Long-Term Outcome After Primary Stenting Versus Balloon Angioplasty for Acute Myocardial Infarction

Five-year Follow-up of a Case-control Study

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SUMMARY

The objective of the present prospective multicenter case-control study was to investigate the long-term clinical outcome (5 years) of primary stenting compared to primary percutaneous transluminal coronary angioplasty (PTCA) without stenting (POBA) in patients with acute myocardial infarction at 7 cardiovascular centers in Hokkaido, Japan. Forty-one patients with acute myocardial infarction treated with successful primary stenting (stent group: case) and paired with 41 matched control subjects with acute myocardial infarction treated by successful primary PTCA without stenting (POBA group: control) were analyzed. After 1 year, the stent group had a lower incidence of the combined clinical endpoint (death, rehospitalization due to congestive heart failure, nonfatal myocardial infarction, repeat angioplasty, CABG, or cerebrovascular events) compared to the POBA group (17.1% versus 39.0%, $P = 0.049$). After 5 years, the incidences of congestive heart failure and cardiac death were the same in both groups. However, compared to the POBA group, the stent group had a lower combined clinical endpoint (34.1% versus 61.0%, $P = 0.027$). The Kaplan-Meier event-free survival curves of the stent group showed a significantly lower occurrence of clinical events compared to the POBA group ($P = 0.0116$). Multiple logistic regression analysis of clinical events identified age ≥ 69 years ($P = 0.0092$, odds ratio = 4.179) and stenting ($P = 0.0158$, odds ratio = 0.279) as explanatory factors. Compared with POBA, primary stenting for acute myocardial infarction results in a better long-term clinical outcome. (Int Heart J 2006; 47: 47-57)

Key words: Acute myocardial infarction, Primary angioplasty, Long-term outcome

ORGANIZED prospective, randomized trials of primary stenting in acute myocardial infarction have demonstrated a reduction in the incidence of cardiac

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events related to recurrent ischemia and lower rates of angiographic restenosis or occlusion of the infarct-related artery.¹⁻⁴⁾ Previously published data indicated that primary stenting was superior to primary angioplasty without stenting (plain old balloon angioplasty; POBA) in terms of the prognosis in patients with acute myocardial infarction.⁵⁻⁷⁾ Moreover, previously published data indicate that primary stenting in acute myocardial infarction may be effective for preventing myocardial injury and preserving regional wall motion and left ventricular function and remodeling.^{8,9)} The long-term outcome after an acute myocardial infarction is related to left ventricular function. Therefore, to test the effects of primary stenting on the long-term (5years) clinical outcome in patients with acute myocardial infarction, we performed a comparative case-control study between successful cases of primary PTCA with and without stenting at 7 cardiovascular centers belonging to the Network of Revascularization Therapy in Hokkaido (NORTH) group of investigators.

METHODS

Patient population: Forty-five consecutive patients with acute myocardial infarction treated by successful and uncomplicated primary stenting (stent group) and who did not have restenosis in the subacute phase (28 ± 8 days) were prospectively enrolled between January 1996 and December 1998. The controls were 45 patients with acute myocardial infarction treated by successful (optimal) primary PTCA without stenting (plain old balloon angioplasty (POBA) group); they were also prospectively enrolled from each institute and were paired with the patients in the stent group. The controls were closely matched to the stent group in terms of age, month of revascularization (between January 1996 and December 1998), angiographic findings (vessel numbers involved, collateral grade before revascularization, and infarct-related coronary artery), and inclusion/exclusion criteria. If a stent group patient fulfilled the exclusion criteria mentioned above owing to restenosis and cardiovascular complications, they were excluded from the study. The inclusion and exclusion criteria have been previously described.⁸⁾ All patients in the stent and POBA groups had an infarct-related artery with a reference diameter of > 2.5 mm that was suitable for coronary stent implantation. Two patients in the stent group (4.4%) and 2 in the POBA group (4.4%) were lost to follow-up. Because these 4 patients and 4 matched case or control subjects were excluded, 82 patients were included in the follow-up study.

Procedure: During the acute intervention, heparin (150 U/kg) was given intravenously, and this was continued at a maintenance dose of 150 U/kg/day for 3 days after angioplasty; subsequently oral aspirin (81 mg/day) was prescribed in all cases. In subjects with stenting, the antiplatelet agent ticlopidine (200 mg/day)

was given for at least 3 months to prevent abrupt thrombotic closure. A coil stent was used in 7 cases (Wiktor in 5, GR-II in 2), and a rigid stent in 34 cases (Palmaz-Schatz in 12, Multilink in 12, GFX in 10). The diameter of the stent was at least 3.0 mm in all cases.

