



# Enhanced outcomes for coronary artery disease obtained by a multidisciplinary heart team approach

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## Abstract

**Background** We implemented our multidisciplinary heart team (MHT) approach since 2012 for patients with coronary artery disease (CAD) and assessed the effectiveness of it by comparing outcomes in patients treated before and after the introduction of the MHT approach.

**Methods** Percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG) for CAD were performed in 802 and 57 patients from 2009 to 2011 in Group NH, and were performed in 867 and 160 patients from 2012 to 2014 in Group H, respectively. The primary outcome was major adverse cardiovascular and cerebrovascular events (MACCE), defined as the composite of all-cause death, myocardial infarction, stroke, cardiac-related readmission and target vessel repeat revascularisation (TVR) for PCI or revascularisation on grafted vessels for CABG.

**Results** MACCE occurred significantly more often in Group NH than in Group H at 3 years postoperatively (28.1% vs 21.1%) (log rank  $P=0.001$ ). Cox regression analysis showed that the MHT approach [hazard ratio (HR), 0.737; 95% confidence interval (CI), 0.60–0.91;  $P=0.004$ ] and ejection fraction (HR 0.976; 95% CI, 0.97–0.98;  $P<0.0001$ ) were associated with significantly lower rates of MACCE events, while SYNTAX score (HR 1.023; 95% CI 1.00–1.03,  $P<0.0001$ ) and EuroSCORE II (HR 1.014, 95% CI 0.60–0.91,  $P=0.004$ ) were associated with a higher rate of MACCE events.

**Conclusion** Our MHT approach was able to reduce the MACCE events of treatment for CAD. The dedicated MHT approach might be beneficial for patients with CAD.

**Keywords** Heart team · PCI · CABG

## Introduction

Since the pivotal SYNTAX trial was published [1] and the terminology ‘Heart Team’ was established in ESC/EACTS 2010 Guidelines [2], the multidisciplinary heart team

(MHT), which consists of interventional cardiologists, cardiac surgeons and non-interventional cardiologists, who are in a neutral position throughout decision-making, has been recognized as significant for revascularisation in patients with complex coronary artery disease (CAD). The most updated guidelines of the ESC assign the MHT approach as Class 1c for the treatment of patients with complex CAD [3].

However, introduction of the MHT approach in the real world is not always easy for several reasons [4]. As of now, there is only one report determining the safety and efficacy of implementing the MHT approach for revascularisation in patients with complex CAD [5]. However, there is no report comparing the outcomes of treatment for CAD before and after implementation of the MHT approach. This study aimed to compare the outcomes of treatment for CAD before and after the introduction of the MHT approach at our hospital.

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## Methods

### Patient population

We treated 1889 patients with CAD between 2009 and 2014 (1672 patients for PCI and 217 patients for CABG) at our hospital. Since the MHT approach was introduced in 2012, patients were divided into two groups, Group NH including 859 patients (802 patients for PCI and 57 patients for CABG) who were treated between 2009 and 2011 before the introduction of the MHT approach, and Group H including 1030 patients (870 patients for PCI and 160 patients for CABG) who were treated between 2012 and 2014, which was after the introduction of the MHT approach.

This study was retrospective and approved by the institutional review board of the University of St. Luke's International Hospital, Tokyo, Japan. This study complied with the Declaration of Helsinki and about patient consent.

### Our heart team

Originally, three interventional cardiologists, three non-interventional cardiologists and three cardiac surgeons started MHT conference, which was held every weekday morning for about 30 min. Trainees and residents participated in the conferences as far as they can. There, we discussed the cases which the members of MHT would like to consult with, including CAD, valvular disease and vascular disease. On the other hand, surgeons presented the surgical cases using short operative video as feedback to cardiologists.

Sometimes, patients were not able to agree with the decision made by MHT conference.

In such a case, we respected the patients' thinking as far as we can.

