Effectiveness of IVUS in Complex Cases

Satoru Sumituji,M.D.　　Rinku General Medical Center

IVUS is can provide images of the vessel wall and the tissue around the vessel which cannot be viewed by angiography. It is reported that use of this capability may improve acute and chronic outcomes after percutaneous coronary intervention (PCI). This report will focus on ways to use IVUS effectively in complex cases.

Major complex cases effectively diagnosed by IVUS are;

1. Chronic total occlusions (CTOs)
2. Severe dissection with coronary flow disturbance
3. Coronary perforation

The use of IVUS in the above cases is explained with the help of case studies.

How to Use IVUS in CTOs

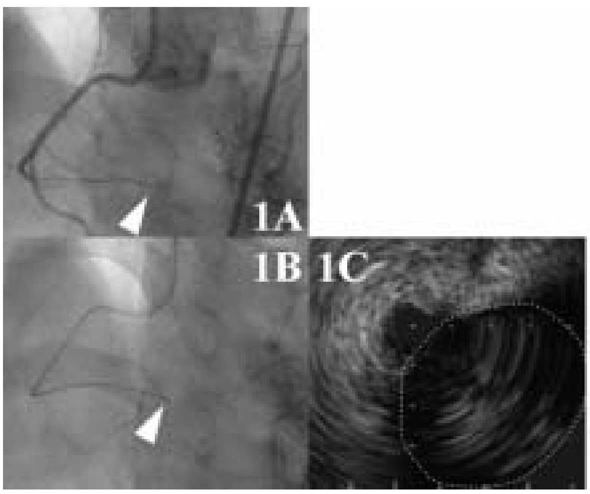
The use of IVUS in CTOs is useful for;

1. Identifying and confirming the position of the CTO ostium (CTO Case 1)
2. Guiding and confirming wire path through the occlusion (CTO Case 2)

IVUS is also useful for obtaining information on lesion characteristics, especially in CTO lesions with complex morphology. (CTO Case 3)

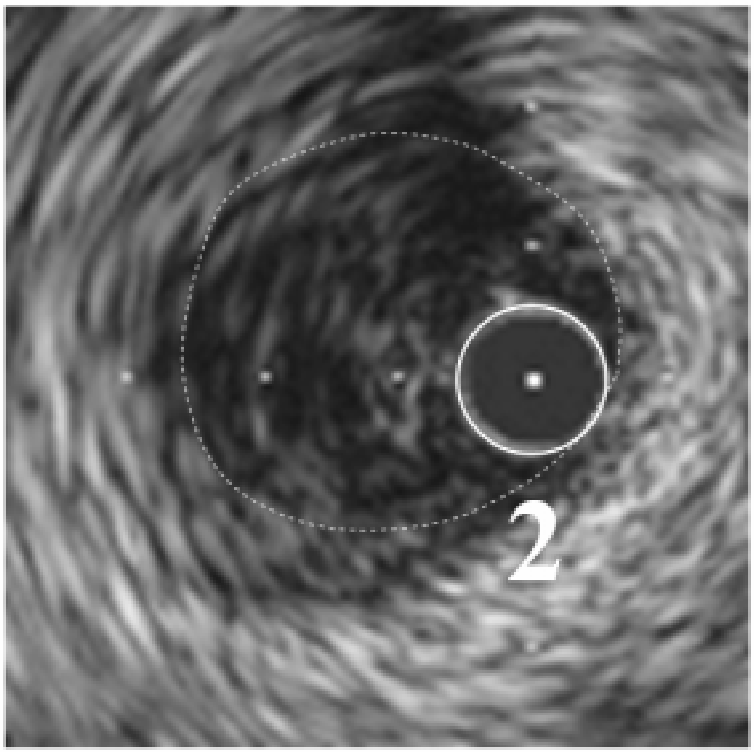
Using IVUS to image CTOs

CTO lesions can not be imaged by angiography due to the fact that the lumen is totally occluded. IVUS can elucidate vessel structure, and even lesion composition at the occluded lumen. The IVUS images in this case show a vessel structure with no presence of blood flow signals inside, again due to the occluded lumen (Figure 1A-C).

