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How to solve difficult side branch access?

Francesco Burzotta[1]*, MD; Maria De Vita[2], MD; Gregory Sgueglia[3], MD; Daniel Todaro[3], MD; Carlo Trani[1], MD

1. Institute of Cardiology, Catholic University of Sacred Heart, Rome Italy; 2. Cardiovascular Department, Ospedale Morgani, Forlì Italy; 3. UOC Emodinamica e Cardiologia Interventistica, Ospedale Santa Maria Goretti, Latina, Italy

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Abstract

Safe guidewire placement in the main vessel (MV) and in the side branch (SB) does represent the key point for successful percutaneous coronary interventions (PCI) in bifurcated lesions.

During bifurcation PCI, SB wiring is systematically performed as a first step and is often repeated ("rewiring") during the procedure in order to treat the SB after MV stenting. Wiring and rewiring are crucial phases of bifurcation PCI which require, in the most complex cases, specific operator experience.

In the present paper, the classic SB wiring techniques necessary for routine bifurcation interventions (antegrade and pullback wiring technique) as well as "advanced" wiring techniques ("reverse wire" technique, Venture-facilitate wiring, MV balloon predilation or debulking) are described.

Moreover, the rewiring technique is discussed in detail, with particular attention on the tips and tricks which may facilitate the achievement of optimal result with provisional stenting (pullback rewiring) and help manage bail out situations like acute SB flow impairment after MV stenting.

Introduction

Bifurcations are complex target coronary lesions in which the adoption of the most suitable treatment technique is of primary importance. An increasing amount of clinical evidence suggests that drug-eluting stent (DES) implantation using a "provisional" approach is the gold standard for unselected bifurcated lesions[1,2].

Safe guidewire placement in the main vessel (MV) and in the side branch (SB) does represent the first step of any bifurcation PCI. Indeed, even if the selected technique is the most simple (i.e., stenting the MV only), the placement of a guidewire into the SB according to the so-called "jailed wire technique" has been shown to improve the outcome of bifurcation PCI[3]. Experienced operators are used to routinely and successfully wire the SBs in their clinical practice. Yet, the complex pattern of bifurcation coronary anatomies (with wide variations of SB take-off angle) and the different pattern of atherosclerotic disease distribution (with variable degrees of MV and SB involvement) may render SB wiring highly challenging. Thus, specific skills are required to succeed.

Moreover, once the stent has been placed in the MV, complex bifurcated lesions often require further interventions in the SB (ballooning, stenting) which need guidewire re-crossing of the MV stent to get into the SB. Such "rewiring" phase, although usually not prohibitive, may sometimes result in extreme challenges and occasionally lead to technical failure.

In this manuscript we review and graphically describe the tips and tricks useful to successfully perform SB wiring and rewiring during bifurcation PCI.

Characteristics of bifurcations with difficult side branch access

The characteristics causing difficulties in SB wiring have not been identified in clinical studies but come from the experience of operator/leaders in the field of bifurcation PCI. In particular, angiographic predictors of difficult SBs wiring are severe calcifications involving the proximal MV and/or ostial SB, severe stenosis with a large plaque burden in the proximal MV, tortuosity in the proximal MV limiting guidewire manipulations and consequently access to the SB, severe stenosis of the SB ostium and flow less then TIMI 3 in the SB[4,5]. Moreover, angulation between the main axis of the MV and main axis of the SB (distal bifurcation angle) is an important issue in terms of access to SBs. Indeed, SB wiring is usually easy when the distal bifurcation angle is less than 70°, while

* *Corresponding author: L.go Gemelli 1, 00168 Rome, Italy*

E-mail: f.burzotta@rm.unicatt.it

access to the SB is usually more difficult in distal bifurcation angles of more than 70°, and can be particularly difficult when it exceeds 90°[6]. Of note, the distal bifurcation angle is favourably modified after SB wiring, specially in wider bifurcations, thus facilitating SB rewiring after MV stenting[6]. Interestingly, Pflederer et al[7] assessed the natural distribution of four main coronary artery distal bifurcation angles by 16-slice MDCT in 100 patients with suspected coronary artery disease reporting the following average values: 80±27 degrees for LAD/LCX, 46±19 degrees for LAD/Diagonal 1, 48±24 degrees for LCX/OM1 and 53±27 degrees for PDA/PLA, respectively. Similar results comes from another study conducted in 209 patients using a 64-slice MDCT that additionally demonstrated a significantly higher incidence of wider distal bifurcation angles (defined as more than 70°) in LAD/LCX bifurcation as compared to the other main bifurcation analysed (LAD/Diagonal 1, LCX/OM1 and PDA/PLA)[8], suggesting that wiring SB (LCX, in this case) in LM bifurcation lesions can be more difficult than in other bifurcation types.

Another step of PCI bifurcation lesions in which SB wiring can be challenging is the rewiring phase after MV stenting, particularly in complex cases when SB flow is compromised or SB is occluded.

