Received: 28 October 2019 | Accepted: 12 November 2019
DOI: 10.1002/ccd.28607

CORE CURRICULUM

WILEY

Advances in CrossBoss/Stingray use in antegrade dissection reentry from the Asia Pacific Chronic Total Occlusion Club

Eugene B. Wu MD[1] | Emmanouil S. Brilakis MD, PhD[2] | Sidney Lo MD[3] | Arun Kalyanasundaram MD[4] | Kambis Mashayekhi MD[5] | Hsien-Li Kao MD[6] | Soo-Teik Lim MD[7] | Lei Ge MD[8] | Ji-Yan Chen MD[9] | Jie Qian MD[10] | Seung-Whan Lee MD, PhD[11] | Scott A. Harding MD[12] | Etsuo Tsuchikane MD, PhD[13]

[1]Department of Medicine and Therapeutics, Prince of Wales Hospital, Chinese University Hong Kong, Shatin, Hong Kong
[2]Department of Cardiology, Minneapolis Heart Institute and Minneapolis Heart Institute Foundation Abbott Northwestern Hospital, Minneapolis, Minnesota
[3]Department of Cardiology, Liverpool Hospital, Sydney, Australia
[4]Department of Cardiology, Promed Hospital, Chennai, India
[5]Division of Cardiology and Angiology II, University Heart Center Freiburg—Bad Krozingen, Bad Krozingen, Germany
[6]Department of Internal Medicine, National Taiwan University Hospital, Taipei, Taiwan
[7]Department of Cardiology, National Heart Centre, Singapore, Singapore
[8]Department of Cardiology, Shanghai Zhongshan Hospital, Shanghai, China
[9]Department of Cardiology, Guangdong General Hospital, Guangzhou, Guangdong, China
[10]Department of Cardiology, Beijing Fuwai Hospital, Beijing, China
[11]Department of Cardiology, Asan Medical Centre, Seoul, South Korea
[12]Department of Cardiology, Wellington Hospital, Wellington, New Zealand
[13]Department of Cardiovascular Medicine, Toyohashi Heart Centre, Toyohashi, Aichi, Japan

Correspondence
Eugene B. Wu, Department of Medicine and Therapeutics, Prince of Wales Hospital, Chinese University Hong Kong, Ngan Shing Road, Shatin, Hong Kong.
Email: cto.demon@gmail.com

Abstract

Antegrade dissection reentry with Stingray device (Boston Scientific, Marlborough, MA) accounts for 20–34% of the chronic total occlusion (CTO) cases in the various hybrid operators' CTO registries and is an important component of CTO crossing algorithms. The Stingray device can facilitate antegrade dissection and reentry, however its use is low outside North America and Europe. The Asia Pacific CTO Club along with three experience Stingray operators from the US, Europe and India, created an algorithm guiding use of the CrossBoss and Stingray catheter. This APCTO Stingray algorithm defines when to use the CrossBoss and Stingray device recommending a reduction in CrossBoss use except for in-stent restenosis lesions and immediate transition from knuckle wiring to the Stingray device. When antegrade wiring fails, choice of Stingray-facilitated reentry versus parallel wiring depends on operator experience, device availability, cost concerns, and anatomical factors. When the antegrade wire enters the subintimal space, we recommend using a rotational microcatheter to produce a channel and deliver the Stingray balloon—so called the “bougie technique.” We recommend early switch to Stingray rather than persisting with single wire redirection or parallel wire. We recommend choosing a suitable reentry zone based on preprocedural computer tomography or angiogram, routine use of stick and swap, routine use of Subintimal TRAnscatheter Withdrawal (STRAW) through the Stingray balloon, and the multi stick and swap technique. We believe these techniques and algorithm can facilitate incorporation of the Stingray balloon into the practice of CTO interventionists globally.

KEYWORDS
CAD—coronary artery disease, PCI—percutaneous coronary intervention, CTO—Chronic Total occlusion, HRC—hybrid revascularization coronary

1 | INTRODUCTION

Antegrade dissection reentry (ADR) with the Stingray device (Boston Scientific, Marlborough, MA) is one of the pillars of the hybrid algorithm.[1] The Stingray is an over-the-wire, self-orientating, flat winged balloon that inflates in the subintimal space and self-orients by wrapping around part of the circumference of the vessel outside the plaque. It has three ports, a distal exit port, and two contralaterally located side ports that allow the Stingray wire to puncture toward the lumen or toward the adventitia (Figure 1). The current version is the low profile version (LP) which is 6 Fr guiding compatible with proximal outer shaft diameter of 3.2 Fr (0.042″) and distal outer diameter of 2.7 Fr (0.036″). The Stingray balloon can be used with a 6 French Trapliner (Teleflex, Wayne, PA). It has Z-glide hydrophilic coating (Boston Scientific) on the distal 25 cm and silicon coating on the balloon that allows improved pushability. It has become an essential device for the hybrid operators and is used in 20–34% of cases i.[2–4] Unlike the “older” ADR methods such as subintimal tracking and reentry (STAR) and limited antegrade subintimal tracking (LAST), Stingray use is not associated with a markedly increase major adverse cardiac events (MACE).[5,6] Initial studies[7–9] also suggest that Stingray use does not impair long-term outcomes. The device can achieve up to 86% success rates.[2] Improvements in the Stingray techniques, including the “stick-and-swap” technique and the “double-blind stick-and-swap,”[10] subintimal transcatheter withdrawal (STRAW) technique,[11] and the “double Stingray technique to deal with bifurcation at the distal cap,[12] have further increased the applicability and success of the Stingray. Despite this and the widespread proctoring and availability of Stingray, Stingray use has remained low outside the US. This can be attributed to the dominance of wire-based techniques and the reluctance to move into the subintimal space especially with knuckle wiring. The Asia Pacific Chronic Total Occlusion Club (APCTO) has published a CTO algorithm[13] (Figure 2) which delineates the role of Stingray device in our practice. In this article, we describe various concepts on optimal Stingray use.

2 | WHEN TO USE CROSSBOSS (BOSTON SCIENTIFIC) AND STINGRAY DEVICES?

