Overaggressive stent expansion without intravascular imaging: impact on restenosis

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ABSTRACT

Objective Aggressive stent expansion is required for optimal strut apposition, but risk of stent deformation, fracture and subsequent restenosis is potentially greater when performed without intravascular imaging guidance. We investigated how frequently stents are 'overexpanded' and whether this correlates with restenosis.

Design and setting Single-centre prospective database study at a high-volume tertiary university hospital.

Patients 243 patients undergoing single-vessel stenting for de novo stenosis in 277 lesions. Exclusion criteria were bifurcational, graft or left main disease and intravascular imaging use. All had ischaemia-driven repeat coronary angiography up to 48 months later. Degree of stent overexpansion was the difference between nominal and final stent size.

Results Stents were expanded above nominal in 99% of cases and above rated burst pressure in 52%. Stents were expanded >20% above nominal in 12% of cases. Stents overexpanded by >20% were smaller (2.87 vs 3.19 mm), longer (24 vs 19 mm) and more often drug-eluting (53% vs 27%). Angiographic restenosis was observed in 80 lesions (29%). There was no correlation between degree of overexpansion and per cent angiographic restenosis across the whole group (R^2=−0.01; p=0.09), in those with stent overexpansion >20% (p=0.31) or small stents <3 mm (p=0.71). Indeed, in the group with stent overexpansion >25%, the greater the overexpansion, the less the per cent angiographic restenosis (p=0.02).

Conclusions In this real-world population undergoing non-complex percutaneous coronary intervention without intravascular imaging, any tendency to overaggressive stent expansion did not predispose at all to restenosis.

BACKGROUND

Several studies encourage the use of intravascular ultrasound (IVUS) and optical coherence tomography (OCT) to guide optimal stent expansion.[1–7] In practice, this often involves stent expansion above nominal size. Despite IVUS and OCT evidence promoting the 'overexpansion' of stents to achieve optimal strut apposition and the greatest luminal area, cost and time constraints conspire to reduce the uptake of routine intravascular imaging in many busy publicly-funded centres. In such laboratories where intravascular imaging is available but not routine, angiographically-guided overexpansion of stents above nominal size to maximise luminal diameter is commonly practised especially in non-complex cases. Outcome data however are limited to support this real-world practice.[8–10]

Stent overexpansion raises concerns that stent distortion, compromised strut integrity and exaggerated arterial wall stress may predispose to restenosis and lead to poorer short- and long-term outcomes, especially in small vessels or when the stent used is much smaller than vessel size. The angiographically-guided use of oversized balloons in the balloon angioplasty era led to alarmingly high rates of dissection and emergent bypass surgery.[11] Animal studies have demonstrated that greater stent impact against the neo-intima causes increased neo-intimal injury and hyperplasia.[12] Human data indicate that proliferative/inflammatory processes occurring as a result of injury sustained during aggressive dilatation contribute to restenosis.[13]

We therefore hypothesised that when intravascular imaging is not used to guide sizing, stent overexpansion—reflected in the degree of 'mismatch' between nominal stent size and final stent size—predisposes to instent restenosis. The mismatch might be magnified if too small a stent is deployed and then has to be aggressively expanded to match the true vessel size.

METHODS

To test this hypothesis, we examined the prospective percutaneous coronary intervention (PCI) database at our high-volume (900 cases per annum) tertiary referral centre in Australia. Data collected included demographics; stent type, size, location and number; diabetic status; angiographic per cent restenosis; and target lesion revascularisation (TLR). Patients were included if they had ischaemia-driven repeat angiography up to 48 months following the index single-vessel PCI for de novo stenosis.

Repeat angiography was considered ischaemia-driven if the patient re-presented with recurrent or increasing anginal symptoms, a positive stress test or acute coronary syndrome including unstable angina and myocardial infarction. Bifurcational, left main or graft stenting, rotablation and IVUS or OCT use were exclusion criteria.

Final stent size was determined from manufacturers' balloon compliance charts, a validated method[14] in non-complex stenting cases that does not require intravascular imaging techniques such as IVUS. Intracoronary nitrates were used routinely. High-pressure postdilatation was carried out at the operator's discretion and corresponding compliance chart measurements recorded: the greatest diameter achieved was taken as the final stent size. Stent size mismatch in millimetre was the difference between final stent size and nominal stent size.

For the purpose of this study, if more than one stent was used for a single lesion, the total stent length was the sum of the stent lengths. For lesions treated with multiple stents, we took the nominal size of the smallest stent used to derive the maximal stent size mismatch.

