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ARTYKUŁ SPECJALNY / *STATE-OF-THE-ART REVIEW*

Is it possible to further improve clinical results with coronary bifurcation stenting, or what is more important — the technique or the stent?

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INTRODUCTION

Coronary bifurcation are involved in 20–25% of all percutaneous coronary interventions (PCI) [1, 2]. Bifurcation interventions, when compared with non-bifurcation interventions, have a lower rate of procedural success and a higher rate of restenosis, which is definitely true for the era of bare metal stents (BMS) and early experience with drug-eluting stents (DES) [2]. Different techniques with the use of one or two stents have been developed to optimise the treatment of this subset of lesions. Although stenting of individual lesions has been shown to be superior to balloon angioplasty, stenting of both branches seems to offer no advantage over stenting of the main branch (MB) alone. The introduction of DESs has resulted in a lower event rate and reduction of MB restenosis in comparison with historical controls [3, 4]. Of definite concern is the higher rate of stent thrombosis (ST) early (even during the procedure), late, and very late after interventional procedure (PCI). Rates up to 4% were reported with the first-generation DESs for the first year and up to more than 6% for very late ST at longer follow-up drew the attention of experts in the field, mainly for patients treated with two-stent techniques [5–7].

One important point can be observed if we look closer at the results from the Italian I-BIGIS registry of 4314 patients with treated coronary bifurcation stenoses — the long-term clinical outcome at median follow-up of 24 ± 12 months showed major adverse cardiac events (MACE) occurrence in 17.7%, cardiac death in 3.4%, myocardial infarction (MI) in 4.0%, target lesion revascularisation (TLR) in 13.2%, and ST in 2.9%. However, a significant temporal trend in MACE rate was demonstrated from 2002 (27.8%) to 2006 (13.0%), mainly related to reduction of TLR throughout the study period: from 23.1% in 2002 to 20.4% in 2003 and 15.7% in 2004, lowering further to 11.1% in 2005 and 9.1% in 2006 ($p < 0.01$) [7]. What actually changed during that time period was the widespread introduction of DESs and many more skilled operators obtained with time, as well as knowledge about best mechanical treatment when a stent is placed for coronary bifurcation. It will be interesting to explore independently those two factors (device progress vs. treatment knowledge). The same tendency is observed from data from a German centre [3]. The DESs were superior to BMSs, with some additional possible advantages. The results from the first-generation DESs demonstrate that stenting side branches (SBs) had a survival advantage in comparison with stenting only the main vessel. Side-branch stenting has a much smaller impact on long-term MACE with DESs compared with BMSs. Although this study does not support routine SB stenting, when SB stenting is required, DESs are associated with fewer adverse outcomes. Bare-metal stenting without SB stenting had 10% (95% confidence interval [CI] 3–16%, $p < 0.01$) higher MACE and 10% (95% CI 4–17%, $p < 0.01$) higher target vessel revascularisation (TVR), whereas bare-metal SB stenting had 31% (95% CI 23–39%, $p < 0.001$) higher MACE and 19% (95% CI 10–28%, $p < 0.001$) higher TVR. And finally, the three-year TLR rate from the RESOLUTE studies of 6.9% in bifurcation lesions was even lower than the rate in the Arterial Revascularisation Therapies Study (ARTS) II (9% at one year), the Bifurcations-Bad-Krozingen registry (15% at two years), and the Italian Multicentre Registry on Bifurcations with DES (13% at two years) [3, 4, 7].

