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Does Hospital Admission/Observation for Chest Pain Improve Patient Outcomes After Emergency Department Evaluation for Suspected Acute Coronary Syndrome?

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Abstract

Background: Chest pain is the top reason for hospitalization/observation in the U.S., but it is unclear if this strategy improves patient outcomes.

Objective: The objective of this study was to compare 30-day outcomes for patients admitted versus discharged after a negative emergency department (ED) evaluation for suspected acute coronary syndrome.

Design: A retrospective, multi-site, cohort study of adult encounters with chest pain presenting to one of 13 Kaiser Permanente Southern California EDs between January 1, 2015 and December 1, 2017. Instrumental variable analysis was used to mitigate potential confounding by unobserved factors.

Patients: All adult patients presenting to an ED with chest pain, in whom an acute myocardial infarction was not diagnosed in the ED were included.

Main Measures: The primary outcome was 30-day acute myocardial infarction or all-cause mortality, and secondary outcomes included 30-day revascularization and major adverse cardiac events.

Key Results: 77,652 patient encounters were included in the study (n=11,026 admitted, 14.2%). 322 (0.4%) had an acute myocardial infarction (n=193, 0.2%) or death (n=137, 0.2%) within 30-days of ED visit (1.5% hospitalized versus 0.2% discharged). Very few (0.3%) patients underwent coronary revascularization within 30-days (0.7% hospitalized versus 0.2% discharged). Instrumental variable analysis found no adjusted differences in 30-day patient outcomes between the hospitalized cohort and those discharged (risk reduction 0.002, 95% CI -

0.002 to 0.007). Similarly, there were no differences in coronary revascularization (risk reduction 0.003, 95% CI -0.002 to 0.007).

Conclusion: Among ED patients with chest pain not diagnosed with an acute myocardial infarction, risk of major adverse cardiac events is quite low, and there does not appear to be any benefit in 30-day outcomes for those admitted or observed in the hospital compared to those discharged with outpatient follow-up.

INTRODUCTION

Cardiovascular disease remains the leading cause of worldwide morbidity and mortality[1], leading to substantial health care utilization. Chest pain, the most common presenting symptom for patients with acute coronary syndrome, results in millions of emergency department (ED) visits annually and is the top reason for hospitalization or observation.[2,3]

The ED acute coronary syndrome (ACS) evaluation includes cardiac biomarker testing, an electrocardiogram (ECG), and careful history taking and physical examination. Evaluation focuses on identifying acute myocardial infarction (AMI), is defined by rise and fall of cardiac biomarker (troponin) values in conjunction with clinical symptoms, ECG findings, or imaging evidence of myocardial injury.[4,5] However, there is substantial and unexplained variation in hospital admission rates for chest pain[6], and recent evidence raises doubts about patient benefits related to hospitalization[7] and the associated non-invasive cardiac testing.[8,9] Despite evidence supporting the accuracy of non-invasive imaging[10], there is need for studies designed to specifically evaluate any measurable short term benefit for patients hospitalized, as past studies have focused more on risks after admission and non-invasive testing, and been limited to administrative data only without troponin values and other relevant clinical information. Understanding the benefits of hospitalization among ED patients with chest pain without acute myocardial infarction among community hospitals accounting for relevant clinical variables will inform physician decision making and future health care policies.

The ideal study design to assess the benefits of hospitalization for patients with chest pain would be a randomized trial. However, this strategy poses ethical and feasibility challenges, and is most likely cost-prohibitive. Alternatively, instrumental variable (IV) analysis is an effective approach for comparative effectiveness and safety research.[11] IV methods attempt to control for hidden

confounding in observational data, and they may lead to robust inferences among health care interventions in non-randomized study designs.[12,13] Our study takes advantage of the comprehensive data inherent to an integrated health system to compare 30-day outcomes for patients admitted versus discharged after an ED evaluation for chest pain.