### Clinical follow-up

All clinical data, such as patient demographics (age, sex, body weight and height), clinical history (chronic kidney disease, myocardial infarction, stroke, peripheral artery disease, percutaneous coronary intervention, and coronary artery bypass grafting), risk factors (diabetes mellitus, dyslipidaemia, hypertension, chronic obstructive pulmonary disease and smoking), angiographic and echocardiographic findings (number of diseased vessels, presence of left main CAD, proximal left anterior descending CAD, SYNTAX score and left ventricular dysfunction), revascularisation strategies and clinical outcomes during follow-up (all-cause death, cardiac death, myocardial infarction, stroke and repeat revascularisation) were obtained from inpatient records and

telephone and letter interviews. The overall follow-up rate was 91.6%. The data obtained were compared between the two groups to determine the effect of introduction of the MHT approach.

About clinical follow-up, cardiac interventionalists take care of the patients who underwent treatment at their outpatient clinic with doctors who introduced them. On the other hand, cardiac surgeons take care of patients at their outpatient clinic for a few months after surgery, and then patients go back to the doctors who introduced them.

### Cardiac rehabilitation (CR)

About elective surgical cases, physical therapists (PT) who are registered instructors of CR checked patients' activity of daily life before surgery at outpatient clinic.

After surgery, about both elective and emergent cases, all patients started CR when they are ready for it, and continued until discharge.

After discharge, most of patients continued outpatient CR for about 5 months.

### Statistical analysis

Baseline characteristics were compared between patients who underwent PCI or CABG before introduction of the MHT approach and the cohort that underwent these procedures after introduction of the MHT approach. The two-sample *t* test and Wilcoxon rank-sum test were used for the evaluation of parametric and nonparametric continuous variables, respectively. All categorical variables (reported as frequency and percentage) were compared using the standardized difference.

We used propensity score matching to control for observed confounding factors. The propensity score was estimated using a nonparsimonious multivariable logistic regression model, with heart team as the dependent variable and all the baseline characteristics in Table S1 (in the Supplementary Appendix) as dependent variables.

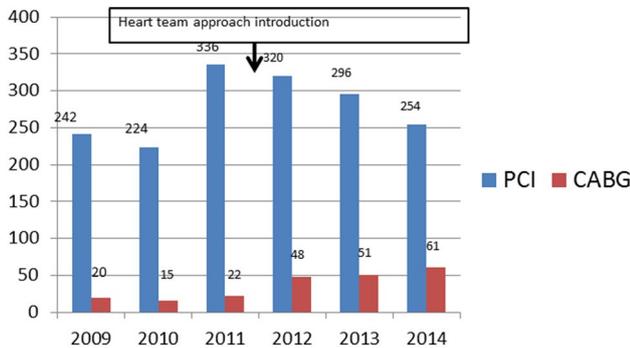
One-to-one propensity score matching was performed using a caliper distance of 0.2 standard deviation of the logit of the estimated propensity scores. Matching was performed as nearest neighbour matching without replacement.

Cox proportional hazard regression model was used to compare the hazard of the primary outcome between the matched groups.

SPSS software (version 22.0, SPSS Inc., Chicago, IL, USA) was used for analysis other than propensity score matching. Stata/IC software (version 14, Stata Corp, College Station, TX, USA) was used for analysis for propensity score matching. A two-tailed *p* value < 0.05 was considered statistically significant.

### Definitions and study outcomes

The primary outcome was a major adverse cardio-cerebral event (MACCE), defined as the composite of all-cause death, myocardial infarction, stroke or target vessel repeat revascularisation for PCI or revascularisation of a grafted vessel for CABG (TVR). The secondary outcome assessed was TVR.



**Fig. 1** Annual variation of patients who underwent PCI or CABG before and after the introduction of heart team approach

### Results

#### Study population and patient characteristics

The number of patients who newly underwent PCI or CABG between 2009 and 2014 and the PCI/CABG ratio changed dramatically over the study period (Fig. 1). Between 2009 and 2011, before introduction of the MHT approach, the number of cases that underwent PCI and CABG and the PCI/CABG ratio was 242, 20 and 12.1 in 2009, 224, 15 and 14.9 in 2010 and 336, 22 and 15.3 in 2011, respectively. Between 2012 and 2014, after the introduction of the MHT approach, the number of cases that underwent PCI and CABG and the PCI/CABG ratio were 320, 48 and 6.7 in 2012, 296, 51 and 5.8 in 2013 and 254, 61 and 4.2 in 2014, respectively (Fig. 1).

