Journal of Critical Care 30 (2015) 460–464

Contents lists available at ScienceDirect

Journal of Critical Care

journal homepage: www.jccjournal.org

Advanced imaging use in intensive care units has decreased, resulting in lower charges without negative effects on patient outcomes☆,☆☆,★

Jarone Lee, MD, MPH [a,*], Brian Geyer, MD [b], Leily Naraghi, MD [c], Haytham M.A. Kaafarani, MD, MPH [c], Matthias Eikermann, MD, PhD [d], D. Dante Yeh, MD [c], Ednan K. Bajwa, MD [e], J. Perren Cobb, MD [d], Ali S. Raja, MD, MBA, MPH [f]

[a] Departments of Surgery and Emergency Medicine, Massachusetts General Hospital & Harvard Medical School, Boston, MA
[b] Department of Emergency Medicine, Brigham and Women's Hospital and Massachusetts General Hospital, Boston, MA
[c] Division of Trauma, Emergency Surgery and Surgical Critical Care, Massachusetts General Hospital & Harvard Medical School, Boston, MA
[d] Department of Anesthesia, Critical Care and Pain Medicine, Massachusetts General Hospital & Harvard Medical School, Boston, MA
[e] Department of Pulmonary and Critical Care Medicine, Massachusetts General Hospital & Harvard Medical School, Boston, MA
[f] Department of Emergency Medicine, Brigham and Women's Hospital, Boston, MA

ARTICLE INFO

Keywords:
Radiology use
Intensive care units
Resource use
Computed tomography

ABSTRACT

Purpose: There has been both greater recognition and scrutiny of the increased use of advanced imaging. Our aim was to determine whether there has been a change over time in the use of computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US) modalities in the intensive care units (ICUs).
Materials and Methods: A retrospective review of 75 657 admissions to 20 ICUs was conducted. Results were analyzed with multivariate linear, negative binomial, and Poisson regressions. Primary outcomes were rates of use of CT, MRI, and US per 1000 ICU admissions every 6 months. Secondary outcomes were changes in radiology use associated with impacts on mortality, hospital length of stay (LOS), ICU LOS, and hospital charges.
Results: The rate of imaging use decreased by 13.5% between 2007 and 2011 (incidence rate ratio [IRR], 0.982; $P < .001$). Most of this decrease was by CTs (21.0%; IRR, 0.973; $P < .001$). Use of MRI decreased by 6.0% (IRR, 0.991; $P = .04$), whereas US increased by 18.9% (IRR, 1.012; $P < .001$). The charges associated with imaging decreased by $74 per ICU admission, which would save an estimated $1.2 million in charges during 2011. Decreased imaging was not associated with changes in mortality, hospital, and ICU LOS.
Conclusion: Advanced imaging use decreased for 5 years in the ICUs, resulting in decreased charges without negative effects on patient outcomes.

1. Introduction

According to the Congressional Budget Office, the costs of the US health care system have been outpacing the national economic output by 2% per year over the past few decades [1]. The US health care system spent $2.6 trillion in 2010, approximately 18.0% of the gross domestic product [1]. A major part of this expenditure results from intensive care units (ICUs), where critical care medicine costs increased from an estimated $56.6 to $81.7 billion from 2000 to 2005 [2,3], representing 0.7% of our gross domestic product [2,3]. Maeda et al [4] reviewed discharges in community hospitals of 9 states from 2001 to 2006 and found that ICU charges are responsible for 17.6% of the increase in mean cost per discharge among all discharges. This contribution was 23.4% of medical discharges and 14.6% of surgical discharges [4].

As a result, policymakers at both the national and local levels have begun looking for novel solutions designed to contain costs while maintaining quality of care within ICUs. One potential area is the use of diagnostic imaging, which in addition to high costs, has potential safety concerns as well. The BEIR VII report, published in 2006, highlighted the potential long-term consequences of the ionizing radiation used in medical imaging, and a number of subsequent publications have continued to reemphasize these issues [5–8]. In addition, recent reports emphasize the risks of transporting critical ill and unstable patients outside the ICU environment [9,10]. Although the trend of increasing radiologic testing is well documented in emergency departments (EDs), little is known regarding trends in the use of radiologic testing among patients admitted to ICUs [11–19]. To our knowledge, the only utilization studies of ICU imaging involve chest x-rays (CXRs) [20–22].

☆ Conflicts of interest: The authors report no conflicts of interest.
☆☆ Financial support: None.
★ Abstract presentation: Society of Critical Care Medicine, 2014 Annual Scientific Congress; January 10, 2014; San Francisco, CA.

* Corresponding author. Massachusetts General Hospital, 165 Cambridge St, Suite 810, Boston, MA 02114. Tel.: +1 617 643 2418.
E-mail addresses: Lee.jarone@mgh.harvard.edu (J. Lee), bgeyer@partners.org (B. Geyer), leily.n@aol.com (L. Naraghi), Hkaafarani@partners.org (H.M.A. Kaafarani), MEikermann@partners.org (M. Eikermann), DYeh2@partners.org (D.D. Yeh), ebajwa@partners.org (E.K. Bajwa), jpcobb@partners.org (J.P. Cobb), asraja@partners.org (A.S. Raja).

http://dx.doi.org/10.1016/j.jcrc.2014.12.012
0883-9441/

The primary objective of this study was to examine whether advanced imaging use and charges in the ICUs of 2 major academic hospitals have changed since 2007, with a focus on computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography (US). Our secondary objectives were to examine imaging trends by anatomical region and to determine whether any changes in use were associated with negative effects on the patient-oriented outcomes of mortality, hospital length of stay (LOS), ICU LOS, and hospital charges. We hypothesized that, overall, advanced imaging use and charges have increased without negatively affecting patient outcomes.

