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EUROPEAN BIFURCATION CLUB WHITE PAPER ON STENTING TECHNIQUES FOR PATIENTS WITH BIFURCATED CORONARY ARTERY LESIONS

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This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/ccd.29071

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Disclosures:
Burzotta disclosed to have received speaker fees from Medtronic, Abiomed, Abbott.
Lassen disclosed to have received speaker fees from Medtronic, Boston scientific, Biotronik, Abbott and Biosensors.
Banning disclosed to have institutional funding of a fellowship form Boston Scientific and Speaker fees Boston, Abbott, Medtronic, Phillips/Volcano and Miracor.
Hildick-Smith disclosed to have received Ad Board/Consultancy/Research Funding from Terumo, Medtronic, Abbott, Boston.
Pan disclosed to have received speaker fees from Abbott, Terumo and Volcano. Chieffo disclosed to have received speaker fees from Abiomed and GADA.

Chatzizisis disclosed to have received speaker fees, consultation fees and research grant from Boston Scientific, and research support from Medtronic.

Murasato disclosed to have received speaker fees from Abbott, Terumo, Medtronic, Kaneka and Orbus Neich.

Serruys disclosed to have received personal fees from Abbott Laboraotories, AstraZeneca, Biotronik, Cardialysis, GLG Research, Medtronic, Sino Medical Sciences Technology, Société Europa Digital Publishing, Stentys France, Svelte Medical Systems, Philips/ Volcano, St Jude Medical, Qualimed, Xeltis

All other authors reported to have no conflict of interest to disclose.

Running title: bifurcation stenting techniques EBC white paper

Word Count: 4848 (including references)

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ABSTRACT

Background

Defining the optimal conduction of percutaneous-coronary-intervention (PCI) to treat bifurcation lesions has been the subject of many clinical studies showing that the applied stenting technique may influence clinical outcome. Accordingly, bifurcation stenting, classification and technical sequences should be standardized to allow proper reporting and comparison.

Methods

The European Bifurcation Club (EBC) is a multidisciplinary group dedicated to optimize the treatment of bifurcations and unprotected left main and previously created a classification of bifurcation stenting techniques that is based on the first stent implantation site. Since some techniques have been abandoned, other have been refined and dedicated devices became available, EBC promoted an international task force aimed at updating the classification of bifurcation stenting techniques as well as at highlighting the best practices for most popular techniques.

Original descriptive images obtained by drawings, bench tests and micro-computed-tomographic reconstructions have been created in order to serve as tutorials in both procedure reporting and clinical practice.

Results

An updated Main-Across-Distal-Side (MADS)-2, classification of bifurcation stenting techniques has been realized and is reported in the present paper allowing standardized procedure reporting in both clinical practice and scientific studies.

The EBC-promoted task force deeply discussed, agreed on and described (using original drawings and bench tests) the optimal steps for the following major bifurcation stenting techniques:

- 1-stent techniques ("provisional" and "inverted provisional");

- 2-stent techniques ("T / TAP", "culotte" and "DK-crush")

Conclusions

The present EBC-promoted paper is intended to facilitate technique selection, reporting and performance for PCI on bifurcated lesions during daily clinical practice.

KEY WORDS: Bifurcation lesions, stenting technique, PCI, DES, personalized medicine.

CONDENSED ABSTRACT

The applied stenting technique influences the clinical outcome for patients undergoing percutaneous coronary intervention on bifurcation lesions. Various procedural steps during treatment of a bifurcation lesion determine the final stent conformation. Accordingly, bifurcation stenting, classification and technical sequences should be standardized to allow comparison. The international European Bifurcation Club (EBC)-promoted task force present the MADS-2 classification and the optimal technical sequences for the 1-stent and 2-stent bifurcation stenting.

ABBREVIATION LIST

DES= drug-eluting stent

DK= double kissing

EBC= European Bifurcation Club

MADS= Main-Across-Distal-Side

MV= main vessel

PCI= percutaneous coronary interventions

SB= side-branch

TAP= T and protrusion

INTRODUCTION

Initiated in 2004, the European Bifurcation Club (EBC) has focused on improving bifurcation PCI practice by organizing annual meetings and promoting general consensus statements (1-9) and consensus documents dedicated to specific bifurcation-related topics (10-17). One of the most important concept arose from EBC events was the recognition that the final conformation of stent struts into a bifurcated coronary lesion is strongly influenced by different factors including stent characteristics (18), technique selection and procedural steps. Accordingly, technical standardization represents a major clinical need. This recognition resulted in an EBC-promoted task force of international experts who collaborated on this document.

BIFURCATION STENTING TECHNIQUES CLASSIFICATION: MADS-2

The list of proposed, applied or simply theorized techniques to implant tubular stents in bifurcated coronary lesions is continuously expanding. In 2008, the EBC organized a dedicated international task force led by Yves Louvard (with Ran Kornowski's significant contribution) that conceived a classification based on the position of the first stent and was called "MADS" (main vessel or across side branch or double lumen in proximal main vessel or side branch) (10). The efficacy of this classification for reporting technique during procedures has recently been confirmed by the large (more than 15,000 patients) GLOBAL LEADERS trial (19). During the past decade some techniques have been abandoned or proven not effective, others have been refined. Thus, the original classification has been updated to generate the MADS-2 technique classification reported in Figure 1. Among the novelties, three types of balloon dilation techniques have been inserted in the MADS-2 using the following single letter ballooning technique code:

1. P: post-dilation of the proximal main vessel (usually reported as proximal optimization technique, POT)
2. S: balloon dilation of the SB ostium
3. K: balloon inflation in the MV and SB (usually reported as kissing balloon inflation technique).

Combinations of the ballooning techniques can be easily highlighted by appropriately ordered ballooning letter sequences. As an example, “PKP” stands for POT, followed by kissing, followed by new POT.

Finally, MADS-2 classification is flexible enough to host bifurcation-dedicated devices. This may facilitate the understanding of the technical sequence that is “facilitated” by each specific future or contemporary device. As an example, the Tryton stent (a bare metal bifurcation device which was tested in a large prospective randomized trial (20)) is depicted in MADS-2 as a device aimed at facilitating an “inverted culotte” (Figure 1).

FROM TECHNIQUES CLASSIFICATION COMPREHESIVENESS TO IDEAL TECHNICAL SEQUENCES FOR MAJOR TECHNIQUES

A 1-stent technique, also called “the provisional approach (the implantation of one drug-eluting stent in the MV with additional balloon dilation /stent implantation within the SB only in the case of need) is recognized as the gold standard approach for the majority of bifurcation lesions (9, 21). Yet, the use of 2-stent implantation techniques is advised to treat in selected patients with complex bifurcated lesions with relevant and significantly diseased SB (9,21).

The EBC consider that:

- when using a 1-stent technique, some specific procedural steps may reduce SB complications and need for second stent implantation
- when using a 2-stent techniques, the performance of final kissing balloon inflation may reduce target lesion complications and that its performance is probably more important than the specific technique adopted to implant the stents.

Some technical sequences may increase efficacy of stenting techniques. These steps are reported in the present paper for the major 1-stent and 2-stent techniques. To facilitate interpretation, dedicated bench tests have been performed collecting both fluoroscopy images and micro-CT. Bench tests have been performed according to EBC recommendations (14) in a catheterization laboratory equipped by Allura X-ray imaging technology (Philips Healthcare, Best, The Netherlands). Silicone phantoms were constructed with angles between the MV and SB of 60° and sizes mimicking a possible left main bifurcation (proximal MV diameter of 5 mm, distal MV diameter of 3.5 mm, and the SB diameter of 3.0). The stents implanted were Resolute Onyx (Medtronic, Santa Rosa, California). The balloons used were Euphora (Medtronic, Santa Rosa, California) semi-compliant or non-compliant in the different needed sizes and Trek 5x12 mm (Abbott, Abbott Vascular, Redwood City, CA, USA) for proximal MV. Following deployment, the stents were imaged using micro-computed tomography (CT). The micro-CT images obtained were manipulated electronically to color the stent struts (black and blue color code for the two stents in double stenting techniques to facilitate interpretation).