In order to avoid SB compromise or occlusion, to know the predictors of SB occlusion can be useful. Indeed, angiographic studies[9-11] identified the following predictors of SB compromise or occlusion: small reference SB diameter, ostial SB stenosis more than 50% before MV stenting, involvement of SB origin within the lesion of the MV and steeper distal bifurcation angle[12,13]. An IVUS study conducted by Furukama et al[14] confirmed that the presence of a stenosis more than 50% at ostial SB is a strong predictor of SB occlusion, and showed that the presence of diffuse plaque around the SB ostium is the most important independent predictor of SB occlusion. Table 1 shows the rates of SB flow compromise after MV stenting in the provisional MV stenting arm of the contemporary randomised trials comparing a simple stenting strategy (provisional T stenting technique) to a complex stenting strategy (double stenting technique) in bifurcation lesions[15-20]. Overall, it is evident that when applying the provisional approach the need to rewire the SB as a bail-out strategy is a relatively frequent event, so that effective rewiring techniques should be gained by operators performing bifurcation interventions.

Primary side branch wiring

General advices and non-complex side branch access

The SB wiring phase has a variable degree of technical difficulty. Although in the non-complex bifurcated lesions the successful placement of "workhorse" guidewire in both the MV and the SB is generally obtained by every experienced interventionalist without any trouble, some advice may help to adequately perform a bifurcation intervention.

The guidewire's tip should be appropriately shaped to facilitate MV and SB wiring[21]. The curves typically used to wire the branches in bifurcations are basically four: a single bend with short (2-3 mm) tip, a single bend with long tip (4-6 mm), a single wide bend and a double bend shape (Figure 1). Each configuration may favour SB wiring under specific circumstances (see below). However, it is worth noting that when the MV wire is going to be used for SB rewiring after MV stent implantation, the wider curves are more suitable.

As a first step of a bifurcation PCI, it is usually advisable to wire the branch (either MV or SV) which appears more difficult to do (or less easy) (Figure 2). Adherence to this rule minimises the risk of wire twisting caused by excessive guidewire manipulations around a previously placed wire.

Complex side branch access

As previously stated, in a sizable number of bifurcated lesions, the mix of plaque distribution and vessel anatomy determines scenarios in which the SB wiring requires great experience and technical skill. The most common step for successful difficult SB access wiring is represented by the advancement toward the SB ostium of an appropriate guidewire (workhorse or stiff or with hydrophilic polymer coating) with an appropriately shaped tip curvature. When the problem is a wide angle between the proximal MV and the SB axes (a pattern which is typically encountered in the circumflex take-off from the left main), a useful solution is to shape the tip with a wide smooth bend or with a double bend (the second solution being more practical when the SB lesion is tighter) (Figure 1). Moreover,

Table 1. Rate of side branch flow impairment (TIMI < 3) after main vessel stenting in the provisional arm of randomised trials comparing simple versus complex stenting strategies in bifurcation lesions.

Study	Patients (n)	True bifurcations (%)	Medina 1,1,1 (%)	Distal (mean±SD) bifurcation angle (°)	Baseline SB RVD (mm) (mean±SD)	Baseline SB stenosis rate (%) (mean±SD)	SB TIMI flow <3 after MV stenting (%)
Pan et al[15]	47	100%	NA	NA	2.5±0.3	64±13	2%§
Colombo et al[16]	43	100%	NA	NA	2.1±0.3*	46±22*	51.2%§
NORDIC[17]	207	NA	NA	Distal BA <70° in 64.4%	2.6±0.4	NA	32%
Ferenc et al[18]	101	69%	36%	49.9±59.9	2.4±0.3	53±24	5%§
CACTUS[19]	173	94%	75%	NA	2.2±0.3	61±13	1.2% (rate of SB occlusion)
BBC1[20]	250	81%	60%	Distal BA < 60° in 85%	NA	63±31	26.4%¶

RVD: Reference vessel diameter; SB: side branch; MV main vessel; NA: not available; §rates of SB TIMI flow <3 after MV stenting and SB balloon dilation; ¶rate of TIMI flow <3 or SB ostial stenosis > 90% or SB dissection greater than type A after MV stenting; * data from the 22 patients treated with only MV stenting (per protocol analysis)

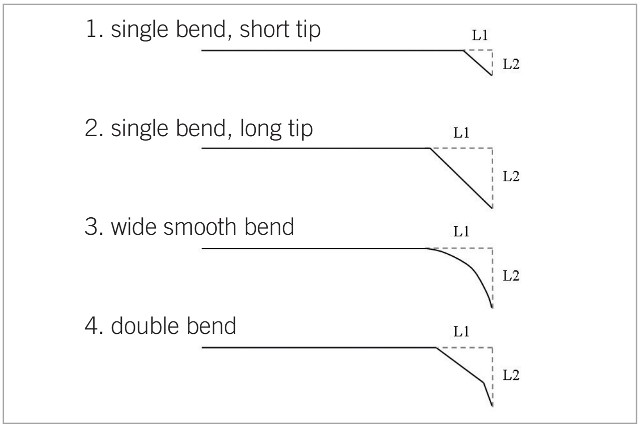

Figure 1. Common types of guidewire tip shape for bifurcated lesions. (1) Single bend with short 2-3 mm) tip. (2) Single bend with long tip (4-6 mm). (3) Single wide bend. (4) Double bend shape. L1 is usually modulated according to the side branch take off angle and depends on the angle between the axis of wire shaft and the axis of the tip (long L1 corresponds to wide angulation of tip bend, short L1 corresponds to acute angulation of tip bend). L2 is usually adjusted according to the diameter of the main vessel lumen (long L2 is usually needed to reach side branches arising from large vessels, short L2 to reach side branches arising from smaller vessels). Disease in the main vessel may limit the advancement of guidewires shaped with long L2. During rewiring, L2 should be similar to the diameter of the stent implanted in the main vessel.