2.1 | The position of CrossBoss in the APCTO algorithm

The CrossBoss catheter (Figure 3) is an over-the-wire metallic microcatheter with a 1.0 mm (0.04″) blunt distal tip that can create a

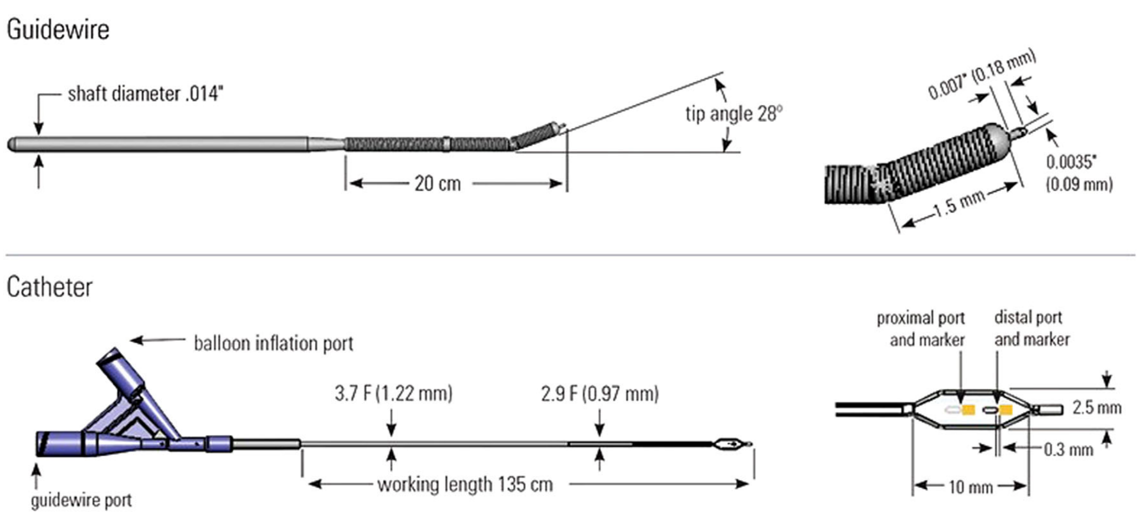

FIGURE 1 Stingray balloon catheter specs and enlarged view of balloon [Color figure can be viewed at wileyonlinelibrary.com]

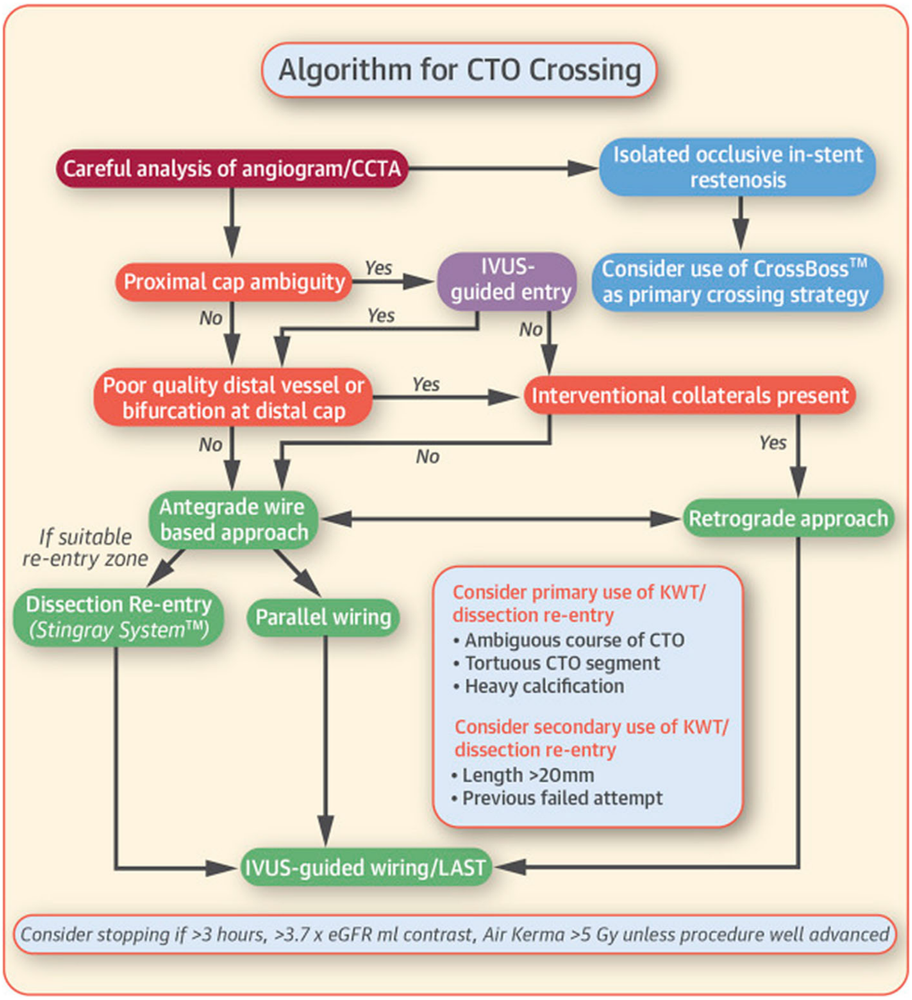

FIGURE 2 APCTO Club Algorithm for CTO crossing [Color figure can be viewed at wileyonlinelibrary.com]

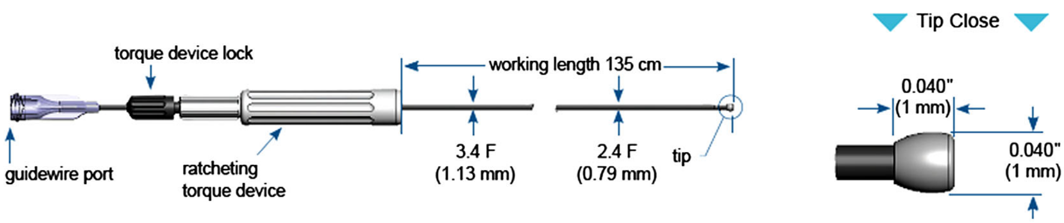

FIGURE 3 CrossBoss catheter specs and enlarged tip [Color figure can be viewed at wileyonlinelibrary.com]

1.0 mm channel when it is rapidly rotated through a CTO. It has a 135 cm working length with a proximal shaft of 3.4 Fr (0.045″) and a distal shaft of 2.4 Fr (0.032″). It is manipulated by rapidly rotating the catheter using the ratcheting torque device with locking mechanism that controls the distance the device can move forward. It can travel within the intraplaque space but it can also migrate into the subintimal space and move quickly through the subintimal space.

The CrossBoss device appears in two places in the APCTO club CTO algorithm.[13] At the beginning of our algorithm (Figure 2), for in-stent restenosis (ISR) CTO the algorithm recommends to "consider CrossBoss." Like many of these recommendations, there are clinical and angiographic features that favor CrossBoss. For a straight ISR CTO, with shorter history of occlusion, without obvious under expansion of the previous stent, CrossBoss should be considered, as it would often cross spontaneously into the distal true lumen. Longer duration ISR are more likely due to neoatherosclerosis and therefore contain more calcium which may impede CrossBoss crossing. Tapered proximal cap (vs. blunt cap), the proximal cap being inside the stent (vs. outside), the distal cap is inside the stent (vs. outside), and lack of underexpansion of the stent all favor CrossBoss versus wire-based strategy first.

In these straight ISR CTOs, however, the use of a Pilot 200 (Abbott Vascular, Santa Clara, CA) wire can often cross into the true lumen, raising questions on the need for the CrossBoss device. However, for less experienced operators using today's very thin strut stents, there is the risk of inadvertent unnoticed passage of the wire under the stent strut with wire crossing techniques. Once a microcatheter is inserted under the strut, it can make true lumen rewiring and device crossing of the CTO extremely difficult. This might be prevented when utilizing a CrossBoss in ISR CTO, as opposed to a wire-based strategy. Also, there are small studies in the UK[14] as well as subgroup analysis of a randomized trial in the US[15] suggesting that use of CrossBoss is associated with shorter CTO crossing time in ISR CTOs.