Many pre-operative patient characteristics were similar in both groups (Table 1). However, the mean age of patients in group H ( $67.5 \pm 12.0$  years) was significantly higher than that in group NH ( $66.2 \pm 11.1$  years) ( $P=0.021$ ). The mean ejection fraction of group NH ( $58.3 \pm 12.4$ ) was significantly higher than that of group H ( $55.0 \pm 11.5$ ) ( $P=0.001$ ).

**Table 1** Baseline characteristics of patients who underwent percutaneous coronary intervention (PCI) or coronary artery bypass grafting (n = 1889)

Characteristics	Total (n = 1889)	Heart team (+) (n = 1030)	Heart team (-) (n = 859)	P value
Age, years (mean ± SD)	66.9 ± 11.6	67.5 ± 12.0	66.2 ± 11.1	0.021
Male, no. (%)	1511 (80)	828 (80)	683 (79.5)	0.63
BSA, m <sup>2</sup> (mean ± SD)	1.71 ± 0.22	1.72 ± 0.24	1.71 ± 0.19	0.91
BMI (mean ± SD)	24.6 ± 7.70	24.6 ± 9.76	24.7 ± 3.82	0.73
Ejection fraction, % (mean ± SD)	56.5 ± 11.9	55.0 ± 11.5	58.3 ± 12.4	0.0001
Pre-operative creatinine, mg/dl (mean ± SD)	1.25 ± 1.82	1.22 ± 1.78	1.28 ± 1.87	0.49
History of PCI, no. (%)	510 (27)	268 (26.0)	242 (28.2)	0.29
History of CABG, no. (%)	94 (5)	56 (5.4)	47 (5.5)	0.97
History of CHF, no. (%)	95 (6)	67 (6.5)	39 (4.5)	0.065
History of CVA, no. (%)	189 (10)	118 (11.5)	76 (8.8)	0.063
Pre-operative hypertension, no. (%)	1511 (80)	802 (77.9)	708 (82.4)	0.014
Pre-operative dyslipidemia, no. (%)	1322 (70)	659 (64.0)	657 (76.5)	0.0001
Peripheral vascular disease, no. (%)	95 (8)	74 (7.2)	68 (7.9)	0.54
Pre-operative diabetes mellitus, no. (%)	888 (47)	467 (45.3)	412 (48.0)	0.255
Pre-operative diabetes mellitus (insulin dependent), no. (%)	113 (6)	59 (5.7)	52 (6.1)	0.765
Pre-operative COPD, no. (%)	61 (3.2)	39 (3.8)	22 (2.6)	0.085
Pre-operative HD, no. (%)	132 (7)	66 (6.4)	58 (6.8)	0.76
Syntax score (mean ± SD)	14.2 ± 9.59	13.6 ± 9.56	15.1 ± 9.59	0.002
Euro II score (mean ± SD)	4.67 ± 7.36	4.82 ± 7.48	4.49 ± 7.21	0.337

Values are mean ± SD or n (%). \* P value compares the difference in the pre-operative demographics between the patients with heart team (n = 1030) and the other patients without heart team (n = 859) among patients who underwent PCI or CABG (n = 1889)

BSA body surface area, BMI body mass index, PCI percutaneous coronary intervention, CABG coronary artery bypass grafting, CHF congestive heart failure, CVA cerebral vascular accident, HD hemodialysis, COPD chronic obstructive pulmonary disease

The proportion of patients who were diagnosed with hypertension and dyslipidaemia pre-operatively was significantly higher in group NH (82.4% and 76.5%) than group H (77.9% and 64.0%) ( $P=0.014$  and  $P=0.0001$ ). SYNTAX score in group NH ( $15.1 \pm 9.59$ ) was significantly higher than that in group H ( $13.6 \pm 9.56$ ) ( $P=0.02$ ).

