ORIGINAL RESEARCH

Association Between Intensive Care Unit Usage and Long-Term Medication Adherence, Mortality, and Readmission Among Initially Stable Patients With Non–ST-Segment–Elevation Myocardial Infarction

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BACKGROUND: Hospitals in the United States vary in their use of intensive care units (ICUs) for hemodynamically stable patients with non–ST-segment–elevation myocardial infarction (NSTEMI). The association between ICU use and long-term outcomes after NSTEMI is unknown.

METHODS AND RESULTS: Using data from the National Cardiovascular Data Registry linked to Medicare claims, we identified 65,256 NSTEMI patients aged ≥ 65 years without cardiogenic shock or cardiac arrest on presentation between 2011 and 2014. We compared 1-year medication non-adherence, cardiovascular readmission, and mortality across hospitals by ICU use using multivariable regression models. Among 520 hospitals, 154 (29.6%) were high ICU users (>70% of stable NSTEMI patients admitted to ICU), 270 (51.9%) were intermediate (30%–70%), and 196 (37.7%) were low (<30%). Compared with low ICU usage hospitals, no differences were observed in the risks of 1-year medication non-adherence (adjusted odds ratio 1.08, 95% CI, 0.97–1.21), mortality (adjusted hazard ratio 1.06, 95% CI, 0.98–1.15), and cardiovascular readmission (adjusted hazard ratio 0.99, 95% CI, 0.95–1.04) at high usage hospitals. Patients hospitalized at intermediate ICU usage hospitals had lower rates of evidence-based therapy and diagnostic catheterization within 24 hours of hospital arrival, and higher risks of 1-year mortality (adjusted hazard ratio 1.07, 95% CI, 1.02–1.12) and medication non-adherence (adjusted odds ratio 1.09, 95% CI, 1.02–1.15) compared with low ICU usage hospitals.

CONCLUSIONS: Routine ICU use is unlikely to be beneficial for hemodynamically stable NSTEMI patients; medication adherence, long-term mortality, and cardiovascular readmission did not differ for high ICU usage hospitals compared with hospitals with low ICU usage rates.

Key Words: acute coronary syndrome ■ healthcare quality ■ hospital readmission ■ intensive care unit ■ medication adherence ■ non–ST-segment–elevation myocardial infarction

Considerable inter-hospital variability in intensive care unit (ICU) usage has been observed for patients with non–ST-segment–elevation myocardial infarction (NSTEMI).1–4 Severity of illness on presentation is similar for NSTEMI patients treated and not treated in the ICU, suggesting that...
ICU admission decisions are largely based on hospital policies and local provider preferences rather than severity of illness. As a result, a number of NSTEMI patients without a compelling indication for ICU care are admitted to the ICU. Among such non-critically ill patients, higher hospital-level ICU usage has not been associated with lower short-term mortality; however, there may be other benefits and risks to higher intensity care in the ICU.

Hospital processes of care may affect patients’ post-discharge medication adherence, and via this mechanism, their long-term outcomes. The ICU environment’s lower ratio of nurses to patients may facilitate detailed education on the benefits of secondary prevention medications, which, along with reinforcement of severity of illness through continuous monitoring and intensive nursing care, could increase post-discharge medication adherence. Adherence to secondary prevention medications is low among post-MI patients, if ICU usage effectively increases medication adherence, it has the potential to improve long-term outcomes. Conversely, ICU admission for non-critically ill patients with NSTEMI can lead to multiple care transitions during a short hospital stay and divert resources allocated to optimizing transition of care such that long-term medication adherence and outcomes are adversely impacted.

The NCDR (National Cardiovascular Data Registry) includes consecutive patients with acute myocardial infarction (MI) presenting to participating hospitals. By linking this registry to Medicare claims, we examined the association of hospital-level ICU usage rates with long-term medication adherence and clinical outcomes.

METHODS
The data, analytic methods, and study materials used in this article will not be made available to other researchers.

Patient Population
The NCDR CPMI (Chest Pain Myocardial Infarction) Registry captures consecutive patients admitted to participating hospitals with ST-segment–elevation myocardial infarction and NSTEMI. Trained data abstractors at each hospital collect detailed information on medical history, clinical presentation, and in-hospital treatment via retrospective chart review. Real-time data quality feedback and annual audits ensure data accuracy. Patients aged ≥65 years in this registry have previously been linked to their Medicare claims data using indirect identifiers (date of birth, sex, hospital identifier, date of admission, and date of discharge). We used this linked data source to determine ICU usage, medication adherence, and post-discharge outcomes.

