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# Impact of Board-Certified Cardiologist Characteristics on Risk of In-Hospital Mortality

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***Background:*** This study examined the influence of board-certified cardiologist characteristics on the in-hospital mortality of patients with cardiovascular disease.

***Methods and Results:*** Data were collected between 2012 and 2014 from a nationwide database of acute care hospitals in Japan. Overall, there were 1,422,703 patients, of whom 883,746 were analyzed. The primary outcome was all-cause in-hospital mortality. The association between board-certified cardiologist characteristics and in-hospital mortality was estimated using multilevel mixed-effect logistic regression modeling. Median age of cardiologists in a hospital was not related to in-hospital mortality (OR, 1.003; 95% CI: 0.998–1.008, P=0.316), but a greater cardiologist age range was associated with a lower risk of in-hospital mortality (OR, 0.992; 95% CI: 0.988–0.995 per 1-unit increment in age range, P<0.001). Meanwhile, the average years of experience of the board-certified cardiologists in a hospital was not associated with a lower risk of in-hospital mortality (OR, 1.002; 95% CI: 0.996–1.007, P=0.525), but a greater range of years of experience was (OR, 0.986; 95% CI: 0.983–0.990 per 1-unit increment in range of years of experience, P<0.001).

***Conclusions:*** Median board-certified cardiologist age/experience at an institution is not related to in-hospital mortality, but a greater range in age/experience is associated with a lower risk of mortality.

**Key Words:** Board-certified cardiologist; Cardiovascular disease; In-hospital mortality

Recent advancements in the treatment of cardiovascular disease (CVD) have resulted in substantial decreases in related mortality rates.[1,2] CVD, however, still causes 17.9 million deaths every year, corresponding to 31% of all deaths worldwide. Further, according to World Health Organization projections, the worldwide CVD-related burden will reach 47 million disability adjusted life years (years lost due to disability, ill-health, or death) by 2020.[2]

The expanded use of medical therapies is increasing the quality of cardiac medical care, and hopefully decreasing mortality rates.[3–6] Board-certified physicians are skilled, knowledgeable experts in their specialty, and practice a higher standard of medicine in their fields. Patients who are hospitalized as a result of CVD have been found to receive better care from cardiologists than from physicians who specialize in other disciplines,[7–9] but no study has yet investigated the influence that board-certified physicians have on patient prognosis.

In this study, using the Japanese Registry of all Cardiac and Vascular Diseases (JROAD), we examined the relationship between the characteristics (e.g., age and years of experience) of hospital board-certified cardiologists and the hospitals' respective patient outcomes. JROAD is a nationwide database that stores data concerning hospital and patient characteristics, principal diagnoses, comorbidities at admission, complications after admission, procedures during hospitalization, and discharge status.

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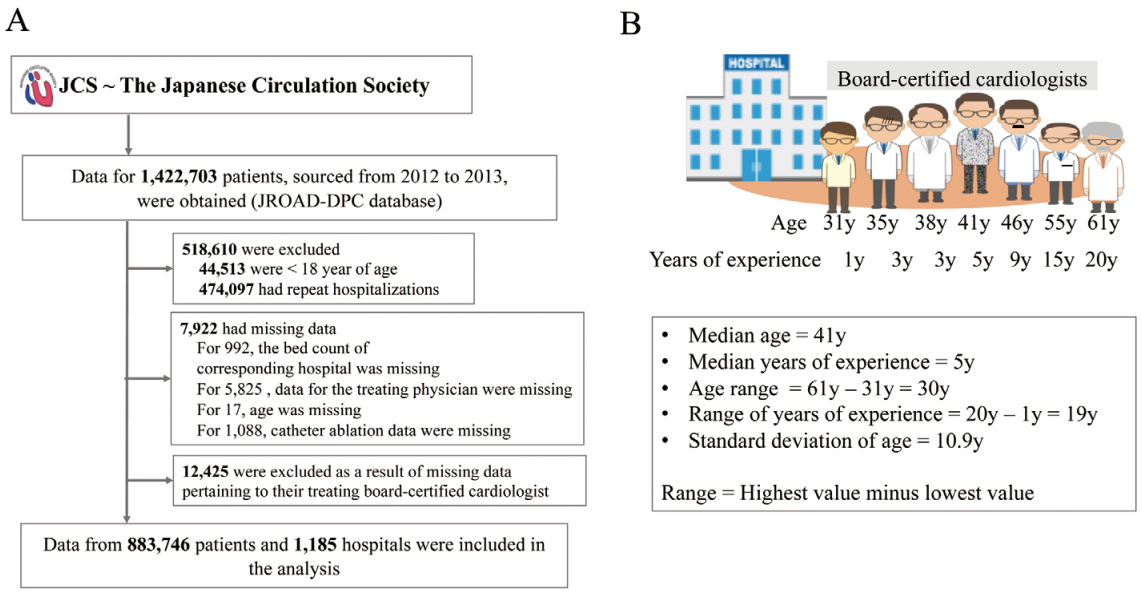