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Table 1 Stent sizes

Smallest nominal stent size (mm)	Frequency (%)	Mean final stent size (mm)
2.25	12 (4.3)	2.86
2.50	35 (12.6)	2.93
2.75	17 (6.1)	3.18
3.00	104 (37.5)	3.34
3.50	78 (28.2)	3.90
4.00	26 (9.4)	4.35
4.50	3 (1.1)	4.79
5.00	2 (0.07)	5.26

Per cent instent restenosis was visually estimated by experienced operators. TLR was defined as repeat PCI or bypass grafting for the previously stented lesion.

STATISTICAL ANALYSIS

The data were analysed using SAS V.9.1 (SAS Institute, Cary, North Carolina, USA) and R V.2.12.0 (R Foundation for Statistical Computing, Vienna, Austria). The χ^2 test and t test were used to compare discrete and continuous variables, respectively. The coefficient R^2 was used to assess the correlation between stent mismatch and per cent restenosis. All statistical tests were evaluated at the 5% level of significance.

RESULTS

Data were analysed in 243 patients who had ischaemia-driven repeat angiography after undergoing stenting for single-vessel de novo stenosis in 277 coronary artery lesions. Vessels stented were the left anterior descending in 133 (48%), right coronary in 81 (29.2%), circumflex in 62 (22.4%) and intermediate in 1 (0.4%). The mean age was 61 years (35–85) and 177 (73%) were men. Diabetes mellitus was present in 31 patients (13%).

Of the 277 lesions, 194 (70%) were treated with bare-metal stents (BMS) and 83 (30%) with drug-eluting stents (DES). A single stent was deployed in 244 (88%), two in 28 (10%), three in 3 (1%) patients and four in 2 (0.7%) patients. In 274 (99%) lesions, the stent was deployed at above nominal size. Mean stent length was 19.98 mm (8–91).

Table 2 Stent size and per cent overexpansion: correlation with per cent restenosis

	Number	R^2	p Value
Final stent size (mm)			
<3	36	−0.004	0.07
3–3.49	102	−0.039	0.05
≥3.5	139	−0.001	0.10
All	277	−0.01	0.09
Degree of stent overexpansion* (%)			
<20	243	−0.006	0.23
>20†	34	−0.03	0.31
>25	22	−0.26	0.02

*((Final—nominal stent size)/nominal stent size)×100%.
†Includes >25%.

Smallest nominal stent size in the 277 lesions and corresponding mean final stent size (diameter) are described in table 1.

There was no significant positive correlation between stent size mismatch (overexpansion) and per cent restenosis for the entire group (R^2=−0.01, p=0.09) (figure 1 and table 2).

Further analysis stratified by final stent size (figure 2 and table 2) was undertaken as small vessels <3 mm are known to be at increased risk of restenosis.[15 16] However, stent size mismatch did not predispose to restenosis in lesions with final stent size <3 mm (p=0.07), there being an inverse relationship. In those with final stent size 3.00–3.49 mm, there was also an inverse correlation: greater mismatch tended to correlate with less per cent restenosis.

Stents were expanded >20% above nominal stent size in 12% of cases and >25% above nominal in 8%. No correlation was seen between restenosis and overexpansion by >20%. However, there was a significant inverse relationship between stent overexpansion >25% and restenosis (figure 3 and table 2). Stents overexpanded by >20% were smaller (2.87 vs 3.19 mm, p=0.0004), longer (24 vs 19 mm, p=0.014) and more often drug-eluting (53% vs 27%, p=0.004). Stents were expanded to sizes above the balloon rated burst pressure in 52% of lesions. This group did not have a higher rate of restenosis or TLR (p=0.33).

In this select population undergoing ischaemia-driven repeat coronary angiography, binary restenosis (angiographic stenosis ≥50%) was present in 80 (29%) lesions. The mean degree of

