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Short communication

Estimated life expectancy and risk of death from cancer by quartiles in the older Japanese population: 2010 vital statistics

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ABSTRACT

Data on life expectancies and risk of death from cancer are essential information to have when making informed decisions about cancer screening and treatment options, but has never been presented in a way that is readily available to use for physicians in Japan. We provided estimates of life expectancies and predicted risk of death from seven most common types of cancer (lung, gastric, liver, colon, prostate, breast, and cervical) by quartiles for the older Japanese population above 50 years old, using 2010 life tables and cancer mortality statistics data. We found that there was a large difference in life expectancy between older persons in the upper and lower quartiles. Risk of death from breast cancer was low. By using this data, physicians can more accurately obtain life expectancy estimates by assessing which quartile the patient is most likely to fall under, and help patients make better informed decisions.

1. Introduction

Treatment of older patients with cancer is a challenge for many clinicians. Standards of cancer care are often based on evidence from clinical trials obtained from younger uncomplicated patients, and may not be applicable to older patients with multiple comorbidities who may experience greater and prolonged side effects. The benefits of cancer treatment are also uncertain as physicians need to evaluate how long the patient has left to live, given that cancer treatment is successful, and whether the patient will consider the time gained from treatment to be worth the potential side-effects and complications. Cancer screening for older patients is also controversial, as screening could result in unnecessary psychological stress and physical complications in patients whose caner may never have resulted in symptomatic diseases until reaching their life expectancy or death from other comorbidities [1,2].

In order to address these issues, the Senior Adult Oncology Guidelines published by the National Comprehensive Cancer Network [3,4] recommend asking two questions when managing older patients with cancer: what is the likelihood that the cancer will shorten the patient's anticipated life expectancy, and the likelihood that the patient will experience or suffer from symptoms of cancer considering their overall life expectancy. These questions are crucial in making informed decisions, and require information on average life expectancies and risk of death from cancer for older persons of similar age and health status.

Walter and Covinsky [5] have provided this life expectancy data for the older American population using vital statistics from the United States (US). Although their results are informative for practitioners in the US, it is pertinent to provide this information for the Japanese population in a way that is readily available to use for practicing physicians in Japan. Therefore, the purpose of this study is to provide estimates of life expectancies and predicted risk of death from cancer by quartiles as a reference for physicians to use when counseling cancer screening and treatment options for older patients.

2. Methods

Although there is no tool for accurately predicting the life-expectancies of individuals, physicians can estimate the relative wellbeing of a person compared to other persons of similar age; if

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they are above, around, or below the average. By applying this clinical judgment to data on life expectancies by quartiles, physicians can obtain more clinically relevant estimates regarding the life expectancies of their patients. We used a similar framework introduced by Walter and Covinsky [5] and provided the life expectancies and risk of death from cancer by quartiles in the Japanese older population.

2.1. Life expectancies by quartiles

We calculated the remaining life expectancies for persons in the lower, median, and upper quartiles for men and women of ages 50 and above, by increments of 10 or 5 years, using the most recent life tables statistics (The 21st Complete Life Tables of Japan) [6]. Complete Life Tables are published every five years in Japan by the Statistics and Information Department of the Ministry of Health, Labor and Welfare using information from Annual Vital Statistics and Population Census Data. Life expectancies by quartiles were calculated by obtaining the number of years it takes for the population at a specific age to decrease to by 25%, 50%, and 75%. Therefore, the lower quartile represents the midpoint life expectancy between the shortest and the median life expectancy for a population at a specific age, and the upper quartile represents the midpoint between the longest and the median life expectancy.

2.2. Risk of death from cancer by quartiles

We estimated the risk of death for the seven most common types of cancer (lung, gastric, liver, colorectal, prostate, breast and cervical) in Japan by quartiles of life expectancy for specific ages using 2010 cancer mortality rates [7].

Risk of death from cancer was calculated by multiplying the number of years a person is expected to live by the mortality rate of cancer for the same age group, assuming that the patient had survived to reach that age group. Data on cancer mortality rates are provided by increments of 5 years [7]. Therefore, the 2.7% risk of death from lung cancer for a 70-year-old male person in the lower quartile was calculated by multiplying the mortality rate of lung cancer (237.1 deaths per 100,000 persons for ages 70–74, 384.4 deaths per 100,000 for ages 75–79) by his life expectancy of 9.4 years. According to the 2010 Life Tables, 89.19% of those who are 70 years old survive to 75 years of age. Therefore, the risk of death was obtained by $(5 \times 0.002371) + (0.8919 \times 4.4 \times 0.003844)$, which is the sum of the risk of death for the first 5 years (5×0.002371) and