**Figure 1.** Flow chart of subject selection. Almost all diagnostic procedure combination (DPC) hospitals with cardiovascular beds meet the Japanese Circulation Society (JCS) requirements. All training hospitals and hospitals associated with JCS must provide institutional data (hospital bed count, number of board-certified cardiologists etc.) and DPC hospitals must also provide patient data (age, gender, International Classification of Diseases and Injuries 10th revision codes etc.). JROAD, Japanese Registry of all Cardiac and Vascular Diseases.

## Methods

### Patient and Public Involvement

The JROAD database is a nationwide prospective registry that was designed to assess the clinical activity of every Japanese institution that provides cardiovascular care, and to provide adequate feedback to teaching hospitals regarding improving patient care. A detailed description of the database's design and methods has previously been published.[9–11] Briefly, however, the JROAD database, which has stored demographic information for every hospital since 2004, and the JROAD-DPC nationwide database, which has stored data pertaining to the Japanese Diagnosis Procedure Combination/Per Diem Payment System (DPC/PDPS) since 2012, were developed by the Japanese Circulation Society (JCS). The DPC database is a mixed-case classification system linked with a lump-sum payment system, and was launched in 2002 by the Ministry of Health, Labour and Welfare of Japan.[12] Compared with other registry databases, the DPC database enables researchers to conduct nationwide studies of both descriptive and/or analytical epidemiology in real-world clinical settings. The DPC database includes data on the following elements: patient demographics (e.g., age and gender); principal diagnosis (coded according to the International Classification of Diseases and Injuries, 10th revision; ICD-10); comorbidities at admission (ICD-10 coded); complications after admission (ICD-10-coded); procedures, including surgery, medication, and devices used during hospitalization; length of stay; discharge status; and medical expenses.[10,12–14] A wide variety of centers, including academic, urban, and rural hospitals, use the DPC system.[10,15]

Considering the aforementioned characteristics of the JROAD-DPC database, we considered it to be an ideal source for the present research topic: namely, the effects of the characteristics of board-certified cardiologists on patient outcome.

All data obtained for this study from the JROAD database concerned hospitalized patients with clinically apparent CVD. This research was approved by the institutional review board of St. Marianna University School of Medicine (registration no. 3419). Further, all patient data were anonymized, given that each hospital used code-change equations to encrypt patient IDs in the database. Individual data (including age, gender, and hospital bed count) were sent to the JROAD data center using an electronic data capture system or recordable compact disc.

### Study Design and Sampling

We conducted a cross-sectional study using both the JROAD and JROAD-DPC databases, recording entries made in the databases between 1 April 2012 and 31 March 2014. A total of 2,407 hospitals are included in the JROAD database and, of these, 1,247 (52%) have adopted the DPC system and have agreed to participate in the JROAD-DPC database project (**Figure 1**). The characteristics of hospitals that did provide JROAD-DPC data and those that did not, along with the ICD-10 diagnosis codes, have been summarized in a previous study.[10] A total of 1,422,703 consecutive patients were initially included in this study, but 538,957 patients were later excluded because of missing data, being <18 years of age with no pediatrician data, or having a history of prior hospitalization. Patients who had no missing variables were included in the analyses (n=883,746).