Between April 2011 and December 2014, 106,801 patients aged ≥65 years with MI were admitted with NSTEMI to 689 hospitals and included in the linked database. We excluded patients who were transferred
into (n=29,425) or out of (n=3947) a CPMI hospital, since patient experience and post-discharge outcomes in these cases cannot be ascribed only to the NCDR hospital. Patients who had cardiac arrest or cardiogenic shock on first medical contact as identified on the registry’s case report form (n=2384) were also excluded, since these patients have a compelling indication for ICU care other than NSTEMI. To avoid double counting of patients with multiple MI admissions during the study period, we started follow-up after the first admission (3939 subsequent NCDR records for MI readmission were excluded). Because analyses were conducted on the hospital level, we excluded hospitals admitting <25 patients during the study period (169 hospitals treating 1850 patients). Our final study population included 65,256 initially hemodynamically stable NSTEMI patients treated at 520 hospitals (Figure 1). For analyses of post-discharge outcomes, we further excluded 3004 patients who died while hospitalized. For analyses of medication non-adherence, we included only patients with Part D Medicare prescription coverage (n=28,185).

**Definitions and Outcomes**

Patients with revenue center codes for ICU or cardiac ICU usage during the index MI hospitalization were classified as having been treated in an ICU. Patients without these revenue center codes were classified as not having been treated in an ICU. We prospectively defined hospitals as having: high ICU usage (>70% of all initially stable patients with NSTEMI treated in the ICU), intermediate ICU usage (30%–70%), and low ICU usage (≤30%) groups. Definitions of abstracted NCDR data variables are available online (https://www.ncdr.com/webncdr/action/home/datacollection). Community socioeconomic variables were drawn from the Area Health Resource File, which is collected at the county level, and matched to patients by zip code.

In the subgroup of patients with Medicare Part D, medication adherence was assessed using Part D prescription filling data with non-adherence defined as the proportion of days covered of medications <80%. We assessed adherence to 4 classes of medications: beta blocker, statin, P2Y12 inhibitor, and angiotensin-converting enzyme inhibitor/angiotensin II receptor blocker among patients prescribed each medication at discharge.

One-year mortality was assessed from Medicare denominator files. Cardiovascular readmission was defined as time to any readmissions for recurrent MI, heart failure, or stroke; these were identified from the first...
models with generalized estimating equations to ac -
test, and then used multivariable logistic regression
intermediate, and low ICU usage hospitals. We com-
pared the unadjusted proportion of patients adherent
to all 4 classes of medication at high, intermediate,
low ICU usage hospitals. Of 65 256 hemody-
amic stable NSTEMI patients, 23 658 (35.3%) were
admitted to low ICU usage hospitals, 35 293 (54.1%)
and 6305 (9.7%) were admitted to high ICU usage hospitals as the reference standard. As a
sensitivity analysis, we examined the association
between ICU usage, as a continuous variable, and
1-year death and cardiovascular readmission risks.
As the associations between ICU usage and these
outcomes were non-linear, we fit a model using 3
spline terms with knots at 30% and 60% ICU usage;
spline knots were selected based on visual inspec-
tion of plots of mortality and cardiovascular readmis-
sion by hospital-level ICU usage.21 We report HR for
a 5% increase in hospital-level ICU usage. As a sen-
sitivity analysis, we repeated these analyses among
patients who never developed an indication for ICU-
level care during their hospitalization, as defined
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patients admitted to all 3 types of hospitals was 77 and 46% were women. The prevalence of medical comorbidities was similar for patients treated at low, intermediate, and high ICU usage hospitals. The ACTION (Acute Coronary Treatment and Intervention Outcomes Network) inhospital mortality risk score was also similar for patients admitted to the 3 groups of hospitals. Initial serum troponin values were also similar at the 3 groups. Findings were similar in the cohort of patients discharged alive from the index MI admission (Table S2).

Patients admitted to intermediate ICU usage hospitals were less likely to undergo diagnostic catheterization within 24 hours of admission (37.5% versus 34.7% versus 37.5% at low versus intermediate versus high ICU usage hospitals, \(P<0.001\)) (Table 2). Likelihood of revascularization during the hospitalization and prescription of evidence-based secondary prevention medications at discharge was similar at all 3 types of hospitals. Patients at intermediate and high ICU usage hospitals had significantly higher but clinically similar rates of cardiac arrest and major bleeding while hospitalized, but no significant differences in cardiogenic shock or stroke. Overall, 3004 patients died while hospitalized (4.6%): 970 at low ICU usage hospitals (4.1%), 1727 at intermediate ICU usage hospitals (4.9%), and 307 at high ICU usage hospitals (4.9%).

### Medication Non-Adherence
At 90 days, 36.6% of patients were non-adherent to beta blockers, 39.8% to statins, 37.8% to P2Y12 inhibitors, and 43.8% to angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers. For all medications, rates of non-adherence were modestly higher for patients discharged from

