A comparison of critical care research funding and the financial burden of critical illness in the United States*

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Objectives: **To estimate federal dollars spent on critical care research, the cost of providing critical care, and to determine whether the percentage of federal research dollars spent on critical care research is commensurate with the financial burden of critical care.**

Design and Data Sources: **The National Institutes of Health Computer Retrieval of Information on Scientific Projects database was queried to identify funded grants whose title or abstract contained a key word potentially related to critical care. Each grant identified was analyzed by two reviewers (three if the analysis was discordant) to subjectively determine whether it was definitely, possibly, or definitely not related to critical care. Hospital and total costs of critical care were estimated from the Premier Database, state discharge data, and Medicare data. To estimate healthcare expenditures associated with caring for critically ill patients, total costs were calculated as the combination of hospitalization costs that included critical illness as well as additional costs in the year after hospital discharge.**

Measurements and Main Results: **Of 19,257 grants funded by the National Institutes of Health, 332 (1.7%) were definitely related to critical care and a maximum of 1212 (6.3%) grants were possibly related to critical care. Between 17.4% and 39.0% of total hospital costs were spent on critical care, and a total of between $121 and $263 billion was estimated to be spent on patients who required intensive care. This represents 5.2% to 11.2%, respectively, of total U.S. healthcare spending.**

Conclusions: **The proportion of research dollars spent on critical care is lower than the percentage of healthcare expenditures related to critical illness. (Crit Care Med 2012; 40:1072–1079)**

Key Words: critical care; expenditure; grant; healthcare; National Institutes of Health; research

Critical illness frequently is lethal. Certain subsets of critically ill patients (such as those with severe sepsis or the acute respiratory distress syndrome) have a hospital mortality as high as 20% to 40% (1, 2). Many patients discharged from the intensive care unit (ICU) do not immediately, if ever, return to their previous quality of life, and ICU survivors have high mortality rates after hospital discharge (3–8).

Despite the significant public health impact of critical illness, little is known about the availability of funding for critical care research. A major reason for this lack of knowledge is that federal funding for critical illness research comes from a variety of sources. Although the National Institutes of Health (NIH) has 27 institutes and centers devoted to disease entities such as cancer or heart disease, none of these entities is specifically dedicated to critical care. Additionally, there are no specific study sections within the Center for Scientific Research dedicated to reviewing grants on critical care. Rather, multiple study sections review and multiple institutes fund elements of critical care as part of their larger mission (9). Part of this may be secondary to the fact that critical care medicine is a relatively new specialty in American medicine (10). This may also be the result of the systemic nature of critical illness, in which multiple organs are affected by the same underlying disease process. The lack of a singular funding entity is also consistent with the multiple pathways through which physician providers in critical care can enter the field through fellowships in pulmonary, surgical, anesthesiology, pediatric, neurologic, or neonatal critical care and the multiprofessional nature (physician, nursing, pharmacy, respiratory, nutrition support) of critical care science.

***See also. p. 1337**.

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The computer program to query the National Institutes of Health Computer Retrieval of Information on Scientific Projects database was written by full-time staff members of the Society of Critical Care Medicine who provided the raw material to the research team.

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This study examines the amount of federally funded critical care research, the financial burden of caring for critically ill patients in the United States, and whether the relative percentages compared with overall research and healthcare spending, respectively, are commensurate.

MATERIALS AND METHODS

Percentage of Federal Research Dollars Spent on Critical Care Research. The impetus for this study arose during the deliberations of a task force appointed by the President of the Society of Critical Care Medicine that was charged with developing a blueprint for future research in critical care. The task force included researchers with a broad range of critical care expertise including intensivists (trained in surgical critical care, anesthesiology critical care, pulmonary/critical care or pediatric critical care), critical care pharmacists, and critical care nurses. Part of the discussion that arose in the task force concerned allocation of resources for investigations into critical illness and how this compared with overall spending on critical illness. An inability to answer this question directly led to this study.

The initial phase of this project was to develop a set of key words or phrases likely to identify the vast majority of grants related to critical care related research. To accomplish this, the task force examined a list of all 3744 terms on file to describe reviewer expertise for the journal *Critical Care Medicine*. The list of 3744 terms was reviewed to eliminate identical or closely related entries. For example, there were 96 variations on intensive care, 62 variations on sepsis, and 60 variations on trauma. This list was then narrowed down to 133 individual key words or phrases (Table 1) felt to be sufficiently broad as to capture >95% of grants related to critical care.