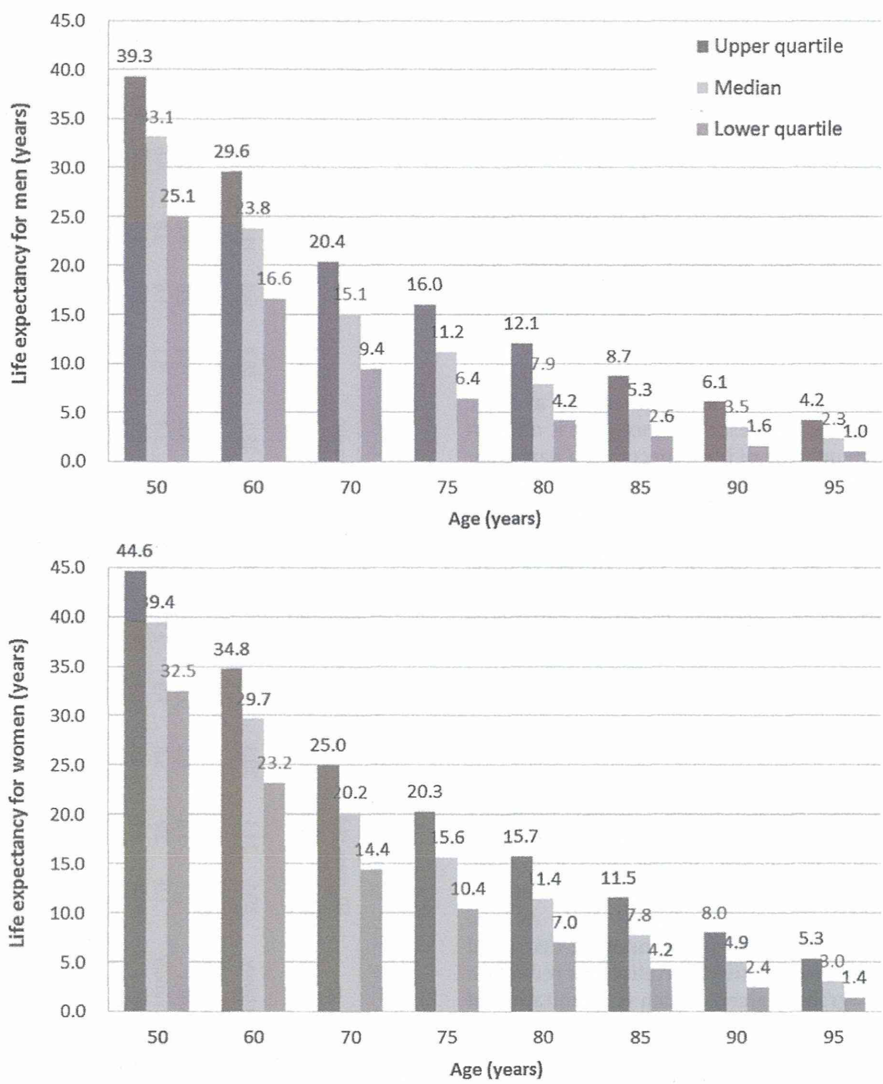

Fig. 1. Remaining life expectancies for men and women by quartiles (2010).

the risk for the next 4.4 years, given that he had survived the first 5 years (0.8919 × 4.4 × 0.003844).

3. Results

3.1. Life expectancies by quartiles

Remaining life expectancies for men and women by quartiles are presented in Fig. 1. When considering a cohort of Japanese men who are 80 years old, Fig. 1 shows that the upper quartile will live for another 12.1 years, the median for another 7.9 years, and the lowest quartile for 4.2 years on average.

3.2. Risk of death from cancer by quartiles

Risk of death from cancer by quartiles of life expectancy is presented in Table 1. Results show that 9.1% of 50 year olds who are above average in health and survive for 39.3 years will eventually die from lung cancer. Table 1 also shows that a 90 year old male person in the upper quartile, with remaining life expectancy of 6.1 years, has a higher risk of death from lung cancer (4.0%) compared to a 75 year old male person in the lower quartile with 6.4 years (2.6%), despite both men having similar life expectancies. This is because the mortality risk of cancer generally increases with advancing age.

4. Discussion

We presented the life expectancy and risk of death from cancer by quartiles for those who are 50 and older, using 2010 vital statistics of Japan. Compared to data provided by Walter and Covinsky [5], the Japanese population who are 50 years or older had life expectancy that was longer than the US population of the same age and sex by 2–3 years. Similarly to the US, there was a wide difference in life expectancy between the healthiest and sickest quartile of the Japanese population. Risk of death from breast cancer for older persons was lower compared to the US population.

If physicians are to follow practice guidelines presented by the NCCN, similar tables should be created for each country as these statistics differ greatly across countries [8]. Although it is difficult to accurately predict which quartile of life expectancy a particular patient may fall under, physicians can conduct a comprehensive geriatric assessment (CGA) to evaluate if patients have higher, moderate, or lower health risks compared to the average population of similar age. Cancer specific CGA introduced by Extermann et al. [9] recommend evaluating the patient's functional status, comorbidities, cognitive function, nutritional status, polypharmacy, geriatric syndromes, social support and psychological state for cancer patients before treatment decisions are made.

