Research Article

Hospitalization outcome of heart diseases between patients who received medical care by cardiologists and non-cardiologist physicians: A propensity-score matched study

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Abstract

Background and aims

The effects of physician specialty on the outcome of heart disease remains incompletely understood because of inconsistent findings from some previous studies. Our purpose is to compare the admission outcomes of heart disease in patients receiving care by cardiologists and noncardiologist (NC) physicians.

Methods

Using reimbursement claims data of Taiwan’s National Health Insurance from 2008–2013, we conducted a matched study of 6264 patients aged ≥20 years who received a cardiologist’s care during admission for heart disease. Using a propensity score matching procedure adjusted for sociodemographic characteristics, medical condition, and type of heart disease, 6264 controls who received an NC physician’s care were selected. Logistic regressions were used to calculate odds ratios (ORs) with 95% confidence intervals (CIs) for complications and mortality during admission for heart disease associated with a cardiologist’s care.
Results

Patients who received a cardiologist’s care had a lower risk of pneumonia (OR = 0.61; 95% CI, 0.53–0.70), septicemia (OR = 0.49; 95% CI, 0.39–0.61), urinary tract infection (OR = 0.76; 95% CI, 0.66–0.88), and in-hospital mortality (OR = 0.37; 95% CI, 0.29–0.47) than did patients who received an NC physician’s care. The association between a cardiologist’s care and reduced adverse events following admission was significant in both sexes and in patients aged ≥ 40 years.

Conclusion

We raised the possibility that cardiologist care was associated with reduced infectious complications and mortality among patients who were admitted due to heart disease.

Introduction

Cardiovascular diseases, which include diseases of the heart and blood vessels caused by atherosclerosis, have been identified as one of the leading causes of death globally [1]. An estimated 17.7 million people died from cardiovascular diseases in 2015, representing 31% of all global deaths [2]. Additionally, cardiovascular diseases contribute extensively to the escalating costs of healthcare, which has become a worldwide burden. The annual direct cost of cardiovascular diseases was estimated at $250.8 billion in 2012–2013 in the United States and about €106 billion in Europe [3], representing approximately 9% of the total healthcare expenditure across the European Union in 2009 [4].

While caring for patients with cardiovascular diseases, cardiologists are more likely to use clinical guideline-supported therapies or be more knowledgeable about therapies than general physicians, a fact which has been shown to reduce mortality [5]. Previous studies reported that patients treated by cardiologists may have a lower mortality or better outcome than general physicians [6–13]. However, other studies reported that there was no significant difference in the patients’ outcomes between cardiologists and general physicians [14–17]. The inconsistent findings from previous studies may be due to the presence of some limitations, such as small sample sizes [10], the lack of matching procedures [6–10,14–16], inadequate control for confounding factors [7,8,11], and a focus on specific cardiovascular diseases or populations [6–11,14–16].

Limited information is available regarding the effects of a physician’s specialty on the outcomes of admission due to cardiovascular diseases in the Asian population. Using the claims data of national health insurance database, we conducted a population-based study to investigate the association between specialty care and admission outcomes in hospitalized patients suffering from cardiovascular diseases.

Methods

Source of data

The data used in this study were obtained from the reimbursement claims of Taiwan’s National Health Insurance, which contains inpatient and outpatient demographic characteristics, physicians’ primary and secondary diagnoses, treatment procedures, prescriptions, and medical expenditures. More than 99% of people in Taiwan received medical services from the...
National Health Insurance that cooperated with 471 hospitals and 20,692 clinics in June 2018. Several scientific articles based on data from Taiwan’s National Health Insurance have been accepted in outstanding journals [18–20].

As these reimbursement claims were used in this study, the electronic database was decoded with patient identifications scrambled for further academic access for research to protect privacy. Although the National Health Research Institutes exempt such uses from informed consent, the guidelines of the Helsinki Declaration were obeyed during the execution of this study. This study was approved by the institutional review board of Taipei Medical University (TMU-JIRB-201701050; TMU-JIRB-201808012; TMU-JIRB-202006057).