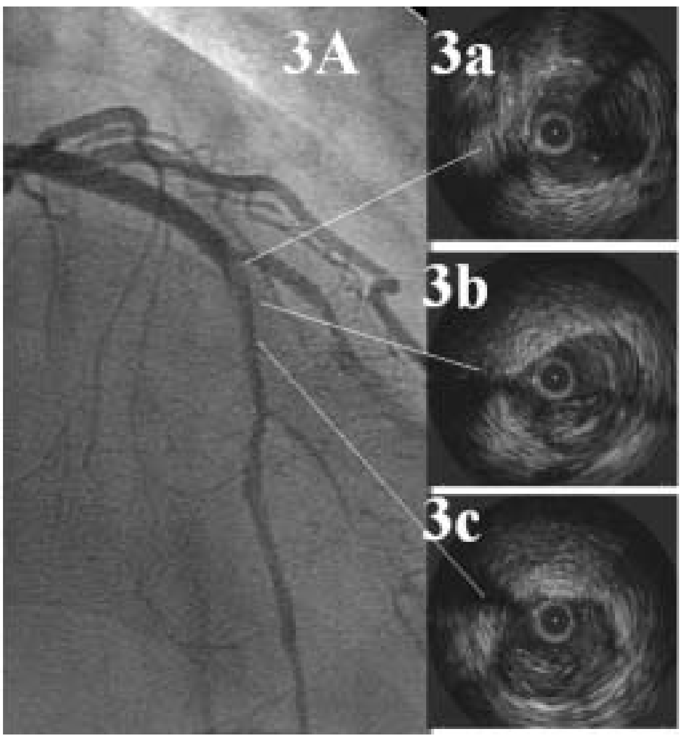


If there is a side branch at the entrance to the CTO, you can precisely confirm the direction of the CTO ostium, by inserting the IVUS catheter into the side branch then using pull-back to mark the position of the transducer.

IVUS makes it possible to differentiate, in "interventional terms", a true lumen from a false one. Both guidewires and IVUS catheters pass near to the center of the vessel when crossing a true lumen, but when crossing a false lumen, the IVUS catheter will pass along the lumen's outer rim of (Figure 2).



This may be more complicated in small vessels, especially after full dilation even with a 1.5mm balloon or dissection, but it will still usually be possible to distinguish a true lumen from a false one. If you mistakenly get a guidewire to pass and dilate a false lumen, spiral dissections are relatively common (Figure 3A). This is because the false lumen is dilated crescent-shaped in 2D and spiral-shaped in 3D (Figure 3a-c).



The Concept of IVUS Use for CTOs

Your chances of procedural success are reduced if you cannot identify the CTO ostium. A typical CTO will have an abrupt-type entrance with a proximal side branch. We try to identify the CTO ostium from the feel of the guidewire, but this largely depends on operator experience. IVUS can usually help you identify the CTO ostium or entrance if there are any side branches nearby.

Case 1 shows a CTO lesion in the distal RCA. The wire did not initially cross the vessel and the vessel was punctured. An IVUS catheter was then positioned at the AM branch to identify the direction and position of the CTO entrance, which enabled to advance the wire in the right direction.

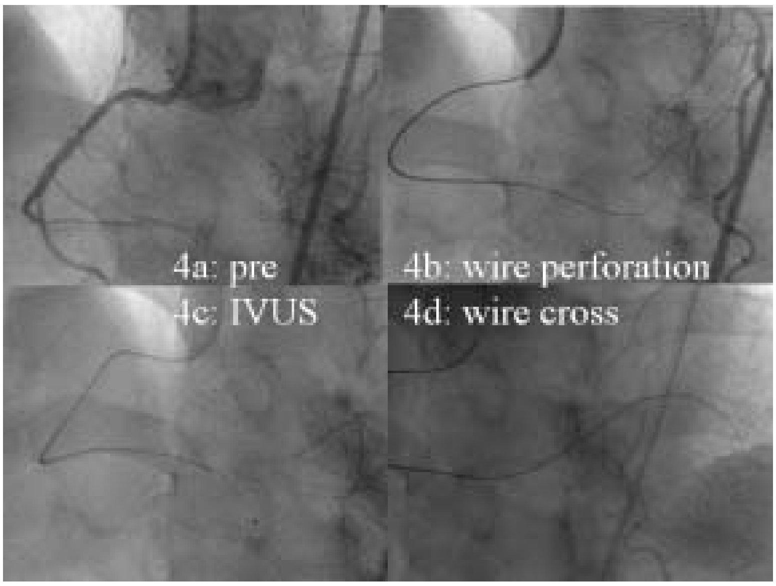
Case 2 is a CTO lesion in the proximal LAD. The wire could not get through because the point we initially thought was the best point to enter the CTO was too hard. However, IVUS showed there was no possibility of another entry-point at a different site and confirmed the entry-point initially assessed was the best point.