Data for board-certified cardiologists were collected from JCS. According to the JCS website (http://www.j-circ.or.jp/information/senmoni/index.htm), board-certified

**Table 1. Patient, Facility, and Cardiologist Characteristics**

| | Nationwide database |
|---|---|
| **Patient demographics (n=883,746)** | |
| Age (years) | 73 (64–81) |
| Male gender | 547,558 (62) |
| Cardiovascular disease | |
| Angina | 233,404 (26) |
| Acute MI | 46,922 (5) |
| Heart failure | 145,431 (16) |
| Aortic disease | 72,058 (8) |
| Pulmonary embolism | 6,073 (0.7) |
| Atrial fibrillation or flutter | 46,645 (5) |
| Cardiac arrest | 52,155 (6) |
| Coexisting condition | |
| Charlson comorbidity index | 1 (0–2) |
| Outcome | |
| In-hospital death rate | 102,667 (13.2) |
| **Facility demographics (n=1,185)** | |
| No. hospital beds | 476 (334–646) |
| Cardiac surgery facility | 710,631 (80) |
| No. board-certified cardiologists | 5 (4–9) |
| No. hospitals with: | |
| <300 beds | 143,621 (16) |
| 300–449 beds | 254,721 (29) |
| 450–749 beds | 347,679 (39) |
| >749 beds | 137,725 (16) |
| **Board-certified cardiologist demographics (n=14,276)** | |
| Age (years) | 47 (41–55) |
| Male | 12,747 (89) |
| Years of experience (years) | 9 (4–17) |
| Age range per hospital (years) | 33 (32–65)† |
| Range of years of experience per hospital (years) | 23 (0–23)† |

Data given as n (%), median (IQR) or †median (range). MI, myocardial infarction.

cardiologists must (1) be regular members of the JCS for a minimum of 6 years; (2) be board-certified members of the Japanese Society of Internal Medicine, the Japan Surgical Society, the Japan Pediatric Society, the Japanese Association of Thoracic Surgery, or the American Society of Internal Medicine; (3) have completed 3 years of training at a certified institution; and (4) have passed the board certification examination offered by the JCS. Years of experience was calculated as the difference between the year we sourced the data (2012 or 2013) and the year the individual in question became a board-certified cardiologist.

Each hospital annually confirms the certifications of their board-certified cardiologists, but only records in the JROAD database the total number of board-certified cardiologists employed by the hospital (i.e., no identifying information is provided); this means that we were unable to create a merged dataset through which we could identify which physician was responsible for treating which patients.

For each hospital, the number of non-board-certified cardiologists per year was defined as the total number of cardiologists at a given hospital minus the number of board-certified cardiologists at the hospital. Finally, the ratio of beds to board-certified cardiologists was calculated by dividing the number of beds per hospital by the number of board-certified cardiologists for that same hospital. A higher index represents a greater number of beds per board-certified cardiologist.

### Outcome

The primary outcome was the occurrence of in-hospital mortality for any cause (i.e., not necessarily cardiac related). This was possible because JROAD-DPC data can provide a relatively complete perspective of mortality during hospitalization.

### Statistical Analysis

For each hospital, board-certified cardiologist age, years of experience, and the range of each of these characteristics were divided into quartiles. If patients were hospitalized more than once during the study period, we used only the data associated with the last admission, while recording the total number of prior hospitalizations. To assess the association between the characteristics of the board-certified cardiologists and in-hospital mortality, we used multilevel mixed-effects logistic regression models to estimate the odds ratios (OR) for in-hospital mortality. Each of the multilevel mixed-effects logistic regression model variables included a hierarchy level (hospital) that considered the random effects of hospital variation. All estimates were adjusted for hospital demographics (number of board-certified cardiologists, board-certified cardiologist gender, number of non-board-certified cardiologists, number of hospital beds, number of coronary care units, cardiac surgery facility, 8 regional divisions of Japan), patient demographics (patient age, gender, Charlson comorbidity index, and incidence rates of angina pectoris, myocardial infarction, atrial fibrillation, heart failure, aortic disease, cardiac arrest, pulmonary thromboembolism, primary pulmonary hypertension, tetralogy of Fallot, incident pneumonia during hospitalizations, and number of prior hospitalizations), and patient therapy (percutaneous coronary intervention, coronary artery bypass grafting, catheter ablation, implantable cardioverter defibrillator, and cardiac resynchronization therapy). The adjusted probabilities of in-hospital mortality were calculated in STATA using marginsplot, after the multilevel mixed-effects logistic regression analysis. All analyses were performed using STATA version 14 (Stata Corp, College Station, TX, USA).

