

Full Length Research Paper

Coronary artery bypass grafting and lung lobectomy: Functional outcomes at discharge

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Mortality and complication rates after on-pump versus off-pump coronary artery bypass grafting (CABG), and open lung lobectomy (OL) versus video-assisted lobectomy (VAL), have previously been reported, but further research regarding functional outcomes is needed. This study compared functional recovery at discharge between patients who underwent on-pump versus off-pump CABG, and OL versus VAL. In patients discharged during July to December, from 2006 to 2010, functional recovery was measured by comparing the Barthel index at admission and discharge. Complication rates and functional deterioration were compared in propensity score-matched groups of patients aged over 15 years who underwent isolated CABG of two or more arteries or lobectomy, and survived until discharge. The study included 3,901 on-pump CABG patients, 3,672 off-pump CABG patients, 6,029 OL patients, and 14,378 VAL patients. Patient and hospital characteristics, comorbidities, and preoperative care procedures were associated with on-pump versus off-pump CABG, and OL versus VAL, but functional deterioration was not. The complication rate was lower after VAL than OL. Dependent functional status at admission was associated with functional deterioration in patients who underwent lobectomy. Multidisciplinary treatment strategies to maintain functional status should be developed, and appropriate indications for lobectomy according to functional status at admission should be determined.

Key words: Coronary artery bypass grafting, complications, functional outcomes, lung lobectomy.

INTRODUCTION

With the increasing size of the elderly population, the number of disabled elderly individuals is increasing. According to the Organization for Economic Co-operation

and Development (OECD) StatExtracts 2011, the proportion of the Japanese population aged over 65 years increased from 9.1% in 1980 to 23.1% in 2010 (for the United States, this proportion increased from 11.3 to 13.0% during the same time period) (OECD StatExtracts, 2011). As a growing number of elderly individuals develop cardiovascular and lung diseases, there is an increasing need for treatments that are less invasive and provide

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better functional outcomes. Previous studies have compared postoperative complication and mortality rates between patients who underwent on-pump versus off-pump coronary artery bypass grafting (CABG), and open lung lobectomy (OL) versus video-assisted lobectomy (VAL) (Angelini et al., 2009; Gopaldas et al., 2010; Kapetanakis et al., 2008; Kiernan et al., 2011; Kuss et al., 2010; Lim et al., 2006; Mishra et al., 2006; Motallebzadeh et al., 2006; Rivera et al., 2011).

Although the usefulness of off-pump CABG and VAL have been validated in randomized studies of selected subjects, it is desirable to conduct community-based studies to confirm the safety and effectiveness of minimally invasive surgery (MIS) procedures (off-pump CABG and VAL) versus conventional procedures (on-pump CABG and OL), to assist in determining appropriate procedure choices, and in implementing relevant healthcare policies (Kiernan et al., 2011; Kuss et al., 2010; Lim et al., 2006; Mishra et al., 2006; Rivera et al., 2011).

Previous studies used variable designs and definitions of disease severity (Kuss et al., 2010; Lim et al., 2006). The effects of selection bias have also been discussed (Gopaldas et al., 2010; Kiernan et al., 2011; Mishra et al., 2006; Rivera et al., 2011). Outcomes have been investigated in terms of mortality and complication rates, but functional recovery at discharge has not been sufficiently investigated (Angelini et al., 2009; Kapetanakis et al., 2008; Motallebzadeh et al., 2006). Our Japanese database which includes both functional status information and procedure-based severity information, enables comparisons of functional recovery between propensity score-matched groups of patients who underwent MIS versus conventional procedures. Analysis of such a large population-based database can help to determine the appropriate indications for surgical procedures.

This study used the Japanese administrative database, including data describing functional status at admission and discharge, and the dates and quantities of medical care items used to compare functional outcomes between on-pump versus off-pump CABG and OL versus VAL.

MATERIALS AND METHODS

Database

This was a secondary data analysis embedded in a government research project to develop the Japanese case-mix classification. In cooperation with the Ministry of Health, Labour and Welfare (MHLW), our research team started this project in 2001, using the administrative database for 2001 and 2002 to profile hospital performance and develop the payment system. All 82 academic hospitals in Japan participated in this project, and the number of participating community hospitals increased from 92 in 2003 to 1,650 in 2010 (Ministry of Health, Labour and Welfare, 2011). The database includes clinical data as well as claims data such as the date, charge, and quantity of medical care items used. The data of patients discharged between July 1 and October 31, during 2002 through 2005, and between July 1 and December 31 during 2006 through 2009, were collected and merged into a standardized

electronic format by the MHLW. Original database included 13,604,026 patients from the 1,101 acute care hospitals participating in our project from 2004 to 2010. The study protocol was approved by the Ethics Committee of the University of Occupational and Environmental Health, Fukuoka.