In some CTOs, mini-vessels thought to run along the vessel surface may function as channels.
Case 3 is a CTO lesion at the mid-RCA. The narrowed distal true lumen was seen by angiography, but IVUS confirmed that the true lumen ran alongside the very outer part of the vessel from inside the CTO, and was distinctively different from the regular lumen,.

It is also important to use IVUS after the wire has crossed the CTOs. Operators can directly judge the results the pattern of the wire's path. IVUS allows you to make an evidence-based call on whether the wire has crossed the true lumen or a partially false lumen, or on which directions the wire is taking. These rely once again, though, on operator experience.

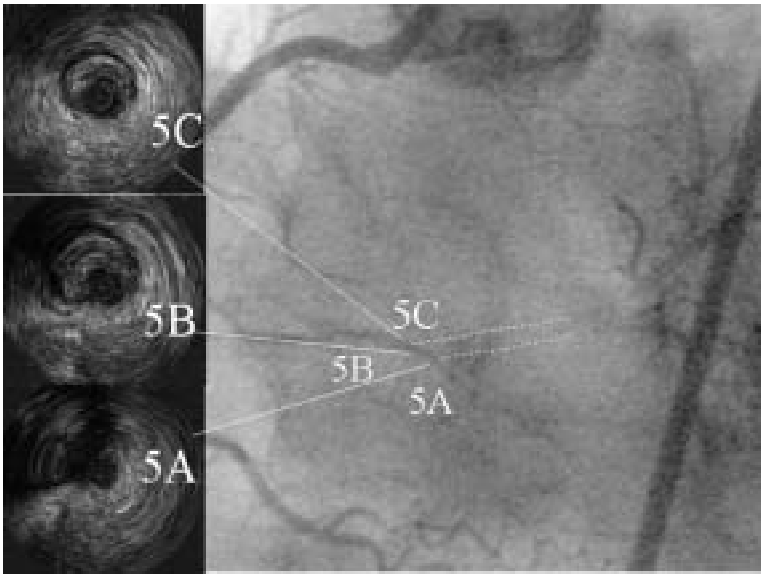
CTO Case 1

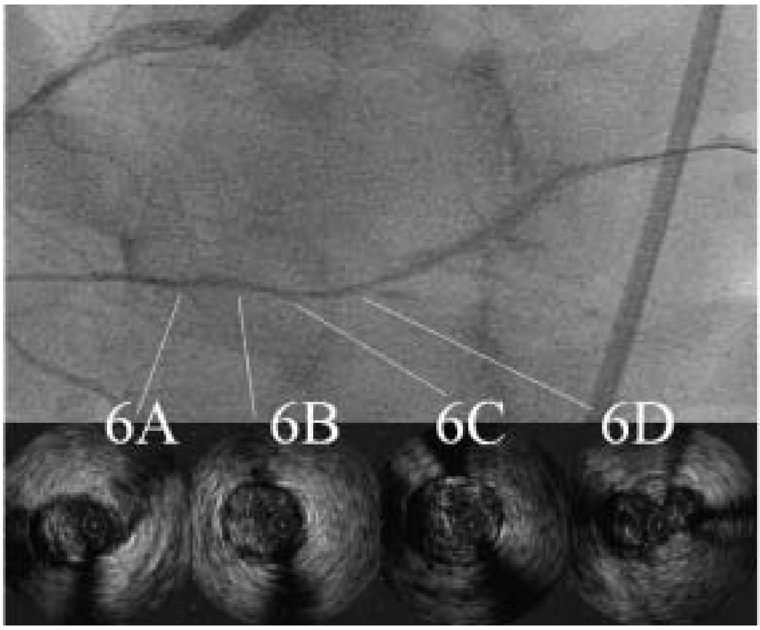
This case was a CTO lesion at the distal RCA from mid-#3 to the 4PD-AV bifurcation (Figure 4a). First we crossed the guidewire to the small AM branch at the mid-#3. IVUS was not initially used because we thought the AM branch was too small to get the catheter through it. Although we started to maneuver the guidewire when we felt its tip coming up against resistance, it moved in a different direction from the distal true lumen and caused a perforation (Figure 4b). In order to precisely assess the lumen's direction, the small AM branch was dilated with a 1.5mm balloon and evaluated by IVUS (Figure 4c).



