ORIGINAL ARTICLE

Long-term mortality following interhospital transfer for acute myocardial infarction

Isuru Ranasinghe,[1,2] Federica Barzi,[2,3] David Brieger,[2,4] Martin Gallagher[2,3,4]

▶ Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/heartjnl-2014-306966).

[1]The University of Adelaide, Adelaide, Australia
[2]The George Institute for Global Health, Sydney, Australia
[3]University of Sydney, Sydney, Australia
[4]Concord Repatriation & General Hospital, Sydney, Australia

Correspondence to
Dr Isuru Ranasinghe, Discipline of Medicine, The Queen Elizabeth Hospital, University of Adelaide, 28 Woodville Road, Woodville South, Adelaide, SA 5011, Australia; isuru.ranasinghe@adelaide.edu.au

Received 13 October 2014
Revised 24 January 2015
Accepted 1 February 2015
Published Online First 3 March 2015

To cite: Ranasinghe I, Barzi F, Brieger D, *et al*. *Heart* 2015;**101**:1032–1040.

ABSTRACT

Background Interhospital transfer of patients admitted with an acute myocardial infarction for specialised care is common and costly. However, the long-term mortality of transferred patients compared with patients solely treated at the presenting hospital has not been evaluated. Here, we assess the long-term mortality of patients who undergo interhospital transfer during their acute myocardial infarction admission.

Methods We evaluated 40 482 patients with a ICD10-AM diagnosis of acute myocardial infarction admitted to hospitals in New South Wales, Australia, from 2004 to 2008, of whom 10 107 (25%) were transferred. We compared in-hospital and mortality up to 5.5 years postdischarge among transferred and non-transferred patients. We created a 1:1 propensity score matched cohort (n=16 854; 8427 per group) to account for selection bias.

Results In the matched cohort, transferred patients were more likely to undergo revascularisation (55.6% vs 13.7%, RR 4.05; 95% CI 3.83 to 4.29) and had lower mortality at 30 days (3.5% vs 5.7%, HR 0.60; 95% CI 0.52 to 0.70), 1 year (7.5% vs 12.6%, HR 0.58; 95% CI 0.52 to 0.64) and at the end of follow-up (15.3% vs 22.5%, HR 0.65; 95% CI 0.61 to 0.70) than patients treated in presenting hospitals. With the exception of transfers originating from revascularisation capable hospitals, these findings were consistent across a range of subgroups, including patients of all ages, ST-elevation myocardial infarction and non ST-elevation myocardial infarction patients, and transfers originating from hospitals in regional and major city areas. Sensitivity analyses showed that these findings are unlikely to be due to survival bias or to confounding by unmeasured variables.

Conclusions Patients hospitalised for an acute myocardial infarction who are transferred to one or more hospitals for specialised care have higher rates of coronary revascularisation and experience lower long-term mortality.

INTRODUCTION

Interhospital transfer (IHT) of patients hospitalised for acute myocardial infarction (AMI) is common in contemporary AMI care. Indeed, 28%–45% of patients hospitalised for AMI are now transferred to another hospital during their AMI event[1–4] with practice driven by clinical guidelines[5 6] that suggest patients with AMI benefit from highly specialised services and interventions, most notably early coronary angiography and revascularisation by percutaneous coronary intervention (PCI). These specialised services are not universally available among hospitals, and IHT is the primary means for accessing these services for many hospitalised patients with AMI.

Recent observations, however, have questioned whether IHT leads to improved patient outcomes. Prior studies have shown that transferred AMI patients have a lower risk profile compared with non-transferred patients.[2 3 7] This observation has raised concerns that patients who undergo IHT may not necessarily have improved outcomes from such intervention because high risk patients generally derive greater benefit from specialized care such as PCI.[5 6] However, the absolute risk profile and outcomes of transferred patients have not been previously described. Furthermore, a recent US study showed no difference in hospital level, risk-standardised 30-day mortality between hospitals with a high versus low transfer rate for patients with AMI.[8] While this was a hospital-level rather than a patient-level analysis, it nevertheless suggested that transfer was not beneficial as an intervention in AMI care to improve patient outcomes.

Existing observational studies of transferred patients with AMI have limited ability to address these concerns. Although many studies have evaluated emergent transfer of ST-elevation myocardial infarction (STEMI) patients, relatively few have evaluated transfer of admitted patients, most of whom have a non-ST-elevation myocardial infarction (NSTEMI), and who are further along in their illness. The few studies that have evaluated admitted patients report lower 30-day mortality among transferred patients, yet these studies are often from selected populations and rarely report risk-adjusted outcomes.[1 2 7] Most importantly, prior studies have not reported long-term patient mortality.

Accordingly, we assessed whether hospitalised patients with AMI who are transferred for specialised care during their AMI event have lower long-term mortality compared with similar patients solely treated at the presenting hospital using data from a large population cohort from Australia. We specifically sought to assess patient mortality based on the risk profile of transferred patients and the consistency of findings among various population subgroups.

METHOD

Study population

The study population was derived from New South Wales (NSW), the most populous state of Australia. NSW has 7.24 million residents who are covered by national health insurance, with a proportion having supplementary private insurance.

All hospitalisations and deaths are recorded within the NSW Admitted Patient Data Collection (APDC) and the linked Register of Births, Deaths and Marriages, respectively.[9] Diagnostic and procedural coding within the APDC is based on the International Classification of Disease 10 Australian Modification (ICD10-AM). Reported coding accuracy of Australian hospital admissions data sets is 85% with the coding of cardiac diagnoses having a high correlation with chart extracted data.[10]

We included all patients with a principal diagnosis of AMI as defined by ICD10-AM codes I21.0-I21.3 (STEMI) and I21.4 (NSTEMI) with a hospitalisation between 1 July 2004 and 30 June 2008. For patients with multiple AMI admissions during this study period, only the first admission contributed to the analysis. We excluded patients with a length of stay ≤1 day unless the patient died or was transferred to another hospital as these admissions were unlikely to represent an AMI admission. Patients were stratified into those who were solely treated at their presenting hospital and those who required IHT to one or more acute care hospitals. We excluded episodes of transfers to or from non-acute care facilities such as aged-care facilities.

Outcome measure

The primary outcome was all cause mortality assessed in-hospital and at 30 days, 1 year and long term. Long-term mortality was defined as any death occurring during the overall follow-up period from the index admission. Vital status was confirmed up to 1 January 2010 for all patients providing a follow-up period of up to 5.5 years (median 3.5 years). The secondary outcomes were in-hospital receipt of coronary angiography, PCI or coronary artery bypass grafting (CABG) at any time during the AMI event.

Statistical analysis

Data are summarised as frequencies and percentages for categorical variables. Continuous variables are presented as mean±SD or median and IQR. The χ^2 statistic and Student's t test were used to compare those who did and did not undergo IHT as appropriate.

Propensity score analysis

We used propensity matching to account for differences in baseline characteristics arising from non-random assignment of transfer status. We developed a propensity score, indicating the conditional probability that any individual patient would undergo IHT, using a non-parsimonious logistic regression model. Patient demographic characteristics, diagnosis (STEMI/NSTEMI), cardiac history, comorbidities and acute complications were included in the model. Cardiac history and comorbidities were derived from the secondary diagnosis and procedure codes from the index hospitalisation and the principal and secondary codes from all hospitalisations in the preceding 12 months. These ICD10-AM codes were grouped into condition categories used in prior studies[11–13] after cross-walking from ICD9 to ICD10-AM. Acute complications were derived solely from the secondary diagnosis and procedure codes from the index hospitalisation. Additionally, presentation hospital characteristics including hospital region, revascularisation (PCI and CABG) capability, and hospital type were included in the propensity score model. Selected variables from the propensity score model are displayed in table 1 (complete list of included variables are provided in the online supplementary appendix).

Transferred patients were then matched 1:1 without replacement to the closest non-transferred patients based on the propensity score using published algorithms[14] to derive a propensity score matched (PSM) cohort. Significance testing in the PSM cohort was performed using McNemar's test for categorical variables and paired t test for continuous variables. Non time-to-event outcomes were compared using relative risk (RR) estimate with 95% CI for the PSM cohort derived as described by Agresti *et al*[15] Unadjusted event free survival curves were generated using Kaplan–Meier estimates and compared using the log-rank test. Adjusted survival curves were estimated using a marginal survival model with robust SEs. All time-to-event outcomes (30 days, 1 year and long-term mortality) were reported as HRs and 95% CI.

Subgroup analysis

To assess patient outcomes based on the patient risk profile at presentation, we assessed outcomes by patient's predicted risk at presentation. Patient's predicted risk strata were derived from a logistic regression analysis using baseline characteristics to predict 30-day mortality using published methods[12] and stratifying patients to quartiles of risk.

Due to the potential heterogeneity of transferred patients, we evaluated the outcomes in prespecified subgroups. Specifically, we performed prespecified subgroup analyses of mortality by age, gender, diagnosis, presence of private medical insurance, hospital revascularisation capacity and the region of the presenting hospital. For example, we compared the outcomes of patients undergoing IHT from non-revascularisation capable hospitals and from revascularisation capable hospitals because reasons for IHTs occurring in the former situation (primarily for coronary angiography and revascularisation) may be distinctly different from transfers occurring from revascularisation capable hospitals.

Sensitivity analysis

Sensitivity analyses were performed to evaluate the robustness of the parameter estimates. Since survival bias resulting from the death of patients without the opportunity for transfer is a possible confounder, we repeated the analysis excluding patients who died in hospital. Since clinical variables that may influence IHT such as pathology results and clinical examination findings are not recorded in the APDC, a sensitivity analysis was conducted to explore the effects of potential unmeasured confounders using published methods.[16] Lastly, to derive an estimate the effect of transfer status on mortality using data from the entire cohort, we performed a propensity analysis using stabilised inverse probability treatment weights.[17] A p value of <0.05 was used as a cut-off for statistical significance. All analyses were performed using SAS V.9.2 (SAS Institute, Cary, North Carolina, USA).

The NSW Population Health Research Ethics Committee provided ethical approval for the study.

RESULTS

Characteristics of the overall study cohort

The final study cohort consisted of 40 482 patients from 161 hospitals that met the study inclusion and exclusion criteria (figure 1 and table 1). IHT to one or more acute hospitals occurred for 10 107 (25.0%) patients while 30 375 (75.0%) patients received care solely at the presenting hospital. Overall, transferred patients were younger and more likely to be male, had private health insurance, and had a diagnosis of STEMI. Transferred patients also had fewer cardiovascular risk factors, comorbidities, and acute complications at presentation (all p values <0.05 with the exception of prior CABG).

