7. Angioplasty for Calcified Lesions

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1. Evaluation of calcified lesions – Angiography and IVUS

Evaluating the size and depth of calcified lesions prior to intervention is crucial. In our experience, angiography and IVUS are give different results. For example, Colombo et al have evaluated target lesion calcification using both angiography and IVUS, and found that angiography indicated calcification in 15% of the total number of lesions studied, while IVUS indicated calcification in 85% [1]. IVUS is also superior to angiography for measuring depth.

Our experience is the opposite though, in that IVUS indicated calcification in the tunica adventitia while the lumen area was normal, and angiography indicated calcification in the vessel. Therefore, ideally you should do angiography *and* IVUS prior to surgery to get the most detailed picture of the lesion. There will always be some cases where the IVUS catheter doesn't pass the calcified lesion because of stenosis severity or the tip of the catheter pressing against the solid part of the lesion, and for these patients, we are forced to rely solely on the angiographical information.

2. Strategies for calcified lesions

At our Institution, IVUS is currently used in almost all patients undergoing intervention in order to precisely evaluate lesion calcification. These IVUS findings inform on strategy selection However, if we cannot do IVUS because the IVUS catheter won't pass, as described above, we first ablate using a rotablator (1.5 mm burr), and the move on to IVUS.   Cases are categorized into one of two groups according to the size of the blood vessel (i.e. vessel diameter </=2.5mm and vessel diameter >2.5mm). Assessment is based on angiography or IVUS. If coronary artery dissection occurs during the procedure, we consider whether to implant a stent or not. There is considerable date suggesting that if the diameter of the artery is 2.5 mm or less, an indwelling stent is more likely to cause restenosis. In other words, when the diameter of the artery is small, careful consideration is necessary in regard to stent implantation. As such, you must always be aware of the need for different strategies for small and large vessels. IVUS sometimes imply that target vessel diameter is smaller than it actually is. This is due to superficial calcification, which is indicated by a bright echo and acoustic shadow, and is quite common with diffuse disease.

① **Vessel diameter </= 2.5mm**

If most of the lesion is calcified, use a rotablator as much as circumstances allow. It is safest to commence with a 1.25- 1.5 mm rotablator burr.

In some cases, you will need to change the burr size according to the angle of the vessel and the length of the lesion. After ablating some of the superficially calcified lesion, post-dilatation may be performed using a balloon at a low-pressure for an extended period. Even if coronary artery dissection occurs, stent implantation is usually avoided – unless blood flow has been obstructed.

② **Vessel diameter > 2.5 mm**

[a] Lesions with superficial calcification

If calcification is 90° or less, a balloon may be used instead of the rotablator. In particular, we have often found that a Cutting Balloon is quite capable of dilating such lesions. If the non-calcified area is effectively incised, the vessel can be effectively dilated. However, this sometimes causes coronary artery dissection. In such cases, we are forced to consider stenting. If the balloon is not fully inflated, stenting may fail (inadequate stent dilatation, difficulty passing, or dislocation). It is therefore desirable to dilate the lesion fully before stenting. The lesion can be fully dilated using a high-pressure balloon. If there is localized coronary artery dissection, a rotablator may be used before high-pressure ballooning.

If the calcification is greater than 180° (severe calcification), plain balloon angioplasty tends to cause coronary artery dissection. Therefore, rotablator is your first choice. However, for cases of left ventricular dysfunction or severe thrombus, it may be inappropriate to use a rotablator, and another device must be selected. If a rotablator is used, it is generally desirable to start with a burr size of 1.5 mm, although other sizes may be used in accordance with the diameter of the vessel or MLD. The final burr size is usually 70- 80% of the diameter of the reference vessel; however, if slow flow due to ablation particles is observed repeatedly, a smaller burr may be used for the final ablation. Following ablation, observe the lumen area with IVUS. If adequate lumen area is observed, consider the procedure complete. However, post-dilatation may be necessary, especially if only one side of the calcified lesion has been ablated. Ideally, inflate the balloon to a low-pressure and for an extended period if the diameter of the vessel is small, as stenting should be avoided as much as possible. However, if the diameter is 3 mm or more, allow yourself to be a little bit more positive about stenting.

[b] Deep calcification

The strategies for deep calcification are different from those employed for superficial calcification. Balloon angioplasty by itself is often able to dilate the vessel fully. Vessel characteristics (lesion length, vessel diameter, etc.) are observed with IVUS and a suitable procedure (balloon angioplasty, DCA, or stenting) performed. If the lesion does not have a large calcified area inside the plaque, and vessel diameter is 4mm or greater, it is possible to ablate the plaque using DCA.