2. Materials and methods

2.1. Data source and study population

We performed an electronic chart review of all admissions to the ICU at 2 major academic hospitals from January 2007 to December 2011. All CT scans, MRIs, and US performed on these patients during their ICU stays were identified. The joint institutional review board at both hospitals reviewed and approved this research protocol.

2.2. Study setting

This study was conducted at 2 major academic, quaternary-care hospitals with a total of 20 ICUs. Both institutions have neonatal, surgical, medical, dedicated coronary care units, and burn/trauma ICUs, but only one has a pediatric ICU.

2.3. Data collection and processing

We identified radiologic tests and demographic and clinical information by using a systemwide longitudinal patient data registry, which was queried to pull records for all patients admitted to the ICUs of both institutions during the study period. Predetermined data elements were extracted by trained abstractors onto standardized forms in Microsoft Excel and Access. Specific elements on the forms included age, sex, ethnicity, race, diagnosis, admitting service, ICU type, hospital admission and discharge dates, ICU admission and discharge dates, imaging modality, and body area imaged. All radiologic procedures that were completed before ICU admission and after ICU admission were removed from the analyses.

2.4. Outcome measures

The primary objective of this study was to examine whether advanced imaging use and charges in the ICUs of 2 major academic hospitals have changed since 2007, with a focus on the 3 major modalities of CT, MRI, and US. Secondary objectives included imaging trends by anatomical region and whether any changes in use were associated with any negative effects on the patient-oriented outcomes of mortality, hospital LOS, ICU LOS, and hospital charges. All rates were defined as per 1000 ICU admissions at every 6 months.

2.5. Hospital charges

Charges were estimated based on the 2014 Center for Medicare & Medicaid Services Physician Fee Schedule, which was applied to the entire data set to normalize for temporal changes in the fee schedule. We used the global facility prices for diagnostic services and the national payment amounts, so as not to be biased by any regional or local variation in price. The data were analyzed with standard descriptive statistics.

2.6. Data analysis

Negative binomial regression modeling was used to examine the trends of advanced imaging use, including CT, MRI, and US. Mortality was analyzed using multivariate Poisson regression modeling. For both ICU and hospital LOS, the data were transferred using the natural log and analyzed using a multivariable linear regression model. We used SAS software (SAS Institute Inc, Cary, NC) and Microsoft Excel 2008 (Microsoft, Redmond, WA) for analysis. Statistical significance was set at .05 for regression modeling, and confidence intervals (CIs) were set at 95%.

3. Results

3.1. Characteristics of the study population

From January 1, 2007, to December 31, 2011, there were 75657 admissions to the ICUs of both hospitals. Of the patients admitted, 42.6% were women and 78.9% were white, with a mean age of 59.3 years (range, 0-107 years). Overall severity during this period slightly increased, with an average Deyo-Charlson Comorbidity Index of 7.1 (range, 0-27) and Elixhauser Comorbidity Index of 16.1 (range, −14 to 69; Table 1). The mean Deyo-Charlson Comorbidity Index per ICU admission increased steadily from 0.71 in 2007 to 1.06 in 2011 ($\beta = 0.10$, $P = .06$). Similarly, the mean Elixhauser score increased from 1.62 in 2007 to 2.44 in 2011 ($\beta = 0.24$, $P = .06$). Most patients were admitted to the surgical and neurological ICUs (Table 1). During the study period, there was a significant increase in the number of ICU admissions per year, from 14420 in 2007 to 15929 in 2011 ($P = .004$).

Table 1
Study population

	Mean	Range
Age (y)	59.3	0 to 107
Risk adjustment		
Deyo-Charlson Comorbidity Index	7.1	0 to 27
Elixhauser Comorbidity Index	16.1	−14 to 69
	n	%
Total	75657	
Sex		
Male	43427	57.4
Female	32230	42.6
Race		
White	59710	78.9
Black	4055	5.4
Hispanic	3967	5.2
Asian	1904	2.5
Other	6021	8.0
ICU type		
Surgical ICU	27715	36.6
Neurologic ICU	15849	20.9
Medical ICU	12409	16.4
Cororany care unit	9554	12.6
Trauma/Burn ICU	4521	6.0
Pediatric ICU	3609	4.8
Neonatal ICU	1999	2.6
Comorbidities		
Any malignancy	23502	31.0
Myocardial infarction	18133	23.9
Congestive heart failure	22503	29.7
Diabetes	17315	22.9
Chronic kidney disease	13157	17.4
Liver disease	4669	6.2
HIV/AIDS	373	0.5
Mortality		
30 d	6583	8.7
90 d	9680	12.8
6 mo	11998	15.8
1 y	14595	19.3