Because bifurcation lesion, by its definition, is a disease extending into SBs, it was assumed that placement of a second stent into the SB could improve the outcome. However, the results from the BMS era were highly disappointing. With the introduction of first-generation DESs the situation improved a little, as the clinical results with two stents techniques equalised with single-stent techniques. Because the studies included a limited number of patients, several meta-analyses were performed, giving almost identical results. For example, Niccoli et al. [7] demonstrated that the final minimal lumen diameter (MLD) of the SB was significantly smaller in the single stent strategy group (weighted mean difference) –0.50 mm, 95% CI –0.76 – –0.24, $p < 0.00001$). The risk of main vessel restenosis (relative risk [RR] 0.66, 95% CI 0.38–1.17, $p = 0.16$), SB restenosis (RR 0.62, 95% CI 0.24–1.56, $p = 0.31$), follow-up death (RR 0.60, 95% CI 0.19–1.86, $p = 0.38$), follow-up MI (RR 0.71, 95% CI 0.46–1.10, $p = 0.13$), or TVR (RR 0.90, 95% CI 0.56–1.46, $p = 0.67$) was similar between the two strategies. The simple strategy showed a trend towards a lower risk of early MI (RR 0.65, 95% CI 0.41–1.05, $p = 0.08$) [7, 8]. A slight disadvantage of the single-stent approach may be the somewhat higher risk of SB occlusion after stenting the MB, as will be discussed in more detail below. However, there remains concern about the higher rate of ST. The clinical consequences of ST are frequently catastrophic and include death in 20–48% of major MI in 60–70% of cases. In the DES era, ST and especially very late ST remain a concern in coronary intervention [9]. Bifurcation lesions and bifurcation stenting have been reported to be the risk factors for ST. ST is a complex process that may be a culmination of device, patient, lesion, and procedural factors. The exact cause of the higher risk of ST in bifurcation lesions is unknown although pathological studies have suggested that the arterial branch points are predisposed to development of atherosclerotic plaque, thrombus, and inflammation because they are foci of low shear stress.

From the second half of the first decade of the 21st century second- and currently even third-generation DESs were introduced [10–20]. The novel DES systems demonstrated better safety (much lower rate of all types of ST, including very late thrombosis rates below 0.5%) and efficacy (single-digit restenosis rates are a must not, with most currently available DESs less than 5% in one-year follow-up). It is logical that with new devices the results will be much better than in historical trials.

WHAT DO THE DATA CURRENTLY DEMONSTRATE ABOUT BIFURCATION TREATMENT EFFECTIVENESS WITH OUR RECENT DEVICES?

Did bifurcation lesions confer higher risk for adverse cardiac events when treated with the latest-generation DESs? If the answer is yes, then we have to pay special attention to this coronary lesion subset. Alternatively, if the answer is "no", then we have wasted a lot of time and effort up to now. Unfortunately, there is no randomised study with the latest DES systems comparing safety and effectiveness of such a device in non-bifurcation and bifurcation coronary lesions with follow-up more than one year. So, let us look at the non-randomised data we have up to now. Table 1 summarises the data from the most recent trials with a patient population at least 100 patients and with follow-up at least one year [10–22].

Several conclusions could be drawn from the data of the table. First, there is no difference in survival rate, spontaneous MI, and even clinically indicated TLR rates between bifurcation and non-bifurcation lesion treated patients. Second, importantly the rates of so-called "periprocedural myocardial infarction" or "periprocedural myocardial injury" (PMI) are higher in patients with coronary bifurcation in comparison with non-bifurcation lesions, even with the newest devices. There is a graded relation between the amount of PMIs and the lesion-technique relationship — it is rare in non-bifurcation PCIs, more frequent in simple bifurcation crossover stenting, and highest in double-stent techniques for treatment of complex coronary bifurcation lesions. PMI (discussed in detail below) in the treatment of bifurcated lesions may result from stent-induced closure of SBs, flow-limiting dissections, distal embolisation, or the occurrence of slow flow or no reflow. It should be underlined that with the current DESs the stent thickness is greatly decreased, the number of interconnecting struts is decreased, and the stent cell circumference is increased [23]. This permits much better stent strut apposition to the vessel wall, promoting endothelial healing, and decreasing neointima proliferation, respectively, resulting in less restenosis. Recently, Ferenc et al. [24] analysed their results on 2197 patients after stenting coronary bifurcations with different generations of DES. Patients treated with paclitaxel eluting stent (PES) had significantly higher rates of MACE compared with patients treated with sirolimus-eluting stents (SES) or zotarolimus eluting stents (ZES)/everolimus eluting stents (EES): the hazard ratio (HR) (95% CI) of PES vs. SES was 1.34 (1.04–1.71), $p = 0.023$, and that of PES vs. EES/ZES was 1.75 (1.19–2.57), $p = 0.004$. TLR differed significantly ($p = 0.005$) between the stent groups, reaching 11.3% in the PES group, 7.3% in the SES group, and 5.8% in the EES/ZES group. These results are comparable with results from other studies shown in the Table 1. The most important asset of this analysis is the large number of patients constituting a homogenous group treated systematically with provisional T-stenting, currently the most recommended strategy [2]. These results from Germany are in accordance with the pooled analysis of coronary bifurcation patients treated with a first- and second-generation DES [25]. A total of 3129 patients were included into the analysis, taken from three different registries. With first-generation DESs, rates of patient-oriented clinical events (POCE) at three years were significantly higher after the two-stenting than the one-stenting technique (target lesion failure [TLF] 8.6% vs. 17.5%; $p < 0.001$; POCE 18.1% vs. 28.5%, $p < 0.001$). With second-generation DES, however, there was no difference between one- and two-stenting techniques (TLF 5.4% vs. 5.8%; $p = 0.768$; POCE 11.2% vs. 12.9%; $p = 0.995$). The two-stenting technique was a significant independent predictor of TLF in first-generation DES (HR 2.046, 95% CI 1.114–3.759, $p < 0.001$), but not in second-generation DES (HR 0.667; 95% CI 0.247–1.802, $p = 0.425$). It is interesting also that the rates of spontaneous MI with first-generation one-stent technique was significantly lower (1.7% vs. 3.1%, $p = 0.012$), which is no longer the case with second-generation DESs (0.2% vs. 1.1%, $p = 0.199$). The same is true for TLR rates with one- vs. two-stent techniques with first- (6.7% vs. 13.5%, $p < 0.001$) and second-generation DESs (3.7% vs. 3.6%, $p = 0.571$). Importantly, the two-stent technique with first-generation DESs bears significantly greater risk of all-cause death (HR = 1.7, 95% CI 1.2–2.4, $p = 0.003$), which is no longer the case with second-generation DESs. When comparing patients enrolled in the COBIS II and EXCELLENT/RESOLUTE-Korea registries, the patients enrolled from the EXCELLENT and REOLUTE-Korea registries showed more severe risk factor profiles, higher SYNTAX scores, higher proportion of true bifurcation lesions, and more usage of two-stenting techniques.