Life expectancy data could also be used when determining whether cancer screening is beneficial for older persons considering his or her life expectancy. In cancer screening, benefits of undergoing screening are generally expressed in terms of number needed to screen (NNS), which is obtained by taking the inverse of the difference in mortality risk of cancer among those who were not screened from among those who were. The absolute benefits of cancer screening for older patients in Japan, such as one demonstrated by Walter and Covinsky [5], cannot be discussed in full detail unless estimates for relative mortality risk reduction for a specific screening program is given, which is a limitation of this study. There has not been enough randomized clinical trials conducted to obtain a pooled effect estimate for publicly subsidized cancer screening programs using a population of senior Japanese citizens. Future studies are warranted to investigate the

Table 1
Risk of death from cancer by quartiles of life expectancy at specific ages for the Japanese population (2010).[a]

	50 years old			60 years old			70 years old			75 years old			80 years old			85 years old			90 years old			95 years old		
	Lower	Median	Upper	Lower	Median	Upper	Lower	Median	Upper	Lower	Median	Upper	Lower	Median	Upper	Lower	Median	Upper	Lower	Median	Upper	Lower	Median	Upper
Men																								
Life expectancy (years)	25.1	33.1	39.3	16.6	23.8	29.6	9.4	15.1	20.4	6.4	11.2	16.0	4.2	7.9	12.1	2.6	5.3	8.7	1.6	3.5	6.1	1.0	2.3	4.2
Risk of death from cancer[b]																								
Lung cancer	2.7	5.9	9.1	2.9	5.9	8.9	2.7	5.4	8.1	2.6	5.0	7.3	2.5	4.5	6.4	1.9	3.8	5.2	1.2	2.6	4.0	0.7	1.7	3.1
Gastric cancer	1.9	3.8	5.8	1.9	3.7	5.6	1.7	3.3	5.1	1.6	3.0	4.6	1.4	2.7	4.0	1.3	2.6	3.6	0.8	1.8	2.8	0.5	1.2	2.2
Liver cancer	1.4	2.7	3.6	1.4	2.6	3.4	1.3	2.2	2.9	1.1	1.9	2.5	0.8	1.4	1.9	0.5	1.0	1.4	0.3	0.7	1.1	0.2	0.5	0.8
Colorectal cancer	1.4	2.7	3.2	1.4	2.6	3.0	1.2	2.2	2.4	1.1	1.8	1.9	1.0	1.2	1.3	0.1	0.2	0.3	0.1	0.1	0.2	0.04	0.1	0.2
Prostate cancer	0.3	1.1	2.3	0.4	1.1	2.4	0.5	1.2	2.4	0.6	1.3	2.4	0.7	1.5	2.3	0.9	1.7	2.3	0.5	1.2	1.8	0.3	0.8	1.4
Women																								
Life expectancy (years)	32.5	39.4	44.6	23.2	29.7	34.8	14.4	20.2	25.0	10.4	15.6	20.3	7.0	11.4	15.7	4.2	7.8	11.5	2.4	4.9	8.0	1.4	3.0	5.3
Risk of death from cancer[b]																								
Colorectal cancer	1.4	2.7	3.6	1.4	2.6	3.5	1.2	2.4	3.2	1.1	2.2	3.0	1.1	1.8	2.7	1.1	1.8	2.3	0.6	1.2	1.6	0.4	0.8	1.3
Lung cancer	1.5	2.6	3.4	1.5	2.5	3.3	1.3	2.3	3.0	1.1	2.0	2.7	1.0	1.6	2.4	0.9	1.5	1.9	0.5	1.0	1.4	0.3	0.6	1.1
Gastric cancer	1.2	2.3	3.1	1.1	2.2	3.0	1.0	2.0	2.7	0.9	1.9	2.6	0.9	1.5	2.3	0.9	1.5	2.0	0.5	1.1	1.4	0.3	0.7	1.1
Liver cancer	1.0	1.5	1.9	1.0	1.5	1.9	0.9	1.4	1.8	0.8	1.2	1.6	0.6	0.9	1.3	0.4	0.7	1.0	0.2	0.5	0.7	0.1	0.3	0.5
Breast cancer	1.1	1.4	1.6	0.8	1.1	1.3	0.5	0.7	0.9	0.4	0.6	0.8	0.3	0.4	0.7	0.2	0.4	0.5	0.1	0.3	0.4	0.1	0.2	0.3
Cervical cancer	0.2	0.3	0.3	0.2	0.2	0.3	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.03	0.1	0.1	0.02	0.04	0.1

[a] Quartiles are presented as lower quartile, median, and upper quartile.
[b] Risk of death is given in percentages, as the number of deaths per 100 persons.

benefits of various cancer screening programs in Japan among the older population.

Lastly, it is important to note that age alone should not be the basis for or against cancer screening or treatment by itself. Factors such as performance status and comorbidities have been found to be independent risk factors for mortality among elderly cancer patients [4,10]. Clinicians also need to pay careful attention to patient preference, and their capacity to make decisions upon explanation of the potential harms of undergoing or forgoing screening and treatment. Information provided in this study is insufficient to base any clinical judgments on, and should only be used as a reference. Nevertheless, providing quantitative data to patients and the general public can promote rational discussions with their practitioners, and better allocation of limited health service resources within the society. Although we will need much more data than the information provided here, our analysis is a good start for such exploration.

Conflict of interest

The authors have no conflict of interest.

Authorship contribution

Data acquisition and analysis was performed by Momoko Iwamoto and Fumiaki Nakamura. Data was interpreted by Momoko Iwamoto, Fumiaki Nakamura and Takahiro Higashi. Critical revision of manuscript was done by Fumiaki Nakamura and Takahiro Higashi. Study conception and design was performed by Momoko Iwamoto, Fumiaki Nakamura and Takahiro Higashi. Manuscript was drafted by Momoko Iwamoto. Fumiaki Nakamura double checked data analysis. All authors have given their final approval of the revised paper to be published, and are accountable for the accuracy and integrity of this paper.

