded that the cost-effectiveness of mechanical ventilation varied little based on patient age. For example, the incremental cost-effectiveness ratio for mechanical ventilation in persons younger than 65 years was $32,000 per QALY as compared with $46,000 per QALY for those older than 75 years. It appeared that initial prognosis was a more important determinant of cost-effectiveness than age.

Korkeila et al. [14] conducted a similar analysis in patients requiring RRT. They identified patients needing RRT in their ICU over a 12-month period and contacted the patients and their families to compute mortality rates and quality of life. They concluded that RRT costs $80,000 per 6-month survivor. Unfortunately, these researchers did not incorporate the findings from their quality-of-life analysis into their final cost-effectiveness model. Their method for cost accounting was also flawed in that they did not collect data on actual patient costs. Rather, they retrospectively determined the intensity of care delivered based on the therapeutic intervention scoring system (TISS) and then multiplied TISS points by a fixed charge to calculate patient costs [15]. They also did not estimate costs for care and treatment after discharge or perform sensitivity analysis.

Mechanical ventilation and RRT represent specific technologies that are only appropriate for a narrow group of patients. The general results of ICU care, though, may also be the subject of cost-effectiveness analysis. Sznajder et al. [16••] attempted to gauge the overall cost-effectiveness of ICU care. They prospectively followed 211 patients in seven French ICUs and collected cost information and quality-of-life data. As shown in multiple studies, costs for nonsurvivors were higher than those for survivors, and severity of illness directly affected cost-effectiveness. For the entire cohort, the mean total ICU costs were $14,130, and the incremental cost-effectiveness was $1,150 per life-year saved and $4,100 per QALY saved. For patients with severe but rapidly reversible processes (eg, intoxication), ICU care was highly cost-effective as compared with other disease states for which long-term survival is more limited (eg, acute renal failure). Sznajder et al.’s findings indicate that ICUs are very cost-effective.

**Intensive care unit organization**

How ICU organization influences outcomes remains uncertain. Although the vast majority of ICUs are managed in an “open” format, observational studies suggest that reliance on full-time intensivists and a “closed” structure...
may improve outcomes. In fact, the American College of Critical Care Medicine recommends that units be managed in a closed fashion if resources allow [17]. However, formal cost-effectiveness analysis of different ICU organizational schemes is hampered by estimates of the costs of changing ICU structure. More importantly, cost-effectiveness analysis may not be necessary in evaluating alternative models of ICU structure, because some researchers have noted both improved mortality and cost savings with the creation of both formal treatment protocols and closed ICUs. An intervention that yields better outcomes with less resource use is referred to as dominant. In other words, there are no competing tradeoffs that must be weighed [7].

One reason closed ICUs may yield superior results is that they may also prevent the development of nosocomial pneumonia. In a retrospective study, Kollef et al. [19] reported more cases of pneumonia in patients treated with continuous infusions of sedatives, whereas two recent prospective studies have clearly demonstrated that sedation protocols may limit the duration of mechanical ventilation and the associated risks [3,20]. Protocols may be difficult to create in that they must be individualized to meet the unique needs of each institution; however, evidence demonstrating their cost-effectiveness continues to mount. Through the combination of an educational effort and the implementation of formal sedation guidelines, Mascia et al. [21•] were able to decrease the need for neuromuscular blockade by 83%. Direct drug costs for sedative, narcotics, and neuromuscular blockers also decreased after implementation of their guidelines. Unlike earlier studies that did not prospectively quantify the pharmacy savings from this approach, this study showed a nearly 75% decline in mean daily per-patient costs for these types of agents. Unfortunately, the investigators did not formally ascertain the costs resulting from the creation of their guidelines, so one cannot compute formal cost-effectiveness ratios. Moreover, they did not attempt to determine the economic savings arising from the decrease in ICU length of stay after the implementation of their approach.

In the area of trauma care, Park et al. [22] reported that creating a trauma-specific ICU separate from a surgical ICU led to decreased duration of mechanical ventilation, shortened ICU length of stay, and lower hospital charges. They noted that simply by placing patients under the care of a dedicated group of trauma ICU nurses and surgical intensivists, the mean length of stay in the ICU decreased by 3 days.

