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Mid-term Follow-up of Coronary Artery Aneurysm After Directional Coronary Atherectomy

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Abstract

Coronary artery aneurysm (CAA) occurs in 6–12% of lesions after directional coronary atherectomy (DCA). The prognosis and the optimal treatment for DCA-related CAAs have not been well known. Therefore, we reviewed the clinical course of 214 consecutive patients with DCA-related CAAs who underwent DCA in our hospital.

Follow-up coronary angiography 6 months after DCA was completed in 193 patients (212 lesions) and 14 lesions with CAAs (14 patients) were detected. We evaluated these 14 lesions by repeat coronary angiography at an average of 32 months after DCA in comparison with the adjacent reference vessel. Twelve of the 14 patients have been uneventful but 2 suffered from *de novo* angina due to new stenotic lesion unrelated to the DCA procedures. We compared the preprocedual angiographic characteristics and periprocedural parameters between the 14 lesions with CAAs [CAA (+) group] and the 198 without CAAs [CAA (−) group], but found no significant differences. Histological examination of specimens retrieved during atherectomy demonstrated that subintimal resection was more frequent in the CAA (+) group (57%) than the CAA (−) group (31%). The diameter of the aneurysm divided by the reference diameter was significantly larger at 6 months immediately after DCA (1.71 ± 0.21 vs 1.31 ± 0.18, $p < 0.05$) but did not change subsequently (1.68 ± 0.23).

Our retrospective analysis revealed a good mid-term (an average of 32 months) prognosis for CAAs found by routine follow-up coronary angiography and also demonstrated that the depth of resection was significantly associated with aneurysm formation.

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Key Words

■ Atherectomy ■ Aneurysms (coronary artery) ■ Prognosis

INTRODUCTION

Coronary artery aneurysm (CAA) occurs in 6–12% of lesions after directional coronary atherectomy (DCA)[1,2]. DCA-related CAAs can be classified into 2 types; early and late aneurysms[3,4]. Early CAA is a relatively rare complication occurring during or immediately after the procedure and appears to be a false aneurysm caused by contained perforation. Late aneurysm is a more common

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complication of DCA and is not associated with coronary perforation at the original procedure. There is a report that one case of an 8-mm aneurysm found 1 month after DCA was a true aneurysm[5], but the histological nature of CAAs has not yet been clarified. Furthermore, the prognosis of DCA-related CAAs has not been well known. We reviewed the clinical course of 14 patients with DCA-related CAAs found at 6-month follow-up coronary angiography among 214 consecutive patients who underwent DCA.

METHODS

Patients

This study was approved by the Institutional Ethics Committee. The study included 214 consecutive patients (169 males, 45 females) who successfully underwent DCA at the Mitsui Memorial Hospital between December 1992 and August 1994 (**Table 1**). The mean age was 60.4 years (range 27 to 84 years). All patients had myocardial ischemia that required revascularization. Fifty-one patients had a history of prior myocardial infarction and 19 patients had undergone coronary artery bypass surgery. Follow-up coronary angiography at 6 months after the original procedure was completed in 193 patients (212 lesions) and identified 14 CAAs in 14 patients. These 14 lesions were evaluated at repeat angiography at an average of 32 months after DCA to compare the size of the CAAs at 6 months and >1 year after the procedure. No patient died or suffered myocardial infarction. Two patients suffered angina pectoris due to new stenotic lesions which had no relation to the previous DCA site.

Table 1 Baseline characteristics

No. of patients	214
Sex (male/female)	169/45
Age (yr)	60.4 (range 27–84)
Prior MI	51 (AMI 2 included)
Prior CABG	19
Multivessel disease	59
De novo/restenotic lesion	142/72
Location	
LAD	172
RCA	30
LCX	16
LMT	12
SVG	4
ACC/AHA type	
A	28
B	163
C	29

(A) MI = (acute) myocardial infarction; CABG = coronary artery bypass grafting; LAD = left anterior descending artery; RCA = right coronary artery; LCX = left circumflex artery; LMT = left main coronary trunk; SVG = saphenous vein graft; ACC = American College of Cardiology; AHA = American Heart Association.