Using a computer program written by full-time Society of Critical Care Medicine staff members, all grants in the NIH Computer Retrieval of Information on Scientific Projects database were surveyed for these 133 key words or phrases to identify research grants funded in 2006 that might be related to critical care. For each grant whose title or abstract contained one or more of the key words, the program supplied the grant title, abstract, funding institute within the NIH, grant type (i.e., R01, T32, etc.), and years of funding.

The title and abstract for each identified grant were independently analyzed by two different reviewers. These individuals subjectively determined if a grant was definitely, definitely not, or possibly related to critical care. Each reviewer electronically filled in a box labeled Y (for yes), N (for no), or P (for possibly) based on a review of each grant title

Table 1. Key words used to search the National Institutes of Health Computer Retrieval of Information on Scientific Projects database

Abdominal compartment syndrome	Abdominal hypertension
Activated protein C	Acidosis
Acute coronary syndrome	Acute lung injury
Acute renal failure	Acute respiratory distress syndrome
Anaphylaxis	Antibiotics
Acute respiratory distress syndrome	Arrhythmias
Bacteria	Bacterial translocation
Bioterrorism	Blood substitutes
Brain death	Brain injury
Brain natriuretic peptide	Burns
Carbon monoxide	Catheter-related bloodstream infection
Central venous catheter	Cerebral perfusion pressure
Cerebrovascular autoregulation	Coagulopathy
Community acquired pneumonia	Continuous renal replacement therapy
Cardiopulmonary resuscitation	Critical care
Critical care medicine	Critical illness
Critical illness polyneuropathy	C-reactive protein
Defibrillation	Delirium
Disaster	Disseminated intravascular coagulation
Dobutamine	Dopamine
Drowning	Extracorporeal membrane oxygenation
Emerging pathogens	Endotoxin
Endotracheal tube	End of life
Epinephrine	Ethyl pyruvate
Goal-directed therapy	Glutamine
Gut barrier dysfunction	Heat shock response
Heat stroke	Heme oxygenase-1
Hemodynamic monitoring	Hemorrhage
Heparin-induced thrombocytopenia	Hepatorenal syndrome
Hepatopulmonary syndrome	High-frequency ventilation
High mobility group box 1	Hyperbaric
Hyperthermia	Hypertonic saline
Hypothermia	Hypoxia
Intensive care unit	Immunonutrition
Infection	Inhalation
Inotrope	Intensive care
Intensive care medicine	Intensive Care Unit
Intensivist	Interleukin-6
Interleukin-10	Intracranial pressure
Ischemia/reperfusion	Lactate
Liquid ventilation	Mechanical ventilation
Methicillin-resistant *Staphylococcus aureus*	Multiple organ dysfunction syndrome
Multiple organ failure	Neonatology
Neurointensive care	Neuromuscular blockade
Nitric oxide	Noninvasive ventilation
Norepinephrine	Nuclear factor κB
Oxidative stress	Oxygen delivery
Oxygen transport	Pancreatitis
Positive end-expiratory pressure	Phenylephrine
Pneumonia	Poisoning
Pressor	Pressure support ventilation
Procalcitonin	*Pseudomonas aeruginosa*
Pulmonary artery catheter	Pulmonary embolus
Pulmonary hypertension	Reactive oxygen species
Resuscitation	Rhabdomyolysis
Right ventricular performance	Sedation
Selective decontamination	Sepsis
Shock	Sepsis inflammatory response syndrome
Status asthmaticus	Status epilepticus
Stress response	Subarachnoid hemorrhage
Surfactant	Systemic inflammatory response syndrome
Toxicology	Tracheostomy
Transfusion-related acute lung injury	Trauma
Traumatic brain injury	Tumor necrosis factor
Vasospasm	Vasopressin
Vasopressor	Ventilation
Ventilator-induced lung injury	Ventilator-associated pneumonia

and abstract they believed was, was not, or was possibly related to critical care. When there was concordance between the first two reviewers, no further analysis was performed. When there was discordance between the first two reviewers, a third reviewer independently analyzed the grants using the same criteria.

Proportion of National Healthcare Budget Spent on Critical Illness. A range of estimates of the proportion of national healthcare spending that is spent on the care of the critically ill was generated using two approaches. The first involved estimating the proportion of inpatient spending on patients in intensive care settings. The second involved estimating total direct healthcare spending for critically ill patients incorporating 1-yr cost streams after critical illness to estimate the spending on critical illness as a proportion of total healthcare spending.