The most important difference in our algorithm compared with the hybrid algorithm in using the Stingray device is how we get to the distal cap subintimal position. While the Hybrid ADR technique is based on primary knuckle wire technique or primary CrossBoss to achieve a subintimal track, our algorithm is based on AWE techniques. Therefore, most of our CTO cases begin with antegrade single wire escalation and when that fails, the wire has already reached a subintimal position parallel to the distal cap. Then the choice of parallel wiring versus Stingray device is given in our algorithm, with or without the use of CrossBoss (Figure 2). With the advent of the Stingray LP balloon we have found that we can often track the Stingray balloon to the required position once the antegrade rotational microcatheter (such as Corsair [Asahi Intecc, Nagoya, Aichi, Japan] or Turnpike [Teleflex, Wayne, PA]) has dilated the passage, so called "bougie technique." If this kind of rotational microcatheter cannot pass, the CrossBoss would also often not pass and so we would recommend the use of a 1.5 mm balloon for dilatation. If the rotational microcatheter can pass but the Stingray balloon cannot, this is most commonly due to abutting calcium and therefore balloon dilatation is superior to use of CrossBoss in facilitating stingray balloon crossing. On rare occasions, where intentional subintimal wiring or knuckle wiring has been used and the wire spirals around the vessel making it impossible to pass the Stingray balloon through these spiral turns, the CrossBoss can produce a new straight subintimal track allowing the Stingray balloon to pass. This "straightening boss" maybe useful in a minority of cases. The CrossBoss can also be used to make a final 1.0 mm lumen in the subintimal space to allow the Stingray balloon to inflate in a controlled space, so called "finishing Boss." Finishing Boss can control the size of the space created as well as improve the orientation of the Stingray balloon increasing the success rate of Stingray. The use of "finishing Boss" is only useful when there has been knuckle wiring into the subintimal space. However, for operators with good wire skills, we would usually reach the subintimal space by conventional antegrade wiring and not knuckle wire. There is little added value of finishing Boss in these cases where the antegrade wire channel is dilated only with a rotational microcatheter as the subintimal space is not enlarged by knuckling wire. For "long plus" CTOs (Figure 2), which are long CTOs with ambiguous course, tortuosity, or heavy calcification, knuckle wire is recommended in the APCTO algorithm. However, even in these cases, we would often stop short of knuckling into the distal cap and revert back to single wire to attempt to wire the subintimal space parallel to the distal lumen. In this case, there is also no need for finishing Boss as the last portion of the subintimal space is dilated only with a rotational microcatheter. We do not recommend attempting to wire the distal true lumen after knuckle wiring as the success rate of high penetration force wire to puncture the distal true lumen from the subinitmal space is not high and it may well increase hematoma leading to more difficult Stingray. If the operator has attempted to wire the distal true lumen after knuckle wiring, we should consider finishing Boss to create a clean small channel for Stingray. We do not recommend the use of CrossBoss device to overcome vessel course ambiguity. In agreement with the Hybrid algorithm, knuckle wiring should be used to safely overcome ambiguity. If the CrossBoss is advanced into a side branch, such as an overlapping diagonal (Figure 4a) or RV marginal branch (Figure 4b) it can cause massive perforation (Figure 4c,d). Therefore, in our new style Stingray, when the AWE has achieved wire next to the distal true lumen, we recommend simply advancing the supporting microcatheter toward the wire tip and then exchanging to a supportive wire such as Miracle 12 g (Asahi Intecc) to exchange for a Stingray LP balloon. The Miracle 12 g wire has enough stiffness all the way to the tip to allow the easy tracking of the stingray balloon to the desired position without losing wire position. Therefore, in our algorithm, the CrossBoss catheter is reserved for the straight ISR CTOs and the rare occasions in which CrossBoss straightening or CrossBoss finishing is desired.

2.2 | The position of Stingray in the APCTO club algorithm

Contrary to the hybrid algorithm,[1] Stingray is not the only method for ADR in the APCTO club algorithm[13] as parallel wiring/ IVUS guided wiring are valid alternatives. We must decide early on whether Stingray or parallel wire should be used and not attempt to switch between one and the other as an attempt with Stingray will make parallel wiring very difficult and similarly an attempt with parallel wiring would make Stingray very difficult, but not impossible.

The factors that guide us toward choosing Stingray versus parallel wiring are complex and include both anatomical factors as well as operator experience, availability, and economic factors.

The most important concept to understand for choosing Stingray versus parallel wiring is the mechanism of these techniques. Ideally, parallel wiring is manipulation of an intraplaque wire in front of the distal cap to puncture the distal cap into the true lumen while Stingray is a reentry from subintimal space beyond the distal cap at a reentry zone. Of course, one can successfully Sting from an intraplaque position and also one can successful perform parallel wiring from subintimal position. However, for parallel wiring, wire control is diminished and the risk of subintimal space expansion is increased when the wire is in the subintimal space. Thereby reducing the chance of successful parallel wiring.

The anatomical factors that favor Stingray include: a large disease and calcium free reentry zone, distal Right coronary artery (RCA) reentry zone, wire position less than 0.5 mm from true lumen,[16] absence of bifurcation in distal cap, lack of hematoma expansion, good retrograde filling, and ease of delivery of the Stingray catheter to the reentry zone.

Distal RCA is usually an easy reentry zone as the vessel is straight and there are no significant branches minimizing the risk of side branch loss. Conversely, mid RCA is usually more difficult, but possible in expert hands, and left anterior descending (LAD) has increased risk of side branch loss. Therefore, a distal RCA reentry zone is a favorable factor for Stingray. Tsuchikane et al[16] compared thickness of plaque in successful versus unsuccessful Stingray case and found that unsuccessful case had thickness of 1.32 mm versus 0.33 mm in successful case and so the thickness of plaque in the reentry zone also influences Stingray success.

Factors that favor parallel wiring include: softer distal cap, intraplaque position of first wire, lack of expansion of peri-wire space with preserved antegrade wire control (assuming the wire is intraplaque), large distal true lumen size, good retrograde filling, and ease of delivering a dual lumen catheter (DLC) to the distal cap.

Parallel wiring technique usually requires the second wire to penetrate the distal cap into the true lumen, therefore a very hard distal cap with calcification would make parallel wire difficult. However, for Stingray we can bypass the hard distal cap and make a puncture into the true lumen in the reentry zone where the plaque maybe soft. Preserved antegrade wire control is very important for parallel wire. Wire control is better when the wire is in the intraplaque space than when it is in the subintimal space, because wire control is dependent upon having plaque tightly surrounding the wire providing support to torque and enhance penetration forces of the wire. With manipulation of the wire, the peri-wire space expands due to plaque displacement by wire rotation, and with increasing peri-wire space expansion, there is decreasing wire control as the wire is no longer tightly supported by surrounding plaque. Therefore, a lack of excessive peri-wire space expansion from wire manipulation favors parallel wiring. This also makes it important to move promptly to parallel wire and not do excessive single wire redirection.