METHODS

A retrospective cohort study was conducted in the member population of Kaiser Permanente Southern California (KPSC), an integrated healthcare organization with over 7,600 physicians, 15 medical centers and 234 medical offices. KPSC provides comprehensive health care to over 4.6 million racially and socio-economically diverse members residing within seven counties of Southern California. Health care at KPSC is coordinated through region-wide electronic medical records (EMR) that capture detailed information about care provided to members at outpatient visits and during inpatient stays, as well as pharmacy, immunizations, imaging, and laboratory services received at KPSC-owned and contracting facilities. Our research database also includes administrative claims data for our members that capture any out of network clinical care and patient outcomes.

KPSC hospitals provide care to over 1 million ED patients per year (study sites ranging from ≈25,000 to 95,000 ED visits per year). Of these ED visits, approximately 80% are health plan members. All sites use the same troponin lab assay (Beckman Coulter Access AccuTnI+3) as well as a uniform 0.5 ng/ml threshold and a 0.04-0.5 ng/ml elevated risk cutoff.

The study was approved by the Institutional Review Board of KPSC.

Selection of Participants

We included all KPSC members aged 18 years or older with a visit for chest pain between 01/01/2015 to 12/01/2017 at 13 EDs operated by KPSC. To ensure complete comorbidity and outcomes capture, all included patients were required to have continuous health plan enrollment in the 12 months prior to and for at least 30 days post-discharge from their ED visit. ED encounters were included in the study if a valid troponin biomarker assay result was available for that encounter.

We excluded patients (Figure 1) if they (1) had acute myocardial infarction identified using ICD9/10 codes, during the ED encounter, (2) had an initial troponin level greater than 0.5 ng/mL, (3) had invalid ED discharge status (e.g., against medical advice) (4) were transferred from another hospital, (5) died in the ED, (6) were in hospice status, (7) had a documented "do not resuscitate" order in the EMR.

Measurements and Outcomes

The primary outcome was the composite risk of 30-day acute myocardial infarction (see ICD9/10 codes in e-supplement) or all-cause death from the time of the initial ED visit. Death data were obtained from KPSC administrative records, EMR as well as claims for out of network deaths. These data were supplemented with California state death files and Social Security Administration records for out-of-state deaths.

As our secondary outcome, we measured 30-day incidence of revascularization by percutaneous coronary intervention or coronary artery bypass grafting. We also measured 30-day incidence of acute myocardial infarction and death independently as secondary outcomes. Lastly, we defined major adverse cardiac event as the composite outcome of all-cause death, myocardial infarction, or revascularization within 30 days.

The 30-day time frame is consistent with ED acute coronary syndrome research guidelines as more extended time frames are unlikely to affect ED decision making.[14]

The exposure was hospital admission for management of acute coronary sydrome, defined as either an inpatient or under observation status. We compared the effect of hospitalization disposition to discharge to home disposition.

Covariates included patient demographic information and clinical history. Age, sex, race, and insurance type were obtained from the health plan's administrative records. Clinical data were obtained from the EMR. Comorbidities and cardiac risk factors were defined using laboratory values, diagnostic or procedure codes along with the Elixhauser index. The Elixhauser index[15,16] is a well validated comorbidity score, similar to the Charleson score, but more comprehensive. Body mass index (BMI) was measured from ED intake documentation or the most recently available visit, while smoking and family history of coronary artery disease/stroke were self-reported EMR fields. Those with a history of percutaneous coronary intervention or coronary artery bypass grafting were considered to have had prior coronary revascularization. Initial troponin level was dichotomized with a value below 0.04 ng/mL indicating a normal result and results between 0.04-0.49 ng/mL representing an elevated acute coronary syndrome risk. Lastly, using pharmacy prescription records, we identified patients on active antidiabetic, anticoagulants, anti-hyperlipidemia, and anti-hypertension treatment, in the 90-days prior to their ED encounter.