Study patients

Of the 12,502,528 patients discharged during the 5 years from 2006, 26,472 patients who underwent coronary artery surgery (CABG or intraoperative angioplasty) in 408 hospitals, and 84,564 patients who underwent lung resection (wedge resection, partial lobectomy, lobectomy, or sleeve resection) in 900 hospitals, were identified. Patients who underwent CABG of two or more coronary vessels (22,506 patients in 404 hospitals), or resection of one or more lobes with or without sleeve resection (54,462 patients in 774 hospitals), were included in this study. Next, we enrolled the patients who were discharged from the hospitals participating in our project during the 5 consecutive years, from 2006 in this study. Patients aged less than 15 years, who had missing Barthel index (BI) data, and who underwent aneurysmectomy or valve surgery during the same hospitalization were excluded.

Definitions of variables

The following variables were compared between on-pump and off-pump CABG, and between OL and VAL: age, sex, ambulance use, functional status measured by the BI, weighted comorbidity score measured by the Charlson comorbidity index (CCI), complication rates, length of intensive care unit (ICU) stay, percutaneous coronary intervention (PCI), critical care procedures, blood transfusion, chemoradiation therapy, operating room (OR) time, hospital patient volume, hospital teaching status (academic or community) and fiscal year (FY).

The critical care procedures recorded were pre- and post-operative mechanical ventilation, blood purification (hemodialysis, hemodiafiltration, or hemadsorption), and use of cardiac support devices (intra-aortic balloon pump, percutaneous cardiopulmonary support, or ventricular assist system). Preoperative critical care procedures and blood transfusion were used as markers of preoperative organ failure and anemia, respectively. PCI included pre- and postoperative thrombolysis, balloon angioplasty, stent insertion, and atherectomy because hybrid coronary artery revascularization was advocated (Holzhey et al., 2008). OR time included the time to implement monitoring, induce anesthesia, position the patient, and perform surgery.

Functional change was measured by the change in BI during hospitalization in patients who survived to discharge. The BI measures the ability performance in 10 activities of daily living (feeding, grooming, bathing, dressing, bowel and bladder care, toilet use, ambulation, transfers, and stair climbing) on a five-point scale, with scores ranging from 0 (totally dependent) to 100 (fully independent) (Sulter et al., 1999). The BI at admission was categorized as dependent (< 59), partially independent requiring assistance (60 to 84), or nearly completely independent (≥ 85), because it was expected that change in functional status during hospitalization would be associated with the functional status at admission (Kugler et al., 2003). Functional outcome was defined as BI at discharge minus BI at admission, and was categorized as improvement, no change, or deterioration (Kugler et al., 2003).

Age was divided into three categories: 15 to 64, 65 to 74, and ≥ 75 years. Up to four comorbidities and four complications were recorded per patient, and were indexed according to the International Classification of Diseases (ICD), 10th edition. The severity of chronic comorbid conditions was assessed using the

CCI (Sundararajan et al., 2004). Minor and major complications were examined. Minor complications were classified as present if the ICD codes corresponded with wound complications, hematoma and laceration, or disruption of organs by instrumentation or manipulation (T81 to T87) (Zhan and Miller, 2003). Major complications were defined as complications requiring reoperation for hemostasis and evacuation of hematoma, or intra-thoracic abscess. As information regarding surgeon experience was not recorded, hospital CABG and lung resection volumes were averaged over 5 years and divided into three groups: high-volume hospitals (HVHs), medium-volume hospitals (MVHs), and low-volume hospitals (LVHs); so that the three groups consisted of relatively equal numbers of patients (CABG: 105 LVHs, ≤ 32 /year; 40 MVHs, 33 to 56/year; 25 HVHs, ≥ 57 /year. Lung lobectomy: 197 LVHs, ≤ 61 /year; 50 MVHs, 62 to 103/year; 31 HVHs, ≥ 104 /year). Since 2006, hospital fee calculations have depended on the functional status of patients according to the BI which was recorded every day by well-trained nurses and audited by the MHLW.

Statistical analysis

Categorical data were compared between the on- and off-pump CABG groups and between the OL and VAL groups using the Chi-square test. Continuous variables were compared between MIS and conventional procedures using analysis of variance. Logistic regression models were used to identify recorded preoperative variables associated with the choice of on-pump versus off-pump CABG, and OL versus VAL. Propensity score-matched cohorts with equal proportions of patients likely to receive on-pump versus off-pump CABG, or OL versus VAL, were selected. Postoperative critical care procedures, blood transfusion, complication rates, and deterioration in BI were compared between these cohorts. Logistic regression models were also used to analyze associations between MIS versus conventional procedures, and complication rates or deterioration in BI. The model for analysis of complication rates included preoperative critical care procedures, deterioration in BI, and overall critical care procedures. Statistical analyses were performed using International business machines- Statistical package for the social sciences (IBM-SPSS) version 19.0. A value of $p < 0.05$ was considered to be statistically significant.

RESULTS

Of all the patients reviewed in 263 hospitals, 3,901 on-pump CABG patients in 164 hospitals (692 in 36 academic hospitals), 3,672 off-pump CABG patients in 152 hospitals (1,126 in 34 academic hospitals), 6,029 OL patients in 225 hospitals (1,759 in 36 academic hospitals), and 14,378 VAL patients in 242 hospitals (4,975 in 37 academic hospitals) were identified. Comparisons of patient characteristics between groups showed that the categories of age, sex, and BI at admission were significantly different between patients who underwent on-pump versus off-pump CABG, and the categories of sex and CCI were significantly different between patients who underwent OL versus VAL. Comparisons of hospital characteristics between groups showed that there were significant differences in the categories of hospital patient volume and hospital teaching status between patients who underwent on-pump versus off-pump CABG, and OL versus VAL (Table 1).