Table 1 Selected patient characteristics at presentation*

	Overall cohort			Propensity score matched (PSM) cohort		
	Transfer N=10 107	Non-transfer N=30 375	p Value	Transfer N=8427	Non-transfer N=8427	p Value
Age (mean± SD)	65.1±12.9	70.8±14.1	<0.01	66.9±12.5	67.3±14.6	0.06
% Male	7129 (70.5)	18 809 (61.9)	<0.01	5684 (67.5)	5634 (66.9)	0.41
Private health insurance	2599 (25.7)	6406 (21.1)	<0.01	1969 (23.4)	1995 (23.7)	0.64
Principal diagnosis						
STEMI	4175 (41.3)	10 015 (33.0)	<0.01	3124 (37.1)	3037 (36.0)	0.16
NSTEMI	5932 (58.7)	20 360 (67.0)		5303 (62.9)	5390 (64.0)	
Cardiovascular history†						
PCI	100 (1.0)	388 (1.3)	0.02	91 (1.1)	76 (0.9)	0.24
CABG	14 (0.1)	71 (0.2)	0.07	13 (0.2)	15 (0.2)	0.71
Heart failure	1026 (10.2)	6379 (21.0)	<0.01	239 (2.8)	267 (3.2)	0.21
AMI	1378 (13.6)	4626 (15.2)	<0.01	119 (1.4)	145 (1.7)	0.11
Unstable angina	2044 (20.2)	7374 (24.3)	<0.01	394 (4.7)	427 (5.1)	0.24
Chronic atherosclerosis	5776 (57.2)	22 254 (73.3)	<0.01	3216 (38.2)	3140 (37.3)	0.23
Valvular heart disease	439 (4.34)	2752 (9.06)	<0.01	263 (3.1)	324 (3.8)	0.01
Comorbidities†						
Hypertension	6027 (59.6)	20 013 (65.9)	<0.01	4412 (52.4)	4444 (52.7)	0.62
Stroke	183 (0.5)	850 (2.80)	<0.01	38 (0.5)	38 (0.5)	1.00
Cerebrovascular disease	255 (2.5)	1211 (4.0)	<0.01	75 (0.9)	76 (0.9)	0.94
Renal failure	693 (6.9)	3877 (12.8)	<0.01	149 (1.8)	153 (1.8)	0.82
Chronic obstructive airway disease	666 (6.6)	3409 (11.2)	<0.01	439 (5.2)	449 (5.3)	0.73
Pneumonia	271 (2.7)	1596 (5.3)	<0.01	75 (0.9)	81 (1.0)	0.63
Diabetes	1706 (16.9)	6328 (20.8)	<0.01	1134 (13.5)	1117 (13.3)	0.70
Dementia	207 (2.1)	2430 (8.0)	<0.01	86 (1.0)	111 (1.3)	0.07
Hemiplegia, paraplegia, paralysis, and functional disability	474 (4.7)	2417 (8.0)	<0.01	153 (1.8)	169 (2.0)	0.37
Peripheral vascular disease	789 (7.8)	3342 (11.0)	<0.01	212 (2.5)	228 (2.7)	0.44
Metastatic cancer	214 (2.1)	1025 (3.4)	<0.01	58 (0.7)	71 (0.8)	0.25
Major psychiatric disorder	88 (0.9)	398 (1.3)	<0.01	45 (0.5)	45 (0.5)	1.00
Chronic liver disease	84 (0.8)	349 (1.2)	<0.01	43 (0.5)	42 (0.5)	0.91
Acute complications						
Mechanical complication of AMI	8 (0.1)	61 (0.2)	0.01	8 (0.1)	9 (0.1)	0.81
Cardiogenic shock	74 (0.7)	611 (2.0)	<0.01	71 (0.8)	76 (0.9)	0.68
Cardiac arrest	138 (1.4)	800 (2.6)	<0.01	124 (1.5)	116 (1.4)	0.60
Ventricular arrhythmia (VT/VF)	234 (2.3)	976 (3.2)	<0.01	194 (2.3)	197 (2.3)	0.88
Acute renal failure	144 (1.4)	1658 (5.5)	<0.01	143 (1.7)	154 (1.8)	0.52
Ischaemic stroke	10 (0.1)	192 (0.6)	<0.01	10 (0.1)	10 (0.1)	1.00
Major bleeding	157 (1.6)	1318 (4.3)	<0.01	156 (1.9)	168 (2.0)	0.50
Heart failure	739 (7.3)	5439 (17.9)	<0.01	731 (8.7)	736 (8.7)	0.89
Presenting hospital characteristics						
Hospital region						
Major city area	6746 (66.8)	23 934 (78.8)	<0.0001	5459 (64.8)	5489 (65.1)	0.63
Regional hospital	3361 (33.3)	6441 (21.2)	<0.0001	2968 (35.2)	2938 (35.9)	
Hospital type						
Tertiary referral hospital	5783 (57.2)	21 539 (70.9)	<0.0001	4946 (58.7)	4953 (58.8)	0.32
Large hospital	2799 (27.7)	4235 (14.5)		2115 (25.1)	2171 (25.8)	
Medium hospital	826 (8.2)	1970 (6.5)		784 (9.3)	735 (8.7)	
Small acute hospital	340 (3.4)	373 (1.2)		229 (2.7)	248 (0.9)	
Private hospital	359 (3.6)	2258 (7.4)		353 (4.2)	320 (3.2)	
Revascularisation (PCI±CABG) Capable Hospital	2269 (22.5)	17 966 (59.2)	<0.01	2260 (26.8)	2181 (25.9)	0.17

*Only selected baseline characteristics are presented. Refer to the online supplementary appendix for detail description of all variables included.
†Cardiovascular history and comorbidities as recorded during index admission or during any admissions occurring in the 12 months prior to index hospitalisation. PCI and CABG are recorded only at the time of the procedure. On subsequent admissions the underlying disease process (ie, coronary disease) is typically recorded (depicted in this table under chronic atherosclerosis).
AMI, acute myocardial infarction; CABG, coronary artery bypass grafting; NSTEMI, non-ST elevation myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction; VF, ventricular fibrillation; VT, ventricular tachycardia.

Transferred patients were more likely to present to hospitals in regional and remote areas and to a hospital without revascularisation capability. The first transfer mainly occurred to hospitals located in major cities (92.0%) with revascularisation capabilities (94.3%) and these were mainly public principal referral (64.9%) or private (32.8%) hospitals.

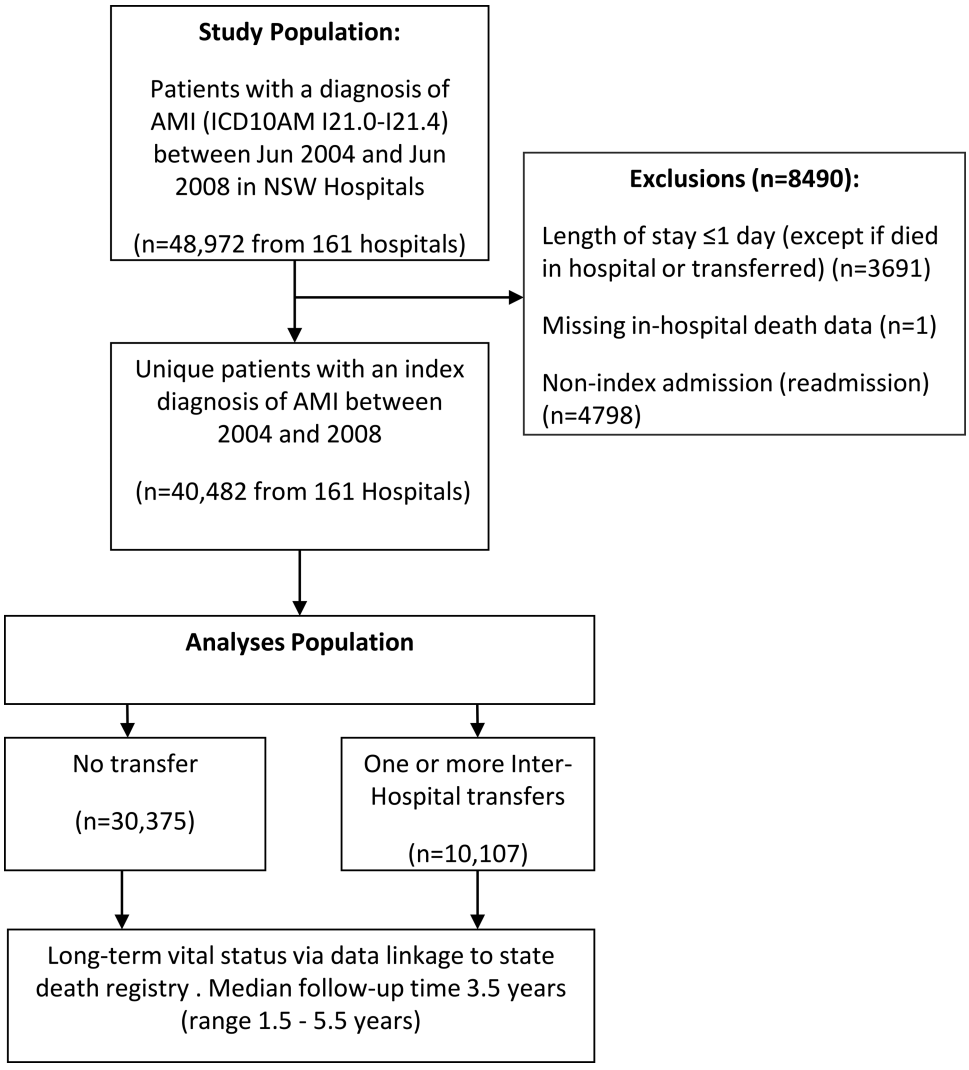


Figure 1 Patient selection flow diagram. Abbreviations are as described within the manuscript.

