

Critical Care Economics

Alma Rivera, Joseph F. Dasta, Joseph Varon

Abstract

Health care costs represent a large percentage of the gross domestic product all over the world. According to the National Health Statistics Group, health care expenditure in the United States accounted for as much as 14% of the gross national product in 1992 and it is projected to reach 30% by 2030.

The intensive care unit (ICU) represents the hallmark of highly competent modern hospitals, offering highly trained staff and life-saving technology and it is also one of the most expensive units in the hospital. Expenses related to running the ICU have been estimated at approximately 20% of total hospital costs, despite only representing 10% of all hospital beds.

Assisted mechanical ventilation particularly affects the high costs in the ICU. Actually, a mere of 1 million persons per year receive mechanical ventilation during their stay in the ICU. A variety of different approaches to stabilize or reduce costs in the ICU have been suggested. Reducing the length of ICU stay, improving the patient's condition to prevent co-morbid events, and introducing specialized teams to round in the ICU are some of the recent actions taken in the search for cost-effective therapies.

The aim of this article is to provide some of the basic principles of economic assessment in critically ill patients and present an overall review of the strategies followed to reduce costs and resource usage in the ICUs around the world.

Key words: Critical care, economics, health care, intensive care, expenditures, gross national product.

Introduction

Health care costs have been exponentially rising for the last several years. (1) This is particularly evident when

considering the recent United States (US) healthcare expenditures. In 1980, US\$ 253 billion were spent, in 1990 US\$ 714 billion were spent, and in 2006 that figure rose to US\$ 2 trillion spent. (2) This same year, 2006, health care expenditures in the United States constituted 16% of the gross national product, equivalent to US\$ 7,026 per person. (3) This percentage is expected to increase up to 20% by the year 2015, to approximately US\$ 11,000 per person. (4)

The United States healthcare budget is not only the most demanding, but also has the smallest contribution (44.3% in 2000) from government taxation revenues. (5) However, since the peak reached by private health insurance in 1998, where it paid for one third of the total health expenditure, United States expenditures rely strongly on private funding. (6) In 2007 official data revealed that as much as 54% of the total National Health Expenditure came from private funds.

From Universidad Autónoma de Chihuahua, Chihuahua, México (Alma Rivera), College of Pharmacy, The Ohio State University and College of Pharmacy, The University of Texas, Austin, Texas, USA (Joseph F. Dasta), and The University of Texas Health Science Center at Houston and The University of Texas Medical Branch at Galveston, St. Luke's Episcopal Hospital, Houston, Texas, USA (Joseph Varon).

Address for correspondence:

Joseph Varon, MD, FACP, FCCP, FCCM
2219 Dorrington St
Houston, TX 77030-3209, USA
Tel: +1-713-669-1670
Fax: +1-713-669-1671
E-mail: Joseph.Varon@uth.tmc.edu

(2) Despite the much publicized controversies of health care reform and Medicare and Medicaid programs, United States financing is held in a great percentage by private health insurance and consumer-out-of-pocket finances.

These rising costs not only concern payers and suppliers but most importantly consumers (ie, patients) who may be responsible for much of their healthcare cost and whose care may be influenced by the ability to pay or otherwise have the expenses reimbursed. (7)

Costs in the Intensive Care Unit

The intensive care unit (ICU) represents the hallmark of highly competent modern hospitals, offering highly trained staff and life-saving technology. It is also one of the most expensive units in the hospital. Expenses related to running the ICU have been estimated at approximately 20% of total hospital costs despite representing only 10% of ICU beds. (2) As the ICU is often supportive rather than curative, the main goal is to stabilize and provide the patient with supportive therapy. For this reason, a substantial amount of ICU expenses are attributed to staffing and use of consumables (ie, drugs, fluids, and disposable equipment). (8,9) Nurse staffing is particularly important in the ICU and along with medical staff, it accounts for as much as 51% of the expenditure. (8) Noseworthy and associates reported that the United States expenditure on staff and consumables alone accounted for approximately 70% of the total ICU costs. (10) Other expenses include routine diagnostic tests (eg, laboratory and plain radiographs) and medical devices, such as ventilators, intraaortic balloon pumps, and renal replacement units which contribute substantially up to 38-56% of the ICU costs. (5) Assisted mechanical ventilation particularly affects the high costs in the ICU.