when the SB take-off is ≥90% and the stenosis is sub-occlusive, to successfully place highly bended wires in the SB there are two techniques: the antegrade wiring, by pushing the wire directly into the SB from proximal MV (Figures 3 and 4), and the pullback wiring, consisting in the engagement of the SB ostium by retrieving the wire from the MV distal to the bifurcation (Figures 5 and 6). An evolution of this approach, is represented by the "reverse wire" technique[22] in which two sharp curves are created at the guidewire tip: a longer proximal one which should create a loop in the distal MV and an opposite short distal one which should engage the SB ostium during the wire pullback (Figure 7).

Recently, a deflectable-tip catheter system, the Venture catheter (St. Jude Medical, St. Paul, MN, USA), became available offering a novel way to solve difficult SB access (Figure 8). With this system, the guidewire may be directed toward the SB after deflection of the

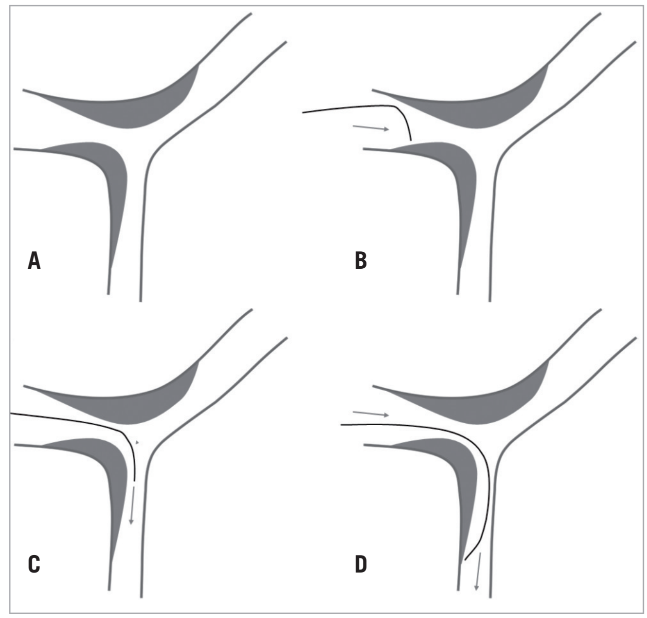

Figure 3. Complex side branch wiring: antegrade wiring technique. (A) A Medina 1,1,1 bifurcation with an unfavourable 90° angle. (B) A guidewire that has been gently curved proximally to its J tip is advanced toward the bifurcation. (C) Owing to its second bend, the guidewire engages the side branch effectively. (D) Gentle turning counter-clockwise advances the guidewire in the side branch.

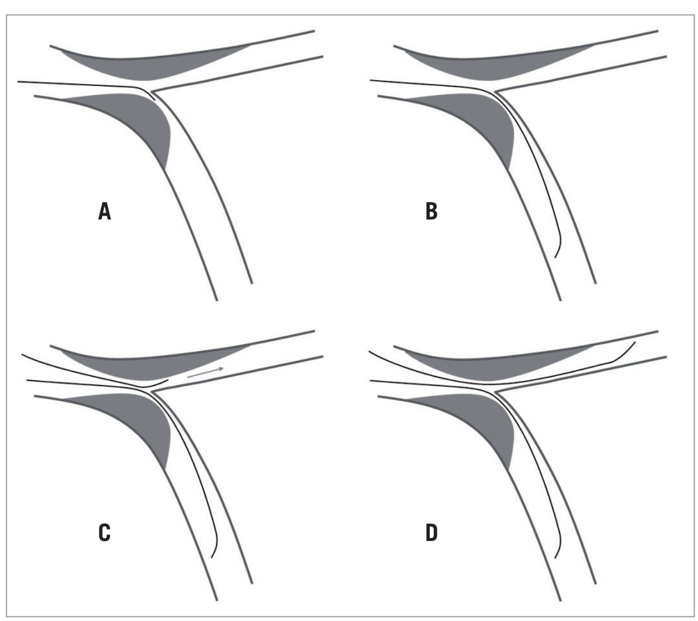

Figure 2. Standard wiring sequence for unselected bifurcated lesions. (A,B) The branch that is anticipated to be the most difficult is wired first. (C,D) The simpler branch is wired hereafter.