Clinical characteristics: The clinical characteristics of the 82 subjects studied are summarized in Table I. The characteristics examined included coronary risk factors (hypertension, hyperlipidemia, diabetes mellitus, smoking), preinfarction angina (defined as chest pain episodes limited to the 48 hours before infarction), Killip classification on admission, time from symptom onset to revascularization, peak creatine kinase value, and drug treatment given after admission (angiotensin-converting enzyme inhibitors, calcium antagonists, nitrates, and beta-blockers).

Quantitative coronary angiography: Quantitative coronary angiography of an infarct-related artery was performed with a contrast filled catheter as a reference.

Table I. Clinical and Angiographic Characteristics of Study Groups

	Stent (<i>n</i> = 41)	POBA (<i>n</i> = 41)	<i>P</i>
Age (years)	62.7 ± 10.7	61.9 ± 10.8	0.737
Gender, male (%)	31 (76%)	29 (71%)	0.803
Coronary risk (%)			
Hypertension	20 (49%)	21 (51%)	1
Hyperlipidemia	16 (34%)	10 (24%)	0.235
Diabetes mellitus	10 (24%)	12 (29%)	0.803
Smoking habits	24 (59%)	25 (61%)	1
Prior MI (LAD/RCA/LCX)	4 (2/1/1)	1 (0/0/1)	0.356
Preinfarction angina	22 (54%)	27 (66%)	0.368
Peak CK (IU/L)	2422 ± 1680	2539 ± 1812	0.763
Killip class ≥ II (%)	6 (15%)	3 (7%)	0.48
Coronary angiography			
Infarct-related artery (LAD/RCA/LCX)	(18/18/5)	(18/18/5)	1
Lesion numbers (SVD/DVD/TVD)	(31/9/1)	(31/9/1)	1
Collateral grade (≥ 2/< 2)	13/28	14/27	1
Angioplasty			
Time to reperfusion (hours)	8.4 ± 9.8	5.5 ± 4.7	0.091
Postprocedural QCA			
Reference (mm)	3.21 ± 0.31	3.04 ± 0.33	0.019
MLD (mm)	2.80 ± 0.36	2.32 ± 0.29	0.0001
% Diameter stenosis	13.3 ± 7.1	23.5 ± 4.2	0.0001
Follow-up QCA			
Interval (days)	28.2 ± 10.2	28.3 ± 6.2	0.957
Reference (mm)	3.26 ± 0.28	3.08 ± 0.36	0.013
MLD (mm)	2.74 ± 0.37	2.34 ± 0.36	0.0001
% Diameter stenosis	16.4 ± 7.8	24.5 ± 5.7	0.0001

Values are mean ± SD or *n* (%).

CK indicates creatine kinase; DVD, double vessel disease; LAD, left anterior descending; LCX, left circumflex; MLD, minimum lumen diameter; MI, myocardial infarction; QCA, quantitative coronary angiography; RCA, right coronary artery; SVD, single vessel disease; and TVD, triple vessel disease.

The diameters of the normal segments proximal and distal to the treated area were averaged to determine the reference diameter. The minimum lumen diameter and the percentage diameter stenosis were calculated by single plane, worst view angulation. Collateral flow was graded from the initial angiography according to the scale described by Rentrop, *et al*,¹⁰⁾ as follows: 3, complete filling of the epicardial segment; 2, partial filling of the epicardial segment; 1, filling of side branches without visualization of the epicardial segment; 0, no collaterals.

Quantitative assessment of regional wall motion: Regional wall motion of the left ventricle was assessed by the centerline method,¹¹⁾ using contrast left ventriculography of the 30 degree right anterior oblique projection, during the subacute phase (28 ± 8 days after the onset), at the same time as follow-up coronary angiography. The area of myocardium at risk (risk area) was angiographically defined as the area depicted on the 30 degree right anterior oblique projection that was supplied by the infarct-related coronary artery.¹²⁾ The proximal limit of the risk area was taken from the “culprit” lesion; defined as either the lesion associated with total occlusion or thrombus, or the most proximal severe stenosis. The distal limit of the risk area was defined as the termination of the infarct-related artery, as viewed in the right anterior oblique projection. The proximal and distal limits were marked on the diastolic contour, and the chords thus encompassed were described as the risk area. In subjects with infarction caused by a left circumflex coronary artery lesion, only those with a dominant left circumflex artery were included. Reference values were derived from 50 angiographically normal control subjects investigated in our laboratory, who were considered to have normal left ventricular function. Regional wall motion abnormality, or hypokinesis area, was defined as chord numbers with depression of regional shortening to less than -1 SD of the control values. Left ventricular ejection fraction was calculated by the area-length method.