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Appropriateness Ratings of Percutaneous Coronary Intervention in Japan and Its Association With the Trend of Noninvasive Testing

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ABSTRACT

OBJECTIVES The aim of this study was to evaluate the appropriateness of percutaneous coronary intervention (PCI) in Japan and clarify the association between trends of pre-procedural noninvasive testing and changes in appropriateness ratings.

BACKGROUND Although PCI appropriateness criteria are widely used for quality-of-care improvement, they have not been validated internationally. Furthermore, the correlation of appropriateness ratings with implementation of newly developed noninvasive testing is unclear.

METHODS We assigned an appropriateness rating to 11,258 consecutive PCIs registered in the Japanese Cardiovascular Database according to appropriateness use criteria developed in 2009 (AUC/2009) and the 2012 revised version (AUC/2012). Trends of pre-procedural noninvasive testing and appropriateness ratings were plotted; logistic regression was performed to identify inappropriate PCI predictors.

RESULTS In nonacute settings, 15% of PCIs were rated inappropriate under AUC/2009, and this percent increased to 30.7% under AUC/2012 criteria. This was mostly because of the focused update of AUC, in which the patients were newly classified as inappropriate if they lacked proximal left anterior descending lesions and did not undergo pre-procedural noninvasive testing. However, these cases were simply not rated under AUC/2009. The amount of inappropriate PCIs increased over 5 years, proportional to the increase in coronary computed tomography angiography use. Use of coronary computed tomography angiography was independently associated with inappropriate PCIs (odds ratio: 1.33; $p = 0.027$).

CONCLUSIONS In a multicenter, Japanese PCI registry, approximately one-sixth of nonacute PCIs were rated as inappropriate under AUC/2009, increasing to approximately one-third under the revised AUC/2012. This significant gap may reflect a needed shift in appropriateness recognition of methods for noninvasive pre-procedural evaluation of coronary artery disease. (J Am Coll Cardiol Intv 2014;7:1000-9) © 2014 by the American College of Cardiology Foundation.

The advent of percutaneous coronary intervention (PCI) has significantly changed the treatment strategy for patients with coronary artery disease (CAD). However, although PCI has a significant benefit for reducing mortality and recurrent myocardial infarction among patients presenting

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with acute coronary syndrome (1), its survival benefit has not been clearly established for patients with stable CAD (2). Because the patients who undergo PCI are exposed to the risks of periprocedural complications such as bleeding or procedure-related myocardial infarction, the appropriate indications of PCI are of significant importance.

To promote the appropriate and judicious implementation of PCI, the American College of Cardiology Foundation and 6 other societies published joint appropriateness use criteria (AUC) for PCI in 2009 (AUC/2009) (3). These AUC have been applied to real-world clinical practice along with various registry data, and studies have demonstrated a strong possibility of PCI overuse in real-world practice in Western countries (4-6). However, reports on AUC application to patients outside of North America are sparse.

SEE PAGE 1010

In Japan, the number of PCI procedures has been increasing. More than 200,000 procedures in >800 hospitals were performed in 2012; this number is disproportionately large compared with the number of coronary artery bypass grafting (CABG) procedures. The number of PCI procedures is estimated to be >14 times greater than CABG procedures (7). Consequently, whereas the proportion of elective PCIs accounts for < 40% in the United States, as many as three-fourths of PCIs are performed in nonacute settings in Japan (7,8), and a greater number of patients with multivessel diseases are treated with PCI in Japan than in the United States (9). Furthermore, the pre-procedural evaluation is also quite different between the 2 countries: the performance of coronary CT angiography (CTA) is increasing remarkably in Japan, whereas the stress testing remains the main modality in the United States. These unique characteristics in Japan underscore the need for a proper evaluation of PCI appropriateness.

The purpose of our study was to evaluate the appropriateness of PCI indications in Japan on the basis of U.S. criteria and to compare the rate and characteristics of inappropriate PCIs between both countries. At present, 2 versions of AUC have been published in the United States. The original AUC/2009 was updated in 2012 (AUC/2012), emphasizing the importance of performing noninvasive stress testing before elective PCIs (10). The use of coronary CTA as a pre-procedural test is increasing in Japan and may have significantly altered appropriateness ratings. Although the risk of adverse cardiovascular events could be stratified by the extent of anatomic lesions on the basis of coronary CTA, computed tomography (CT)-based PCIs are rarely recognized as appropriate indications under current AUC. Therefore, in addition to reviewing the overall rating of PCI appropriateness, we sought to clarify its association with the trend in performing various noninvasive diagnostic tests.

ABBREVIATIONS AND ACRONYMS

AUC = appropriateness use criteria

CABG = coronary artery bypass grafting

CAD = coronary artery disease

CTA = computed tomography angiography

CT = computed tomography

FFR = fractional flow reserve

JCD = Japan Cardiovascular Database

PCI = percutaneous coronary intervention

PLAD = proximal left anterior descending artery

METHODS

DATA SOURCE. The Japan Cardiovascular Database (JCD) is an ongoing, prospective multicenter registry designed to collect clinical background and outcome data on consecutive PCI patients (11). In this registry, 16 teaching hospitals within the metropolitan Tokyo area participated and registered all PCI procedures performed during the study period, including failure cases, using an Internet-based interface. Approximately 200 variables were collected for each patient; clinical variables and in-hospital outcomes for JCD were defined in accordance with the National Cardiovascular Data Registry version 4.1. This registry, sponsored by the American College of Cardiology (12,13), is the largest national clinical registry program for diagnostic cardiac catheterization and PCI, with >1,500 centers currently participating across the United States. Additionally, in the JCD-PCI registry, the subgroup of patients who underwent an intracoronary infusion of acetylcholine to induce coronary vasospasm was also registered because vasospastic angina accounts for a significant portion of patients with CAD and acute coronary syndromes in Japan (14). Clinical research coordinators specifically trained in registering PCI procedures confirmed the proper registration of each patient. In addition, data reported on the Internet-based system were checked, and investigators visited each hospital quarterly to audit the database for completeness and consistency.