Although large distal true lumen size, good retrograde filing, and ease of delivery of Stingray balloon and DLC are favorable to both Stingray and parallel wire, our experience has been that Stingray can often be successful even in very small distal lumen and suboptimal retrograde filling, but the deliverability of the newer low profile DLC (such as Sasuke [Asahi Intecc] or Crusade R [Kaneka Medix

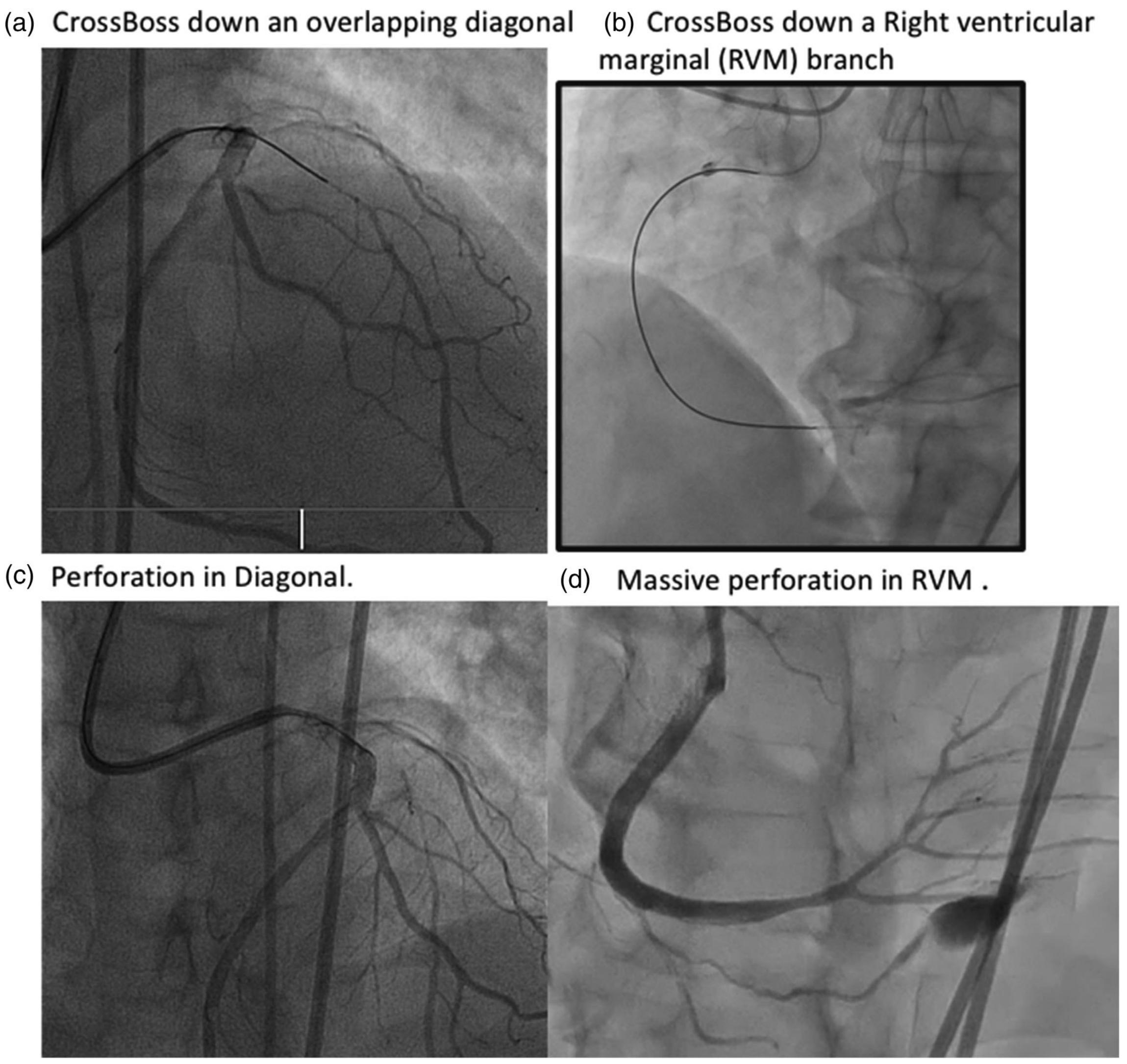

FIGURE 4 CrossBoss perforation. (a) CrossBoss down an overlapping diagonal; (b) CrossBoss down a right ventricular marginal (RVM) branch; (c) perforation in diagonal; and (d) massive perforation in RVM

TABLE 1 Anatomical factors to guide the choice between Stingray and parallel wiring

Factors	Stingray	Parallel wiring	Notes
Bifurcation at distal cap	–	+	Retrograde is the best option but if no retrograde option parallel wire is favored
Soft distal cap	–	+++	
First wire position subintimal Intraplaque	++	–	Subintimal manipulation of wire increases risks of hematoma expansion.
Good reentry zone	+++	–	
Mid RCA distal cap	–	++	Mid RCA is often difficult to sting and so parallel wiring is preferable.
First wire near to lumen	+++	+	
Good antegrade wire control	–	+++	If Antegrade wire control is poor we should lean toward Stingray
Calcium in reentry zone	–	+++	Calcium in reentry zone does not influence parallel wire
Calcium in CTO	++	–	Calcium reduces parallel wire control

Corporation, Kanagawa, Japan]) is still superior to the deliverability of the Stingray LP balloon.

Other nonanatomical factors may affect the decision far more than anatomical factors including: operator experience with parallel wire and Stingray, availability of Stingray device, cost concerns, and operator preference (Table 1). Availability and experience are absolute conditions while costs and operator preference are more relative. Parallel wiring carries slightly lower cost than Stingray (in most countries).

In conclusion, Stingray's position in the APCTO algorithm is one of two main options when antegrade wire escalation has failed and retrograde options are not easy. The choice will depend on a wide range of factors which the algorithm gives guidance on.

3 | HOW TO USE STINGRAY?

Having addressed when to use Stingray, we now turn to how to use Stingray. We have to acknowledge the excellent work the hybrid operators have done in promoting, proctoring, and perfecting the Stingray techniques,[1,2,8–12] and our contribution in the article builds upon their groundwork.

3.1 | Preparation of the Stingray balloon

Meticulous preparation of the Stingray balloon is important as it allows contrast to fill the wings and for the operator to see clearly the direction of the exiting wire. After attaching a three way to the balloon port, a 20 mL luer lock syringe with pure contrast should be attached and pulled negative and lock the three way. The same syringe is reattached and after release of the three way it is pulled negative for at least 5 s and then slowly released. We should wait for another 10 s to allow contrast to fill into the balloon. The three way is then again turned off and the space inside the three way is filled with contrast. A final negative pull is done once more and then released again to prepare the Stingray balloon properly.