Analysis

When using an observational study design, there remains a possibility of bias because some patients receive the treatment (or exposure) due to unrecorded factors strongly related to their

148 prognosis. This bias creates a risk of confounding by indication. To mitigate this bias, we used
149 the potential outcomes framework associated with the Rubin causal model (RCM) to evaluate the
150 effect of hospitalization on death/acute myocardial infarction, revascularization and major
151 adverse cardiac event separately.[17] We employed the generalized method of moments based
152 residual inclusion instrumental variables (IV) techniques to relax the restrictive RCM assumption
153 of un-confoundedness.[18,19] The residuals were based on a binary probit model that was used for
154 the treatment choice (hospitalization vs. discharge to home) for the study cohort. GMM estimates
155 a system of equations simultaneously and unlike multistep estimators, also provides correct
156 standard errors for IV analysis in a single step.

157 We specified separate models for the binary outcomes associated with death, acute myocardial
158 infarction, coronary revascularization, and major adverse cardiovascular events. All models were
159 adjusted for age, sex, race, smoking, BMI, insurance type, self and family history of coronary
160 artery disease, initial troponin, antidiabetic medication, anticoagulant medication, anti-
161 hyperlipidemia medication, anti-hypertension medication, and Elixhauser comorbidities.

162 Based on prior research and previously validated methods[20], we chose apriori to evaluate (1) the
163 KPSC medical center's historical practice pattern for hospitalization and (2) ED arrival time
164 (categorized as 6am-3pm; 4pm-11pm and 12am-5am), as two excluded instruments for the IV
165 analysis, which we validated as part of our analysis.[8] We postulated that patient arrival to ED
166 during the late evening shift would make it more likely that the patient would be hospitalized as
167 compared to those arriving early in the day. Each medical center's practice pattern was
168 calculated as the percent of suspected acute coronary syndrome patients who were hospitalized,
169 in the one year prior to the ED date of each included cohort case with suspected acute coronary
170 syndrome. The medical center's practice pattern synthesizes consensus, experience and training

of the ED professional staff, medical center's protocol/policies and available infrastructure for hospitalization. The calculation of the medical center's practice pattern based on presenting patient's ED encounter date, made it dynamic and allowed capturing changes over time at the same medical center based on changes to any system or human capital factors (Supplementary Tables 1 & 2). Our final analysis was done using both of these instrumental variables.

We postulate that the time of ED arrival or population level medical center is unrelated to an individual patient's death or myocardial infarction outcomes, except through the exposure. Therefore, we used these instrumental variables as a surrogate marker for the decision to hospitalize the patient or not, as a method to adjust for unmeasured patient or clinical factors that we did not expect to be effected based on these IVs. The IV specification testing presented in supplemental Table 2 indicated that the two excluded instruments: 1. Medical Center Practice Pattern and 2. Time of ED arrival were a) strongly correlated to the treatment (i.e. Hospital admission); b) were not weak instruments; c) satisfy the order as well as rank condition; d) were not redundant and lastly were orthogonal to the outcome error and appropriately excluded from the outcome model since they only acted through the exposure of Hospitalization.

We report the Number Need to Treat (NNT) as the inverse of the adjusted Absolute Risk Reduction (ARR) where: ARR = (Absolute Risk of outcomes for patients not hospitalized, i.e., controls) – (Absolute Risk of outcomes for patients hospitalized, i.e., intervention).

In the sensitivity analysis, we analyzed the data using doubly robust inverse probability of treatment weighted and regression adjusted (IPWRA) models assuming the un-confoundedness requirement was not violated. All hypothesis tests were two-sided with an *a priori* type I error set at 5%. Stata/MP® version 15 software was used for data analysis (Stata Corp LLC, College Station TX).

RESULTS

Our study sample included 77,652 ED patient encounters with a chest pain diagnosis and troponin order eligible for analysis (Figure 1). 11,026 (14.2%) were admitted or observed in the hospital representing patients that were older, more likely to have a history of coronary artery disease, taking cardiac medications, and having more comorbidities compared to those patients not admitted (Table 1).

Overall, 322 (0.4%) patients experienced the primary adverse outcome (Death n=137, 0.2% or acute myocardial infarction n=193, 0.2%) within 30-days of the ED. Among these patients, 200 (0.3%) underwent coronary revascularization. All unadjusted adverse outcomes were lower among the group of patients not hospitalized demonstrating an absolute standardized mean difference of 0.13 for death or acute myocardial infarction (Table 2).