Atherectomy procedure

All procedures were performed with the Simpson Atherocath (Devices for Vascular Intervention). The device and the details of the procedure have been described previously[6,7]. Premedication with aspirin (162–243 mg) was started 24 hours before the procedure and continued indefinitely in all patients. Heparin was administered to maintain the activated clotting time at over 250 sec during the procedure. The atherectomy device was positioned across the lesion over a 0.014 in guidewire advanced through a 10 F guiding catheter (Devices for Vascular Intervention). The number of cuts performed, the maximal balloon inflation pressure, and the final device size were determined from the diameter of the reference vessel and the residual stenosis after atherectomy. Generally, 6 F, 7 F, and 7 F graft devices were used when the reference diameter was <3.0 mm, ≥ 3.0 mm, and ≥ 4.0 mm, respectively. Predilation with a conventional angioplasty balloon was only performed if difficulty crossing the lesion occurred or was anticipated because of lesion morphology. Initial cuts were directed toward the angiographically apparent plaque as guided by multiple orthogonal views. Initial balloon inflation pressures of 5–10 psi were used. If repeat angiography demonstrated a residual stenosis over 15%, additional atherectomy was performed using higher inflation pressures (maximum 40 psi). If residual stenosis over 15% was still evident, DCA was performed with a larger cutter or other procedure. Conventional angioplasty was reserved for unacceptable residual stenosis, mild to moderate dissections, or the rescue of compromised side branches. Successful DCA was defined as tissue removal with residual diameter stenosis $<50\%$ and the absence of major complication (emergency coronary artery bypass graft surgery, Q wave myocardial infarction or death).

Definition of coronary artery aneurysm

CAA has been defined as a localized dilation of a coronary artery over 1.2−2.0 times the diameter of the normal adjacent segments[8−10]. We defined CAA as a coronary dilation with a diameter exceeding 1.2 times that of the normal adjacent segments or the patient's largest coronary vessel.

Angiographic analysis

Coronary angiograms were evaluated by 2 independent experienced angiographers. Stenotic lesions were classified in accordance with the American Heart Association/American College of Cardiology (AHA/ACC) classification grade. Quantitative analysis to assess the severity of stenosis used cineangiograms obtained before and immediately after DCA. Digital calipers were used to measure the lumen diameter. Stenotic lesions were evaluated using frames obtained in the orthogonal view that demonstrated the stenosis in its least foreshortened projection. A computer-assisted edge-detection algorithm was applied to the digitized images, and the absolute coronary dimensions and percentage stenosis were obtained using the guiding catheter as the reference standard. The ectasic lesion was evaluated in the projection showing the largest diameter. Manual caliper measurements were obtained to determine the diameter of enlarged vessel using the adjacent reference for comparison. The diameter of the coronary angiography catheter was used as a reference to determine the absolute size of the lesions.

Tissue analysis

Directional coronary atherectomy specimens were fixed in 10% buffered formalin and embedded in paraffin, and then 6 μm sections were cut and stained with hematoxylin-eosin, Masson's trichrome, and elastica van Gieson stain. Standard light microscopy was performed by 2 independent experienced pathologists who evaluated specimens for the presence of atheromatous plaque, intimal hyperplasia, media, adventitia, and thrombus.

Statistical analysis

Continuous data are presented as mean ± SD. Group comparisons were performed using the χ^2 test for discrete variables and the unpaired *t*-test for continuous variables. Statistical significance was assumed at $p < 0.05$.

RESULTS

Aneurysmal dilation was noted in 14 lesions (7%) at follow-up angiography 6 months after the procedure. This frequency was quite similar to that reported previously[1,2]. Seven of these 14 lesions, were already over 1.2 times the diameter of the normal adjacent segments immediately after the procedure and were considered to be early aneurysms. These early aneurysms showed no perforation or rupture and were followed conservatively without intervention. The other 7 lesions were defined as late aneurysms. We compared the preprocedural angiographic characteristics and periprocedural parameters including pathology between the early and late aneurysms but found no significant differences (data not shown).