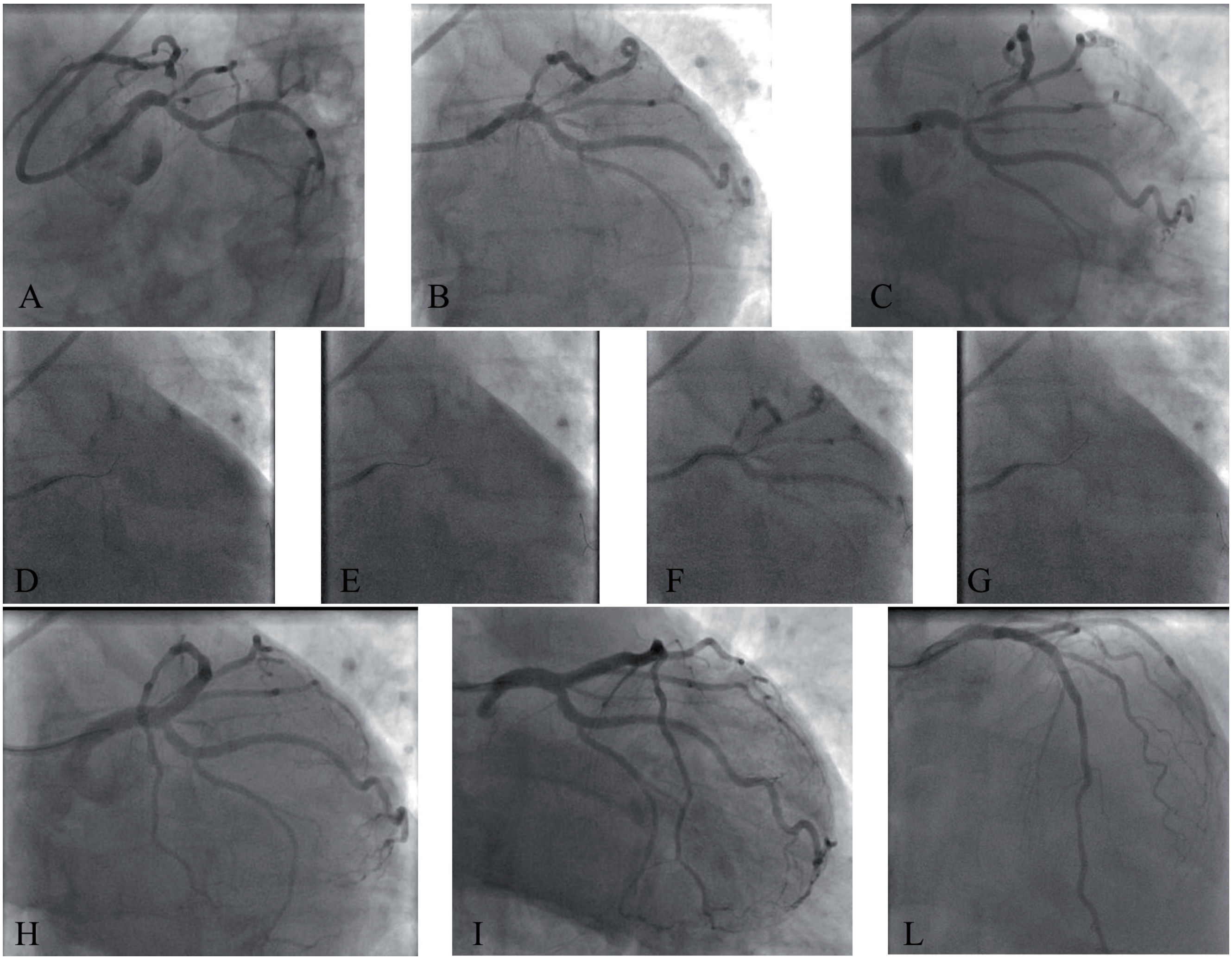

Figure 4. Example of antegrade wiring technique in a complex bifurcated lesion. (A-C) A distal left main moderate lesion followed by significant ostial disease of the left anterior descending artery which presents also a complex sub-occlusive lesion after the first diagonal in a curved segment. (D-G) Antegrade wiring is performed using a "workhorse" guidewire with an appropriately shaped (double bend) tip. (H-L) Final result after provisional approach with two stents on the left main-left anterior descending artery axis and kissing balloon inflation on the left main bifurcation.

catheter tip and then advanced in the SB over the strong support of the catheter. A series of reports supported the feasibility and usefulness of this technique for complex bifurcation interventions[23-26].

Many operators consider the use of MV balloon predilation as a "last resort" strategy to wire the SB. Indeed, this technique is basically not advisable in the vast majority of bifurcated lesions as it may cause plaque and carina shift finally resulting in SB occlusion. Nevertheless, it may be considered in highly selected cases when all other techniques have failed. The typical situation is represented by bifurcated lesions with large plaque burden in both the MV and the SB and a wide take-off angle. As this anatomy may prevent the advancement of any appropriately curved wires and devices at the bifurcation site, a gentle predilation of the proximal MV may create enough space in the MV for successful advancement of a bended wire toward the SB (Figure 9).

Finally, when the SB access is prevented by excessive atherosclerotic burden in the MV, some operators consider the use of debulking techniques, like rotational atherectomy or laser, to modify the plaque (Figure 9), although no randomised data regarding the role of debulking techniques in bifurcation interventions exist[27].

Continuous access to SB with unfavourable anatomy

Although SB stenting, using "S family" treatment of MADS classification[28], represents a reasonable way to manage complex bifurcations with difficult SB access, when a SB stenting strategy is not anticipated and a provisional approach is considered, there might be the need to maintain the access to a difficult SB during MV stenting. To this end, there are two specifically developed techniques: the "jailed balloon protection" technique[29] and the "highway technique"[30]. These techniques rely on the use of a SB balloon which is respectively jailed un-inflated under the MV stent struts or inflated during MV stenting. Both techniques, although highly technically demanding, warrant access to the SB after MV stenting and can be considered in the presence of relevant SB with difficult take off and at high risk of occlusion.