Preoperative critical care, ICU care, blood transfusion,

and mechanical ventilation were more frequent in patients who underwent on-pump versus off-pump CABG. ICU care, blood transfusion, mechanical ventilation, and chemoradiation therapy were more frequent in patients who underwent OL versus VAL. OR time was significantly longer in patients who underwent on-pump versus off-pump CABG, and OL versus VAL. The proportions of patients who developed deterioration in BI were higher in patients who underwent on-pump versus off-pump CABG, and OL versus VAL. The complication rate was higher in patients who underwent OL versus VAL (Table 2).

Age, sex, CCI, preoperative PCI, preoperative blood transfusion, hospital teaching status, hospital patient volume, and FY were associated with the choice of on-pump versus off-pump CABG; and sex, CCI, BI at admission, preoperative blood transfusion, preoperative blood purification, hospital teaching status, hospital patient volume, and FY were associated with the choice of OL versus VAL (Table 3).

Table 4 shows the intensive care procedures and outcomes in propensity score-matched CABG patients ($n = 3,672$) and lobectomy patients ($n = 12,002$). The rates of overall ICU stay, blood transfusion, and mechanical ventilation were higher in patients who underwent on-pump versus off-pump CABG, and VAL versus OL. OR time was significantly longer in patients who underwent on-pump versus off-pump CABG, and OL versus VAL. The complication rate was higher in patients who underwent OL versus VAL, but not in those who underwent on-pump versus off-pump CABG.

Complication rates were associated with the type of lung lobectomy but not the type of CABG (off-pump CABG: odds ratio 1.143 [95% confidence interval 0.973 to 1.344]; VAL: odds ratio 0.774 [95% confidence interval 0.688 to 0.870]). Off-pump CABG and VAL were not associated with deterioration in BI. In patients who underwent lobectomy, functional status at admission, mechanical ventilation, and blood transfusion were significantly associated with deterioration in BI, but complications were not (Table 5).

DISCUSSION

This study evaluated whether undergoing off-pump versus on-pump CABG, or VAL versus OL was associated with complication rates or functional outcomes. After adjustment for patient characteristics, preoperative critical care procedures and hospital characteristics, VAL was associated with a lower complication rate than OL. Complication rates and functional deterioration were not associated with on-pump versus off-pump CABG.

Previous studies evaluated the usefulness of off-pump CABG and VAL based on complication and mortality rates. Quality improvement initiatives in ICUs and multi-disciplinary cardiac rehabilitation programs have decreased mortality and complication rates and increased quality of life (Brahmbhatt et al., 2010; Suaya et al., 2009).

Table 1. Patient characteristics among patients receiving study surgical procedures (%) [SD].

Parameter	CABG		P	Lobectomy		P
	On-pump	Off-pump		Open	VAL	
Number	3901	3672		6029	14378	
Patient, hospital (academic, community)	128, 36	118, 34		189, 36	205, 37	
Age (Years)						
65-74	1568 (40.2)	1451 (39.5)		2319 (38.5)	5342 (37.2)	0.147
≥75	1012 (25.9)	1132 (30.8)	<0.001	1573 (26.1)	3906 (27.2)	
Mean, [SD]	67.7 (9.6)	68.9 (9.3)		67.0 (10.8)	67.3 (10.5)	0.058
Gender						
Male	2904 (74.4)	2887 (78.6)	<0.001	4186 (69.4)	8483 (59.0)	<0.001
Ambulance						
Use	526 (13.5)	425 (11.6)	0.012	22 (0.4)	32 (0.2)	0.071
Charlson comorbidity index						
1	1415 (36.3)	1317 (35.9)		1386 (23.0)	2753 (19.1)	
2	834 (21.4)	779 (21.2)		871 (14.4)	2393 (16.6)	
3	295 (7.6)	333 (9.1)	<0.001	422 (7.0)	1011 (7.0)	<0.001
4 or more	128 (3.3)	142 (3.9)		215 (3.6)	572 (4.0)	
BI at admission category						
Dependent	521 (13.4)	388 (10.6)	<0.001	47 (0.8)	133 (0.9)	0.183
Partially independent	128 (3.3)	117 (3.2)		70 (1.2)	133 (0.9)	
Hospital patient volume						
LVH	1396 (56.2)	1088 (43.8)		1942 (32.8)	3978 (67.2)	
MVH	1007 (44.1)	1275 (55.9)	<0.001	1938 (28.0)	4978 (72.0)	<0.001
HVH	1498 (53.4)	1309 (46.6)		2149 (28.4)	5422 (71.6)	
Teaching status						
Academic	692 (17.7)	1126 (30.7)	<0.001	1759 (29.2)	4975 (34.6)	<0.001
Fiscal year						
2006	980 (50.9)	945 (49.1)		1475 (34.8)	2758 (65.2)	
2007	601 (47.7)	659 (52.3)		1027 (35.5)	1862 (64.5)	
2008	643 (54.4)	540 (45.6)	0.007	1022 (34.0)	1982 (66.0)	<0.001
2009	692 (51.0)	665 (49.0)		1194 (29.9)	2802 (70.1)	
2010	985 (53.3)	863 (46.7)		1311 (20.9)	4974 (79.1)	

SD: Standard deviation. †: compared using analysis of variance. Other comparisons were made using chi-square test. CABG: coronary artery bypass graft, VAL: video assisted lobectomy, BI: barthel index, HVH: high volume hospital, LVH: low volume hospital, MVH: middle volume hospital.