Mechanical Ventilation in the ICU

Due to the nature of the conditions dealt with in an ICU, a common therapeutic intervention for many patients is mechanical ventilation. Data from 2003 disclosed that approximately 300,000 patients received mechanical ventilation. (11) Actually, a mere of 1 million persons per year receive mechanical ventilation during their stay in

the ICU. (12) A study performed by Dasta and colleagues in 2005 included 51,009 patients admitted to an ICU in a 3-month period. Approximately one third of the patients included in the study required mechanical ventilation during their stay in the ICU. Length of stay and total costs were calculated for all the patients, including daily incremental costs from those patients in mechanical ventilation. Their results revealed that the mean ICU cost and duration was US\$ 31,574±42,570 and 14.4±15.8 days for patients requiring mechanical ventilation. Conversely, for those patients that didn't require mechanical ventilation, costs and lengths of stay were lower at US\$ 12,931±20,569 and 8.5±10.5 days, respectively. It is evident from this data that the daily cost was directly related to the use of mechanical ventilation and the additional requirements related to it. The mean incremental cost of mechanical ventilation in ICU patients according to these investigators was significant: US\$ 1,522 per day ($p<0.01$).

Moreover, an interesting cost pattern was identified for both mechanical-ventilated and non mechanical-ventilated patients; that is the first day is always the most expensive in the ICU and cost typically decreases by the second day and stabilizes the third day. Daily costs in the ICU ranged from US\$ 3000 to US\$ 4000.

Mechanical ventilation has a large impact in total ICU costs. (13) Thus, actions performed to reduce length of ICU stay, and reducing the need and duration of mechanical ventilation may result in considerable reductions in total costs. Other cost preventive measures include establishing protective practices during mechanical ventilation and prevention of potential complications.

Cohen and Bari performed a clinical trial to evaluate the effect of having a formal interdisciplinary team managing ICU patients requiring mechanical ventilation. (14) This team included an ICU attending physician, a nurse and a respiratory therapist, and they conducted rounds regularly to control the ventilator management of each patient admitted to the ICU. During the trial, the ICU costs for patients admitted 1 year prior to the onset of the study were compared to those admitted for 1 year after. The results revealed a reduction of resource utilization and number of days on mechanical ventilation for those patients who received the specialized team attention. Number of days in the ICU, and

number of laboratory tests ordered and indwelling arterial catheters used decreased as well. The estimated cost saving reported by these authors was US\$ 1,303 per episode of mechanical ventilation, an important reduction considering the percentage of patients mechanically ventilated in an ICU. These authors concluded that a ventilator management team accelerates the process of weaning patients from mechanical ventilation and offers a safe and individualized care to patients.

Time is an important variable related to mechanical ventilation cost. Prolonged mechanical ventilation is defined by more than 21 days of ventilation or more than 4 days if a tracheostomy is placed, and it is required in nearly 10% of all critically ill patients. (12) Unfortunately, prolonged mechanical ventilation results in elevated costs and the outcome is generally poor, with less than 50% of survival rate after 1 year. (12)

In a 2007 study, Cox and coworkers analyzed cost-effectiveness of prolonged mechanical ventilation in elderly patients and compared their results with those who only received comfort care. Their study revealed that prolonged mechanical ventilation gained 2.5 life years at a cost of US\$ 143,808 approximately US\$ 55,460 per life-year gained. Costs were higher in patients older than 68 years with more than 50% of predicted 1-year-mortality.