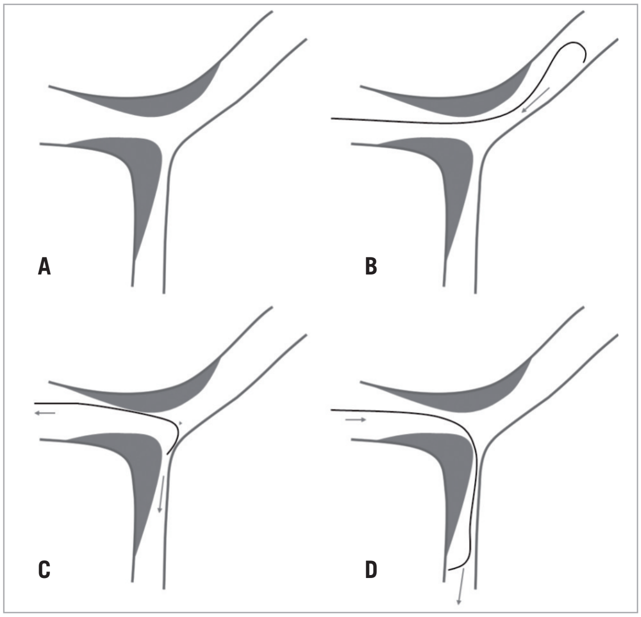

Figure 5. Complex side branch wiring: pullback wiring technique. (A) A Medina 1,1,1 bifurcation with an unfavourable 90° angle. (B) A guidewire that has been smoothly curved to shape a broad distal bend is advanced in the distal main vessel where it is pulled back toward the bifurcation. (C) Owing to the hook-like bend, the distal tip of the guidewire engages the side branch. (D) Gentle turning counter-clockwise advances the guidewire in the side branch.

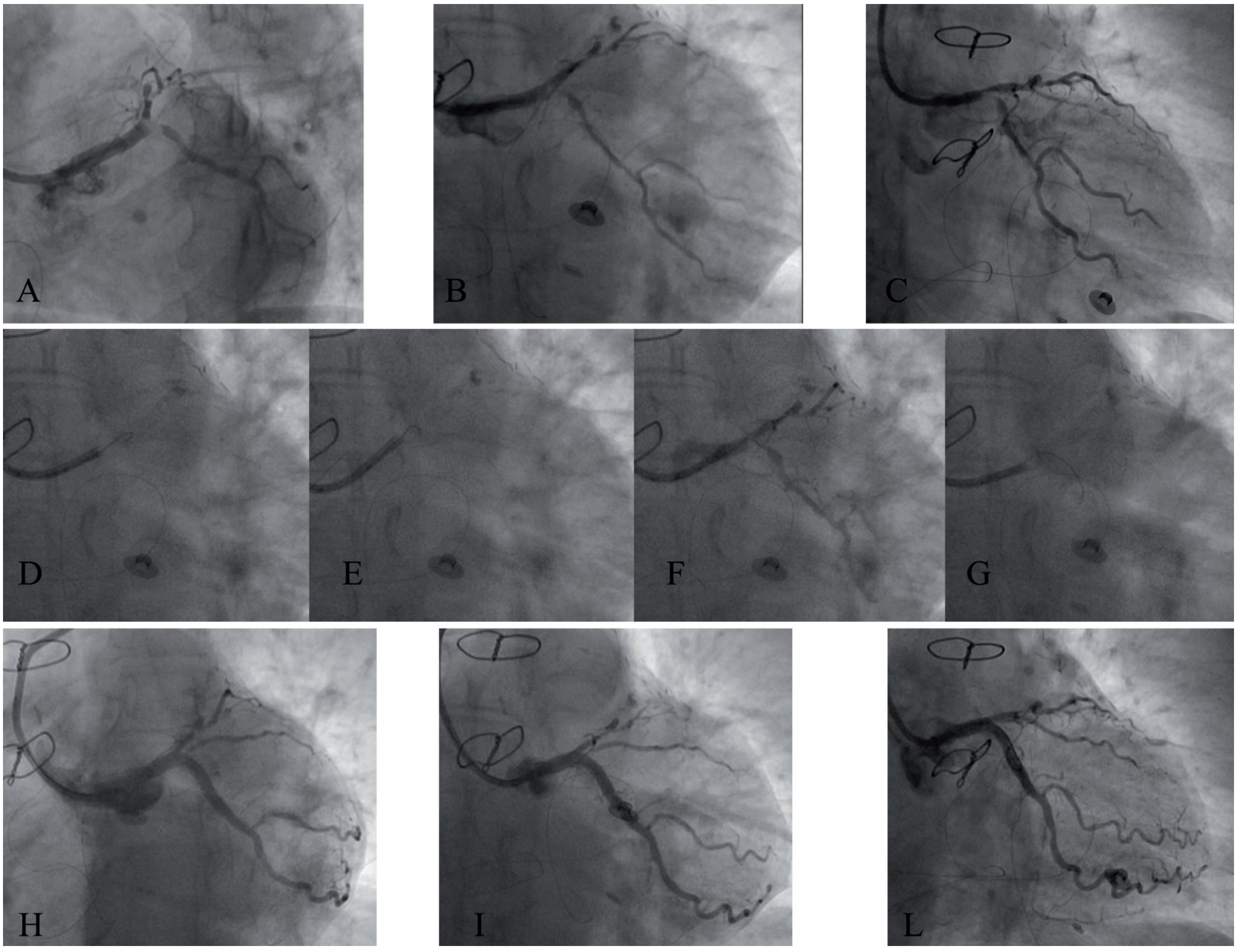

Figure 6. Example of pullback wiring technique in a complex bifurcated lesion. (A-C) A sub-occlusive, calcific, protected left main lesion-circumflex artery lesion. (D-G) Pullback wiring is performed using a plastic-coated hydrophilic guidewire mounted on an over-the-wire small balloon. (H-L) Final result implantation of two long stents on the left main-circumflex artery axis.