Primary instrumental variable analysis comparing adjusted risks between the patients hospitalized to those not hospitalized found no statistically significant risk reduction (RR) between groups for the primary outcome (0.002, 95% CI -0.002 to 0.007), or any of the individual outcomes (death <0.001, 95% CI -0.001 to 0.001; acute myocardial infarction 0.003, 95% CI -0.003 to 0.010; coronary revascularization <-0.001, 95% CI -0.002 to 0.001; major adverse cardiac event 0.003, 95% CI -0.002 to 0.007). We could not calculate the "number needed to treat" because there was no identifiable benefit to the hospitalization/observation group (Table 3).

Sensitivity analysis using IPWRA could not mitigate residual confounding and found small increase in risk for the hospitalization group for death/acute myocardial infarction (0.004, 95% CI 0.003-0.005, number needed to harm (NNH) = 250). There were also small increases in risk

for hospitalization among each individual outcome (death 0.001, 95% CI <0.001 to 0.002, NNH = 1000; acute myocardial infarction 0.003, 95% CI <0.001 to 0.002, NNH = 333; coronary revascularization 0.002, 95% CI 0.001 to 0.003, NNH = 500; major adverse cardiac event 0.004, 95% CI 0.003 to 0.006, NNH = 250). Though there was a trend toward harm in the IPWRA analysis, the very high NNH and very low rates of adverse outcomes make this result more mathematically significant and less clinically relevant.

DISCUSSION

Our primary study analysis evaluating ED patients with chest pain and suspected acute coronary syndrome found hospitalization was not associated with improved 30-day patient outcomes (death/acute myocardial infarction). Adjusting for patient characteristics, medication use and troponin lab values, we used medical center practice variations, and the time of patient presentation as instruments to estimate the risk reduction attributed to hospital-based care. However, we found no measurable benefit among a sample of over 77,000 patients with a low overall risk for major adverse cardiac event.

Weinstock et al, previously reported few adverse cardiac events among patients hospitalized after an ED visit.[7]. Our study confirms this work and adds to it beyond the hospitalization period. Our study has multiple strengths that add to the evidence describing the risks and the benefits of hospital admission for ED patients, after an acute myocardial infarction has been ruled out.[7] First, our patient population is large and represents community EDs of various sizes including all patients, not just those classified as low-risk.[21] Second, our EHR data set contains greater details that are not available in administrative data (i.e. Troponin lab values). These data allowed us to adjust for important clinical variables and identify a valid instrument for our primary analysis, which allowed us to account for unobserved confounding and measurement error. We also

239 performed an IWPRA sensitivity analysis that found slightly different results and demonstrated
240 small potential harm from hospital-based care.[22] Last, since the study sites are part of an
241 integrated health system, our results can inform the impact of hospital-based care on patient
242 outcomes, in a setting where fee-for-service incentives do not strongly influence disposition
243 decisions.

244 A strength of our results, of clinical relevance, is the lack of any identifiable difference in 30-day
245 AMI or mortality between the much higher risk hospitalized cohort and the much healthier
246 patient group discharged. You will note our results in Table 1, which highlight that the
247 hospitalized group was older, with much higher risk in nearly every category, including
248 comorbidities (CAD, prior stroke, prior PTCA/CABG, CHF, and overall Elixhauser score) and
249 had higher troponin values. Our sensitivity analysis with IPWRA was not able to adjust for
250 unobservable patient differences and indicated net harm at 30-days among the hospitalized
251 group. These results may even call into question the 30-day benefits of admitting any patients for
252 chest pain who have ruled out in the ED. It is possible these patients were already medically
253 optimized, as those hospitalized were much more likely to be prescribed anticoagulant, anti-
254 diabetic, anti-hypertensive and anti-hyperlipidemia medications, therefore obtained minimal
255 benefit from hospitalization.