This must be analyzed in terms of life quality as well, which must be a priority regardless the cost. A study performed in 2004 included 817 elderly patients receiving prolonged mechanical ventilation and measured 1-year mortality and functional status, defined as the inability to perform instrumental activities of daily living (IADLs). (15) Results revealed a 46% survival rate and 57% of these survivors still needed caregiver assistance after one year. Variables related to survival and functional statuses were underlying diseases and severity of illness score at the time of admission to the ICU. Previous functional status played a decisive role in these patients, considering that those patients previously dependant were approximately two times more likely to need assistance for one year or more after the discharge. (15) A suitable approach should include identifying the patients that are likely to receive benefits from mechanical ventilation and taking the right decision regarding life support therapy for high-risk patients. Continued research

is needed to develop interventions that impact positively in long term survival and improve remaining physical limitations after mechanical ventilation. (15)

Efforts to Lower the Resource Usage in the ICU

A variety of different approaches to stabilize or reduce costs in the ICU have been suggested. (16-19) Improving the patient's condition during their stay in the ICU may prevent cost-generating morbid events. Many critically ill patients develop hyperglycemia or some degree of insulin resistance, even when they were not diagnosed with diabetes before admission to the ICU. (19) Accomplishing normal levels of glycemia in the critically ill patient may reduce the predisposition to suffer from neurological, cardiovascular and infectious outcomes which are common in hyperglycemic patients. As a result, the risks of multisystem organ failure or sepsis decrease, hence reducing mortality and morbidity among patients. (9)

An investigation by Van den Berghe et al, studied the effect of intensive insulin therapy on the cost of hospitalization. (19) Length of stay and the frequency of negative events were documented for treatment groups receiving a conventional therapy and an intensive insulin therapy. (19) Results in this study revealed that even though the intensive treatment was more expensive (US\$ 202 per patient) than the conventional treatment (US\$ 100 per patient), the total ICU cost for patients in the second group was higher (US\$ 11,100 vs. US\$ 14,800). This is translated into US\$ 3,700 that can be saved by implementing this therapy. (19) Results for the group under intensive insulin therapy also experienced a 46% reduction in episodes of septicemia, a reduced length of stay in the ICU, and a 32% total reduction in intensive care mortality. (19)

Reducing Length of Stay in the ICU

Decreasing time spent in the ICU may represent an efficient way to reduce costs. Previous research by Cheng in patients that underwent coronary artery bypass graft (CABG) surgery showed that the application of fast-track anesthesia, which shortens total operation time results in early extubation, thus decreasing time in the ICU and saving resources. (20) It also

revealed that early extubation performed in the first 6 hours after arrival to the ICU was not related to an increase of postoperative morbidity and mortality, both outcomes that raise ICU costs. (20) Early extubations are related to reduced mechanical ventilator and critical care costs because the patient is transferred directly to an intermediate care unit for observation. (20) However, it is crucial to evaluate if there is an actual cost reduction, or if costs are only being shifted to a different unit in the hospital.

A retrospective study performed from 2000 to 2006 on 9,120 patients with a goal-oriented strategy revealed that an extubation time of ≥ 4 hours is related to a successful discharge from the ICU that subsequently results in resource saving. (18) No additional complications were observed for this extubation time but it must be noted that lower extubation times (ie, 2-3 hours) resulted in important neurological damage. However, it should be noted that extubation time was not as important as other preoperative (eg, age, underlying diseases, relevant past medical history of cardiovascular injury, etc) and intraoperative (type of operation, repeat surgery, cardiopulmonary bypass duration, etc) factors related to early discharge from the ICU. (18)

An important secondary result of this study brings up how goal-oriented strategies can make a change in resource management in the ICU. The result is a care level enhancement and early discharges based on evidence. Yet, benefits and disadvantages must be further evaluated in order to apply these strategies and find a reasonable distribution of the hours spent in each unit.