ONE-STENT TECHNIQUES ("PROVISIONAL" AND "INVERTED PROVISIONAL")

STEP-BY-STEP

One-stent techniques may be applied to many bifurcation anatomies (Table 1) and represent the gold standard for the vast majority of non-complex bifurcated lesions. Of note, 1-stent technique may be practiced according to "provisional" (more commonly adopted) and "inverted provisional" (selected cases).

The recommended steps for "provisional" (Figure 2) are:

- stent implantation across the side-branch (also called "crossover stenting") following these rules: DES diameter selected 1:1 according to the distal MV size, DES length selected (even in the absence of relevant disease) allowing for proximal MV coverage of a segment equal or longer than the shortest available balloon (usually 8 mm).
- systematic post-dilation of the stent at the level of proximal MV up to the carina level with a balloon diameter sized 1:1 according to the proximal MV (POT technique). Although either semi-compliant and non-compliant balloons can be selected, non-compliant balloon is favored in the presence of stent under-expansion and ascertained proximal MV reference size. Semi-compliant balloons have been found to be able to appropriately displace the stent struts to obtain vessel wall apposition in the absence of disease. Of note, meticulous attention should be paid to POT balloon position since when its distal shoulder is positioned accurately at the carina better results are expected (22).

These initial two steps are regarded as mandatory, whereas the possible adoption of further steps is a matter of discussion. When an important SB is jeopardized after MV stenting, further intervention

has to be performed and the kissing balloon technique is the usual initial approach. Recently the alternative to perform SB dilation and then repeated POT has been described (23) but confirmatory clinical validation is awaited (9).

When SB intervention is required during a provisional approach to a bifurcation, the following steps are advised (figure 2):

- The aim of crossing the "distal" stent struts (9) close to bifurcation carina (maneuver usually called "distal re-wiring"). A pullback rewiring technique with appropriately bended guidewire tip shape (24) may facilitate this "distal re-wiring"
- Perform kissing balloon inflation using short balloons and MV balloon sized 1:1 according to the distal MV diameter. According to bench test data, minimal balloon overlap in the proximal MV (25), with sequential balloon inflation (alternate inflation of MV and SB balloon followed by simultaneous inflation/deflation) using non-compliant balloons (26) is advisable in order to minimize stent distortion and SB dissection risk
- Perform post-dilation of the stent at the level of proximal MV up to the carina level with a balloon diameter sized 1:1 according to the proximal MV (repeat POT or re-POT).

In selected anatomic conditions, the provisional 1-stent technique may be practiced according to the "inverted provisional" approach (Table 1). This specific sequence is summarized in Figure 2 (panel B). Notably, the selection of inverted provisional approach might require implantation of a different stent platform compared to the standard provisional technique. This selection of a smaller stent with different structure may result in a different proximal MV metallic coverage achieved by provisional and inverted provisional in the same bifurcation (Figure 3).

T / TAP STENTING STEP-BY-STEP

The potential to implant a second stent during a provisional approach to a bifurcation (or inverted provisional) is one of the major assets of this approach. T and TAP stenting represent the easiest way to implant the second stent.

Initially, all the steps of the provisional technique including distal rewiring and kissing should be performed. Then if the bifurcation angle is very close to 90°, placement of the second stent in a T configuration is possible and this allows stent strut coverage of the bifurcation without the need of floating or overlapping stent struts (27). Obviously, achieving the optimal angiographic view (eventually facilitated by stent enhancement tools) is critical for successful T stenting. However extensive clinical experience, supported by bench test data, has documented the important pitfalls in T stenting. Commonly the angle is not 90° and this results in incomplete SB ostium scaffolding as the stent is either too distal or there is protrusion inside the proximal MV if the SB stent is placed too proximally. A suboptimal result at the SB ostium may lead to restenosis and/or jeopardize access to distal MV if there are protruding struts.

Recognition of these limitations of T stenting resulted in the evolution of the TAP technique (28). The TAP technique creates a metallic neocarina in the center of bifurcation but aims to ensure the systematic and complete stent coverage of the SB ostium. During the performance of TAP, operators should systematically aim to create the shortest neocarina that is possible, while still achieving full coverage of the side-branch ostium.

To systematically perform effective T/TAP, all the initial steps for provisional up to kissing inflation are needed (since they allow for good SB ostium opening and scaffolding). Then, after having found the best view to assess the SB ostium, the recommended steps are:

- advancement of a DES of the appropriate length and size into the SB.
- placement of a balloon into the MV (sized 1:1 according to the distal MV diameter -this will be used for final kissing balloon).
- after having carefully selected the best position of the SB stent to fully cover the proximal (or "upper") part of the SB ostium (and minimizing protrusion inside the MV), the stent is inflated while the MV balloon is kept un-inflated into the MV.
- after SB stent deployment, the balloon of the stent is slightly pulled back and repeated inflation at high pressure is performed in order to warrant optimal stent expansion at the level of SB ostium (the balloon inside the MV is still kept uninflated during this phase)
- after alignment of the MV balloon and SB stent's delivery balloon, kissing balloon inflation is performed by inflating simultaneously these two balloons. Some bench tests suggest "sequential" high pressure inflation with non-compliant balloons can be considered as an option but kissing balloon should follow and the kissing balloon deflation should be simultaneous (to keep the neocarina in a central position).
- a repeat final POT is considered when there is a long segment of stent in the MV and long overlaps between the balloons during kissing have occurred (this can result in an oval MV result). However with TAP, meticulous attention must be paid during POT balloon placement to ensure it is proximal to the neocarina, as the metallic neocarina can be easily displaced

causing the removal from its central position achieved during the kissing balloon inflation (29).

Figure 4 illustrates the recommended steps for TAP. The T and TAP can be considered as a continuum and Figure 5 shows (by micro-CT) the different final appearance of neocarina achieved in two different tests by following the same recommended sequence with the same DES. Despite a different neocarina length, optimal ostium scaffolding and stent expansion has been achieved in both cases. Consequently, if during an intended T stent the operator feels doubtful about the efficacy of distal recrossing and/or the perfection of SB stent positioning, switching to a TAP is recommended as this will facilitate procedure completion (i.e. kissing balloon inflation after SB stenting).

CULOTTE STENTING STEP-BY-STEP

The culotte technique was first reported by Chevalier et al. (30) as a technique to compliment the provisional approach when a second (usually SB) stent is required (table 1). In contemporary clinical practice, this "classic" culotte is practiced by implanting the first stent into the distal MV. When the first stent is placed in the SB this is considered to be an "inverted" culotte technique but the sequencing of the technique is the same thereafter.

The recommended steps for classic culotte are:

- after appropriate predilation of both branches, stent implantation across the SB into the distal MV. The stent is sized according to the diameter of the distal MB and usually long enough to allow POT in the MB proximal to the bifurcation.

- POT dilation with post-dilation of the stent at the level of proximal MV up to the carina level with a balloon diameter sized 1:1 according to the proximal MV (POT technique).
- distal rewiring of the jailed SB using the pullback technique.
- single balloon dilation of jailed branch although kissing inflation can be considered if there is uncertainty that a second stent is mandated
- second stent implantation to cover the branch "jailed" during first stent implantation. DES diameter selected 1:1 according to the distal branch size, DES length selected to ensure sufficient proximal MV coverage of a segment equal or longer than the shorter available balloon (usually 8 mm).
- systematic post-dilation of the stent at the level of proximal MV up to the carina level with a balloon diameter sized 1:1 according to the proximal MV (repeat POT).
- distal rewiring of the jailed branch according to the pullback technique
- sequential inflation at high pressure is advisable using short non-compliant balloons with MV balloon sized 1:1 according to the distal MV diameter then kissing balloon inflation.
- post-dilation of the stent at the level of proximal MV up to the carina level with a balloon diameter sized 1:1 according to the proximal MV (final POT).