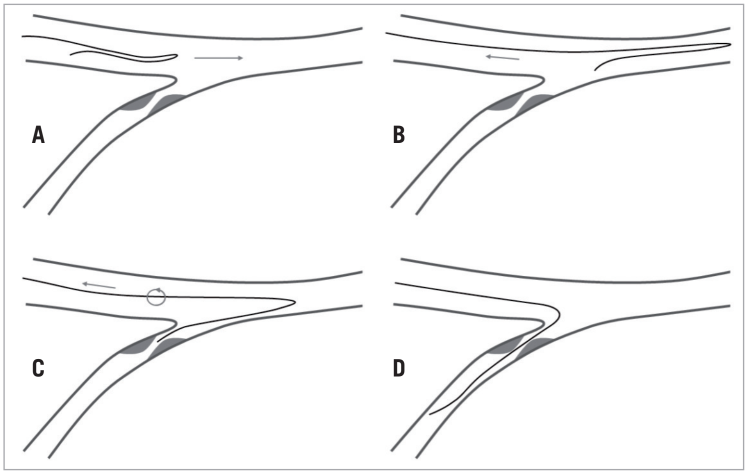

Figure 7. Complex side branch wiring: "reverse wire" technique. (A) Medina 0,0,1 bifurcation with extreme angulation (150°) of the side branch. (B) A guidewire with a hair-pin bend at about 5 cm from its distal tip is advanced in the main vessel. (C) When in the distal main vessel, the guidewire is pulled back toward the bifurcation. (D) Owing to the straight bend, the distal tip of the guidewire engages the side branch. (E) Gentle turning counter-clockwise advances the guidewire in the side branch.

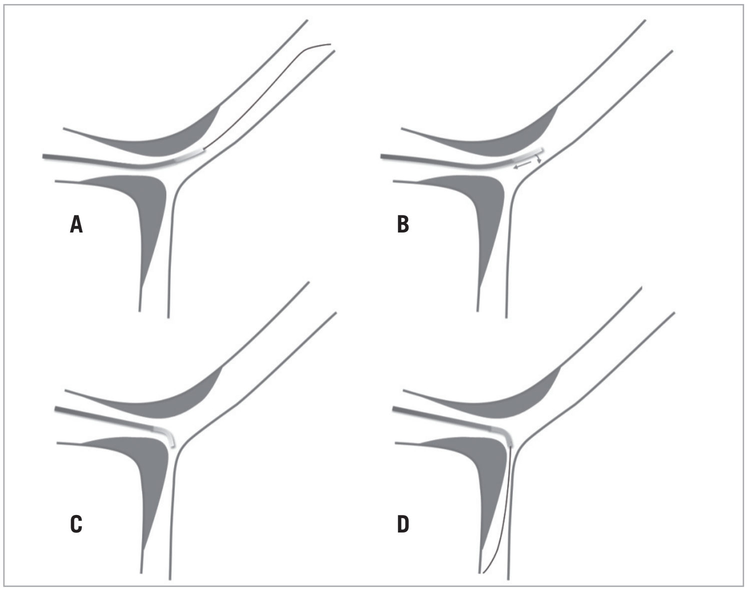

Figure 8. Complex side branch wiring: deflectable-tip guidewire system technique. (A) A Venture catheter (St. Jude Medical, St. Paul, MN, USA) is loaded onto a guidewire placed in the distal main vessel and tracked just distal to the side branch origin. (B) The guidewire is withdrawn from the main vessel into the deflectable catheter. (C) The catheter's tip is deflected toward the side branch. (D) The guidewire is easily advanced through the deflected catheter in the side branch.

Side branch re-wiring after main vessel stent implantation

Once a provisional approach has been adopted, it may be necessary to proceed with further interventions on the SB after MV stent implantation. The first step in any further intervention on the SB is rewiring, which may present variable technical complexity. Indeed, after MV stenting, a variety of situations (ranging from those in which a SB with favourable take-off is perfectly patent to those in which a SB with difficult take off has completely disappeared) exists. Each interventional cardiologist has his or her own favourite guidewire and tip configuration for MV stent side-cells crossing: as the success in SB rewiring is the key point of bifurcation interventions, it is not so important how each operator specifically acts.