Clinical follow-up and endpoints: Clinical follow-up data were obtained by either hospital records or telephone contact with the patient or the referring physicians. Clinical endpoints were defined as death, nonfatal myocardial infarction, coronary artery bypass graft surgery, repeat coronary angioplasty of the target lesion and nonculprit lesions (new lesion), congestive heart failure, and cerebrovascular events. Target lesion revascularization was indicated by the presence of clinical or functional ischemia and more than 75% diameter stenosis or a restenosed lesion more than 90% in the absence of documented ischemia. Bypass graft surgery was defined as any surgical revascularization, even if the target lesion was patent.

Statistical analysis: All data are expressed as the mean $\pm$ SD. The difference in mean values between the 2 groups was compared using an unpaired *t* test. The incidence between the 2 groups was compared by the chi-square test. An event-

free curve was created by the Kaplan-Meier method to determine the time-dependent cumulative event-free rate and compared using log rank tests. An SPSS Advanced Statistics 10.0 package for Macintosh (SPSS Japan, Inc.) was used to determine independent explanatory factors correlated with events. Multiple logistic regression analysis was indicated after confirmation of several statistically significant factors by single logistic regression analysis, and the odds ratio with a 95% confidence interval was calculated. We included age (< 69 or ≥ 69), coronary risk factor (presence or absence), preinfarction angina (presence or absence), method of primary PTCA (stenting or POBA), infarct-related artery (left anterior descending artery or not), hypokinesis area/risk area on left ventriculography in the subacute phase ($\geq 50\%$ or $< 50\%$), % diameter stenosis of post-procedural QCA ($\leq 20\%$ or $> 20\%$), and angiotensin-converting enzyme inhibitor administration (taken after infarction or not) as factors in the multiple logistic regression analysis. A P value < 0.05 was considered significant.

Table II. Major Adverse Cardiac and Cerebrovascular Events

Event	Stent ($n = 41$)	POBA ($n = 41$)	P
1 year			
Death	0 (0%)	1 (2.4%)	1
Cardiac	0 (0%)	0 (0%)	-
Noncardiac	0 (0%)	1 (2.4%)	1
Congestive heart failure	0 (0%)	1 (2.4%)	1
Nonfatal MI	0 (0%)	0 (0%)	-
Repeat angioplasty	5 (12.2%)	12 (29.3%)	0.102
TLR	4 (9.8%)	12 (29.3%)	0.051
New lesion	1 (2.4%)	0 (0%)	1
CABG	1 (2.4%)	3 (7.3%)	0.608
Any cardiac event	6 (14.6%)	15 (36.6%)	0.043
Cerebrovascular accident	1 (2.4%)	1 (2.4%)	0.474
Any event	7 (17.1%)	16 (39.0%)	0.049
5 years			
Death	5 (12.2%)	8 (19.5%)	0.545
Cardiac	1 (2.4%)	1 (2.4%)	0.474
Noncardiac	4 (9.8%)	7 (17.1%)	0.517
Congestive heart failure	1 (2.4%)	2 (4.9%)	1
Nonfatal MI	1 (2.4%)	0 (0%)	1
Repeat angioplasty	8 (19.5%)	13 (31.7%)	0.312
TLR	5 (12.1%)	12 (29.3%)	0.102
New lesion	3 (7.3%)	1 (2.4%)	0.608
CABG	1 (2.4%)	5 (12.2%)	0.203
Any cardiac event	10 (24.4%)	18 (43.9%)	0.103
Cerebrovascular accident	2 (4.9%)	3 (7.3%)	1
Any event	14 (34.1%)	25 (61.0%)	0.027

Values are mean $\pm$ SD or n (%).

CABG indicates coronary artery bypass graft; MI, myocardial infarction; and TLR, target lesion revascularization.

RESULTS

Clinical and angiographic characteristics: Table I shows the clinical and angiographic characteristics of the 2 groups. There were no significant differences between the groups in terms of age, sex, coronary risk factors, preinfarction angina, or Killip classification. The stent group had significantly larger reference and minimum lumen diameters and a smaller percent diameter stenosis than the POBA group, as determined by postprocedural quantitative coronary angiography.

One-year clinical follow-up: Table II shows the major adverse cardiac and cerebrovascular events in the 2 groups. After 1 year, there was a significantly lower incidence of the combined clinical endpoints in the stent group (17.1%) compared to the POBA group (39.0%) ($P = 0.049$). Subsequent target lesion revascularization was necessary in 4 patients (9.8%) in the stent group and in 12 patients (29.3%) in the POBA group ($P = 0.051$) after 1 year.