The EBC strongly recommends systematic POT immediately after each stent deployment in order to avoid the presence of malapposed struts in the proximal MV that may cause abluminal rewiring. Figure 6 (panel A) reports the graphic demonstration of a possible sequence of technical steps to perform culotte when double stenting is planned and the first branch considered suitable for the first stent is the SB ("inverted culotte"). Figure 6 (panels B and C) shows (by micro-CT) the final appearance of culotte stenting.

The main limitation of the culotte technique is the reality that both stents (needed to cover the two bifurcation branches: distal MV and SB) also have to cover the proximal MV. Consequently care is required to ensure that expansion of the chosen DES is possible to the MV diameter. Accordingly, culotte may not be the optimal technique for bifurcation lesions with very different sized distal branches (table 1).

DK-CRUSH STENTING STEP-BY-STEP

The initial crush technique was reported by Colombo in 2003 (31). Subsequently, clinical experience recognized a lack of predictability in wire/balloon recrossing after deployment of the second stent and performance of final kissing was identified as a main modulator for crush technique safety (32). Thus, several modifications were proposed (33) and Chen and colleagues developed the DK-crush (34). A series of landmark trials has documented the efficacy of this technique, including a IIb recommendation in the European clinical guidelines for revascularization (21). EBC recognizes the importance of the DK-crush but highlights the potential complexity of the technique. Accordingly, careful lesion selection (Table 1) and appropriate training is advocated for interventional cardiologists willing to adopt this technique.

The recommended steps for "DK-crush" are:

- optimal balloon pre-dilation of both branches, then advancement in the SB of a DES (appropriate length to cover SB disease and sized 1:1 according to the SB). The stent should protrude into the MV but this should not be more then 2-3 mm.

- placement of a balloon into the distal MV (sized according to the proximal MV) which will be used for crushing, comparable to the POT technique.
- the stent is inflated whilst the MV balloon is kept uninflated in the MV.
- after SB stent deployment, the balloon of the stent might be slightly pulled back and repeated inflation at high pressure can be performed (the balloon inside the MV is still kept uninflated during this phase). This step ("SB optimization" by Dr Francesco Lavarra, oral communication at EBC meeting 2018) is aimed at achieving the best stent apposition and expansion at the SB ostium).
- the SB stent delivery balloon and the SB guidewire are removed
- the MV balloon is positioned at the level of the SB take-off and high pressure inflation is performed in order to crush the stent struts protruding inside the MV ("balloon-crushing"). The balloon size should be adjusted according to amount of atherosclerosis and MV size but bench tests show this POT technique is needed to achieve complete stent crushing.
- the SB is rewired using a guidewire with an appropriately shaped tip aiming at crossing the SB ostium through a *non-distal* cell (35). This is noteably different to culotte and TAP techniques and it allows optimal scaffolding. Any unintended distal tracking behind the stent of the wire at the ostium of the SB should be carefully excluded as it may result in stent strut removal from the vessel wall (36).
- two balloons are advanced in the SB (diameter size 1:1 according to SB) and the MV (diameter size 1:1 according to distal MV) and kissing balloon inflation is performed according to sequential technique (alternating isolated high pressure inflations of each followed by final simultaneous kissing inflation and deflation).

- balloons and SB guidewire are removed
- a stent is advanced and inflated in the MV across SB (size 1:1 with distal MV diameter) covering up all proximal MV segment that is intended to be treated
- The SB is rewired using a guidewire with an appropriately bent tip aiming to cross the SB ostium through a *non-distal* cell. Once again the rewiring should carefully checked to prevent stent strut removal from the SB ostium (36).
- simultaneous kissing balloon inflation with two balloons (MV balloon sized 1:1 to distal MV; SB balloon sized 1:1 to SB diameter) according to sequential technique (alternating isolated high-pressure inflations of each followed by final simultaneous kissing inflation and deflation) (37).
- post-dilation of the stent at the level of proximal MV up to the carina level with a balloon diameter sized 1:1 according to the proximal MV (final POT) is performed.

Figure 7 (panel A) reports the graphic demonstration of an ideal sequence of technical steps to perform DK-crush. Figure 7 (panels B and C) shows (by micro-CT) the final appearance of DK-crush stenting.

CONCLUSIONS

In the present paper, the EBC-promoted expert task force provides an update of a comprehensive bifurcation stenting techniques classification and a detailed description of recommended sequences for both 1-stent and 2-stent techniques. The present expert consensus may facilitate technique

reporting in future studies and provides practical tools for the selection and performance of PCI on bifurcated lesions during the daily clinical practice.

ACKNOWLEDGEMENTS

The authors wish to thank the physicians who attended the bifurcation techniques meeting held in Brussels on 12th October 2018 for their invaluable help.

The bench tests have been done with the help of an independent senior interventional cardiologist (Dr. Cristina Aurigemma) using materials donated by Medtronic. Of note, Medtronic did not influence in any way the selection of materials nor the sequences of technical steps performed. In particular, the authors wish to thank Mr. Chuck W. O'Neil for his attitude in facilitating the collection and processing of bench test materials.

The drawings of the different steps for the described techniques have been personally realized by an independent senior interventional cardiologist (Dr. Osama Shoeib).

MAIN MESSAGES OF THE PAPER

- Percutaneous treatment of bifurcated lesions is based on the implantation of tubular drug-eluting stents using various techniques. Technique selection (and the different technical steps selected to practice them) are known to determine the final configuration of the implanted stent(s) and have the potential to influence the clinical outcome (restenosis and stent thrombosis).
- An original, updated, comprehensive bifurcation stenting techniques classification is provided in order to standardize technique description and reporting.
- Since some techniques are more commonly adopted, the recommended sequences for major 1-stent and 2-stent techniques are described and graphically reported to facilitate clinical practice.

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FIGURE LEGENDS

FIGURE 1. MADS-2 CLASSIFICATION OF BIFURCATION STENTING TECHNIQUES.

The figure comprises two panels. Upper panel shows the standard techniques while the lower panel shows the “inverted” techniques. Blue capital letters describe ballooning techniques (see text for explanation). Common combinations of ballooning techniques are described as the sequential blue capital letters.

FIGURE 2. RECOMMENDED STEPS FOR PROVISIONAL AND INVERTED TECHNIQUE

PANEL A: PROVISIONAL

1: MV stenting across SB take-off with DES sized 1:1 according to distal MV diameter

2: POT with balloon sized 1:1 to proximal MV. Note that, due to long stented area in the proximal MV, two inflations were needed to appropriately post-dilate the entire proximal MV stent segment.

3: distal SB rewiring according to the pullback technique. Note the double bended guidewire tip shape that allows entering easily the SB ostium.

4. simultaneous kissing balloon inflation with MV balloon sized 1:1 according to distal MV and SB balloon sized 1:1 according to SB diameter.

5. repeat POT with balloon sized 1:1 to proximal MV

PANEL B: INVERTED PROVISIONAL

1: stent implantation from proximal MV into the SB across distal MV with DES sized 1:1 according to SB

2: POT with balloon sized 1:1 to proximal MV (Euphora 5x12 mm at 14 atm). Note that, due to long stented area in the proximal MV, two inflations were needed to appropriately post-dilate the whole proximal MV.

3: distal SB rewiring according to the pullback technique. Note the double bended guidewire tip shape that allows entering easily the SB ostium.

4. simultaneous kissing balloon inflation with with MV balloon sized 1:1 according to distal MV and SB balloon sized 1:1 according to SB diameter.