Here is the point where we have to go back to the technique. The recently published results from the COBIS II Korean registry were in strikingly contradictory to previously published results from the same group in an earlier report from the COBIS I registry [26, 27]. In COBIS I, patients, after kissing balloon inflation (KBI), performed worse regarding patients with no KBI despite higher TLR rates, while in the COBIS II registry the reverse was true — patients after final KBI had better results, with less in-stent restenosis. Both registries are relatively homogenous, with more than 1000 patients each (COBIS I, n = 1668; COBIS II, n = 1901), so there is no doubt about the statistical power of the results. There are several possible explanations for these results. First, in the COBIS II registry 26% of patients were treated with second-generation DESs. Second, in COBIS II the main-vessel final MLD was larger than in COBIS I (mean values 2.73–3.27 mm vs. 2.51––2.83 mm); moreover, the size of SBs in COBIS II was considerably larger than in COBIS I (> 2.3 mm vs. > 2.0 mm). There was considerable undersizing of the main vessel balloon used for final KBI when COBIS I was performed, which resulted

Table 1. Summary of MACE at mid- and long-term follow-up after coronary bifurcation and non-bifurcation stenting with the second- and third-generation of drug-eluting stents

Study name	Patients — total/ /bifurcation	Type of DES	FU [years]	Death- -BL	Death- -nBL	PMI- -BL	PMI- -nBL	MI- -BL	MI- -nBL	TLR- -BL	TLR- -nBL	TVR- -BL	TVR- -nBL	ST- -BL	ST- nBL	MACE/ /POCE-BL	MACE/ /POCE-nBL
RESOLUTE, Diletti et al. Heart 2013	2292/392 (17%)	ZES (Resolute) vs. EES (Xience V)	2	3.4	3.5	6.5	3.4*	0.8	1.4			13.8	9.7*	3.1	3	15.1	11.5
Ferenc et al. J Invasive Cardiol, 2014	3489/703 (20%)	ZES (Resolute) vs. EES (Xience V)	3	4.8	6.1	5.3	2.2*	1.2	1.5	6.9	5.3	9.6	7*	2.5	1.2*	15.2	14.1
Hermiller et al. Catheter Cardiovasc Interv, 2015	4768/511 (10.7%)	EES	4	13.5	14.1				10	10.1	19.1	18.3	2.3	1.4			
LEADERS, Grundeken et al. Catheter Cardiovasc Interv, 2015	1707/497 (28%)	BES vs. EES	5	12.9	12.6	7.2	4.3*	4.7	4.6	13	9.9	18.5	15.6	4.4	4.4	26.6/37	22.4*/37.4
TWENTE, Lam et al. Am Heart J, 2015	1391/362 (26%)	ZES (Resolute) vs. EES (Xience V)	3	5	6	6.9	3.1*	1.3	1.9	3.3	5.1	4.4	7.1	0.8	1.8	14.4/16.4	14.4/17.1
DUTCH-PEERS, van der Heijden, Clin Res Cardiol, 2016	1811/465 (26%)	ZES (Resolute Integrity) vs. EES (Promus Element)	2	1.7	2.3	3.2	1.1	0.2	0.5	4.5	4.8		0.4	1	9.2/12.9	8.3/12.5	