Introducing Flexible Schedules for Staff

Another approach to reducing ICU costs is directly related to staffing. Due to the continuous need for support and care for patients in the ICU, the nursing staff is a constant in all ICUs. These highly-trained nurse teams deployed in a one-nurse per one-to-three patients basis means large teams must be employed to cover the ICU demands. Nursing staff salaries represent a major cost in ICU, making flexibility in nurse scheduling necessary for efficient resource utilization. (5) Flexible strategies may

include sharing personnel between units (thus dividing workload), and creating part-time teams for backup when needed. By applying this strategy, it is expected for mean costs to decrease as the nursing staff adapt to workload redistribution. (5)

The Role of Sedatives on ICU Costs

The use of IV sedatives can have an impact on ICU costs since some sedatives cause respiratory depression, which can prolong time on the mechanical ventilator and ICU length of stay. (16). In addition, some agents like the benzodiazepines predispose patients to develop delirium, which has also been shown to prolong time on the ventilator and lengthen stay in the ICU. The increased costs of oversedation also may result from additional diagnostic tests and neurology consults. The inability to perform a proper neurologic examination may delay the diagnosis and prolonged time to receive appropriate therapy. Adverse drug events from specific sedatives can also increase cost. Examples include propylene glycol toxicity from high-dose lorazepam which can cause acute kidney injury and the propofol-related infusion syndrome which can ultimately result in death. In contrast, the cost of under-sedation can also increase ICU costs. For example, these patients may be tachycardic and exacerbate myocardial ischemia leading to an acute myocardial infarction. Finally, the cost of patients who pull out lines and catheters has been estimated to be US\$ 181 per event in 1997. (21)

There have been a few cost studies of sedatives in the ICU. An economic analysis of a randomized clinical trial of propofol vs. lorazepam revealed propofol to be cost effective and it lowered hospital costs by US\$ 6378. (16) A cost minimization study was recently conducted on the randomized clinical trial of dexmedetomidine vs. midazolam in adult mechanically-ventilated patients requiring long-term sedation. (16) The percent of time at goal sedation range was equivalent between the two groups hence a cost minimization analysis was performed on the difference in total ICU costs in the two treatment arms. Despite a significantly higher acquisition cost in the dexmedetomidine group, this drug resulted in a median total ICU cost savings of US\$ 9679. This saving was driven primarily by reduced costs associated with ICU stay and time on the ventilator.

Introducing a Clinical Pharmacist to Round in the ICU

Another component of effective ICU care is the documented cost savings and improved outcomes of the clinical pharmacist rounding in the ICU. Pharmacists on rounds make recommendations on optimizing pharmacotherapy such as reducing dosage of renally cleared drugs in patients with renal insufficiency, discontinuing antibiotics when the infection has been effectively treated, and eliminating duplicate pharmacotherapy. A review article summarized 38 articles published up to 2002 evaluating the impact of the clinical pharmacist on drug costs. (22) Annualized cost savings ranged from US\$ 25,000 to US\$ 319,000. A recent study evaluated a MEDPAR database of 50,000 patients with infections from 270 hospitals. (23) Mortality rates were 24% higher in hospitals without a clinical pharmacist. Furthermore, hospital bills were 13% higher, which resulted in an additional US\$ 224 million in excessive charges. This type of analysis was more recently reported in 141,000 patients with thromboembolic or infarction-related events with and without the presence of a clinical pharmacist. Without a clinical pharmacist, bleeding complications increased 49% resulting in 39% more patients requiring transfusions. Finally, in the absence of a clinical pharmacist, extra Medicare charges were US\$ 215 million and extra drug charges totaled US\$ 26 million. (17)

Optimizing the Use of Laboratory Tests

Another approach has investigated the reduction of ICU costs by changing the way laboratory tests and medical devices are used. (24) Against common belief, laboratory tests globally account for a greater percentage of costs than medical devices such as ventilators and renal replacement machines, despite the operative and engineering costs associated with these devices. The reason for this is that the ICU requires 24/7 acute laboratory services to monitor severely ill patients. Acute laboratory services are imperative in providing optimal care for patients in the ICU. Reducing unnecessary test ordering might be more effective strategy to reduce costs than trying to save on medical devices. (5)