STUDY POPULATION. A total of 11,258 consecutive patients who underwent PCI procedures between September 2008 and March 2013 for acute and nonacute indications were registered in the database. A total of 1,208 patients were excluded because they underwent serial PCIs during the same hospitalization, there were insufficient baseline data, or they only underwent the acetylcholine challenge test. The remaining 10,050 patients were included in our study (Figure 1).

DEVELOPMENT OF AUC/2009 AND ITS RATING ASSIGNMENTS. AUC/2009 was developed by a collaboration of 6 American professional organizations

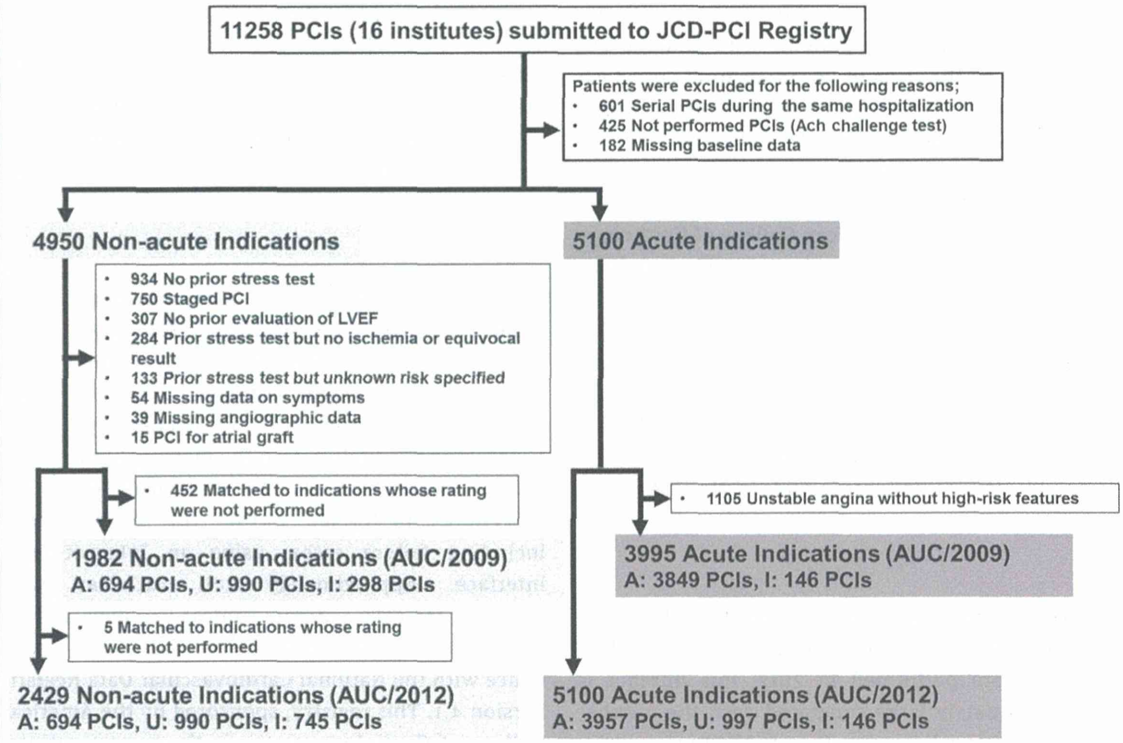

FIGURE 1 **Study Cohort Creation**

Patients registered in JCD-PCI Registry were divided into 2 groups (nonacute and acute indications). Each group was rated under AUC/2009 and AUC/2012. A = appropriate; Ach = acetylcholine; AUC = appropriateness use criteria; I = inappropriate; JCD-PCI = Japan Cardiovascular Database-Percutaneous Coronary Intervention; LVEF = left ventricular ejection fraction; U = uncertain.

(the American College of Cardiology Foundation, the Society for Cardiovascular Angiography and Intervention, the Society of Thoracic Surgeons, the American Association for Thoracic Surgery, the American Heart Association, and the American Society of Nuclear Radiology) in 2009. The methodology to develop the AUC for coronary revascularization was previously described (3).

We used an algorithm to map PCIs in the JCD-PCI registry to AUC/2009 and rate the procedures as appropriate, uncertain, or inappropriate. This algorithm, which was validated in a previous study (6), enabled the mapping to be performed in an efficient manner. All the definitions in our study were identical to those in AUC/2009. We optimized our mapping algorithm to maximize the use of existing data and minimize the influence of missing data. For example, certain nonacute indications can be assigned the appropriateness rating independent of noninvasive risk results (e.g., 3-vessel CAD with abnormal left ventricular systolic function). In these scenarios, an appropriateness classification could be provided even when noninvasive risk testing was not performed or results were not available.