## Results

### Patient, Facility, and Cardiologist Characteristics

The final study sample consisted of 883,746 patients with CVD who were admitted to DPC-participating hospitals. Both clinical presentation and facility characteristics are listed in **Table 1**. Overall, average patient age was 73 years, and 62% were male. The most common CVD were angina (26%), heart failure (16%), aortic disease (8%), and myocardial infarction (5%). Meanwhile, the median bed count of the institutions was 476, and the mean number of board-certified cardiologists per institution was 5. The average age of the board-certified cardiologists was 47 years, and 89% were male; meanwhile, average years of experience was 9. The average age range of the board-certified cardiologists per institution was 33 years (range, 32–65 years), while the average range of years of experience was 23 years (range, 0–23 years).

**Table 2. Cardiologist Board Certification and In-Hospital Death**

| In-hospital death (No. events: 102,667/883,746) | Adjusted OR (95% CI)† | | |
|---|---|---|---|
| | Adjusted for facility‡ | Adjusted for clinical characteristics§ | Adjusted for treatment¶ |
| **Board-certified cardiologists** | | | |
| Age (years) | 1.003 (0.998–1.008)†† | 1.006 (1.001–1.010)* | 1.006 (1.001–1.011)* |
| Age range (years) | 0.993 (0.990–0.996)*** | 0.991 (0.988–0.994)*** | 0.992 (0.988–0.995)*** |
| SD of age (years) | 0.991 (0.982–1.000) | 0.989 (0.98–0.997)* | 0.990 (0.982–0.999)* |
| **Years of experience as board-certified cardiologists** | | | |
| Years of experience (years) | 0.996 (0.99–1.002) | 1.002 (0.996–1.007) | 1.002 (0.996–1.007) |
| Range of years of experience (years) | 0.983 (0.979–0.987)*** | 0.986 (0.982–0.990)*** | 0.986 (0.983–0.990)*** |
| SD of years of experience | 0.976 (0.965–0.986)*** | 0.982 (0.972–0.991)*** | 0.982 (0.973–0.992)*** |

*P<0.05, ***P<0.001, ††P=0.316. †Multilevel mixed-effects logistic regression. ‡Model included no. board-certified cardiologists, board-certified cardiologist gender, no. non-board-certified cardiologists, no. hospital beds, no. coronary care units, cardiac surgery facility, 8-region division. §Model included, in addition to the facility model, patient age, gender, Charlson comorbidity index, and incidence of angina pectoris, myocardial infarction, atrial fibrillation, heart failure, aortic disease, cardiac arrest, pulmonary thromboembolism, primary pulmonary hypertension, tetralogy of Fallot, and incident pneumonia during hospitalizations. It also included no. prior hospitalizations. ¶Model included, in addition to the clinical characteristics model, percutaneous coronary intervention, coronary artery bypass grafting, catheter ablation, implantable cardioverter defibrillators, and cardiac resynchronization therapy.