Data extracted from references: [10–22]; BL — bifurcation lesion; FU — follow-up; nBL — non-bifurcation lesion; SES — sirolimus eluting stent; ZES — zotarolimus eluting stent; BES — biolimus eluting stent; EES — everolimus eluting stent; PMI — periprocedural myocardial injury (infarction); MI — myocardial infarction at follow-up; TLR — target lesion revascularisation; TVR — target vessel revascularisation; ST — stent thrombosis; MACE — major adverse cardiac events (composite from death [all-cause or cardiac], MI and TLR/TVR); POCE — patient oriented clinical events (composite of all cause death, spontaneous myocardial infarction, clinically indicated TLR/TVR); *$p < 0.05$

in worse main vessel stent expansion, finally causing lower restenosis rates in COBIS II (COBIS II, KBI vs. non-KBI: 5.9% vs. 7.9%, p = 0.02; COBIS I, KBI vs. non-KBI: 5.7% vs. 3.1%, p = 0.019). As we and others have pointed out, when KBI is performed, the main vessel balloon should have the diameter of the distal main vessel [23, 27–30]. In summary, a better device and better understanding of how to perform a given technique gives better results. The understanding that when KBI is performed the main vessel balloon must be same size as the stent distal reference diameter results in larger final MLD in main vessel, which is one of the strongest predictors of restenosis, no matter what type of device is used.

SIDE-BRANCH COMPROMISE AND PERIPROCEDURAL MYONECROSIS: HOW MUCH IS ACCEPTABLE?