Among the 10,050 patients, a rating could not be determined for 2,968 nonacute and 1,105 acute PCIs, leaving a total of 1,982 nonacute and 3,995 acute PCIs that could be rated (Figure 1). Among the acute indications, unstable angina without high-risk features was the main cause of rating failure. In the nonacute settings, mapping failure was mainly due to one of the following: no previous stress test performed, staged PCI, previous stress test with no ischemia or equivocal result, previous evaluation of left ventricular systolic function, and matched to indications that were not rated.

REVISED AUC/2012 AND ITS RATING ASSIGNMENTS. AUC/2009 was updated in 2012 (AUC/2012) (10). In the revised AUC/2012 version, unstable angina without high-risk features, which was an excluded clinical scenario in AUC/2009, was successfully mapped and divided into 2 indications according to the Thrombolysis In Myocardial Infarction score. In AUC/2009, the clinical scenario of an asymptomatic patient without previous bypass surgery and with 1- or 2-vessel disease not involving the proximal left anterior descending artery (PLAD) who underwent no noninvasive testing was not evaluated because it was thought to be uncommon. However, in the revised AUC/2012, this clinical scenario was determined to be inappropriate. Accordingly, successfully mapped procedures increased, and 2,429 nonacute and 5,100 acute PCIs were rated (Figure 1).

STATISTICAL ANALYSIS. The proportion of PCIs classified as appropriate, uncertain, or inappropriate was determined, after stratification by acute versus nonacute indications on the basis of AUC/2009 and AUC/2012. Baseline characteristics and clinical variables of patients were compared by appropriateness categories. Differences were evaluated using the chi-square or Fisher exact test for categorical variables and the Student unpaired *t* test for continuous variables. Cochran-Armitage analysis was used to evaluate the trends of the proportion of inappropriate PCIs and of the implementation of various tests. Multivariate logistic regression analysis was performed to examine the relationship between the implementation of coronary CTA and inappropriate PCI, adjusting for potential confounders. The covariates included in the model were symptomatic status (symptomatic vs. asymptomatic), extent of ischemic burden (low risk vs. intermediate or high risk), antianginal medication (optimal vs. suboptimal medication), angiographic characteristics (left main trunk, triple-vessel disease, chronic total occlusion, or PLAD), and the time period when the PCI was performed (divided into 8 categories: September 2008 to June 2009, July 2009 to December 2009, January 2010 to June 2010, July 2010 to December 2010, January 2011 to June 2011, July 2011 to December 2011, January 2012 to June 2012, and July 2012 to March 2013). Data were analyzed using SPSS, version 20 (SPSS Inc., Chicago, Illinois). All p values were 2-sided, and significance was defined as $p < 0.05$ for all analyses.

RESULTS

PATIENT CHARACTERISTICS. Table 1 summarizes the clinical characteristics of patients who underwent PCIs in acute and nonacute settings. The mean age was 67.9 ± 10.9 years; 79.4% were male. Coronary risk factors, including a history of myocardial infarction and PCI, hypertension, hypercholesterolemia, and diabetes mellitus, were common; however, the prevalence of a history of CABG was lower than that in previous reports (4).

TABLE 1 Baseline Characteristics of Acute and Nonacute PCIs

	Total (N = 10,050)	Acute (n = 5100)	Nonacute (n = 4950)
Demographics			
Male	7,978 (79.4)	3,972 (77.9)	4,006 (80.9)
Age, yrs	67.9 ± 10.9	67.5 ± 11.8	68.2 ± 9.7
Clinical factors			
Hypertension	7,462 (74.3)	3,588 (70.4)	3,874 (78.3)
Hypercholesterolemia	6,681 (66.6)	3,109 (61.1)	3,572 (72.2)
Diabetes mellitus	4,229 (42.1)	1,901 (37.4)	2,328 (47.0)
Current and past smoking	3,517 (35.1)	2,022 (39.8)	1,495 (30.3)
History of MI	2,501 (24.9)	799 (15.7)	1,702 (34.4)
Previous PCI	3,613 (36.0)	990 (19.4)	2,623 (53.0)
Previous CABG	532 (5.3)	195 (3.8)	337 (6.8)
Hemodialysis	430 (4.3)	181 (3.6)	249 (5.0)
Cerebrovascular disease	909 (9.1)	454 (8.9)	455 (9.2)
Peripheral arterial disease	817 (8.1)	292 (5.7)	525 (10.6)
Chronic lung disease	309 (3.1)	153 (3.0)	156 (3.2)

Values are n (%) or mean ± SD.

CABG = coronary artery bypass grafting; MI = myocardial infarction; PCI = percutaneous coronary intervention.