5. repeat POT with balloon sized 1:1 to proximal MV

FIGURE 3. MICRO-CT IMAGE OF STENT DEFORMATION OBTAINED BY PROVISIONAL AND INVERTED PROVISIONAL IN THE SAME BIFURCATION MODEL

PANEL A AND B: result after provisional using a 3.5 mm DES (this micro-CT has been obtained in the bench test reported in figure 2)

PANEL C AND D: result after inverted provisional using a 3.0 DES (this micro-CT has been obtained in the bench test reported in figure 3).

FIGURE 4. RECOMMENDED STEPS FOR T/TAP STENTING TECHNIQUE

1: The recommended steps of provisional have been followed up to kissing balloon inflation.

2. SB stent and MV balloon positioning: an appropriately sized SB stent is placed in the SB and a balloon sized 1:1 according to the distal MV is advanced in the distal MV.

3. SB stenting: when the best position (to allow cover the SB ostium and minimally protruding inside the MV) for SB stent has been selected, the SB stent is delivered with the MV balloon left uninflated.

4. SB ostium post-dilation and kissing balloon inflation: after SB stent deployment, the balloon of the stent is slightly pulled back and repeated inflation at high pressure is performed in order to warrant optimal stent expansion at the level of SB ostium (the balloon inside the MV is still kept uninflated during this phase). Then, after alignment of the MV balloon and SB stent's balloon, kissing balloon inflation is performed by inflating simultaneously the two balloons.

5. repeat POT. This step is not mandatory. If this step is adopted, the POT balloon is inflated in the proximal MV in a position that is far from the metallic neocarina.

FIGURE 5. MICRO-CT IMAGE OF T/TAP STENTING WITH DIFFERENT NEOCARINA LENGTH

PANEL A AND B: T/TAP stenting sequence applied successfully and resulting in full bifurcation coverage and appreciable neocarina (this micro-CT has been obtained in the bench test reported in figure 5)

PANEL C AND D: T/TAP stenting sequence applied successfully and resulting in full bifurcation coverage and virtual absence of neocarina (true T configuration)

FIGURE 6. CULOTTE STENTING

PANEL A: RECOMMENDED STEPS FOR CULOTTE STENTING (IN THE CASE OF ELECTIVE DOUBLE STENTING)

1: stent implantation from proximal MV into the SB across distal MV with DES sized 1:1 according to SB. When culotte is used for elective double stenting, usually a short proximal MV coverage may be selected in order to limit the area with overlapping stents.

2: POT with balloon sized 1:1 to proximal MV.

3: distal MV rewiring and dilation. Distal MV rewiring is performed according to the pullback technique. Distal MV dilation may be performed either using kissing balloon inflation (see inverted provisional) or by simple balloon dilation with balloon selected 1:1 according to distal MV size.

4: MV stenting followed by repeat POT: after SB guidewire removal, stent implantation across the side-branch with DES diameter selected 1:1 according to the distal MV size is performed. Thereafter, repeat POT with semi-compliant balloon sized 1:1 to proximal MV is done.

5: Distal SB rewiring and kissing: distal SB rewiring is performed according to the pullback technique. Simultaneous kissing balloon inflation (usually with non-compliant balloons at high pressure) is performed selecting MV balloon sized 1:1 according to distal MV and SB balloon sized 1:1 according to SB diameter.

5. final POT: performed with balloon sized 1:1 to proximal MV.

PANEL B AND C. MICRO-CT IMAGE OF STENT CONFORMATION OBTAINED BY CULOTTE

FIGURE 7. DK-CRUSH

PANEL A: RECOMMENDED STEPS FOR DK-CRUSH

1: SB stenting. While the MV balloon is kept un-inflated into the MV, the stent sized 1:1 according to SB is implanted in the SB protruding inside the proximal MV for 2-3 mm. After SB stent deployment, the balloon of the stent might be slightly pulled back and repeated inflation at high pressure can be performed (the balloon inside the MV is still kept uninflated during this phase).

2: Balloon crush. After removal of SB stent's balloon and the SB guidewire, the protruding struts of the SB are crushed by an appropriately sized balloon. Of note, the ideal balloon size to warrant optimal crushing is a balloon sized 1:1 to proximal MV. During the clinical practice, smaller balloons are often selected but this is theoretically associated with risk of incomplete stent crush resulting in floating struts in the MV.

3: Non-distal SB rewiring and first kissing. The SB is rewired using a guidewire with an appropriately bended tip aiming at crossing the SB ostium through a non-distal cell. The absence of unintended distal tracking at the ostium level should be carefully checked before further steps are done. Two non-compliant balloon (eventually after undersized balloon SB dilation) are advanced in the SB (diameter size 1:1 according to SB) and in the MV (diameter size 1:1 according to distal MV) and kissing balloon inflation is performed according to a sequential technique (alternating isolated high pressure inflations of each followed by final simultaneous kissing).

4: MV stenting followed by repeat POT: after SB guidewire removal, stent implantation across the SB take-off with DES diameter selected 1:1 according to the distal MV size is performed. Thereafter, repeat POT with compliant balloon sized 1:1 to proximal MV is done.

5: SB rewiring and second kissing: the SB is rewired using a guidewire with an appropriately bended tip aiming at crossing the SB ostium through a non-distal cell. The “centrality” of rewiring should carefully checked before further steps are done. Simultaneous kissing balloon inflation (usually with non-compliant balloons at high pressure according to the sequential technique) is performed selecting MV balloon sized 1:1 according to distal MV and SB balloon sized 1:1 according to SB diameter.

5. final POT: performed with balloon sized 1:1 to proximal MV.

PANEL B AND C. MICRO-CT IMAGE OF STENT CONFORMATION OBTAINED BY DK-CRUSH

TABLE 1: MAJOR BIFURCATION STENTING TECHNIQUES AND ANATOMIC CONDITIONS THAT MAY FAVOR THEIR ADOPTION

	FAVORABLE SETTINGS	SPECIFIC ISSUES
ONE-STENT TECHNIQUES		
- PROVISIONAL	- any non-complex bifurcation lesion - complex bifurcation lesions provided that risk of SB occlusion or difficulty in its bail-out management have been ruled out	- SB occlusion risk
- INVERTED PROVISIONAL	Medina 0,0,1 lesion of a bifurcation with very large SB like ostial left circumflex lesion or left anterior descending/diagonal bifurcation lesion	- distal MV occlusion risk - distal MV patency is dependent on the stent's side-cell - distal MV integrity (absence of dissections) should be carefully ascertained
TWO-STENT TECHNIQUES		
- T / TAP STENTING	- bail-out management of any SB in the course of provisional - complex bifurcations without very acute angle - complex bifurcations with large and diseased SB (in that case, inverted technique advised)	-meticulous attention to SB stent implantation is critical to avoid long protrusion or SB ostium uncoverage
- CULOTTE STENTING	- bail-out management of large-sized SB in the course of provisional - complex bifurcations with SB size comparable with distal MV size	- multiple steps required - double stent layers in the proximal MV
- DK-CRUSH	- complex bifurcations, with extensive side-branch disease and/or anticipated difficulty in accessing an important sidebranch	- multiple steps required - so far, efficacy proven only when practiced by operators with high experience with the technique - double stent layers in the proximal MV