There is a long-standing discussion about the significance of periprocedural myocardial necrosis — using different terms and definitions [31–37]. The large SB closure, subtending a significant amount of myocardium, despite lacking collateral blood supply to the branch territory, will result in significant myonecrosis, which can affect the survival of the patient. In a study by Park et al. [38] PMI was classified according to its underlying angiographic mechanisms as type 1 (due to SB occlusion), type 2 (due to other angiographic complications), or type 3 (without angiographically identifiable causes). Among 10,889 patients treated with DES, 768 (7.1%) experienced PMI; 463 (60.3%) cases were driven by type 1 cause, 138 (18.0%) by type 2 cause, and 167 (21.7%) by type 3 cause. Mortality rates at two years were higher in patients with PMI than in those without (3.5% vs. 2.1%, respectively). Significant differences in mortality were observed according to the angiographic mechanisms of MI (type 1: 2.8% vs. type 2: 6.1% vs. type 3: 3.1%). After multivariable adjustment, type 2 MI was significantly associated with an increased risk of mortality (HR 2.65), whereas type 1 and type 3 MI were not related with increased mortality. Thus, SB occlusion was the most frequent event of angiographic complication, but in most cases not resulting in significant myonecrosis. In a recent study Idris et al. [39] explored how the definition of PMI could affect the prognosis after PCI from 742 patients; 492 (66%) had normal troponin T (TnT) levels and 250 (34%) had elevated, but stable or falling, TnT levels. PMI, using the 2007 [40] and the 2012 [41] universal definition, occurred in 172 (23.2%) and in 99 (13.3%) patients, respectively, whereas only 19 (2.6%) met the Society for Cardiovascular Angiography and Interventions (SCAI) PMI definition (p < 0.0001). Among patients with PMI using the 2012 definition, SB occlusion occurred in 53 (54%) patients; SB diameters were ≤ 1 mm in 48 patients, > 1 mm to < 2 mm in three patients, and ≥ 2 mm in two patients and was the most common angiographic finding for PMI. The rates of death/MI at two years in patients with, compared to those without, PMI was 14.7% vs. 10.1% (p = 0.087) based on the 2007 definition, 16.9% vs. 10.3% (p = 0.059) based on the 2012 definition, and 29.4% vs. 10.7% (p = 0.015) based on the SCAI definition. Again, the SB occlusion was the most frequent event, but only when resulting in large myonecrosis (troponin increase of more than 70 × UNL or CK-MB > 10 × UNL) had a prognostic impact. These results are similar to data from Herrmann et al. [31] in almost 6000 patients, where the short-term mortality was influenced only if the troponin increase was more than 25 × UNL or CK-MB > 5 × UNL. It seems that some degree of ischaemia-induced periprocedural increase in troponin level is acceptable and did not influence the prognosis of patients, mainly regarding death. Also troponin rise is not necessarily associated with future cardiac events. We should take into account here also the results from the COBIS I and COBIS II registries, analysing the influence of SB occlusion on long-term prognosis. In COBIS II (as we mentioned above, the reference SB diameter was ≥ 2.3 mm) 187 (8.4%) had SB occlusion after main vessel stenting (defined as decrease of TIMI flow by more than one degree; practically meaning TIMI flow < 3). It occurred more frequently in patients with true bifurcation lesions (initial SB ostial diameter stenosis > 50%) — 74% vs. 44%, p < 0.001. Independent predictors of SB occlusion were pre-procedural percentage diameter stenosis of the SB > 50% (odds ratio [OR] 2.34; p < 0.001), proximal main vessel stenosis > 50% (OR: 2.34; p < 0.001), SB lesion length (OR 1.03; p = 0.03), and acute coronary syndrome (OR 1.53; p = 0.02). The cardiac rate as well as the ST rates were significantly higher in the group with SB occlusion in comparison with the group without (3.7% vs. 1.0%, p = 0.002 for cardiac death; 3.2% vs. 0.4%, p = 0.002 for ST). Importantly, when SB could not be opened and remained closed at the end of PCI (which occurred in 31% of SBs closed after stenting), the all-cause death and cardiac death were significantly higher, as well as in those patients when SBs were opened successfully (13.8% vs. 0.6%, p = 0.005, all-cause death; 8.6% vs. 1.6%, p = 0.04, cardiac death). Practically, temporal closure of SBs does not influence death rates, meaning that TIMI 3 flow in all SBs is necessary, but there is more than a nine-fold increase in death rates if SB remains closed. The only predictor of opening closed SBs was jailing of the guide wire (branches with jailed wire were opened in 2/3 of cases, while branches without jailed wire were opened only in half of the cases). This is in contradiction with the results from the COBIS I registry, which demonstrated the reverse — that PMI associated with SB closure is not related with death rates (despite the fact that there was a severe trend for all-cause death increase in univariational analysis, 2.5% vs. 0.7%, p = 0.07). This discrepancy is probably related to larger SBs that were treated in COBIS II vs. COBIS I (≥ 2.3 mm vs. ≥ 2.0 mm). Additionally, the role of the device type use (first- vs. second-generation DES) should not be underestimated.

