INTRA VASCULAR ULTRASOUND IN CORONARY SYNDROMES: AN OVERVIEW

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The conventional coronary angiogram provides details of the lumen of the coronary arteries. The angiogram, however, does not provide information of the structure of the intima, media, and adventitia. With intracoronary ultrasound probes, it is possible to directly obtain information not only of the coronary lumen but also of the type of intraluminal structures and to differentiate cholesterol from thrombotic material and from calcifications. Intravascular ultrasound also provides us with many information about the results of intracoronary maneuvers. Small and large dissections, broken atheroma, flaps, and insufficient dilatation results can easily be detected. The correct placement of intracoronary stent systems can easily be controlled. This new development contributes to the improvement of coronary diagnosis and invasive intracoronary treatment.

Advantages of Intravascular Ultrasound

Coronary arteriography can only give information about the coronary lumen and may reveal stenoses, plaques, plaque ruptures, and dissections. Information about the wall structure, especially of the intima and media, cannot be obtained in spite of high resolution x-ray systems which can detect very small a.1-mm vessels. Small intraluminal changes and flat plaques are often missed (Figure I). Intravascular ultrasound allows a more accurate insight into the size and composition of coronary arteries. This technique has important advantages over coronary angiography. Despite potential inaccuracies in stenosed coronary arteries, intravascular ultrasound is much more specific in detecting early atherosclerosis. It can identify flat atherosclerotic plaques and abnormal wall structures within angiographically normal coronary artery segments.

We have analyzed angiographically normal coronary arteries in 55 patients. Intravascular ultrasound was able to show flat plaques in 45% of...
the patients (Figure 2). The analyses of 413 sites within those 55 patients showed that only in 83% of the samples, the coronary arteries were normal while in 17% plaques were detected. The technique can also be used in analyzing the lumen and the wall of bypass grafts (Figure 3). In cases of aortic dissections, intravascular ultrasound is able to differentiate the true from the false lumen; in spiral dissections the wall composition, dissection membranes, thrombotic areas, and flaps can be detected (Figure 4). In patients with acute lung embolism, not only the intracavitary thrombi but also thrombotic elements adhering to the wall and occlusions can be detected (Figure 5).

The intravascular ultrasound systems are advanced via the monorail catheter technique. The ultrasound probe is located at the tip of the catheter. Different probes with a rotating mirror or a rotating probe with different angles of the ultrasound beam are available. With special computerized systems, three-dimensional, colored reconstructions can be achieved (Figure 6). Intravascular ultrasound technique and the catheter types are in a stage of rapid development. The catheter size, the technical items, and the picture resolution, however, are very good (Table 1). Careful placement of the guidewire and the probe is necessary in order to avoid complications and to achieve good pictures. Potential problems or complications may occur with this intraluminal procedure. Because of their size, the probes may occlude the vessels within the stenotic areas or at least result in alterations of blood flow.

**Vessel Calcifications**

With a special drawback technique, coronary arteries can be analyzed millimeter by millimeter (Figure 6). Their free lumen may be measured in all three dimensions. The size and the composition of the plaque and eventual plaque ruptures with the endothelial flaps can easily be detected. Plaque
components, particularly calcifications, are often an important determinant of the arterial response to intravascular therapy. In calcified lesions, balloon angioplasty results in more complicated dissections while directional atherectomy does not often cut at the correct site. The calcification of the intima and media is easily detected by the shadow thrown behind the calcification. Mintz et al. have shown that not only the target segment for angioplasty but also only nonnal reference segments may show calcifications (38% vs 17%), fibrotic elements (43% vs 19%), or soft plaques (46% vs 73%). The concentricity and the eccentricity of the vessel lumen can be measured part by part. The main items for vessel calcification as assessed by intravascular ultrasound are given in Table 2.

The acute results of intravascular maneuvers in percutaneous transluminal coronary angioplasty (PTCA), atherectomy, laser, and rotablations are

| Catheter size | 2.9-5.0F |
| Minimal vessel diameter | 1.5 mm |
| Guide (monorail) Rotation speed | 0.3 - 0.37 mm 600 - SOO/min 10-12Is |
| Picture rate | 20 - 30 - (50) MHz |
| Frequency rate Minimal resolution: |
| - Axial | 150-170Jlm |
| - Lateral | approximate 250 Jlm |
| - Longitudinal | approximate 250 Jlm |

Figure 4. Serial intravascular ultrasound in aortic dissection. Differentiation between true (TL) and false vessel lumen (FL). c = catheter.

Figure 5. Angiogram and intravascular ultrasound in acute severe lung embolism. Occlusion of right pulmonary artery branches seen in angiogram and ultrasound. In the left lung partly free-floating thrombi, partly wall-adhesive structures.