| Table 1. Baseline Patient Characteristics and Details of the Index Myocardial Infarction at Low, Intermediate, and High Intensive Care Unit Usage Hospitals |
|---------------------------------------------------------------|
| **Demographics**                                              | **Low ICU Usage (n=23 658 Patients at 196 Hospitals)** | **Intermediate ICU Usage (n=35 293 Patients at 270 Hospitals)** | **High ICU Usage (n=6305 Patients at 54 Hospitals)** |
| Age, y                                                        | 77 (70, 84)                                             | 77 (70, 84)                                             | 77 (71, 84)                                             |
| Female sex                                                   | 10 669 (45.1%)                                         | 16 333 (46.3%)                                        | 2945 (46.7%)                                            |
| Non-white race                                               | 3155 (13.3%)                                           | 5488 (15.5%)                                           | 1145 (18.2%)                                           |
| Median household income ($)                                  | 50 811 (43 417, 60 134)                                | 49 758 (43 047, 56 647)                                | 49 353 (41 889, 56 326)                                |
| **Medical history**                                          |                                                         |                                                         |                                                         |
| Prior MI                                                     | 7616 (32.2%)                                           | 10 145 (28.8%)                                        | 1928 (30.6%)                                            |
| Prior PCI                                                    | 7309 (30.9%)                                           | 10 169 (28.8%)                                        | 1886 (29.9%)                                            |
| Prior CABG                                                   | 5860 (24.8%)                                           | 8342 (23.6%)                                           | 1484 (23.5%)                                            |
| Cerebrovascular disease                                      | 5151 (21.8%)                                           | 7194 (20.4%)                                           | 1323 (21.0%)                                            |
| Peripheral artery disease                                    | 4014 (17.0%)                                           | 5259 (14.9%)                                           | 910 (14.4%)                                             |
| Prior heart failure                                          | 5557 (23.5%)                                           | 8203 (23.2%)                                           | 1504 (23.9%)                                            |
| Atrial fibrillation                                          | 3701 (15.6%)                                           | 5263 (14.9%)                                           | 957 (15.2%)                                             |
| Hypertension                                                 | 20 450 (86.4%)                                         | 30 366 (86.0%)                                        | 5496 (87.2%)                                            |
| Dyslipidemia                                                 | 17 044 (72.0%)                                         | 24 780 (70.2%)                                        | 4561 (72.3%)                                            |
| Diabetes mellitus                                            | 9421 (39.8%)                                           | 14 298 (40.5%)                                        | 2570 (40.8%)                                            |
| Dialysis                                                     | 838 (3.5%)                                             | 1412 (4.0%)                                            | 262 (4.2%)                                              |
| Current/recent smoker                                        | 2985 (12.6%)                                           | 4532 (12.8%)                                           | 808 (12.8%)                                             |
| Chronic lung disease                                         | 4824 (20.4%)                                           | 7294 (20.7%)                                           | 1314 (20.8%)                                            |
| **Details of index presentation**                           |                                                         |                                                         |                                                         |
| Ischemia on ECG                                              | 8329 (35.2%)                                           | 10 718 (30.4%)                                        | 1994 (31.6%)                                            |
| Signs of heart failure                                       | 5386 (22.8%)                                           | 8634 (24.5%)                                           | 1450 (23.0%)                                            |
| Initial systolic blood pressure                              | 148 (127, 170)                                         | 147 (126, 170)                                        | 148 (128, 170)                                         |
| Initial serum creatinine                                     | 1.1 (0.9, 1.4)                                         | 1.1 (0.9, 1.5)                                        | 1.1 (0.9, 1.4)                                         |
| Initial troponin (× ULN)                                     | 2.8 (0.8, 13.0)                                        | 2.8 (0.8, 13.4)                                        | 3.0 (0.9, 14.4)                                        |
| ACTION in-hospital mortality risk score                      | 36 (29, 44)                                            | 37 (29, 45)                                            | 37 (29, 45)                                            |

**ACTION** indicates Acute Coronary Treatment and Intervention Outcomes Network; CABG, coronary artery bypass graft surgery; ECG, electrocardiogram; ICU, intensive care unit; MI, myocardial infarction; PCI, percutaneous coronary intervention; and ULN, upper limit of normal.

Low ICU usage hospitals admitted <30% of non–ST-segment–elevation myocardial infarction patients to the ICU; intermediate, 30% to 70%; high, >70%.
hospitals admitting 30% to 70% of NSTEMI patients to the ICU (Figure 2A). Overall, 61.8% of patients discharged from low ICU usage hospitals, 63.4% of patients discharged from intermediate ICU usage hospitals, and 61.8% of patients discharged from high ICU usage hospitals were non-adherent to at least 1 class of medication that was prescribed at discharge ($P=0.001$). After adjustment for patient and hospital characteristics, hospital ICU usage remained significantly associated with 90-day medication non-adherence ($P=0.001$). There was no significant difference in the odds of non-adherence for patients discharged from high ICU usage hospitals compared with low on adjusted or unadjusted analyses (unadjusted OR 1.00, 95% CI, 0.91–1.10; adjusted OR 0.98, 95% CI, 0.91–1.06); patients discharged from intermediate ICU usage hospitals had an unadjusted OR of 1.09 (95% CI, 1.02–1.19) and an adjusted OR of 1.07 (95% CI, 1.02–1.12) for non-adherence compared with patients discharged from low ICU usage hospitals (Table 3).