Study design
From the database of Taiwan’s National Health Insurance, we identified 34,553 patients with a nonsurgical admission due to heart disease (HD) in 2008–2013, with 23,482 of them receiving inpatient care by a cardiologist. To obtain the appropriate study subjects, we used a propensity-score matching technique to select 6,264 patients receiving a cardiologist’s inpatient care and 6,264 patients receiving inpatient care by a noncardiologist (NC) physician. Factors in the propensity-score matching included sociodemographics (such as age, sex, low income), types of HD, history of disease (such as hypertension, diabetes, mental disorders, chronic obstructive pulmonary disease, hyperlipidemia, chronic kidney disease, end-stage renal disease, liver cirrhosis, and Parkinson’s disease), number of recent hospitalizations, and number of recent emergency visits. We compared the complications, mortality, intensity of care, length of hospital stay, medical expenditures during the admission due to HD between patients receiving inpatient care by a cardiologist and those receiving inpatient care by NC physicians.

Measures and definition
The criterion of low income used in this study is based on the definition from the Bureau of National Health Insurance in Taiwan and details were described in our previous report [18–20]. Previous medical use before admission due to HD was considered as a potential covariate in this study along with number of emergency visits and hospitalizations. Based on the administration code and The International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), coexisting medical conditions were determined from medical claims for the 24-month preadmission period including hypertension (ICD-9-CM codes 401–405), diabetes (ICD-9-CM code 250), mental disorders (ICD-9-CM codes 290–319), chronic obstructive pulmonary disease (ICD-9-CM codes 491,492, 496), hyperlipidemia, chronic kidney disease, end-stage renal disease (D8 and D9), liver cirrhosis (ICD-9-CM codes 571.2, 571.5, 571.6), and Parkinson’s disease (ICD-9-CM code 332). Types of HD were also identified by the ICD-9-CM codes including myocardial infarction (ICD-9-CM codes 410, 412), other acute and subacute ischemic heart disease (ICD-9-CM code 411), angina pectoris (ICD-9-CM code 413), other chronic ischemic heart disease (ICD-9-CM code 414), acute and subacute endocarditis (ICD-9-CM code 421), acute myocarditis (ICD-9-CM code 422), other diseases of pericardium (ICD-9-CM code 423), other diseases of endocardium (ICD-9-CM code 424), cardiomyopathy (ICD-9-CM code 425), conduction disorders (ICD-9-CM code 426), cardiac dysrhythmias (ICD-9-CM code 427), heart failure (ICD-9-CM code 428), and ill-defined descriptions and complications of heart disease (ICD-9-CM code 429). Pneumonia (ICD-9-CM codes 480–486), septicemia (ICD-9-CM codes 038 and 998.5), urinary tract infection (ICD-9-CM code 599.0), mortality, length of hospital stay, and medical expenditures during the patients’ stays were considered as study outcomes. In this study, the non-cardiologist physicians included physicians with medical specialists in general medicine, family medicine,
neurology, nephrology, gastroenterology, thoracic medicine, endocrinology, and infectious
disease.

**Statistical analysis**

The propensity score-matched pair analysis was used to examine the associations between
physician specialty and outcomes of HD admission. A nonparsimonious multivariable logistic
regression model was used to estimate a propensity score for patients receiving a cardiologist’s
service or not. Covariates in this model included age, sex, low income, types of HD, hyperten-
sion, diabetes, mental disorders, chronic obstructive pulmonary disease, hyperlipidemia,
chronic kidney disease, end-stage renal disease, liver cirrhosis, Parkinson’s disease, number
of hospitalizations, and number of emergency visits. We matched the cardiologists’ patients to
the NC physicians’ patients, using a greedy matching algorithm (without replacement) with a
caliper width of 0.2 SDs of the log odds of the estimated propensity score. Categorical variables
between cardiologists’ patients and NC physicians’ patients were analyzed by using frequencies
(percentages) and chi-square tests. Continuous variables between cardiologists’ patients and
NC physicians’ patients are presented as means ± standard deviations and analyzed using t
tests. We used logistic regression to calculate the adjusted odds ratios (ORs) and 95% confi-
dence intervals (CIs) of the outcomes of HD admission associated with physician specialty. In
addition, subgroup analysis was also used to stratify the subjects according to age, sex, number
of medical conditions, and type of HD, to examine the outcomes of HD admission between
patients receiving a cardiologist’s care or not in these strata.