Because access to dedicated intensivists is limited in many regions of the United States, telemedicine represents an attractive alternative for bringing specialist care to patients who might not have access to it otherwise. Telemedicine has proven to be an important adjunct in many other fields of medicine, but, until recently, its efficacy in the ICU had not been evaluated. Rosenfeld et al. [23••] retrospectively collected baseline data on patient case-mix, disease severity, and ICU resource use at a community hospital ICU during two 16-week periods. They then compared their findings with those obtained after the ICU in question was equipped with telemedicine services linked to full-time intensivists. These intensivists provided continuous oversight. They evaluated patients electronically and with the aid of video equipment each day and formulated care plans in conjunction with on-site physicians.

Because of the availability of the intensivists, Rosenfeld et al. [23••] noted that both mortality rate and costs decreased. When they examined the reason for the decline in costs, three important factors surfaced. First, ICU length of stay was an average of 1 day less per patient. Second, with full-time intensivists accessible, there were fewer complications. During the two baseline periods, 15.1% and 18.1% of subjects, respectively, suffered a complication as compared with only 9.5% of persons treated using the telemedicine model (P < 0.05). Third, an analysis of individual cost elements indicated that there was less use of routine laboratory and radiologic testing. Unlike the other ICU organization studies cited previously, Rosenfeld et al. [23••] undertook a complex and complete accounting of patient costs that included adjustments for inflation.

**Prevention**

Often preventive strategies prove cost-effective. Efforts at both primary and secondary prevention are attractive because the costs of averting poor outcomes are often exorbitant and because the benefit generated persists for an extensive period of time. The impressive cost-effectiveness of childhood immunizations demonstrates this principle. Hypothetically, in the ICU setting, preventive interventions may be less cost-effective. In many instances, the evidence supporting the efficacy of prevention is limited, and the impact of preventive interventions may be small to trivial. Conversely, if the targeted outcome is costly, preventive approaches, even if of limited efficacy, may prove attractive. Thus, critical care physicians need to be aware of express cost-
effectiveness and cost-minimization analyses performed in ICU populations.

Nosocomial pneumonia generally, and ventilator-associated pneumonia specifically, confers an attributable mortality of approximately 35% and may increase the duration of required mechanical ventilation by up to 9 days [24]. Simple interventions such as improved hand washing and elevating the head of the bed have a profound impact and are essentially cost-free. For other interventions with express costs, the benefit is less clear. Continuous subglottic suctioning (CSS) represents a new mechanism for preventing ventilator-associated pneumonia. Endotracheal tubes designed for this are relatively expensive, however, and the risk reduction one may obtain with their use is limited [25]. To evaluate the cost-effectiveness of CSS, Shorr and O’Malley [26•] modeled the potential cost implications of this strategy. In instances in which direct cost data do not exist or are not easily obtained, decision modeling is a helpful tool in estimating cost and treatment effects.

Creating model inputs from a literature review allowed Shorr and O’Malley [26•] to estimate that the use of CSS would save nearly $5,000 per case of ventilator-associated pneumonia averted. Although the CSS endotracheal tubes were more expensive, the dominant issue was the cost resulting from ventilator-associated pneumonia. This study illustrates the need to understand the perspective from which cost-effectiveness analysis is performed. If one examines the question from a hospital supply point of view, CSS is not attractive because it consumes budgetary resources. From the vantage point of either hospital administration or a third-party payer, however, endotracheal tubes capable of CSS appear superior.

Urinary tract infections are a similar burden because they represent the most frequent nosocomial infection seen in ICU patients. Urinary catheters, which are crucial for patient management in the ICU, are the most significant risk factor for the development of urinary tract infections. Impregnating such devices with silver effectively reduces the risk of urinary tract infections by threefold, a result that is comparable to that achieved by bonding central lines with antibiotics [27]. Earlier research has shown antibiotic-bonded central venous catheters to be cost-effective [28]. However, many patients with central line colonization progress to bacteremia as compared with only 4% of patients who have nosocomial urinary tract infections [29]. Realizing the many competing concerns, Saint et al. [29] undertook a cost-effectiveness analysis of silver alloy urinary catheters. Approaching the issue conservatively by biasing their model against the newer urinary catheters, these investigators concluded that the use of silver alloy urinary catheters yields cost savings. They estimated that reliance on the newer catheter would save approximately $4 per patient. Sensitivity analysis did not alter their conclusions. Although the savings were modest, the researchers modeled a hypothetical cohort of inpatients, including both those on a general ward and those in an ICU. Because the cost of bacteremia is clearly higher in ICU patients, it seems reasonable to argue that, likewise, the cost-effectiveness of silver alloy catheters is greater for patients in the ICU.