However, in the recent years it has been recognised that SB rewiring site may influence the type of MV stent distortion after SB dilation, as crossing of the distal side cells of the MV stent is associated to better ostium scaffolding and reduced need of SB stenting[13,31]. Accordingly, regardless the selection of type and shape of guidewire, the operators should focus their attention, not only in getting into the SB through the stent, but also in doing this in the very distal part of the SB ostium. To do this, it is now commonly accepted that the best way is to wire the side branch by using a pullback rewiring technique (Figure 10). With this technique, it should be emphasised that, regardless of the guidewire's tip (i.e., single bend, double bend etc.), it is important to obtain a curve sufficiently wide to let the wire scratch the MV stent struts (curves 2-

4 of Figure 1) as this will warrant immediate protrusion of the wire into the SB as soon as it is reached by the pullback (Figure 10). Although the rewiring does not represent a problem in the majority of bifurcated lesions, there are some procedures that are highly technically demanding. The first reaction to difficulties in rewiring the SB is changing either the shape of the guidewire's tip or the guidewire in favour of stiffer or more hydrophilic ones. Regarding the wire tip, it should be underlined that longer tips and wide curves are often

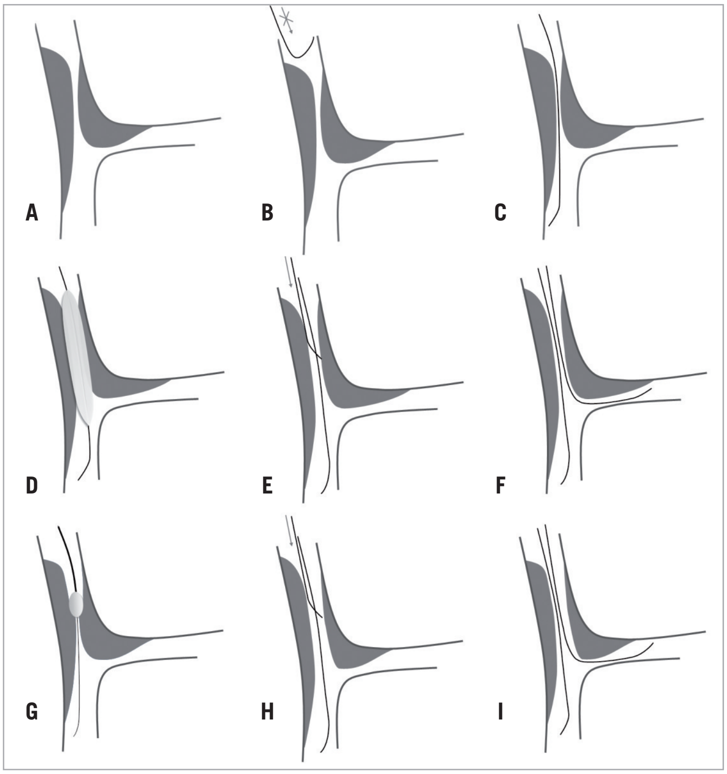

Figure 9. "Last resort" strategies for complex side branch wiring: main vessel balloon predilation and debulking. (A,B) A Medina 1,1,1 bifurcation with a plaque configuration preventing to track an appropriately curved guidewire toward the bifurcation. (C) The main vessel is wired alone. (D) A small diameter balloon is inflated in the main vessel with the aim to reshape the plaque creating space for curved wire advancement. (E,F) An appropriately curved guidewire can now be tracked to the bifurcation and accesses the side branch. (G) Alternatively, the guidewire in the main vessel is exchanged for a RotaWire which is loaded with a small burr. (H,I) Following debulking of the lesion, an appropriately curved guidewire can now be tracked to the bifurcation and access the side branch.

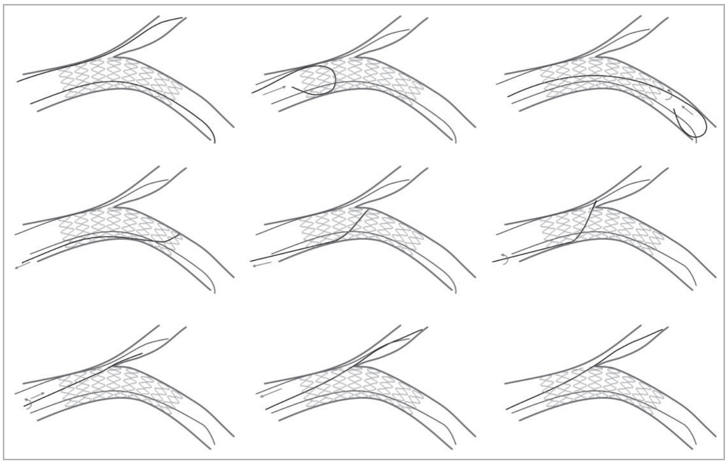

Figure 10. Pull back rewiring technique. (A) A successfully expanded stent in the main vessel has caused carina shift reducing the lumen of the side branch ostium that is protected by a jailed guidewire. (B) An appropriately shaped guidewire is advanced in the expanded stent with its curved part at first, to avoid passage between stent strut and vessel wall. (C) When distal to the stent, the guidewire is pulled-back to resolve the broad bend in favour of the shape that has been manually made according to the main vessel diameter and side branch angulation. (D,E) To increase the chance of crossing through the distal cell, pullback rewiring is performed with the tip of the guidewire rasping on the stent struts. (F) When the tip of the guidewire reaches the first side-cell covering the side branch ostium, it engages the side branch and careful steering allows crossing into the side branch. (G) Gentle torque maneuver helps to advance the guidewire progressively. (H,I) When the guidewire is in place in the side branch, the jailed wire is removed.

required in the case of occluded SB. Conversely, regarding the selection of guidewires different from the "workhorse" ones, no data are available in favour of higher stiffness versus higher lubricity. Overall, the use of hydrophilic plastic coated wires may shorten the times and facilitate recrossing, but may enhance the risk of subintimal navigation in the SB (especially if SB wall has previously been injured by balloon dilation), while stiff wires may enhance precision in torque control at the expense of a more difficult manipulation.