The primary approach defined spending on critical illness as the cost incurred daily on patients in an ICU during the hospitalization and calculated the cost of care in the ICU as a percentage of total hospital costs for all patients. Estimates of hospital costs of critical care (numerator) and total hospital costs (denominator) were generated using the Premier Database from 2008. Premier is a privately owned database developed for measuring quality and use of health care. The 419 participating hospitals represent all regions of the United States and serve a largely urban patient population. In addition to standard information available in hospital discharge files, the Premier Database contains a date-stamped log of all billed items, including medications, laboratory, diagnostic, and therapeutic services for each patient. Consequently, it is possible to identify the charges that are associated only with the time a patient spends in an ICU. These cost estimates include all billed items for patients but exclude costs associated with physician billing and out-of-pocket costs. These estimates of critical care spending are likely to be more accurate than data generated from other sources such as Medicare, because they include all patients regardless of insurance status and age as well as details on costs of the process of care, including specific services provided during the ICU stay (11). We then used an inflator of 17% to account for physician services (12). The database also provides projection weights to arrive at U.S. national estimates.

Estimates were also calculated of the proportion of total U.S. healthcare expenditure that is spent on caring for critically ill patients as opposed to other noncritically ill hospitalized patients and general outpatient care. Total costs were defined as the costs of hospitalization that includes critical illness and the additional costs associated with care for survivors of critical illness in the year after hospital discharge. The rationale for including costs after discharge is the increasing recognition of the long-term consequences of critical care, indicating that critical illness does not end on discharge from the ICU but rather continues to have a lasting impact on healthcare services required by many patients. The estimate of the additional costs associated with having been critically ill was defined as the mean Medicare spending in the year after hospital discharge for survivors of critical illness minus the mean Medicare spending for matched general population controls using all inpatient and outpatient records for a 2.5% sample of Medicare beneficiaries with the year of follow-up occurring in 2004. These estimates are based on unpublished data from a previously described cohort of Medicare beneficiaries who received intensive care and survived to hospital discharge (4) (see Appendix for further details). As a result of data constraints, the estimates of care after hospital discharge are from a different year of data (2004). The consumer price index inflation calculator was used to adjust these costs to 2008 dollars.

The study was reviewed by the institutional review board at Emory University and was approved as not requiring informed consent.

RESULTS

Number of Grants Potentially Related to Critical Care. A total of 8,327 unique grants (42.9% of all grants funded by the NIH) contained at least one of the 133 key words or phrases (Fig. 1). Further review by two or three independent examiners determined if each grant identified by the key word screen was definitely ("Y"), possibly ("P"), or definitely not ("N") related to critical care. There was concordance between the two reviewers on a total of 7671 grants (92.8%, see Supplemental Table 1 for details [Supplemental Digital Content 1, http://links.lww.com/CCM/A411]).

Percentage of Grants Potentially Related to Critical Care. To determine the overall percentage of grants related to critical care, the data were analyzed using four different standards (Table 2). In the most liberal standard, the grant needed only to be rated as "definitely" or "possibly" critical care by a single reviewer irrespective of the opinion of the other reviewers. Using this definition, a total of 1212 grants (6.3% of all NIH grants) were definitely or possibly related to critical care. In contrast, the most conservative standard required that two reviewers rate a grant as definitely critical care (Y/Y, Y/P/Y, or Y/N/Y). Under this definition, a total of 332 grants (1.7% of all NIH grants) were related to critical care. Two moderate standards identified between 2.6% and 4.1% of all NIH grants funded as related to critical care. Further analysis was performed using only the most conservative and liberal standards.