ACUTE INDICATIONS. Among the patients with acute indications for PCI, ST-segment elevation myocardial infarction was found in 49.3%, whereas cardiogenic shock was found in 16.9%. All clinical indications for appropriate and inappropriate PCIs in the acute settings are outlined in Table 2. Overall, most acute indications (96.3%) were categorized as appropriate under AUC/2009 (Figure 2, Online Table 1), whereas all inappropriate procedures were categorized as hemodynamic and electrically stable patients, with

TABLE 2 All the Clinical Scenarios in the Acute Setting

AUC/2009 Indication No.	Indication	n (%)
Appropriate PCI		
1	STEMI, ≤12 h from onset of symptoms Revascularization of the culprit artery	1,397 (35.0)
9	UA/NSTEMI and high-risk features of short-term risk if death or nonfatal MI Revascularization of the presumed culprit artery	1,361 (34.1)
11	Patients with acute myocardial infarction (STEMI or NSTEMI) Evidence of cardiogenic shock Revascularization of ≥1 coronary arteries	755 (18.9)
2	STEMI, onset of symptoms within the previous 12-24 h Severe HF, persistent ischemic symptoms, or hemodynamic or electrical instability present	336 (8.4)
Inappropriate PCI		
3	STEMI, >12 h from symptom onset Asymptomatic; no hemodynamic instability and no electrical instability	146 (3.7)

AUC = appropriateness use criteria; HF = heart failure; MI = myocardial infarction; NSTEMI = non-ST-segment elevation myocardial infarction; PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction; UA = unstable angina.

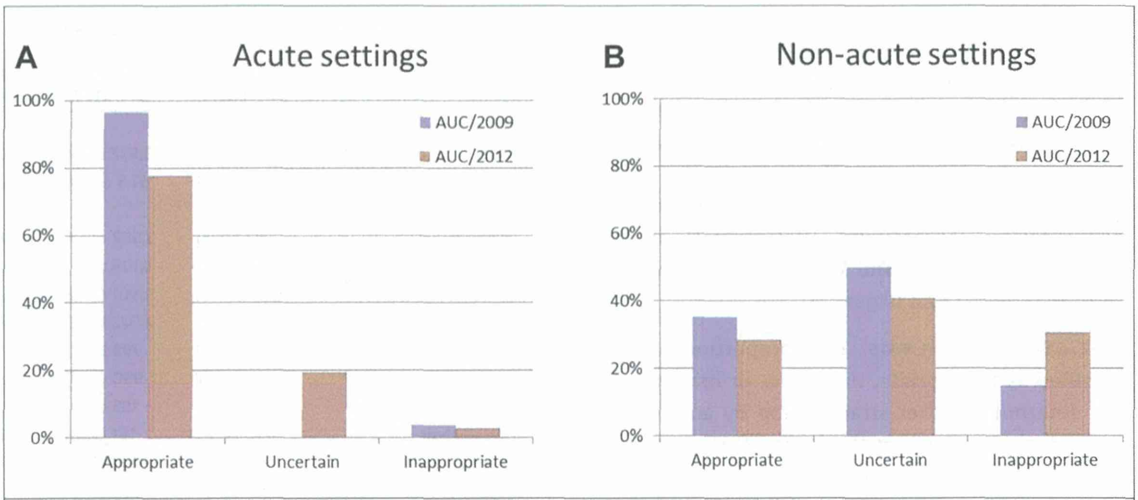

FIGURE 2 Appropriate Ratings Under Each Criterion

Appropriate ratings under each criterion in acute **(A)** settings and nonacute **(B)** settings. AUC = appropriateness use criteria.

PCI performed >12 h after symptom onset after ST-segment elevation myocardial infarction.

On the basis of AUC/2012, almost all cases of unstable angina without high-risk features (997 [90.2%]) were classified as uncertain, whereas 108 (9.8%) were considered appropriate. Overall, nearly 80% of acute procedures were categorized as appropriate (3,957 [77.6%]), whereas 997 (19.5%) were categorized uncertain and 146 (2.9%) were inappropriate (Figure 2, Online Table 1). All clinical indications for acute PCIs assessed by AUC/2012 are shown in Online Table 2.

NONACUTE INDICATIONS. In nonacute settings, 35.1% of PCIs were classified as appropriate, 49.9% as uncertain, and 15.0% as inappropriate under AUC/2009 (Figure 2, Online Table 1). Compared with procedures classified as appropriate or uncertain,

TABLE 3 Key Variables in Classifying Appropriateness for Nonacute PCIs in AUC/2009

		Procedural Appropriateness			
	Total (N = 1,982)	Appropriate (n = 694)	Uncertain (n = 990)	Inappropriate (n = 298)	p Value
Angina					<0.001
No symptoms	555 (32.2)	172 (24.8)	145 (14.6)	238 (79.9)	
CCS angina class					
I	377 (19.0)	67 (9.7)	283 (28.6)	27 (9.1)	
II	750 (37.8)	188 (27.1)	529 (53.4)	33 (11.1)	
III	239 (12.1)	214 (30.8)	25 (2.5)	0 (0)	
IV	38 (1.9)	30 (4.3)	8 (0.8)	0 (0)	
Unknown	23 (1.2)	23 (3.3)	0 (0)	0 (0)	
Noninvasive ischemia evaluation					<0.001
Low risk	228 (11.5)	19 (2.7)	82 (8.3)	127 (42.6)	
Intermediate risk	742 (37.4)	228 (32.9)	343 (34.6)	171 (57.4)	
High risk	195 (9.8)	156 (22.5)	39 (3.9)	0 (0)	
Maximal antianginal medications	117 (5.9)	70 (10.1)	45 (4.5)	2 (0.7)	<0.001
Angiographic characteristics					
Left main trunk	111 (5.6)	109 (15.7)	1 (0.1)	1 (0.3)	<0.001
3VD without left main trunk	345 (17.4)	290 (41.8)	46 (4.6)	9 (3.0)	<0.001
CTO without other coronary stenosis	77 (3.9)	15 (2.2)	44 (4.4)	18 (6.0)	0.007
Presence of proximal LAD stenosis	508 (25.6)	316 (45.5)	183 (18.5)	9 (3.0)	<0.001

Values are n (%).