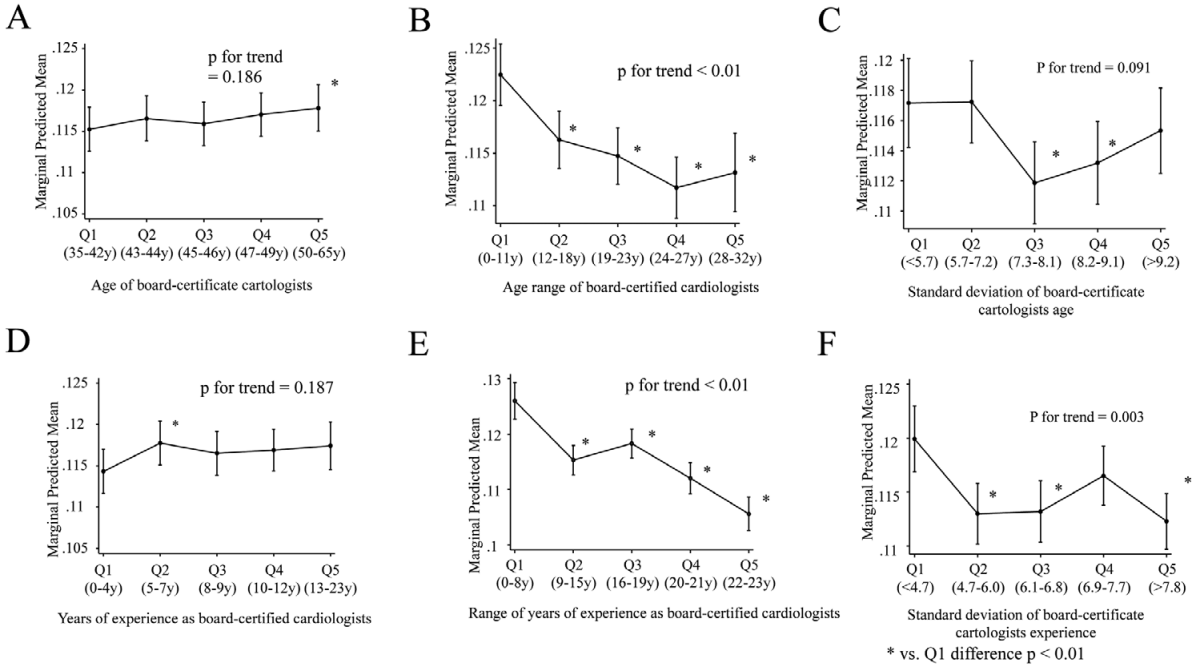


**Figure 2.** In-hospital mortality rates for cardiovascular disease vs. quintiles of (**A**) age, (**B**) age range, (**C**) age SD, (**D**) years of experience, (**E**) range of years of experience and (**F**) SD of range of years of experience of board-certified cardiologists, on a per-institution basis. Bars, 95% CI. Adjusted probability was calculated using the marginsplot command in STATA, and was adjusted as indicated in Table 2.

### Cardiologist Board Certification and In-Hospital Mortality

The overall in-hospital mortality rate was 13.2%. On multilevel mixed-effects logistic regression modeling (**Table 2**), the median age of the board-certified cardiologists per institution was not related to in-hospital mortality (OR, 1.003; 95% CI: 0.998–1.008; P=0.316), after adjusting for facility. A greater board-certified cardiologist age range at an institution, however, and a greater SD of age were found to be associated with a lower risk of in-hospital mortality (age range: OR, 0.992; 95% CI: 0.988–0.995 per 1-unit increment in age range, P<0.001; age SD: OR, 0.990; 95% CI: 0.982–0.999 per 1-unit increment in age range, P<0.05), after adjusting for facility, patient clinical characteristics, and treatment. On a per-institution basis, board-certified cardiologist average years of experience were not associated with a lower risk of in-hospital mortality (OR, 1.002; 95% CI: 0.996–1.007; P=0.525). A greater range of board-certified cardiologist years of experience at an institution, however, and a greater SD were found to be associated with a lower risk of respective in-hospital mortality (age range:

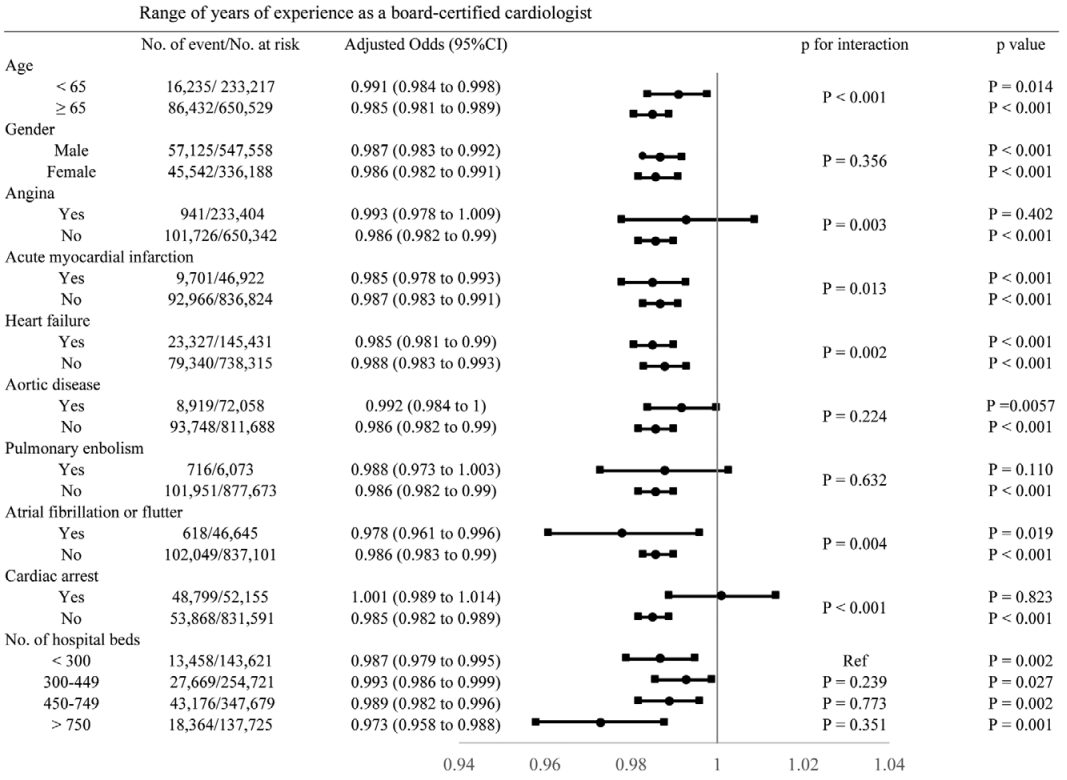


**Figure 3.** Adjusted OR and 95% CI for in-hospital mortality from cardiovascular disease according to board-certified cardiologist years of experience. OR <1.0 represents a decreased risk of in-hospital mortality as board-certified cardiologist years of experience increase. OR, dot; 95% CI, lines. OR were adjusted for both facility and patient characteristics and treatment, as indicated in Table 2.

OR, 0.986; 95% CI: 0.983–0.990, per 1-unit increment of years of experience, P<0.001; age SD: OR, 0.982; 95% CI: 0.973–0.992, per 1-unit increment in age range, P<0.001), after adjusting for facility, patient clinical characteristics, and treatment.

The association between board-certified cardiologists and in-hospital mortality is shown in **Figure 2**. A non-linear association was observed across the quartile of board-certified cardiologist age (P for trend=0.186; **Figure 2A**) for in-hospital mortality, SD of age (P for trend=0.091, **Figure 2C**), and quartile of board-certified cardiologist years of experience (P for trend=0.187; **Figure 2D**). A linear association was observed, however, across the quartile of board-certified cardiologist age range (P for trend<0.01; **Figure 2B**) for in-hospital mortality, and quartile of board-certified cardiologist range of years of experience (P for trend<0.01, **Figure 2E**), and SD of experience (P for trend=0.003; **Figure 2F**).

### Subgroup Analysis According to Heart Disease

Analysis of the association between board-certified cardiologist years of experience and in-hospital mortality according to disease is shown in **Figure 3**. On multilevel mixed-effects logistic regression modeling, significant interactions were seen between board-certified cardiologist years of experience in an institution and respective patient age (P<0.001), angina (P=0.0030; myocardial infarction (P=0.013), heart failure (P=0.002), atrial fibrillation (P=0.004), and cardiac arrest (P<0.001). There was no interaction effect, however, between board-certified cardiologist years of experience (on a per-institution basis), hospital volume, and in-hospital mortality.