## Clinical endpoints

The proportion of MACCE of group NH (mean follow-up:  $49.0 \pm 34.1$  months) and group H (mean follow-up:  $38.6 \pm 19.9$  months) [MACCE: 287/859 (33.4%) vs. 236/1030 (22.9%)] is depicted in Table 2, although we were not able to compare the proportion due to the deference of follow-up period. The incidence of freedom from MACCE is depicted in Fig. 2. The number of MACCE was significantly higher in group NH than group H at both 1 and 3 years (17.5% and 27.9% vs. 11.9% and 21.1%) (log rank  $P=0.001$ ). The results of freedom from TVR for PCI or revascularisation of grafted vessels for CABG are depicted in Fig. 3; TVR was required significantly more often in group NH than group H patients at 1 and 3 years

postoperatively (11.1% and 16.3% vs. 4.3% and 9.2%) (log rank  $P<0.0001$ ).

According to multivariate analysis using a Cox proportional hazards model (Fig. 4), the MHT approach and better EF independently reduced MACCE events (hazard ratio [HR]: 0.737, 95% confidence interval [CI] [0.599–0.906],  $P=0.004$ , and HR: 0.976, 95% CI [0.967–0.984],  $P<0.0001$ ).

On the other hand, an increase in age [HR: 1.011, 95% CI (1.001–1.022),  $P=0.038$ ], SYNTAX score [HR: 1.023, 95% CI (1.012–1.034),  $P<0.0001$ ] and EuroSCORE II [HR: 1.014, 95% CI (1.004–1.025),  $P=0.006$ ], and a previous history of congestive heart failure [HR: 1.525, 95% CI (1.062–2.188),  $P=0.022$ ] and haemodialysis [HR: 2.167, 95% CI (1.585–2.964),  $P<0.0001$ ] were independent risk factors of MACCE events.

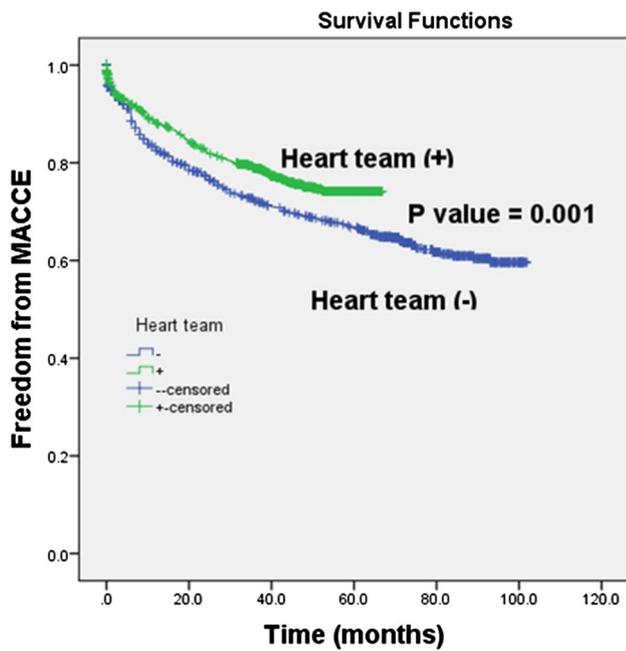
Additionally, PCI was an independent risk factor of MACCE events compared with CABG [HR: 2.032, 95% CI (1.435–2.878),  $P<0.0001$ ].

Lastly, with the use of propensity score matching, 709 patients who underwent PCI or CABG with heart team were matched with 709 patients who underwent PCI or CABG without heart team. The C-statistic for the model was 0.634.