PSM cohort

A propensity score model with a good discriminatory capacity (c statistic 0.79) was derived using 72 measured baseline variables. The propensity score distributions for transferred and non-transferred patients showed good overlap (see online supplementary appendix figure 1). Based on 1:1 matching, 8427 matched pairs were derived (n=16 854). Covariate balance was achieved post matching as shown by a lack of a difference between groups for 71/72 variables (all $p>0.05$ except valvular heart disease, see table 1) and a reduction in the absolute standardised difference to negligible levels (median standardised difference at baseline of 8.31 (IQR 4.2–16.0) vs 0.74 (IQR 0.28–1.42) postmatching, $p<0.01$).

Outcomes

Coronary angiography and revascularisation

Overall, an invasive cardiac procedure (coronary angiography, PCI or CABG) was performed in 23 202 (57%) of patients with 13 805 (34%) undergoing revascularisation (PCI or CABG) during their AMI event. An invasive cardiac procedure was performed in 90% of transferred patients. Once matched for baseline characteristics, transferred patients were more likely to receive a cardiac procedure (PSM 89.2% vs 30.4%, RR 2.93; 95% CI 2.84 to 3.04) and in-hospital revascularisation (PSM 55.6% vs 13.7%, RR 4.05; 95% CI 3.83 to 4.29) compared with non-transferred patients (table 2).

All-cause mortality

In the overall cohort, 10 759 (26.6%) patients had died at the end of the follow-up period with a lower crude mortality rate among transferred patients (table 2, figure 2). Once PSM for baseline patient characteristics, transferred patients had lower in-hospital mortality (PSM 2.9% vs 4.2%, RR 0.67; 95% CI 0.57 to 0.79), 30-day mortality (PSM 3.5% vs 5.7%, HR 0.60; 95% CI 0.52 to 0.70), 1-year mortality (PSM 7.5% vs 12.6%, HR 0.58; 95% CI 0.52 to 0.64) and long-term mortality (PSM 15.3% vs 22.5%, HR 0.65; 95% CI 0.61 to 0.70, figure 3).

The 30-day and long-term mortality benefit of IHT was reduced, but remained significant following adjustment for receipt of in-hospital revascularisation in the PSM cohort (adjusted PSM HR for 30-day mortality 0.81; 95% CI 0.70 to 0.95, adjusted PSM HR for long-term mortality 0.89; 95% CI 0.83 to 0.96, figure 4).

Subgroup analyses

Stratifying patients in the PSM cohort into risk strata, based on predicted mortality at presentation, appropriately stratified patients into quartiles of *actual* 30-day and long-term mortality

Table 2 Patient outcomes

	Overall cohort			Propensity score matched (PSM) cohort		
	Transfer	Non-transfer	Point estimate* (95% CI)	Transfer	Non-transfer	Point estimate* (95% CI)
Revascularisation						
In-hospital invasive procedure (Cath, PCI or CABG)	9100 (90.0)	14 102 (46.4)	1.94 (1.91 to 1.97)	7517 (89.2)	2562 (30.4)	2.93 (2.84 to 3.04)
In-hospital revascularisation (PCI and/or CABG) only	5743 (56.8)	8062 (26.5)	2.14 (2.09 to 2.20)	4689 (55.6)	1158 (13.7)	4.05 (3.83 to 4.29)
Mortality						
In-hospital	261 (2.6)	2105 (6.9)	0.37 (0.33 to 0.42)	240 (2.9)	357 (4.2)	0.67 (0.57 to 0.79)
30 days	316 (3.1)	2683 (8.8)	0.35 (0.31 to 0.40)	292 (3.5)	481 (5.7)	0.60 (0.52 to 0.70)
1 year	671 (6.6)	5592 (18.4)	0.34 (0.31 to 0.37)	631 (7.5)	1064 (12.6)	0.58 (0.52 to 0.64)
Long term†	1358 (13.4)	9401 (31.0)	0.40 (0.38 to 0.42)	1285 (15.3)	1894 (22.5)	0.65 (0.61 to 0.70)

*Point estimate shown are relative risk (RR) for revascularisation and in-hospital mortality. Point estimate shown for 30-day, 1-year and long-term mortality are HRs. In both cases the non-transfer group is referent group.
†Median follow-up time of 3.5 years (min 1.5 years, max 5.5 years).
Cath, coronary angiography; CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention.

(table 3). Our results show most transferred patients (75% or top 3 quartiles of risk) have an absolute risk profile indicative of moderate-to-high patient risk as indicated by an actual mortality within quartiles ≥1.3% at 30-days and ≥8.7% at the end of follow-up. Within each risk strata, transferred patients also had lower mortality compared with patients treated solely at the presenting hospital.

Further subgroup analysis showed that transferred patients had lower 30-day and 1-year mortality in all subgroups except in patients transferred from revascularisation capable hospitals where IHT was not associated with a lower mortality (p for interaction <0.001, figure 5 and see online supplementary appendix figure 2). Patients aged ≥65 years may have a greater long-term benefit from IHT as indicated by weak effect modification (p for interaction 0.028). Subgroup analysis conducted by stratifying the overall cohort by the type of AMI (STEMI vs NSTEMI) and performing propensity score matching within each strata to derive a matched cohort for STEMI and NSTEMI respectively yielded results that were similar to the overall analyses (see online supplementary appendix).

Sensitivity analyses

The lower mortality among transferred patients persisted with the exclusion of in-hospital deaths (30-day mortality HR 0.41;

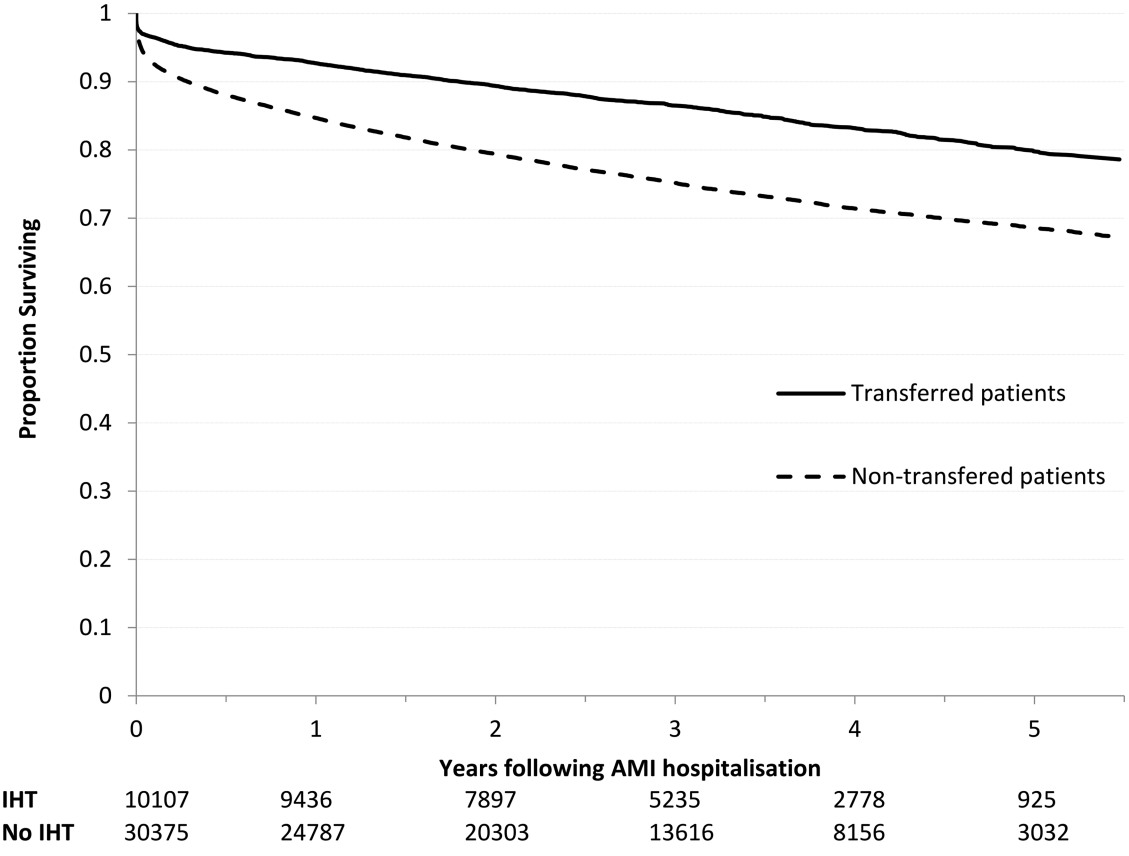
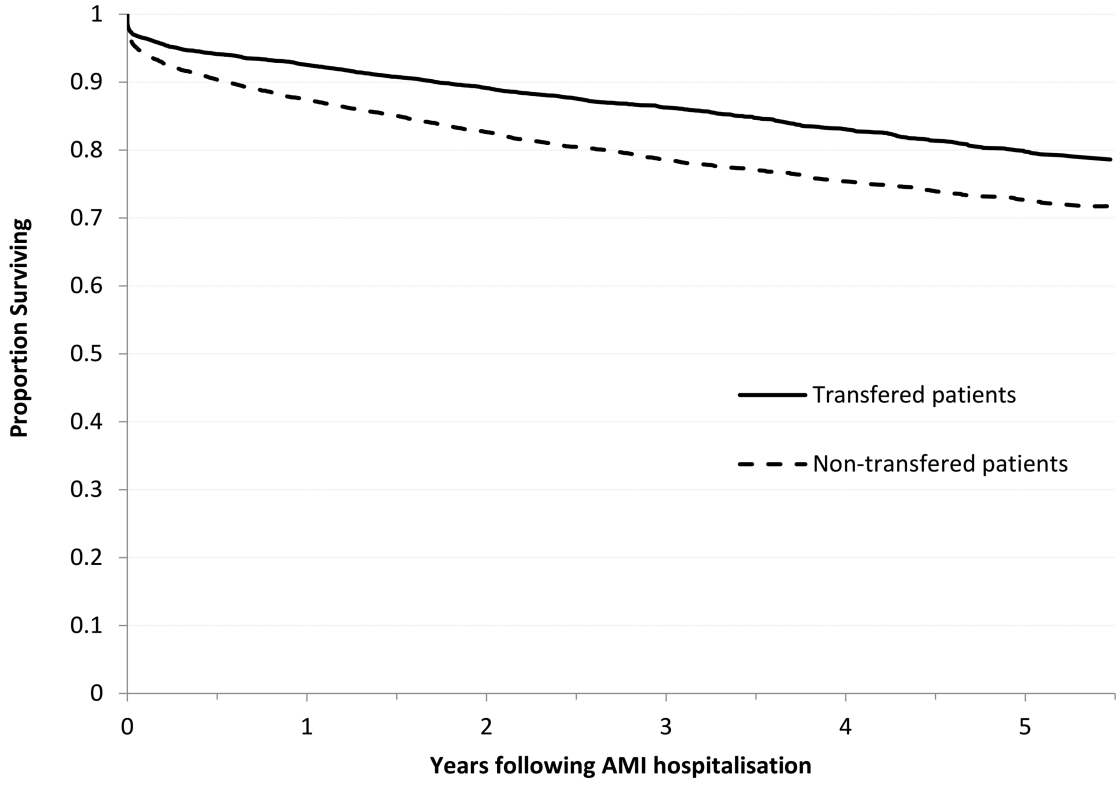
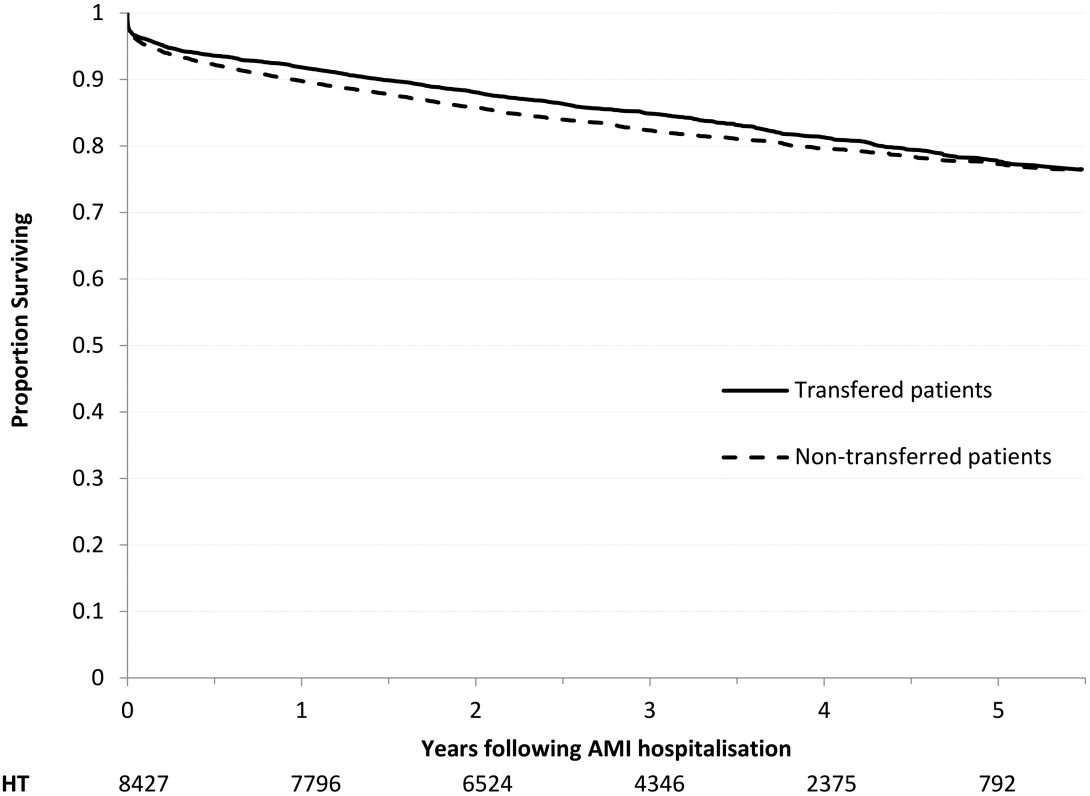