Institutes Funding Critical Care. A total of 8 institutes within the NIH funded >90% of all grants related to critical care regardless of whether a liberal or

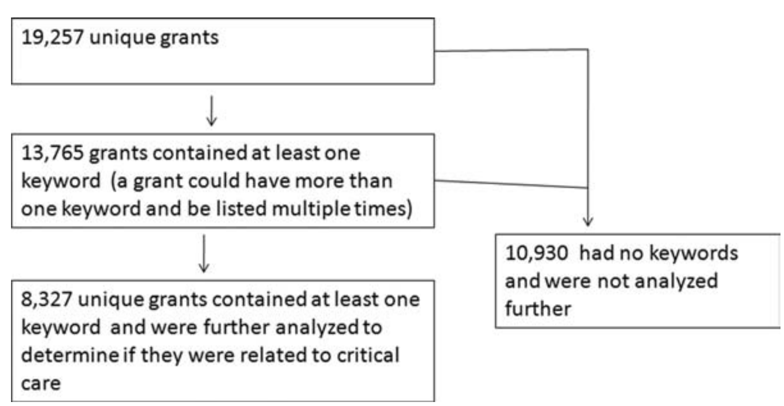

Figure 1. Flowchart outlining which grant abstracts were analyzed to determine whether or not they were related to critical care.

Table 2. Standards to define critical care

Standard	Definition	Number of Grants	Percent of Grants (of 19,257)
Liberal	Any grant with a single Y or P	1212	6.3%
Moderate 1	Any grant with Y/Y, P/P or Y/P	796	4.1%
Moderate 2	Any grant with a single Y	494	2.6%
Conservative	Any grant with 2 Ys	332	1.7%

Y, definitely; P, possibly.

Table 3. Funding institute and grant type

Institute	Liberal (%)	Conservative (%)	Conservative/Liberal[a]
Total	1212 (100%)	332 (100%)	27%
National Heart, Lung and Blood Institute	469 (38.7%)	122 (36.7%)	26%
National Institute of Allergy and Infectious Diseases	166 (13.7%)	25 (7.5%)	15%
National Institute of Neurologic Disorders and Stroke	164 (13.5%)	28 (8.4%)	17%
National Institute of General Medical Sciences	122 (10.1%)	76 (22.9%)	62%
National Institute of Diabetes and Digestive and Kidney Diseases	75 (6.2%)	12 (3.6%)	16%
Eunice Kennedy Shriver National Institute of Child Health and Human Development	58 (4.8%)	21 (6.3%)	37%
National Institute on Aging	21 (1.7%)	3 (0.9%)	14%
National Institute of Nursing Research	17 (1%)	12 (3.6%)	71%
All others	120 (9.9%)	33 (9.9%)	28%

[a]Conservative/liberal represents the ratio of grants identified by the conservative standard divided by grants identified by the liberal standard. Hypothetically, if all grants identified by the conservative standard were also identified by the liberal standard, this percentage would be 100%. The lower the percentage identified, the less likely it is that grants identified using the liberal standard truly represent grants related to critical care.

conservative standard was used (Table 3). However, there was significant variance between institutes in the percentage of grants that were rated as critical care using the different standards. A total of 27% (332 of 1212) of grants that were defined as critical care using the liberal standard also were defined as critical care using the conservative standard. A similar percentage (26%) was found in grants funded by the National Heart, Lung and Blood Institute, the agency that funds the largest number of grants identified as critical care research. Although they funded a smaller number of grants, the majority of grants funded by both the National Institute of General Medical Sciences and the National Institute of Nursing Research identified by the liberal strategy also were identified by the conservative strategy (62% and 71%, respectively) demonstrating the reviewers were very confident that grants from these entities related to critical care. In contrast, >80% of grants that were identified as critical care research using the liberal strategy from the National Institute of Allergy and Infectious Diseases, the National Institute of Neurologic Disorders and Stroke, and the National Institute on Aging were not identified using a conservative strategy, suggesting the reviewers were not confident that most of the grants funded by these agencies actually related to critical care.

Types of Grants Funded. The Computer Retrieval of Information on Scientific Projects database indicated that a total of 71 different types of grants were funded in 2006. Of these, 18 funding mechanisms accounted for >90% of all federally funded grants (Table 4). A total of 38 different types of grants were funded using the liberal standard of critical care and 23 different types of grants were funded using the conservative standard. The percentage of each type of critical care grant funded generally reflected that of all federally funded grants (Table 4).

Spending on Critical Care. To determine the overall spending related to critical care in the hospital, data were analyzed using a range of estimates. The conservative estimate included costs from days in adult, pediatric, and neonatal ICUs. The moderate estimate additionally included costs of days in intermediate ICUs. The liberal estimate also included coronary care and intermediate coronary care units. The denominator was the cost of all care for patients in the hospital over the same time period.