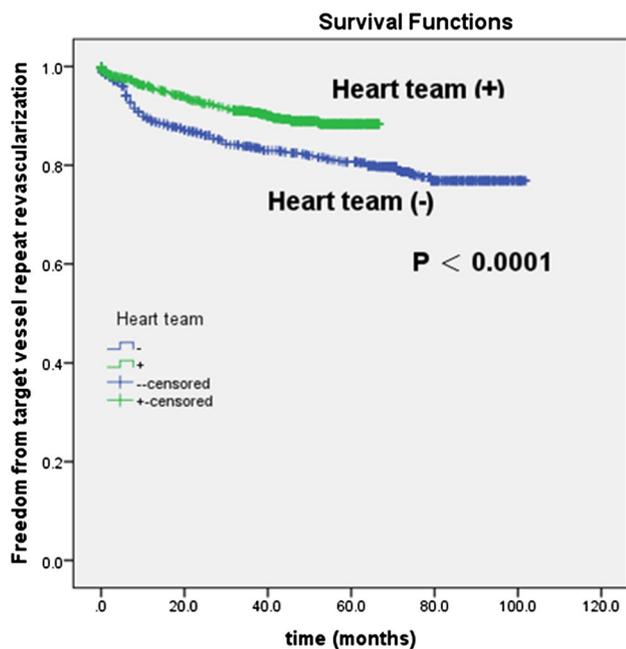
**Table 2** Clinical end points between Group NH and Group H

	Group NH ( $N=859$ )	Group H ( $N=1030$ )
Follow-up period, months (mean $\pm$ SD)	$49.0 \pm 34.1$	$38.6 \pm 19.9$
MACCE, no. (%)	287 (33.4)	236 (22.9)
All-cause death, no. (%)	120 (14.0)	101 (9.8)
Cardiac death, no. (%)	42 (4.9)	39 (3.9)
Late nonfatal MI, no. (%)	11 (1.3)	11 (1.1)
Re-intervention (PCI or CABG), no. (%)	138 (17.1)	112 (10.9)
Cerebral vascular accident, no. (%)	28 (3.3)	31 (3.0)
Congestive heart failure, no. (%)	13 (1.5)	9 (0.9)
	PCI in Group NH ( $N=802$ )	PCI in Group H ( $N=870$ )
MACCE, no. (%)	265 (33.0)	206 (23.6)
All-cause death, no. (%)	107 (13.3)	82 (9.4)
Cardiac death, no. (%)	40 (5.0)	36 (4.1)
Late nonfatal MI, no. (%)	11 (1.3)	11 (1.3)
Re-intervention (PCI or CABG), no. (%)	138 (17.2)	102 (11.7)
Cerebral vascular accident, no. (%)	25 (3.1)	29 (3.3)
Congestive heart failure, no. (%)	13 (1.6)	7 (0.8)
	CABG in Group NH ( $N=57$ )	CABG in Group H ( $N=160$ )
MACCE, no. (%)	22 (38.5)	30 (16.7)
All-cause death, no. (%)	13 (22.8)	19 (11.9)
Cardiac death, no. (%)	2 (3.5)	3 (1.9)
Re-intervention (PCI or CABG), no. (%)	9 (15.7)	10 (6.3)
Cerebral vascular accident, no. (%)	3 (5.3)	2 (1.3)
Congestive heart failure, no. (%)	0 (0.0)	2 (1.3)

MACCE all-cause death, myocardial infarction, stroke, cardiac-related readmission and target vessel repeat revascularisation (TVR) for PCI or revascularisation on grafted vessels for CABG, MACCE major adverse cardiac and cerebral–vascular events, MI myocardial infarction, PCI percutaneous coronary intervention



**Fig. 2** MACCE-free survival. The log rank *p* value is testing for statistical significance of the MACCE curves between patients with and without heart team. MACCE is defined as the composite of all-cause death, myocardial infarction, stroke, cardiac-related readmission and target vessel repeat revascularisation (TVR) for PCI or revascularisation on grafted vessels for CABG



**Fig. 3** Target vessel repeat revascularization-free survival. The log rank *p* value is testing for statistical significance of the target vessel repeat revascularization curves between patients with and without heart team. Target vessel repeat revascularization is defined as target vessel repeat revascularization for PCI or revascularization on grafted vessel for CABG (TVR)

