Original Article

Changes in Primary Noncardiac Diagnoses Over Time Among Elderly Cardiac Intensive Care Unit Patients in the United States

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Background—Early reports suggest the number of cardiac intensive care unit (CICU) patients with primary noncardiac diagnoses is rising in the United States, but no national data currently exist. We examined changes in primary noncardiac diagnoses among elderly patients admitted to a CICU during the past decade.

Methods and Results—Using 2003 to 2013 Medicare data, we grouped elderly patients admitted to CICUs into 2 categories based on principal diagnosis at discharge: (1) primary noncardiac diagnoses and (2) primary cardiac diagnoses. We examined changes in patient demographics, comorbidities, procedure use, and risk-adjusted in-hospital mortality. Among 3.4 million admissions with a CICU stay, primary noncardiac diagnoses rose in prevalence from 38.0% to 51.7% between 2003 and 2013. The fastest rising primary noncardiac diagnoses were infectious diseases (7.8%–15.1%) and respiratory diseases (6.0%–7.6%; P<0.001 for both), whereas the fastest declining primary cardiac diagnosis was coronary artery disease (32.3%–19.0%; P<0.001). Simultaneously, the prevalence of both cardiovascular and noncardiovascular comorbidities rose: heart failure (13.9%–34.4%), pulmonary vascular disease (1.2%–7.1%), valvular heart disease (5.0%–9.8%), and renal failure (7.1%–19.6%; P<0.001 for all). As compared with those with primary cardiac diagnoses, elderly CICU patients with primary noncardiac diagnoses had higher rates of noncardiac procedure use and risk-adjusted in-hospital mortality (P<0.001 for all). Risk-adjusted in-hospital mortality declined slightly in the overall cohort from 9.3% to 8.9% (P<0.001).

Conclusions—More than half of all elderly patients with a CICU stay across the United States now have primary noncardiac diagnoses at discharge. These patients receive different types of care and have worse outcomes than patients with primary cardiac diagnoses. Our work has important implications for the development of appropriate training and staffing models for the future critical care workforce. (Circ Cardiovasc Qual Outcomes. 2017;10:e003616. DOI: 10.1161/CIRCOUTCOMES.117.003616.)

Key Words: coronary artery disease ■ critical care ■ health services research ■ heart failure ■ intensive care units

Cardiologists initially developed and staffed coronary care units in the 1960s to improve the rapid detection and defibrillation of life-threatening ventricular arrhythmias during acute myocardial infarction.1–4 These early units demonstrated substantial gains in survival for patients with acute myocardial infarction, subsequently evolving into cardiac intensive care units (CICUs) that treat a wider array of acute cardiovascular diseases, including cardiogenic shock, heart failure, and complex arrhythmias.5,6 More recently, a handful of reports from large academic centers have suggested that CICUs are expanding their roles even further by caring for a growing number of patients with chronic cardiovascular conditions who present with acute noncardiac illnesses, such as sepsis and renal failure.7–9 This latest trend has raised some concern among cardiologists because caring for these groups of patients may require expertise in critical care and noncardiac procedures that fall beyond the purview of typical general cardiology training.8,10

See Editorial by Morrow

In response, the American Heart Association issued a scientific statement on the future of critical care cardiology

Received February 2, 2017; accepted May 31, 2017.

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The views expressed herein are those of the authors and do not necessarily represent those of the U.S. Department of Veterans Affairs.

Guest Editor for this article was Dennis T. Ko, MD, MSc. The editors had no role in the evaluation of the manuscript or in the decision about its acceptance.


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Circ Cardiovasc Qual Outcomes is available at http://circoutcomes.ahajournals.org

DOI: 10.1161/CIRCOUTCOMES.117.003616
WHAT IS KNOWN

- Prior reports suggest that CICUs are increasingly managing complex patients with acute noncardiac illnesses, such as sepsis and renal failure, but this evidence is derived from a handful of large academic centers.
- No national data on the number, types, and outcomes of patients admitted to CICUs across the United States with primary noncardiac diagnoses currently exist.

WHAT THE STUDY ADDS

- Using national data from fee-for-service Medicare beneficiaries with CICU stays in the United States, we found declining rates of discharges associated with primary cardiac diagnoses accompanied by a concomitant rise in patients with primary noncardiac diagnoses and secondary cardiovascular comorbidities. Patients with primary noncardiac diagnoses also had higher rates of procedure use and worse outcomes, but overall rates of risk-adjusted mortality declined slightly over time.
- These findings have important clinical and policy implications, including the development of appropriate training and staffing models for the future critical care workforce within cardiology.

Table 1. Baseline Characteristics Among Fee-for-Service Medicare Beneficiaries With a CICU Stay Between 2003 and 2013