Next, we compared several parameters between the 14 CAAs [CAA (+) group] including the early and late aneurysms and the 198 lesions without CAA [CAA (−) group]. The angiographic characteristics of the 2 groups are shown in **Table 2**. There were no significantly different preprocedural angiographic parameters of CAA such as percentage stenosis, reference vessel diameter, or character of the target lesions (ACC/AHA classification). The DCA procedure used no statistical differences in the number of cuts, the maximum inflation pressure, the size of atherocatheter or the rate of adjunctive percutaneous transluminal coronary angioplasty. Examination of specimens retrieved during atherectomy demonstrated that the weight of resected tissues showed no difference but subintimal resection (media with or without adventitia) was more frequent in the CAA (+) group than in the CAA (−) group [57% (8 lesions) vs 31% (61 lesions), $p < 0.05$]. Resection extending to the adventitia was also more frequent in the CAA (+) group than in the CAA (−) group [29% (4 lesions) vs 10% (20 lesions), $p < 0.05$]. These data also demonstrated that only 12% of lesions with subintimal resection and 17% of lesions with resection to the adventitia developed CAA.

The coronary arteriograms of a typical case in our series are shown in **Fig. 1**. The luminal dimensions (aneurysm/reference ratio) of every CAA lesion at baseline, immediately after the procedure and at follow-up are shown in **Fig. 2**. The aneurysm/reference ratio was significantly higher at 6 months than immediately after the procedure (1.71 ± 0.21 vs 1.32 ± 0.18, $p > 0.05$). However,

Table 2 Angiographic and pathologic characteristics of patients with and without coronary artery aneurysm

	Aneurysm(+)	Aneurysm(−)	*p* value
Lesions	14	198	
Restenotic lesion	5(36%)	61(31%)	NS
Patient characteristics (coronary risk factors)			
Hypertension	6(43%)	95(48%)	NS
Diabetes mellitus	5(36%)	63(32%)	NS
Hypercholesterolemia	7(50%)	108(55%)	NS
Current smoking	6(43%)	81(41%)	NS
Pre DCA parameters			
Reference diameter (mm)	3.15±0.24	3.00±0.73	NS
% stenosis	79±6	69±4	NS
ACC/AHA type			
A	2	24	
B	8	117	NS
C	5	58	
DCA procedure			
Number of cuts	28.3±10.6	29.0±11.6	NS
Maximum inflation pressure (psi)	22.1±8.5	25.2±10.7	NS
Size of atherocatheter			
7F graft	2	24	
7F	9	117	NS
6F	3	57	
Adjunctive PTCA	2(14%)	23(12%)	NS
Post DCA parameters			
Lesion diameter (mm)	3.75±0.54	3.37±0.69	<0.05
% stenosis	−32±18	−7±22	<0.05
Pathology			
Tissue weight (mg)	33.5±19.0	26.1±19.7	NS
Media±adventitia	8(57%)	61(31%)	<0.05
Adventitia	4(29%)	20(10%)	<0.05

DCA=directional coronary atherectomy; PTCA=percutaneous transluminal coronary angioplasty. Other abbreviations as in Table 1.

the ratio at the chronic stage (1.68 ± 0.23) was unchanged compared to 6 months after the procedure for both early or late aneurysms. All our patients with CAA related to deep resection fortunately escaped from restenosis, so the evaluation of more cases with CAA is needed to find whether the cases with CAA have lower restenosis rate.

DISCUSSION

This retrospective analysis revealed a good midterm (mean 32 months) prognosis for CAA with a maximum diameter of 8 mm and showed that the frequency of DCA-related coronary aneurysm was 7% in our series. Histological examination of specimens retrieved during atherectomy demonstrated that subintimal resection was more frequent in the lesions with CAA than in those without CAA.

The pathogenesis of CAA formation after DCA remains to be elucidated, but resection of subintimal tissue could theoretically lead to vessel dilation and wall thinning, ultimately resulting in aneurysm formation[1]. Our data support this hypothesis. In some patients, aneurysms developed in the absence of subintimal tissue resection, but subintimal injury by devices including the cutter and nose cone or overdilation could be related to aneurysm formation.