Similar results were seen at 1 year (Figure 2B). Overall, 66.3% of patients discharged from low ICU usage hospitals were non-adherent to at least 1 class of medication by 1 year, compared with 67.9% of patients discharged from intermediate ICU usage hospitals and 68.0% of patients discharged from high ICU usage hospitals ($P=0.01$). After multivariable adjustment, hospital ICU usage remained significantly associated with 1-year medication non-adherence ($P=0.02$). There was no significant difference in risk of medication non-adherence between patients discharged from high- versus low-ICU usage hospitals (unadjusted OR 1.08, 95% CI, 0.96–1.19; adjusted OR 1.06, 95% CI, 0.97–1.16); the unadjusted OR was 1.10 (95% CI, 1.03–1.18) and adjusted OR was 1.09 (95% CI, 1.02–1.15) for patients discharged from intermediate- versus low-ICU usage hospitals.

### One-Year Mortality and Cardiovascular Readmission

Over 1-year follow-up, 13 197 (21.2%) patients died: 20.3% of those discharged from low ICU usage hospitals, 22.0% from intermediate ICU usage hospitals, and 20.9% from high ICU usage hospitals ($P=0.06$; Figure 3A). After adjusting for baseline characteristics and details of the index admission, hospital level ICU usage was associated with 1-year mortality ($P=0.03$). No difference in 1-year mortality was observed when comparing hospitals with high and low ICU usage rates on both unadjusted and adjusted analyses (unadjusted HR 1.04, 95% CI, 0.93–1.17; adjusted HR 1.06, 95% CI, 0.98–1.15); however, discharge from an intermediate ICU usage hospital was associated with a higher adjusted risk of mortality at 1 year on both adjusted and unadjusted analyses (unadjusted HR 1.10, 95% CI, 1.02–1.19; adjusted HR 1.07, 95% CI, 1.02–1.12). Results were similar in the subset of patients who did not develop complications requiring ICU care (high versus low: adjusted HR 1.09, 95% CI, 1.00–1.18; intermediate versus low: adjusted HR 1.07, 95% CI, 1.02–1.13). There was no association between ICU usage, expressed continuously, and 1-year mortality in the full cohort (Table 4), or the subset that did not develop complications requiring ICU-level care (Table S3). There was no interaction between ICU usage, 1-year mortality, and either hospital size or teaching status (Table S4).

The cumulative incidence of cardiovascular readmission over 1 year was 48.4%: 47.6% at low ICU
usage hospitals, 49.0% at intermediate ICU usage hospitals, and 48.5% at high ICU usage hospitals (P=0.10; Figure 3B). After adjustment, there remained no significant association between hospital-level ICU usage and 1-year cardiovascular readmission (P=0.24). No difference in 1-year cardiovascular readmission was observed when comparing hospitals with high and low ICU usage rates on both unadjusted and adjusted analyses (unadjusted HR 1.02, 95% CI, 0.96–1.09; adjusted HR 1.00, 95% CI, 0.95–1.04), or comparing hospitals with intermediate and low ICU usage rates (unadjusted HR 1.05, 95% CI, 1.00–1.15; adjusted HR 1.02, 95% CI, 0.99–1.06) (Table 3). Results were similar in the subset of patients who did not develop complications requiring ICU care (high versus low: adjusted HR 1.00, 95% CI, 0.95–1.05; intermediate versus low: adjusted HR 1.02, 95% CI, 0.99–1.06). Comparisons of individual components of cardiovascular readmission (MI, stroke, heart failure) are shown in Table S5; there were no significant differences in unadjusted or risk-adjusted outcomes between high versus low and intermediate versus low ICU-usage hospitals. When ICU usage was expressed continuously, there was no association between ICU usage and 1-year cardiovascular readmission in both the full cohort (Table 4) and the subset that did not develop complications requiring ICU-level care (Table S3). There was no interaction between ICU usage, 1-year cardiovascular readmission, and either hospital size or teaching status (Table S4).

**DISCUSSION**

In this nationwide study, we found that patients with initially stable NSTEMI hospitalized at high ICU usage hospitals had no significant differences in 1-year mortality or cardiovascular readmission compared with those admitted to low ICU usage hospitals.

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**Figure 2.** Non-adherence at 90 days (A) and 1-year (B) by intensive care unit (ICU) usage rate at discharging hospital.

There was no difference in rates of adherence to evidence-based medicine at 90 days for patients discharged from low and high ICU usage hospitals; patients discharged from intermediate ICU usage hospitals had a significantly lower rate of adherence to all classes of evidence-based medication at 90 days (A, P<0.05 for all comparisons). By 1 year, differences in medication adherence between patients discharged from high, intermediate, and low ICU usage hospitals were largely attenuated and non-significant (B, P>0.05 for all comparisons except statin and overall). ACE indicates angiotensin-converting enzyme; and ARB, angiotensin II receptor blocker.
Similarly, there were no differences between high and low ICU usage hospitals in 90-day or 1-year medication adherence. When comparing low and intermediate ICU usage hospitals, there were small but statistically significant differences: patients discharged from intermediate ICU usage hospitals had a higher rate of 1-year mortality, cardiovascular readmission, and medication non-adherence. Together, these data suggest that selective, rather than routine ICU usage, may be appropriate for hemodynamically stable NSTEMI patients.