**Results**

Table 1 shows the baseline characteristics of the patients suffering from cardiovascular diseases
and the controls who underwent different specialty physician cares. After the propensity score
matching, there were no significant differences in the groups including the patients suffering
from cardiovascular diseases with and without a cardiologist’s care analyzed by age, sex, low
income, medical conditions (hypertension, diabetes, mental disorders, chronic obstructive
pulmonary disease, hyperlipidemia, chronic kidney disease, end-stage renal disease, liver cir-
rhosis and Parkinson’s disease), type of HD, number of hospitalizations and number of emer-
gency visits.

Compared with HD patients receiving medical service by an NC physician (Table 2), those
receiving care by a cardiologist had lower risks of pneumonia (OR = 0.61; 95% CI, 0.53–0.70),
septicemia (OR = 0.49; 95% CI, 0.39–0.61), urinary tract infection (OR = 0.76; 95% CI, 0.66–
0.88), and in-hospital mortality (OR = 0.37; 95% CI, 0.29–0.47). The average length of hospital
stay (7.7±19.7 vs 5.7±7.0 days; \( P < .001 \)) was shorter in cardiologists’ patients than in NC phy-
sicians’ patients.

The stratified analysis show that the association between cardiology specialty and reduced
postadmission adverse events was significant in females (OR = 0.66; 95% CI, 0.57–0.76), males
(OR = 0.59; 95% CI, 0.51–0.67), and people aged 40–49 years (OR = 0.55; 95% CI, 0.33–0.92),
50–59 years (OR = 0.56; 95% CI, 0.41–0.79), 60–69 years (OR = 0.58; 95% CI, 0.45–0.76), 70–
79 years (OR = 0.64; 95% CI, 0.54–0.76), and ≥80 years (OR = 0.60; 95% CI, 0.51–0.72)
(Table 3).