2009). It is important to conduct studies of functional outcomes after MIS procedures to determine efficient allocation of healthcare financing and to improve outcomes in elderly patients (OECD StatExtracts, 2011; Suzuki, 2009).

In this study, the use of VAL was found to increase over the years, but the use of off-pump CABG was not. Some minimally invasive procedures may not have significant

advantages over conventional procedures. For example, it was determined that the differences in outcomes after laparoscopic versus open appendectomy did not justify the increased costs of laparoscopic surgery, and the type of appendectomy performed is now determined by the preferences of patients and physicians (Cothren et al., 2005).

Table 2. Care process and outcomes among patients receiving study surgical procedures (%) [SD] (Cont).

Parameter	CABG			Lobectomy		
	On-pump	Off-pump	P	Open	VAL	P
PCI						
Overall	254 (6.5)	237 (6.5)	0.920			
Preoperative	125 (3.2)	118 (3.2)	0.982		***	
Postoperative	132 (3.4)	125 (3.4)	0.961			
ICU stay						
Overall	3375 (86.5)	2989 (81.4)	<0.001	2396 (39.7)	4080 (28.4)	<0.001
Preoperative	615 (15.8)	422 (11.5)	<0.001	16 (0.3)	16 (0.1)	0.011
Postoperative	3337 (85.5)	2958 (80.6)	<0.001	2392 (39.7)	4076 (28.3)	<0.001
Blood transfusion						
Overall	2890 (74.1)	2003 (54.5)	<0.001	663 (11.0)	508 (3.5)	<0.001
Preoperative	90 (2.3)	117 (3.2)	0.019	40 (0.7)	35 (0.2)	<0.001
Postoperative	2885 (74.0)	1996 (54.4)	<0.001	651 (10.8)	487 (3.4)	<0.001
Ventilation						
Overall	2767 (70.9)	2171 (59.1)	<0.001	226 (3.7)	217 (1.5)	<0.001
Preoperative	99 (2.5)	77 (2.1)	0.203	6 (0.1)	4 (0.0)	0.035
Postoperative	2751 (70.5)	2153 (58.6)	<0.001	223 (3.7)	215 (1.5)	<0.001
Cardiac support device						
Overall	740 (19.0)	637 (17.3)	0.067			
Preoperative	244 (6.3)	172 (4.7)	0.003		***	
Postoperative	681 (17.5)	604 (16.4)	0.243			
Blood purification						
Overall	394 (10.1)	355 (9.7)	0.529	38 (0.6)	123 (0.9)	0.097
Preoperative	273 (7.0)	274 (7.5)	0.436	30 (0.5)	106 (0.7)	0.055
Postoperative	386 (9.9)	345 (9.4)	0.462	38 (0.6)	120 (0.8)	0.129
Chemoradiation						
Chemotherapy				231 (3.8)	454 (3.2)	<0.001
Radiation		***		21 (0.3)	18 (0.1)	
Chemoradiation				23 (0.4)	16 (0.1)	
Operating room time (min)	475.5 [200.8]	409.1 [103.1]	<0.001 [†]	328.4 [121.7]	280.5 [231]	<0.001 [†]
Complications						
Minor complication	798 (20.5)	698 (19.0)	0.199	704 (11.7)	1652 (11.5)	<0.001
Major complication	16 (0.4)	11 (0.3)		31 (0.5)	21 (0.1)	
Abscess drainage	3 (0.1)	5 (0.1)	0.428	17 (0.3)	7 (0.0)	<0.001
Operative hemostasis	14 (0.4)	6 (0.2)	0.098	16 (0.3)	14 (0.1)	0.004
BI change						
Deterioration	235 (6.0)	203 (5.5)	<0.001	155 (2.6)	299 (2.1)	0.006

†: Compared using analysis of variance. Other comparisons were made using chi-square test. SD: standard deviation, BI: barthel index, CABG: coronary artery bypass graft, VAL: video assisted lobectomy, ICU: intensive care unit, PCI: percutaneous coronary intervention, ***: not examined.

Table 3. Factors associated with off-pump CABG and VAL.