ICU usage for initially stable patients with NSTEMI is highly variable between hospitals, and is only minimally correlated with severity of illness. As a result, many low-risk patients with NSTEMI are treated in the ICU: In one study, 41% of NSTEMI patients with a predicted risk of in-hospital mortality <1% were treated in the ICU. In this study, we again found no difference in case mix at hospitals with low, intermediate, and high ICU usage hospitals, highlighting the arbitrary nature of ICU usage in initially stable NSTEMI patients. Given lack of alignment between severity of illness and ICU usage, it is perhaps not surprising that prior studies have failed to demonstrate an association between hospital-level ICU usage for patients with MI and in-hospital or 30-day outcomes. This study’s results demonstrate that the lack of mortality difference between high and low ICU usage hospitals remains constant at 1 year, and that there is also no difference in cardiovascular readmission over this time frame.

Though routine admission to the ICU for hemodynamically stable NSTEMI patients has no association with short-term outcomes, routine ICU admission could affect long-term outcomes via an effect on medication adherence. The reasons for non-adherence are complex, but are governed in part by a patient’s perception of illness severity, evaluation of the efficaciousness of medication adherence, and external cues to action. Admission to an ICU, with the attendant enhanced monitoring, may make patients believe their illness is more severe. On the other hand, stable NSTEMI patients in the ICU may be relatively ignored by providers and nurses focused on critically ill patients, reducing opportunities for education and leading to lower medication adherence. At hospitals with closed ICUs, ICU providers may be appropriately distracted by truly critically ill patients and may focus less on providing timely care for stable NSTEMI patients. At hospitals with open ICUs, stable NSTEMI patients in the ICU are geographically isolated from other patients on the inpatient cardiology or hospitalist service, potentially interrupting communication and delaying care. Furthermore, stable patients admitted to the ICU will almost always be transferred from the ICU to a non-ICU setting before discharge. In the context of a short hospital stay, this transfer may disrupt continuity of care. Hospital patterns of care delivery have the potential to affect downstream adherence to medications, with educational efforts from providers on medication side effects and use of team-based care models particularly effective. Caring for stable NSTEMI patients in the ICU may disrupt these efforts and reduce downstream medication adherence.

The lack of differences in 1-year mortality and medication adherence for initially stable NSTEMI patients admitted to high versus low ICU admission hospitals

### Table 3. Association Between High, Intermediate, and Low Hospital-Level ICU Usage, Medication Non-Adherence and Cardiovascular Outcomes

|                      | Unadjusted | Adjusted |
|----------------------|------------|----------|
|                      | OR (95% CI)|       Global P | OR (95% CI) |       Global P |
| 90-d medication non-adherence |            | 0.001 |            | 0.03 |
| High vs low          | 1.00 (0.91–1.10) | 0.98 (0.91–1.06) |  |
| Intermediate vs low  | 1.09 (1.04–1.16) | 1.05 (1.01–1.11) |  |
| 1-y medication non-adherence |            | 0.01 |            | 0.02 |
| High vs low          | 1.08 (0.96–1.19) | 1.06 (0.97–1.16) |  |
| Intermediate vs low  | 1.10 (1.03–1.18) | 1.09 (1.02–1.15) |  |
| 1-y mortality        |            | 0.06 |            | 0.03 |
| High vs low          | 1.04 (0.93–1.17) | 1.06 (0.98–1.15) |  |
| Intermediate vs low  | 1.10 (1.02–1.19) | 1.07 (1.02–1.12) |  |
| 1-y cardiovascular readmission |            | 0.10 |            | 0.24 |
| High vs low          | 1.02 (0.96–1.09) | 1.00 (0.96–1.04) |  |
| Intermediate vs low  | 1.05 (1.00–1.10) | 1.03 (0.99–1.06) |  |

Low ICU usage hospitals admitted <30% of non-ST-segment-elevation myocardial infarction patients to the ICU; intermediate, 30% to 70%; high, >70%. HR indicates hazard ratio; and OR, odds ratio.
suggests that ICU admission may not affect patient beliefs on the severity of their illness or the educational efforts of the healthcare team to a degree sufficient to affect outcomes. However, there were small differences in long-term outcomes and medication adherence between low and intermediate ICU usage hospitals, and a lower rate of evidence-based therapy and diagnostic catheterization within 24 hours of hospital arrival at intermediate ICU usage hospitals than at high or low ICU usage hospitals. This difficulty with care coordination and timely delivery of care at intermediate ICU usage hospitals may extend to education about secondary prevention medications. Similar difficulties with care coordination and timely delivery of care were not observed at high ICU usage hospitals, nor were in-hospital or post-discharge outcomes different. At high ICU usage hospitals, nearly all initially stable NSTEMI patients are admitted to the ICU, and these hospitals may have developed care processes for ICU-treated NSTEMI patients that reduce the likelihood of these patients receiving disrupted and suboptimal care.