Venous thromboembolism also remains a significant complication in the ICU. The optimal prophylactic approach is unclear and likely will vary based on the patient’s underlying risk for venous thromboembolism. Trauma patients have been identified as facing a substantial risk for developing venous thromboembolism. Trauma induces a procoagulant state, and trauma victims often have multiple orthopedic injuries. A randomized, controlled trial of enoxaparin in trauma patients showed that this agent substantially reduced the risk for deep vein thrombosis [30].

However, low molecular weight heparins are relatively costly and may be associated with an increased risk of bleeding. Because of possible competing issues and to compare the cost implications and outcomes of low molecular weight heparins for thromboprophylaxis in trauma, Shorr and Ramage [31] conducted a cost-effectiveness analysis using the outcomes data from a primary prospective trial of this agent. Their study demonstrates a theme also found in the two projects mentioned previously: although prevention may require the initial allocation of resources, it is often cost-effective when all outcomes, particularly the effect on ICU length of stay, are considered. When restricted to trauma patients at highest risk for venous thromboembolism, Shorr and Ramage [31] noted that reliance on a low molecular weight heparin would save nearly $400 per deep vein thrombosis averted.

Additional issues

Few cost-effectiveness studies in critical care prospectively collect charge data in parallel with the recording of primary data. In many cases, cost-effectiveness is viewed as a secondary endpoint and, thus, may not be given sufficient attention during protocol design. However, a recent study examining use of percutaneous tracheostomy incorporated cost accounting into the prospective data collection. In this trial conducted by Freeman et al. [32••], patients requiring a tracheostomy were randomly selected to receive either surgical placement in the operating room or percutaneous placement in their ICU bed. Although the outcomes of the two approaches were comparable, total charges were reduced by nearly 50% for patients who had the tracheostomy placed in the ICU instead of in the operating room. The majority of these savings occurred because the need for operating room time and personnel was eliminated. The investigators
Economic issues permeate the practice of critical care medicine. Because the ICU consumes a disproportionate amount of financial resources, it will be a growing focus of efforts directed at cost containment. Cost-effectiveness studies represent an important analytic tool for these debates. Both the number and quality of formal cost-effectiveness analyses in critical care is increasing in response to pressures to reduce costs. Clinicians should view cost-effectiveness analysis as an instrument that may simultaneously help them marshal resources more efficiently and improve patient care. They need not approach cost-effectiveness with trepidation. As with medical literature in general, there are principles that underlie the conduct of these studies that one can use to evaluate the quality of the expanding literature in this field.

**Conclusions**

Economic issues permeate the practice of critical care medicine. Because the ICU consumes a disproportionate amount of financial resources, it will be a growing focus of efforts directed at cost containment. Cost-effectiveness studies represent an important analytic tool for these debates. Both the number and quality of formal cost-effectiveness analyses in critical care is increasing in response to pressures to reduce costs. Clinicians should view cost-effectiveness analysis as an instrument that may simultaneously help them marshal resources more efficiently and improve patient care. They need not approach cost-effectiveness with trepidation. As with medical literature in general, there are principles that underlie the conduct of these studies that one can use to evaluate the quality of the expanding literature in this field.


This study represents an effort to assess the economic value of education and guidelines in the management of sedation and paralysis. However, there are a number of limitations because cost data other than direct pharmaceutical expenses were not included, and it is only a before–after study as opposed to a randomized, controlled trial.


A crucial, rigorous analysis that demonstrates the utility of full-time intensivists on outcomes. Economically, the study examines many endpoints and includes a thorough cost accounting. To minimize bias, the investigators also made comparisons to two baseline periods. They showed that full-time intensivists can simultaneously improve patient safety and outcomes while minimizing overall cost.


This is a decision analysis that reveals the value of preventive strategies in the ICU. The investigators used modeling because of the lack of primary data in this area. The analysis followed published guidelines, had a complete sensitivity analysis, and underscores the value of this approach in clinical decision making when information is limited.


This study is unique in that it is a randomized trial that simultaneously collected cost data. Thus, in one sense, it represents the most rigorous form of economic evaluation possible in healthcare. Randomization should limit the effect of bias not only on the primary endpoint (placement of a tracheostomy) but also on the costs associated with that process. Hopefully, future clinical trials in critical care medicine will use this framework for outcomes and cost analysis.