Coronary Balloon Angioplasty Dissections: "The Good, the Bad and the Ugly"*

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Since the introduction of percutaneous coronary balloon angioplasty nearly 15 years ago (1), there has been considerable interest in the recognition of angiographic patterns of successful dilation, angiographic predictors of angioplasty complications and identification of angiographic factors associated with restenosis. Similarly, there has been considerable morphologic interest in distinguishing mechanisms of successful balloon angioplasty from those associated with complications of dilation. Several human necropsy studies (1-17) have indicated that mechanisms of successful balloon angioplasty involve plaque "cracking," "fracturing," "breaking," "tearing," "spitting," "lifting," "separating" and "cleaving."

Postangioplasty Dissection

Initial human observations (2) suggested that angioplasty injury was primarily confined to the intimal layer (that is, atherosclerotic plaque) with occasional extension of the injury into the vessel media. Waller and colleagues (3-6,10) subsequently reported that plaque fracture and localized medial dissection were ingredients of the major mechanism of successful balloon angioplasty. Expansion of coronary lumen cross-sectional area after angioplasty results from channels created by intimal fractures or tears (occasionally creating intimal flaps) and extension of these tears into the underlying media. Failure to obtain localized and limited medial involvement (dissection) in addition to the intimal cracks is a cause for early clinical restenosis (17,18). Thus, postangioplasty dissection is a common and desirable ("good") histologic finding. Histologically, the term dissection simply means involvement or penetration of the vessel media (17). Clinically, however, it often conveys a sense of failure, complication ("bad") or impending doom ("ugly").

Angiographic evidence of dissection. Angiographically, the term dissection has been freely used (and perhaps wrongly so) for various lumiographic appearances (19-30). These include 1) the "presence of intimal flap with a double contour or persistent staining of the vessel wall by contrast material" ("intimal dissection") (19,22,25,28); 2) "angiographically evident intimal tear causing major luminal obstruction or associated coronary occlusion, myocardial infarction or deterioration of flow requiring emergency bypass surgery ("intimal tear associated with a functional change") (20); 3) "linear intraluminal filling defect ("intimal tear") or luminal staining . . . . considered 'large' if evidenced in 2 projections" ("intimal tear") (21); 4) "intimal damage ("internal dissection") producing an intraluminal filling defect, extraluminal extravasation of contrast material, linear luminal density or luminal staining" (intimal damage) (26); 5) "either a single, linear radiolucent area with minimal or no persistence of luminal staining, or a large radiolucent spiral with more than one tract and persistence of contrast material in the vessel wall" (27); 6) "intimal flap" with a double lumen contour extending beyond the site of the lesion ("intimal flap") (29); and 7) "an irregular or disrupted lumen with hang up of contrast in the area of inflation ("raised flap") (30).

In nearly all of these angiographic definitions, dissection has been interpreted to mean variations in injury patterns of the intima. In an attempt to improve on the interpretation of various angiographic patterns produced by balloon angioplasty, Holmes et al. (31) studied 100 consecutive patients. In their group, "smooth-walled" dilation was the most common angiographic pattern (41%), followed by "intimal flaps (split and dissection)" (22%) and "intraluminal haziness" (17%). No anatomic correlation of these changes was available. Waller (32) correlated various angiographic patterns with morphologic-histologic observations at 76 angioplasty sites in 66 necropsy patients and found that intimal...
Localized Extensin?

Raps and intraluminal haziness were the two most common angiographic patterns and were associated anatomically with intimal splits or cracks with localized medial dissection. In angioplasty sites with intimal tears, all had various degrees of intimal-medial tears. Thus, angiographic patterns of intimal dissection and intimal splits correlated morphologically with intimal-medial cracks with localized medial dissection (32).