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>2003</th>
<th>2005</th>
<th>2007</th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
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<tr>
<td>No. of CICU hospitalizations</td>
<td>367587</td>
<td>354585</td>
<td>333314</td>
<td>290820</td>
<td>276155</td>
<td>237524</td>
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<tr>
<td>No. of CICU per 1000 FFS hospitalizations (%)</td>
<td>93.7</td>
<td>89.2</td>
<td>88.4</td>
<td>81.2</td>
<td>80.0</td>
<td>74.3</td>
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<td>Age (mean), y</td>
<td>77.1</td>
<td>77.2</td>
<td>77.4</td>
<td>77.5</td>
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<td>65–74</td>
<td>39.5</td>
<td>39.2</td>
<td>38.8</td>
<td>39.3</td>
<td>39.0</td>
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<td>75–84</td>
<td>42.7</td>
<td>42.0</td>
<td>40.7</td>
<td>38.6</td>
<td>37.8</td>
<td>36.6</td>
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<tr>
<td>85–94</td>
<td>16.6</td>
<td>17.5</td>
<td>19.0</td>
<td>20.3</td>
<td>21.3</td>
<td>21.5</td>
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<td>95+</td>
<td>1.2</td>
<td>1.3</td>
<td>1.5</td>
<td>1.7</td>
<td>1.9</td>
<td>2.1</td>
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<tr>
<td>Sex</td>
<td></td>
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<td></td>
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<tr>
<td>Male</td>
<td>50.0</td>
<td>50.2</td>
<td>50.1</td>
<td>50.3</td>
<td>49.6</td>
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<tr>
<td>Female</td>
<td>50.0</td>
<td>49.8</td>
<td>49.9</td>
<td>49.7</td>
<td>50.5</td>
<td>49.2</td>
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<td></td>
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<tr>
<td>White</td>
<td>87.0</td>
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<td>85.3</td>
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<tr>
<td>Black</td>
<td>8.3</td>
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<td>8.8</td>
<td>9.4</td>
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<tr>
<td>Other</td>
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<td>5.0</td>
<td>5.3</td>
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<td>Elixhauser comorbidities</td>
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<td>0–1</td>
<td>37.2</td>
<td>32.7</td>
<td>27.1</td>
<td>22.8</td>
<td>18.8</td>
<td>18.5</td>
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<td>2</td>
<td>29.9</td>
<td>30.0</td>
<td>29.7</td>
<td>28.9</td>
<td>26.4</td>
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<td>≥3</td>
<td>32.9</td>
<td>37.4</td>
<td>43.2</td>
<td>48.3</td>
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<td>Hypertension</td>
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<td>56.2</td>
<td>54.8</td>
<td>57.5</td>
<td>60.5</td>
<td>56.8</td>
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<td>Diabetes mellitus</td>
<td>24.7</td>
<td>24.2</td>
<td>23.4</td>
<td>22.9</td>
<td>24.9</td>
<td>24.5</td>
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<tr>
<td>Obesity</td>
<td>3.0</td>
<td>3.3</td>
<td>3.5</td>
<td>4.4</td>
<td>4.6</td>
<td>5.2</td>
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<tr>
<td>Congestive heart failure</td>
<td>13.9</td>
<td>15.8</td>
<td>19.5</td>
<td>29.9</td>
<td>32.7</td>
<td>34.4</td>
</tr>
<tr>
<td>Valvular heart disease</td>
<td>5.0</td>
<td>5.7</td>
<td>7.7</td>
<td>10.1</td>
<td>10.2</td>
<td>9.8</td>
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<tr>
<td>Pulmonary vascular disease</td>
<td>1.2</td>
<td>1.4</td>
<td>2.4</td>
<td>5.2</td>
<td>6.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>9.0</td>
<td>9.0</td>
<td>8.7</td>
<td>9.0</td>
<td>9.2</td>
<td>8.3</td>
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<tr>
<td>Chronic pulmonary disease</td>
<td>24.4</td>
<td>26.2</td>
<td>25.0</td>
<td>20.0</td>
<td>20.9</td>
<td>20.3</td>
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<tr>
<td>Renal failure</td>
<td>7.1</td>
<td>10.8</td>
<td>18.3</td>
<td>16.6</td>
<td>19.8</td>
<td>19.6</td>
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<tr>
<td>Malignancy</td>
<td>4.2</td>
<td>4.4</td>
<td>4.9</td>
<td>5.3</td>
<td>5.7</td>
<td>5.7</td>
</tr>
</tbody>
</table>

P<0.001 for all comparisons. All values are reported as percentages unless otherwise noted. CICU indicates cardiac intensive care unit; and FFS, fee-for-service.
Methods

Data Sources and Study Population
We performed a retrospective cohort study of acute-care hospitalizations with CICU stays among fee-for-service (FFS) Medicare beneficiaries aged 65 years using the 100% Medicare Provider Analysis and Review files from 2003 to 2013. Medicare Provider Analysis and Review data capture all billable diagnoses, procedures, demographics, and in-hospital outcomes from hospitalized patients admitted with a CICU stay. All patients with FFS eligibility at the time of admission were included.

For this study, we defined hospitalization with a CICU stay using revenue center codes within the claim records. Revenue center codes are used to identify billed services from divisions or units within a hospital (eg, radiology, emergency room, CICU, and other ICUs). If charges were listed for ICU services from both the CICU and other ICUs (eg, Medical ICU) during the same hospitalization, we classified the hospitalization as having a CICU stay when the patient spent the largest number of ICU days in a CICU. We excluded patients with hospitalizations in intermediate care units only. To avoid counting hospitalizations for patients without cardiovascular disease temporarily boarding in the CICU, we excluded any patients who did not have a primary or secondary cardiac diagnosis at discharge (ie, 5.1% of total patients). This approach to excluding boarders was evaluated in a sensitivity analysis that showed consistent results (not reported but available from authors). Finally, to ensure a consistent cohort of hospitals with CICUs, we included only those 806 hospitals billing >20 hospitalizations with a CICU stay during every year throughout the study period (ie, from 2003 to 2013, consecutively).

Definition of Cardiac and Noncardiac Diagnoses
For all patients, we included demographic data (age, sex, and race), as well as extracted information on hospital and CICU length of stay, principal and secondary International Classification of Diseases, 9th Revision, Clinical Modification diagnosis codes, procedure codes, and discharge status (alive or dead). A patient could have only 1 primary discharge diagnosis code but multiple secondary diagnosis codes. We used the Clinical Classification Software (CCS) developed by the Agency for Healthcare Research and Quality to aggregate International Classification of Diseases, 9th Revision, Clinical Modification diagnosis codes into 281 unique diagnoses based on the multilevel CCS categories. Primary cardiac diseases encompassed those primary discharge diagnosis codes delineated in multilevel CCS Category 7, Diseases of the Circulatory System, and were consolidated into CAD, congestive heart failure, valvular disease, dysrhythmias, and other circulatory diseases. Primary noncardiac diseases included primary discharge diagnosis codes comprising other CCS categories, including respiratory, gastrointestinal, infectious, musculoskeletal/injuries, neurological, hematologic, and oncological disease, with infections specific to an organ system (eg, pneumonia) grouped under the infectious category. Details of assignments of individual diagnoses into CCS categories can be found in Appendix Table A in the Data Supplement.