Based on the IVUS findings, we deduced that the CTO site was located more on the atrial side than where the wire had initially been positioned. IVUS showed that the position where the wire initially entered (5A) was at the most apical side of the occluded vessel. Point 5B is proximal to 5A and is just about the center of the occluded vessel, while 5C is located at the atrial side of the occluded vessel. We then sharpened the guidewire tip and advanced it from the side of the atrium, A. This technique enabled us to get the wire into the true lumen (Figure 4d).

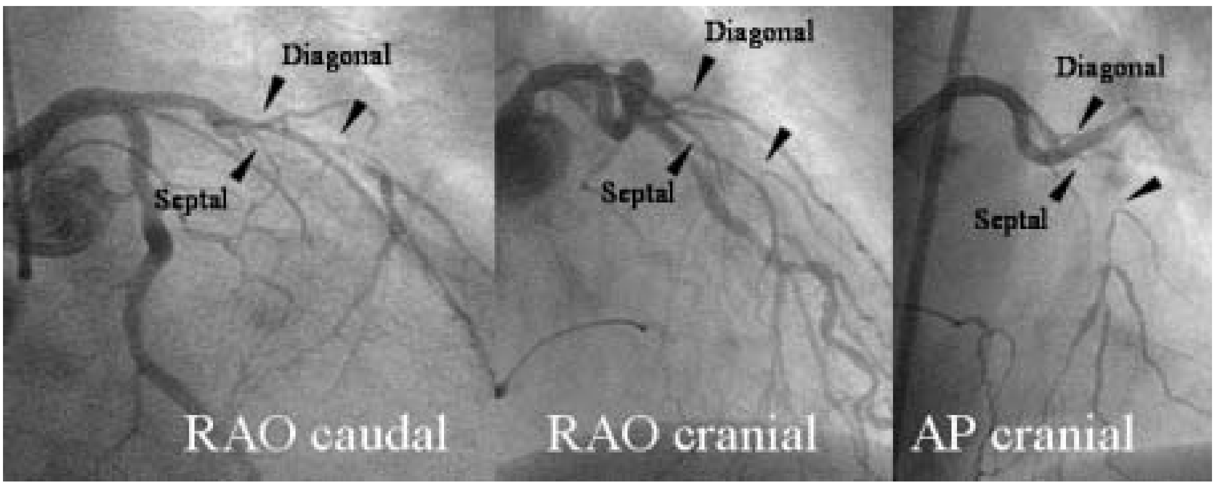
The CAG and IVUS findings after the lesion was crossed by the wire and dilated by 1.5mm balloon are shown (Figure 6). The guidewire was advanced from the apical direction (2 o'clock) at the CTO entrance and crossed to the intima all the way inside the CTO lesion.