Figure 2 Kaplan–Meier survival curves indicating unadjusted rates of survival in the transferred and non-transferred patients in the overall cohort. AMI, acute myocardial infarction; IHT, interhospital transfer.



IHT	8427	7796	6524	4346	2375	792
No IHT	8427	7364	6052	3964	2224	772

Figure 3 Kaplan–Meier survival curves indicating rates of survival in the transferred and non-transferred patients in the propensity score matched cohort. AMI, acute myocardial infarction; IHT, interhospital transfer.



IHT	8427	7796	6524	4346	2375	792
No IHT	8427	7364	6052	3964	2224	772

Figure 4 Rates of survival in the transferred and non-transferred patients in propensity score matched cohort adjusted for difference in receipt of in-hospital revascularisation. AMI, acute myocardial infarction; IHT, interhospital transfer.

Table 3 Mortality in the propensity score matched cohort by risk-strata (quartiles) at presentation

Risk quartile based on predicted risk at presentation*	30-day mortality				Long-term mortality†			
	Overall quartile (%)	Transfer	Non-transfer	HR (95% CI)‡	Overall quartile (%)	Transfer	Non-transfer	HR (95% CI)‡
Quartile 1 (n=4239)	0.50	9/1984	12/2255	0.42 (0.19 to 0.96)	3.4	59/1984	85/2255	0.71 (0.52 to 0.95)
Quartile 2 (n=4239)	1.3	25/2232	28/2007	0.64 (0.42 to 0.97)	8.7	167/2232	201/2007	0.75 (0.63 to 0.91)
Quartile 3 (n=4239)	2.8	53/2252	64/1987	0.67 (0.51 to 0.95)	19.3	361/2252	458/1987	0.67 (0.68 to 0.76
Quartile 4 (n=4239)	14.0	206/2010	387/2229	0.62 (0.52 to 0.75)	43.1	705/2010	1123/2229	0.60 (0.54 to 0.66)

*The entire propensity score matched cohort (n=16 956, 8478 transferred and 8478 non-transferred patients) was stratified into four quartiles of equal patient number based on estimated risk of 30-day mortality at presentation. No interaction between risk-strata were observed for 30-day mortality or for long-term mortality (both p for interaction >0.05).
†Mortality at a median follow-up time of 3.5 years (min 1.5 years, max 5.5 years).
‡HR shown is for transfer group compared with the non-transfer group as the referent group.

95% CI 0.30 to 0.56; long-term mortality HR 0.64; 95% CI 0.59 to 0.70). This suggests that survivorship bias is unlikely to explain the mortality difference observed.

Our results show that for a single independent unmeasured binary confounder, present prior to transfer, to explain the observed lower mortality with IHT, the confounder would require a markedly higher (1.6-fold to 20.0-fold) prevalence among the non-transferred patients with an accompanying increase in mortality with HR varying between 1.5 (if the confounder is common) to 6.0 (if the confounder is uncommon) (see online supplementary appendix figure 3). These large imbalances would have to occur despite matching for other measurable characteristics. Lastly, analysis using inverse probability treatment weights showed that IHT continued to be associated with lower mortality although the effect size was reduced compared with the analysis (HR for long-term mortality 0.76, 95% CI 0.74 to 0.79, see online supplementary appendix).

DISCUSSION

In this study, we show that a quarter of hospitalised patients with AMI undergo transfer to another acute care hospital during their AMI event. These transferred patients have higher

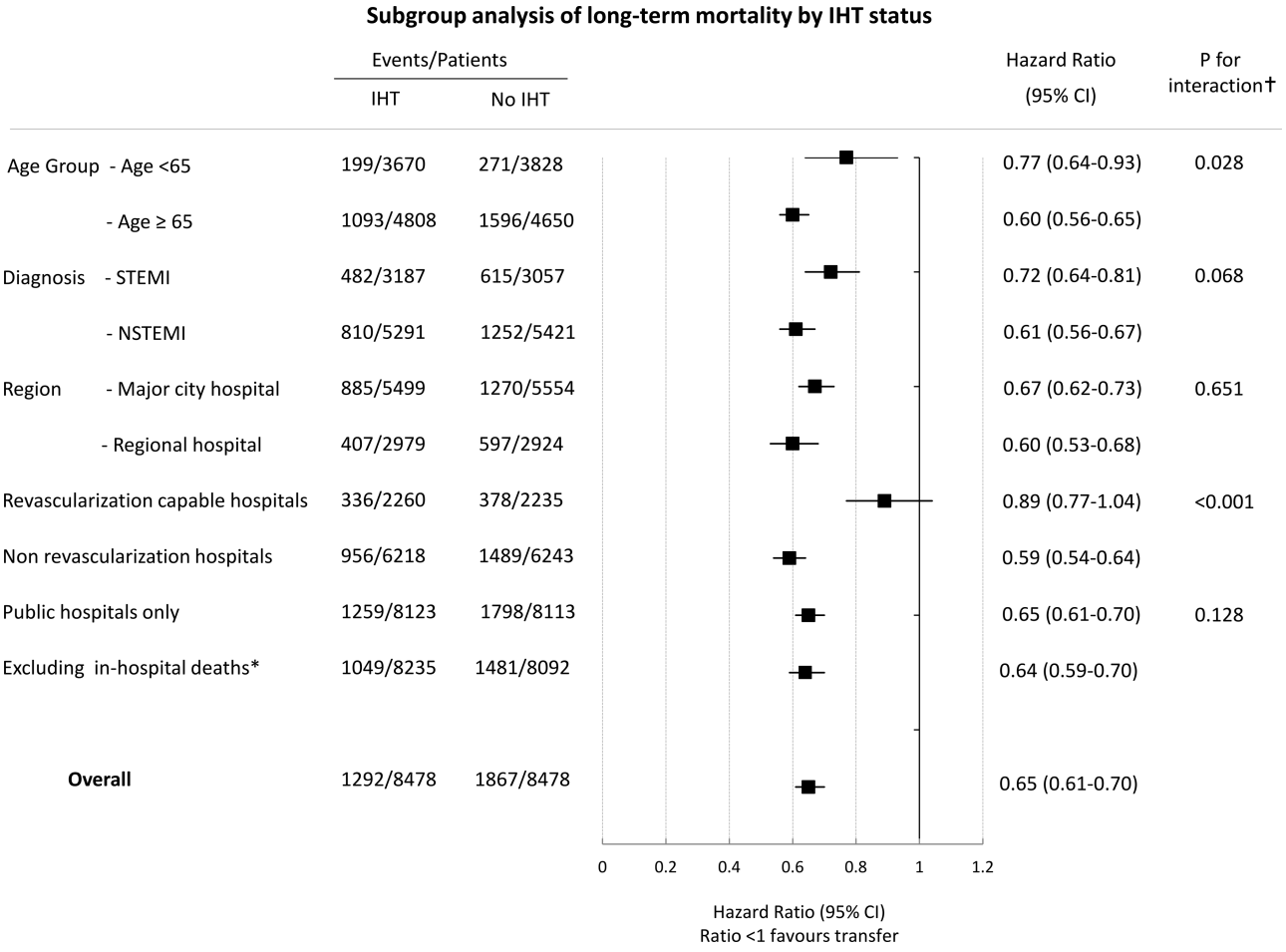


Figure 5 Subgroup analysis of long-term mortality between transferred and non-transferred patients. †P for statistical interaction with IHT, *No interaction term calculated as in-hospital death directly affects long-term mortality. AMI, acute myocardial infarction; IHT, interhospital transfer; STEMI, ST-elevation myocardial infarction; NSTEMI, non-ST-elevation myocardial infarction.

rates of coronary revascularisation and experience lower long-term mortality than similar patients treated solely at the presenting hospital. With the exception of transfers originating from procedural hospitals, these findings were consistent across a range of subgroups, including patients younger and older than 65 years of age, STEMI and NSTEMI patients, and transfers originating from hospitals in regional and major city areas. Sensitivity analyses showed that these findings are robust and unlikely to be due to survival bias or to confounding by unmeasured variables.