There is no consensus regarding the optimal

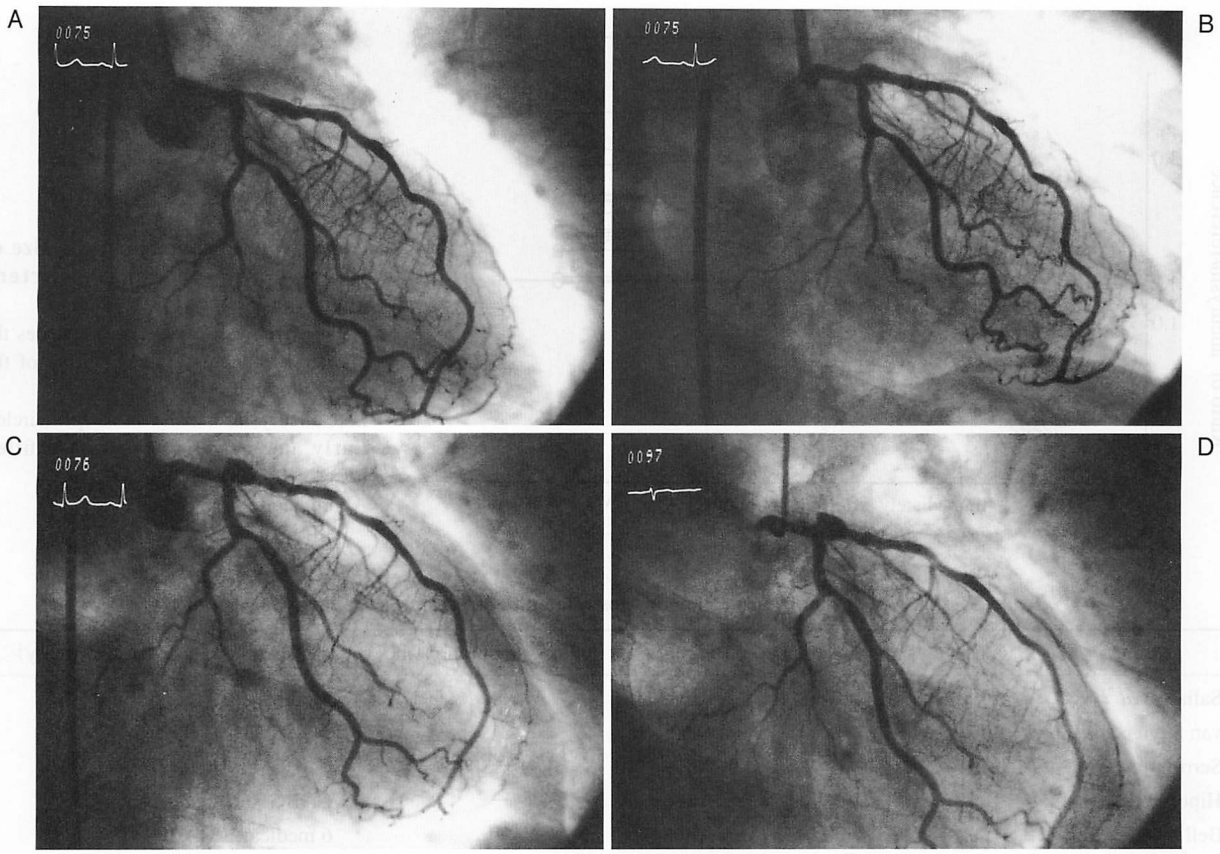

Fig. 1 Coronary arteriograms in a typical case of coronary artery aneurysm(right anterior oblique view)
A: Before DCA. *B*: Immediately after DCA. *C*: After 6 months. *D*: After 4 years.
Abbreviation as in Table 2.