Figure 3. One-year mortality and readmission by intensive care unit (ICU) usage rate at discharging hospital.

There were no differences in 1-year mortality for patients admitted to high and low ICU usage hospitals; patients admitted to intermediate ICU usage hospitals had a mildly but significantly higher rate of death at 1-year than those admitted to high and low ICU usage hospitals (A), even after adjusting for patient characteristics and in-hospital processes of care. There were no significant differences in the rates of readmission for cardiovascular causes by hospital-level ICU admission group (B). HR indicates hazard ratio.
Together with prior data showing similar short-term outcomes for patients admitted to high and low ICU usage hospitals, and the high cost of routine ICU care, the lack of difference in long-term outcomes and medication adherence suggests that routine ICU admission for initially stable NSTEMI patients is unlikely to be beneficial. If anything, higher rates of long-term mortality, hospital readmission, and medication non-adherence at intermediate compared with low ICU usage hospitals, along with lower levels of timely revascularization, suggests that higher hospital-level ICU usage may disrupt continuity of care. However, though most initially stable NSTEMI patients will remain stable throughout their course, ≈1 in 6 will deteriorate and develop a condition requiring ICU care, and outcomes are worse when patients are transferred to the ICU after deteriorating clinically than if they are initially admitted there on admission. A strategy of selective ICU admission for initially stable NSTEMI patients at highest risk of clinical deterioration requiring ICU care may be ideal to maintain patient safety while reducing ICU capacity strain and controlling costs. The level of risk of clinical deterioration tolerated outside of the ICU at a given hospital will be determined by local resources and different hospitals are likely to have different thresholds.

Several limitations should be acknowledged. This is an observational analysis and is subject to unmeasured confounding. Though baseline characteristics and severity of illness were similar for patients admitted to low, intermediate, and high ICU usage hospitals, patients admitted to these hospitals may differ in unmeasured ways, contributing to hospitals’ admitting of more or fewer patients to the ICU, as well as to processes of care and patient outcomes. This may be especially relevant when considering long-term outcomes, as unmeasured differences in social determinants of health and quality of outpatient care may affect patient outcomes. In addition, we did not adjust for multiplicity, increasing risk of type 1 error. Furthermore, observed differences in outcomes are small, and statistically significant findings may not be clinically relevant. The Chest Pain—MI Registry does not capture clinical variables, such as persistent chest pain, dynamic ECG changes, electrical instability, or refractory hypoxemia, that hospitals may use to make clinical decisions about ICU admission. We cannot distinguish whether patients were admitted electively to the ICU or transferred after clinical deterioration. However, we have previously shown similar rates of in-hospital complications requiring ICU care at high, intermediate, and low ICU usage hospitals. Lastly, our study population includes only patients aged ≥65 years; however, this group comprises a large and growing cohort of patients with MI, and it is unlikely that any effects of the ICU on outcomes among initially stable NSTEMI patients would be mediated by age.

## CONCLUSIONS

Hospitals with high ICU usage had no significant differences in medication adherence, long-term mortality, and cardiovascular readmission compared with hospitals with low ICU usage rates. Selective, rather than routine ICU usage, may be appropriate for hemodynamically stable NSTEMI patients.

## ARTICLE INFORMATION

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Supplementary Materials

Data S1
Tables S1–S5

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SUPPLEMENTAL MATERIALS
**Data S1 (Supplemental Methods)**: Covariates included in the multivariable models for long-term death and readmission and medication adherence

**Table S1**: Characteristics of low, intermediate, and high ICU utilization hospitals

**Table S2**: Baseline patient characteristics and details of the index MI at low, intermediate, and high ICU utilization hospitals among patients discharged alive

**Table S3**: Association between hospital-level ICU utilization and cardiovascular outcomes among patients who did not develop an indication for ICU-level care

**Table S4**: Interaction between ICU utilization, cardiovascular outcomes, and hospital size or teaching status

**Table S5**: 1-year cause-specific readmission by ICU utilization rate at discharging hospital
Data S1: Covariates included in the multivariable models for long-term death and readmission and medication adherence

Demographics: age, race, sex, median household income in patient’s zip code

Medical history: hypertension, dyslipidemia, current/recent smoker, diabetes mellitus, prior stroke, prior myocardial infarction, prior heart failure, prior percutaneous coronary intervention, prior coronary artery bypass graft surgery, prior peripheral arterial disease, atrial fibrillation, chronic lung disease

Presentation details: body mass index, signs or symptoms of heart failure on presentation

In-hospital procedures and discharge status: diagnostic catheterization, percutaneous coronary intervention, coronary artery bypass graft surgery, drug-eluting stent (among patients undergoing percutaneous coronary intervention), left ventricular ejection fraction, lowest hemoglobin, lowest creatinine clearance (calculated by Cockcroft-Gault formula), peak troponin (as a ratio of the upper limit of normal), cardiac rehabilitation referral at discharge, discharge location