Seguin and Bleichner performed a clinical trial in a 21-bed surgical ICU of a university hospital, where price information of several commonly used laboratory tests

was included in the test ordering form. Mortality and patient's length of stay were recorded. The trial revealed an important reduction in arterial blood gases and urine tests ordered, and a significant ($p < 0.05$) 22% decrease in the overall analysis of the expenditures. (24) Length of stay and mortality rate did not change, which means quality of care was not affected during the trial. The conclusions were that including price information in the laboratory test orders resulted in a reduction of almost all tests orders, with the exception of liver function tests, which were generally prescribed only when the patient's disease evaluation required them. (24)

Searching for Outcome Predictors

Reducing ICU costs becomes more complex as the patient's reason to be in the ICU is evaluated. Many of the strategies described previously were related to patients' length of stay in the ICU and resource utilization, but not to the event that triggers their need for intensive care. When physicians face prognostic uncertainty, which happens often when dealing with severely ill patients, the plan usually followed is to continue life support (5) with the resulting prolonged expenses.

It is the physician's responsibility to judge when life-support treatment will only prolong life without changing the patient's prognosis. Luce and Rubenfeld stated that particularly these patients with unpredictable outcomes actually account for large expenses in the ICU. (25) Thus, research for diagnostic and prognostic tools available for physicians may help to prioritize patient's admission to the ICU and lead to the early identification and transfer of patients too desperately ill to benefit from critical care to receive adequate palliative care. Important factors for this decision-making process include underlying disease, patient's age, severity of illness, and likely prognosis. The implication of these actions is highlighted when considering that patients who die in the ICU account for greater expenses than those who survive. (25)

Conclusions

The ICU is considered as a life-saving resource, with 24-hour available laboratory evaluation and medical devices

at the ready. Patients that likely would have died in other circumstances are revived and sustained in ICUs all over the world. Care in the ICU results in substantial resource usage, and accounts for considerable costs. This should encourage clinicians to search for solutions that would optimize resource usage.

It is important to consider that economics is a dynamic factor in critical care, and cost management strategies may change constantly over time. Critical care economics involves a variety of issues equally relevant, therefore in the attempt to reduce resource usage it is crucial to evaluate not only the costs of therapeutics delivered in an ICU, but the decision-

making process by which patients are selected for entry and discharge from this unit. Cost-effective therapies should be employed. Through concerted efforts and diligence an overall strategy to reduce costs associated with ICU care can be effectively managed without adversely affecting the patients' welfare.

Acknowledgements

The authors would like to thank Dr. Richard Pistolese for his assistance in the preparation and review of this manuscript.