There were a total of 22,902,908 hospital days and 5,150,994 discharges from the 419 hospitals in the Premier database. Depending on the standard used, between 10.1% and 28.5% of total patients had critical care days (Table 5). Furthermore, the unweighted estimates of the proportion of hospital days that involved critical care services ranged from 10.3% to 28.8% of all hospital days. The costs of these critical care services as a proportion of all hospital costs ranged from 17.4% to 39.0%. Using weights to generate national projections, between 16.9% and 38.4% of total hospital costs are the result of critical care costs.

In an attempt to incorporate additional costs of care in the year after discharge from the hospital for critically ill patients, a separate estimate of spending on critically ill patients as a proportion of total healthcare spending was calculated (Table 5). These estimates included all hospital costs for critically ill patients and an estimate for spending on postdischarge care that was attributable to the critical illness. These estimates ranged from $121 billion to $263 billion, representing 5.2% to 11.2% of total U.S. healthcare spending.

DISCUSSION

Research funding for critical care represents between 1.7% and 6.3% of the federal research budget. Care for critically ill patients is estimated to cost between $121 billion and $263 billion annually in the United States, which represents between 5.2% and 11.2% of national healthcare expenditures.

The most cautious way to interpret the data is using the most liberal definition of research funding and the most conservative definition of healthcare expenditures. Only using this technique is there a similarity between funding for research related to critical illness and the financial burden of critical illness. This differential potentially underestimates the discrepancy because it assumes that 1) every grant that was identified by only a single reviewer as "possibly related to critical care" was actually related to critical care even if the other two reviewers rated it "definitely not related to critical care" (liberal definition of grant funding); and 2) there are no critically ill patients in coronary care units or intermediate care areas (conservative definition of healthcare expenditures). At the other end of the spectrum, using the most conservative definition of research funding and the most liberal definition of healthcare expenditures, there is a more than sixfold discrepancy between the federal dollars directed toward critical care research and the financial burden that critical illness places on the U.S. healthcare system although it is likely that this overestimates the true difference.

It is possible to make some direct comparisons to other common causes of death in the United States. The NIH recently began reporting estimates of funding in 229 areas of research and disease areas (13). According to NIH data, funding for cancer research and cardiovascular

Table 4. Funding mechanism by grant type

Grant Type	Total (% of 19,257)	Liberal (% of 1,212)	Conservative (% of 332)
R series	12,802 (66.5%)	801 (66.1%)	196 (59.0%)
R01	10,292 (53.4%)	717 (59.2%)	171 (51.5%)
R21	1,001 (5.2%)	24 (2.0%)	6 (1.8%)
R03	334 (1.7%)	5 (0.4%)	2 (0.6%)
R37	251 (1.3%)	15 (1.2)	4 (1.2%)
R43	220 (1.1%)	17 (1.4%)	8 (2.4%)
R44	213 (1.1%)	6 (0.5%)	0 (0%)
Other	491 (2.5%)	27 (2.2%)	5 (1.5%)
P series	2,032 (10.6%)	131 (10.8%)	36 (10.8%)
P01	1,253 (6.5%)	90 (7.4%)	19 (5.7%)
P50	358 (1.8%)	36 (3.0%)	17 (5.1%)
P30	215 (1.1%)	3 (0.2%)	0 (0%)
Other	206 (1.1%)	2 (0.2%)	0 (0%)
K series	1,378 (7.2%)	123 (10.1%)	50 (15.1%)
K08	515 (2.7%)	66 (5.4%)	26 (7.8%)
K23	320 (1.7%)	29 (2.4%)	16 (4.8%)
K01	221 (1.1%)	6 (0.5%)	2 (0.6%)
Other	322 (1.6%)	22 (1.8%)	6 (1.8%)
T&F series	1,064 (5.5%)	77 (6.4%)	28 (8.4%)
F32	378 (2.0%)	10 (0.8%)	1 (0.3%)
T32	336 (1.7%)	54 (4.4%)	23 (6.9%)
F31	251 (1.3%)	7 (0.6%)	3 (0.9%)
Other	322 (1.7%)	6 (4.9%)	1 (0.3%)
Other	1,981 (10.3%)		
Z01	581 (3.0%)	18 (1.5%)	9 (2.7%)
U01	577 (3.0%)	16 (1.3%)	1 (0.3%)
U10	150 (0.8%)	17 (1.4%)	8 (2.4%)
Other	673 (3.5%)	76 (6.3%)	16 (4.8%)

disease were $5549 million and $1942 million in 2007, representing 19.4% and 6.8% of the NIH budget, respectively (13). The financial burden for cancer care ranges from $124.7 to $157.8 billion (14), whereas the cost of cardiovascular disease has recently been estimated to be $431.8 billion (15). Thus, although critical illness places a similar or slightly greater economic burden on society than cancer care, proportionally 3.1–11.4 times more federal research money was spent on cancer research than on critical care research. In contrast, U.S. healthcare expenditures directed toward cardiovascular disease are twice those of critical care, whereas funding is between 1.1 and 4 times greater. Thus, the discrepancy between research funding and healthcare expenditures could be more, less, or the same as that of critical care depending on the definitions of critical care research used.