Hospital characteristics: region, procedural facilities (diagnostic catheterization only, percutaneous coronary intervention only, cardiac surgery capabilities, none), teaching hospital, total hospital beds, rural (vs. urban) location
**Table S1: Characteristics of low, intermediate, and high ICU utilization hospitals**

|                      | Low ICU utilization (n = 196 hospitals) | Intermediate ICU utilization (n = 270 hospitals) | High ICU utilization (n = 54 hospitals) | P-value |
|----------------------|----------------------------------------|-------------------------------------------------|----------------------------------------|---------|
| **Region**           |                                        |                                                 |                                        |         |
| West                 | 41 (20.9)                              | 29 (10.7)                                       | 11 (20.4)                              | 0.06    |
| Northeast            | 15 (7.7)                               | 19 (7.0)                                        | 2 (3.7)                                |         |
| Midwest              | 50 (25.5)                              | 84 (31.1)                                       | 18 (33.3)                              |         |
| South                | 90 (45.9)                              | 138 (51.1)                                      | 23 (42.6)                              |         |
| **Procedural services** |                                        |                                                 |                                        | 0.86    |
| No procedural services | 1 (0.5)                              | 1 (0.4)                                         | 0 (0.0)                                |         |
| Diagnostic cath only | 3 (1.5)                               | 4 (1.5)                                         | 0 (0.0)                                |         |
| PCI only             | 46 (23.5)                              | 51 (18.9)                                       | 12 (22.2)                              |         |
| Cardiac surgery      | 146 (74.5)                             | 214 (79.3)                                      | 42 (77.8)                              |         |
| Teaching hospital    | 31 (15.8)                              | 44 (16.3)                                       | 8 (14.8)                               | 0.96    |
| Total beds           | 290 (183, 421)                         | 320 (209, 477)                                  | 260 (189, 394)                         | 0.11    |
| Rural hospital       | 37 (18.9)                              | 41 (15.2)                                       | 13 (24.1)                              | 0.24    |
Table S2: Baseline patient characteristics and details of the index MI at low, intermediate, and high ICU utilization hospitals among patients discharged alive

| Demographics | Low ICU utilization (n = 22,688 patients at 196 hospitals) | Intermediate ICU utilization (n = 33,566 patients at 270 hospitals) | High ICU utilization (n = 5,998 patients at 54 hospitals) |
|--------------|----------------------------------------------------------|------------------------------------------------------------------|----------------------------------------------------------|
| Age          | 77 (70, 84)                                              | 77 (70, 84)                                                      | 77 (70, 84)                                               |
| Female sex   | 10,207 (45.0%)                                           | 15,493 (46.2%)                                                  | 2,800 (46.7%)                                            |
| Non-white race | 3,052 (13.5%)                                         | 5,202 (15.5%)                                                  | 1,093 (18.2%)                                            |
| Median household income ($) | 50,817 (43,428, 60,134)                                  | 49,778 (43,047, 56,659)                                       | 49,380 (41,895, 56,326)                                  |
| Medical history |                                                |                                                                  |                                                          |
| Prior MI     | 7,301 (32.2%)                                           | 9,626 (28.7%)                                                  | 1,824 (30.4%)                                            |
| Prior PCI    | 7,086 (31.2%)                                           | 9,791 (29.2%)                                                  | 1,813 (30.2%)                                            |
| Prior CABG   | 5,614 (24.7%)                                           | 7,931 (23.6%)                                                  | 1,403 (23.4%)                                            |
| Cerebrovascular disease | 4,866 (21.4%)                                      | 6,743 (20.1%)                                                  | 1,250 (20.8%)                                            |
| Peripheral arterial disease | 3,812 (16.8%)                                      | 4,936 (14.7%)                                                  | 850 (14.2%)                                               |
| Condition                          | Low ICU utilization | Intermediate ICU utilization | High ICU utilization |
|-----------------------------------|--------------------|------------------------------|----------------------|
|                                   | (n = 22,688 patients at 196 hospitals) | (n = 33,566 patients at 270 hospitals) | (n = 5,998 patients at 54 hospitals) |
| Prior heart failure               | 5,198 (22.9%)      | 7,567 (22.5%)               | 1,384 (23.1%)        |
| Atrial fibrillation               | 3,476 (15.3%)      | 4,923 (14.7%)               | 887 (14.8%)          |
| Hypertension                      | 19,604 (86.4%)     | 28,863 (86.0%)              | 5,234 (87.3%)        |
| Dyslipidemia                      | 16,428 (72.4%)     | 23,680 (70.6%)              | 4,346 (72.5%)        |
| Diabetes mellitus                 | 9,021 (39.8%)      | 13,544 (40.4%)              | 2,429 (40.5%)        |
| Dialysis                          | 777 (3.4%)         | 1,289 (3.8%)                | 244 (4.1%)           |
| Current/recent smoker             | 2,882 (12.7%)      | 4,353 (13.0%)               | 775 (12.9%)          |
| Chronic lung disease              | 4,560 (20.1%)      | 6,831 (20.4%)               | 1,220 (20.3%)        |
| **Details of index presentation** |                    |                              |                      |
| Ischemia on ECG                   | 7,951 (35.0%)      | 10,104 (30.1%)              | 1,896 (31.6%)        |
| Signs of heart failure            | 4,953 (21.8%)      | 7,859 (23.4%)               | 1,311 (21.9%)        |
| Initial systolic blood pressure   | 148 (128, 170)     | 148 (127, 170)              | 148 (128, 171)       |
| Initial serum creatinine          | 1.1 (0.9, 1.4)     | 1.1 (0.9, 1.4)              | 1.1 (0.9, 1.4)       |
|                        | Low ICU utilization (n = 22,688 patients at 196 hospitals) | Intermediate ICU utilization (n = 33,566 patients at 270 hospitals) | High ICU utilization (n = 5,998 patients at 54 hospitals) |
|------------------------|-----------------------------------------------------------|------------------------------------------------------------------|---------------------------------------------------|
| Initial troponin (× ULN) | 2.6 (0.7, 12.3)                                           | 2.7 (0.7, 12.4)                                                  | 2.8 (0.8, 13.7)                                   |
| ACTION in-hospital mortality risk score | 36 (29, 44)                                               | 36 (29, 44)                                                     | 36 (29, 44)                                      |
| **Discharge medications** |                                                           |                                                                  |                                                  |
| Aspirin                | 20,170 (97.7%)                                            | 29,361 (96.9%)                                                  | 5,269 (97.6%)                                    |
| P2Y<sub>12</sub> inhibitor | 14,557 (68.7%)                                           | 20,730 (66.2%)                                                  | 3,798 (68.6%)                                    |
| Beta blocker           | 19,474 (96.6%)                                            | 28,451 (96.0%)                                                  | 5,055 (95.5%)                                    |
| ACE inhibitor or ARB*  | 2,890 (86.4%)                                             | 4,438 (85.7%)                                                   | 866 (84.9%)                                      |