3.2 | Wire-based Stingray

In Asia pacific, China, Australia, and Europe, there is a strong wire-based practice for addressing CTO. With the improvements of wire technology, many operators can easily wire into the distal true lumen even in long CTOs, within a reasonable period of time. Therefore, the consideration of using Stingray device often comes when the first antegrade wire has already reached the subintimal space parallel to the distal cap. It makes sense to recommend simply to drill the antegrade rotational microcatheter toward the wire tip and switch for Stingray, the "bougie technique." While knuckle wiring is useful and indeed increases safety in cases where the vessel course is unknown and allows rapid traversing of tortuosity or calcium, knuckle wiring without a clear indication is not recommended.[13] In this RCA CTO (Figure 5a) the operator successfully wired into the space parallel to the distal cap (Figure 5b), but once he decided to use the Stingray, he pulled back his wire to knuckle. Unfortunately, the knuckle wire entered the right ventricular marginal (RVM) branch repeatedly (Figure 5c) and so in the end the operator had to redirect a non-knuckle wire back to the original space (Figure 5d). Although the knuckle wire did not travel far down the RVM, nonetheless, the knuckle wiring into the proximal RVM ostium led to hematoma expansion and flow compromise of the RVM. After this, it was easy to drill the Turnpike microcatheter down and exchange for Stingray balloon (Figure 5e) and successfully sting the distal true lumen (Figure 5f) leading to an excellent stenting result. However, the knuckle wire into the RVM led to hematoma in the RVM and the patient suffered a hypotensive episode due to RV ischemia (Figure 5g) in recovery requiring inotropic support. This kind of unnecessary knuckling should be separated from good Stingray practice. In APCTO club, we recommend the bougie technique—a primary rotational microcatheter follow wire to dilate a track for directly delivering the Stingray balloon without routine knuckle wiring or CrossBoss use.

3.3 | Stingray when using knuckle wiring

The APCTO algorithm does recommend knuckle wiring for long plus CTO. In these cases, the knuckle wire should stop short of the distal cap and a microcatheter pushed toward the knuckle wire tip. Then a nonknuckle nontapered intermediate penetration force wire should be used to deliberately wire the subintimal space. When the wire goes parallel to the distal cap, we should drill the microcatheter forward and exchange out for the Stingray balloon for sting. This method

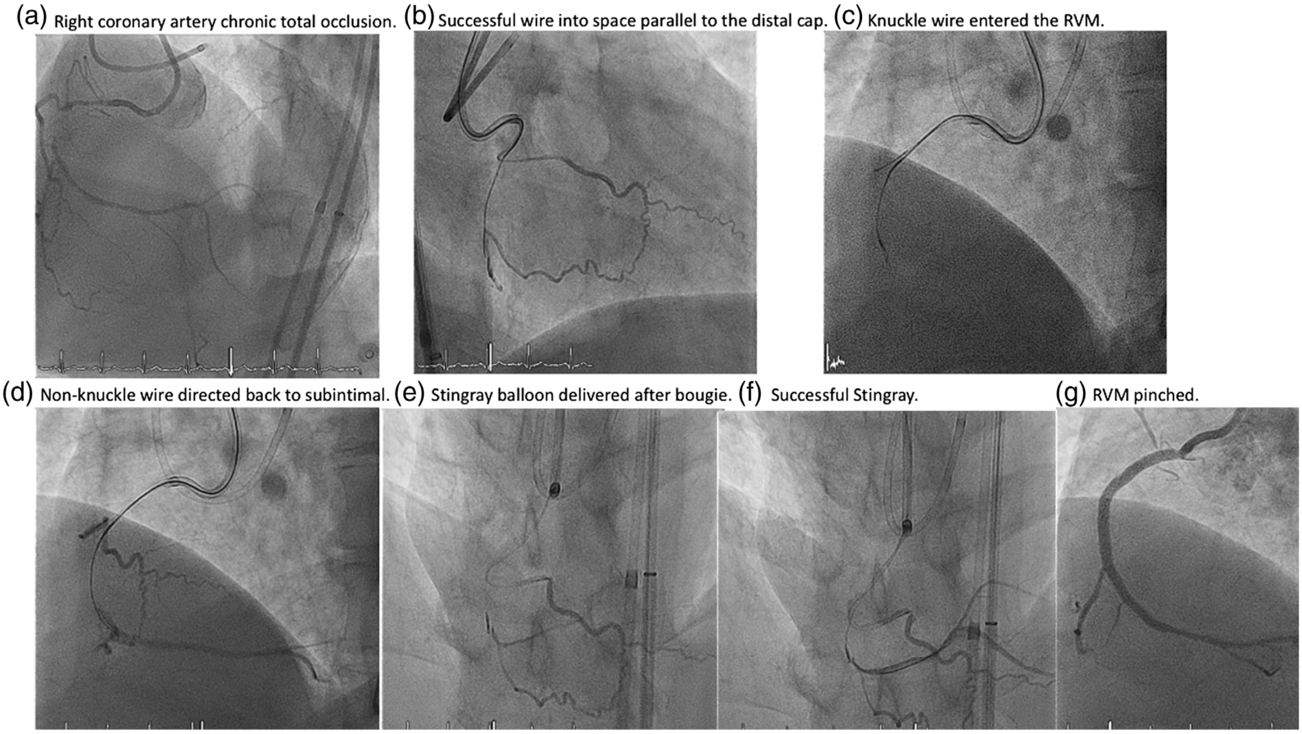

FIGURE 5 Complication from unneeded knuckle wiring. (a) Right coronary artery chronic total occlusion; (b) successful wire into the space parallel to the distal cap; (c) knuckle wire entered RVM; (d) nonknuckle wire directed back to subintimal; (e) stingray balloon delivered after bougie; (f) successful Stingray; and (g) RVM pinched

avoids long segment of enlarged subintimal space by knuckle wire and avoids the need for finishing CrossBoss.

3.4 | Choosing a reentry zone

Multiple factors affect the suitability of a reentry zone. Calcification, plaque load, lumen size, plaque thickness, distance of first wire to true lumen, hematoma size, distal lumen pressure, tortuosity of zone, stability of Stingray balloon, and operator experience.

The availability of preprocedural CT may be helpful. Tsuchikane et al.[16] has shown that the thickness of the plaque at the reentry zone impacts success. However, this is not the sole factor. Preprocedural analysis, especially with CT, can help us decide on a good reentry zone based on estimation of the thickness of the plaque and calcium location, enhanced with angiographic coregistration.[17]

Understanding how plaque thickness influences the Stingray success can also change our practice. If the antegrade wire is far away from the true lumen, instead of proceeding to Stingray, we may attempt to redirect the antegrade wire, not into the true lumen but to a location slightly closer to the true lumen to maximize the chance of successful sting. In this left anterior descending artery (LAD) CTO the first antegrade wire went subintimal to the distal cap, but the distance to the true lumen is quite far (Figure 6a) therefore, instead of Stingray into the true lumen, the Stingray balloon is placed inside the CTO body (Figure 6b) and a stick and swap sting was made to bring the antegrade wire from the subintimal space into the intraplaque space (Figure 6c). Then the antegrade wire can be manipulated to a position very close to the distal true lumen (Figure 6d) and after repeat bougie with rotational microcatheter, the Stingray balloon can be delivered for a second sting from this position (Figure 6e) and can get into distal true lumen with good results (Figure 6f).