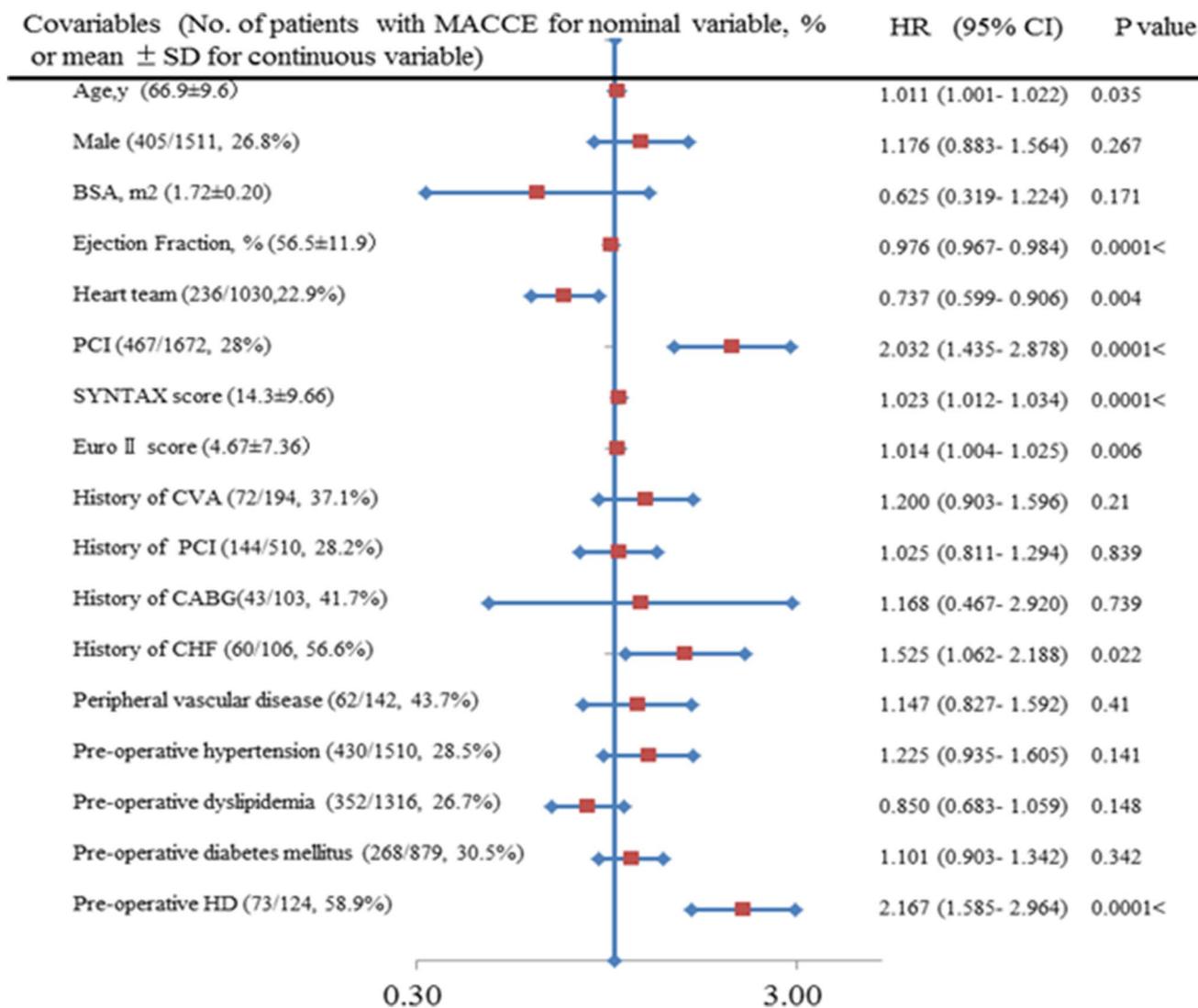
The covariables used for matching and pre-operative patient characteristics after matching are shown in Supplementary Table 1. The proportion of MACCE was significantly higher in group NH compared with group H (log rank  $P = 0.0055$ ) (Supplementary Fig. 1). In addition, according to Cox proportional hazards model, the MHT approach independently reduced MACCE events [HR: 0.74, 95% CI (0.60–0.91),  $P = 0.004$ ].