## Discussion

Data om 1,185 hospitals and 896,171 patients, sourced from the JROAD and JROAD-DPC databases, were analyzed in this study, making it one of the largest, cross-sectional, retrospective studies conducted to date on nationwide, in-hospital health outcomes. We found that the median age/experience of the board-certified cardiologists in an institution is not related to respective in-hospital mortality, but that a greater range of board-certified cardiologist age/experience at an institution is associated with a lower risk of respective in-hospital mortality (**Figure 4**). This suggests that variation in board-certified cardiologist age/experience may have a meaningful impact on patient outcome.

Furthermore, in the present study median board-certified cardiologist age/experience at an institution was not related to respective in-hospital mortality. Patients treated by older physicians have been found to have higher mortality rates than patients treated by younger physicians.[16,17] It has also been reported that invasive treatments performed by specialists result in lower mortality rates than do similar treatments performed by non-specialists.[18,19] The present results are not consistent with those of previous studies.

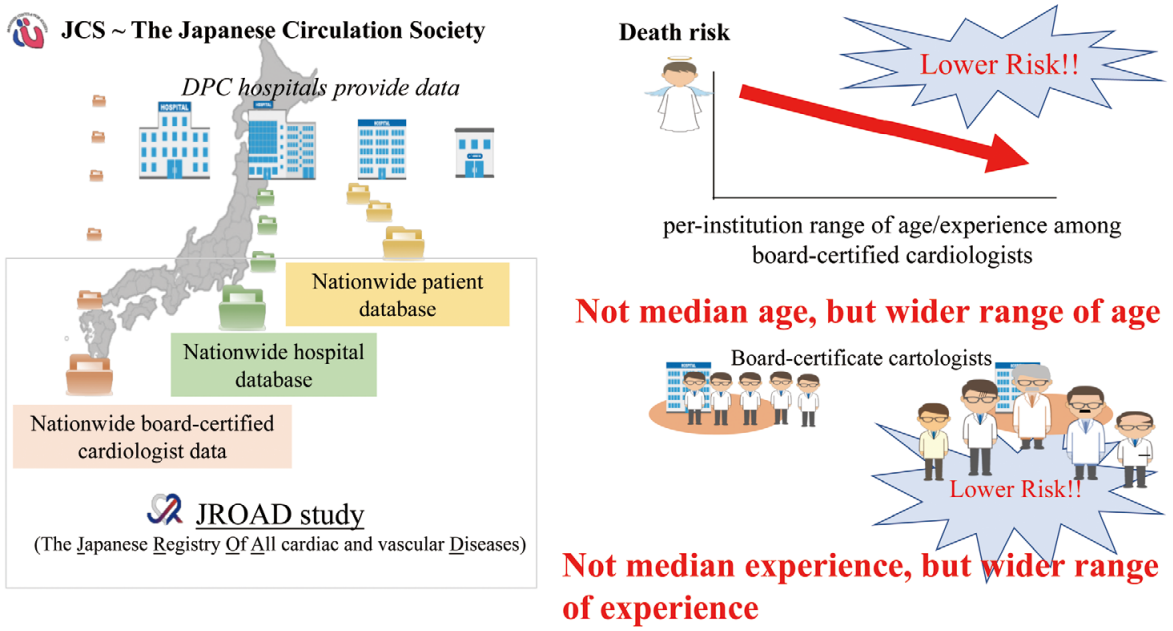


**Figure 4.** Summary of the present results. Data from the nationwide database of acute care hospitals in Japan, comprising 2,371 hospitals, were collected between 2012 and 2013. DPC, diagnostic procedure combination.