Case Mix and Procedures
To better characterize changes in patient case mix during the study period, we identified patients with cardiovascular and noncardiovascular comorbidities using all primary and secondary diagnosis codes from their index hospitalization according to the method previously described by Elixhauser et al. We used International Classification of Diseases, 9th Revision, Clinical Modification procedure codes to identify noncardiac procedures, including invasive mechanical ventilation (96.70, 96.71, 96.72), noninvasive mechanical ventilation (93.90), central venous catheterization (38.93), blood transfusion (99.0X), and hemodialysis (39.95). For cardiac procedures, we used the following International Classification of Diseases, 9th Revision, Clinical Modification procedure codes: pulmonary artery catheterization (89.63, 89.64, 89.66, 89.67, 89.68); right heart catheterization (37.21); implantation of pulsation balloon (37.61); ventricular assist device (37.62, 37.63, 37.65, 37.66, 37.68); diagnostic cardiac catheterization (37.22, 37.23, 88.50, 88.53); percutaneous coronary intervention (00.66, 17.55, 36.06, 36.07, 36.09, 00.4X); and coronary artery bypass grafting (36.1X, 36.2, 36.3, 36.9).

Statistical Analysis
Baseline distributions for patient demographics (age, sex, race, and comorbidities), procedure use, and outcomes are presented in 2-year intervals from 2003 to 2013 as means or percentages of total admissions for the entire patient cohort. Categorical variables are expressed as frequencies (percentages) and continuous variables as means or medians where appropriate. We calculated the percentage of total hospitalizations with a CICU stay in each disease category for each year. The denominator for these calculations was the total number of hospitalizations each year in FFS Medicare beneficiaries. The results are presented using stacked bar graphs, with the total height of each bar representing 100% of admissions. We describe changes in the rankings of primary diagnoses across years, presenting the results in Appendix Table B in the Data Supplement and as online interactive data visualization tools shown in Appendix C in the Data Supplement.

Both unadjusted and risk-adjusted in-hospital mortality were reported. Risk-adjusted in-hospital mortality rates were calculated using a logistic regression model that adjusted for age, sex, race, and total number of Elixhauser comorbidities. We also examined whether trends in primary noncardiac diagnoses and risk-adjusted mortality varied across small (<250 beds), medium (250–500 beds), and large (>20 beds) hospitals with CICUs, we included only those 806 hospitals billing >20 hospitalizations with a CICU stay during every year throughout the study period (ie, from 2003 to 2013, consecutively).

Figure 1. Primary diagnosis by disease category among elderly patients with a cardiac intensive care unit stay between 2003 and 2013.
large (>500 beds) hospitals during the study period after linking the Medicare data to yearly data from the American Hospital Association Annual Survey.

A P<0.05 was used to determine statistical significance. All data management and statistical analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC) and STATA version 14.0 (StataCorp, College Station, TX). The protocol for data analysis was formally reviewed and approved by the Institutional Review Board of the University of Michigan, Ann Arbor, MI.

Results

Demographic Trends
For the study period of January 1, 2003, to December 31, 2013, a total of 3.4 million hospitalizations with a CICU stay were identified. The rate of CICU admissions per 1000 Medicare hospitalizations in the study cohort decreased from 93.7 in 2003 to 74.3 in 2013 (P<0.001). Table 1 shows baseline characteristics of hospitalizations with a CICU stay between 2003 and 2013. Demographic characteristics, including sex and race, remained relatively stable during the study period. The mean age increased minimally from 77.1 to 77.6 years, whereas the proportion of patients aged ≥85 years grew from 17.8% to 23.6% (P<0.001).

Rise in Primary Noncardiac and Primary Cardiac Diagnoses Over Time
Primary noncardiac diagnoses rose from 38.0% of hospitalizations with a CICU admission in 2003 to 51.7% of hospitalizations in 2013 (P<0.001; Figure 1). The rise in primary noncardiac diagnoses was not attributable to a single condition, but the largest increases resulted from primary diagnoses of infectious diseases (7.8%–15.1%) and noninfectious respiratory diseases (6.0%–7.6%; P<0.001 for both; Figure 1). During the same interval, a corresponding decline in primary cardiac diagnoses was observed (Figure 1) largely because of a substantial decrease in primary diagnoses of CAD from 32.3% to 19.0% (P for trend <0.001). A more modest decrease in primary diagnoses of congestive heart failure was noted from 9.8% to 7.5% (P for trend <0.001). When individual discharge diagnoses were considered as opposed to grouped CCS categories, similar patterns were observed. For instance, acute myocardial infarction declined from 16.0% to 12.0% during the study period although it remained the single most common discharge diagnosis in 2013. Sepsis increased from the 11th most common individual discharge diagnosis in 2003 (1.9%) to the second most common discharge diagnosis in 2013 (9.2%). A complete list of the individual diagnoses categorized by the CCS and their changes over time are illustrated through online data visualization tools shown in Appendix C in the Data Supplement.

Changes in Comorbidities Over Time
From 2003 to 2013, the percentage of CICU patients with comorbidities increased (Table 1). The number of patients with ≥3 comorbidities grew from 32.9% in 2003 to 54.6% in 2013 (P<0.001). For cardiovascular comorbidities, the number of patients with congestive heart failure increased 2.6-fold (13.9%–34.4%), pulmonary vascular disease 5.9-fold (1.2%–7.1%), and valvular heart disease 2.0-fold (5.0%–9.8%; P<0.001 for all; Table 1). However, the number of patients with hypertension (54.5%–56.8%), diabetes mellitus (24.7%–24.5%), and anemia (9.9% to 10.4%) remained relatively stable during this time period (Table 1).