Five-year clinical follow-up: After 5 years, no significant differences in mortality, congestive heart failure, myocardial infarction, or cerebrovascular events were found between the stent and POBA groups. However, the combined clinical endpoint in the stent group (34.1%) was significantly lower than that in the POBA group (61.0%) ($P = 0.027$). The Figure shows Kaplan-Meier 5-year event free survival curves for the stent and POBA groups. After a follow-up period of 60 months, the occurrence of clinical events was lower in the stent group than in the POBA group ($P = 0.0116$).

Figure. Kaplan-Meier curves for event-free survival in both groups.

Table III. Comparison of Clinical and Angiographic Parameters Between Patients With and Without Cardiac and Cerebrovascular Events

	With event (<i>n</i> = 32)	Without event (<i>n</i> = 43)	<i>P</i>
Age			
years	64.8 ± 9.2	59.1 ± 11.4	0.023
≥ 69	16 (50%)	10 (23%)	0.031
Gender, male (%)	26 (81%)	30 (70%)	0.388
Coronary risk			
Hypertension	18 (56%)	20 (47%)	0.548
Hyperlipidemia	10 (31%)	15 (35%)	0.934
Diabetes mellitus	9 (28%)	12 (28%)	0.843
Smoking	19 (59%)	27 (63%)	0.952
Preinfarction angina	20 (63%)	24 (56%)	0.73
IRA (LAD/non-LAD)	15/17	19/24	0.998
Multivessel disease	11 (34%)	9 (21%)	0.229
Stent/POBA	12/20	27/16	0.053
% Diameter stenosis >20%	14 (44%)	13 (30%)	0.336
Left ventricular ejection fraction (%)	58.3 ± 12.4	60.1 ± 11.3	0.515
Hypokinesis area	23.6 ± 23.9	19.9 ± 18.6	0.453
Hypokinesis area/risk area < 50%	17 (53%)	19 (44%)	0.594

Values are mean ± SD or *n* (%).

IRA indicates infarct-related artery and LAD, left anterior descending.

Table IV. Multiple Logistic Regression Analysis Results for Cardiac and Cerebrovascular Events

Variable	Standard error	Chi-square (Wald)	<i>P</i>	Odds ratio (95%CI)
Method of revascularization				
Stent	0.529	5.830	0.0158	0.279 (0.099-0.786)
POBA				1
Age				
≥ 69	0.549	6.776	0.0092	4.179 (1.424-12.268)
< 69				1

CI indicates confidence interval.

Multiple logistic regression analysis of clinical events: Table III shows a comparison of the patient group with and without cardiac events. Seven patients died of a noncardiac cause (2 lung carcinoma, 1 laryngeal carcinoma, 1 rectal carcinoma, 1 leukemia, 2 pneumonia) without cardiac or cerebrovascular events. These patients were excluded from further clinical event analysis. The clinical event group had a greater prevalence of age ≥ 69 years (*P* = 0.031) and without stent (*P* = 0.053) compared to the no clinical event group. Single logistic regression analysis showed that cardiac and cerebrovascular events were significantly correlated with age ≥ 69 years and stenting, but not with gender, coronary risk factors, preinfarction angina, infarct-related artery (left anterior descending artery or not),

postprocedural residual % diameter stenosis ($> 20\%$), left ventricular ejection fraction in the subacute phase, or regional wall motion (number of hypokinesis chords or hypokinesis area/risk area $< 50\%$) in the subacute phase. Multiple logistic regression analysis of cardiac and cerebrovascular events identified age ≥ 69 years ($P = 0.0092$, odds ratio = 4.179) and stenting ($P = 0.0158$, odds ratio = 0.279) as explanatory factors (Table IV).

DISCUSSION

The findings of the present study suggest that compared with primary balloon angioplasty without stenting, primary stenting for acute myocardial infarction results in a better long-term clinical outcome.

