Original Investigation

Cardiothoracic MRI in the ICU: A 10-Year Experience

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Rationale and Objective: The objective of this study was to identify the feasibility and pitfalls of cardiothoracic magnetic resonance imaging (MRI) in intensive care unit (ICU) patients.

Materials and Methods: This retrospective study identified adult ICU patients scheduled for cardiothoracic MRIs during a 10-year study period. ICU patients scheduled for brain MRIs served as a comparison group. A chart review was performed to identify factors impacting a patient's ability to undergo an MRI. Differences between completed and canceled examinations for both cardiothoracic and brain MRIs were evaluated. For the cardiothoracic group, clinical indications and the diagnostic value of the study performed were also identified.

Results: A total of 143 cardiothoracic MRIs and 1011 brain MRIs were requested. Cardiothoracic MRI patients were less frequently completed (52% vs 62%), more frequently men (64% vs 43%), younger (55 vs 63 years), less likely mechanically ventilated (8% vs 29%), more likely to require intravenous contrast (83% vs 23%), and had longer examination times compared to brain MRI patients (64 vs 21 minutes). Successful completion of cardiothoracic MRI was associated with lower serum creatinine, higher glomerular filtration rate, and the absence of mechanical ventilation; significant differences were not seen with regard to gender and use of vasoactive agents. Cardiothoracic MRI results were diagnostic in 69% of examinations, most frequently when performed for myocardial disease (84%) and aortic disease (33%), and less frequently for viability (33%).

Conclusions: In an ICU population, successful completion of cardiothoracic MRI is challenging but feasible in patients with intact renal function and the absence of mechanical ventilation. Examinations were most frequently diagnostic for myocardial and aortic disease indications.

Key Words: Cardiothoracic MRI; ICU; cardiac; thoracic; critically ill.

INTRODUCTION

Cardiothoracic magnetic resonance imaging (MRI) is being requested with increasing frequency (1,2). Anecdotally, at our institution, we have seen an increasing number of requests for cardiothoracic MRIs in intensive care unit (ICU) patients. However, there is no literature that examines the practicality of cardiothoracic MRIs in a critically ill population.

Imaging critically ill patients presents several problems. These patients are often unstable and may be ventilator or pressor dependent, which presents logistical challenges in bringing them to the radiology department, including potential adverse events associated with transport (3–5). Although some imaging modalities can be easily brought to the patient in the unit through portable machines, including radiography, sonography, and even computed tomography (CT), portable MRI is not practically feasible for adult patients (6). Critically ill patients also often have renal impairment, which may preclude the intravenous use of gadolinium-based contrast agents potentially limiting the diagnostic information obtained from a cardiothoracic MRI. Critically ill patients may also not be able to tolerate long examination times and multiple breath-hold sequences, which could potentially limit the ability to get diagnostic quality imaging. Numerous studies have examined the use of other imaging in the ICU, including chest radiography, CT, positron emission tomography-CT, brain MRI, echocardiography, general sonography, cholescintigraphy, and ventilation-perfusion scintigraphy, often finding that critically ill patients can be safely imaged with diagnostic quality information (7–20).

The use of cardiothoracic MRIs is well established for a number of clinical indications, including ischemic heart disease, cardiomyopathy, pericardial disease, valvular disease, thoracic aortic aneurysm, and dissection (21–23). Recent literature examining the clinical utility of cardiothoracic MRI generally finds that cardiothoracic MRI adds clinical value and important prognostic information that can change management (1,2,24–29). However, there is a notable paucity of literature specifically evaluating the use of cardiothoracic MRI in ICU patients. The present study is designed to examine whether cardiothoracic MRIs can be performed in a critically

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ill population with diagnostic quality images and to identify potential pitfalls.

MATERIALS AND METHODS

This retrospective, institutional review board-approved study comprised all adult (age 18 years and older) ICU patients scheduled for a cardiothoracic MRI from 2005 to 2014 at our academic medical center. The study population was drawn from two inpatient sites with separate ICUs dedicated to the care of critically ill medical, surgical, cardiac, and cardiothoracic surgery patients. ICU patients scheduled for brain MRIs during the study period served as a comparison group. Both cases and comparisons were identified by searching our institutional electronic databases. Because of the large number of brain examinations as compared to cardiothoracic examinations, we randomly selected brain MRIs matched to the total number of cardiothoracic MRIs with approximately 1 in every 14 brain MRIs selected. The overall proportion of this randomized cohort was similar to the total brain MRI population in terms of cancellation rate and usage of intravenous contrast (total brain MRI population: 38% [387/1011] canceled and 23.2% [235/1011] contrast vs randomized brain MRI examinations: 47% [67/143] canceled and 23.1% [33/143] contrast [all examinations]).