Morphologic definitions of angioplasty dissection. It is important to be able to distinguish localized medial dissection as a mechanism of successful balloon angioplasty from medial dissection resulting in a complication of angioplasty. Figure 1 displays tomographic cross sections of a coronary artery after angioplasty showing a localized medial dissection. If the medial dissection involves 1% to 50% of the vessel circumference as viewed in the short-axis plane, this degree of medial dissection is defined as a mechanism of angioplasty. If the medial tear involves >50% of the vessel circumference (short-axis view), this degree of medial dissection is extensive and is defined as a complication of angioplasty. As the circumferential dissection approaches 100%, a large intimal-medial flap may coil up within the vessel lumen (i.e., abrupt closure).

Angioplasty dissection can also extend anterograde or retrograde from the site of initial intimal-medial tear (Fig. 2). Thus, a longitudinal vessel view (long-axis plane) is also necessary to assess a dissection as either a mechanism or a complication. Anterograde or retrograde medial injury totaling ≤1 cm is defined as a mechanism of angioplasty, and anterograde or retrograde medial injury totaling >1 cm in length is defined as a complication of angioplasty. A combination of dissection >50% of short-axis circumference and >1 cm anterograde or retrograde of long-axis length may result in "intussusception" of intimal-medial tissue (Fig. 2).

Although an attempt has been made to classify various types of angioplasty dissection by planar involvement (33), this classification remains severely limited by the use of angiography to assess the extent of vessel injury.

Intravascular Ultrasound Assessment of Angioplasty Dissection

Intravascular ultrasound is one of the newest tomographic imaging techniques capable of providing cross-sectional images of the human coronary artery that can define normal arterial wall layers (intima, internal elastic membrane, media, external elastic membrane, adventitia), diseased intima (atherosclerotic plaque) and injured media (dissection) and adventitia (confined or frank rupture) (17,34). Intravascular ultrasound is capable of providing a morphologic assessment of angioplasty dissection (Fig. 1 and 2). Real-time intravascular two-dimensional ultrasound images have successfully detected postangioplasty dissection in vitro (35,36) and in vivo (37). Davidson et al. (37) detected coronary artery dissections after angioplasty or after atherectomy more often with intravascular ultrasound than with contrast cineangiography. In 70 interventions qualitatively evaluated by intravascular ultrasound and angiography, vessel dissection was noted by ultrasound in 41% and by angiography in only 20% (p < 0.05) (37). Coronary dissections were noted by ultrasound in 27% of sites not detected angiographically.

Present study. In this issue of the Journal, Coy and et al. (38) provide an added dimension of dissection imaging after angioplasty with on-line three-dimensional reconstruction of two-dimensional ultrasound images. These images permit visualization of an entire arterial segment and show the
circumferential (depth) and longitudinal (length) extent of angioplasty dissection (Fig. 1 and 2). Of 41 necropsy arterial segments dilated, histologic dissection was correctly identified by ultrasound imaging in 92% of normal arteries, 100% of fibrotic atherosclerotic arteries but only 69% of calcified arteries (38). Calcific deposits represent a limitation of ultrasound imaging and may lead to false positive or false negative detection of tears and dissections. Alternatively, the recognition of heavy atherosclerotic calcific deposits by ultrasound imaging before angioplasty may prevent the creation of complicated intimal cracks and medial dissections (39). Coy and associates (38) should be congratulated for providing another dimensional use of interventional intravascular ultrasound.

**Therapeutic Implications of Detection of Dissection by Ultrasound**

Discussion and debate are underway concerning the value and clinical implications of the use of intravascular ultrasound (34). To date, contrast angiography has not provided adequate visualization of the extent of vessel injury after angioplasty. The presence and extent of arterial dissection after angioplasty are among the most important predictors of clinical success, acute (abrupt closure) and chronic (restenosis) complications. Intravascular ultrasound will allow significant advancement in detection and understanding of angioplasty dissection.

Dissection as mechanism ("the good"). Several angiographic studies have indicated a common finding of intimal tears after clinically successful balloon angioplasty: Dorros et al. (23) (9.2%), Cowley et al. (20) (2.9%) and Sipmdendorfer et al. (21) (78%). The frequency of this finding suggests that limited dissection by angiography does not represent a complication of angioplasty in the majority of patients (69%) (23) but probably represents the most common mechanism of successful balloon angioplasty—an intimal-medial tear with localized dissection (3–6,17). Intravascular ultrasound will confirm, deny or clarify these observations.

