Angiographic Classification of Coronary Dissections after Plain Old Balloon Angioplasty for Prediction of Regression at Follow-up

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SUMMARY

Coronary dissection after plain old balloon angioplasty often shows regression during follow-up. This study sought to determine whether we can predict such phenomenon angiographically. We analyzed 64 patients with 71 type B-D coronary dissections determined by the National Heart, Lung, and Blood Institute (NHLBI) criteria. Regression was considered present when minimal lumen diameter increased by more than 0.3 mm during follow-up. Dissections were divided into subgroups using the NHLBI criteria and our classification in which type a and b dissections were characterized by the width of a dissection lumen exceeding one quarter of the reference diameter with the outer edge of the dissection lumen within the boundary of reference in type a and beyond it in type b. In type c and type d dissections, the width of the dissection lumen was within one quarter of the reference with its outer edge within the boundary of reference in type c and beyond it in type d. Type e dissection had a protruding flap or spiral appearance. Regression was recognized in 23.9%. The distribution of dissection types was similar in the groups with and without regression by the NHLBI criteria, but type c dissection had regression more frequently than the other types of coronary dissections (p<0.001) using our classification.

Key words: Coronary intervention, Dissection, Restenosis, Coronary angiography, Quantitative coronary angiography

CORONARY stenting reduces the restenosis rate in selected lesions and prevents acute occlusions induced by severe flow-limiting dissection. On the other hand, the cost-effectiveness and limitations of stents for unfavorable coronary artery lesions must be considered when we use stents routinely in coronary intervention. Although the use of stenting is widespread, the concept of...
"optimal balloon angioplasty" has only recently emerged. Optimal balloon angioplasty could be achieved at a higher balloon/artery ratio with the use of intravascular ultrasound than with a conventional approach, resulting in a higher frequency of coronary dissection. Thus, discrimination of those dissections that regress during follow-up is very important in attaining optimal balloon angioplasty. Against this background, the long-term outcome of coronary dissection after plain old balloon angioplasty (POBA) has become important again even in the era of stenting. Unquestionably, flow-limiting coronary dissections (types E and F in the National, Heart, Lung, and Blood Institute (NHLBI) criteria) require stents to avoid coronary bypass grafting. However, we often find that lumen narrowing associated with non-flow limiting dissections (types A, B, C, and D in NHLBI criteria) after POBA regress spontaneously during long-term follow-up. In this study, we sought to determine whether regression can be predicted angiographically using our novel method of classification of dissections.

**PATIENTS AND METHODS**

*Study population:* The population consisted of 180 consecutive patients with 240 lesions who underwent POBA at four centers between 1993-1995. They were retrospectively identified from the PTCA database. There was a total of 86 dissected lesions that included type A dissection in 8 lesions, types B-D dissections in 76 lesions, and types E-F lesions in 2 lesions according to the NHLBI criteria. In the present study, we analyzed 64 patients with 71 lesions with types B-D dissections in which a follow-up angiogram was available. The patients underwent no additional interventions after POBA. No stents were commercially available during the study period in Japan. Angiographic follow-up was performed 6 months after POBA in all eligible patients. Written informed consent for the procedure and return for repeat angiography at 6 months was obtained from all patients.

*POBA procedure:* POBA was performed in a standard manner via a femoral artery after administration of 5,000 U of heparin. Guiding catheters, guide wires and balloon catheters were selected at the discretion of the primary operator. No patients underwent emergency coronary artery bypass grafting because of acute closure or threatened occlusion after PTCA due to non flow-limiting dissections.

