EDITORIAL

Coronary stenting: why size matters

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See articles on pages 1562 and 1609

Despite remarkable advances in coronary interventional cardiology, in-stent restenosis of bare metal stents (BMS) and late thrombosis of drug-eluting stents (DES) are perceived as the most important limitations of coronary stenting today. Predictors have been identified for both, and poor stent expansion is one of the common denominators. It is therefore a daily concern in current clinical practice.[1]

Two interesting papers published in the current issue of *Heart* highlight this concern. Russo *et al*, using a non atherosclerotic porcine model, evaluate the intimal response after BMS implantation with different balloon to artery ratios (BA ratio) (***see article on page 1609***).[2] After assessing vessel size by intravascular ultrasound (IVUS), stent size was matched with different BA ratios ranging from 1.0:1 to 1.4:1. The main result of the study is that the bigger the size of the stent implanted, the more intimal hyperplasia is found at 28 days. The authors also note that the degree of intimal response is specific to each animal and that vessels do not respond independently of each other, suggesting an individual response to overstretch. Prior work by Hoffmann *et al* in the clinical setting[3] had already shown that a more aggressive stent implantation technique is associated with an increase in neointimal hyperplasia evaluated by IVUS. This confirmed the seminal work performed in animals in the early 1990s[4] that had showed a relationship between the degree of deep injury of the internal elastic membrane and neointimal thickening.

How do these results fit with the available data from clinical trials? Some interventional cardiologists may be surprised by such results since most have adopted the concept that the bigger the stent, the lower the restenosis rate will be. It should be emphasised that this is only true when the ''oversizing'' of the stent is reasonable in comparison with the vessel size, and certainly does not apply with BA ratios as high as 1.2:1 or above.

Also, four specific aspects of this paper should be emphasised. (*a*) This animal study was performed on healthy elastic vessels whose response to barotrauma may not necessarily reflect that of atherosclerotic coronary vessels with a combination of soft and calcified plaques. (*b*) The vessel size was assessed by IVUS, which is known to measure the vessel size more accurately than the systematic underestimation obtained with angiography, the latter being by far the most commonly used method to measure reference diameter and size of the stent in the clinical setting. Thus, this model represents an already exaggerated situation, where even the group with a BA ratio of 1.0:1 probably represents ''oversizing'' relative to normal clinical practice. (*c*) As mentioned by the authors, on the one hand, intimal hyperplasia is of less concern after stent implantation when using a DES since most drugs markedly decrease the intimal response. On the other hand, stent malapposition, an event that is partially related to the initial degree of stent expansion, has been implicated in the occurrence of late stent thrombosis.[5] (*d*) The problem of how best to size a coronary stent is thus regaining considerable interest; although it was first believed that a DES could be implanted at moderate pressures aiming for a 1:1 BA ratio, most experienced operators now take extra care to expand the DES fully using high pressures, after dilatation with non-compliant balloons, and generous BA ratios.

The second paper, by Aziz *et al*, focuses on the final ''real'' mean luminal diameter obtained after stent implantation in the clinical setting (***see article on page 1562***).[6] Based on the compliance chart supplied by the manufacturer, the final mean luminal diameter as assessed by quantitative coronary angiography was only 73% of the expected diameter, owing to underexpansion of the balloon and also to a 10% acute stent recoil. Interestingly, this phenomenon was independent both of the vessel reference diameter and of the use of balloon before dilatation. Similar data have been published in a porcine model with a stent recoil of 15–30% as assessed by IVUS.[7] In humans, Bermejo *et al* have also reported that, despite high-pressure inflation, lumen dimensions after stenting were only 57% of that theoretically expected.[8]

Although this paper focuses on a point that is worthy of attention, it should be emphasised that the results reflect the high BA ratio of 1.25:1 that was used by the authors. If a large stent is implanted in a small vessel, then underexpansion and stent recoil are likely to be more pronounced. This was verified for underexpansion in the present study, but not for stent recoil. Also, all measurements were done by angiography and not with a combined approach with IVUS or optical coherence tomography, which would have generated more robust data.[9]

CLINICAL IMPLICATIONS

Larger stents induce more trauma to vessels and therefore more intimal hyperplasia, more edge dissections and more coronary ruptures. Conversely, underexpanded stents increase both the risk of restenosis and the likelihood of stent thrombosis. Most operators today aim for a BA ratio

Abbreviations: BA ratio, balloon to artery ratio; BMS, bare metal stent(s); DES, drug-eluting stent(s); IVUS, intravascular ultrasound

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of 1.1:1, using either visual estimate of the angiogram or quantitative coronary angiography, and this is also the standard protocol recommendation in most contemporary randomised trial of coronary stenting. One should be aware, however, that most stents will then still remain underexpanded relative to their nominal diameter, even when inflated at higher pressures than those recommended by the manufacturer.[10] As a mitigation of this, Hoffmann *et al* showed 11 years ago that BMS restenosis was strongly correlated with tissue growth ($r = 0.975$, $p<0.0001$) but only weakly related to stent recoil ($r = 0.2$, $p<0.0001$).[11] Although IVUS is better than contrast angiography at defining post-deployment stent dimensions, confirming complete stent apposition and excluding edge dissections, well-conducted studies evaluating IVUS-guided bare metal stenting failed to show a reduction in the restenosis or thrombosis rate when compared with a conventional strategy based on angiographic assessment alone.[12–14] Whether a more systematic use of IVUS might help to decrease the late thrombotic complications associated with DES remains to be evaluated.[15 16]

As assessed by IVUS, both Cypher and Taxus stents achieve only 75 (10)% of their nominal diameter when inflated at the recommended pressure, thus confirming that underexpansion in the DES era is still a matter of concern.[17] Recently, Cook *et al* have importantly shown that incomplete stent apposition was present in 77% of patients presenting with acute late DES thrombosis, versus only 12% in matched controls.[5]

Therefore, at a time when major concern exists about the complex biological interactions of DES with the arterial wall, we should not forget the basic mechanical issues at hand: stent size must be carefully matched with the target vessel reference diameter, generally aiming for a 1.1:1 BA ratio; high pressure after dilatation with short non-compliant balloons should be considered whenever expansion appears less than optimal; and IVUS should be available for most high-risk situations. These all remain necessary ingredients for ensuring the best immediate result and the lowest possible long-term complication rate, and the advent of DES has given them added importance.

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