MV: main vessel; SB: side branch

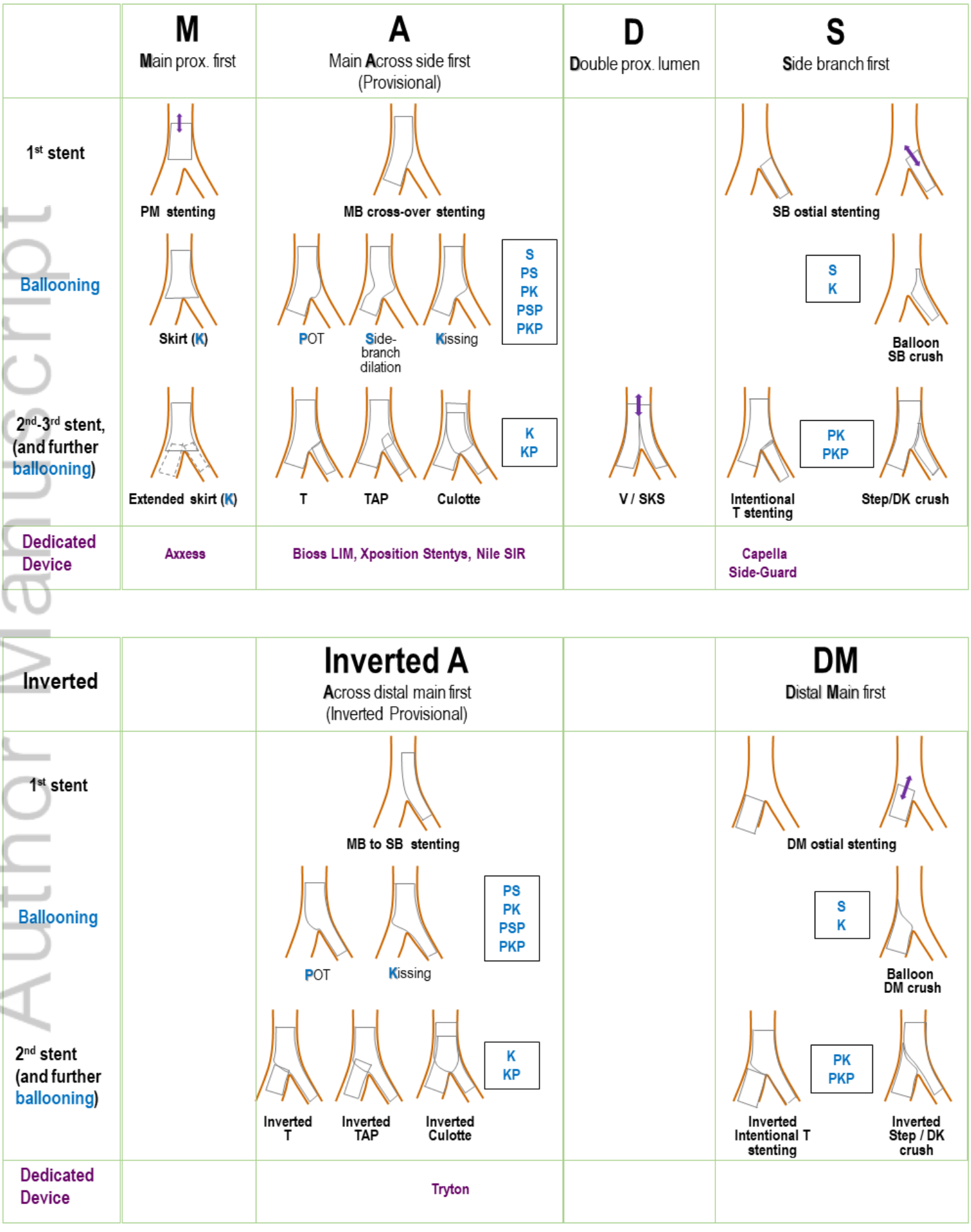

Figure 1

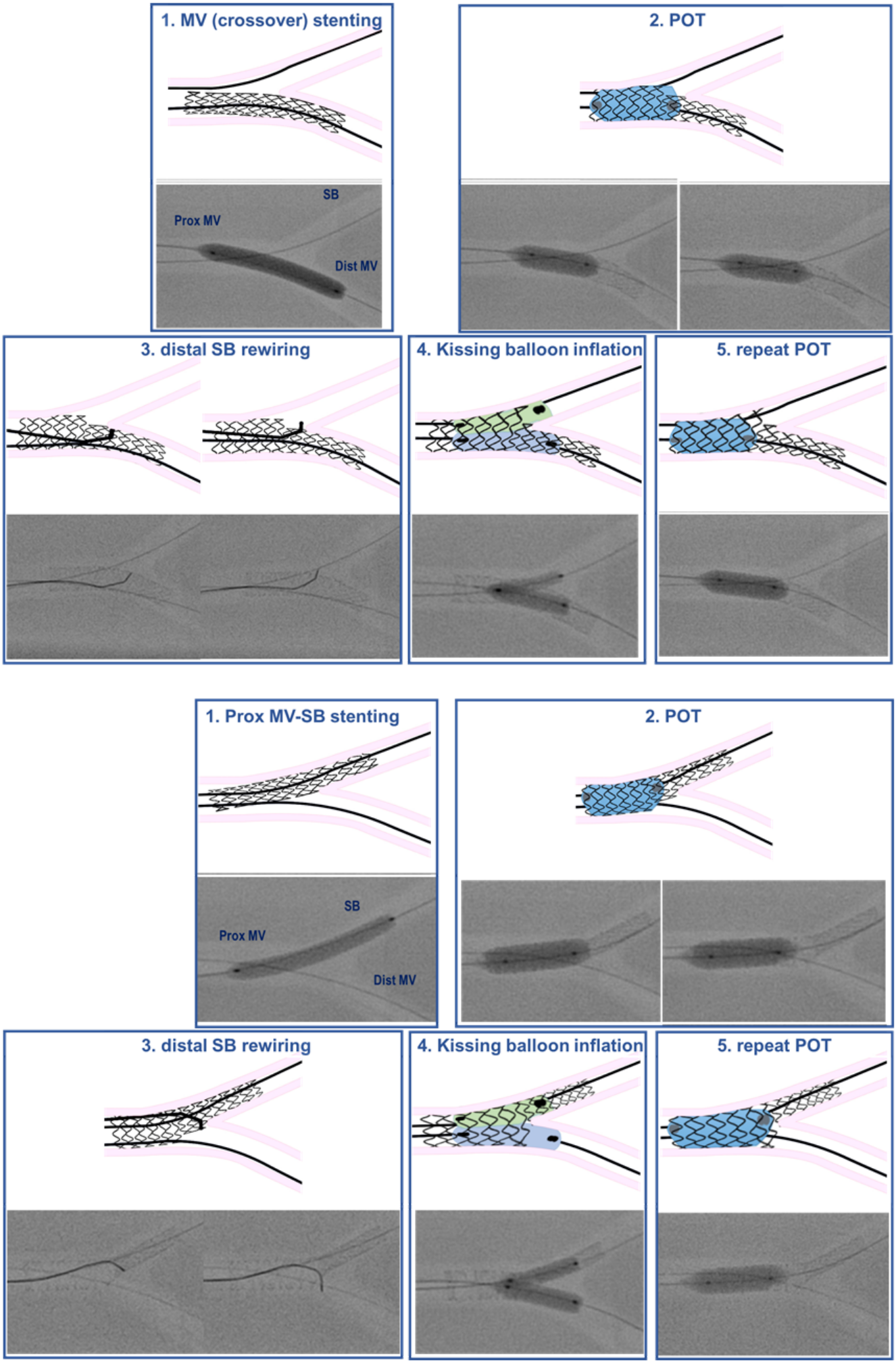

Figure 2