*Dissection type:* To determine whether there is a relationship between the incidence of regression and type of non flow-limiting dissections, all lesions were divided into subgroups according to: 1) the NHLBI criteria, and 2) our classification consisting of five distinct morphological patterns (Figure 1). We developed a new classification of coronary dissection prospectively using another
Figure 1. Angiographic subtypes of coronary artery dissection after balloon angioplasty in schematic drawings proposed in the present study. This classification is based on the depth and breadth of dissection and the presence of intimal flap or spiral appearance. A and B: Type a and type b dissections are characterized by a wide dissection lumen. The diameter of the dissection cap exceeds at least one quarter of the diameter of the apparent normal lumen. The outer edge of dissection cap is within the true lumen of the reference in type a dissection and beyond it in type b dissection. C and D: Type c and type d dissections are characterized by a thin dissection lumen. The diameter of dissection lumen is within one quarter of the reference diameter. Its outer edge is within the true lumen of the reference in type c dissection and beyond it in type d dissection. E: Type e dissection is characterized by the presence of a flap protruding into the true lumen or spiral appearance.
series of coronary dissections before starting the analysis for the present subjects. Using the NHLBI criteria, type A dissection was defined as the presence of radiolucent areas within the coronary lumen during contrast injection, with minimal or no persistence of contrast after the dye has cleared. Type B dissection meant parallel tracts or a double lumen separated by a radiolucent area during contrast injection, with minimal or no persistence after dye clearance. Type C appeared angiographically as contrast outside the coronary lumen, with persistence of contrast in the area after clearance of dye from the coronary lumen. A dissection was classified as type D in the presence of a spiral-shaped filling defect with delayed distal flow. The classification proposed in this study was based on the depth and breadth of dissection and the presence of intimal flap, as shown in Figure 1. Serial angiograms of a representative case for each type are presented in Figures 2-6. Type a and type b dissections were characterized by a wide dissection lumen. The diameter of the dissection lumen was expected to exceed at least one quarter of the diameter of the apparent normal lumen by visual estimation. The outer edge of the dissection lumen was expected to be within the true lumen.

![Type a dissection](image)

**Figure 2.** A representative case of type a dissection. An eccentric stenosis of the proximal segment of the right coronary artery with anomalous origin (A) was treated with a conventional balloon, resulting in the development of type a dissection (B). No regression was observed at 5 months follow-up (C).
Figure 3. Representative case of type b dissection. Balloon angioplasty for a diffuse stenosis of the mid segment of the left anterior descending artery (A) was performed. The result was a type b dissection (B). A follow-up examination 6 months later revealed no regression (C).

Figure 4. A type c dissection with a representative serial change. A linear and thin dissection (B) was demonstrated after balloon angioplasty for a segmental mid left circumflex artery lesion (A). Angiography performed 5 months later demonstrated healing of the dissection and regression (C).
Figure 5. A typical case of type d dissection. A lesion of the distal portion of the left circumflex artery (A) was noted. A linear thin dissection with its outer edge beyond the boundary of reference was noted after balloon angioplasty (B). No change in minimal lumen diameter was demonstrated at 6 months follow-up (C).

Figure 6. A representative case of type e dissection. A midsegment right coronary artery lesion (A) was treated by balloon angioplasty with a resultant type e dissection that showed an intimal flap protruding into the lumen (B). Restenosis was seen at 6 months follow-up (C).
of the reference site in type a and beyond it in type b. Type c and type d dissections were characterized by a thin dissection lumen. The diameter of the dissection lumen was expected to be within one quarter of the reference diameter by visual estimation. Its outer edge was within the true lumen of the reference site in type c dissection and beyond it in type d dissection. Type e dissection was characterized by the presence of a flap protruding into the true lumen or a spiral appearance. The relationship between dissection length and the incidence of regression of dissection was also determined. We evaluated the interobserver and intraobserver variabilities of our classification. Two independent observers (J.S. and S.I.) classified 71 lesions, and the interobserver agreement ratio was determined. One observer (S.I.) classified 71 lesions twice 6 months apart, and the intraobserver agreement ratio was determined. Intraobserver and interobserver agreements for classification of the dissections were calculated as the percentages of dissections with agreement on the type of dissection.