**Discussion**

In this population-based study with a propensity-score matching analysis, we found that
patients admitted due to cardiovascular diseases receiving treatment by cardiologists had
lower risks of pneumonia, septicemia and urinary tract infection and 30-day in-hospital
|                      | NC physicians (N = 6264) | Cardiologists (N = 6264) | P value |
|----------------------|--------------------------|--------------------------|---------|
| **Sex**              |                          |                          | 1.0000  |
| Female               | 2519 (40.2)              | 2519 (40.2)              |         |
| Male                 | 3745 (59.8)              | 3745 (59.8)              |         |
| **Age, years**       |                          |                          | 1.0000  |
| 20–29                | 70 (1.1)                 | 70 (1.1)                 |         |
| 30–39                | 169 (2.7)                | 169 (2.7)                |         |
| 40–49                | 503 (8.0)                | 503 (8.0)                |         |
| 50–59                | 1099 (17.5)              | 1099 (17.5)              |         |
| 60–69                | 1270 (20.3)              | 1270 (20.3)              |         |
| 70–79                | 1825 (29.1)              | 1825 (29.1)              |         |
| ≥80                  | 1328 (21.2)              | 1328 (21.2)              |         |
| **Low income**       |                          |                          | 1.0000  |
| No                   | 6160 (98.3)              | 6160 (98.3)              |         |
| Yes                  | 104 (1.7)                | 104 (1.7)                |         |
| **Medical conditions**|                         |                          |         |
| Hypertension         | 3044 (48.6)              | 3044 (48.6)              | 1.0000  |
| Diabetes             | 1218 (19.4)              | 1218 (19.4)              | 1.0000  |
| Mental disorders     | 816 (13.0)               | 816 (13.0)               | 1.0000  |
| COPD                 | 713 (11.4)               | 713 (11.4)               | 1.0000  |
| Hyperlipidemia       | 235 (3.8)                | 235 (3.8)                | 1.0000  |
| Chronic kidney disease| 95 (1.5)                | 95 (1.5)                 | 1.0000  |
| End-stage renal disease | 47 (0.8)            | 47 (0.8)                 | 1.0000  |
| Liver cirrhosis      | 32 (0.5)                 | 32 (0.5)                 | 1.0000  |
| Parkinson’s disease  | 24 (0.4)                 | 24 (0.4)                 | 1.0000  |
| **Type of heart disease** |                     |                          | 1.0000  |
| Acute myocardial infarction | 1014 (16.2) | 1014 (16.2) |         |
| Other acute and subacute IHD | 254 (4.1)   | 254 (4.1) |         |
| Angina pectoris       | 286 (4.6)                | 286 (4.6)                |         |
| Other chronic IHD    | 2199 (35.1)              | 2199 (35.1)              |         |
| Acute and subacute endocarditis | 25 (0.4) | 25 (0.4) |         |
| Acute myocarditis     | 4 (0.1)                  | 4 (0.1)                  |         |
| Other diseases of pericardium | 11 (0.2) | 11 (0.2) |         |
| Other diseases of endocardium | 89 (1.4) | 89 (1.4) |         |
| Cardiomyopathy        | 43 (0.7)                 | 43 (0.7)                 |         |
| Conduction disorders  | 57 (0.9)                 | 57 (0.9)                 |         |
| Cardiac dysrhythmias  | 892 (14.2)               | 892 (14.2)               |         |
| Heart failure         | 1383 (22.1)              | 1383 (22.1)              |         |
| Ill-defined descriptions and complications of heart disease | 7 (0.1) | 7 (0.1) |         |
| Number of hospitalizations |            |                          | 1.0000  |
| 0                    | 4173 (66.6)              | 4173 (66.6)              |         |
| 1                    | 1184 (18.9)              | 1184 (18.9)              |         |
| 2                    | 352 (5.6)                | 352 (5.6)                |         |
| ≥3                   | 555 (8.9)                | 555 (8.9)                |         |
| Number of emergency visits |          |                          | 1.0000  |
| 0                    | 2956 (47.2)              | 2956 (47.2)              |         |
| 1                    | 1547 (24.7)              | 1547 (24.7)              |         |
| 2                    | 703 (11.2)               | 703 (11.2)               |         |

(Continued)
mortality compared with those cared by general physicians. Shorter length of hospital stays was also noted in inpatients receiving a cardiologist’s medical services. The association between a cardiologist’s care and less adverse events following admission was significant in several of the subgroups including gender, age group of more than 40 years and patients with various medical conditions, previous emergency and inpatient care.

We proposed some possible explanations to clarify the beneficial effects of receiving a cardiologist’s care on the outcome of admission due to cardiovascular disease. First, the cardiologists tended to use more exact diagnostic procedures and were characterized by better adherence to certain evidence-based processes of care [8,9,12,14,21–24], such as beta-blockers [9,10,25–29], calcium channel blockers or angiotensin-converting enzyme inhibitors [28,29]. Second, a cardiologist is also associated with a better disease guideline compliance, which not only includes the acute phase of the disease medical care but also the disease risk factor survey, emergency care, management during hospitalization and at discharge, long-term therapies and complication management [12,13,15,30]. Third, the cardiologist is also more aggressive when selecting the most appropriate intervention procedure or when transferring the patient to a surgeon for operation if they are unable to cure the patient [8,14,18]. Although the previous study suggested that the differences of outcome disappeared after adjusting for differences in patient demographics and comorbidities between cardiologist and non-cardiologist treated patients [31], our study found the less infectious complications and mortality in patients received inpatient care by cardiologists after the propensity-score matching. It revealed that future well-design studies even randomized clinical trials are necessary for presenting the reliable evidence.

Fourth, another explanation is the distribution of cardiologists between hospitals and the complexity of the hospital. In Taiwan, the medical center usually has an integrated specialist departmental system, more medical resources and more cardiologists. A patient suffering

Table 1. (Continued)

| Number ≥3 | NC physicians (N = 6264) | Cardiologists (N = 6264) | P value |
|-----------|--------------------------|--------------------------|---------|
|           | 1058                     | (16.9)                   |         |

COPD, chronic obstructive pulmonary disease; NC, non-cardiologist; IHD, ischemic heart disease.