We report outcomes for large groups of transferred patients that have not been previously studied, and our findings show for the first time that transferred patients with AMI have lower long-term mortality. IHT has been evaluated only in a randomised manner for emergent transfer in STEMI.[18–22] In contrast, the transfer of admitted patients, most of whom have an NSTEMI, and who are further along in their illness, stems from generalisation of trials of routine invasive management.[23–25] This is reasonable given many of these trials included transferred patients and were in the absence of randomised trials of IHT as an intervention in NSTEMI. Prior observation studies of IHT have focused on selected populations such as Medicare beneficiaries aged ≥65 years, and transfers originating from rural, community or non-procedural hospital.[1–3 7] This is, in part, because IHT is thought to occur mainly in these populations. However, we show that 37.6% of transferred patients are among patients aged ≤65 years, 66.8% of transfers originate from major cities, 57.2% from tertiary hospitals and 22.5% originate from revascularisation capable hospitals; large groups of transferred patients with AMI who had been hitherto unstudied. Of the existing observational studies of IHT, three have reported lower crude 30-day mortality among transferred patients with AMI (crude OR/RR 0.32–0.57)[1 2 7] with one study reporting a 20% lower adjusted 30-day mortality,[1] comparable with the lower 30-day mortality among transferred patients in our study. We extend these prior observations by showing for the first time that transferred patients with AMI experience lower long-term mortality.

Our findings suggest that many patients who undergo IHT have an intermediate-to-high absolute risk of mortality. Although transferred patients do have a lower baseline risk profile compared with non-transferred patients consistent with prior studies,[1–3 7] our results show that most transferred patients have an absolute risk profile considered as intermediate-to-high risk when compared with clinical risk models.[26 27] For example, 75% of transferred patients had an absolute mortality of at least 1.3% at 30 days and 8.7% long term (table 3). This provides reassurance that patients who are transferred are likely to derive benefit from invasive therapy and other specialised care, given that intermediate-to-high risk patients are known to derive the greatest benefits from contemporary AMI therapies.[5 6]

Our observations show that the lower mortality among transferred patients is explained only partially by greater access to revascularisation. Benefits of IHT are often perceived to be solely due to increased access to invasive coronary procedures. However, we hypothesise that important differences in other aspects of care such as greater use of evidence-based treatments among transferred patients are likely to also contribute to the lower mortality among transferred patients. Our study did not measure these treatments as they are not recorded in the NSW APDC. However, our reasoning stems from prior studies that have shown transferred patients are more likely to receive evidence-based therapies such as antiplatelet and antithrombotic agents,[1 2] are more likely to be cared for under a cardiology service, and are more likely to undergo prognostically significant evaluations such as stress testing or assessment of LV function.[3] Higher rates of these beneficial therapies may explain the residual difference in mortality following adjustment for receipt of revascularisation. Our hypothesis is further supported by our observation that a significant difference in mortality was not observed for transfers originating from revascularisation capable hospitals. This may reflect the lack of a treatment differential between groups at these better resourced feeder hospitals. These observations are important because improving medical care at acute hospitals without specialised cardiac services may improve outcomes for patients with an AMI.

Our analysis has strengths and limitations. Hospital administrative data sets vary in accuracy and may underestimate the prevalence of risk factors and comorbidities. However, the accuracy of Australian hospital administrative data sets is only marginally inferior to accuracy reported in registry data sets.[28] The effect of selection bias on our findings is further minimised by propensity score matching with minimal residual confounding. Propensity score matching is accepted as the optimal posthoc statistical method to derive an unbiased estimate of the treatment effect when subjects are not randomly assigned to treatment groups.[29] APDC is an administrative database and does not contain clinical variables such as receipt of medical therapy including thrombolysis for STEMI patients that may influence the decision to transfer. However, our sensitivity analysis suggested the lower mortality observed among transferred patients unlikely to be negated by the presence of an unmeasured confounder. Nevertheless, residual bias due to unmeasured confounding is not completely excluded due to the observational nature of the study. Lastly, our time-to-event analysis does not take into consideration clustering of patients within hospitals, which may affect the estimate of effect size associated with IHT.

Key messages

What is already known on this subject?

Interhospital transfer of patients hospitalised for acute myocardial infarction (AMI) is exceedingly common in contemporary AMI care.

However, this practice is not supported by a wealth of data and there is concern that many transferred patients with AMI in clinical practice may not experience improved long-term outcomes.

What might this study add?

Most patients with an AMI transferred to one or more hospitals for specialised care are at moderate to high risk of long-term mortality.

Transferred patients have higher rates of coronary revascularisation (55.6% vs 13.7%, RR 4.05; 95% CI 3.83 to 4.29) and experience lower long-term mortality (15.3% vs 22.5%, HR 0.65; 95% CI 0.61 to 0.70) compared with patients treated solely at the presenting hospital.

How might this impact on clinical practice?

These findings support interhospital transfer of hospitalised AMI patients as an effective intervention for gaining access to specialised services and may improve long-term outcomes for appropriate patients with AMI.

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Contributors IR: conceived the study, analysed the data, and wrote the draft manuscript. FB: assisted with statistical analysis and contributed to the preparation of the manuscript. DB: contributed to the critical review of the manuscript. MG: obtained the data and the ethical approval for the study and contributed to the critical review of the manuscript.

Funding IR is supported by an early career fellowship co-funded by the National Health and Medical Research Council and the National Heart Foundation of Australia (Grant ID 1054353).

Competing interests None.

Ethics approval The NSW Population Health Research Ethics Committee.

Provenance and peer review Not commissioned; externally peer reviewed.

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Long-Term Mortality Following Inter-hospital Transfer for Acute Myocardial Infarction: An Observational Cohort Study

Isuru Ranasinghe, MBChB, MMed(Clin. Epi.), PhD, Federica Barzi, PhD, David Brieger, MBBS, PhD, Martin Gallagher, MBBS, MPH, PhD

Supplementary Appendix

Contents

1. Variables considered in the propensity analysis

1A. Variables included in the propensity score analysis

(1) Demographic characteristics and diagnosis at index presentation as coded in the New South Wales admitted patient data collection (NSWAPDC). These specifically include age at admission, sex, proportion of patients using private health insurance cover, admission year, and principle ICD10AM diagnosis at index presentation

(2) Variables encompassing past cardiac history and comorbidities at presentation derived from index admission and admissions occurring within the 12 months immediately preceding the date of index hospitalization (see below)

(3) Variables encompassing acute complications typical of AMI admission derived from secondary diagnosis codes at the initial presenting hospital at index hospitalization (see below)

(4) Variables encompassing hospital service/capacity and hospital region- diagnostic angiography and revascularization capability, region (major cities vs. regional or remote hospitals) and hospital peer group category. The Australian hospital peer group categories classify all public hospitals based on size and number of case mix adjusted acute presentations and are categorized as principle referral, large, medium and small acute hospitals. Private hospitals are not categorized based on this classification and therefore are recorded as private hospitals only.

Variables representing patient past cardiac history and comorbidities were derived from the administrative diagnostic codes assembled in to condition categories (CC) which group clinically coherent diagnostic codes into single variables. The CC candidate variables considered for this analysis were derived from the secondary diagnosis and procedure codes from the index hospitalization and from the principal and secondary ICD10AM diagnosis codes from all hospitalizations in the 12 months preceding the index hospitalization. The

methods for deriving CC variables from administrative data have been extensively described elsewhere(1, 2). The CC derived variables included in the analysis has been previously shown to be a robust measure of patient risk status and to be superior to other methods in predicting mortality including AMI specific mortality.(3, 4) In this analysis, ICD9 diagnosis codes were cross-walked to matching ICD10AM diagnostic code for each CC and were only derived from inpatient data.

1B. Acute Complications

Acute complications were derived from secondary ICD10 diagnostic coding from the initial hospital of presentation during the index hospitalization (i.e. acute complication occurring prior to potential transfer). Acute complications included typical complications encountered during AMI presentations and are indicated below with the corresponding ICD10 coding. With the exception of CHF, the ICD10AM coding used to derive the acute complications represent acute complications only and are specifically excluded from assessment of background history derived from the CC model described above to present double counting. ICD10AM coding does not distinguish congestive heart failure (CHF) as acute or chronic.