Qualitative and quantitative analysis of coronary angiography: Three angiograms were obtained in the same view for each patient, immediately before coronary angioplasty, immediately after coronary angioplasty, and at follow-up. We paid special attention to take good quality angiograms that were suitable for qualitative 19) and quantitative 20) analyses. Qualitative analysis of the lesions was carefully performed based on standardized criteria for preprocedural lesion morphology,19,21) and the lesions were also classified according to the modified ACC/AHA classification.22) QCA (CMS, MEDIS, edge detection method), which had been validated elsewhere,23) was used to evaluate the initial and long-term results of POBA. Lesion length (shoulder to shoulder), reference diameter, and minimal lumen diameter (MLD) were measured immediately before POBA and immediately after POBA, and an average of 5.3 months after POBA. A contrast filled guiding catheter was used as a scaling device. Two nearly orthogonal views that included the single view showing the most severe stenosis with the least foreshortening were selected, and the results of analysis for the two views were averaged. In this study, false lumens were not included in the measurement of MLD after POBA. Thus, if automated edge detection included the dissection in the analysis, we delineated the true lumen manually.

Definitions: Initial success was defined as % diameter stenosis < 50% after POBA without major complications (any death, emergent coronary artery bypass grafting, or Q-wave myocardial infarction). Restenosis was considered to have occurred when % diameter stenosis was >50% at follow-up. "Regression" was considered to have occurred when the MLD increased by more than 0.3 mm (two times of a mean reproducibility of ±0.15 mm with the MLD after POBA in the present study) during the follow-up period. The degree of mean reproducibility with MLD in the present study was similar to that previously validated by Haase,
et al.\textsuperscript{24} (±0.08 mm with 0.5-1.9 mm phantoms) using the same QCA system even in the dissected lesions. We also evaluated the symmetricalness of the true lumen after POBA using a symmetry index that was defined angiographically as the ratio of the minor diameter of the true lumen/major diameter of the true lumen. A symmetry index of 1.0 would indicate a purely concentric true lumen.

Statistics: Data were analyzed with Statview 4.5 (Abacus Concepts, Berkeley, California). Data are presented as mean±1 SD. The chi-square test was used to assess the significance of differences in categorical variables followed by five pair-wise tests (lesions with each dissection versus the other lesions using the Holland-Copenhaver method,\textsuperscript{25}) where a significant \( p \) value was set at 0.0102. Student's \( t \)-test or one-way analysis of variance with posthoc comparison using the Bonferroni correction for Student's \( t \)-test was used to assess the significance of differences in continuous variables between two or more groups, and a significant \( p \) value was set at \( p<0.05 \) or \( <0.005 \) (0.05/number of observations), respectively.

RESULTS

During the study period, 69 patients with 76 lesions had non flow-limiting dissection and only 5 patients with 5 lesions did not have angiographic follow-up because it was rejected by the patient. The dissection type was a type in 2 lesions, b type in 1 lesion, c type in 1 lesion, and type e in 1 lesion and there was no clinical evidence of restenosis. No lesions without angiographic follow-up had target

Table I. Clinical Characteristics of Patients with Coronary Dissections after Balloon Angioplasty

<table>
<thead>
<tr>
<th></th>
<th>Number of Patients (Lesions)</th>
<th>Age (Years)</th>
<th>Male Gender</th>
<th>Old myocardial infarction</th>
<th>CCS class 0/1/2/3/4</th>
<th>Coronary risk factors</th>
<th>Target Vessels</th>
<th>Dissection type</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>64 (71)</td>
<td>64 ± 9</td>
<td>34 (53%)</td>
<td>29 (45%)</td>
<td>13/24/21/11/3</td>
<td>Diabetes Mellitus</td>
<td>LAD/LCX/RCA</td>
<td>29/18/24</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>Hypertension</td>
<td></td>
<td>B/C/D 48/18/5</td>
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<td></td>
<td></td>
<td></td>
<td>Hyperlipidemia</td>
<td></td>
<td>a/b/c/d/e 15/12/9/14/21</td>
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CCS=Canadian Coronary Society; LAD=left anterior descending coronary artery; LCX=left circumflex coronary artery; RCA=right coronary artery; NHLBI=National, Heart, Lung, and Blood Institute.
vessel revascularization. There was no difference in dissection type between the patients with and without angiographic follow-up. Subsequently, we studied 64 patients with 71 lesions who underwent angiographic follow-up.