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Table 2. Adverse events after admission of heart disease in patients who received care by cardiologists and NC physicians.

| Outcomes after admission     | NC physicians (N = 6264) | Cardiologists (N = 6264) | Outcome risk |
|------------------------------|--------------------------|--------------------------|--------------|
|                              | Events | %          | Event | %          | OR (95% CI) |
| 30-day in-hospital mortality | 249    | 4.0        | 94    | 1.5        | 0.37 (0.29–0.47) |
| Pneumonia                    | 530    | 8.5        | 334   | 5.3        | 0.61 (0.53–0.70) |
| Septicemia                   | 238    | 3.8        | 118   | 1.9        | 0.49 (0.39–0.61) |
| Urinary tract infection      | 429    | 6.9        | 331   | 5.3        | 0.76 (0.66–0.88) |
| ICU stay                     | 2072   | 33.1       | 2139  | 34.2       | 1.05 (0.97–1.13) |
| Medical expenditure, USD     | 2454±3053 | p = .0860  | 2542±2645 | p = .0001 |
| Length of hospital stay, days| 7.7±19.7 | p = .0001  | 5.7±7.0 | p = .0001  |

NC, non-cardiologist; CI, confidence interval; OR, odds ratio.

b Analyzed by univariate logistic regressions after propensity-score matching.

Means±SD; In the multiple regressions, the medical expenditure (beta = 87.6, P = .0774) and length of hospital stay (beta = -1.98, P < .0001) were associated with cardiologists.