256 The current clinical approach to ED patients with chest pain, or symptoms suspicious for acute
257 coronary syndrome, is highly conservative, resulting in over $3 billion in annual hospital
258 expenditures and vast variability among regions and systems.[6] Our findings confirm previous
259 preliminary reports which have failed to identify improvements in patient outcomes associated
260 with hospitalization after an ED evaluation has ruled out acute myocardial infarction.[7] In the
261 past, hospital admission may have been justifiable because it facilitated rapid non-invasive

cardiac stress testing; however, multiple studies now question the use of these diagnostic tests due to limited benefits patient outcomes, increased costs and potential harm.[23-25] Similarly, evidence continues to demonstrate that cardiac revascularization procedures may improve some anginal symptoms, but have questionable benefits in the prevention of AMI or patient death, specifically when compared to medical management.[26-28] In the absence of tangible benefits from hospital observation, non-invasive testing, or cardiac revascularization, policymakers and physicians must strongly question the rationale to routinely incur the costs and risks of inpatient management for most of these patients. It is in this context that our results were demonstrating no identifiable benefit for hospital care among ED patients with chest pain that should cause policymakers and physicians to reconsider current clinical recommendations.

LIMITATIONS

There are limitations to our study. Our observational study design is unable to definitively attribute causation of hospital care or non-hospital care to the patient outcomes of interest. However, our IV analysis has been a recommended approach for this type of research and is a validated strategy to account for unmeasured confounders.[11,13,19] Additionally, results do not apply to acute myocardial infarction cases presenting without chest pain, which can be seen in older patients, women, and people with diabetes or heart failure. Also, the patient population is geographically limited to Southern California and belongs to a single integrated healthcare system, which may limit practice pattern variation observed across the U.S. and in fee-for-service systems. Our study does not account for the types of diagnostic tests or interventions affiliated with hospital care; therefore, our study results cannot account for the variations in care that may have been delivered among patients hospitalized. During our study period, the EDs in our health system did not have high-sensitivity troponin testing available, therefore our results

may differ among those hospitals with differing labs used in the evaluation of patients with chest pain. Lastly, our major adverse cardiac event outcome could include patients receiving elective revascularization, instead of emergent revascularization associated with acute coronary syndrome. We attempted to mitigate this possibility by limiting our outcomes to within 30-days of the ED encounter for chest pain. In conclusion, among ED encounters with patients reporting chest pain, but no acute myocardial infarction, there does not appear to be a benefit in 30-day outcomes for those hospitalized/observed compared to those discharged with outpatient follow-up.

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CONFLICTS OF INTEREST

Authors AS, AK, AB, RR, ML, MF,YW, ES, CZ, and SP have no conflicts of interest to report. Authors BS, SG, and PT were consultants for Medtronic, Creavo Industries, and Roche, respectively.