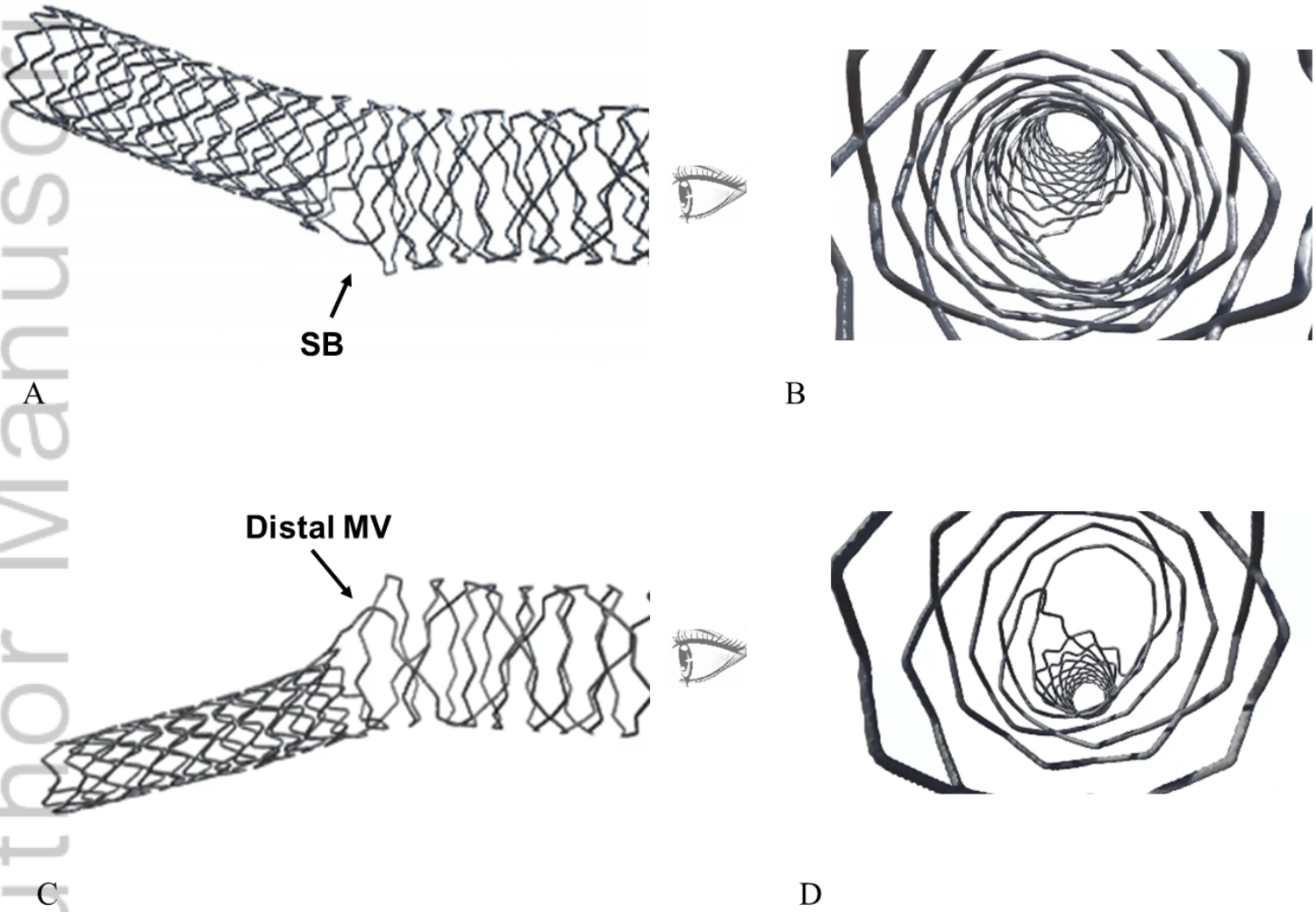

Figure 3

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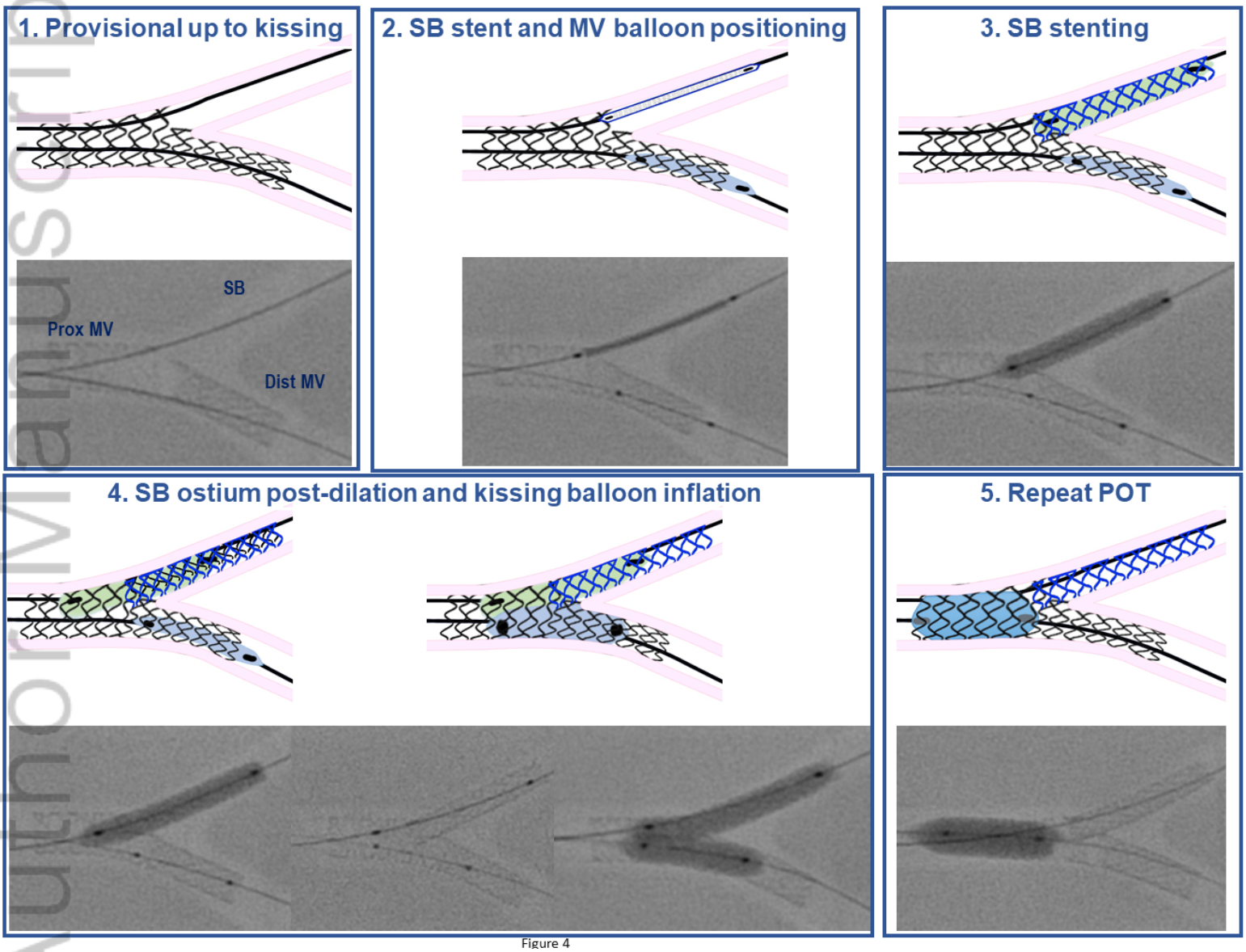