### Discussion

Previously, CABG was considered the gold standard treatment for complex CAD since it was associated with a lower revascularisation rate [6, 7] and better survival rate [8, 9] than PCI with a bare metal stent. One report suggests that the MACCE rate with CABG is lower than that with even drug-eluting stents (DES) [10].

The pivotal SYNTAX trial described that CABG was associated with a lower MACCE rate in patients with complex CAD with a high SYNTAX score at 1-year follow-up (10.9% vs. 23.4%) ( $p < 0.001$ ). In addition, the follow-up SYNTAX trial described that CABG was associated with lower MACCE events than PCI in intermediate- and high-SYNTAX-score groups at 5-year follow-up (MACCE rate with intermediate SYNTAX score: 25.8% in the CABG group vs. 36.0% in the PCI group [ $p = 0.008$ ]; and with high SYNTAX score: 26.8% in the CABG group vs. 44.0% in the PCI group [ $P < 0.0001$ ]) [11]. Similarly, the EXCEL trial showed that PCI was associated with more MACCE events, including TVR, than CABG [12].

In terms of CAD with left main trunk (LMT) lesions as well, the NOBLE trial reported that PCI was associated with more MACCE events, including TVR [13]. On the other hand, the PRECOMBAT and EXCEL trials described that CABG and PCI were not significantly different in terms of the occurrence of MACCE events, excluding TVR [14, 15]. Hence, as far as long-term survival after PCI or CABG is concerned, most trials showed no significant differences between PCI and CABG for complex CAD with multi-vessel disease and LMT lesions. The SYNTAX trial showed that CABG had significantly better survival rates than PCI in the high-SYNTAX-score group. Mack et al. explained that the superiority of complete revascularisation with CABG in the SYNTAX trial was due to its ability to reduce residual ischemia and prevent postoperative cardiac events [16]. We believe that the results of these trials comparing the outcomes between PCI and CABG imply that the choice of PCI or CABG should be based on the individual patient’s clinical background and anatomical risk score, and that the MHT approach should be implemented when patients have complex CAD, such as multi-vessel and LMT disease.



**Fig. 4** Covariable analyses with hazard ratios and 95% confidence intervals are shown for the MACCE events. The *p* value for interaction represents the likelihood of interaction between the vari-

ables and the relative treatment effect. CI=confidence interval; MACCE=major adverse cardiac or cerebrovascular events; other abbreviations as in Fig. 1

Since the ESC 2010 guidelines advocate the MHT approach for complex CAD cases and the updated ESC 2014 guidelines defined that as Class 1c, collaboration between cardiologists and cardiac surgeons for the treatment of complex CAD is becoming standardized, although the evidence level of the efficacy of the MHT approach in cases with complex CAD is still ranked as C due to its short history and small number of implementations. In the field of medical oncology and organ transplantation, a multidisciplinary team approach has already been established and has been reported to improve the quality of patient care [17, 18]. The efficacy of a team approach was also established in the field of congestive heart failure and congenital heart disease [19, 20].

Cohen et al. well described the benefits of the MHT approach for complex CAD cases [21], and suggested

that broader input by different physicians into a complex decision-making process minimizes fragmented decision-making, improves coordination of care, and facilitates shared decision-making with patients and families.

However, the MHT approach for complex CAD is associated with certain challenges, including the involvement of different physicians from a broad range of specialties in a complex decision-making process, the need to establish a streamlined process for integrating and summarizing input from the multiple viewpoints of the heart team in a systematic manner, and fostering active participation by patients and their families regarding the decision-making process by heart teams while maintaining the efficiency of treatment. Therefore, when creating the heart team at our hospital, we referenced the concept of the four pillars (1. Speaking up,

2. Collaboration, 3. Experimentation, and 4. Reflection) advocated by Amy C. Edmondson from Harvard business school [22].