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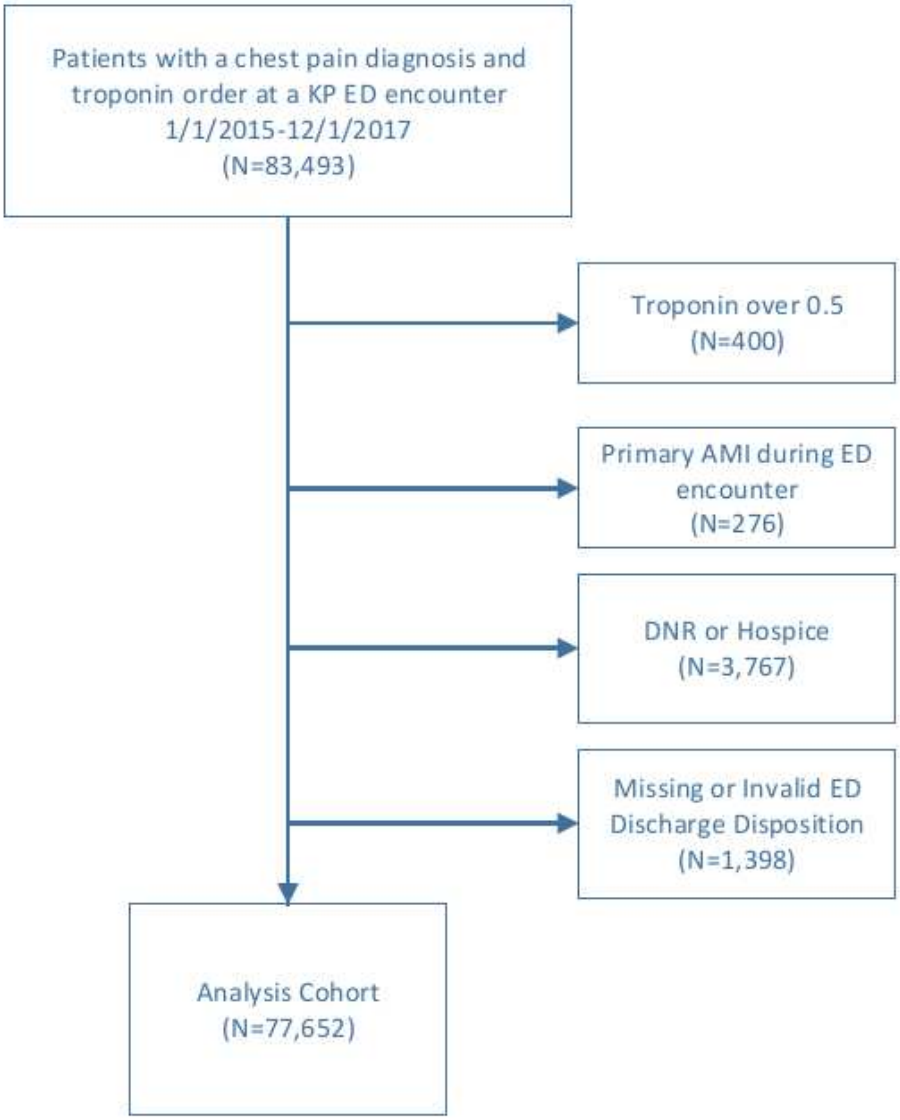
Figure 1: Describes the patients included in the sample, those excluded based on study criteria and the cohort eligible for analysis in the final study cohort.



385 **Table 1.** Descriptive statistics of the emergency department patients with chest pain evaluated
386 for suspected ACS included in the study cohort, also stratified by those discharged and
387 hospitalized or observed.

	Total Cohort	**Discharged**	**Hospitalized**	**Absolute Standardized Mean Differences**
	N= 77,652	**N= 66,626 (86%)**	**N=11,026 (14%)**	
Age – Mean (SD)	57.1 (16.29)	55.5 (16.21)	66.3 (13.49)	0.72
Age 65 and Above*	26955 (34.7%)	20506 (30.8%)	6449 (58.5%)	0.58
Female*	44897 (57.8%)	39399 (59.1%)	5498 (49.9%)	0.18
White*	40021 (51.5%)	33760 (50.7%)	6261 (56.8%)	0.12
Active/Passive Smoker	5474 (7%)	4741 (7.1%)	733 (6.6%)	0.03
BMI – Mean (SD)	30.0 (6.88)	30.1 (6.88)	29.6 (6.87)	0.08
Overweight or Obese	59141 (76.2%)	50902 (76.4%)	8239 (74.7%)	0.04
Troponin Between 0.04-0.5*	2787 (3.6%)	1175 (1.8%)	1612 (14.6%)	0.47
Coronary Artery Disease (CAD)*	13689 (17.6%)	9174 (13.8%)	4515 (40.9%)	0.63
Stroke*	1959 (2.5%)	1388 (2.1%)	571 (5.2%)	0.16
PTCA or CABG in year prior*	993 (1.3%)	622 (0.9%)	371 (3.4%)	0.17
Family history: CAD	25884 (33.3%)	21874 (32.8%)	4010 (36.4%)	0.07
Family history: Stroke	14222 (18.3%)	12337 (18.5%)	1885 (17.1%)	0.03
Antidiabetic Medications*	12249 (15.8%)	9385 (14.1%)	2864 (26%)	0.30
Anticoagulant Medications*	7329 (9.4%)	5158 (7.7%)	2171 (19.7%)	0.35
Anti-Hyperlipidemia Medications*	23510 (30.3%)	18244 (27.4%)	5266 (47.8%)	0.43
Anti-Hypertension Medications*	33042 (42.6%)	26053 (39.1%)	6989 (63.4%)	0.50
Elixhauser*	3.6 (2.98)	3.3 (2.82)	5.3 (3.30)	0.66