Figure 4

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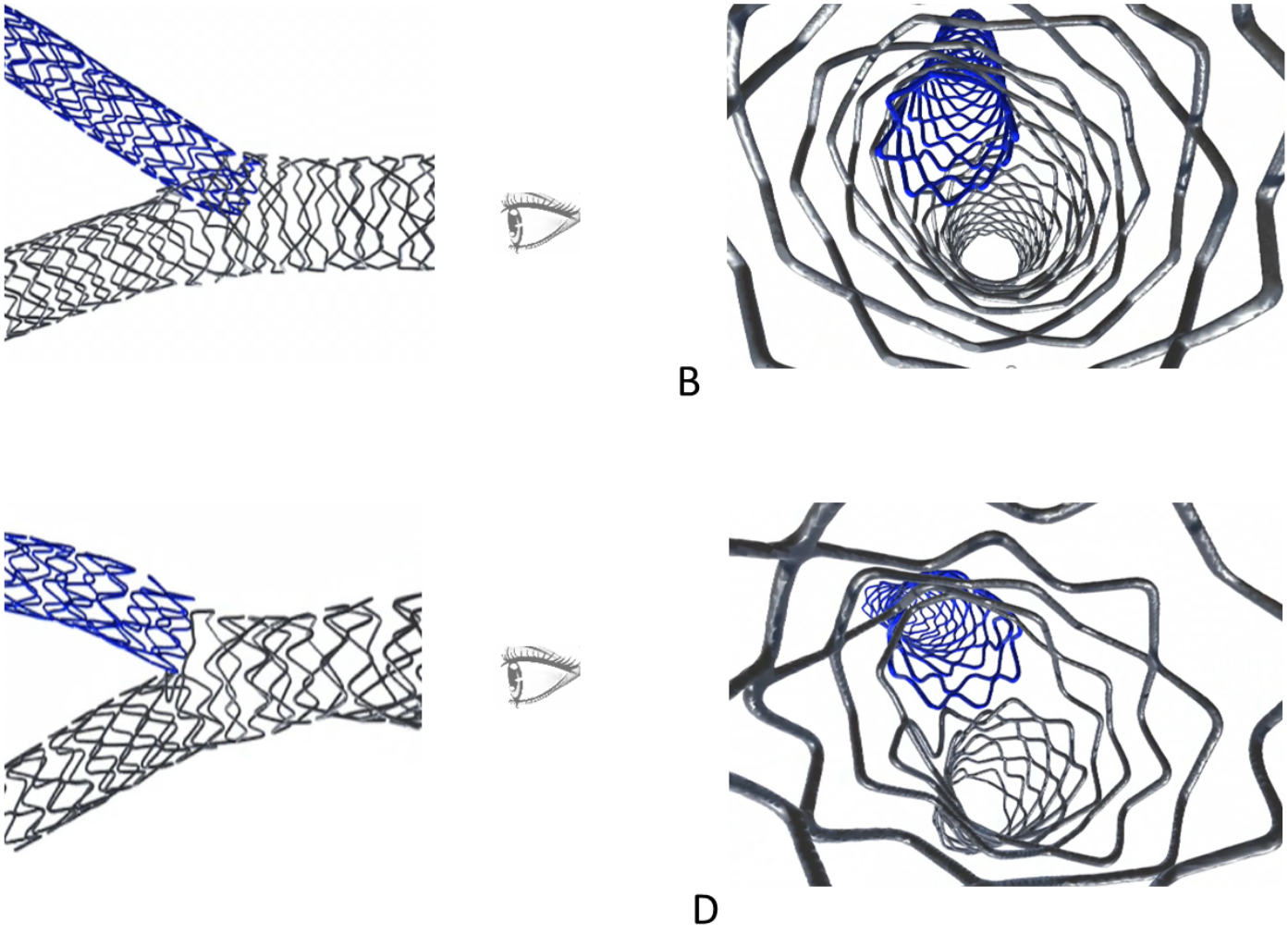

Figure 5

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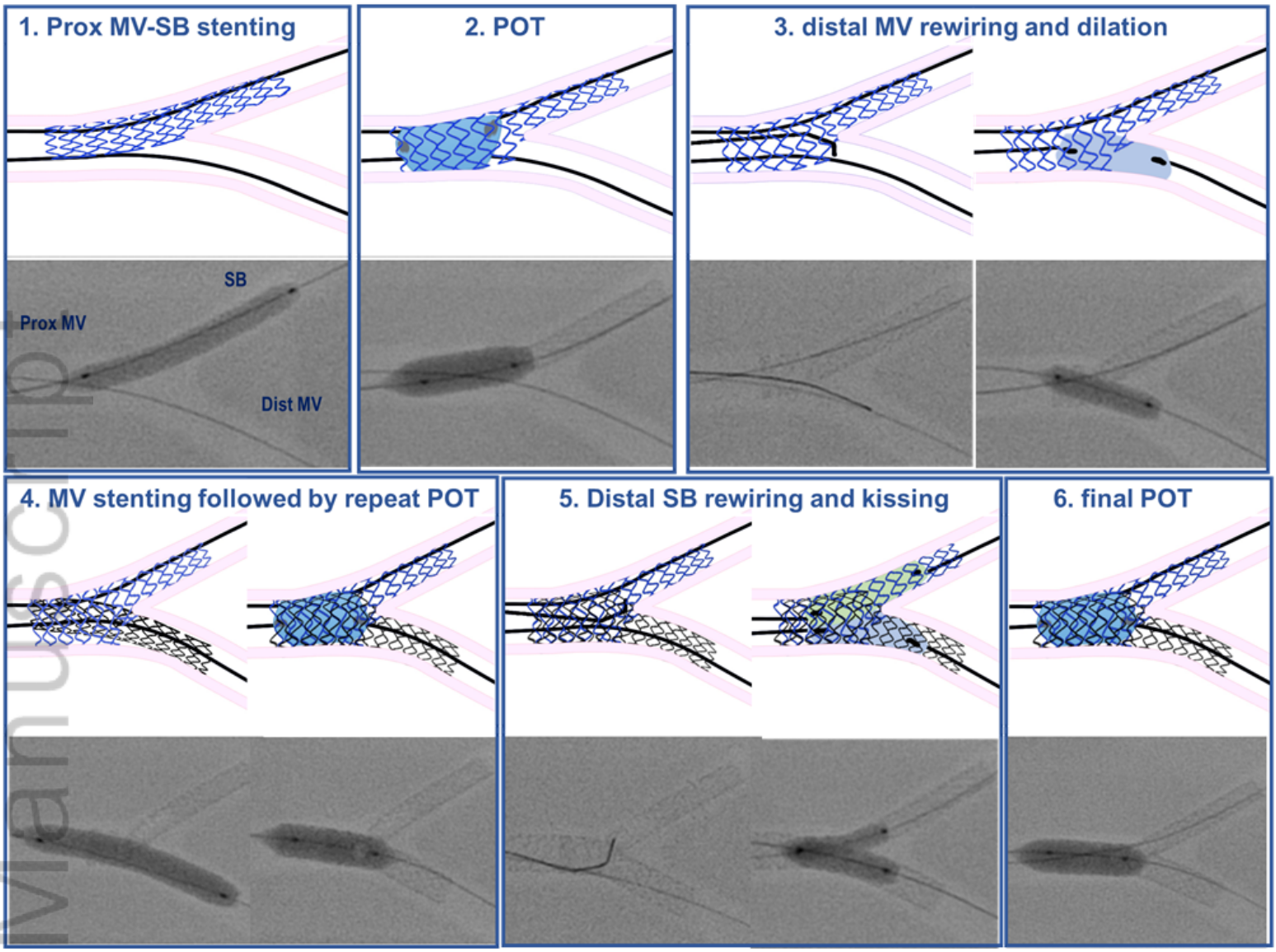