Acute complication	**ICD10AM coding**
Mechanical Complication of AMI	123.0-123.8
Cardiogenic Shock	R57.0
Cardiac Arrest	I46.0, I46.1, I46.9,
Ventricular arrhythmia	VT (I47.2), Vfib/flutter (I49.0)
Acute renal failure	N17.0-N17.2,N17.8, N17.9
Ischemic Stroke	I63.0-I63.9
Major Bleeding (all cause)	Multiple codes to identify all cause bleeding derived from 1CD10AM equivalent of ICD9 diagnostic codes previously published in the literature to identify major bleeding(5) I85.0, K22.6, K25.0, K25.2, K25.4, K25.6, K26.0, K26.2, K26.4, K26.6, K27.0, K27.2 K27.4, K27.6, K28.0, K28.4,

	K28.6, K29.0, K62.5, K66.1, K92.0, K92.1, K92.2, I60.0, I60.1 I60.2, I60.3, I60.4, I60.5, I60.6, I60.7, I60.8, I60.9, I61.0, I61.1, I61.2, I61.3, I61.4, I61.5, I61.6, I61.8, I61.9, I62.0, I62.1, I62.9, N02.0, N02.1, N02.2, N02.3, N02.4, N02.5, N02.6, N02.7, N02.8, N02.9, R31, R31.0, R31.1, R31.8, R04.0, R04.1, R04.2, R04.8, R04.9, R58, T81.0
Congestive Heart Failure	I50.0, I50.1 and I50.9

1C. Covariate balance pre and post propensity score matching (all variables)

Supplementary Table 1: Baseline Characteristics (All Variables)

	Unadjusted data			PS matched cohort		
	Transfer	**Non- Transfer**	**P Value**	**Transfer**	**Non-Transfer**	**P Value**
	N=10107	N=30375		N=8427	N=8427	
Age (median± SD)	65.1±12.9	70.8±14.1	<0.01	66.9±12.5	67.3±14.6	0.06
% Male	7129 (70.5)	18809 (61.9)	<0.01	5684 (67.5)	5634 (66.9)	0.41
Private insurance	2599 (25.7)	6406 (21.1)		1969 (23.4)	1995 (23.7)	0.64
Year of presentation						
- 2004	1140 (11.3)	4630 (15.2)	<0.01	1030 (12.3)	1023 (12.1)	0.99
- 2005	2181 (21.6)	7372 (24.3)		1868 (22.2)	1854 (22.0)	
- 2006	2638 (26.1)	7211 (23.7)		2171 (25.8)	2157 (25.6)	
- 2007	2772 (27.4)	7580 (25.0)		2242 (26.6)	2267 (26.9)	
- 2008	1376 (13.6)	3582 (11.8)		1116 (13.2)	1126 (13.4)	
Principle diagnosis at index admission						
- STEMI	4175 (41.3)	10015 (33.0)	<0.01	3124 (37.1)	3037 (36.0)	0.16
- NSTEMI	5932 (58.7)	20360 (67.0)		5303 (62.9)	5390 (64.0)	
Cardiovascular history*						
PTCA (CC 199)	100 (1.0)	388 (1.3)	0.02	91 (1.1)	76 (0.9)	0.24
CABG (CC 200)	14 (0.14)	71 (0.23)	0.07	13 (0.2)	15 (0.2)	0.71
Heart failure (CC 80)	1026 (10.2)	6379 (21.0)	<0.01	239 (2.8)	267 (3.2)	0.21

AMI (CC 81)	1378 (13.6)	4626 (15.2)	<0.01	119 (1.4)	145 (1.7)	0.11
Unstable angina (CC 82)	2044 (20.2)	7374 (24.3)	<0.01	394 (4.7)	427 (5.1)	0.24
Chronic atherosclerosis (CC 83, 84)	5776 (57.2)	22254 (73.3)	<0.01	3216 (38.2)	3140 (37.3)	0.23
Cardiopulmonary-respiratory failure or shock (CC 79)	324 (3.2)	1538 (5.1)	<0.01	45 (0.5)	39 (0.5)	0.51
Valvular heart disease (CC 86)	439 (4.3)	2752 (9.1)	<0.01	263 (3.1)	324 (3.8)	0.01
Comorbidity*						
Hypertension (CC 89, 91)	6027 (59.6)	20013 (65.9)	<0.01	4412 (52.4)	4444 (52.7)	0.62
Stroke (CC 95, 96)	183 (0.5)	850 (2.8)	<0.01	38 (0.5)	38 (0.5)	1.00
Cerebrovascular disease (CC 97,98,99,103)	255 (2.5)	1211 (4.0)	<0.01	75 (0.9)	76(0.9)	0.93
Renal failure (CC 131)	693 (6.9)	3877 (12.8)	<0.01	149 (1.8)	153 (1.8)	0.82
COPD (CC 108)	666 (6.6)	3409 (11.2)	<0.01	439 (5.2)	449 (5.3)	0.73
Pneumonia (CC 111, 112, 113)	271 (2.7)	1596 (5.3)	<0.01	75 (0.9)	81 (1.0)	0.63
Diabetes (CC 15-20, 120)	1706 (16.9)	6328 (20.8)	<0.01	1134 (13.5)	1117 (13.3)	0.70
Protein-caloric malnutrition (CC 21)	55 (0.5)	351 (1.2)	<0.01	10 (0.1)	11 (0.1)	0.83
Dementia (CC 49-50)	207 (2.1)	2430 (8.0)	<0.01	86 (1.0)	111 (1.3)	0.07
Hemiplegia, paraplegia, paralysis, functional disability (CC 68,69,100-102, 177,178)	474 (4.7)	2417 (8.0)	<0.01	153 (1.8)	169 (2.0)	0.37
Peripheral vascular disease (CC 104, 105)	789 (7.8)	3342 (11.0)	<0.01	212 (2.5)	228 (2.7)	0.44
Metastatic cancer (CC 7,8)	214 (2.1)	1025 (3.4)	<0.01	58 (0.7)	71 (0.8)	0.26
Trauma (CC 154-156, 158-162)	641 (6.3)	3277 (10.8)	<0.01	230 (2.7)	266 (3.2)	0.10
Major psychiatric disorder (CC 54-56)	88 (0.9)	398 (1.3)	0.05	45 (0.5)	45 (0.5)	1.00
Chronic liver disease (CC 25-27)	84 (0.8)	349 (1.2)	0.01	43 (0.5)	42 (0.5)	0.91
HIV/AIDS (CC1)	54 (0.2)	7 (0.1)	0.01	9 (0.1)	7 (0.1)	0.62
Septicemia/Shock (CC2)	310 (1.0)	34 (0.3)	<0.01	30 (0.4)	33 (0.4)	0.70
Opportunistic infections (CC5)	93 (0.3)	7 (0.1)	<0.01	7 (0.1)	6 (0.1)	0.78
Lymphatic, head and neck, brain, and other major cancers (CC9)	206 (0.7)	31 (0.3)	<0.01	37 (0.4)	31 (0.4)	0.47
Breast, prostate, colorectal and other cancers and tumors (CC10)	697 (2.3)	145 (1.4)	<0.01	134 (1.6)	137 (1.6)	0.85
Intestinal obstruction/perforation	257 (0.9)	45 (0.5)	<0.01	45 (0.5)	44 (0.5)	0.92
Pancreatic disease (CC 32)	68 (0.2)	14 (0.1)	0.10	5 (0.1)	13 (0.2)	0.06
Inflammatory bowel disease (CC 33)	64 (0.2)	16 (0.2)	0.30	18 (0.2)	16 (0.2)	0.73
Bone/joint/muscle infections/necrosis (CC 37)	117 (0.4)	14 (0.1)	<0.01	11 (0.1)	14 (0.2)	0.55

Rheumatoid Arthritis, Inflammatory Connective Tissue Disease (CC 38)	349 (1.2)	76 (0.8)	<0.01	69 (0.8)	72 (0.9)	0.78
Severe Hematological Disorders (CC 44)	167 (0.6)	19 (0.2)	<0.01	18 (0.2)	19 (0.2)	0.87
Disorders of Immunity (CC 45)	38 (0.1)	4 (0.0)	0.02	4 (0.1)	4 (0.1)	1.00
Drug/Alcohol Psychosis (CC 51)	213 (0.7)	45 (0.5)	0.01	50 (0.6)	42 (0.5)	0.40
Drug/Alcohol Dependence (CC 52)	325 (1.1)	93 (0.9)	0.12	89 (1.1)	87 (1.0)	0.88
Schizophrenia (CC 54)	98 (0.3)	21 (0.2)	0.06	24 (0.3)	20 (0.2)	0.55
Major Depressive, Bipolar, and Paranoid Disorders (CCC 55)	154 (0.5)	28 (0.3)	<0.01	25 (0.3)	27 (0.3)	0.78
Polyneuropathy (CC 71)	407 (1.3)	72 (0.7)	<0.01	71 (0.8)	71 (0.8)	1.00
Multiple Sclerosis (CC 72)	20 (0.1)	8 (0.1)	0.66	8 (0.1)	8 (0.1)	1.00
Parkinson's and Huntington's Diseases (CC 73)	276 (0.9)	26 (0.3)	<0.01	25 (0.3)	26 (0.3)	0.89
Seizure Disorders and Convulsions (CC 74)	169 (0.6)	23 (0.2)	<0.01	24 (0.3)	23 (0.3)	0.88
Coma, Brain Compression/Anoxic Damage (CC 75)	166 (0.6)	11 (0.1)	<0.01	11 (0.1)	11 (0.1)	1.00
Respirator Dependence/Tracheostomy Status (CC 77)	32 (0.1)	3 (0.0)	0.03	7 (0.1)	3 (0.0)	0.20
Respiratory Arrest (CC 78)	45 (0.2)	7 (0.1)	0.06	9 (0.1)	6 (0.1)	0.44
Proliferative Diabetic Retinopathy and Vitreous Hemorrhage (CC 119)	13 (0.0)	3 (0.0)	0.56	2 (0.0)	3 (0.0)	1.00
Dialysis Status (CC 130)	242 (0.8)	34 (0.3)	<0.01	22 (0.3)	34 (0.4)	0.11
Nephritis (CC 132)	47 (0.2)	8 (0.1)	0.07	9 (0.1)	8 (0.1)	0.81
Specified Heart Arrhythmias (CC 92)	2256 (7.4)	325 (3.2)	<0.01	346 (4.1)	314 (3.7)	0.20
Decubitus Ulcer of Skin (CC 148)	226 (0.7)	20 (0.2)	<0.01	15 (0.2)	20 (0.2)	0.40
Chronic Ulcer of Skin, Except Decubitus (CC 149)	508 (1.7)	63 (0.6)	<0.01	76 (0.9)	62 (0.7)	0.23
Vertebral Fractures without Spinal Cord Injury (CC 157)	11 (0.0)	3 (0.0)	0.76	6 (0.1)	3 (0.0)	0.32
Major Complications of Medical Care and Trauma (CC 164)	1183 (3.9)	188 (1.9)	<0.01	176 (2.1)	184 (2.2)	0.67
Major Organ Transplant Status (CC 174)	36 (0.1)	12 (0.1)	1.00	11 (0.1)	11 (0.1)	1.00
Artificial Openings for Feeding or Elimination (CC 176)	258 (0.9)	45 (0.5)	<0.01	40 (0.5)	42 (0.5)	0.82
Acute Complications						
Mechanical Complication of AMI	8 (0.1)	61 (0.2)	0.01	8 (0.1)	9 (0.1)	0.81
Cardiogenic Shock	74 (0.7)	611 (2.0)	<0.01	71 (0.8)	76 (0.9)	0.68
Cardiac Arrest	138 (1.4)	800 (2.6)	<0.01	124 (1.5)	116 (1.4)	0.60
Ventricular Arrhythmia(VT/VF)	234 (2.3)	976 (3.2)	<0.01	194 (2.3)	197 (2.3)	0.88
Acute Renal Failure	144 (1.4)	1658 (5.5)	<0.01	143 (1.7)	154 (1.8)	0.52