treatment of CAA in the chronic phase. In our series, all patients with CAA were managed conservatively and no patients had any adverse outcome that could be attributed to the presence of aneurysm. In our series, the maximum CAA diameter was around 8 mm. Although we cannot comment on aneurysms over 8 mm in diameter, we suppose that CAAs with a maximum diameter of 8 mm showed enlargement early after DCA but remained stable and free from rupture in the remote stage. Review of the literature on CAA after directional coronary atherectomy shows that most early CAAs including perforation and impending rupture were surgically treated for fear of rupture (**Table 3**)[1-5,7,11-14]. In the case of late aneurysms, many lesions were observed conservatively but some received surgical intervention. However, the mere presence of an aneurysm did not lead to the decision to operate. Most lesions were treated surgically for other concomitant indications : Restenosis of the affected vessel, progression of multivessel coronary artery disease, or the need for a concomitant cardiac procedure. Recently, a novel transcatheter technique for coronary aneurysm repair using a composite autologous cephalic vein-coated stent was reported by Wong and colleagues[15], and this technique may be the modality of choice for repair of CAA. On the other hand, several reported cases of CAA were followed conservatively and remained free from cardiac event with a relatively good outcome, but the duration of follow-up was at most 1 year. In our series, the aneurysms were followed for the mean 32 months, and therefore it provided useful information about the longer-term prognosis of DCA-related aneurysms.

Deep resection may be related to lower restenosis rate. All our patients with CAA related to deep resection escaped from restenosis over the mean 32-month follow-up. However, the evaluation of

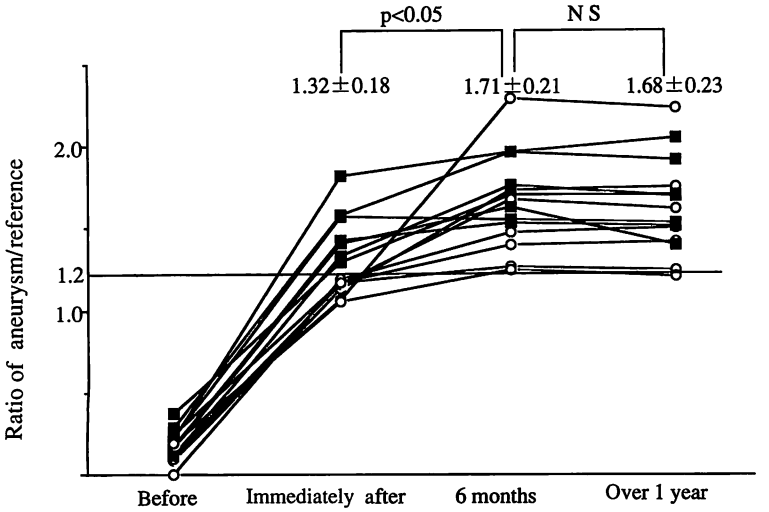

Fig. 2 Angiographic changes in the size of DCA-related coronary artery aneurysm
Ratio of aneurysm/reference indicates the diameter of CAA divided by that of the normal reference.
Late aneurysms are shown in open circles. Early aneurysms are shown in filled boxes.
Abbreviation as in Table 2.

Table 3 Cases of coronary artery aneurysms related to directional coronary atherectomy

Authors	Year	No. of patients	Status	Follow-up duration (mo)	Treatment (reason for surgery)
Safian *et al* [7]	1990	1	Alive	11	Medical
van Suylen *et al* [11]	1991	1	Dead	<1	Medical
Serruys *et al* [12]	1991	1	Alive	—	CABG (threatened rupture)
Hinohara *et al* [2]	1991	2	Alive	—	CABG (threatened rupture)
Bell *et al* [1]	1992	7	Alive	19	6 medical, 1 CABG (MVCAD)
Cohen *et al* [13]	1992	1	Alive	6	Ligation, CABG (restenosis)
Krolick *et al* [5]	1992	1	Alive	6	Medical
Prewitt *et al* [3]	1993	1	Alive	2	CABG (restenosis)
Dralle *et al* [4]	1995	1	Alive	9	Plication, CABG (threatened rupture)
Nakamura *et al* [14]	1996	7	Alive	12	Medical

mo=month; MVCAD=multivessel coronary artery disease. Other abbreviation as in Table 1.

more cases with CAA is necessary to answer whether patients with CAA have lower restenosis rate. We compared the restenosis rate between the lesions with or without subintimal resection among our 214 DCA cases but there was no difference (data not shown). Longer observation than our study may demonstrate a different outcome, thus we will continue to follow these patients and are planning to perform angiography much longer after the procedure.