3. Balloon angioplasty for calcified lesions

Opinion is divided about balloon angioplasty for calcified lesions, because procedural success rate varies in accordance with the degree of calcification (length, depth etc.). Tan has reported that the success rates for initial balloon angioplasty procedures for calcified lesions and non-calcified lesions were 74% and 94%, respectively[2]. Myler's reported rates of 92% and 95%, respectively.

If the calcification is mild, the lesion may be dilated with an ordinary balloon, in some cases. However, in many cases with moderate to severe calcification, it is impossible to dilate the vessel using a balloon only. Problems associated with balloon angioplasty include balloon slip, inflation failure, inadequate dilatation, coronary artery dissection, and balloon rupture.

[a] Balloon slip

In order to avoid balloon slip, use longer balloons and pull or push the balloon catheter when the balloon is inflated. Gradual inflation is effective in avoiding balloon slip.

[b] Inadequate dilatation

Inadequate dilatation of the calcified lesion appears to be due to an inability to inflate the balloon fully because of severe calcification, or it may be due to elastic recoil. In these cases, high-pressure inflation carries risk of balloon rupture, coronary artery dissection, or vessel rupture. Coronary artery dissection occurs because the balloon applies force to the calcified and non-calcified areas unevenly when the balloon is inflated. If inadequate dilatation is likely to occur despite using a high-pressure balloon, rotablate to remove some of the calcified area first, and then perform balloon angioplasty. This process prevents coronary artery dissection. It also increases lesion compliance, and full dilatation becomes possible. If severe dissection occurs, stenting is often necessary.

In any case, stenting too quickly (i.e. before the vessel is fully dilated) must be avoided because it makes subsequent procedures difficult. A rotablator should be considered for use in the early stage of intervention.

[c] Coronary artery dissection and recoil

Coronary artery dissection occurs frequently in balloon angioplasty for calcified lesions. However, stenting should not be taken lightly. In particular, if the lesion is long, one long or multiple stents must be deployed in order to cover the lesion fully. This not only increases the rate of restenosis, but also the frequency of stent occlusion. One approach to dissection is to perform spot stenting in which a stent is deployed only in the area where the obstruction to blood flow is severe.

Stenting because of recoil after dilatation should also be kept to a minimum. In any case, it is necessary to keep in mind that a rotablator should be used before it is too late and bailout stenting has to be performed.

4. New devices for calcified lesions

Rotablator

The rotablator is an extremely effective device for calcified lesions. One of its features is differential cutting. A drill bit with an artificial diamond tip rotates at high-speed and selectively cuts through hard lesions (such as calcified lesions) without disturbing the soft tissue. Lesion compliance increases because the calcified lesions are removed. This makes subsequent balloon angioplasty easier. Optimal burr size is thought to be 70 - 80% of the diameter of the reference vessel. The ablation procedure usually begins using a burr one size smaller. This is later changed to the larger burr. Ablation time is approximately 10-15 seconds a time, with a sufficient interval between each run. Nicorandil, nitroglycerin or verapamil are flushed through the catheter to prevent a reduction and obstruction to the blood flow (no flow and slow flow). Some authors have claimed that aggressive debulking (use of a larger burr or prolonged ablation time) does not necessarily yield good results. Many surgeons presently subscribe to the view that the role of the rotablator is to ablate the calcified stenotic area in the target lesion just enough for revascularization of the target vessel.

Stents

Stenting in severely calcified lesions is difficult in many cases and the rate of restenosis is high. The first problem is the difficulty in inserting the stent into the lesion. If a surgeon tries to force the stent, the stent may become broken or dislocated, and thereby impossible to retrieve. If pre-dilatation causes the lesion to become indented by the balloon, it is safer not to deploy the stent. In this case, ablate the lesion using a rotablator before stenting.

There are reports of cases in which debulking was performed before stenting and the procedural results were good. Hoffmann conducted a randomized study on 306 lesions. He divided these lesions into groups according to the type of treatment used: rotablator only, stenting only, and stenting after the rotablator. He then compared procedural results. Lesions stented after rotablation showed significantly better results in terms of final MLD, final diameter stenosis, and target lesion revascularization.

Stenting can be difficult even after ablation by rotablator because the lesion is hard or tortuous. In such cases, an additional guidewire may be passed, parallel to the first, in order to straighten the tortuous vessel slightly. The stent may then be inserted or ablation performed with a larger burr. This helps to secure the lumen area.

DCA

It is sometimes difficult to insert a DCA catheter into a severely calcified lesion. It is also generally difficult to ablate a calcified lesion with DCA, but ablation may be possible if the housing can fit into the lesion.

(1) Strategies for calcified lesions

(2) Vessel diameter</=2.5mm

(3) Vessel diameter > 2.5mm