Ischemic Stroke	10 (0.1)	192 (0.6)	<0.01	10 (0.1)	10 (0.1)	1.00
Major Bleeding	157 (1.6)	1318 (4.3)	<0.01	156 (1.9)	168 (2.0)	0.50
Heart Failure	739 (7.3)	5439 (17.9)	<0.01	731 (8.7)	736(8.7)	0.89
Presenting Hospital Characteristics						
Hospital region						
- Major city area	6746 (66.8)	23934 (78.8)	<0.01	5459 (64.8)	5489 (65.1)	0.69
- Regional hospital	3361 (33.3)	6441 (21.2)	<0.01	2968 (35.2)	2938 (35.9)	
Hospital Peer Group						
- Principle referral	5783 (57.2)	21539 (70.9)	<0.01	4946 (58.7)	4953 (58.8)	0.32
- Large hospital	2799 (27.7)	4235 (14.5)		2115 (25.1)	2171 (25.8)	
- Medium hospital	826 (8.2)	1970 (6.5)		784 (9.3)	735(8.7)	
- Small acute hospital	340 (3.4)	373 (1.2)		229 (2.7)	248 (2.9)	
- Private hospital	359 (3.6)	2258 (7.4)		353 (4.2)	320 (3.2)	
Revascularization capable (PCI and/or CABG)	2269 (22.5)	17966 (59.2)	<0.01	2260 (26.8)	2181 (25.9)	0.17

Abbreviations are as described within the manuscript text.

2. Subgroup analysis of the effect of inter-hospital transfer on long-term mortality stratified by the type of AMI (STEMI vs NSTEMI)

		STEMI*				NSTEMI*			
Subgroup		**IHT**	**No IHT**	**OR**	**95%CI**	**IHT**	**No IHT**	**OR**	**95%CI**
Age	<65	80/1395	109/1398	0.73	0.54-0.97	111/2263	137/2326	0.83	0.68-1.07
	≥65	371/1547	577/1544	0.59	0.58-0.67	706/3232	1093/3169	0.57	0.52-0.63
Region	Major City	272/1656	384/1677	0.68	0.59-0.80	592/3850	900/3791	0.61	0.55-0.68
	Regional Hospital	179/1286	302/1265	0.56	0.46-0.67	225/1645	330/1704	0.68	0.57-0.80
Revascularization capable hospitals		116/788	121/759	0.90	0.70-1.16	219/1466	268/1439	0.79	0.66-0.95
Non-Revascularization hospitals		335/2154	565/2183	0.57	0.50-0.65	598/4029	962/4056	0.59	0.53-0.65
Public hospitals only		435/2775	652/2762	0.63	0.56-0.71	801/5316	1198/5296	0.63	0.58-0.69
Excluding in-hospital deaths		305/2796	406/2662	0.70	0.61-0.82	727/5405	1105/5370	0.62	0.57-0.68
By risk quartile at presentation									
	Quartile 1 (lowest risk)	27/689	37/782	0.82	0.50-1.34	58/1262	76/1485	0.91	0.65-1.28
	Quartile 2	54/796	58/675	0.80	0.55-1.15	66/1465	96/1283	0.61	0.44-0.82
	Quartile 3	124/784	124/687	0.88	0.69-1.13	229/1513	248/1235	0.72	0.60-0.86
	Quartile 4 (highest risk)	246/673	467/798	0.53	0.45-0.61	464/1255	810/1492	0.58	0.51-0.64

*STEMI cohort included 5,884 patients and NSTEMI cohort included 10,990 patients. Each propensity score matched cohort included an equal proportion of transferred and non-transferred patients.

3. Inverse probability treatment weighted (IPTW) propensity analysis

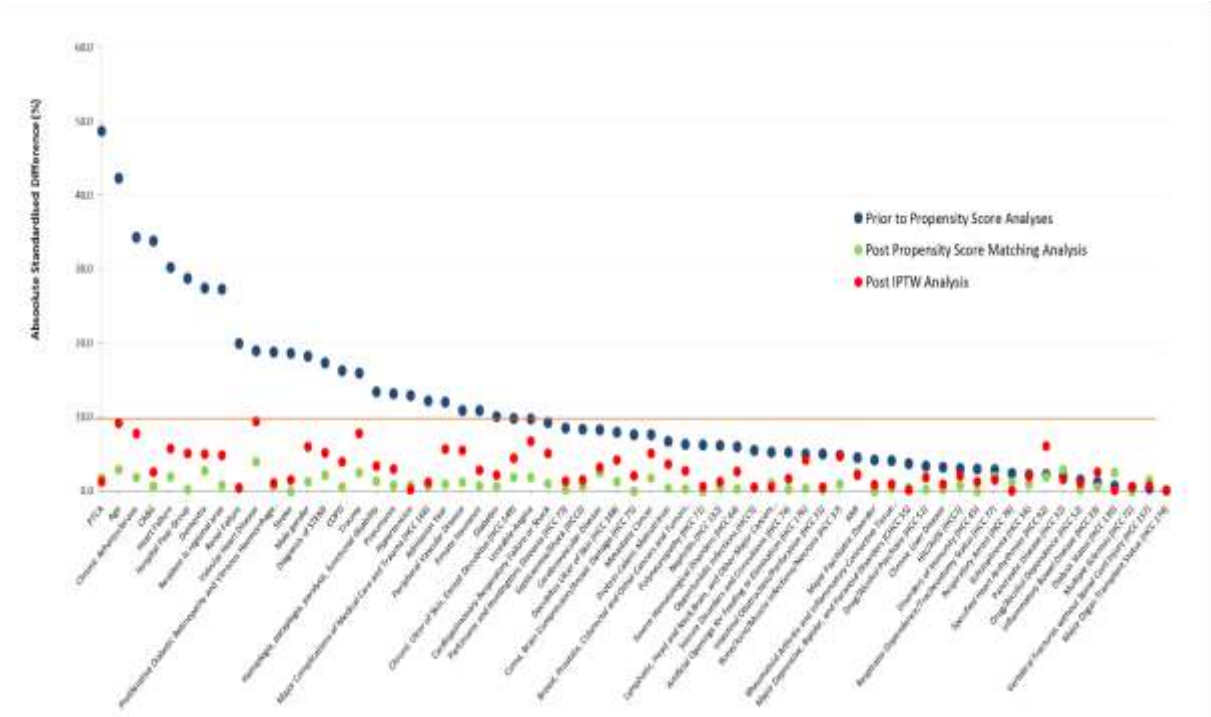
3A. Method

Propensity score matching allows the most robust estimation of the average treatment effect for the treated (ATT), i.e. the effect on mortality for those who were transferred.(6) However, matching excludes a significant proportion of the population who are unmatched. To evaluate whether the survival benefit of IHT evident in the PSM cohort is applicable to the entire population, we conducted an Inverse Probability Treatment Weighted (IPTW) propensity score analysis. For this analysis morality was adjusted for baseline covariates by weighting the analysis using IPTWs derived from the propensity score. IPTW method allow estimation of the average effect of treatment in the entire study population, i.e. the expected effect on mortality for the entire population if the entire population was assumed to have received IHT.(6) Adequacy of the IPTW propensity score model was assessed by comparing covariate balance before and after IPTW adjustment using standardized differences.

3B. Covariate balance post IPTW PS analysis

Covariate Balance post IPTW analysis is indicated in figure below. Median standardized difference post IPTW analysis was 2.20 (IQR 1.13-4.51) indicating a significant improvement in covariate balance from baseline (median standardized difference 8.31, IQR 4.2-16.0) but slightly inferior to covariate balance following propensity score matching (median standardized difference 0.74, IQR 0.28-1.42). Irrespective, all covariates were at or below 10, the general accepted threshold below which covariate imbalance is considered insignificant.(6)

Figure: Covariate balance between transferred and non-transferred cohorts for individual covariates (as measured by the absolute standardised difference) prior to propensity score analyses and following propensity score matching and IPTW analyses respectively. The figure shows that both propensity score methods achieve good covariate balance (as indicated by a standardised difference <10 for all covariates [red line]). However, propensity score matching (green dots) achieved a slightly superior covariate balance compared with the IPTW method (red dots) as indicated by a lower standardised difference for most covariates.



3C. Comparison of mortality following IPTW adjusted analysis

Mortality	Unadjusted Point Estimate† (95%CI)	PSM cohort Point Estimate† (95%CI)	IPTW adjusted Point Estimate† (95%CI)
In-hospital Mortality	0.37 (0.33-0.42)	0.67 (0.57- 0.79)	0.69 (0.61-0.77)
30 day	0.35 (0.31-0.40)	0.60 (0.52-0.70)	0.65 (0.59-0.71)
1 year	0.34 (0.31-0.37)	0.58 (0.52-0.64)	0.67 (0.62-0.71)
Long-term Mortality#	0.40 (0.38-0.42)	0.65 (0.61-0.70)	0.76 (0.74-0.79)

† Point estimate given are Relative Risk (RR) for revascularization and in-hospital mortality. Point estimate shown for 30 day, 1 year and long-term mortality are Hazard Ratios (HR). In both cases the non-transfer group is referent group

Mean follow-up time 3.5 years (min 1.5 years, max 5.5 years).

4. Supplemental Figures

Figure S1: The distribution of the Propensity Score by the actual transfer status.