Parameter	Off pump CABG	VAL
	Odds ratio (95% CI)	Odds ratio (95% CI)
Age (for 15 64 years)		
65-74 years	1.172 (1.049-1.309)	0.987 (0.919-1.060)
≥75 years	1.468 (1.298-1.660)	1.073 (0.991-1.161)
Gender		
Male	1.335 (1.194-1.493)	0.643 (0.603-0.687)
Ambulance		
Use	0.945 (0.803-1.113)	0.778 (0.435-1.391)
Charlson comorbidity index		
1	1.077 (0.961-1.207)	0.805 (0.744-0.871)
2	1.105 (0.967-1.262)	1.100 (1.005-1.204)
3	1.304 (1.080-1.575)	0.960 (0.848-1.087)
4 or more	1.373 (1.045-1.805)	1.055 (0.894-1.246)
BI at admission category (for nearly completely independent)		
Dependent	0.914 (0.772-1.082)	1.293 (0.909-1.840)
Partially independent	0.870 (0.668-1.134)	0.687 (0.509-0.929)
Preoperative PCI	1.368 (1.031-1.814)	-
Preoperative ICU stay	0.724 (0.606-0.866)	0.608 (0.283-1.307)
Preoperative Blood transfusion	1.615 (1.188-2.196)	0.412 (0.255-0.665)
Preoperative Ventilation	0.958 (0.683-1.344)	0.754 (0.177-3.204)
Preoperative Blood purification	0.973 (0.798-1.186)	1.529 (1.006-2.324)
Preoperative Cardiac support device	0.884 (0.691-1.130)	-
Teaching status (for community)		
Academic	2.048 (1.829-2.293)	1.180 (1.099-1.266)
Hospital patient volume		
MVH	1.492 (1.326-1.679)	1.241 (1.146-1.344)
HVH	0.975 (0.870-1.092)	1.198 (1.107-1.297)
Fiscal year		
2007	1.256 (1.085-1.453)	0.952 (0.861-1.052)
2008	0.931 (0.801-1.081)	1.018 (0.921-1.125)
2009	1.025 (0.888-1.182)	1.251 (1.139-1.374)
2010	0.869 (0.761-0.992)	2.024 (1.852-2.213)
Hosmer Lemeshow goodness of model fit		
p-value	0.266	0.026

CABG: Coronary artery bypass graft, VAL: video assisted lobectomy, CI: confidence interval, BI: barthel index, PCI: percutaneous coronary intervention, ICU: intensive care unit, HVH: high volume hospital. LVH: low volume hospital. MVH: middle volume hospital.

Researchers may well discover other advantages of MIS procedures that would justify our study (Angelini et al., 2009; Kapetanakis et al., 2008; Kiernan et al., 2011; Motallebzadeh et al., 2006; Rivera et al., 2011).

Administrative databases such as the one used in this study are useful for the evaluation of functional outcomes after MIS procedures. Studies in stroke patients found that functional status was low immediately after discharge

Table 4. Care process and outcomes among the propensity score matched patients receiving study surgical procedures (% [SD]).

Parameter	CABG			Lobectomy		
	On pump	Off pump	P	Open	VAL	P
Number of matched pairs	1836	1836		6001	6001	
PCI						
Overall	133 (7.2)	115 (6.3)	0.237			
Preoperative	67 (3.6)	54 (2.9)	0.229		***	
Postoperative	68 (3.7)	63 (3.4)	0.656			
ICU stay						
Overall	1580 (86.1)	1386 (75.5)	<0.001	2382 (39.5)	1551 (10.8)	<0.001
Preoperative	322 (17.5)	303 (16.5)	0.404	10 (0.2)	8 (0.1)	0.637
Postoperative	1561 (85.0)	1368 (74.5)	<0.001	2380 (39.5)	1550 (10.8)	<0.001
Blood transfusion						
Overall	1342 (73.1)	956 (52.1)	<0.001	643 (10.7)	214 (1.5)	<0.001
Preoperative	35 (1.9)	39 (2.1)	0.639	24 (0.4)	23 (0.2)	0.884
Postoperative	1338 (72.9)	953 (51.9)	<0.001	636 (10.5)	202 (1.4)	<0.001
Ventilation						
Overall	1275 (69.4)	1077 (58.7)	<0.001	217 (3.6)	97 (0.7)	<0.001
Preoperative	53 (2.9)	43 (2.3)	0.301	1 (0.0)	2 (0.0)	0.564
Postoperative	1264 (68.8)	1068 (58.2)	<0.001	216 (3.6)	96 (0.7)	<0.001
Cardiac support device						
Overall	362 (19.7)	372 (20.3)	0.680			
Preoperative	132 (7.2)	115 (6.3)	0.263		***	
Postoperative	330 (18.0)	356 (19.4)	0.271			
Blood purification						
Overall	178 (9.7)	159 (8.7)	0.277	38 (0.6)	41 (0.3)	0.735
Preoperative	127 (6.9)	120 (6.5)	0.645	30 (0.5)	32 (0.2)	0.799
Postoperative	173 (9.4)	153 (8.3)	0.246	38 (0.6)	41 (0.3)	0.735
Chemoradiation						
Chemotherapy				228 (3.8)	233 (1.6)	0.002
Radiation		***		21 (0.3)	4 (0.0)	
Chemoradiation				23 (0.4)	12 (0.1)	
Operating room time (min)	467.3 [256.2]	406.4 [98.1]	<0.001	328.4 [121.5]	288.8 [332.4]	<0.001
Complications						
Minor complication	373 (20.3)	412 (22.4)	0.214	702 (11.6)	597 (4.2)	<0.001
Major complication	8 (0.4)	5 (0.3)		31 (0.5)	7 (0.0)	
Abscess drainage	3 (0.1)	3 (0.1)	1.000	17 (0.3)	1 (0.0)	<0.001
Operative hemostasis	6 (0.3)	2 (0.1)	0.157	16 (0.3)	6 (0.0)	0.033
BI change category						
Deterioration	101 (5.5)	92 (5.0)	0.207	150 (2.5)	127 (0.9)	0.374

†: Compared using analysis of variance. Other comparisons were made using chi-square test. SD: standard deviation, CABG: coronary artery bypass graft, VAL: video assisted lobectomy, BI: barthel index, PCI: percutaneous coronary intervention. ***: not examined.