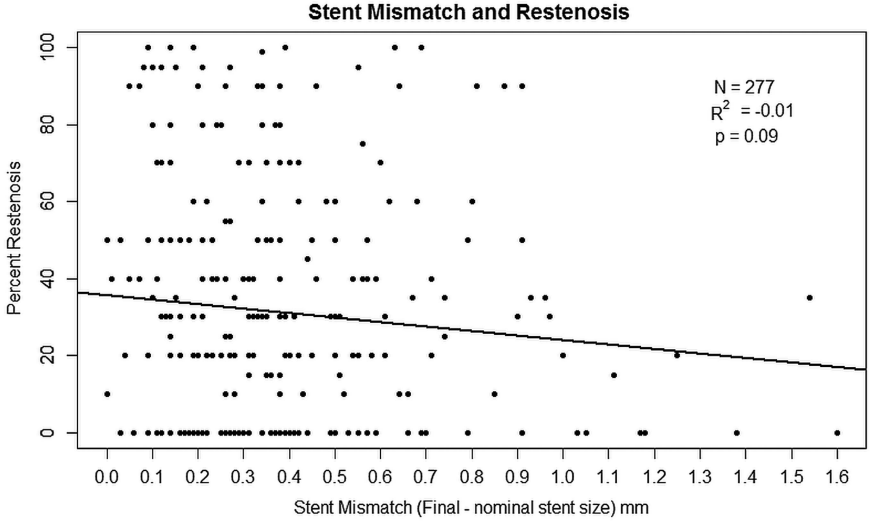

Figure 1 Stent mismatch versus restenosis for all lesions.

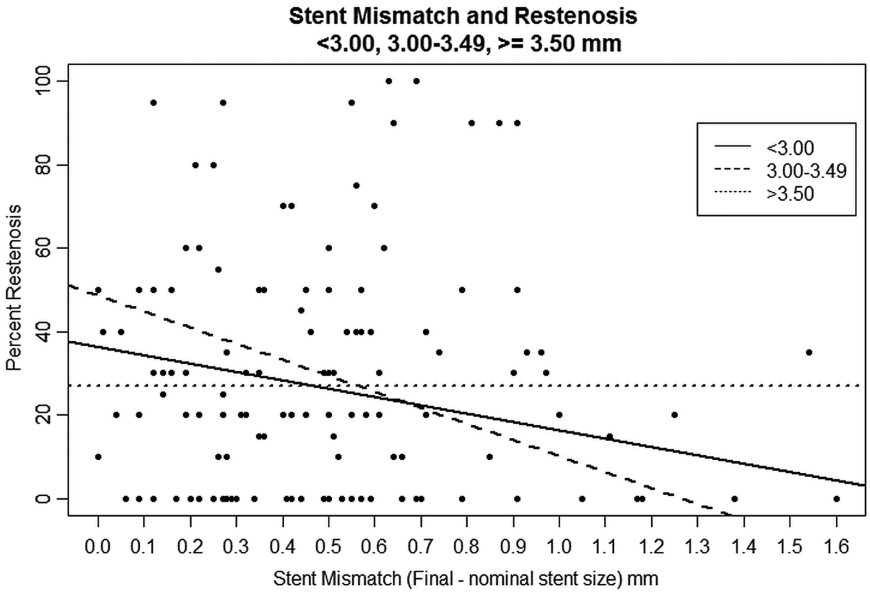

Figure 2 Stent mismatch versus restenosis stratified by final stent size group.

mismatch was significantly greater in patients *without* binary restenosis (0.41 vs 0.34 mm; p=0.049). TLR occurred in 56 (20%). There was no significant relationship between degree of mismatch and TLR (p=0.25).

A multivariate analysis including age, sex, stent length, stent type (BMS/DES), number of stents and diabetic status was performed to identify the variables contributing to restenosis in this select population. None of these showed a significant influence. In particular, there was no significant relationship among type of stent, size mismatch and restenosis (BMS p=0.43, DES p=0.19).

Of 277 lesions, there were only 4 (1.4%) cases of coronary artery dissection. One occurred on predilatation of the lesion. Three related to stents overexpanded by <20% only. No intraprocedural death occurred.

DISCUSSION

Enthusiasm for aggressive balloon dilatation is tempered by high rates of dissection, myocardial infarction and emergency bypass surgery in an early randomised trial using oversized balloons to improve angiographic results.[11]

Early researchers who examined stent postdilatation *without* IVUS guidance found trends in favour of the dogma that 'bigger is better' to achieve less restenosis.[7–10] Gao *et al*[8] found significantly less instent restenosis after postdilatation of DES at 7-month follow-up although there was no difference in mortality or major adverse cardiac events. Haldis *et al*[9] described a 'step up, step down' angiographic image as an objective way to ensure good stent apposition and expansion. They had no adverse outcomes from this modest overexpansion in their small sample (n=13). Although they showed significantly improved optimal stent expansion in the immediate setting, there were no longer term follow-up data.