Compared with the previous reports, JROAD included only teaching hospitals and, in the present study, we included only board-certified physicians who have passed a specific exam of medical knowledge, clinical knowledge, and diagnosis skills. Burke et al reported that teaching hospitals were associated with lower mortality compared with non-teaching hospitals.[20] Teaching hospitals are more likely to be higher volume centers and to provide more technologically intensive care requiring specialized knowledge, than non-teaching hospitals.[20] Although physician age/experience may be an important factor for reducing the risk of patient death, other factors independent of physician age, such as special knowledge, skills, hospital volume, and attending professional training, have been confirmed to reduce the risk of patient death.[19,18,21,22] Therefore, physicians working at major teaching hospitals are more likely to continue advancing their knowledge and utilize the most up-to-date standard practices for patient care.

The second finding in the present study was that institutions with a greater range of board-certified cardiologist age/experience have a lower risk of in-hospital mortality. Compared with younger physicians, physicians who have been practicing for a higher number of years and who are older possess less factual knowledge and are less likely to adhere to appropriate standards of care.[17,23,24] In contrast, surgery mortality rates have been found to be lower for older surgeons than for younger surgeons.[25] Although the present findings did not support those of previous studies, it may be hypothesized that if younger physicians have more up-to-date knowledge, and older physicians have more experience, then a combination of the two, as reflected in a wider range of age/experience per hospital, could lower the risk of in-hospital death. In contrast to previous studies, the present study provides new evidence that hospitals with a wide range of board-certified cardiologist age/experience can provide good medical care in cardiology.

Also, according to the present subgroup analysis, board-certified cardiologist range of age/experience at an institution is associated with lower mortality rates for several diseases, excluding angina, pulmonary embolism (PE), and cardiac arrest. The regression models, after adjustment for patient characteristics, however, indicated that the latter 3 were indeed associated with a lower risk of in-hospital mortality. Given that the number of angina and PE cases was very small, these did not influence the result. Meanwhile, mortality rates concerning cardiac arrest have been found to be associated with, aside from hospital characteristics, shockable rhythm, patient age, time to cardiopulmonary resuscitation, and out-of-home events.[26–29] Thus, in institutions with high mortality rates, the influence of cardiac arrest may not be statistically significant.

## Study Limitations

This study had several limitations. First, we included only DPC hospitals with cardiovascular beds that met JCS requirements; JROAD, however, is the largest cross-sectional study of nationwide cardiac health outcomes in Japan. Second, evaluating only the association of board-certified cardiologists with any cause of death was not possible, because JROAD does not have data on cause of death. Third, the prevalence of in-hospital death of patients with angina, PE, and atrial fibrillation was low. Fourth, although the analysis of median age/years of experience was limited due to the relatively small number of board-certified cardiologists per hospital, this is the largest study yet to evaluate the association of board-certified cardiologists with in-hospital death, thus allowing for a unique investigation of the risk of death at a national level.

### Implications for Clinical Care

According to the present study, institutions with a greater range of board-certified cardiologist age/experience have a lower risk of in-hospital mortality. This suggests that the presence of a wide range of board-certified cardiologist age groups at a hospital is a benefit to clinical cardiac care (by preventing patient deaths), and that such diversity results in the cardiologists successfully maintaining competence and learning new skills and knowledge.

## Conclusions

Median board-certified cardiologist age/experience at an institution is not related to in-hospital mortality, but greater board-certified cardiologist age/experience range is associated with a lower risk of in-hospital mortality.

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### Author Contributions

M.W. and K.Y. contributed equally to this work. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

### Disclosures

K.Y. has received personal fees from Sanofi. Y.S. has received personal fees from Mitsubishi Tanabe Pharma Corporation, Otsuka Pharmaceutical, Novartis Pharma, Amgen Astellas BioPharma, Terumo Corporation, Astellas Pharma, Takeda Pharmaceutical, Teijin Pharma, Bayer Holding, Daiichi Sankyo, and MSD. K.N. has received personal fees from Mitsubishi Tanabe Pharma, Fillips Japan Corporation, and Tokyo Energy Holdings. Y.M., S.Y., T.M., and Y.J.A. are members of *Circulation Reports*' Editorial Team. The other authors declare no conflicts of interest.

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