MI, myocardial infarction; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft surgery; ECG, electrocardiogram; ULN, upper limit of normal; LV, left ventricular; ACE, angiotensin converting enzyme; ARB, angiotensin II receptor blocker. *, among eligible patients (n = 9,490). Low ICU utilization hospitals admitted < 30% of NSTEMI patients to the ICU; intermediate, 30-70%; high, > 70%.
**Table S3:** Association between hospital-level ICU utilization and cardiovascular outcomes among patients who did not develop an indication for ICU-level care

|                                    | ICU utilization     | Unadjusted HR (95% CI) | Adjusted HR (95% CI) |
|------------------------------------|---------------------|------------------------|----------------------|
| 1-year mortality                   |                     |                        |                      |
| Every 5% increase ≤ 30%            | 1.00 (0.95-1.05)    | 1.00 (0.98-1.03)       |                      |
| Every 5% increase 30-60%           | 1.02 (1.00-1.05)    | 1.01 (1.00-1.03)       |                      |
| Every 5% increase > 60%            | 0.95 (0.91-1.00)    | 0.98 (0.96-1.01)       |                      |
| 1-year cardiovascular readmission  |                     |                        |                      |
| Every 5% increase ≤ 30%            | 1.01 (0.99-1.04)    | 1.00 (0.98-1.02)       |                      |
| Every 5% increase 30-60%           | 1.01 (1.00-1.02)    | 1.01 (1.00-1.02)       |                      |
| Every 5% increase > 60%            | 0.98 (0.95-1.00)    | 0.98 (0.96-1.00)       |                      |
Table S4: Interaction between ICU utilization, cardiovascular outcomes, and hospital size or teaching status

|                       | ICU utilization         | P interaction (hospital size) | P interaction (teaching status) |
|-----------------------|-------------------------|-------------------------------|--------------------------------|
| 1-year mortality      | Every 5% increase ≤ 30% | 0.18                          | 0.51                           |
|                       | Every 5% increase 30-60%| 0.98                          | 0.32                           |
|                       | Every 5% increase > 60% | 0.86                          | 0.48                           |
| 1-year cardiovascular readmission | Every 5% increase ≤ 30% | 0.10                          | 0.09                           |
|                       | Every 5% increase 30-60%| 0.94                          | 0.64                           |
|                       | Every 5% increase > 60% | 0.63                          | 0.18                           |
**Table S5:** 1-year cause-specific readmission by ICU utilization rate at discharging hospital

|                | Cumulative incidence rate | Risk-adjusted HR (95% CI) |
|----------------|---------------------------|---------------------------|
|                | Low ICU utilization       | Intermediate ICU utilization | High ICU utilization | Intermediate vs. low | High vs. low |
| MI             | 11.5%                     | 11.5%                     | 10.8%               | 1.01 (0.95-1.08)   | 0.94 (0.82-1.06) |
| Stroke         | 2.8%                      | 3.0%                      | 2.9%                | 1.10 (0.98-1.22)   | 1.03 (0.89-1.20) |
| Heart failure  | 28.6%                     | 30.1%                     | 27.9%               | 1.04 (0.99-1.08)   | 0.93 (0.87-1.00) |