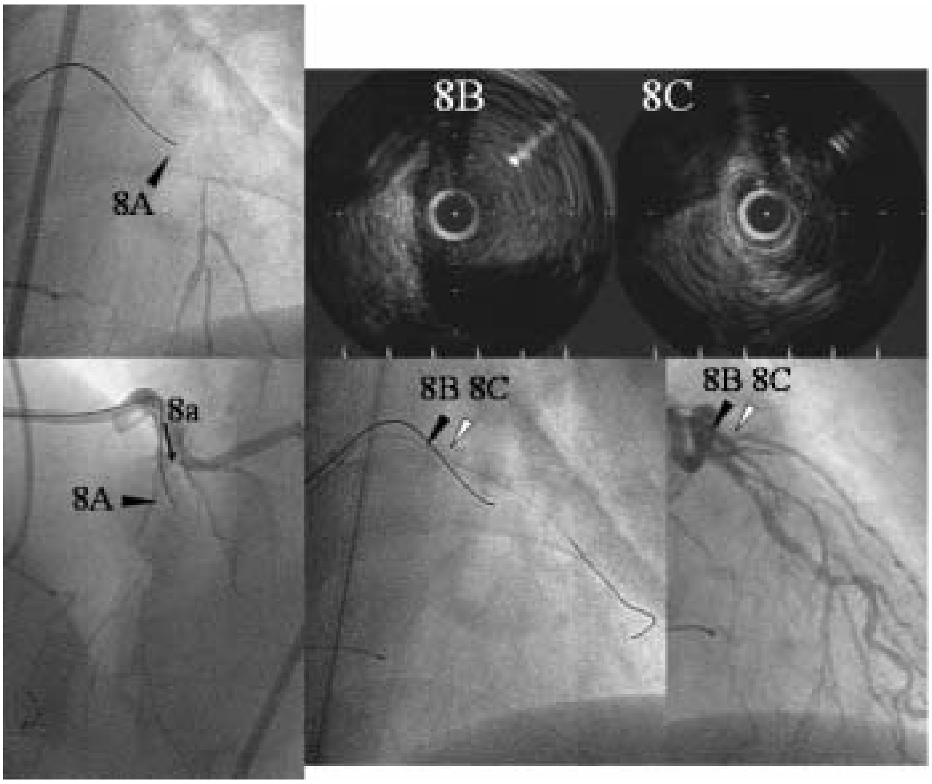


CTO Case 2

This case was a CTO lesion at the proximal LAD. The septal branch and diagonal branch were observed at the proximal edge of the CTO (Figure 7).

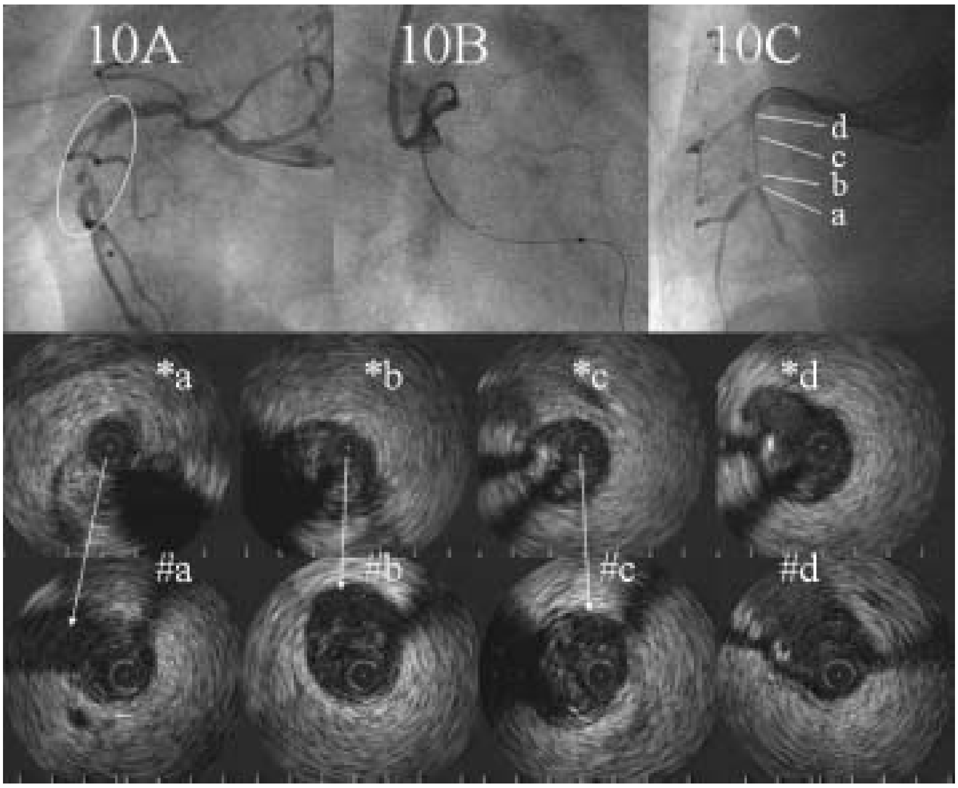


The success rate for wire-crossing usually improves in CTOs in the LAD when the wire is advanced from the septal side. When we were looking for the CTO ostium from the septal branch, the wire tip got stuck at 8A and we started to maneuver the wire so that it would pass. But the wire (an Athlete Intermediate Miracle 4.5g) wouldn't pass. We felt there was a strong possibility that the CTO ostium was located more proximally (8a). If the wire had been forced to pass here, despite position 8A having nothing to do with the actual CTO, we would have caused a perforation. As the diameter of the septal branch was not large enough for the IVUS catheter to cross, IVUS was performed at the diagonal branch. The conjunction site (8B to 8C) of the diagonal branch and LAD had a sufficient lumen size, which convinced us that this site was not the CTO ostium, but that it was most probably 8A. Based on the IVUS data, we changed guidewires, to a Conquest, and advanced it into the CTO, successfully positioning it in the distal true lumen. IVUS confirmed that the wire had passed from the septal side to the distal true lumen along the inner intima after inflation with the 1.5mm balloon.