3.5 | Timing to commence Stingray

Due to the strong wire-based training in many centers, there is a temptation to persist with AWE or parallel wire technique, often resulting in a very late change of strategy to Stingray. This should be avoided, as both wire redirection and parallel wiring increases the risk of hematoma formation and makes subsequent Stingray very difficult. Instead, operators should go for direct Stingray once the wire has "missed" the distal true lumen. This is especially true if: (a) the first wire is far from the lumen, (b) the operator suspects the first wire is subintimal, (c) the distal cap has features that suggests it is very hard, and (d) there is a suitable reentry zone. One of the most common mistakes we see during Stingray proctoring is the delayed use of Stingray.

3.6 | Control of inflow

Controlling the inflow of blood into the CTO vessel can minimize hematoma formation and improve the success of Stingray. Antegrade contrast injection should be avoided once the proximal cap is penetrated and a subintimal space is created. To avoid accidental contrast injection, removal of the antegrade contrast syringe is advisable. If the distal flow is dependent on ipsilateral collateral filling, we should place a microcatheter into the collateral branch to do superselective injection to opacify the distal vessel. Inflating a blocking balloon in the proximal cap of the CTO can also stop inflow allowing ipsilateral guiding injections as well as anchor support for ipsilateral collateral crossing for retrograde approach.

Guide extension catheters (such as the Guideliner or Trapliner [Teleflex] and Guidezilla [Boston scientific]) can be advanced to the proximal cap of the CTO and seal blood inflow. It is important to use a guide extension catheter that is the same size as the guiding to reduce leak as the seal is not complete due to small amounts of blood that can leak through the guide extension catheter tip and vessel wall during manipulation that leads to backing out of the guide extension catheter, and also a small amount of blood can back flow from the guiding tip between the space of the guide extension catheter and the guiding catheter and then enter the guiding extension catheter through the proximal end to flow into the CTO. To enhance the quality of retrograde contrast filling, forward flow in the antegrade guiding can be stopped with depressurisation of the antegrade guiding during retrograde injections simply by opening the O ring on the Y connector. Good control of the inflow will mean an easy sting and reduce the need for more aggressive STRAW techniques.

3.7 | Routine use of STRAW

Hematoma can be reduced by suction through the Stingray balloon, especially when the proximal CTO body is long and likely to provide some occlusion against antegrade blood flow. We recommend routine use of STRAW through the Stingray balloon. This is easily done by simply attaching an empty indeflator to the end of the Stingray balloon when we remove the wire to exchange for the Stingray wire, and keep negative for 4 min (or through a syringe, locking the plunger with a hemostat). This will reduce the hematoma increasing the chance of successful sting. Many cases have extensive hematoma formation before Stingray use due to excessive wiring attempts and should, therefore undergo complete occlusive STRAW. We recommend keeping one or two 2.5–3.5 mm range over the wire balloon so that you can put this besides the Stingray balloon and occlude the proximal vessel and apply suction through the balloon for complete occlusive STRAW (we have used Sprinter [Medtronic], Emerge [Boston Scientific], and Minitrek [Abbott Vascular] OTW balloons successfully in parallel to Stingray LP [Boston] in a 8Fr Guiding Catheter).

3.8 | Routine use of stick and swap

We recommend the routine use of stick and swap technique. The Stingray wire has high penetration force and may result in distal vessel dissection if used to wire a distal true lumen. Many wires can be used

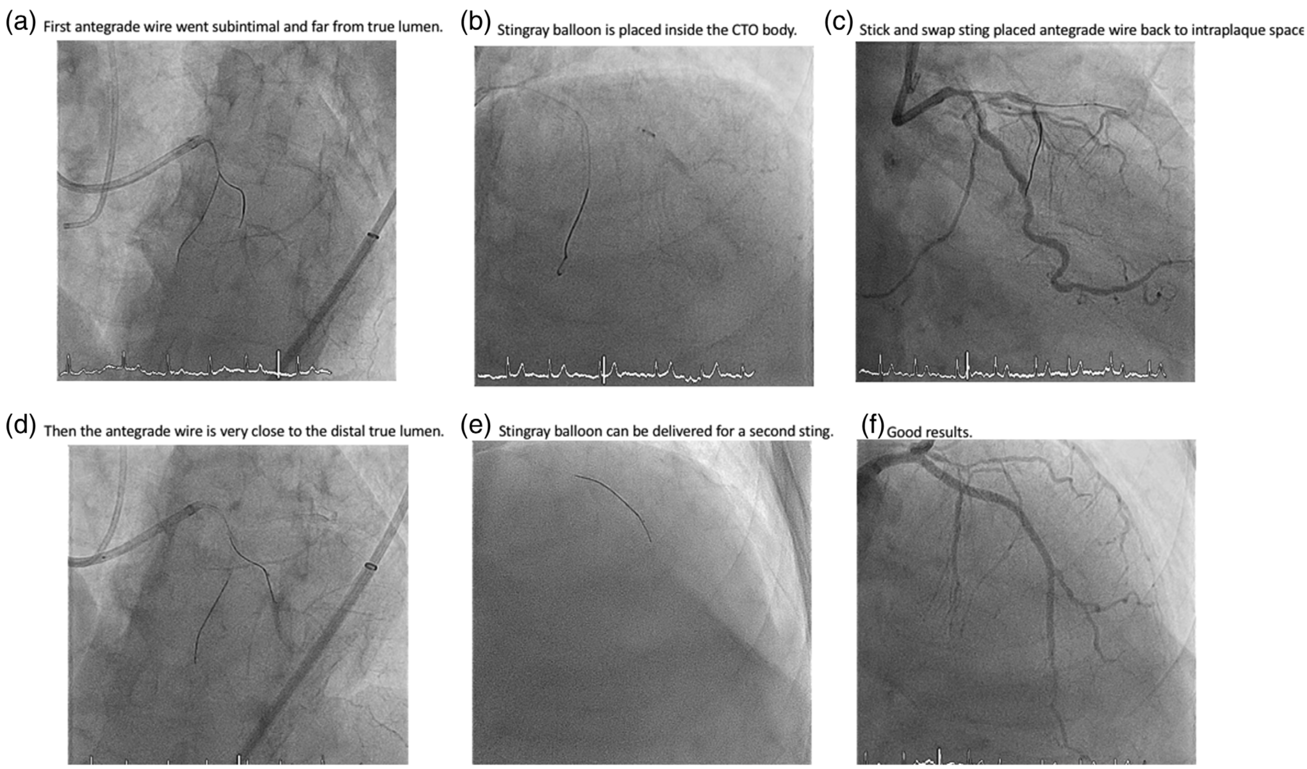

FIGURE 6 Stingray to get into intraplaque position. (a) First antegrade wire went subintimal and far from true lumen; (b) Stingray balloon is placed inside the CTO body; (c) stick and swap sting placed antegrade wire back to intraplaque space; (d) then the antegrade wire is very close to the distal true lumen; (e) Stingray balloon can be delivered for a second sting; and (f) good results

for the swap and it is important that the operator uses a wire that they are most familiar with so that they can feel whether they are in true lumen versus subintimal space. XTR, Sion Black (Asahi Intecc), Pilot 200 (Abbott) or even Sion wire Gladius (Asahi) are all reasonable choices.