It is difficult to compare our results with most components of the NIH's reporting system on research and disease areas because significantly different criteria were used in the NIH report vs. our key word approach. In fact, only three diseases/key words appear on both lists: acute respiratory distress syndrome, septicemia (sepsis on the key words list), and pneumonia. Grants containing the key words "acute respiratory distress syndrome" and "septicemia" received $87 million and $93 million, respectively, out of a total budget of >$28 billion in 2007 per NIH reports. Our analysis indicated that 75% (61% definitely, 13% possibly) and 72% (53% definitely, 19% possibly) of grants containing these key words related to critical care. According to the NIH, pneumonia received $105 million in funding. However, our analysis indicated that only 25% of grants identified by this key word were potentially related to critical care (12% definitely, 13% possibly). Assuming that our reviewers' assessments were correct, this finding means that the NIH funded $158.5 million for critical care research related to the acute respiratory distress syndrome, sepsis, and pneumonia in 2007. This is similar to research dollars allocated for study of anthrax ($160 million), smallpox ($142 million), or tuberculosis ($188 million) and is less than the amount spent on sleep research ($219 million) and chronic pain conditions ($277 million).

The number of deaths related to sepsis, acute respiratory distress syndrome, and pneumonia also varies widely depending on the reporting method used. Official federal government records count pneumonia as the eighth most common cause of death with septicemia being the tenth most common cause of death with 56,000 and 34,000 deaths, respectively (16). However, all patients dying of pneumonia meet established criteria for sepsis (17). Similarly, government estimates of death from septicemia likely rely on definitions focusing on blood culture results. Estimates using broader, more clinically relevant criteria place the number of deaths from sepsis at >200,000 patients per year (18, 19), making it the third most common cause of death in the United States after heart disease and cancer. In addition, 75,000 people die of acute respiratory distress syndrome each year (20, 21), although there assuredly is overlap between patients dying of sepsis and acute respiratory distress syndrome. By comparison, <100 people have died from anthrax attacks in the last decade, small pox was eradicated in 1980 (22), and 545 people died from tuberculosis in the United States in 2007 (23), although tuberculosis continues to be a very common cause of death in developing countries.

Determining the percentage of federal healthcare research dollars related to critical care is complicated because critical care research spans multiple domains, including molecular, clinical, outcomes, epidemiologic, end-of-life, ethics, etc. Furthermore, funding for other medical fields can indirectly help critically ill patients, and there was no way to quantitate this. For example, research on patient safety not directed at the ICU can ultimately prove to be beneficial in the critical care setting. Because this could not be measured, it is possible that our analysis underestimated how healthcare spending in other domains benefited critical care. Estimates also are complicated by the structure of the NIH. Funding for cancer research largely is directed through the National Cancer Institute. Similarly, funding for cardiovascular diseases is predominantly administered by the National Heart, Lung and Blood Institute. In contrast, there is no single center or institute within the NIH that provides the majority of the dollars directed toward critical care research. Although the majority of funding comes from eight institutes, no single entity provided the majority of the dollars. Similarly, there was no institute in which critical care constituted the preponderance of funding outlay. Whether funding decisions are the result of 1) a limited number of submissions from critical care