We identified successfully completed and canceled MRIs for the study and comparison populations. A detailed chart review was performed to identify factors impacting a patient's ability to undergo an MRI; these included demographic (age and gender) and laboratory data (serum creatinine and glomerular filtration rate [GFR]), as well the total examination time. GFR was calculated with the Modification of Diet in Renal Disease formula and categorized as less than 30 mL/min/1.73 m^2 (class 1), between 30 and 60 (class 2) and greater than 60 (class 3). The use of intravenous contrast was documented. Differences between completed and canceled examinations for both cardiothoracic and brain MRIs were evaluated.

For the canceled cardiothoracic and brain MRI examinations, we reviewed each patient's medical record to identify reasons for cancellation, in particular, whether ICU-specific characteristics such as mechanical ventilation or vasoactive medications were a cause. Other cancellation categories included patients unwilling to provide consent, decision to perform alternative imaging instead of an MRI (eg, CT or nuclear thallium viability), patient condition (eg, unable to follow commands and excessive motion), renal failure (for contrast examinations), clinical decision (clinicians changed their mind about pursuing the study or an alternative diagnosis was found to explain patient symptoms), and technical (scanner malfunction, poor signal caused by artifacts, and contraindication to MRI). Vasoactive medications were categorized as inotropes or vasoactive agents (dobutamine, dopamine, epinephrine, isoproterenol, milrinone, norepinephrine, phenylephrine, and vasopressin) and blood pressure support agents (esmolol, nicardipine, and nitroglycerin).

The clinical indication for completed and canceled cardiothoracic MRIs was noted and the clinical value of the completed cardiothoracic MRIs was assessed. Clinical indications were categorized as aortic disease, myocardial viability, other myocardial disease (eg, arrhythmia or arrhythmogenic right ventricular dysplasia (ARVD), cardiomyopathy, heart failure, myocarditis, pericardial disease, sarcoid), and others. Clinical value was assessed by a detailed chart review to determine whether the critical care team considered the MRI results to be of diagnostic value in answering their clinical question; the results were categorized as (1) diagnostic or (2) not diagnostic. Among the diagnostic cases, we also noted whether there was a directed surgical intervention within 48 hours of the study completion.

Statistical Methods

Continuous variables (age, serum creatinine, GFR, and examination time) were analyzed using a two-sample *t* test, and categorical variables (gender, GFR class, presence of mechanical ventilation, and presence of vasoactive medications) were analyzed using a two-tailed Fisher exact test. Laboratory data were collected at two data points (time of examination order and time of examination completion or cancellation), with statistical analysis performed on the initial and combined data points. All statistical tests of comparisons used a 5% level of significance.

RESULTS

A total of 143 cardiothoracic MRIs and 1011 brain MRIs were requested on ICU patients during the 10-year study period (2005–2014). MRIs were completed in 52% (74/143) of cardiothoracic and 62% (624/1011) of brain examinations ($P = 0.028$). Baseline patient characteristics including demographic and laboratory data and examination times are summarized in Table 1 for the cardiothoracic MRIs and

TABLE 1. Baseline Patient Characteristics

Characteristic	Cardiothoracic MRIs (*n* = 143)	Brain MRIs (*n* = 143)	*P* Value
Male	92 (64.3%)	61 (42.7%)	**0.0004**
Age (y)	55	62.5	**0.0001**
Serum creatinine	1.64	1.77	0.5627
GFR (mL/min/1.73m^2)	61.7	64.4	0.5157
GFR class (1/2/3)	19/48/76	29/43/71	0.2928
Inotropes and vasoactive agents	8 (5.6%)	13 (9.1%)	0.3649
BP support	18 (12.6%)	10 (7.0%)	0.1628
Mechanical ventilation	12 (8.4%)	41 (28.7%)	**<0.0001**
Intravenous contrast	118 (82.5%)	33 (23.0%)	**<0.0001**
Exam time (min)	64	21	**<0.0001**

BP, blood pressure; GFR, glomerular filtration rate; MRI, magnetic resonance imaging.
Bold faced values are statistically significant.