3.9 | Guiding catheter size

Although the usual recommendation for use of Stingray is to use an 8 French guiding catheter which will allow a 3.0 mm balloon to be used as guiding trapping balloon to remove the Stingray balloon, in the Asia Pacific region CTO intervention is often performed on a 7 French guiding system. The Stingray LP balloon can be trapped with a 2.5 mm balloon in a 7 French guiding catheter, and the Stingray LP can be trapped with a dedicated trapping balloon such as Kusabi (Kaneka, Japan) or a Trap-Liner (Teleflex) in 6 French guiding catheter. For operators who like to perform CTO intervention with a 5 French guiding, I (EBW) have demonstrated that it is feasible to perform Stingray with a 300 cm wire to walk out the Stingray balloon in a 5 French guiding catheter.[18] Therefore, the Stingray system can be used in all the commonly used CTO intervention guiding catheter French sizes in the AP region.

3.10 | Alternative wires for stick

The Stingray wire is designed specifically for the purpose of successful sting into the true lumen. However, other wires can also achieve similar results. If a high penetration force wire such as Gaia third, Gaia next third, conquest 12, or 8/40 Astato 20 or 40 (Asahi Intecc), Hornet 14 (Boston scientific) it would be reasonable to use these wires to perform stick. Some operators find a particular favorite wire to perform better than even the Stingray wire. This is mostly down to individual operator's familiarity with these high penetration force wires and what wires have already been used if there are costs concerns.

3.11 | Multi stick and swap approach

In CTOs with small distal lumen (Figure 7a), sometimes the standard stick and swap technique does not work. The multi stick and swap technique can be used to overcome this problem. A high penetration force wire

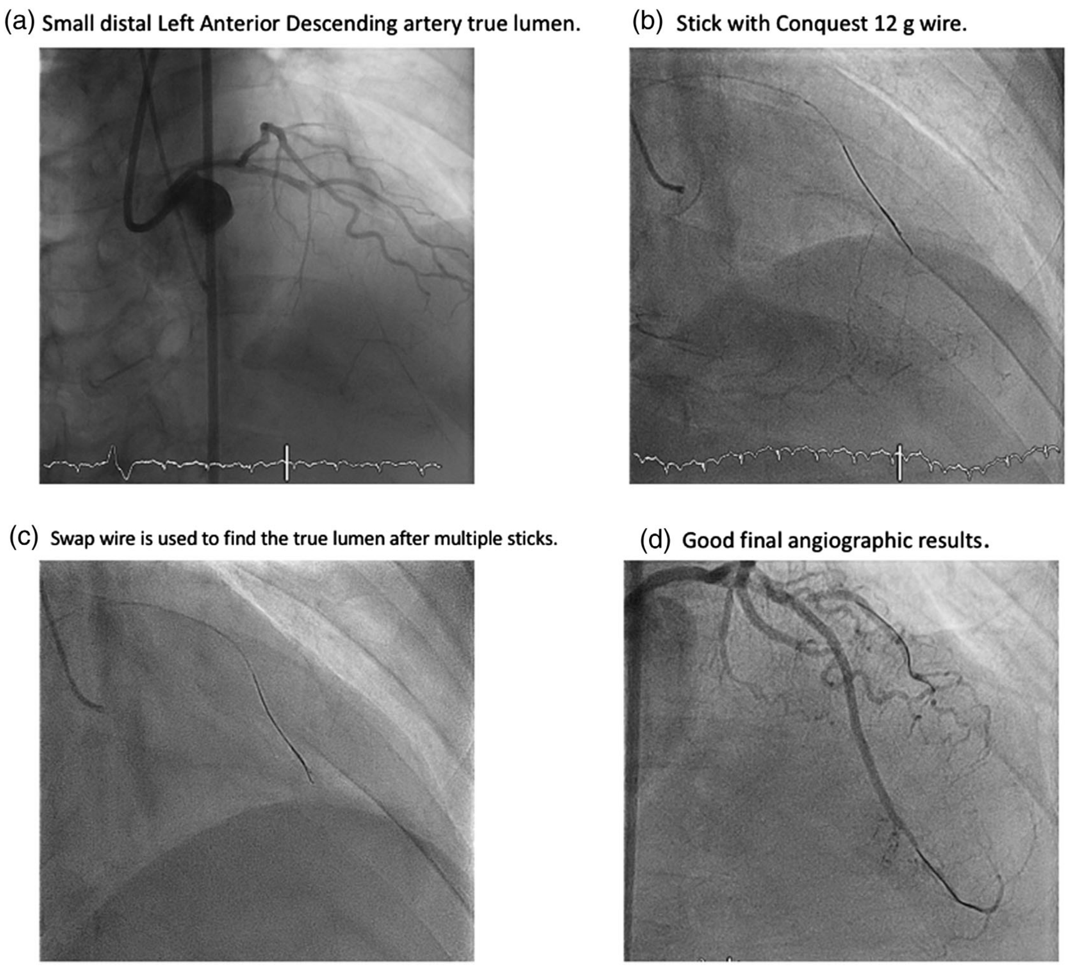

FIGURE 7 Stingray in small distal lumen. (a) Small distal left anterior descending artery true lumen. (b) Stick with Conquest 12 g wire. (c) Swap wire is used to find the true lumen after multiple sticks. (d) Good final angiographic results

such as Conquest 12 g is used to perform the stick, but when it exits toward the vessel, instead of just withdrawing it, we push it back in and out of the same stick point 3–5 times with spinning rotation on the last stick. This creates a slightly bigger "hole" or multiple holes from the stick and allows the swap wire to find these holes more easily. Then a swap wire is used to wire the same hole and to slip down into the true lumen (Figure 7b). This can produce very good angiographic results (Figure 7c).