Table 5. Estimates of costs of critical care compared with total hospital costs for Premier data in 2008 and national projections

n = 4.9 Million Hospital Discharges (Premier, 2008)	Estimates of Critical Care[a]		
	Conservative	Moderate	Liberal
Premier data			
Patients with critical care days (no.)	498,768	848,940	1,405,046
Patients with critical care days as a percent of total hospital patients	10.1%	17.2%	28.5%
Critical care days (millions)	2.3	3.9	6.5
Critical care days as a percent of hospital days	10.3%	17.2%	28.8%
Hospital critical care costs (billions)[b]	$9.5	$13.7	$21.3
Hospital critical care costs as a percent of total hospital costs[b]	17.4%	25.0%	39.0%
National projections (weighted)			
Hospital critical care costs (billions)[b]	$59.5	$77.1	$135.0
Critical care costs as a percent of total hospital costs[b]	16.9%	24.0%	38.4%
Estimate of total national health expenditure on critical illness			
Hospital costs for critically ill patients (billions)[b]	$89.0	$116.2	$165.6
Survivors of critical illness (millions)	3.0	5.1	9.0
Estimate of additional costs for each survivor of critical illness in the first year after discharge[c]	$10,787	$10,787	$10,787
Estimate of total additional costs (billions)	$32.4	$55.0	$97.1
Total costs for critical illness (billions)	$121.4	$171.2	$262.7
National Health Expenditure[d]	$2,339	$2,339	$2,339
Critical illness expenditure as a percent of total National Health Expenditure	5.2%	7.3%	11.2%

[a]Conservative includes adult intensive care, pediatric intensive care, and neonatal intensive care. Moderate includes adult intensive care, pediatric intensive care, neonatal intensive care, and intermediate intensive care. Liberal includes adult intensive care, pediatric intensive care, neonatal intensive care, intermediate intensive care, coronary care, and intermediate coronary care; [b]includes an additional 17% for physician costs not included in the original estimates (1); [c]see Appendix for data on survivors of critical illness; unpublished data from Phua et al (2); [d]http://www.cms.gov/NationalHealthExpendData/Downloads/NHEProjections2009to2019.pdf (data from 2008).

researchers compared to those studying other diseases; 2) the absence of study sections solely dedicated to critical care assuring peer review from multiple experts in the field; 3) the relative poor track record of preclinical critical care trials translating into positive patient outcomes (24); 4) bias that there are other more important funding priorities; or 5) a combination of all of these factors cannot be determined from this study. Furthermore, the impact of newly formed critical care research networks including the U.S. Critical Illness and Injury Trials Group (25) and Collaborative Pediatric Critical Care Research Network (26) is unclear. Similarly, the impact of recently issued NIH requests for applications related to critical care is unknown.

This study shows the significant fiscal burden that critical care places on hospitals in the United States, yet also highlights the challenges of identifying both critical illness and the costs of care that can be attributed solely to critical illness vs. underlying comorbidity. Depending on the standard used, critical care accounted for between 16.9% and 38.4% of hospital costs in 2008, a wide range that underscores the difficulty in defining critical illness. Although it is easy to surmise that an intubated patient on vasopressors in any ICU is critically ill, it is more difficult to characterize patients in an intermediate care unit. These individuals often are too ill to be treated on a regular hospital ward but do not need the level of care provided in an ICU. Similarly, characterizing coronary care is challenging. Many patients in this environment are admitted only for monitoring and may not meet a definition of critical illness. However, 28% of patient days in the coronary care unit involve mechanical ventilation and 44% of patient days are characterized by central venous catheter usage (27). These findings suggest that a significant number of patients in coronary care units are critically ill and eliminating them from analysis likely underestimates the cost and scope of expenditures spent on critical care.

Use of critical care resources in the United States is rapidly expanding (28). A study by Halpern et al (29) showed that between 2000 and 2005, the number of critical care beds and days increased by 6.5% and 10.6%, respectively. In the same period, the cost burden for critical care was estimated to increase from $55.5 billion to $81.7 billion, representing 13.4% of hospital costs and 4.1% of national health expenditures, respectively. In contrast, our data using different methodology estimates that critical care cost between $121 billion and $263 billion in 2008. Our estimates are likely higher for multiple reasons. First, we used data that estimated the hospital costs of critical illness in patients of all ages rather than relying solely on Medicare data that primarily delineates expenditure for elderly patients. Second, our estimates of hospital costs in the ICU were gathered from all billing from each day in the ICU rather than general costs of bed days. Finally, we chose to include an estimate of the additional burden that critical illness places on patients who survive to hospital discharge, recognizing that critical illness does not end at the hospital door but has a lasting impact on the health and care required by many patients (6).