POBA was successful for 56 of 71 lesions (78.9%). The clinical characteristics are shown in Table I. Dissection was type B in 48 lesions, type C in 18 lesions, and type D in 5 lesions according to the NHLBI classification. On the other hand, according to our classification, it was type a in 15 lesions, type b in 12 lesions, type c in 9 lesions, type d in 14 lesions, and type e in 21 lesions. Of the 71 lesions that were classified in 64 patients, there was agreement on dissection type between the two independent reviewers with our method of classification in 64 of the 71 lesions (90%). There was 90% agreement in intraobserver classification. Regression was recognized in 17 lesions (23.9%) at follow-up.

**QCA results:** The QCA results are shown in Tables II and III. The reference diameter and MLD before POBA were larger in the regression-positive group than in regression-negative group. Percent DS before POBA did not differ between the groups with and without regression. MLD was significantly larger and % DS smaller at follow-up in the regression-positive group. The restenosis rate was much lower in the regression-positive group, and no lesions in this group had restenosis ($p=0.001$). Although the distribution of dissection types in the regression-positive group was similar to that in the regression-negative group

| Table II. Comparison of QCA Results between Lesions with and without Regression of Coronary Dissections |
|---------------------------------------------------------------|-------------------|-----------------|------------------|
| Regression Positive ($n=17$)                                   | Regression Negative ($n=54$) | $p$ value        |
| Reference diameter (mm)                                       | 2.93±0.71         | 2.50±0.28       | 0.010            |
| Pre MLD (mm)                                                  | 1.03±0.40         | 0.87±0.26       | 0.060            |
| Final MLD (mm)                                                | 1.43±0.33         | 1.47±0.35       | 0.620            |
| Follow-up MLD (mm)                                            | 2.14±0.46         | 1.23±0.41       | <0.001           |
| Pre %DS (%)                                                   | 65±10             | 65±9            | 0.939            |
| Final %DS (%)                                                 | 49±11             | 42±9            | 0.007            |
| Unsuccessful (%DS>50%)                                        | 5/17 (29%)        | 10/54 (19%)     | 0.337            |
| Stent like result (%DS≤30%)                                   | 1/17 (6%)         | 6/54 (11%)      | 0.528            |
| Symmetry index                                                | 0.81±0.16         | 0.82±0.17       | 0.905            |
| Follow-up %DS (%)                                             | 26±11             | 51±14           | <0.001           |
| Restenosis (%)                                                | 0 (0 %)           | 23 (42.6 %)     | 0.001            |
| Balloon/Artery ratio                                          | 1.06±0.21         | 1.08±0.15       | 0.726            |
| Lesion length                                                 | 15.1±7.4          | 16.7±8.0        | 0.469            |
| Dissection length                                             | 6.6±4.4           | 6.4±3.1         | 0.794            |
| Staining of dissection                                        | 4/17              | 15/54           | 0.726            |

MLD=minimal lumen diameter; DS=diameter stenosis.
According to the NHLBI criteria (Table IV, p=0.898), there was a significant difference between the two groups (Table IV, p=0.001) using our classification. In our classification, type c dissections had a higher incidence of regression at follow-up compared with the other type dissections. Dissections with contrast staining, which are specifically subgrouped as type C in the NHLBI criteria, were detected at similar rates in the regression-positive and -negative groups (4/17 for the regression-positive group vs 15/54 for the regression-negative group, p=0.726). There was no difference in dissection length between the two groups.
(6.6±4.4 mm for the regression-positive group vs. 6.4±3.1 mm for the regression-negative group, \( p=0.794 \)). There was no difference in the symmetry index between groups with and without regression or among groups with 5 types of coronary dissections.

**Initial and long-term results:** None of the patients enrolled in this study experienced an adverse event during acute and late follow-up. No acute occlusion occurred. No significant differences in clinical outcome were found among patients classified by dissection type if clinical outcome was evaluated according to the occurrence or nonoccurrence of either "hard events" (death, non-fatal myocardial infarction or coronary revascularization) or "soft events" (recurrence of angina or no event).

