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Letter to the Editor **· Open Access ·**

Steerable microcatheters for complex percutaneous coronary interventions in octogenarians: from Venture to Swift Ninja

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Octogenarians represent the fastest growing group of patients undergoing percutaneous coronary intervention (PCI), now constituting more than one in five patients treated with PCI in real-world practice.[1,2] Comparing coronary lesion characteristics of patients aged < 80 years to those ≥ 80 years undergoing PCI, the octogenarians have a higher prevalence of calcified and ostial lesions, tortuous coronary anatomy, multi-vessel disease and left main stem (LMS) stenosis.[3] Furthermore, they often have greater ischemic burden than their younger counterparts, suggesting an even greater benefit following revascularization.[4] Although the very elderly are at an increased cardiovascular mortality risk, the proportion of patients who receive revascularization declines as they age beyond the eighth decade, despite its proven prognostic benefit in this age group.[5,6] Consequently, the American Heart Association has developed guidelines to highlight the importance of these treatment options in the very elderly.[7] However, despite this evidence, they are frequently under-represented in clinical revascularization trials and historically there has been a degree of physician reluctance in referring them for PCI procedures, with perceptions of disappointing outcomes, low success and high complication rates.[1–3] Several issues have contributed to this, including the tendency for older patients with ischemic heart disease to present late, with atypical symptoms or non-diagnostic electrocardiograms (ECGs),[8] and reservations regarding their procedural risk-to-benefit ratio, due to shorter life expectancy, presence of comorbidities and complex coronary vasculature.

Nowadays, the continuous progress in guidewire, balloon and stent technology, as well as the growing operator experience has significantly increased the procedural success rate of PCI in octogenarians. Despite this, certain anatomical conditions, such as severe vessel tortuosity or angulation, especially in ostial calcified lesions, continue to represent a real challenge for the interventionist, by making target vessel and lesion access difficult and vessel preparation tricky.[9] Especially bifurcation lesions continue to represent technical difficulties that are accentuated in certain anatomical conditions, such as extreme vessel tortuosity, extreme angulation of the origin of the side branch (SB) in relation to the main vessel, or severe stenosis in both vessels, since they can prevent access and, as a result, treatment of the SB.[10]

In this case series, we describe two cases of complex PCIs in octogenarian patients, where the use of steerable coronary microcatheters and other several adjunctive tools were used to succeed, and we highlight the practical challenges of intervening in such complex coronary anatomy.

Case 1. An 88-year-old gentleman, non-diabetic, hypertensive was admitted in our centre due to typical stable angina CCS class III over the last 6 months. His coronary angiogram (Figure 1) demonstrated: right coronary artery (RCA): dominant vessel with moderate to severe disease just before the crux (white arrow) and diffuse disease in the posterior descending artery (Figure 1A); LMS: there is at least moderate distal calcified disease; left anterior descending (LAD): there is a long segment of moderate calcific disease proximally with severe disease in a large third diagonal (D3) branch (Figure 1C). There is also a large calibre high rising D1 which has a severe ostial calcified lesion (Figure 1B); Circumflex (Cx): non-dominant and unobstructed (Figure 1B). He was subsequently discussed in our multidisciplinary Heart Team meeting and it was decided to consider complex stage multi-vessel PCI.

PCI to RCA (Figure 2) was carried out using a 6F JR4 guiding catheter (GC) and a Guideliner^{TM} extension catheter (Vascular Solutions, Maple Grove, MN) support with de-

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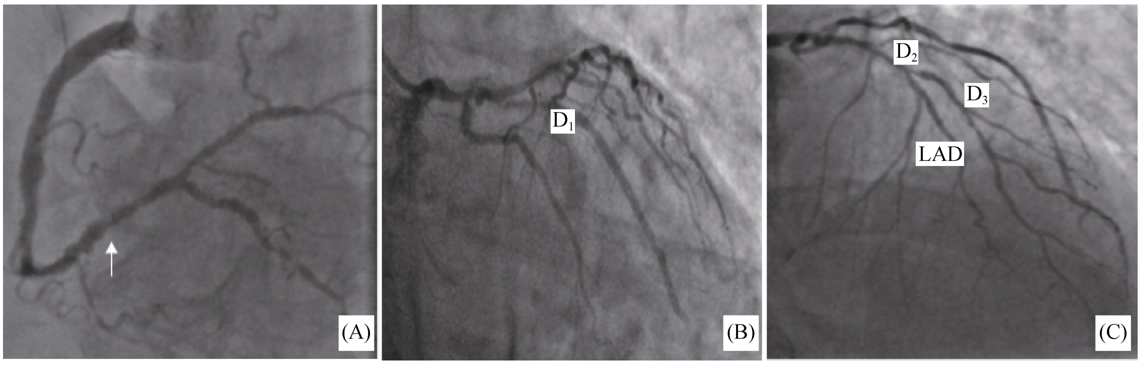