Dissection as acute complication (abrupt closure) ("the bad"). In several studies intimal tear, intimal dissection or flap or haziness at the angioplasty site was associated with a higher incidence of abrupt closure: Sinclair et al. (40) (35%), Cowley et al. (20) (46%), Dorros et al. (23) (31%), Hoffman et al. (25) (17%) and Bredlau et al. (26) (10.4%). The strongest predictor of a major complication after balloon angioplasty is the appearance of an intimal dissection (26). Bredlau et al. (26) found that angiographic evidence of intimal dissection resulted in a 6.5-fold increase in the risk of a major complication. At necropsy, extension of the localized dissection
process creating a large intimal-medial flap was the most common cause of abrupt closure and subsequent death (17). Intravascular ultrasound is capable of detecting angioplasty dissections likely to result in acute complications.

Spiral dissection ("the ugly"). One of the most serious dissection injuries after balloon angioplasty is the so-called spiral dissection in which an alternating side to side dissection appears to extend in anterograde or retrograde direction, or both, from the dilation site (Fig. 3) (33). There are two possible explanations for this angiographic pattern: 1) actual anatomic alteration in the course of dissection (Fig. 3A), and 2) angiographic appearance of anatomically unaltered course of dissection (Fig. 3B). Localized angioplasty dissection extending anterograde or retrograde could shift in its course of dissection if medial layer resistance is encountered. Severe medial scarring from old inflammatory disease or superimposed calcified atherosclerotic plaque increases media resistance and could impede dissection and alter or shift its direction to another portion of the vessel wall. This actual alteration in dissection plane could explain the angiographic appearance of a spiral dissection, but a continuous anatomic shifting seems unlikely. In contrast, a spiral dissection could represent an angiographic illusion in that, despite an extensive circumferential (>50%) and longitudinal (extending the length of the artery) dissection, angiographic views of the dissection give the appearance of side to side shifting (Fig. 1B). The single spiral dissection after angioplasty examined at necropsy by one of us (B.F.W.) was an extensive circumferential-longitudinal medial tear without associated atherosclerotic calcific deposits or altering dissection planes. Three-dimensional intravascular ultrasound reconstruction described by Coy et al. (38) will provide an excellent opportunity to identify and further define this potentially dangerous type of angioplasty dissection.

Dissection-related chronic complications (restenosis). Reports are conflicting concerning the association of angioplasty dissection and restenosis (41-49). Some studies (41-
3.47,48) have indicated that the absence of angiographic dissection is associated with a higher restenosis rate; other studies have indicated that its presence either is similarly associated with a higher restenosis rate (45,49) or is unrelated to restenosis rate (44,46). The disparity in results is directly related to the poor anatomic information available from angiography. As asked by Myler et al. (50): Does a common angiographic pattern of linear lumen density carry the same risk of restenosis as does the uncommon angiographic pattern of extraluminal extravasation of contrast material? Prospective intravascular ultrasound studies correlating these angiographic findings will help answer this important question.

Anatomic Prediction by Ultrasound of Dissection Sites

Morphologic and histologic assessment of atherosclerotic plaque (39) suggest that certain plaque compositions are more or less susceptible to angioplasty dissections. Young, immature plaques with large amounts of intracellular and extracellular lipid, an abundance of foam cells and the absence of calcific deposits are dilated by compression, stretching and superficial intimal indentations with little or no medial involvement. Middle-aged plaques with focal calcific deposits, fibrosis and some foam cells appear to be dilated by intimal-medial cracks with localized medial dissection. Old plaques are densely fibrotic, contain large calcific deposits but lack foam cells and are dilated with deeper cracks and larger medial dissections and potentially extend into the adventitia (39). Intravascular ultrasound imaging has the capability of determining which plaques are best suited for dilation, where cracks will occur within the plaques and which plaques and vessels will be susceptible to localized or extensive dissection.

References