Changes in Procedures and Mortality Over Time
Several changes in noncardiac and cardiac procedures were observed during the study period from 2003 to 2013 (Table 2). For instance, mechanical (9.7%–11.7%) and noninvasive ventilation rates (1.1%–4.8%), central venous catheter use (7.6%–8.8%), hemodialysis rates (3.4%–4.8%), and transfusion use (10.2%–14.0%) increased (P<0.001 for all; Table 2). With respect to cardiac procedures, pulmonary artery catheterization decreased from 1.8% to 1.1%, diagnostic cardiac catheterization declined from 25.7% to 16.5%, and percutaneous coronary intervention decreased from 12.2% to 9.1% with hypertension (54.5%–56.8%), diabetes mellitus (24.7%–24.5%), and anemia (9.9% to 10.4%) remained relatively stable during this time period (Table 1).
Changes in CICU Primary Noncardiac Diagnoses

Similarly, coronary artery bypass grafting declined from 10.1% to 7.2% \( (P<0.001) \). Mechanical circulatory support, in the form of intra-aortic balloon pump and ventricular assist device placement, remained stable during the study period from 1.8% to 1.9% \( (P<0.001) \). The unadjusted in-hospital mortality rate decreased from 9.3% to 8.9% \( (P<0.001) \) while risk-adjusted mortality was lower for patients admitted with primary cardiac diagnoses and remained relatively stable between 6.9% in 2003 and 6.6% in 2013. For the overall cohort, risk-adjusted mortality declined slightly from 9.3% to 8.9% \( (P<0.001) \), similar to what was observed in the unadjusted analysis.

Factors Associated With Primary Noncardiac Diagnoses and Findings Across Hospital Size

Patients with primary noncardiac diagnoses were older (mean age 78 versus 77 years; \( P<0.001 \)) and were more likely to be women (52.5% versus 46.8%; \( P<0.001 \)) and black (10.7% versus 8.9%; \( P<0.001 \)) as compared with patients with primary cardiac diagnoses. Patients with primary noncardiac diagnoses had higher rates of noncardiac procedure use, including mechanical (16.0% versus 6.5%; \( P<0.001 \)) and noninvasive (5.6% versus 3.3%; \( P<0.001 \)) ventilations, central venous catheterization use (13.2% versus 5.1%; \( P<0.001 \)), hemodialysis (5.9% versus 3.5%; \( P<0.001 \)), and transfusion use (18.5% versus 9.7%; \( P<0.001 \); Table 3). Patients with primary noncardiac diagnoses also had higher unadjusted in-hospital mortality during the study period (10.9% versus 6.3%; \( P<0.001 \); Table 3). The proportion of primary noncardiac diagnoses steadily increased at the same rate during the study period across small, medium, and large hospitals \( (P \text{ for interaction effect}>0.05) \) although primary noncardiac diagnoses were more common at small hospitals overall (Figure 3). In particular, primary noncardiac diagnoses increased from 44.7% to 58.1% at small hospitals, 38.2% to 51.0% at medium hospitals, and 29.9% to 45.6% at large hospitals \( (P<0.001 \) for all; Figure 3).

Discussion

Our study describes the changing face of critical care cardiology by examining population shifts and disease compositions during the past decade in FFS Medicare hospitalizations with CICU stays in the United States. Specifically, we found that hospitalizations with a CICU stay are increasing for primary noncardiac diagnoses while hospitalizations with a primary diagnosis of CAD have markedly declined. In addition, we found that comorbidities—both cardiovascular and noncardiovascular—have dramatically increased. CICU stays with primary noncardiac diagnoses had higher rates of noncardiac procedure use and higher risk-adjusted in-hospital mortality. However, overall length of stay and risk-adjusted mortality did not worsen over time, and in fact, declined for the latter. These findings overall suggest that the CICU may be increasingly becoming a setting where patients with cardiovascular disease are treated for a variety of acute, high-risk illnesses without compromising overall care.

We think that many factors are potentially driving the increase in patients with primary noncardiac diagnoses receiving CICU care. Most importantly, significant improvement in the prevention and contemporary management of several acute cardiovascular diseases has occurred in recent years.

Figure 2. Risk-adjusted in-hospital mortality rates among elderly patients with a cardiac intensive care unit stay between 2003 and 2013.
Mechanical circulatory support includes intra-aortic balloon pump placement and ventricular assist device placement. P<0.001 for all comparisons except median CICU LOS. All values are reported as percentages unless otherwise noted. CICU indicates cardiac intensive care unit; IQR, interquartile range; and LOS, length of stay.

For example, population-based rates of acute myocardial infarction have decreased substantially in the United States, and the risk-adjusted mortality associated with those who experience these events has also declined. Concurrent with the improvements in care for primary cardiac disease, the prevalence in cardiovascular comorbidities has also risen over time. This is because of both higher survival rates after acute events and an aging population, leading to a higher prevalence of heart failure, pulmonary vascular disease, and valvular heart disease. As these patients with chronic cardiovascular conditions are hospitalized, more of them may be brought to the CICU for any critical care needs.

A second possibility is that patients who might have been previously treated in traditional ICUs are now being managed in CICUs as hospitals attempt to maintain bed occupancy with declines in CAD. Our findings of a modest decline in the rate of hospitalizations with a CICU stay support this possibility. Third, another reason may be that current noncardiovascular critical care providers may feel unprepared in the management of complex cardiovascular critical illness in medical ICUs, leading to a greater proportion of these patients being managed in the CICU.

Fourth, the shift in coding toward primary noncardiac diagnoses may reflect changes in reimbursement that encourage up-coding or shifting of diagnoses toward higher categories of complex conditions. The fact that we found greater rates of comorbidities despite stable-to-improving risk-adjusted outcomes suggests this possibility. Unfortunately, the extent to which these phenomena are occurring is difficult to determine from the current analyses.