This study has a number of limitations. The analysis of federal research funding is predicated on the fact that the key words and phrases used identified the vast majority of grants related to critical care. Although the source of the 133 key words and phrases was a list of all reviewer expertise on file at the journal *Critical Care Medicine*, a retrospective review after completion of the article identified that both of the terms "myocardial infarction" and "congestive heart failure" were not part of the search. As such, grants related to cardiac critical care may not have been identified, which would mean that our percentage of grants related to critical care may have underestimated the true number. This is especially concerning because 18 key words or phrases identified >100 grants as definitely or possibly related to critical care (Supplemental Table 2 [Supplemental Digital Content 2, http://links.lww.com/CCM/A412]) and we cannot know how many grants we failed to identify. Furthermore, the ability of the key words and phrases varied widely. Only seven identified more than ten grants with a >90% chance of being scored as definitely or possibly critical care, whereas18 identified more than ten grants with a >90% chance of being scored as definitely not related to critical care (Supplemental Table 3 [Supplemental Digital Content 3, http://links.lww.com/CCM/A413]).

Another limitation relates to the fact that the analysis of grant support exclusively examined federal funding agencies. Industry support of healthcare research is double that of federal funding (30). Therefore, a significant component of critical care funding may have been excluded in our analysis. However, there is no reason to believe that industry support of critical care research funding is disproportionately higher than that of the NIH. In fact, the opposite is likely correct because pharmaceutical research frequently is skewed toward investigating agents for chronic conditions that require treatment over an extended period of time (31), which is not the case for treatments provided to the critically ill. Furthermore, the analysis of grant funding was done for a single year only. It is impossible to draw any conclusions about whether critical care funding is increasing over time. Based on NIH records (13), however, funding for acute respiratory distress syndrome, sepsis, and pneumonia cumulatively increased $8 million from 2007 to 2010 (non-American Recovery and Reinvestment Act of 2009). All of this was the result of increased funding for the acute respiratory distress syndrome because funding for both pneumonia and septicemia actually decreased during this time period. In addition, although the authors represented multiple domains within critical care, there were no reviewers with specific expertise in neurologic critical care. The comparison also used data from different years because the estimate of research funding was focused on 1 yr (the year in which the study began), whereas data for the financial burden was calculated using available data sources from 2 different years (based on most recently available data). We therefore cannot rule out that a significant difference in either research funding or financial burden occurred between the years of the study that would not be accounted for in our results.

Estimates of spending on critical care are limited by the available data sources, necessitating the use of a combination of data sets, one of which includes a subset of patients from across the country (Premier) and one which includes only elderly patients (Medicare). We have also had to make large assumptions regarding the additional costs accrued by critically ill patients after discharge, choosing to assume that the majority of additional costs occur only in the first year after hospital discharge and that additional costs accrued by elderly patients who are critically ill are similar for younger patients. Although this is a large assumption, at least half of all ICU patients are aged >65 yrs, so we are likely capturing a reasonable estimate. The estimates of the costs of critical illness also assume that every patient in an ICU is critically ill. Clearly, a subset of patients is admitted to an ICU for monitoring purposes (typically in the postoperative setting). Although these are short-stay patients, it is possible that they substantially contribute to costs, leading to an overestimate of the fiscal burden of critical illness. Finally, we were unable to measure out-of-pocket expenses associated with care of patients.

Despite these limitations, this study provides new insights into both the percentage of federal research dollars dedicated to critical care and the financial burden that critical illness imposes on healthcare in the United States. Multiple factors may account for the discrepancy between the research support and financial burden of critical care. Improved understanding of these factors may help with the development of research and care priorities in the future when the need for critical care services are expected to rise (32) as a result of the aging population.

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Appendix. Additional healthcare costs for Medicare beneficiaries who survived intensive care versus general population controls matched on age, sex, and race

	Intensive Care Unit Survivors	Matched General Controls	Difference
Healthcare costs during 1 yr follow-up, mean ± SD (thousands)	\$14.5 ± 24.2	\$4.4 ± 12.2	+\$10.1

This cohort has been described elsewhere (Wunsch H, Guerra C, Barnato AE, et al: Three-year outcomes for Medicare beneficiaries who survive intensive care. *JAMA* 2010; 303:849–56.). Briefly, the cohort consists of a 2.5% sample of all Medicare beneficiaries >65 yrs who received intensive care defined as "intensive care" or "intermediate intensive care" and survived to hospital discharge in 2003. They were matched, based on age, sex, and race with general population control subjects who were not hospitalized during the same quarter. Costs were calculated as total Medicare payments for the four quarters after hospital discharge using the consumer price index inflation calculator to adjust all costs to 2006 dollars.