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| Adverse events* | n   | Events | Rate, % | OR (95% CI) |
|-----------------|-----|--------|---------|-------------|
| Female          |     |        |         |             |
| NC physicians   | 2519| 580    | 23.0    | 1.00 (reference) |
| Cardiologists   | 2519| 414    | 16.4    | 0.66 (0.57–0.76) |
| Male            |     |        |         |             |
| NC physicians   | 3745| 574    | 15.3    | 1.00 (reference) |
| Cardiologists   | 3745| 359    | 9.6     | 0.59 (0.51–0.67) |
| Age 20–39 years |     |        |         |             |
| NC physicians   | 239 | 26     | 10.9    | 1.00 (reference) |
| Cardiologists   | 239 | 17     | 7.1     | 0.63 (0.33–1.19) |
| Age 40–49 years |     |        |         |             |
| NC physicians   | 503 | 42     | 8.4     | 1.00 (reference) |
| Cardiologists   | 503 | 24     | 4.8     | 0.55 (0.33–0.92) |
| Age 50–59 years |     |        |         |             |
| NC physicians   | 1099| 102    | 9.3     | 1.00 (reference) |
| Cardiologists   | 1099| 60     | 5.5     | 0.56 (0.41–0.79) |
| Age 60–69 years |     |        |         |             |
| NC physicians   | 1270| 159    | 12.5    | 1.00 (reference) |
| Cardiologists   | 1270| 98     | 7.7     | 0.58 (0.45–0.76) |
| Age 70–79 years |     |        |         |             |
| NC physicians   | 1825| 385    | 21.1    | 1.00 (reference) |
| Cardiologists   | 1825| 268    | 14.7    | 0.64 (0.54–0.76) |
| Age ≥80 years   |     |        |         |             |
| NC physicians   | 1328| 440    | 33.1    | 1.00 (reference) |
| Cardiologists   | 1328| 306    | 23.0    | 0.60 (0.51–0.72) |
| 0 medical condition |  |        |         |             |
| NC physicians   | 2051| 362    | 17.7    | 1.00 (reference) |
| Cardiologists   | 2051| 222    | 10.8    | 0.57 (0.47–0.68) |
| 1 medical condition |  |        |         |             |
| NC physicians   | 2586| 472    | 18.3    | 1.00 (reference) |
| Cardiologists   | 2586| 326    | 12.6    | 0.65 (0.55–0.75) |
| ≥2 medical conditions |  |        |         |             |
| NC physicians   | 1627| 320    | 19.7    | 1.00 (reference) |
| Cardiologists   | 1627| 225    | 13.8    | 0.66 (0.54–0.79) |
| 0 hospitalizations |  |        |         |             |
| NC physicians   | 4173| 649    | 15.6    | 1.00 (reference) |
| Cardiologists   | 4173| 436    | 10.5    | 0.63 (0.56–0.72) |
| 1 hospitalizations |  |        |         |             |
| NC physicians   | 1184| 240    | 20.3    | 1.00 (reference) |
| Cardiologists   | 1184| 159    | 13.4    | 0.61 (0.49–0.76) |
| 2 hospitalizations |  |        |         |             |
| NC physicians   | 352 | 90     | 25.6    | 1.00 (reference) |
| Cardiologists   | 352 | 62     | 17.6    | 0.62 (0.43–0.90) |
| ≥3 hospitalizations |  |        |         |             |
| NC physicians   | 555 | 175    | 31.5    | 1.00 (reference) |
| Cardiologists   | 555 | 116    | 20.9    | 0.57 (0.44–0.75) |
| 0 emergency visits |  |        |         |             |
| NC physicians   | 2956| 473    | 16.0    | 1.00 (reference) |
| Cardiologists   | 2956| 318    | 10.8    | 0.63 (0.54–0.74) |
| 1 emergency visits |  |        |         |             |
| NC physicians   | 1547| 307    | 19.8    | 1.00 (reference) |
| Cardiologists   | 1547| 192    | 12.4    | 0.57 (0.47–0.70) |
| 2 emergency visits |  |        |         |             |
| NC physicians   | 703 | 141    | 20.1    | 1.00 (reference) |
| Cardiologists   | 703 | 80     | 11.4    | 0.51 (0.38–0.69) |
| ≥3 emergency visits |  |        |         |             |
| NC physicians   | 1058| 233    | 22.0    | 1.00 (reference) |
| Cardiologists   | 1058| 183    | 17.3    | 0.74 (0.60–0.92) |
| No other chronic IHD |  |        |         |             |
| NC physicians   | 4065| 993    | 24.4    | 1.00 (reference) |
| Cardiologists   | 4065| 648    | 15.9    | 0.59 (0.53–0.66) |
| Other chronic IHD |  |        |         |             |
| NC physicians   | 2199| 161    | 7.3     | 1.00 (reference) |
| Cardiologists   | 2199| 125    | 5.7     | 0.76 (0.60–0.97) |
| No heart failure |  |        |         |             |
| NC physicians   | 4881| 744    | 15.2    | 1.00 (reference) |
| Cardiologists   | 4881| 472    | 9.7     | 0.60 (0.53–0.67) |
| Heart failure   |  |        |         |             |
| NC physicians   | 1383| 410    | 29.7    | 1.00 (reference) |
| Cardiologists   | 1383| 301    | 21.8    | 0.66 (0.56–0.78) |

(Continued)
from a cardiovascular disease admitted to the medical center may receive cardiologist’s care with more ease than others who are admitted to metropolitan hospitals. The relationship between cardiovascular mortality and physician volume, and hospital volume/complexity has been proved [10,32]. In our study database, which involves a national cohort, the type of hospital the patients were admitted to was not included. The difference in distribution between cardiologists and general physicians between hospitals may contribute to the disease outcome. In addition, the type of ward is also related to a patient’s health outcome. Patients admitted to the cardiovascular units at medical centers may benefit from more comprehensive care and a higher number of therapies [11,33–37]. Patients also receive better nursing care focusing on cardiovascular complications, better medical attention by doctors and stay in a less complex medical care unit. A simpler ward environment and patient population may also relate to a lower hospital acquired infection rate. Finally, an increased patient compliance with the attending physician’s instructions, due to a better doctor-patient relationship, is also a possible explanation. Past studies revealed that increasing adherence to attendance may decrease short-term readmission rate or mortality [12,38–40]. We observed that in Taiwan, it is at the discretion of the emergency physicians to shunt patients during admission in many regional or district hospitals. Emergency physicians may also interfere with assignment of the patients to their attending physician. For example, emergency physicians tend to increasingly assign new cases to general physicians, which may increase the misclassification rate.