**DISCUSSIONS**

No previous studies have focused on the relationship between the morphological pattern and the healing of coronary dissections. In this study, we could identify the dissection type following POBA for which regression occurred frequently. By discriminating type c dissection according to our classification, the interventionalist is able to reap the benefits of late regression with the least risk of acute closure.

**Angiographic type of dissection and restenosis:** When POBA was first developed, many studies\(^{26-31}\) were reported on the prognosis of intimal tear or dissection. There is still controversy about whether a relationship exists between dissection type defined by the NHLBI criteria and subsequent restenosis.\(^{18,32,33}\) Leimgruber, et al initially raised the concept of "therapeutic" dissection in 1985. They reported a study, specifically focused on the relationship between dissection and restenosis, wherein 248 patients with angiographic evidence of intimal dissection were found to have a restenosis rate of 24% and 738 patients without dissection had a 30% rate of restenosis (\( p=0.08 \)). However, patients with intimal dissection had a significantly lower restenosis rate than patients without intimal dissection if the final transstenotic pressure gradient was less than 15 mm Hg (19% for the group with intimal dissection vs 28% for the group without intimal dissection; \( p<0.05 \)). If the final gradient was greater than 15 mmHg, the presence or absence of intimal dissection had no significant influence on the restenosis rate, which was 35% and 39%, respectively.\(^{31}\)

Huber, et al\(^{18}\) reported that patients with type B dissection have low rates of complications similar to those of patients without dissection. However, patients with type C to F dissection had significantly higher rates of in-hospital complications. Jain, et al\(^{34}\) supported these findings using IVUS. Plaque fracture was noted in only 30% of the restenosis group patients and 74% of the no-restenosis
group patients \((p=0.04)\). Major dissections were more frequent in the restenosis group than in the no-restenosis group \((78\% \text{ vs } 10\%, \ p=0.009)\). Of the various parameters analyzed, the absence of plaque fracture, the existence of a major dissection, and greater plaque burden were associated with an increased incidence of restenosis. In contrast, Hermans, et al \(^3\) reported that a successfully dilated coronary lesion with an angiographically visible dissection was not associated with a higher restenosis rate or a worse clinical outcome at 6-month follow-up, although they did not mention the severity of the dissections. These studies with the opposite results analyzed type A to F dissections together. However, for flow-limiting dissections defined as type E or F in the NHLBI criteria, stenting is mandatory for the treatment of acute occlusions. Type A dissection in the NHLBI criteria has a good prognosis and is often very hard to differentiate from thrombus angiographically.

The NHLBI criteria focus principally on the grading of all dissections, but do not mention the width or depth of non-flow-limiting dissections. It should be reminded that the results of the present study are applicable for only type B to D dissections of the NHLBI criteria, which are clinically uneventful after POBA with no need of bail-out stenting. Although angiographic intraluminal or extraluminal haziness and even smooth-walled dilation are reported to have intimal-medial injury by histologic data, in this study we excluded these lesions because of an inability to delineate the lumen in these lesions.