Regardless of the drivers of these changes, the significant evolution in the case mix of the CICU may have important ramifications for training and staffing models in cardiology, especially given the complexity of patients with primary noncardiac diagnoses. Advanced, specialized training in critical care has not been specifically a part of most cardiologists’ training. A recent American Heart Association position statement recognized this concern and suggested that the workforce around CICUs be geared toward a broader set of skills extending beyond the toolkit of general cardiologists. Reinforcing these concerns, in a 2012 survey of 178 medical directors of ICUs caring for cardiac patients, 81% of respondents identified an unmet need for cardiologists for intensivist training and expertise. Most recently, Core Cardiovascular Training Statement 4 added a new task force on training in critical care cardiology indicating those who wish to obtain level III or advanced training must complete a 1-year clinical fellowship in critical care medicine within the Department of Medicine in addition to the 3-year cardiovascular medicine fellowship. Thus, given the complex patient care environment and escalating acuity of patients with primary noncardiac diagnoses, the role of the intensivist in the CICU warrants further examination. Whether contemporary CICU providers should either comanage with an intensivist or develop specialized expertise and in-depth knowledge to manage these heterogeneous, high-risk patients remains uncertain. Ultimately, the optimal care delivery model will have significant implications for the entire cardiac critical care team, including nurses, respiratory therapists, and pharmacists among others.
We also found that procedure use has significantly increased in CICUs during the past decade—a trend explained, in part, by the greater numbers of hospitalizations for primary noncardiac diagnoses. Patients with primary noncardiac diagnoses had higher rates of hemodialysis, transfusion use, mechanical and noninvasive ventilations, and central venous catheter use, as well as higher unadjusted and risk-adjusted in-hospital mortality during the study period. Thus, CICUs have a heterogeneous patient case mix that, in many ways, mimics general medical intensive care units.6,18 These findings are consistent with prior single-center studies demonstrating shifts in demographic characteristics, discharge diagnoses, procedure use, and outcomes over time in CICUs.7,26 Our study extends these findings nationally, demonstrating that these important temporal trends are not limited only to select academic medical centers. A final noteworthy observation was a steady decline in CICU hospitalizations from 2003 to 2013 from 93.7% to 74.3% (CICU per 1000 FFS hospitalizations). These findings are potentially explained by recent work demonstrating increases in billing for intermediate care among hospitalized Medicare beneficiaries between 1996 and 2010.27 Additional work is needed to identify drivers of this trend and its implications for CICUs.

Our study should be interpreted in the context of the following limitations. First, our analysis was derived from an administrative database and restricted to elderly patients hospitalized in the CICU, namely FFS Medicare beneficiaries aged ≥65 years. Although national Medicare data provide a reasonable representation of CICU trends with respect to patient characteristics and diagnoses, our findings need to be confirmed in additional studies involving a broader payer mix and age distribution. Second, we did not specifically analyze the type of provider delivering care in the CICU (ie, cardiologist versus intensivist). However, this study illustrates important shifts in patterns of care in the modern CICU regardless of provider type. Understanding the types of providers involved with the care of patients with primary noncardiac diagnoses in the CICU might help evaluate different models for care delivery.28 Third, we excluded boarders from our primary analysis to avoid counting hospitalizations for any patients who did not have a primary or secondary cardiac diagnosis at discharge. Although a sensitivity analysis was performed including these patients, our primary objective was to describe the types of patients being cared for in CICUs and not necessarily delineate the overall burden of critical care in patients with cardiovascular disease. By describing all patients managed in CICUs (rather than cardiac patients in all ICUs), we have extended the literature on the types of patients and procedures provided in that setting and their implications for care delivery, staffing, and training. Fourth, our risk-adjusted in-hospital mortality models could not adjust for physiological variables or severity of illness. Finally, our study relies on Medicare claims data and thus cannot specifically address the mechanisms driving the underlying shifts, such as changes in coding practices, changes in disease burden, or changes in ICU or hospitalized patients overall. Future work should probe these mechanisms and investigate the training and staffing implications of this evolving case mix in the CICU.
Conclusions

We found major shifts in discharge diagnoses among FFS Medicare beneficiaries hospitalized in CICUs from 2003 to 2013, with declining rates of discharges associated with primary cardiac diagnoses accompanied by a rise in patients with primary noncardiac diagnoses and cardiovascular comorbidities. Furthermore, we found that patients with primary noncardiac diagnoses had higher rates of procedure use and worse outcomes although their risk-adjusted in-hospital mortality is declining over time. Our work has important clinical and policy implications, including the development of appropriate training and staffing models for the future critical care workforce.

Acknowledgments

We gratefully acknowledge the contributions of Wenyong Zhang and Phyllis Wright-Slaughter with respect to data acquisition. We also appreciate the statistical support provided by Jyothi Thumma. Finally, we thank Dr Mohammad Kenaan for his critical review of the manuscript. Drs Sinha and Sjoding had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design were developed by Drs Sinha, Sjoding, Sukul, Cooke, and Nallamothu. Acquisition, analysis, or interpretation of data are performed by Drs Sinha, Sjoding, Sukul, Cooke, and Nallamothu. Statistical analysis was performed by Drs Sinha, Sjoding, Sukul, Cooke, and Nallamothu. Drafting of the manuscript was done by Dr Sinha. Critical revision of the manuscript for important intellectual content was done by Drs Sinha, Sjoding, Sukul, Prescott, Iwashyna, Gurum, Cooke, and Nallamothu. Statistical analysis was performed by Drs Sinha, Sjoding, Sukul, Cooke, and Nallamothu. This study obtained funding from Drs Iwashyna, Gurum, Cooke, and Nallamothu. Study supervision was done by Dr Nallamothu.

Sources of Funding

Drs Sinha and Sukul are supported by the National Institutes of Health (NIH) T32 post-doctoral research training grant (5T32HL007853). Dr Sjoding (K01HL136687 and National Heart, Lung, and Blood Institute (NHLBI) T32HL0077490) and Dr Prescott (K08 GM115859) also receive funding from the NIH. Both Drs Iwashyna and Nallamothu are supported by a research grant from the Veterans’ Affairs Health Services Research & Development Program (IIR 13-079-2). Dr Gurum receives research funding from Blue Cross Blue Shield of Michigan and the National Institutes of Health. Dr Cooke is supported by Agency for Healthcare Research and Quality (K08 HS020672). Dr Nallamothu is supported by a research grant from the NHLBI (R01HL123980).