Congestive Heart Failure*	5846 (7.5%)	3843 (5.8%)	2003 (18.2%)	0.38
Cardiac Arrhythmia*	12369 (15.9%)	9293 (13.9%)	3076 (27.9%)	0.34
Valvular Disease*	4118 (5.3%)	2975 (4.5%)	1143 (10.4%)	0.23
Pulmonary Circulation Disorders*	2448 (3.2%)	1831 (2.7%)	617 (5.6%)	0.15
Peripheral Vascular Disorders*	19421 (25%)	14418 (21.6%)	5003 (45.4%)	0.52
Hypertension Uncomplicated*	40003 (51.5%)	31790 (47.7%)	8213 (74.5%)	0.57
Hypertension Complicated*	6844 (8.8%)	4721 (7.1%)	2123 (19.3%)	0.36
Paralysis	759 (1%)	589 (0.9%)	170 (1.5%)	0.06
Other Neurological Disorders*	2908 (3.7%)	2253 (3.4%)	655 (5.9%)	0.12
Chronic Pulmonary Disease*	18200 (23.4%)	15147 (22.7%)	3053 (27.7%)	0.12
Diabetes Uncomplicated*	19190 (24.7%)	14808 (22.2%)	4382 (39.7%)	0.38
Diabetes Complicated*	16009 (20.6%)	11993 (18%)	4016 (36.4%)	0.42
Hypothyroidism*	10262 (13.2%)	8449 (12.7%)	1813 (16.4%)	0.11
Renal Failure*	11188 (14.4%)	7977 (12%)	3211 (29.1%)	0.43
Liver Disease	6926 (8.9%)	5800 (8.7%)	1126 (10.2%)	0.06
Peptic Ulcer Disease excluding bleeding	957 (1.2%)	757 (1.1%)	200 (1.8%)	0.06
Metastatic Cancer	1324 (1.7%)	1079 (1.6%)	245 (2.2%)	0.04
Solid Tumor without Metastasis*	5107 (6.6%)	4106 (6.2%)	1001 (9.1%)	0.11
Rheumatoid Arthritis/collagen	3768 (4.9%)	3088 (4.6%)	680 (6.2%)	0.07
Coagulopathy*	3291 (4.2%)	2381 (3.6%)	910 (8.3%)	0.20
Weight Loss*	3757 (4.8%)	2706 (4.1%)	1051 (9.5%)	0.22
Fluid and Electrolyte Disorders*	10708 (13.8%)	8009 (12%)	2699 (24.5%)	0.32
Blood Loss Anemia*	1101 (1.4%)	794 (1.2%)	307 (2.8%)	0.12
Deficiency Anemia*	5816 (7.5%)	4686 (7%)	1130 (10.2%)	0.11
Alcohol Abuse	3195 (4.1%)	2651 (4%)	544 (4.9%)	0.04
Drug Abuse	5994 (7.7%)	5155 (7.7%)	839 (7.6%)	0.02
Psychoses	1305 (1.7%)	1089 (1.6%)	216 (2%)	0.02
Depression	21487 (27.7%)	18258 (27.4%)	3229 (29.3%)	0.04

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389 *absolute standardized mean difference greater than 0·1

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Table 2: Descriptive statistics (unadjusted) of the 30-day adverse outcomes of our study cohort. Adverse outcomes are stratified by those discharged and hospitalized after an emergency department visit for chest pain. Acute myocardial infarction (AMI) or death were constructed to be mutually exclusive as each has important clinical meaning. Eight patients had both an AMI and died, explaining the total cohort (n=322) used in the primary analysis.