Table 5. Factors associated with complications and BI deterioration.

Parameter	Complications		BI deterioration	
	CABG	Lobectomy	CABG	Lobectomy
	Odds ratio (95% CI)			
Age (for 15-64 years)				
65-74 years	0.889 (0.737-1.073)	1.058 (0.919-1.217)	1.676 (1.090-2.576)	1.863 (1.285-2.700)
≥75 years	0.872 (0.697-1.091)	1.173 (1.010-1.362)	4.505 (2.901-6.996)	4.230 (2.976-6.014)
Gender				
Male	0.920 (0.763-1.110)	0.951 (0.837-1.079)	0.957 (0.683-1.342)	0.951 (0.725-1.248)
Ambulance				
Use	1.218 (0.928-1.598)	0.878 (0.254-3.036)	0.982 (0.585-1.648)	0.670 (0.079-5.694)
Charlson comorbidity index				
1	1.506 (1.228-1.846)	1.248 (1.08-1.442)	0.781 (0.532-1.147)	1.373 (1.015-1.856)
2	1.665 (1.326-2.092)	1.264 (1.065-1.500)	1.052 (0.696-1.59)	1.190 (0.820-1.727)
3	1.225 (0.845-1.777)	0.978 (0.770-1.242)	0.781 (0.380-1.604)	1.656 (1.086-2.526)
4 or more	1.543 (0.930-2.561)	1.671 (1.277-2.188)	1.486 (0.720-3.067)	1.562 (0.886-2.754)
BI at admission category (for nearly completely independent)				
Dependent	1.006 (0.766-1.321)	1.114 (0.556-2.233)	0.320 (0.175-0.586)	3.511 (1.571-7.846)
Partially independent	1.178 (0.773-1.794)	0.979 (0.576-1.665)	1.023 (0.521-2.007)	4.543 (2.607-7.918)
PCI [†]	1.183 (0.732-1.911)	***	0.639 (0.301-1.357)	***
ICU stay [†]	1.041 (0.783-1.384)	1.559 (0.431-5.637)	1.146 (0.741-1.774)	1.199 (0.924-1.555)
Blood transfusion [†]	0.740 (0.371-1.474)	1.028 (0.422-2.502)	1.329 (0.892-1.981)	1.958 (1.368-2.803)
Ventilation [†]	0.690 (0.380-1.255)	-	1.256 (0.887-1.779)	3.331 (2.120-5.234)
Blood purification [†]	0.730 (0.503-1.059)	1.870 (0.959-3.649)	3.079 (1.973-4.803)	2.981 (1.290-6.888)
Cardiac support device [†]	0.646 (0.432-0.967)	***	1.162 (0.782-1.725)	***
Chemotherapy or radiation				
Chemotherapy		0.868 (0.615-1.227)		1.381 (0.771-2.475)
Radiation	***	0.844 (0.191-3.728)	***	3.247 (0.684-15.419)
Chemoradiation		0.296 (0.040-2.212)		**

Table 5. Contd.

Use of innovation				
Off pump or VAL	1.143 (0.973-1.344)	0.774 (0.688-0.870)	1.049 (0.769-1.432)	0.922 (0.717-1.187)
Complication	***	***	1.306 (0.921-1.851)	0.559 (0.365-0.857)
Teaching status (for community)				
Academic	0.984 (0.689-1.407)	0.720 (0.623-0.832)	0.706 (0.344-1.447)	1.133 (0.842-1.523)
Hospital patient volume (for LVH)				
MVH	1.016 (0.795-1.298)	1.593 (1.365-1.860)	1.303 (0.827-2.052)	1.168 (0.852-1.602)
HVH	1.288 (1.079-1.537)	1.146 (0.982-1.338)	1.388 (0.977-1.972)	0.701 (0.500-0.981)
Fiscal year (for 2006)				
2007	1.256 (0.937-1.685)	1.265 (0.999-1.602)	0.731 (0.423-1.265)	1.341 (0.854-2.106)
2008	1.955 (1.499-2.550)	1.625 (1.300-2.032)	0.532 (0.310-0.913)	1.380 (0.877-2.172)
2009	2.238 (1.726-2.903)	2.039 (1.655-2.511)	0.776 (0.474-1.270)	1.721 (1.142-2.592)
2010	2.201 (1.723-2.811)	5.014 (4.152-6.055)	1.328 (0.890-1.981)	2.557 (1.747-3.742)
Operating room time				
One more minute longer	1.0001 (0.9998-1.0005)	1.000 (0.9999-1.0003)	1.0004 (0.9999-1.0008)	1.000 (0.9997-1.0004)
Hosmer Lemeshow goodness of model fit				
P-value	0.094	0.311	0.587	0.577