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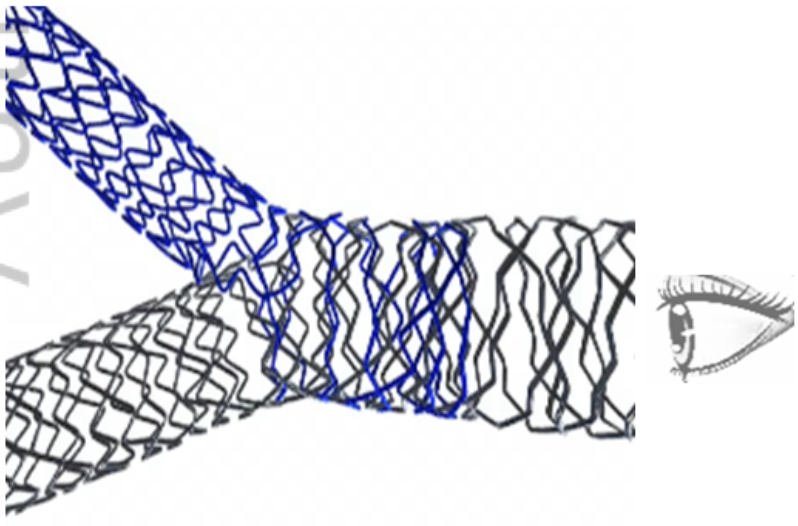

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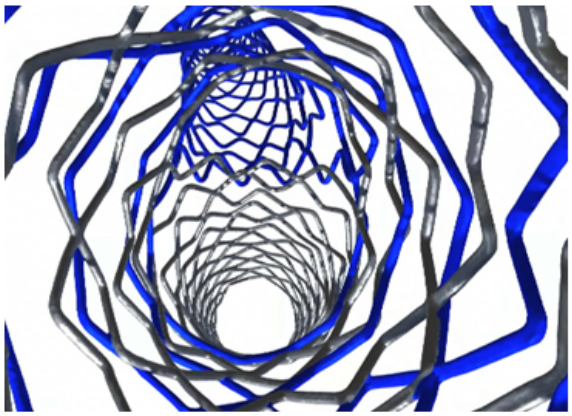

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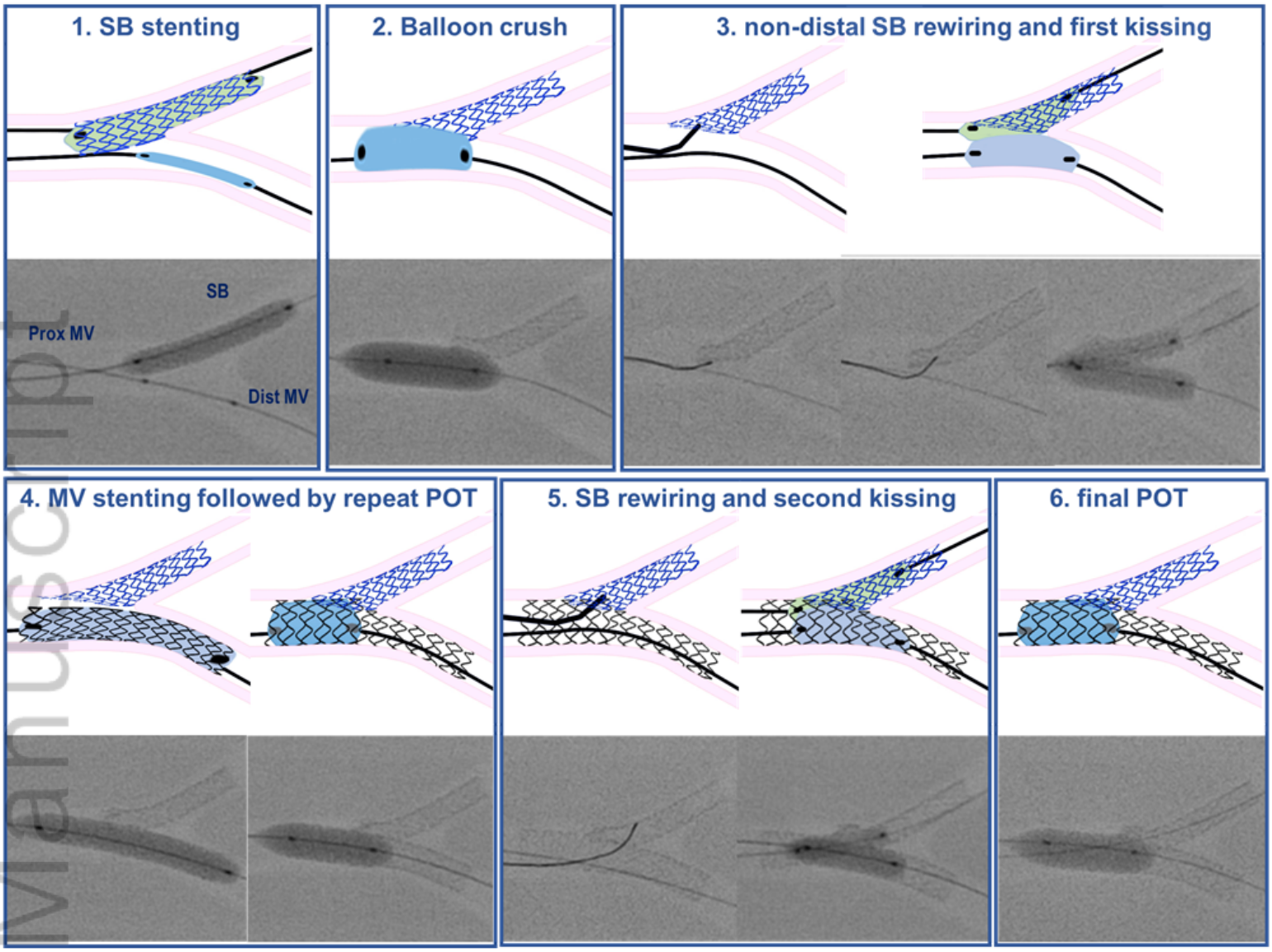
Figure 6

CCD_29071_FIGURE 6 new.tif



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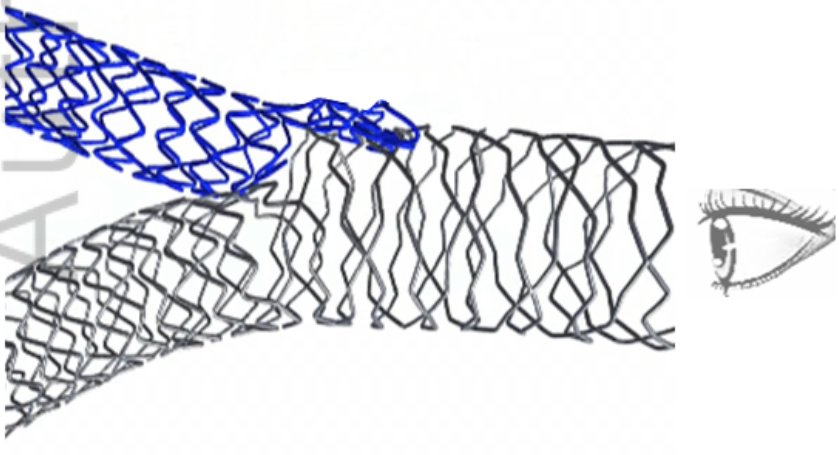

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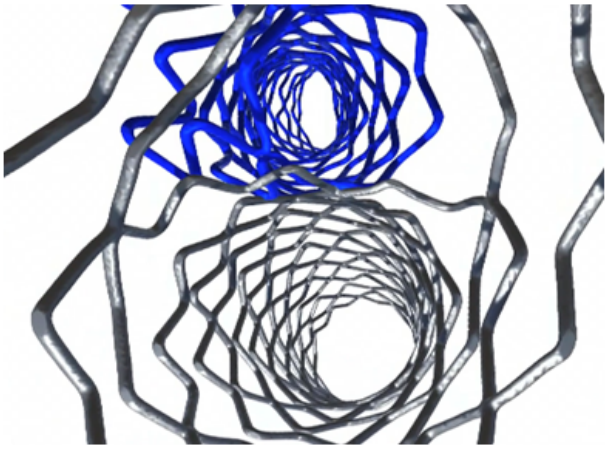

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Figure 7

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