References

- Ginsburg PB. Controlling health care costs. *N Engl J Med* 2004;351:1591-3.
- U.S. Department of Health & Human Services. Centers for Medicare & Medicaid Services. National Health Expenditure Data: NHE Fact Sheet. [Online]. 2009 [cited 2009 Jul 21]; Available from: URL:<http://www.cms.hhs.gov/NationalHealthExpendData/25/NHEFactSheet.asp>.
- Catlin A, Cowan C, Hartman M, Heffler S; National Health Expenditure Accounts Team. National health spending in 2006: a year of change for prescription drugs. *Health Aff (Millwood)* 2008;27:14-29.
- Smith C, Cowan C, Heffler S, Catlin A. National health spending in 2004: recent slowdown led by prescription drug spending. *Health Aff (Millwood)* 2006;25:186-96.
- Adhikari N, Sibbald W. The large cost of critical care: realities and challenges. *Anesth Analg* 2003;96:311-4.
- Levit K, Cowan C, Lazenby H, Sensenig A, McDonnell P, Stiller J, et al. Health spending in 1998: signals of change. The Health Accounts Team. *Health Aff (Millwood)* 2000;19:124-32.
- Dorman T, Pauldine R. Economic stress and misaligned incentives in critical care medicine in the United States. *Crit Care Med* 2007;35:S36-43.
- Edbrooke DL, Corcoran MC, Dean J, Hibbert CL, Coates E, Jacobs P. The costs of intensive care. II International Congress of Critical Care Medicine in Internet (CIMC 2000); 2000 Nov 1-30; <http://www.uninet.edu/cimc2000/>; 2000. p. 195-202.
- Lewis KS, Kane-Gill SL, Bobek MB, Dasta JF. Intensive insulin therapy for critically ill patients. *Ann Pharmacother* 2004;38:1243-51.
- Noseworthy TW, Konopad E, Shustack A, Johnston R, Grace M. Cost accounting of adult intensive care: methods and human and capital inputs. *Crit Care Med* 1996;24:1168-72.
- Zilberberg MD, Shorr AF. Prolonged acute mechanical ventilation and hospital bed utilization in 2020 in the United States: implications for budgets, plant and personnel planning. *BMC Health Serv Res* 2008;8:242.
- Cox CE, Carson SS, Govert JA, Chelluri L, Sanders GD. An economic evaluation of prolonged mechanical ventilation. *Crit Care Med* 2007;35:1918-27.
- Dasta JF, McLaughlin TP, Mody SH, Piech CT. Daily cost of an intensive care unit day: the contribution of mechanical ventilation. *Crit Care Med* 2005;33:1266-71.
- Cohen IL, Bari N, Strosberg MA, Weinberg PF, Wacksman RM, Millstein BH, et al. Reduction of duration and cost of mechanical ventilation in an intensive care unit by use of a ventilatory management team. *Crit Care Med* 1991;19:1278-84.
- Chelluri L, Im KA, Belle SH, Schulz R, Rotondi AJ, Donahoe MP, et al. Long-term mortality and quality of life after prolonged mechanical ventilation. *Crit Care Med* 2004;32:61-9.
- Dasta JF, Kane-Gill S. Pharmacoeconomics of sedation in the ICU. *Crit Care Clin* 2009;25:571-83, ix.
- MacLaren R, Bond CA. Effects of pharmacist participation in intensive care units on clinical and economic outcomes of critically ill patients with thromboembolic or infarction-related events. *Pharmacotherapy* 2009;29:761-8.
- Ranucci M, Bellucci C, Conti D, Cazzaniga A, Maugeri B. Determinants of early discharge from the intensive care unit after cardiac operations. *Ann Thorac Surg* 2007;83:1089-95.
- Van den Berghe G, Wouters PJ, Kesteloot K, Hilleman DE. Analysis of healthcare resource utilization with intensive insulin therapy in critically ill patients. *Crit Care Med* 2006;34:612-6.
- Cheng DC. Fast track cardiac surgery pathways: early extubation, process of care, and cost containment. *Anesthesiology* 1998;88:1429-33.
- Fraser GL, Riker RR, Prato BS, Wilkins ML. The frequency and cost of patient-initiated device removal in the ICU. *Pharmacotherapy* 2001;21:1-6.
- Kane SL, Weber RJ, Dasta JF. The impact of critical care pharmacists on enhancing patient outcomes. *Intensive Care Med* 2003;29:691-8.
- MacLaren R, Bond CA, Martin SJ, Fike D. Clinical and economic outcomes of involving pharmacists in the direct care of critically ill patients with infections. *Crit Care Med* 2008;36:3184-9.
- Seguin P, Bleichner JP, Grolier J, Guillo YM, Malledant Y. Effects of price information on test ordering in an intensive care unit. *Intensive Care Med* 2002;28:332-5.
- Luce JM, Rubenfeld GD. Can health care costs be reduced by limiting intensive care at the end of life? *Am J Respir Crit Care Med* 2002;165:750-4.