Disclosures

Dr Gurum is a consultant for Osprey Medical. The other authors report no conflicts.

References


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_Circ Cardiovasc Qual Outcomes_. 2017;10:e003616
doi: 10.1161/CIRCOOUTCOMES.117.003616
_Circulation: Cardiovascular Quality and Outcomes_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 1941-7705. Online ISSN: 1941-7713

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circoutcomes.ahajournals.org/content/10/8/e003616

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Supplemental Material

Changes in Primary Non-Cardiac Diagnoses over Time Among Elderly Cardiac Intensive Care Unit Patients in the United States

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Supplementary Appendix Table B. Rankings of Primary Diagnosis Among Fee-for-Service Medicare Beneficiaries with a CICU Stay During Hospitalizations in 2003 and 2013

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Supplementary Appendix Table A. Clinical Classification System Diagnoses Assigned to Each Disease Category

**Coronary Artery Disease**
- 101 Coronary atherosclerosis and other heart disease
- 100 Acute myocardial infarction

**Congestive Heart Failure**
- 108 Congestive heart failure; nonhypertensive
- 249 Shock

**Dysrhythmias**
- 105 Conduction disorders
- 106 Cardiac dysrhythmias

**Valvular Heart Disease**
- 96 Heart valve disorders

**Other Circulatory Diseases**
- 114 Peripheral and visceral atherosclerosis
- 99 Hypertension with complications
- 117 Other circulatory disease
- 103 Pulmonary heart disease
- 115 Aortic; peripheral; and visceral artery aneurysms
- 98 Essential hypertension
- 97 Peri-; endo-; and myocarditis; cardiomyopathy
- 116 Aortic and peripheral arterial embolism or thrombosis
- 121 Other diseases of veins and lymphatics
- 107 Cardiac arrest and ventricular fibrillation
- 104 Other and ill-defined heart disease
- 119 Varicose veins of lower extremity
- 245 Syncope
- 213 Cardiac and circulatory congenital anomalies
- 102 Nonspecific chest pain

**Respiratory Diseases**
- 127 Chronic obstructive pulmonary disease and bronchiectasis
- 128 Asthma
- 131 Respiratory failure; insufficiency; arrest (adult)
- 129 Aspiration pneumonitis; food/vomitus
- 133 Other lower respiratory disease
- 130 Pleurisy; pneumothorax; pulmonary collapse
134  Other upper respiratory disease
132  Lung disease due to external agents
  56  Cystic fibrosis

**Gastrointestinal Diseases**
153  Gastrointestinal hemorrhage
145  Intestinal obstruction without hernia
149  Biliary tract disease
155  Other gastrointestinal disorders
143  Abdominal hernia
152  Pancreatic disorders (not diabetes)
138  Esophageal disorders
154  Noninfectious gastroenteritis
151  Other liver diseases
141  Other disorders of stomach and duodenum
147  Anal and rectal conditions
139  Gastroduodenal ulcer (except hemorrhage)
144  Regional enteritis and ulcerative colitis
137  Diseases of mouth; excluding dental
136  Disorders of teeth and jaw
120  Hemorrhoids
250  Nausea and vomiting
214  Digestive congenital anomalies

**Infectious Diseases**
122  Pneumonia (except that caused by tuberculosis or sexually transmitted disease)
125  Acute bronchitis
126  Other upper respiratory infections
123  Influenza
   2  Septicemia (except in labor)
159  Urinary tract infections
  7  Viral infection
  4  Mycoses
  6  Hepatitis
  8  Other infections; including parasitic
  3  Bacterial infection; unspecified site
  5  HIV infection
  1  Tuberculosis
  9  Sexually transmitted infections (not HIV or hepatitis)
10  Immunizations and screening for infectious disease
 76  Meningitis (except that caused by tuberculosis or sexually transmitted disease)
  Inflammation; infection of eye (except that caused by tuberculosis or sexually
  transmitted disease)
77 Encephalitis (except that caused by tuberculosis or sexually transmitted disease)
78 Other CNS infection and poliomyelitis
92 Otitis media and related conditions
124 Acute and chronic tonsillitis
146 Diverticulosis and diverticulitis
135 Intestinal infection
140 Gastritis and duodenitis
142 Appendicitis and other appendiceal conditions
148 Peritonitis and intestinal abscess
197 Skin and subcutaneous tissue infections
248 Gangrene
246 Fever of unknown origin
    Infective arthritis and osteomyelitis (except that caused by tuberculosis or
201 sexually transmitted disease)
247 Lymphadenitis

**Neurologic Conditions**
109 Acute cerebrovascular disease
112 Transient cerebral ischemia
110 Occlusion or stenosis of precerebral arteries
111 Other and ill-defined cerebrovascular disease
113 Late effects of cerebrovascular disease
216 Nervous system congenital anomalies
  89 Blindness and vision defects
91 Other eye disorders
94 Other ear and sense organ disorders
80 Multiple sclerosis
87 Retinal detachments; defects; vascular occlusion; and retinopathy
82 Paralysis
88 Glaucoma
86 Cataract
653 Delirium, dementia, and amnestic and other cognitive disorders
95 Other nervous system disorders
83 Epilepsy; convulsions
93 Conditions associated with dizziness or vertigo
81 Other hereditary and degenerative nervous system conditions
79 Parkinson’s disease
85 Coma; stupor; and brain damage
84 Headache; including migraine