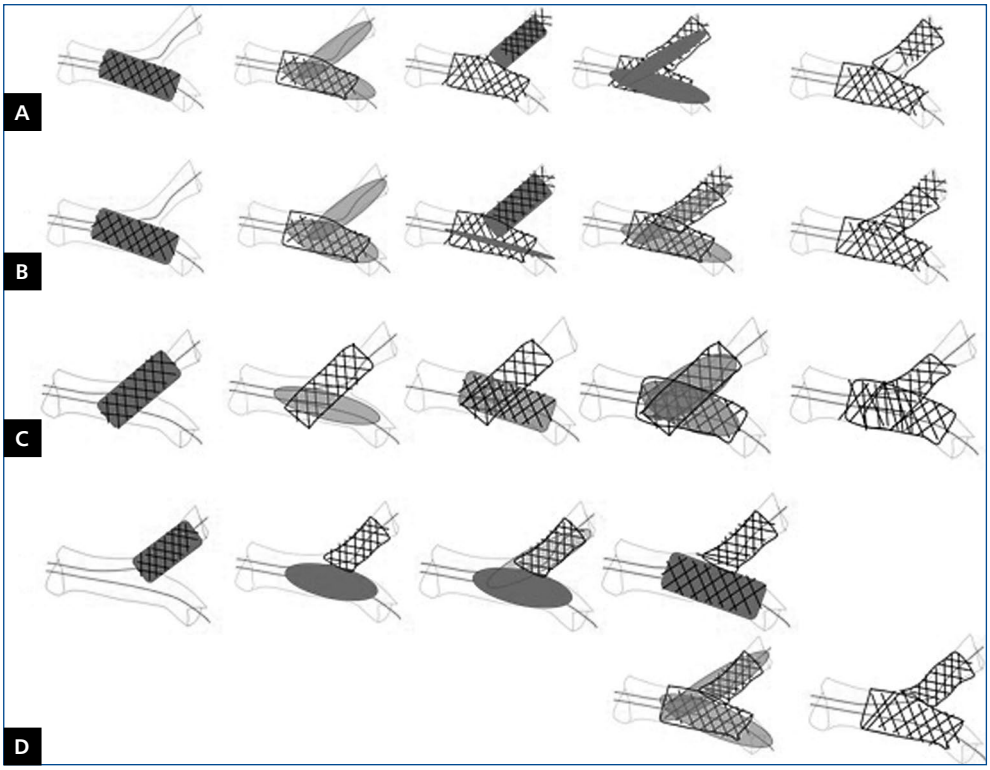

Figure 1. Provisional T-stenting technique stages (**A**); T-And-Protrusion (TAP) technique stages (**B**); culottes stenting stages (**C**); double kissing stenting stages (**D**). It is worth remembering that recently the proximal optimisation technique is strongly recommended after main vessel stenting, before possible final kissing

The point is to define what is significant side branch — a branch, which occlusion will cause significant ischaemia and/or ventricular dysfunction in short-term or long-term follow-up [1–3], but most importantly — how much and what type of ostial compromise (stenosis) or flow in the branch would not result in myonecrosis or significant (symptom causing and electrocardiogram changes causing) ischaemia? We and others [28, 40, 42] have demonstrated that the most important mechanism of SB stenosis occurrence is displacement of the bifurcation carina tip from stent struts in the direction of the SB ostium. The carina displacement is the leading mechanism of SB closure, but additional plaque shifting from the main vessel or plaque redistribution of SB ostium per se is necessary to close the vessel completely [27, 40, 42]. However, even without closure, the branch could be stenosed enough to cause ischaemia. The ischaemic potential of this stenosis could be assessed by measuring fractional flow reserve (FFR) (ratio of distal from lesion intracoronary pressure to aortic pressure, measuring the flow limiting capacity of given stenosis) by coronary pressure wire. It was shown that FFR > 0.75–0.80, no matter how big the ostial stenosis, is associated with favourable mid-term prognosis [41, 43]. As demonstrated in DK-CRUSH VI, the FFR measurement leads to lower rate of stenting SBs and thus reduces cost [43]. However, the FFR measurement in SBs does not result in significant reduction of MACEs or any of its components. Thus, pursuing TIMI 3 flow in all SBs at the end of coronary bifurcation PCI looks to be a plausible and cost effective strategy. The old rule that any important SB should be protected by wire is still valid. No technique could be recommended at that point regarding better SB patency preservation, based on some prior score [44]. Practically just a wire protection is enough. The direct comparison of aggressive strategy (treating any ostial post-stent SB stenosis more than 75% vs. treating only ostial stenosis causing TIMI flow less than 3) yields equivalent results with almost identical TLR rates at one year (9.4% in the conservative group vs. 9.2% in the aggressive group, p = 0.97) [45]. These results reflect the earlier results with SB flow-guided strategy, performed with a first-generation DES (with a difference of more than doubled restenosis rates at shorter follow-up time) [46]. Some authors are against SB predilatation considering the potential for major dissection of the SB ostium, requiring additional stenting (which is also the official position of the European Bifurcation Club) [2]. However, the randomised study comparing predilatation with no-predilatation before main vessel stenting demonstrated improved TIMI flow after MB stenting and less indication to subsequently treat the SB [47]. If rewiring of the SB is required, predilatation