CTO Case 3

This was a CTO lesion at the mid-RCA. A lesion in a morphologically complex lumen was located next to the distal true lumen (Figure 10A). We crossed with a guidewire and performed IVUS (Figure 10B; *a-d). As the wire at *c was passed inside the vessel, but at *b was outside the occluded vessel, we determined the lumen was probably the vasa vasorum. We decided not to dilate this lumen and re-crossed the wire to the occluded vessel (Figure 10C). We searched for the point where the wire got stuck between the two points (#c and #d) in the occluded vessel, and then we found #d in order to get the wire to go further. We then confirmed with IVUS performed after post-dilation with a 1.5mm balloon, that the lumen was the vasa vasorum, located at the direction of 12 o'clock in #b-#c cross section (see arrow in the lumen). According to 10c, the new wire crossed the lumen located at 5 o'clock in the vasa vasorum, which indicated the wire crossed inside the intima.



Summary

The key to success for treating CTO lesions is to identify the CTO ostium and a path for the wire to take through the CTO. For CTO cases with abrupt-type ostia at side branches which have lower success rates, positioning the IVUS catheter in the side branch and determining the direction the wire needs to go in to cross the occluded vessel is a very effective strategy. In order to do this, as in Case 1, dilate the side branch with a 1.5mm balloon when necessary before doing IVUS.

From the IVUS findings after the wire has crossed, detailed information can be obtained about the wire's path, such as wire direction at the CTO ostium, the wire's crossing position at the distal CTO, any false lumens inside the CTO, and so forth. IVUS is an effective tool for evidence-based decision making although one note of caution is that operator experience is still a key part of the process.

IVUS and Dissections

Some dissections may cause flow disturbance, and these are the ones that it is crucial to treat. Dissections can be assessed by angiography, but their complex morphology makes it difficult to interpret them fully. It is particularly difficult to assess the morphology of dissections that cause flow disturbance. With IVUS pull-back, though, we can obtain three-dimensional images to observe dissection morphology and find an effective treatment.