Figure 6. Three-dimensional, colored reconstruction of a severely calcified coronary artery segment. The computer system allows the cutting of the artery.
Table 2. Assessment of vessel calcification by intravascular ultrasound.

1. Arc of calcification
2. Length of calcification
3. Distribution of calcification:
   - Superficial vs deep
   - Lesion-associated vs reference segment
   - Concordant vs opposite to plaque

Intravascular ultrasound gives more insight into the broken atheroma, dissections, flap configuration, and calcification (Figure 7). Gerber et al. have identified different types of postinterventional dissections. The type with a large dissection of more than 1800 of the vessel circumference has shown negative late results with high restenosis rates of more than 50%.

Table 3. Intravascular ultrasound identification of plaque ruptures. (1)

1. Rupture, wash-out of lipids
2. Lower-echo density with thin layer
3. Wall defect: "aneurysm" - plaque ulceration, pseudoaneurysms
4. Spontaneous healing:
   - Incomplete thrombosis: unstable angina
   - Thrombotic vessel occlusion: infarction

Table 4. Advantages of intravascular ultrasound.

- Better early detection of atherosclerosis than angiography
- More accurate information
- Identification of "silent" plaques
- Identification of plaque components (calcium, ulcerations, liquid areas, etc.)
- Explanation of failures in atherectomy or PTCA
- Better information in stent implantation

Intravascular ultrasound can give further insight into the plaque composition in patients with stable and unstable angina. Intravascular ultrasound results have contributed to the pathophysiological understanding of the mechanisms in unstable angina; the ruptured, rough vessel surface, the multiple layers, and echolucent areas as well as the adhesive or floating thrombi can be seen (Table 4). These structures are normally not detected by coronary angiography.

Echofree Spaces

In patients with complicated coronary dissections after PTCA, stent placement plays an important role to prevent acute occlusions and urgent bypass operations. Intracoronary stents, however, may also lead to less restenosis. In cases of doubt or uncertain stent placement (Figure 8), intravascular ultrasound can only semiquantitatively analyzed by angiography.
ultrasound shows very well the vessel lumen, the struts of the stents, calcifications, and echofree spaces.4.13.16.17 Gorge et al. have demonstrated (Table 5) that higher balloon pressure during stent placement (Group B) leads to less distance of the echofree space and bridge area and larger lumen compared to low pressure (Group A).

**Limitations of Intravascular Ultrasound**

Intravascular ultrasound application, however, may be harmful. Any additional intracoronary maneuver after PTCA or stent placement can possibly lead to thrombus formation or even vessel occlusion. Therefore, many studies have been performed to evaluate the safety of intracoronary ultrasound analyses. A multicenter survey, including 2207 examinations, has shown, however,

### Table 5. Echofree spaces after stenting

<table>
<thead>
<tr>
<th></th>
<th>Group A (low)</th>
<th>Group B (high)</th>
<th>P</th>
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<tbody>
<tr>
<td>Total patients echofree</td>
<td>12/28</td>
<td>5/24</td>
<td>ns</td>
</tr>
<tr>
<td>Distal stent</td>
<td>0.56 ± 0.10</td>
<td>0.30 ± 0.10</td>
<td>0.01</td>
</tr>
<tr>
<td>Maximal distance (mm)</td>
<td>0.38 ± 0.07</td>
<td>0.35 ± 0.10</td>
<td>ns</td>
</tr>
<tr>
<td>Bridge area</td>
<td>0.40 ± 0.10</td>
<td>no echofree</td>
<td></td>
</tr>
<tr>
<td>Maximal distance (mm)</td>
<td>0.40 ± 0.10</td>
<td>no echofree</td>
<td></td>
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ns = not significant.

### Table 6. Limitations to ultrasound assessment of target calcified lesion.

Only the leading edge of a calcium deposit is identified, not its thickness. Deep calcifications behind superficial ones may not be detected. Densely fibrotic, noncalcified structures may not be penetrated. Shadows may be confused with calcium. Calcium deposits of different physical properties cannot be identified.

### Table 7. Sensitivity and specificity of intravascular ultrasound technique.

- Sensitivity in fibrosis: 60%
- Sensitivity in lipids: 70% 85%
- Sensitivity in calcifications: 90% 95%
- Specificity in lipids: 98% 100%
- Specificity in calcifications: 95% - 99%

**Conclusion**

There is certainly no need to use intravascular ultrasound routinely in many or even all patients undergoing arteriography. The method should mainly be used with critical responsibility in patients with complicated stenoses, severe dissections after interventions, and in critical stent placements. Its use in selective cases will certainly contribute to better clinical treatment. The technique, however,
may also contribute to higher complication rates, longer stay in the cath lab, and higher expenses for the cath lab procedure. Scientists and cardiologists should carefully follow the development of this exciting technology since it results in a better understanding of both the physiology and pathophysiology of the coronary vascular tree.

References