We noticed that patients aged between 30–39 years old did not have better outcomes under a cardiologist’s care. The possible explanation for this is that patients in this age group are healthier and more resistant to diseases or have a more rapid rehabilitation ability. On the other hand, from the epidemiological point of view, this comprehensive outcome difference between general physicians and cardiologists definitely demonstrates that the attending physician’s specialty affects the quality of the cardiovascular disease treatment.

Interpretation of our findings should be done with caution because of some study limitations. First, information regarding the location of residence, lifestyle, family history of cardiovascular disease, clinical risk scores, clinical blood sample lab data and seniority of the doctors were unavailable in the database and these factors may be residual confounders in our study. The location of residence may be one of factors associated with patients to be in cardiologist group or NC group because the small hospital located in very rural area has no cardiology specialty. Second, we do not have detailed data regarding the consultation of a cardiologist during

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Table 3. (Continued)

|                | Adverse events* | n  | Events | Rate, % | OR (95% CI)* |
|----------------|-----------------|----|--------|---------|--------------|
| No AMI         | NC physicians   | 5250| 886    | 16.9    | 1.00 (reference) |
|                | Cardiologists   | 5250| 592    | 11.3    | 0.63 (0.56–0.70) |
| AMI            | NC physicians   | 1014| 268    | 26.4    | 1.00 (reference) |
|                | Cardiologists   | 1014| 181    | 17.9    | 0.61 (0.49–0.75) |
| No cardiac dysrhythmias | NC physicians   | 5372| 931    | 17.3    | 1.00 (reference) |
|                | Cardiologists   | 5372| 679    | 12.6    | 0.69 (0.62–0.77) |
| Cardiac dysrhythmias | NC physicians   | 892 | 223    | 25.0    | 1.00 (reference) |
|                | Cardiologists   | 892 | 94     | 10.5    | 0.35 (0.27–0.46) |

CI, confidence interval; NC, non-cardiologist; OR, odds ratio.
*Adverse events included with 30-day in-hospital mortality, pneumonia, septicemia, urinary tract infection.
*Analyzed by univariate logistic regressions after propensity-score matching.

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the inpatient care by the general physicians. However, this limitation may contribute to the underestimation of beneficial effects of a cardiologist’s services on inpatients with cardiovascular diseases. Third, we did not match the hospital complexity/volume in both groups, which may be a confounding factor as mentioned before and in past studies [10,32], because there are no related data in Taiwan’s National Health Insurance database. Type of hospital is one of the potential confounding factors in this study. Fourth, we also did not normalize the use of medications, diagnosis procedures and treatment between both groups, which were usually compared in earlier references as the major results and causes. In contrast with other studies that were focused on only one cardiovascular disease [6,8–11,14–15], our analysis included nearly all common cardiovascular diseases along with many subtypes. In addition, our study focused on short-term complications and mortality following admission due to cardiovascular diseases, excluding out-patient outcomes. In contrast, with previous reports [6,7,10,11,15,16], we believed that the short-term and admission outcomes may related to the type of physician service, thus underscoring the a cardiologist’s value. Finally, the validation of Taiwan’s National Health Insurance Research Database remains inadequate although the physician’s diagnosis and codes of diseases were validated in previous studies [41–46]. We also could not exclude the possibility of residual confounding variables although several potential confounders were adjusted for in our analysis models.

In conclusion, we raised that possibility that cardiologist care was associated with reduced infectious complications, mortality, and length of hospital stay among patients admitted due to HD. Our study implicates that the role of the physician specialty is crucial in the inpatient care of cardiovascular disease. Consultation with a cardiologist is encouraged when a general physician is providing medical care to patients with cardiovascular diseases.

Supporting information

S1 Table. Characteristics of patients with cardiovascular admission receiving care by cardiologists and NC physicians.

(DOC)

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