4 | CONCLUSIONS

The APCTO Stingray algorithm clearly defines the position of CrossBoss and Stingray device in CTO intervention. It recommends a reduction in CrossBoss use, a divorce of knuckle wiring from Stingray device reserving knuckle to the long plus CTOs only and the option of Stingray versus parallel wiring when AWE fails. The algorithm gives guidance as to which option to choose depending on operator experience, device availability, cost concerns, and anatomical factors. We propose a wire based strategy for Stingray building upon the wire-based methodology practiced globally. For the majority of cases when the first antegrade wire has missed the distal true lumen, we recommend to simply use the rotational microcatheter to produce a channel to pass the Stingray balloon to perform sting without the use of knuckle wiring or CrossBoss device—so called the bougie technique. Early switch to Stingray rather than persisting with single wire redirection or parallel wire first is critical to success of Stingray. We also explained the concept of choosing a suitable reentry zone based on preprocedural CT or angiogram, routine use of stick and swap, the routine use of STRAW through the Stingray balloon, and the multi stick and swap technique. We believe these techniques and algorithm would bring Stingray into the routine practice of CTO interventionists globally. With this, many more patients may benefit from this device.

CONFLICT OF INTEREST

Dr Wu is a proctor for Boston Scientific and Abbott Vascular. He has research grant from Asahi Intecc and Orbus Neich. Dr Brilakis has consulting/speaker honoraria from Abbott Vascular, American Heart Association (associate editor Circulation), Biotronik, Boston Scientific, Cardiovascular Innovations Foundation (Board of Directors), CSI, Elsevier, GE Healthcare, InfraRedx, Medtronic, Siemens, and Teleflex; research support from Regeneron and Siemens. Shareholder: MHI Ventures. Board of Trustees: Society of Cardiovascular Angiography and Interventions. Dr Tsuchikane is consultant for Boston Scientific, NIPRO, and Asahi. Dr Kalyanasundaram is a consultant for Abbott Vascular and Boston Scientific. Dr Lo has received speaking and proctoring honoraria from Bio-Excel. Dr Lim has received research grant/travel support or speaker honorarium from Orbus Neich, Asahi Intecc, Terumo, Biosensors, Biotronik, Abbott Vascular, Aluimedica, Boston Scientific, and Keneka. Dr Harding has received honoraria for speaking from Boston Scientific, Medtronic and Asahi and acted as a proctor for Boston Scientific and Bio-excel.

ORCID

Eugene B. Wu https://orcid.org/0000-0002-1018-8866
Emmanouil S. Brilakis https://orcid.org/0000-0001-9416-9701
Hsien-Li Kao https://orcid.org/0000-0002-5278-3540
Seung-Whan Lee https://orcid.org/0000-0002-2662-5952

REFERENCES

1. Brilakis ES, Grantham JA, Rinfret S, et al. A percutaneous treatment algorithm for crossing coronary chronic total occlusions. J Am Coll Cardiol Interv. 2012;5:367-379.
2. Whitlow PL, Burke MN, Lombardi WL, et al. Use of a novel crossing and reentry system in coronary chronic total occlusions that have failed standard crossing techniques: results of the FAST-CTOs (facilitated antegrade steering technique in chronic total occlusions) trial. J Am Coll Cardiol Interv. 2012;5:393-401.
3. Maeremans J, Dens J, Spratt JC, et al. Antegrade dissection and reentry as part of the hybrid chronic total occlusion revascularization strategy: a subanalysis of the RECHARGE registry (registry of CrossBoss and hybrid procedures in France, The Netherlands, Belgium and United Kingdom). Circ Cardiovasc Interv. 2017;10:e004791. https://doi.org/10.1161/CIRCINTERVENTIONS.116.004791.
4. Christakopoulos GE, Karmpaliotis D, Alaswad K, et al. Application and outcomes of a hybrid approach to chronic total occlusion percutaneous coronary intervention in a contemporary multicenter US registry. Int J Cardiol. 2015;198:222-228.
5. Azzalini L, Dautov R, Brilakis ES, et al. Impact of crossing strategy on mid-term outcomes following percutaneous revascularisation of coronary chronic total occlusions. EuroIntervention. 2017;13:978-985.
6. Azzalini L, Dautov R, Brilakis ES, et al. Procedural and longer-term outcomes of wire-versus device-based antegrade dissection and re-entry techniques for the percutaneous revascularization of coronary chronic total occlusions. Int J Cardiol. 2017;231:78-83.
7. Amsavelu S, Christakopoulos GE, Karatasakis A, et al. Impact of crossing strategy on intermediate-term outcomes after chronic total occlusion percutaneous coronary intervention. Can J Cardiol. 2016;32:1239.e1-e7.
8. Mogabgab O, Patel VG, Michael TT, et al. Long-term outcomes with use of the CrossBoss and stingray coronary CTO crossing and re-entry devices. J Invasive Cardiol. 2013;25:579-585.
9. Rinfret S, Ribeiro HB, Nguyen CM, Nombela-Franco L, Urena M, Rodes-Cabau J. Dissection and re-entry techniques and longer-term outcomes following successful percutaneous coronary intervention of chronic total occlusion. Am J Cardiol. 2014;114:1354-1360.
10. Christopoulos G, Kotsia AP, Brilakis ES. The double-blind stick-and-swap technique for true lumen reentry after subintimal crossing of coronary chronic total occlusions. J Invasive Cardiol. 2015;27:E199-E202.
11. Smith EJ, Di Mario C, Spratt JC, et al. Subintimal TRAnscatheter withdrawal (STRAW) of hematomas compressing the distal true lumen: a novel technique to facilitate distal reentry during recanalization of chronic total occlusion (CTO). J Invasive Cardiol. 2015;27:E1-E4.
12. Tajti P, Doshi D, Karmpaliotis D, Brilakis ES. The "double stingray technique" for recanalizing chronic total occlusions with bifurcation at the distal cap. Catheter Cardiovasc Interv. 2018;91:1079-1083.
13. Harding SA, Wu EB, Lo S, et al. A new algorithm for crossing chronic total occlusions from the Asia Pacific chronic total occlusion club. J Am Coll Cardiol Interv. 2017;10:2135-2143.

14. Wilson WM, Walsh S, Hanratty C, et al. A novel approach to the management of occlusive in-stent restenosis (ISR). EuroIntervention. 2014;9:1285-1293.
15. Karacsonyi J, Tajti P, Rangan BV, et al. Randomized comparison of a CrossBoss first versus standard wire escalation strategy for crossing coronary chronic total occlusions: the CrossBoss first trial. J Am Coll Cardiol Interv. 2018;11:225-233.
16. Tsuchikane E, Kimura M, Suzuki T, et al. New re-entry device for revascularization of chronic coronary total occlusions: preliminary single Japanese center experience. J Invasive Cardiol. 2012;24:396-400.
17. Ghoshhajra BB, Takx RAP, Stone LL, et al. Real-time fusion of coronary CT angiography with X-ray fluoroscopy during chronic total occlusion PCI. Eur Radiol. 2017;27:2464-2473.
18. Wu EB, Ikari Y. Stingray balloon used in slender percutaneous coronary intervention for chronic total occlusion. J Invasive Cardiol. 2013; 25:E155-E158.

How to cite this article: Wu EB, Brilakis ES, Lo S, et al. Advances in CrossBoss/Stingray use in antegrade dissection reentry from the Asia Pacific Chronic Total Occlusion Club. *Catheter Cardiovasc Interv*. 2020;96:1423–1433. https://doi.org/10.1002/ccd.28607