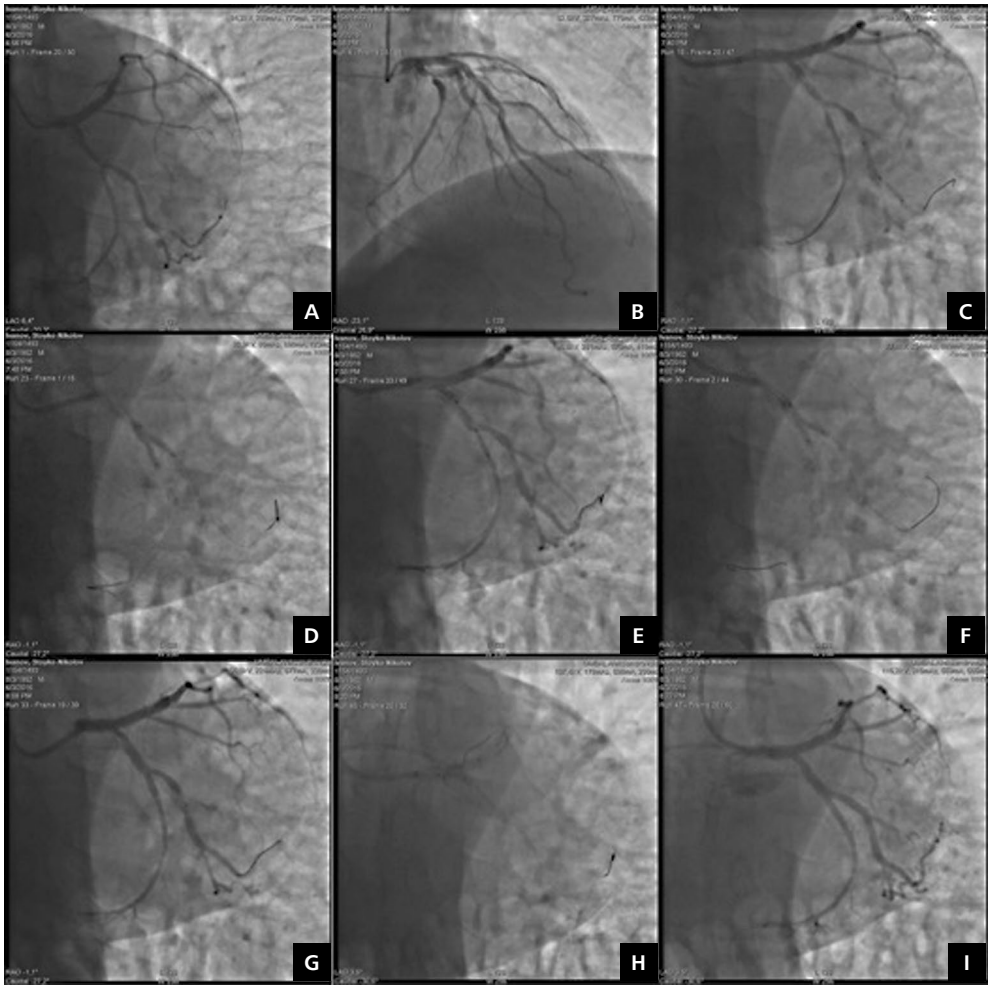

Figure 2. Effect of kissing balloon inflation after two-stent implantation. Two tandem bifurcation lesions stenting with two dedicated bifurcation stents (BiOSS Lim, Balton, Poland) and culottes technique in between; **A, B.** Caudal and cranial view of left circumflex artery — proximal bifurcation stenosis type 111 and distal obtuse marginal branch bifurcation stenosis type 111; **C.** Positioning and implantation of bifurcation dedicated stent BIOSS Lim 3.25 × 2.5 × 23 mm; **D.** First kissing balloon inflation of the proximal bifurcation balloons 2.5 × 15 mm; **E.** Positioning and implantation of bifurcation-dedicated stent BIOSS Lim 3.25 × 2.5 × 18 mm; **F.** Second kissing balloon inflation after stent implantation with balloons 3 × 10 mm and 2.5 × 10 mm; **G.** Results after kissing balloon inflation in proximal bifurcation; **H.** Implantation of Ultimaster 3 × 33 mm stent in ostial left circumflex through proximal bifurcation with obtuse marginal — culotte technique, third and final kissing in the proximal bifurcation balloons 3 × 10 mm and 2.5 × 10 mm and left main final kissing with balloons 3.5 × 15 mm and 3 × 10 mm; **I.** Final result in caudal view