**Injuries and Musculoskeletal Diseases**
226 Fracture of neck of femur (hip)
231 Other fractures
233  Intracranial injury
230  Fracture of lower limb
229  Fracture of upper limb
239  Superficial injury; contusion
244  Other injuries and conditions due to external causes
234  Crushing injury or internal injury
232  Sprains and strains
228  Skull and face fractures
225  Joint disorders and dislocations; trauma-related
235  Open wounds of head; neck; and trunk
236  Open wounds of extremities
240  Burns
227  Spinal cord injury

**Hematologic and Oncologic Diseases**
42  Secondary malignancies
19  Cancer of bronchus; lung
14  Cancer of colon
47  Other and unspecified benign neoplasm
45  Maintenance chemotherapy; radiotherapy
29  Cancer of prostate
24  Cancer of breast
32  Cancer of bladder
44  Neoplasms of unspecified nature or uncertain behavior
33  Cancer of kidney and renal pelvis
38  Non-Hodgkin’s lymphoma
17  Cancer of pancreas
15  Cancer of rectum and anus
25  Cancer of uterus
39  Leukemias
11  Cancer of head and neck
13  Cancer of stomach
18  Cancer of other GI organs; peritoneum
35  Cancer of brain and nervous system
27  Cancer of ovary
40  Multiple myeloma
16  Cancer of liver and intrahepatic bile duct
12  Cancer of esophagus
36  Cancer of thyroid
21  Cancer of bone and connective tissue
23  Other non-epithelial cancer of skin
43  Malignant neoplasm without specification of site
28  Cancer of other female genital organs
<table>
<thead>
<tr>
<th>Code</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>Benign neoplasm of uterus</td>
</tr>
<tr>
<td>34</td>
<td>Cancer of other urinary organs</td>
</tr>
<tr>
<td>41</td>
<td>Cancer; other and unspecified primary</td>
</tr>
<tr>
<td>26</td>
<td>Cancer of cervix</td>
</tr>
<tr>
<td>22</td>
<td>Melanomas of skin</td>
</tr>
<tr>
<td>20</td>
<td>Cancer; other respiratory and intrathoracic</td>
</tr>
<tr>
<td>37</td>
<td>Hodgkin´s disease</td>
</tr>
<tr>
<td>31</td>
<td>Cancer of other male genital organs</td>
</tr>
<tr>
<td>30</td>
<td>Cancer of testis</td>
</tr>
<tr>
<td>118</td>
<td>Phlebitis; thrombophlebitis and thromboembolism</td>
</tr>
<tr>
<td>59</td>
<td>Deficiency and other anemia</td>
</tr>
<tr>
<td>63</td>
<td>Diseases of white blood cells</td>
</tr>
<tr>
<td>60</td>
<td>Acute posthemorrhagic anemia</td>
</tr>
<tr>
<td>62</td>
<td>Coagulation and hemorrhagic disorders</td>
</tr>
<tr>
<td>64</td>
<td>Other hematologic conditions</td>
</tr>
<tr>
<td>61</td>
<td>Sickle cell anemia</td>
</tr>
</tbody>
</table>