A common pitfall associated with rewiring failure relies on the possible presence of under-expanded stents in the MV preventing the wire to reach the (compromised) SB ostium. Accordingly, proximal MV stent post-dilation with the "POT" technique is highly advisable in any case of rewiring troubles. Issues in favour of POT to facilitate rewiring come from bench tests showing protrusion of the MV stent struts into the SB ostium space[28] (Darremont, oral communication at EBC 2009 meeting) and from computer simulations showing stent side cells shape modification with increasing balloon size[32].

Sometimes the difficulty in rewiring is caused by a prohibitive angulation of SB take-off, or by the presence of proximal vessel tortuosities. In such circumstances, the use of Venture catheter and microcatheters (Figure 11), respectively, may be considered[23-26]. Finally, in case of flow compromise of an important SB, and failure after multiple rewiring attempts, a "rescue" jailed balloon technique can be applied by using the wire jailed in the SB for the advancement of a small balloon at the SB ostium under the MV stent (Lefevre, oral communication at EBC 2009 meeting)[33]. Indeed, once the balloon has successfully entered the SB ostium under the MV stent struts, it may be inflated to reopen the SB. The re-establishment of SB flow may facilitate rewiring before correcting the MV stent distortion by re-dilation of the proximal MV stent struts and eventual final kissing balloon inflation.

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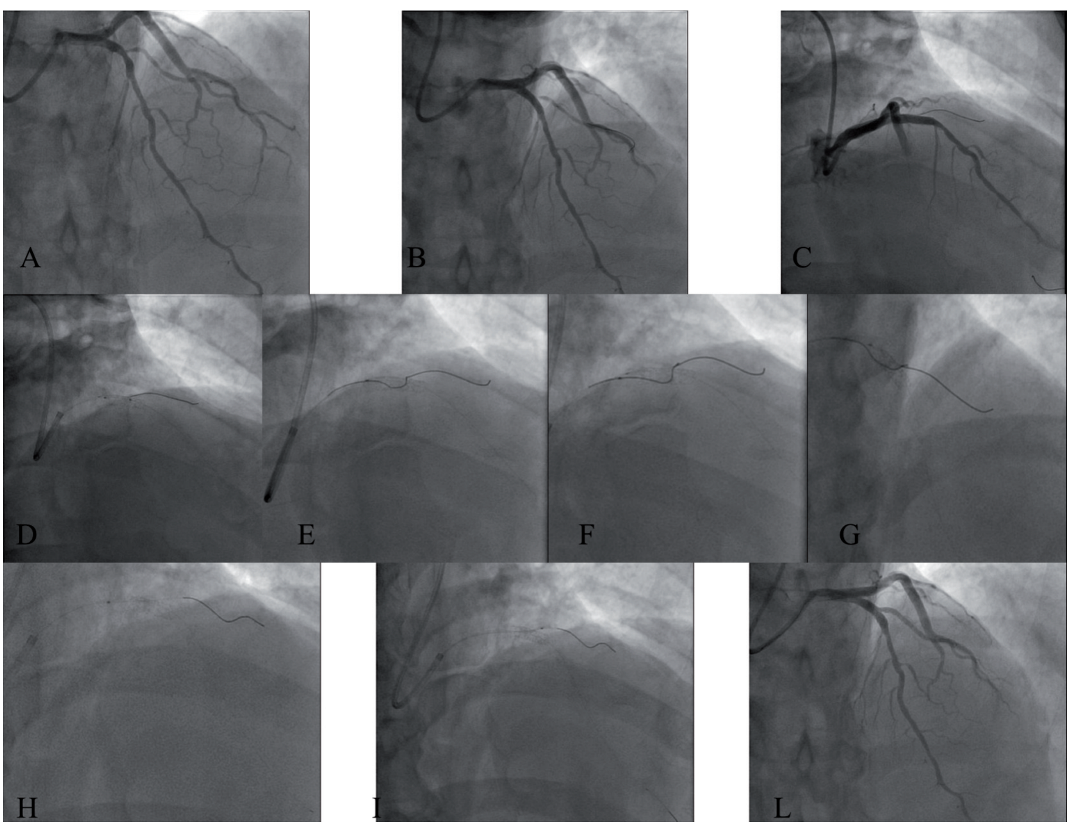

Figure 11. Example of rewiring in a case of occluded side branch after main vessel stenting. (A) A left anterior bifurcated lesion with severely diseased first diagonal ostium is approached according to the provisional technique. (B) After main vessel stenting the side branch is sub-occluded with TIMI 2 flow. (C) After repeated unsuccessful attempts to rewire, the side branch get occluded. (D) The proximal part of the main vessel is dilated avoiding to reach the bifurcation carina using the jailed wire as side branch location marker. (E,F,G) After several unsuccessful attempts, rewiring is performed using an the over-the-wire small balloon as microcatheter to advance safely a double bended stiff wire. (H,I) After removal of the jailed wire, the over-the-wire balloon is used to dilate the side branch. (L) Final result after side branch stenting and final kissing balloon inflation.

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