Complication rates can certainly be improved with IVUS guidance,[17] real-time intravascular imaging giving the interventional cardiologist confidence during stent size selection, deployment and postdilatation especially in small coronary arteries. This safely allows higher balloon pressures to be used leading to larger lumen diameters. However, routine use of IVUS or OCT

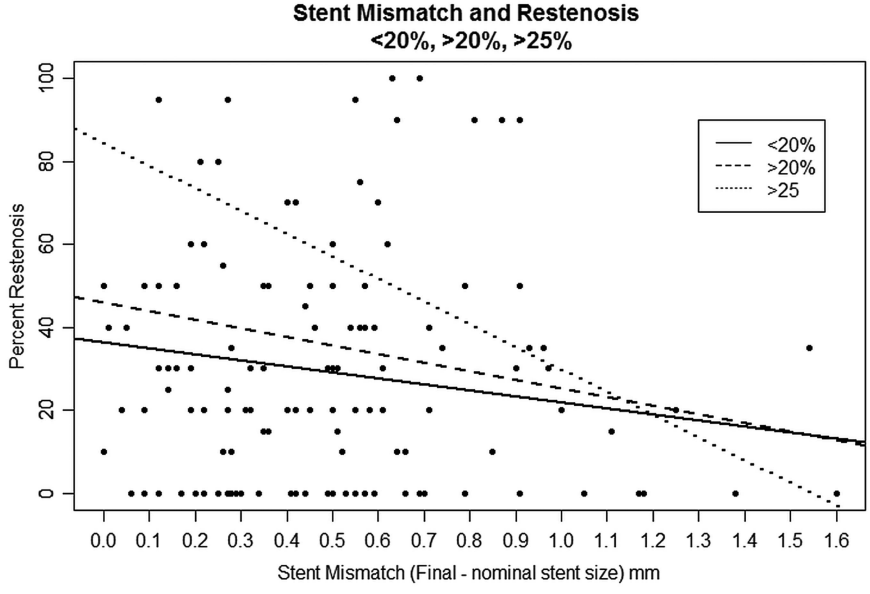

Figure 3 Stent mismatch versus restenosis stratified by per cent overexpansion above nominal stent size.

in non-complex stenting is uncommon, as apart from time and cost constraints, criteria for IVUS- or OCT-guided stent optimisation are not uniformly agreed or applied. Further, the role of IVUS—as the earlier technology—in improving prognosis after DES implantation has not been fully established.[18]

So *angiographically guided* high-pressure stent postdilatation or overexpansion is almost by default routine in many interventional laboratories. This practice is driven by evidence from early IVUS studies showing that suboptimal stent expansion is common and predisposes to restenosis and stent thrombosis in BMS.[1 3 6] When DES are used, concerns that stent thrombosis risk—early or late—may be heightened by poor strut apposition[19] lead to aggressive high-pressure postdilatation. However, aside from short-term adverse outcomes, there are concerns that unrecognised stent distortion or deformation during aggressive stent postdilatation may predispose to restenosis. Deciding on how aggressive or gentle to be during final stent optimisation is a challenge in every case.

This study in an interventional laboratory where intravascular imaging is available but not routine for non-complex stenting shows that aggressive stent expansion is common but there is absolutely no signal that increased stent size mismatch (overexpansion) predisposes to restenosis, even in small coronary arteries. Indeed, this study suggests that increased stent size mismatch, that is, apparent stent overexpansion, offers protection from instent restenosis. Those without binary restenosis had significantly greater stent size mismatch. Overexpansion of stents was not subtle with over half of stents being expanded at pressures greater than balloon rated burst pressure.

Mid-term to long-term outcome data from centres which do not mandate IVUS or OCT for simple stent cases are limited. Our study from contemporary real-world practice in a high-volume publicly-funded tertiary referral centre provides some meaningful insight and reassuring results to support the popular synergistic strategy of combining angiographic assessment of vessel and stent size with reference to manufacturers' compliance charts to guide sizing. There was no indication to suggest that the patient was significantly disadvantaged when occasionally a small stent was used and aggressively expanded because of non-availability of a larger size, a larger stent could not be delivered or simply operator misjudgement. Unlike previous studies, it includes patients with stable and unstable coronary disease. However, this study is limited by its single-centre setting and as patients with multi-vessel stenting, graft, bifurcational, left main and complex stenting requiring IVUS or OCT were excluded, these results are applicable to only simple de novo cases.

CONCLUSIONS

In this real-world population with non-complex de novo stenosis undergoing PCI without intravascular imaging, any tendency to overaggressive stent expansion did not predispose at all to restenosis. Indeed, the data trended toward a protective benefit for stent overexpansion.

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Competing interests None.

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