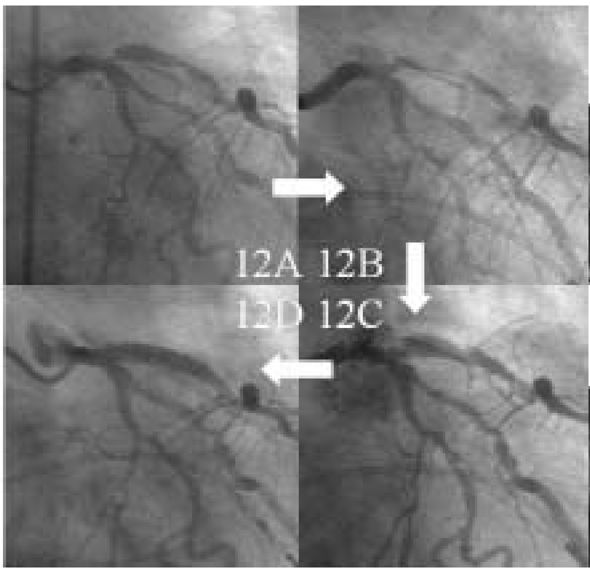
Using IVUS to image Dissections

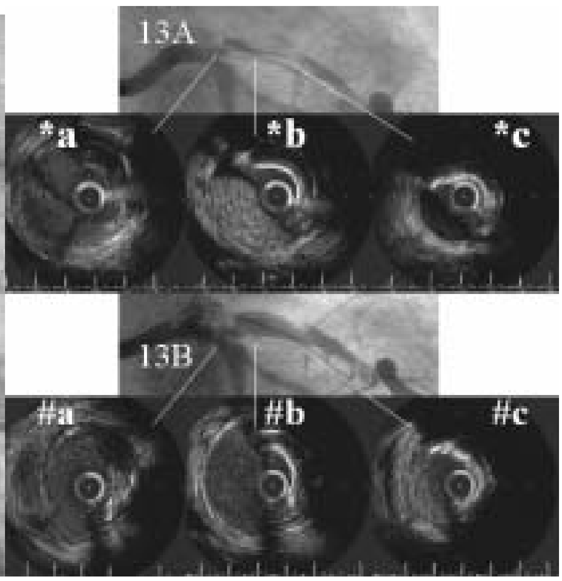
The IVUS image of a dissection shows mainly plaque rupture (Figure 11A). In dissections at risk of potential abrupt closure, there is usually no re-entry of the dissected lumen into the true lumen. IVUS shows flow-delay in case of no reentry by the dissected lumen (Figure 11B), and an echolucent image in the case of contrast medium that has pooled or stagnated in the dissected lumen (Figure 11C).

A Dissection Case

This case was a stenotic lesion in the proximal LAD. We performed rotational atherectomy on calcification, detected by angiography at the LAD ostium, and immediately after the procedure, the lumen at the proximal LAD disappeared on angiogram (Figure 12A, 12B).

We confirmed with IVUS the presence of a large dissection at the ostium LAD (Figure 12*a; at 6-10 o'clock), and that the dissection lumen was pressing on the true lumen (Figure 13 *b-c; image showing no normal flow in the dissection lumen at 6-9 o'clock and the true lumen where the IVUS catheter is showing hematoma). We decided to perform a further debulking of the lesion at the LAD ostium to limit restenosis. In order to create a re-entry point for the false lumen to ensure the distal blood flow during the procedure, we used IVUS to find a site distal to the dissection lumen and dilated it with a 3.5mm Cutting Balloon. Distal blood flow improved immediately after the procedure (Figure 12c). IVUS findings after Cutting Balloon Angioplasty showed normalized blood flow echoes (13*b-c), entirely different from the blood flow in the dissection lumen (13#b-c). We were satisfied that we had created a re-entry channel. Finally, the LAD ostium was treated with directional atherectomy (DCA) and stented to prevent a big dissection. The end result was excellent (Figure 12D).





Summary

IVUS assessment can provide important information on lesion morphology and 3D structure in cases of dissections associated with flow disturbance. An interventional strategy based on IVUS data can also improves the chances of effective bail-out therapy.

IVUS for Perforations

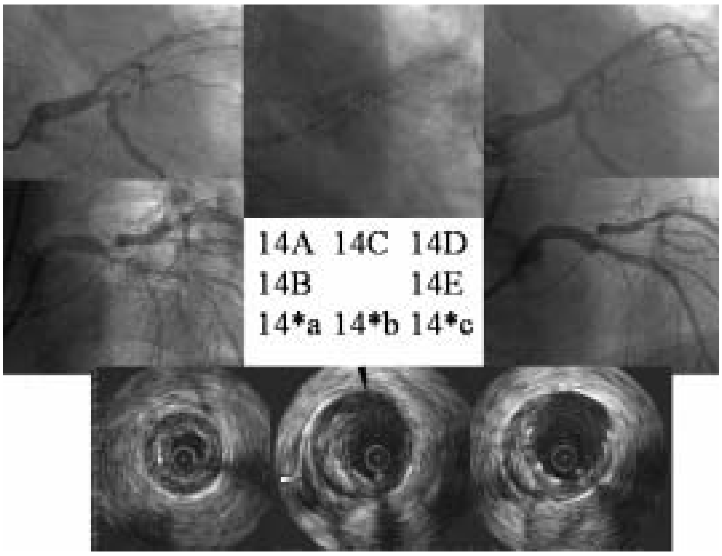
One of the most serious and risky complications, which may cause cardiac tamponade, is coronary perforation incurred during PCI. If perforation, especially an "oozing" perforation, is assessed by IVUS, it can be very effectively treated.

Using IVUS to Image of Perforations

A perforation is a channel created from the lumen to outside of the vessel. IVUS can assess perforation sites by identifying the site's extravascular connection with the lumen (Figure 14*b, 15E). Focusing on the blood flow echo makes it probable to assess whether or not blood is escaping from the vessel.