Our present study has several limitations. Measurement of the diameter of the CAA in the coronary angiography selected the proximal and distal normal segments by location relative to the stenosis and relatively smooth angiographic borders. The definition of CAA was based on selection of a normal reference segment. If the segment selected had significant luminal narrowing due to atherosclerosis that was not apparent angiographically, the size of the ectasic lesion may have been overestimated. Examination of the aneurysms with coronary angiography can only demonstrate the inner lumen and does not show the structure of the aneurysmal wall, including the continuity of the layer, the outer diameter, and the presence of thrombus. Recently, intravascular ultrasound has made remarkable progress and may distinguish between true and false aneurysm. Analysis of intravascular ultrasound images provides insights into vessel wall structure and the vascular remodeling process[16]. Whether the distinction between a true and false aneurysm affects the prognosis and management also remains to be studied. In the future, we should perform further pathological and morphological analysis using new devices like intravascular ultrasound or intravascular endoscopy.

In this series, the study subjects were our initial DCA cases. Recently, due to the popularity and efficacy of coronary stenting and rotational atherectomy, we have treated fewer DCA cases. Fortunately, we have recently experienced no case with DCA-related CAA in our hospital after this study. Today, due to the progress of the DCA technique along with the development of intravascular ultrasound and adjunctive or alternative devices, 2 recent DCA studies have reported more favorable results than previously[17,18]. The ABACAS trial[17] performed in Japan used intravascular ultrasound on a routine basis to guide greater plaque excision by DCA and achieved an overall final restenosis of 14% without an increase in periprocedural complications including coronary aneurysms. The final results of OARS[18] demonstrated that optimal DCA produced a low residual percentage diameter stenosis and a lower restenosis rate than seen in previous trials without an increase in early or late major adverse events. Intravascular ultrasound guidance also significantly decreased the rate of subintimal resection combined with the DCA device (21%) compared with standard DCA (54%), although there was no difference in the extent of tissue removal and final percentage stenosis[19]. Therefore, lesions indicated for DCA have been limited recently but we can perform DCA more safely and effectively with intravascular ultrasound guidance.

In conclusion, a mean 32-month follow-up of CAA demonstrated a good prognosis for DCA-related CAA. Longer observation is mandatory to understand the natural history of this aneurysm Deep resection was significantly associated with CAA formation.

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要　約

方向性冠動脈粥腫切除術により形成された冠動脈瘤の中期予後

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最近の研究では，方向性冠動脈粥腫切除術(DCA)施行後に冠動脈瘤が6−12%の割合で発症するといわれている．DCAに関連して生じる冠動脈瘤の予後および対処法については定説がいまだない．今回我々はDCAに関連して生じる冠動脈瘤の症例の臨床経過につき検討し，非形成例との比較を行った．

対象は当院にて施行されたDCA症例連続214例で，このうち193例212病変について6ヵ月目の確認造影を施行し，14例14病変に冠動脈瘤が認められた．この14例については平均32ヵ月の慢性期に再造影を施行し，瘤径の変化を検討した．冠動脈瘤径/正常血管径の比はDCA施行直後の1.31±0.18から6ヵ月目の確認造影では1.71±0.21と有意に拡大していたが($p<0.05$)，慢性期には1.68±0.23と有意差を認めなかった．この14例のうち新規病変による狭心症が発症した2例以外は，心事故はなかった．冠動脈瘤形成例(14病変)と非形成例(198病変)について病変の径および性状，DCA手技に関して比較検討を行ったが，有意差は認められなかった．DCAに際して得られた組織の病理検討では，中膜または外膜まで切除されていた例が瘤形成例では57%と非形成例(30%)に比べて多く認められた．

我々の今回の研究により，DCA後確認造影で発見される冠動脈瘤の平均32ヵ月の中期予後は比較的良好であったが，冠動脈瘤の自然歴を知るためにはさらに長期の経過観察が必要である．またDCA施行による切除の深度が瘤形成と有意に関連した．

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