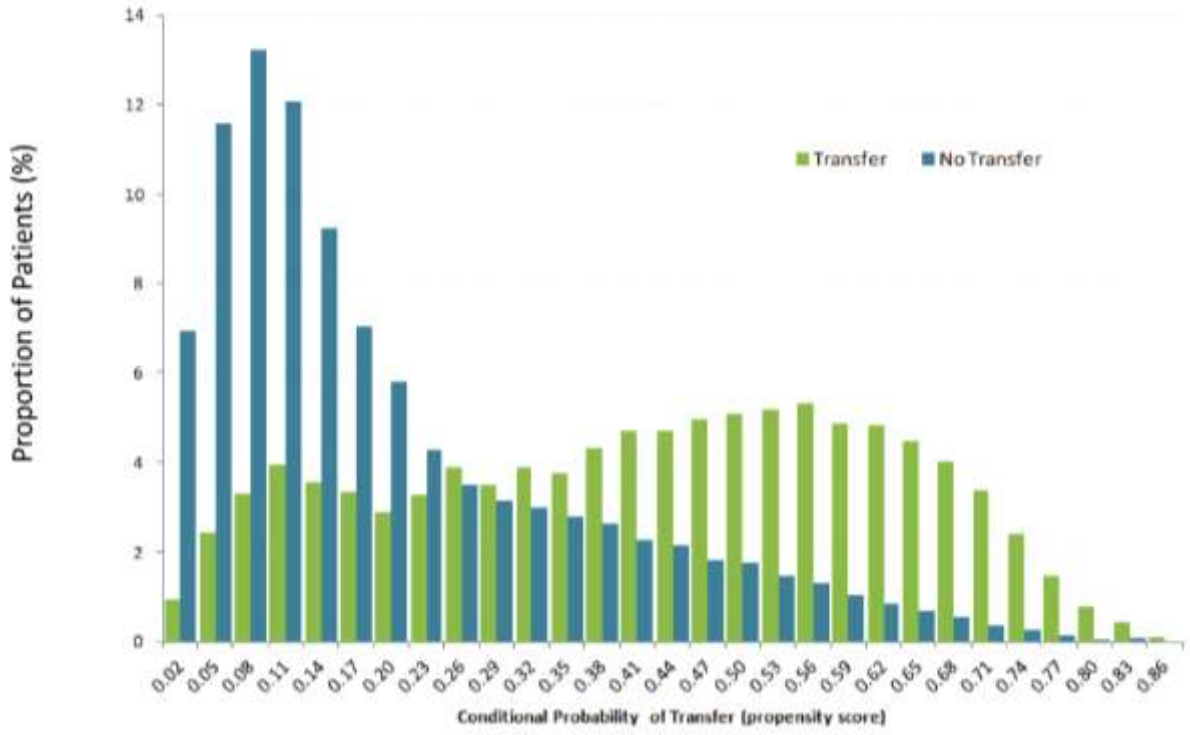


Figure S2: Subgroup analysis of 30-day mortality between transferred and non-transferred patients.†P for statistical interaction with IHT, *No interaction term calculated as in-hospital death directly affects 30-day mortality.

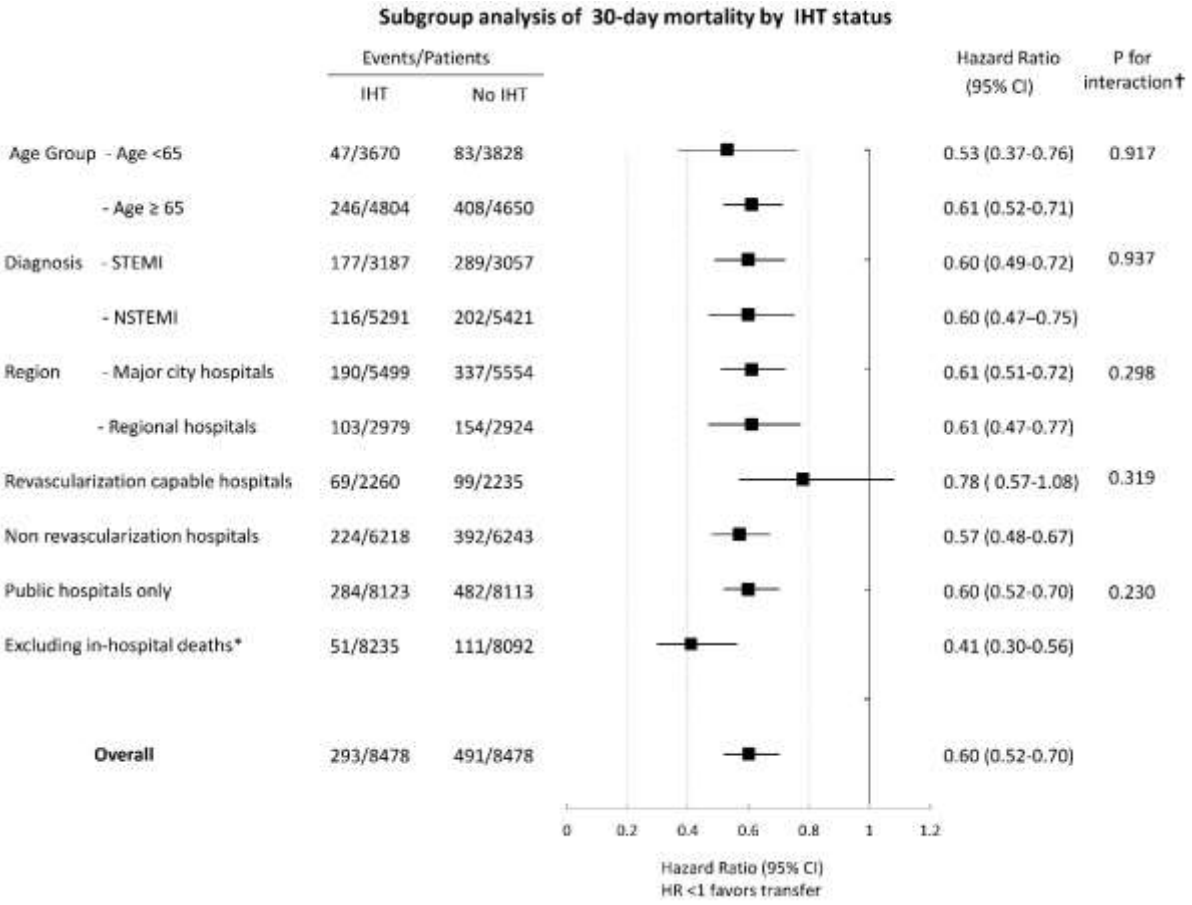
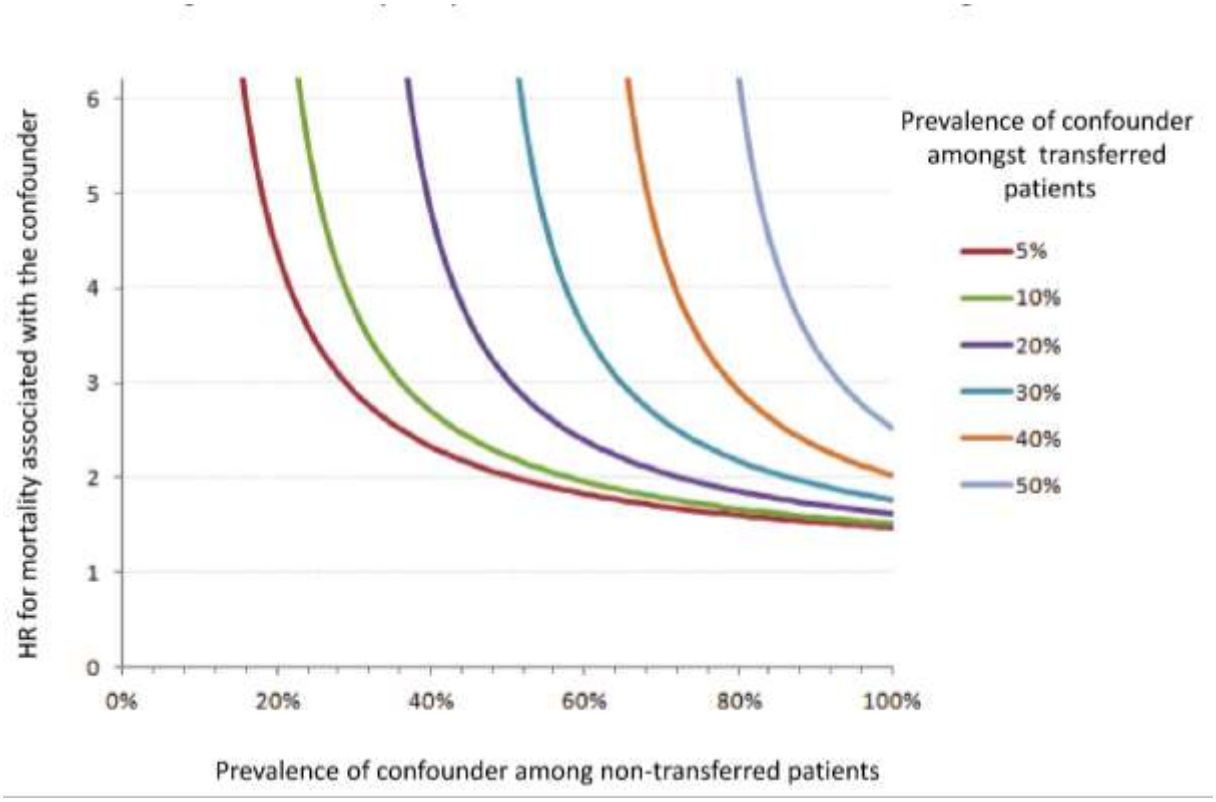


Figure S3: A sensitivity analysis of the potential for a single unmeasured binary confounder to explain the observed hazard ratio (HR) for long-term mortality. It shows the complex relationship required for a confounder to shift the upper 95% confidence interval of the overall treatment effect estimate from 0.70 to 1.00. For example, if an unmeasured baseline confounder were present in 10% of the patients who were transferred (green curved line) then the prevalence of the confounder in the non-transferred population has to be at least 25% and have a HR of 6.0 for mortality. If the prevalence of such a confounder were 40% or 60% in the non-transferred group then the hazard ratios that would be required for an unmeasured confounder to account for the observed lower mortality with transfer would be 2.32, and 1.82, respectively. An unmeasured confounder also has to occur prior to transfer and be independent of all other measured variables.



5. Supplementary appendix references

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