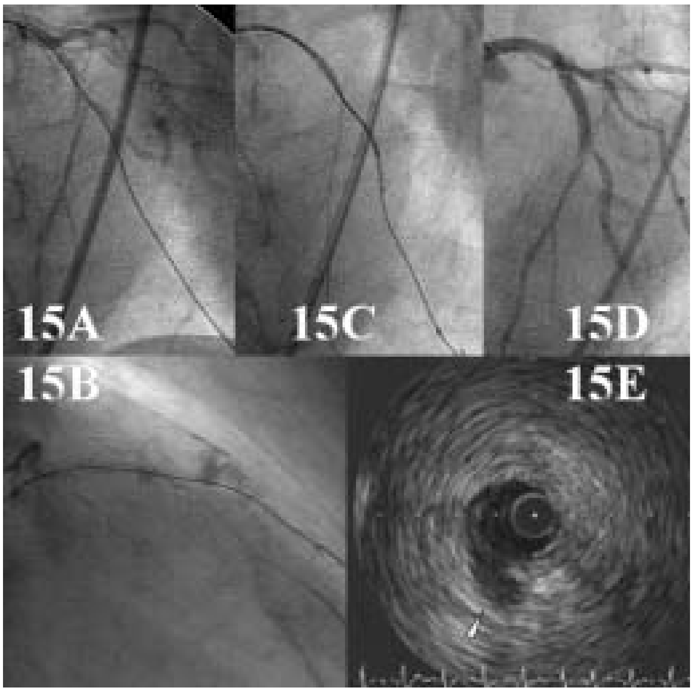
Perforation Case 1

The was a case of stent restenosis in the LAD (Figure 14A, B). The lesion, running from inside the stent to the LAD ostium was dilated by a 4.0mm Cutting Balloon. After dilating the LAD ostium at 8 atm, some contrast medium leakage was observed around the vessel (Figure 14C). However, as the contrast medium was pooling with no detectable leakage to the pericardial cavity, IVUS was used to confirm the perforation site. IVUS revealed that the perforation site was located in a slightly more clockwise direction, approximately 4 mm distal to the LAD ostium, i.e. on the myocardial side (at 12 o'clock, see arrow▲). IVUS also revealed that the contrast medium was leaking in the direction of the epicardial side from the perforation site to the septal-side vessel (8-9 o'clock, see arrow) (Figure 14*b). We stented the site as the safest optimal treatment to cover the perforation site and preserve sufficient lumen as well, after ensuring the following conditions; that there was no increase in stagnation of contrast medium during IVUS, that the perforation site was in the direction of the myocardium, that blood flow was in the direction of the epicardial side around the coronary vessel. The stent was placed slightly proximal to the target site with its distal end less dilated; contrast medium leakage completely disappeared and the lumen was optimally dilated (Figure 14D, E). The final IVUS images showed perforation site at 12 o'clock adequately sealed by the stent (Figure 14*c).



Perforation Case 2

The case was a coronary perforation at the diagonal branch of a CTO in the LAD. When contrast medium leakage was observed proximal to the diagonal branch, hemostasis was performed with a long inflation by balloon, but failed (Figure 15A). Leakage was detected into the pericardial cavity (Figure 15B). As the lumen size of the diagonal branch seemed insufficient for the IVUS catheter to cross and there were fears that the catheter would obstruct blood flow, we first identified the size, site, and direction of the perforation using IVUS (Figure 15E). This revealed that there was a small hole, a little under 0.5 mm, approximately 8 mm distal to the LAD (Figure 15E)., A covered stent was implanted judging from the position of the IVUS transducer, marked on the angiogram (Figure 15c). The leakage of the contrast medium completely disappeared after the covered stent was implanted (Figure 15D), and the CTO lesion in the LAD successfully dilated and stented without neutralized heparin.



Summary of Coronary Perforation

Hemostasis is a top priority for an extremely critical condition such as a coronary perforation, where it is crucial to obtain accurate information about the perforation in order to ensure the best procedure. The location, direction, and size of the perforation site can be easily assessed by IVUS. These data are a key guide to the safest and most effective treatment strategy.

Use of IVUS in Complex lesions/conditions

IVUS obviously has advantages over angiography for identifying lumen and plaque morphology. We interventionists make the most effective use of these advantages when we use them for difficult and complex cases. When you can not be sure with angiography alone, even though you may be reluctant, you should use IVUS. Put simply, no other diagnostic technique can match it for these kinds of cases.