CABG: coronary artery bypass graft. VAL: video assisted lobectomy, CI: confidence interval, BI: barthel index, PCI: percutaneous coronary intervention, ICU: intensive care unit, HVH: high volume hospital, MVH: middle volume hospital, LVH: low volume hospital, ***: originally not included, **: no cases with BI deterioration and chemo-radiation, †: preoperative critical care use in the complication model and overall use during the hospitalization in the BI deterioration model.

and started to recover after about 30 days, reaching a plateau at 90 to 180 days (Dowdy et al., 2005; Sacanella et al., 2011; Sulter et al., 1999). In this study, the mean lengths of stay were 32 or 37 days for CABG and 15 or 22 days for lobectomy, which is longer than the lengths of stay reported in Western countries (Gopaldas et al.,

2010; Kiernan et al., 2011; Mishra et al., 2006; Rivera et al., 2011). The OECD has acknowledged that acute care hospitals have different roles in Japan than in Western countries (OECD, 2005). The longer length of stay in Japanese hospitals gives us additional information regarding postoperative functional outcomes. In this study,

functional outcomes were not significantly better after off-pump versus on-pump CABG, which is consistent with the results of other studies that measured quality of life using the Short-Form 36, and found no significant differences in general health status at 30 to 360 days between patients who underwent on-pump versus off-pump CABG

(Angelini et al., 2009; Kapetanakis et al., 2008; Motallebzadeh et al., 2006). Functional deterioration was not significantly different after VAL versus OL, although the complication rate was lower after VAL. This finding could provide further validation of the usefulness of VAL, in combination with the findings of other studies that evaluated the advantages and disadvantages of VAL versus OL (Kiernan et al., 2011).

As lower BI at admission and advancing FY were associated with higher complication rates and worse functional outcomes in patients who underwent lobectomy, policy-makers may pay more attention to promoting VAL than off-pump CABG. Patients who underwent lobectomy may have had different preoperative characteristics than those who underwent CABG. Unlike CABG, lobectomy inherently reduces vital organ capacity, and functional recovery is therefore expected to be less after lobectomy than after CABG. As pre- and postoperative, some critical care procedures were associated with BI deterioration in BI for lobectomy patients; it is more important to monitor the quality of critical care rather than in CABG patients. As functional status at admission was associated with functional outcomes in this study, as well as in other studies, appropriate indications for lobectomy should be determined, and relevant skills training and coordination of multidisciplinary treatment among intensivists, cardiologists, OR staff, and rehabilitation staff should be encouraged (Brahmbhatt et al., 2010; Holzhey et al., 2008; Suaya, 2009).

This study has some limitations that should be considered. First, only data from patients discharged during a 6-month period each year for 5 years were analyzed. Even though patients were matched for many significant covariates that could affect the choice of MIS versus conventional procedures, there may be additional variables associated with this choice that were not taken into consideration. The database has now started to record the postal codes of patients, and the study period has been extended to include the whole year from 2010. The methodology of future observational studies can therefore be strengthened by analyzing the distance between home and hospital and by using a larger database (Suaya et al., 2009).

Second, some variables such as the American Society of Anesthesiologists score and cancer stage were not included in the analyses. As there are concerns that these scales do give precise indications of functional status, the current study analyzed intensive care procedures, indicating organ failure and advanced cancer stage instead. For example, use of intra-aortic balloon pumping indicates severe coronary artery disease, and administration of chemoradiation therapy indicates advanced cancer stage. These analyses also support the development of quality improvement initiatives for critical care procedures (Brahmbhatt et al., 2010).

Finally, patients aged less than 15 years or with missing BI data were excluded from our analyses. Although the

differences between the included and excluded patient groups appear to be significant, these differences are not large enough to distort our results (Annex Table 1).

Conclusion

This study evaluated differences in complication rates and functional outcomes between patients who underwent on-pump versus off-pump CABG, and OL versus VAL. In propensity score-matched groups of patients who underwent CABG and lobectomy, postoperative complication rates were lower in patients who underwent VAL versus OL, but not off-pump versus on-pump CABG. Functional deterioration was not significantly different between MIS and conventional procedures for either CABG or lobectomy. As the physical status at admission was associated with functional outcome in patients who underwent lobectomy, the appropriate indications for VAL should be determined, and perioperative treatment strategies to maintain functional status during hospitalization should be implemented.

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Annex Table 1. Comparison of patient characteristics, care process and outcomes between the excluded and included population (%) [SD].