Primary angioplasty with versus without stenting and cardiac events: Previous studies have demonstrated that compared with primary balloon angioplasty without stenting, primary stenting for acute myocardial infarction reduces the rate of major adverse cardiac events within 2 year follow-up.¹⁻⁷⁾ In particular, even though in patients with optimal (stent-like) primary balloon angioplasty without stenting (residual lesion stenosis $< 30\%$), compared with primary stenting, results in a higher rate of major adverse cardiac events related to restenosis or reocclusion of the infarct-related artery.^{1,13)} In the present study, patients with cardiac events that included abrupt closure or restenosis during the acute phase were excluded from the study and residual percent diameter stenosis in the POBA group was only $23.5 \pm 4.2\%$. Nevertheless, the rate of cardiac events at 1 year was higher in the POBA group than in the stent group. Furthermore, the event-free survival rate in the stent group at 5-year follow-up was also significantly higher than in the POBA group. In particular, subjects in the POBA group had a higher incidence of target lesion revascularization due to restenosis or reocclusion of the infarct-related artery at 1 year compared to the stent group. This is the main reason for the difference in the events rate between the stent and POBA groups, and this difference has remained unchanged at 5 years. These findings, as well as those of previous studies, suggest that the long-term outcome in patients with acute myocardial infarction treated by successful primary stenting is superior to optimal (stent-like) primary balloon angioplasty without stenting. On the other hand, the incidence of congestive heart failure was similar in both groups (2.4% versus 4.9%, $P = 1$) and only 1 patient (2.4%) from both groups died due to a cardiac cause. Thus, the long-term mortality in patients with acute myocardial infarction treated by successful primary angioplasty and without major adverse cardiac events in the acute phase was favorable.

Predictive factors for cardiac and cerebrovascular events: In the present study, multiple logistic regression analysis demonstrated that age (≥ 69 years) and

method of revascularization (POBA) were independent predictive factors of cardiac and cerebrovascular events. A previous study has found that the 30-day and 1-year mortality rates were markedly higher for elderly patients compared with younger patients.¹⁴⁾ The results of the present study indicate that not only the rate of mortality but also the rates of cardiac and cerebrovascular events after primary angioplasty in older elderly patients (≥ 69 years) were higher compared with younger elderly patients (< 69 years). The association of age with cardiac and cerebrovascular events might be a reflection of the influence of many factors. For example, a decrease in systemic vascular compliance,¹⁵⁾ altered neurohormonal influence,¹⁶⁾ and an increase in coagulation factors (VII, VIII, and IX) compared with anticoagulation factors (antithrombin III, Protein C, and Protein S) leading to a greater risk of thrombosis in older patients.¹⁷⁾ Therefore, older elderly patients with AMI treated by successful primary angioplasty should undergo aggressive therapy and follow-up in order to reduce the incidences of cardiac and cerebrovascular events. The therapy includes aggressive lipid lowering therapy, strict blood pressure control in hypertensive patients, diabetes management in diabetic patients, and smoking cessation.¹⁸⁾

Cardiac function in the subacute phase and long-term clinical outcome: Previous studies have demonstrated that cardiac systolic dysfunction (left ventricular ejection fraction) and infarct size are closely related to further adverse cardiac events in patients with AMI.¹⁹⁻²¹⁾ In the present study, however, cardiac function in the subacute phase was not identified as a predictor of cardiac and cerebrovascular events. In this study, primary angioplasty was successful in all patients and patients with cardiac events during the acute phase were excluded. With these inclusion criteria, relatively good cardiac function was restored in all patients. For this reason, cardiac function might not be identified as a statistically significant predictor of cardiac and cerebrovascular events.

Study limitations: Subjects with suboptimal results, abrupt closure, restenosis, reinfarction, repeat and added surgical or nonsurgical revascularization, and cardiac death in the acute phase were excluded. Thus, we are unable to comment on some of the important information that is required before decisions can be made about methods of revascularization in acute myocardial infarction. Therapeutic cost-effectiveness was also not investigated. The results from the 82 patients suggest the need for a larger patient population. A final limitation is that the stent group subjects (cases) and POBA group subjects (controls) were enrolled prospectively, but the study was not designed as a prospective randomized trial.

Conclusion: Long-term mortality in patients with acute myocardial infarction treated by both successful primary angioplasty with and without stenting and without major adverse cardiac events in the acute phase was favorable. Moreover,

compared with primary angioplasty without stenting (POBA), primary stenting for acute myocardial infarction results in a better long-term clinical outcome.

APPENDIX

The NORTH investigators were as follows: Sapporo Social Insurance General Hospital, Sapporo: Sasao H; Sapporo Medical University Hospital, Sapporo: Tsuchihashi K, Shimamoto K; Hakodate Goryokaku Hospital, Hakodate: Hasegawa K, Endoh A; Muroran-city General Hospital, Muroran: Kyuma M, Noda R; Muroran Shinnittetsu Hospital, Muroran: Matsuki T, Doi A; Sapporo Cardiovascular Clinic, Sapporo: Nagao K, Kobayashi H; Teine Keijinkai Hospital, Sapporo: Hanawa N, Miyamoto K; Kushiro-City General Hospital, Kushiro: Hashimoto A, Shimoshige S.

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