The facility at which the treatment is administered is an important component contributing to the efficacy of the team. Fortunately, our cardiovascular centre facility was reconstructed in 2011, just after the ESC 2010 guidelines advocated the MHT approach for revascularisation of complex CAD. Our facility was reconstructed as a single unit with three procedure rooms (an operating theatre (OR) for cardiovascular surgeries, an angiographic room for cardiovascular interventions and catheter ablation of arrhythmia, and a hybrid operating theatre for structural heart interventions, such as transcatheter aortic valve intervention (TAVI), atrial septal defect closure and cardiovascular surgeries that require fluoroscopy, such as endovascular aortic repair), a conference room, and intensive care units for cardiovascular disease all on the same floor. In addition, physicians and surgeons have their offices in the same room to enable better communication between them.

Besides reconstructing the facility, we also started our heart team conference in 2012, which includes interventional cardiologists, cardiac surgeons, and non-interventional cardiologists who are in a neutral position throughout decision-making. Conferences are held every weekday morning, and cardiologists present their cases for consultations with the surgeons. In turn, surgeons present operative videos to give feedback to the members of the MHT. This environment facilitates consultations between the heart team members, even for emergency cases. We believe that the change in the PCI/CABG ratio at our hospital before and after introduction of the MHT approach might be a partial reflection of the benefits of this approach.

Regarding the definition of MACCE, our study defined TVR as target vessel repeat revascularisation for PCI and repeat revascularisation of the grafted vessel for CABG, to eliminate the influence of staged PCI and hybrid treatment consisting of PCI and CABG. We did not compare outcomes according to the severity of SYNTAX score, because patients in the PCI group in our study included those with both single- and multiple-vessel disease.

In terms of the higher rate of both MACCE events and repeat TVR in Group NH compared with Group H, there are several possible reasons, besides the diverse mean follow-up periods ( $49.0 \pm 34.1$  months vs.  $38.6 \pm 19.9$  months), to explain this discrepancy. First, we used a larger number of second-generation DES, which are reportedly superior to first-generation DES from the view of stent restenosis [23], for PCI in Group H as compared to Group NH. Second, the difference in MACCE between Group NH and Group H was mostly driven by the difference in re-intervention rate (Group NH: all 17.1%, PCI 17.2%, and CABG 15.7% vs. Group H: all 10.9%, PCI 11.7%, and

CABG 6.3%) (Table 2). This result was similar to those of other trials that compared the outcomes between PCI and CABG [1, 8–15] although MACCE rate was a little bit higher in both groups. It was partly due to our study design that included the patients with low cardiac function, previous history of PCI or CABG.

The higher CABG implementation rate in group H might have led to the lower re-intervention rate in group H in our study. Third, we might have performed more fractional flow reserve-guided PCI and CABG in Group H than in Group NH. This can avoid unnecessary interventions and reduce MACCE events and TVR after both PCI and CABG [24, 25].

The introduction of the MHT approach for patients with CAD in our hospital resulted in a significant decrease in both MACCE events and TVR. Our experience implies that daily communication between cardiologists and surgeons provides deeper understanding in terms of the advantages and disadvantages of individual treatments, creating an environment that fosters collaboration and consultation with each other, which would be particularly useful in emergency CAD cases, cases with vascular access complications during interventional cardiology, and postoperative heart failure and intractable arrhythmia.

In addition, fortunately, our MHT consisted of members who can respect the decision made by MHT conference. It might have been other tips of our well functioning.

In fact, we experienced the practical utility of the heart team in a patient who presented for transcatheter aortic valve implantation (TAVI) in 2012. The patient-centred care of the MHT approach enabled us to share the burden of treatment risk and satisfied the patient and the patient's family. In the future, we would like to study whether the MHT approach for CAD can reduce health care costs by avoiding unnecessary intervention.

## Study limitations

This was a retrospective non-randomized single-centre study, which is not a high-volume centre. We did not include patients with CAD who underwent only optimal medical therapy. Also, we did not evaluate the PCI devices used, which might influence the outcomes of the re-intervention rate.

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## Compliance with ethical standards

**Conflict of interest** The authors have nothing to disclose with regard to conflicts of interest.

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