Parameter	CABG			Lung lobectomy		
	Excluded group	Included group	P	Excluded group	Included group	P
Patient number (academic, community)	13523	7573		33490	20407	
Hospital number (academic, community)	78, 302	36, 131		81, 609	37, 218	
Innovation						
Off pump or VAL	7093 (52.5)	3672 (48.5)	0.329 [†]	22168 (66.2)	14378 (70.5)	<0.001 <0.001 [†]
Mean, [SD]	68.2 [9.5]	68.3 [9.5]		66.7 [11.4]	67.2 [10.6]	
Age						
Under 15 years	7 (0.1)	0 (0.0)	0.188	186 (0.6)	0 (0.0)	<0.001
15-64 years	4365 (32.3)	2410 (31.8)		12052 (36.0)	7267 (35.6)	
65-74 years	5399 (39.9)	3019 (39.9)		12560 (37.5)	7661 (37.5)	
≥75 years	3752 (27.7)	2144 (28.3)		8692 (26.0)	5479 (26.8)	
Gender						
Male	10299 (76.2)	5791 (76.5)	0.612	20555 (61.4)	12669 (62.1)	0.102
Ambulance						
Used	2084 (15.4)	951 (12.6)	<0.001	124 (0.4)	54 (0.3)	0.038
Charlson comorbidity index						
1	4695 (34.7)	2732 (36.1)	0.164	6308 (18.8)	4139 (20.3)	<0.001
2	3035 (22.4)	1613 (21.3)		5192 (15.5)	3264 (16.0)	
3	1080 (8.0)	628 (8.3)		2156 (6.4)	1433 (7.0)	
4 or more	476 (3.5)	270 (3.6)		1315 (3.9)	787 (3.9)	
Teaching status						
Academic	4241 (31.4)	1818 (24)	<0.001	10411 (31.1)	6734 (33.0)	<0.001
Fiscal year						
2006	1537 (44.4)	1925 (55.6)	<0.001	2890 (40.6)	4233 (59.4)	<0.001
2007	3517 (73.6)	1260 (26.4)		8472 (74.6)	2889 (25.4)	
2008	3496 (74.7)	1183 (25.3)		8140 (73.0)	3004 (27.0)	
2009	2111 (60.9)	1357 (39.1)		5685 (58.7)	3996 (41.3)	
2010	2862 (60.8)	1848 (39.2)		8303 (56.9)	6285 (43.1)	
PCI						
Overall	929 (6.9)	491 (6.5)	0.283		***	
Preoperative	499 (3.7)	243 (3.2)	0.069			
Postoperative	463 (3.4)	257 (3.4)	0.908			

Annex Table 1. Contd.

Parameter	CABG			Lung lobectomy		
	Excluded group	Included group	P	Excluded group	Included group	P
ICU stay						
Overall	11538 (85.3)	6364 (84)	0.012	11788 (35.2)	6476 (31.7)	<0.001
Preoperative	1975 (14.6)	1037 (13.7)	0.07	75 (0.2)	32 (0.2)	0.089
Postoperative	11373 (84.1)	6295 (83.1)	0.065	11756 (35.1)	6468 (31.7)	<0.001
Blood transfusion						
Overall	8664 (64.1)	4893 (64.6)	0.430	2001 (6)	1171 (5.7)	0.257
Preoperative	468 (3.5)	207 (2.7)	0.004	151 (0.5)	75 (0.4)	0.146
Postoperative	8634 (63.8)	4881 (64.5)	0.379	1922 (5.7)	1138 (5.6)	0.429
Ventilation						
Overall	9281 (68.6)	4938 (65.2)	<0.001	834 (2.5)	443 (2.2)	0.018
Preoperative	382 (2.8)	176 (2.3)	0.030	41 (0.1)	10 (0.0)	0.007
Postoperative	9227 (68.2)	4904 (64.8)	<0.001	813 (2.4)	438 (2.1)	0.035
Cardiac support device						
Overall	2740 (20.3)	1377 (18.2)	<0.001			
Preoperative	949 (7.0)	416 (5.5)	<0.001		***	
Postoperative	2508 (18.5)	1285 (17.0)	0.004			
Blood purification						
Overall	1467 (10.8)	749 (9.9)	0.030	241 (0.7)	161 (0.8)	0.364
Preoperative	1027 (7.6)	547 (7.2)	0.325	212 (0.6)	136 (0.7)	0.639
Postoperative	1428 (10.6)	731 (9.7)	0.037	238 (0.7)	158 (0.8)	0.402
Chemoradiation						
Chemotherapy				1426 (4.3)	685 (3.4)	
Radiation		***		80 (0.2)	39 (0.2)	<0.001
Chemoradiation				91 (0.3)	39 (0.2)	
Operating room time (minute)	435.7 [273.4]	443.3 [164.4]	0.029 [†]	285.3 [112.5]	294.6 [206]	0.772 [†]
Complication						
Minor complication	2423 (17.9)	1496 (19.8)	0.004	4378 (13.1)	2356 (11.5)	<0.001
Major complication	49 (0.4)	27 (0.4)	-	92 (0.3)	52 (0.3)	-
Abscess drainage	17 (0.1)	8 (0.1)	0.684	45 (0.1)	24 (0.1)	0.598
Operative hemostasis	32 (0.2)	20 (0.3)	0.700	50 (0.1)	30 (0.1)	0.947

CABG: coronary artery bypass graft, VAL: video assisted lobectomy, SD: standard deviation, †: compared using analysis of variance. Other comparisons were made using chi-square test. BI: barthel index, ICU: intensive care unit, PCI: percutaneous coronary intervention, ***: not examine.