CCS = Canadian Cardiovascular Society; CTO = chronic total occlusion; LAD = left anterior descending artery; 3VD = 3-vessel disease; all other abbreviations as in Table 2.

TABLE 4 Most Frequent Clinical Scenarios for Nonacute PCIs Classified as Inappropriate and Uncertain by AUC/2009

AUC/2009 Scenario No.	Indication: Anatomy	Previous CABG	Symptoms	Cardiac Risk (Noninvasive Tests)	Antianginal Medication	n (%)
Inappropriate PCIs						298
14a	1- or 2-vessel CAD, no proximal LAD involvement	No	Asymptomatic	Intermediate	None or minimal	146 (7.4)
12a	1- or 2-vessel CAD, no proximal LAD involvement	No	Asymptomatic	Low	None or minimal	60 (3.0)
12b	1- or 2-vessel CAD, no proximal LAD involvement	No	CCS class I or II	Low	None or minimal	57 (2.9)
56a	≥1 stenoses in non-CABG territory all bypass grafts patent	Yes	Asymptomatic	Intermediate	None or minimal	13 (0.7)
24a	CTO of 1 major coronary artery without other coronary stenoses	No	Asymptomatic	Intermediate	None or minimal	12 (0.6)
Uncertain PCIs						990
18b	1- or 2-vessel CAD, no proximal LAD involvement	No	CCS class I or II	Not available	Not available	524 (26.4)
14b	1- or 2-vessel CAD, no proximal LAD involvement	No	CCS class I or II	Intermediate	None or minimal	174 (8.8)
30b	1-vessel CAD involving the proximal LAD	No	CCS class I or II	Intermediate	None or minimal	49 (2.5)
36a	2-vessel CAD involving the proximal LAD	No	Asymptomatic	Intermediate	None or minimal	42 (2.1)
16a	1- or 2-vessel CAD, no proximal LAD involvement	No	Asymptomatic	High	None or minimal	29 (1.5)

CAD = coronary artery disease; all other abbreviations as in Tables 1 to 3.

inappropriate PCIs were more likely to be performed for patients who had no symptoms (appropriate, 24.8%; uncertain, 14.6%; inappropriate, 78.9%; $p < 0.001$), low-risk results from noninvasive testing (appropriate, 2.7%; uncertain, 8.3%; inappropriate, 42.6%; $p < 0.001$), or chronic total occlusion (appropriate, 2.2%; uncertain, 4.4%; inappropriate, 6.0%; $p < 0.007$) (Table 3). Overall, almost all of the inappropriate PCIs were confined to 5 scenarios, as summarized in Table 4. Frequently encountered scenarios included PCIs with suboptimal antianginal medications or involvement of single or multiple epicardial vessels other than the left main trunk or PLAD.

Under AUC/2012, asymptomatic patients with 1- or 2-vessel CAD with no PLAD involvement and without previous noninvasive testing (indication 18a in AUC/2009, indication 20a in AUC/2012) were rated as inappropriate (n = 447). When these scenarios were added, the percent of inappropriate PCIs increased from 15.0% to 30.7% (Figure 2, Online Table 1). Of these cases, as many as 120 (26.8%) were evaluated using coronary CTA before the procedures, and the results were positive in almost all the cases (noninterpretable, 4 cases; negative, 1 case). The most frequent clinical scenarios for nonacute PCIs classified as inappropriate and uncertain by AUC/2012 are summarized in Table 5.

ASSOCIATION BETWEEN TEMPORAL TRENDS OF NONINVASIVE TESTING AND THE RATE OF INAPPROPRIATE RATINGS. Figure 3 summarizes the use of several noninvasive tests such as the stress myocardial perfusion imaging and coronary CTA and fractional flow reserve (FFR). FFR is a pressure wire-based ischemic evaluation during coronary angiography. Figure 3 also demonstrates the temporal trends of the proportion of inappropriate PCIs. Among patients who underwent PCI, the proportion of patients evaluated with coronary CTA and FFR substantially increased (p for trend < 0.001), which coincided with a decrease in use of the stress myocardial perfusion imaging over the course of 5 years (p for trend < 0.001). Contemporaneously, the proportion of inappropriate PCIs increased (p for trend = 0.003) in parallel with the increase in coronary CTA use. Implementation of coronary CTA was associated with the rating of inappropriate PCI (odds ratio: 1.33; 95% confidence interval: 1.03 to 1.70; p = 0.027). Further, the time variables were not independently associated with the rating of inappropriate PCI (Online Table 3).

Figure 4 presents the change in the proportion of PCIs rated as inappropriate. Although the proportion of inappropriate PCIs accounted for 30.7% of all the elective procedures when the CT-based procedures were classified as inappropriate, this proportion decreased substantially (from 5.0% to 25.7%) when the CT-based procedures were classified as appropriate. Although the proportion of inappropriate PCIs tended to increase even when the CT-based procedures were classified as appropriate, the trend was not statistically significant (p for trend = 0.09).

DISCUSSION

In this contemporary, multicenter Japanese PCI registry, almost all acute PCIs were acceptable regardless of the criteria applied. However, approximately one-sixth of nonacute PCIs were rated as inappropriate under the original criteria. Under the updated AUC/