Possible mechanism of regression: There are only a few reports describing the relationship between the angiographic appearance of coronary dissections and pathologic \(^3\) or intravascular ultrasound findings. \(^3\) Savage, et al \(^3\) studied the healing of intimal dissection after balloon angioplasty in the STRESS trial. As determined using the NHLBI criteria, dissection was present after PTCA in 72/202 patients (35%). Our results demonstrated a similar rate of dissection (35.8%, 86/240). Of the 44 patients restudied by late angiography who had post-PTCA dissection (but no bail-out stenting), complete resolution of the intimal flap was observed in 41 or (93.2%) of the cases. Late loss and the restenosis rate were similar for lesions with and without post-POBA dissection. During the healing process, arteriographic irregularities usually regress, and either improvement or deterioration in luminal narrowing can occur. Subsequent retraction and remodeling along the fissure lines and intimal dissection may lead to stabilization or actual improvement of the dilated stenosis. \(^4\) On the other hand, pathologic studies have shown that the dissected lumen becomes occupied with thrombus or intimal hyperplasia during the healing process. \(^3\) It is not known which types of tears or dissections regress during the follow-up period. The following is a possible mechanism of regression after coronary dissections. In lesions exhibiting improvement of lumen occlusion, the extent of vessel remodeling obtained after
mechanical dilatation should overcome the development of intimal hyperplasia or thrombus formation that occurs during the healing process to some extent in all lesions with regression.\textsuperscript{37,38} Remodeling of the vessel could be facilitated by the formation of tear or dissection, which may reduce the elasticity of atherosclerotic plaque. We speculate that in type c dissection, the intimal flap is apt to be re-attached to the vessel wall before thrombus formation or intimal hyperplasia develops because of its thin dissection lumen, resulting in the increase in true lumen size. In type d dissections, intraluminal diameter did not change even after healing of the dissection. The following is our hypothesis. Fractured plaque would be thick in type d dissections by definition. Because this plaque may exhibit less fluctuation hemodynamically than that of type c dissections, adventitia with or without media may shrink to re-attach to the plaque during the healing process. If the dissection lumen is wide as in type a and b dissections, thrombus formation or intimal hyperplasia would occur before the dissected plaque completely adheres to the media to increase lumen size.

**Influence of reference size and lesion length on regression:** Reference size and lesion length are considered to be important determinants of restenosis. In the present study, the group with regression had a larger reference size than the group without regression. Reference size tended to be larger in type c dissections than in the other types of dissections. Thus, reference size might have had an influence on the presence of regression, as well as dissection type. One possible explanation for this result is that a larger reference size evaluated by an angiogram would mean a lower amount of plaque at the reference site, leading to a higher probability of dissection healing. Further, the frequency of regression among different sizes of vessel might have been biased by the definition of regression (increase of MLD by more than 0.3 mm (two times of a mean reproducibility of ±0.15 mm with the MLD after POBA). There was no difference in lesion length between groups with and without regression, although type c dissections might occur in shorter lesions (Table III).

**QCA for dissected lesion:** The development of QCA using an edge detection algorithm enabled us to estimate with precision the change in lumen diameter between post-coronary intervention and follow-up.\textsuperscript{1,2} If dissection was evident on the postangioplasty angiogram, quantification of a coronary lesion could be hampered by consequent indecision; that is, analysts might decide to include or exclude an extraluminal filling defect in the analysis.\textsuperscript{32,43} Although the videodensitometric method has been reported to be superior to the edge detection method for analysis of such dissected indistinct lumen,\textsuperscript{35,36} in this study the edge detection method could be utilized successfully for selected lesions to delineate the true lumen automatically or manually. Standard deviation of repeated measurements for dissected lesions was acceptable (0.15mm) in the present study.
Coronary arteriography provides information on lumen contour, but not on diffuse vessel wall disease or changes that occur in the vessel wall due to coronary angioplasty. Despite this limitation, coronary arteriography has been used for over 30 years as the ultimate diagnostic tool for coronary artery disease. Newer techniques such as intravascular ultrasound imaging can visualize the lumen and the vessel wall and thereby detect dissections not visible on the coronary angiogram. Indeed, we did not include type A dissections which are angiographically indistinct lesions in our analyses, a pathologic study found intimal-medial injury in 2 of 4 cases. Further, of 5 lesions with intraluminal and extraluminal haziness, all exhibited intimal-medial injury. We could not clarify these lesions because of inherent limitations of angiography and the edge detection algorithm. However, we could analyze types B to D dissections by meticulously performed angiographic analysis to provide a novel classification that discriminates "therapeutic" dissections, although IVUS might elucidate more clearly the mechanism of occurrence and healing of coronary dissection. The patient number enrolled in this study is quite small. Although a larger study may be necessary to confirm the results obtained in the present study, at least the higher incidence of regression in the type c dissection was statistically rigorous.

CONCLUSION

By predicting the occurrence of regression of dissection after balloon angioplasty, our novel classification might avoid unnecessary stent implantation.

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