does not hinder this manoeuvre. We must consider also that the Nordic I study, where provisional SB stenting was compared with two stent techniques, demonstrating favourable long-term results, was performed with obligatory SB ostial predilatation [48]. If, however, a second stent is needed (in SB subtending large territory, without collaterals, with severe ostial stenosis, especially if severe calcification is observed or SB incident angulation predisposes to difficulties in rewiring), there is still no preferable technique to recommend, regarding hard end-points at follow-up. In experienced hands the standard T-stenting technique and TAP (T-and-protrusion) techniques together with more complex techniques (culottes stenting and crush stenting, with its later modification with two kissing steps — double kissing crush [DK-crush]) give similar results (Fig. 1) [49]. An important point here is that final KBI is essential in any technique using two stents, which dramatically decreases periprocedural and postprocedural complication rates and dramatically improves long-term results.

GENERAL CONCLUSIONS AND FUTURE DIRECTIONS

Therefore, the best answer to the question: "which is more important — the stent or the technique?" is probably, "the

simplest for the lesion technique with the best available drug-eluting stent, keeping all side branches opened with normal flow".

There is still a belief that we can improve results of percutaneous treatment for coronary bifurcations with new devices; however, the bioresorbable vascular scaffolds (BVS) still cannot be recommended for routine use [50]. Their wider application is still prevented from technology issues in comparison with third-generation DESs. The BVS are thick strut devices that, by themselves, could compromise flow in small branches. The relatively easy fracture of BVS struts makes its use in complex double-stenting techniques problematic, but not impossible. The obligatory requirement for perfect predilatation predisposes to long vessel dissections and covering much longer segments than is needed. Finally, the long-term results with those devices are still missing. The influence of different techniques on clinical effectiveness is limited to a very small number of cases. Thus, in the meantime, BVS could be used in coronary bifurcations with caution, following the general rules for their implantation (perfect 1:1 predilatation, slow inflation, good postdilatation with non-compliant balloon).

Another possible big step forward in our technical armamentarium is the proximal optimisation technique [2]. Here, by using a very short balloon to dilate the proximal main vessel before the carina, a better stent apposition and shape configuration is achieved. The proximal main vessel becomes more circular, disturbing the flow less, and possibly having better optimal shear stress distribution. However, there are still no firm clinical data for recommending proximal optimisation technique over KBI. It is possible that both techniques will be complementary (Fig. 2).

Finally, the dedicated DESs for coronary bifurcation stenting are already available. The main limitations in wider application of dedicated bifurcation devices are larger profile, poorer tractability, difficult orientation, and much more technical skill needed for implantation. Probably the greatest drawback is the limited range of lengths of the devices, which most frequently results in additional stent(s) implantation, increasing the cost of the procedure. The SB-dedicated stenting with Tryton stent (not the drug-eluting version) did not reach its primary non-inferiority end-point in comparison with regular DES [51]. It demonstrated such non-inferiority only in the group with SB reference diameter more than 2.25 mm. The Axxess stent is another device dedicated to stenting only the proximal main vessel of bifurcation. It is a self-expandable DES, requiring very precise positioning and opening. The device has limited application and in more than 80% of cases requires additional stent implantation [52]. No randomised study has given results for this type of stent compared to regular DESs. A BIOSS Lim stent is a dedicated device demonstrating clinical efficacy in a recently published randomised POLBOS II trial [53]. At 12 months, the cumulative MACE incidence was similar in both groups (11.8% [BiOSS] vs. 15% [rDES], $p = 0.08$), as was the TLR rate (9.8% vs. 9%, $p = 0.8$). The binary restenosis rates were significantly lower in the FKBI subgroup of the BiOSS group (5.9% vs. 11.8%, $p < 0.05$). The device is easy to use, tracked over one wire, with very low profile with a wide range of lengths and diameters, making it applicable in almost all types of coronary bifurcations, including left main distal bifurcation. It is worth mentioning that the results achieved in this last location were even better than for regular bifurcations [54]. The 12-month MACE rate was 9.5% without cardiac death or definite ST. TLR and MI rates were 6.8% ($n = 5$) and 2.7% ($n = 2$), respectively. There is hope that the latest chromium-cobalt thin-strut BiOSS stent version (which recently received a Conformité Européene mark) will ensure even better results.

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