	Total Cohort	**Discharged**	**Hospitalized**	**Absolute Standardized Mean Differences**
	N= 77,652	**N= 66,626 (86%)**	**N= 11,026 (14%)**	
AMI or Death within 30 days*	322 (0.4%)	158 (0.2%)	164 (1.5%)	0.13
Death within 30 days	137 (0.2%)	70 (0.1%)	67 (0.6%)	0.09
AMI within 30 days	193 (0.2%)	94 (0.1%)	99 (0.9%)	0.09
Coronary Revascularization within 30 days	200 (0.3%)	124 (0.2%)	76 (0.7%)	0.07
MACE within 30 days*	331 (0.4%)	163 (0.2%)	168 (1.5%)	0.13
*absolute standardized mean difference greater than 0·1				

Table 3: Results from the primary instrumental variable analysis reporting adjusted risks of adverse events among patients hospitalized and discharged after ED evaluation for chest pain. Risk reduction reports the difference between hospitalized (treated) and discharged (control) patients for comparisons among 30-day patient outcomes.

Outcome	**Adjusted Risk**		**Risk Reduction (RR)**	**Number Needed to Treat (NNT)**
	Not Hospitalized (Control) (N= 62,876) Mean (Std Error)	**Hospitalized (Treated)** (N= 16,164) Mean (Std Error)	**Hospitalized Adjusted Risk- Control Adjusted Risk** Mean*# (95% CI)	**1/Absolute Risk Reduction**
Death/AMI	0.003 (0.001)	0.006 (0.002)	0.002 (-0.002 to 0.007)	N/A^
Death	0.001 (<0.001)	0.001 (0.001)	<0.001 (-0.001 to 0.001)	N/A^
Acute MI	0.002 (<0.001)	0.005 (0.003)	0.003 (-0.003 to 0.010)	N/A^
Coronary Revascularization	0.002 (<0.001)	0.002 (0.001)	<-0.001 (-0.002 to 0.001)	N/A^
MACE	0.003 (0.001)	0.006 (0.002)	0.003 (-0.002 to 0.007)	N/A^

#Bold Font indicate statistically significant differences

^ Difference in event rates are not statistically significant at $\alpha=0{\cdot}05$ and the 95% CI contains zero

*All models adjusted for age, sex, race, smoking, BMI, insurance type, self and family history of CVD, initial troponin, antidiabetic medication, anticoagulant medication, anti-hyperlipidemia medication, anti-hypertension medication and Elixhauser comorbidities

Table 4: Results from the sensitivity analysis using inverse probability weighted modeling to report adjusted risks of adverse events among patients hospitalized and discharged after ED evaluation for chest pain. Risk reduction reports the difference between hospitalized (treated) and discharged (control) patients for comparisons among 30-day patient outcomes.

Outcome	**Adjusted Risk**		**Risk Reduction (RR)**	**Number Needed to Harm (NNH)**
	Not Hospitalized (Control) (N= 62,876) Mean (Std Error)	**Hospitalized (Treated)** (N= 16,164) Mean (Std Error)	**Hospitalized Adjusted Risk- Control Adjusted Risk** Mean[#] (95% CI)	**1/Absolute Risk Increase**
Death/AMI*	0.003 (<0.001)	0.007 (0.001)	**0.004 (0.003 to 0.005)**	1/0·004 = **250**
Death*	0.001 (<0.001)	0.003 (<0.001)	**0.001 (<0.001 to 0.002)**	1/0·001 = **1000**
Acute MI*	0.002 (<0.001)	0.004 (0.001)	**0.003 (0.001 to 0.004)**	1/0·003 = **333**
Coronary Revascularization*	0.002 (<0.001)	0.004 (0.001)	**0.002 (0.001 to 0.003)**	1/0·002 = **500**
MACE*	0.003 (<0.001)	0.007 (0.001)	**0.004 (0.003 to 0.006)**	1/0·004 = **250**

#Bold Font indicate statistically significant differences

*Doubly robust inverse probability weighting model models with regression adjustment for age, sex, race, smoking, insurance type, BMI, self and family history of CVD, initial troponin, antidiabetic medication, anticoagulant medication, anti-hyperlipidemia medication, anti-hypertension medication and Elixhauser comorbidities