**Other Diagnoses**

<table>
<thead>
<tr>
<th>Code</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>157</td>
<td>Acute and unspecified renal failure</td>
</tr>
<tr>
<td>164</td>
<td>Hyperplasia of prostate</td>
</tr>
<tr>
<td>170</td>
<td>Prolapse of female genital organs</td>
</tr>
<tr>
<td>160</td>
<td>Calculus of urinary tract</td>
</tr>
<tr>
<td>163</td>
<td>Genitourinary symptoms and ill-defined conditions</td>
</tr>
<tr>
<td>161</td>
<td>Other diseases of kidney and ureters</td>
</tr>
<tr>
<td>162</td>
<td>Other diseases of bladder and urethra</td>
</tr>
<tr>
<td>175</td>
<td>Other female genital disorders</td>
</tr>
<tr>
<td>158</td>
<td>Chronic kidney disease</td>
</tr>
<tr>
<td>165</td>
<td>Inflammatory conditions of male genital organs</td>
</tr>
<tr>
<td>166</td>
<td>Other male genital disorders</td>
</tr>
<tr>
<td>173</td>
<td>Menopausal disorders</td>
</tr>
<tr>
<td>167</td>
<td>Nonmalignant breast conditions</td>
</tr>
<tr>
<td>172</td>
<td>Ovarian cyst</td>
</tr>
<tr>
<td>168</td>
<td>Inflammatory diseases of female pelvic organs</td>
</tr>
<tr>
<td>156</td>
<td>Nephritis; nephrosis; renal sclerosis</td>
</tr>
<tr>
<td>169</td>
<td>Endometriosis</td>
</tr>
<tr>
<td>171</td>
<td>Menstrual disorders</td>
</tr>
<tr>
<td>215</td>
<td>Genitourinary congenital anomalies</td>
</tr>
<tr>
<td>55</td>
<td>Fluid and electrolyte disorders</td>
</tr>
<tr>
<td>50</td>
<td>Diabetes mellitus with complications</td>
</tr>
<tr>
<td>58</td>
<td>Other nutritional; endocrine; and metabolic disorders</td>
</tr>
<tr>
<td>51</td>
<td>Other endocrine disorders</td>
</tr>
<tr>
<td>48</td>
<td>Thyroid disorders</td>
</tr>
<tr>
<td>54</td>
<td>Gout and other crystal arthropathies</td>
</tr>
</tbody>
</table>
52 Nutritional deficiencies
49 Diabetes mellitus without complication
57 Immunity disorders
53 Disorders of lipid metabolism
259 Residual codes; unclassified
251 Abdominal pain
252 Malaise and fatigue
253 Allergic reactions
257 Other aftercare
243 Poisoning by nonmedicinal substances
254 Rehabilitation care; fitting of prostheses; and adjustment of devices
217 Other congenital anomalies
224 Other perinatal conditions
237 Complication of device; implant or graft
238 Complications of surgical procedures or medical care
660 Alcohol-related disorders
663 Screening and history of mental health and substance abuse codes
651 Anxiety disorders
650 Adjustment disorders
670 Miscellaneous disorders
652 Attention-deficit, conduct, and disruptive behavior disorders
654 Developmental disorders
656 Impulse control disorders, NEC
658 Personality disorders
662 Suicide and intentional self-inflicted injury
655 Disorders usually diagnosed in infancy, childhood, or adolescence
241 Poisoning by psychotropic agents
242 Poisoning by other medications and drugs
## Supplementary Appendix Table B. Rankings of Primary Diagnosis Among Fee-for-Service Medicare Beneficiaries with a CICU Stay During Hospitalizations in 2003 and 2013.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Diagnosis</th>
<th>2003</th>
<th>Rank</th>
<th>Diagnosis</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coronary atherosclerosis and other heart disease</td>
<td>16.3%</td>
<td>1</td>
<td>Acute myocardial infarction</td>
<td>12.0%</td>
</tr>
<tr>
<td>2</td>
<td>Acute myocardial infarction</td>
<td>16.0%</td>
<td>2</td>
<td>Septicemia (except in labor)</td>
<td>9.2%</td>
</tr>
<tr>
<td>3</td>
<td>Congestive heart failure; nonhypertensive</td>
<td>9.3%</td>
<td>3</td>
<td>Cardiac dysrhythmias</td>
<td>7.2%</td>
</tr>
<tr>
<td>4</td>
<td>Cardiac dysrhythmias</td>
<td>6.6%</td>
<td>4</td>
<td>Coronary atherosclerosis and other heart disease</td>
<td>7.0%</td>
</tr>
<tr>
<td>5</td>
<td>Pneumonia (except that caused by tuberculosis or sexually transmitted disease)</td>
<td>3.3%</td>
<td>5</td>
<td>Congestive heart failure; nonhypertensive</td>
<td>6.9%</td>
</tr>
<tr>
<td>6</td>
<td>Complication of device; implant or graft</td>
<td>2.8%</td>
<td>6</td>
<td>Heart valve disorders</td>
<td>4.8%</td>
</tr>
<tr>
<td>7</td>
<td>Nonspecific chest pain</td>
<td>2.6%</td>
<td>7</td>
<td>Respiratory failure; insufficiency; arrest (adult)</td>
<td>3.7%</td>
</tr>
<tr>
<td>8</td>
<td>Acute cerebrovascular disease</td>
<td>2.5%</td>
<td>8</td>
<td>Acute cerebrovascular disease</td>
<td>3.4%</td>
</tr>
<tr>
<td>9</td>
<td>Respiratory failure; insufficiency; arrest (adult)</td>
<td>2.3%</td>
<td>9</td>
<td>Pneumonia (except that caused by tuberculosis or sexually transmitted disease)</td>
<td>2.7%</td>
</tr>
<tr>
<td>10</td>
<td>Heart valve disorders</td>
<td>2.3%</td>
<td>10</td>
<td>Complication of device; implant or graft</td>
<td>2.7%</td>
</tr>
<tr>
<td>11</td>
<td>Septicemia (except in labor)</td>
<td>1.9%</td>
<td>11</td>
<td>Acute and unspecified renal failure</td>
<td>1.9%</td>
</tr>
<tr>
<td>12</td>
<td>Occlusion or stenosis of precerebral arteries</td>
<td>1.8%</td>
<td>12</td>
<td>Gastrointestinal hemorrhage</td>
<td>1.9%</td>
</tr>
<tr>
<td>13</td>
<td>Chronic obstructive pulmonary disease and bronchiectasis</td>
<td>1.6%</td>
<td>13</td>
<td>Occlusion or stenosis of precerebral arteries</td>
<td>1.8%</td>
</tr>
<tr>
<td>14</td>
<td>Gastrointestinal hemorrhage</td>
<td>1.4%</td>
<td>14</td>
<td>Chronic obstructive pulmonary disease and bronchiectasis</td>
<td>1.7%</td>
</tr>
<tr>
<td>15</td>
<td>Hypertension with complications and secondary hypertension</td>
<td>1.3%</td>
<td>15</td>
<td>Aortic; peripheral; and visceral artery aneurysms</td>
<td>1.4%</td>
</tr>
<tr>
<td>16</td>
<td>Conduction disorders</td>
<td>1.3%</td>
<td>16</td>
<td>Hypertension with complications and secondary hypertension</td>
<td>1.4%</td>
</tr>
<tr>
<td>17</td>
<td>Peripheral and visceral atherosclerosis</td>
<td>1.2%</td>
<td>17</td>
<td>Conduction disorders</td>
<td>1.4%</td>
</tr>
<tr>
<td>18</td>
<td>Aortic; peripheral; and visceral artery aneurysms</td>
<td>1.2%</td>
<td>18</td>
<td>Peripheral and visceral atherosclerosis</td>
<td>1.2%</td>
</tr>
<tr>
<td>19</td>
<td>Acute and unspecified renal failure</td>
<td>1.1%</td>
<td>19</td>
<td>Complications of surgical procedures or medical care</td>
<td>1.1%</td>
</tr>
<tr>
<td>20</td>
<td>Syncope</td>
<td>1.1%</td>
<td>20</td>
<td>Pulmonary heart disease</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

% of all admissions due to the top 20 diagnoses in 2003 and 2013
Supplementary Appendix C. Data Visualization

We created an online data visualization that allows for comparisons of individual discharge diagnosis rankings among any of the study years, either among the entire cohort or stratified by a specific age (65-74, 75-84, 85 and older) and sex subgroup. We present the data in the form of interactive slope graphs and heat map, respectively. These supplements are accessible at:

https://s3-us-west-2.amazonaws.com/colinrcooke/visualization/slopegraph_Sinha.html

and

https://s3-us-west-2.amazonaws.com/colinrcooke/visualization/heatmap_Sinha.html

For each subgroup, we limited the results to primary diagnoses of greater than 100 admissions in each of the study years. Rankings were created by frequency of admissions in each year and relative changes between years are also reported.