Figure 1. Coronary angiogram. Right coronary artery: dominant vessel with moderate to severe disease (white arrow) and diffuse disease in the posterior descending artery (A); left main stem: at least moderate distal disease (B, C); left anterior descending artery: long segment of moderate calcific disease proximally with proximal severe disease in a large diagonal branch (D3) (C). High rising diagonal branch which has a severe ostial lesion (D1) (B); Circumflex: non-dominant and unobstructed (B).

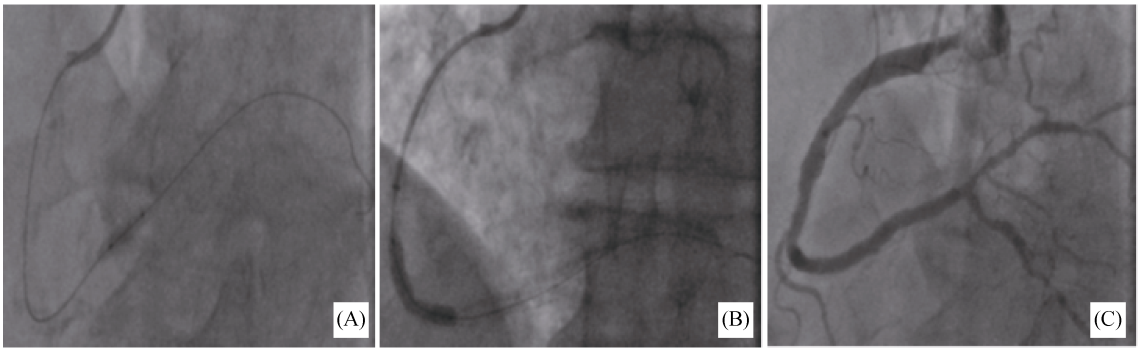


Figure 2. Percutaneous coronary intervention of mid right coronary artery stenosis. A 6F JR4 GC was used and a choice PT wire was placed in the distal RCA (pre-dilatation was performed using a 3.0 × 12 mm semi-compliant balloon (A)). Stent delivery proved difficult and required the use of Guideliner extension catheter support (B). Two Resolute Onyx DES measuring 3.5 × 34 mm and 3.5 × 26 mm were deployed in an overlapping fashion to cover the underlying diseased segment (B, C). An excellent final angiographic result was achieved (C). DES: drug-eluting stent; RCA: right coronary artery.

ployment in an overlapping fashion of two Resolute Onyx (Medtronic) drug eluting stents (DES) 3.5 × 34 mm and 3.5 × 26 mm to cover the underlying diseased segment post-dilated with 4.0 × 15 mm and 3.75 × 20 mm non-compliant balloons (NC) respectively. A 12-month course of clopidogrel in addition to lifelong aspirin was recommended.

PCI to LAD (Figure 3) was carried out two weeks later. The LMS was engaged using a 7F Q3.5 GC (Figure 3A). A Sion blue wire (Asahi) was placed in the distal D3 SB and exchanged with a rota wire through a Fine cross microcatheter (Terumo, Japan). The distal LAD was not treated given its relatively small calibre. The disease in the distal LMS and proximal to mid-LAD was de-bulked using a 1.5 mm rota bur (Figure 3B) of the Rotablator™ (Boston Scientific). Sequential pre-dilatation was performed using a 2.0 × 15 mm NC balloon. Stent delivery proved difficult and required the use of additional Guideliner™ catheter support. A Resolute Onyx 2.5 × 38 mm DES was deployed from the mid-LAD extending into the D3, post-dilated with a 2.75 × 15 mm NC balloon (Figure 3C). A good angiographic result was obtained (Figure 3D). The diseased segment in the proximal LAD was dilated using a 2.5 × 20 mm balloon. Despite the use of a variety of wires we were unable to wire the high rising D1 SB due to a combination of an awkward origin and ostial calcification. We elected to abandon the procedure without any complications and bring the patient in a different time, with a plan to use a steerable microcatheter.

The LMS was engaged again using a 7FQ3.5 GC (Figure 4). There was evidence of a dissection (white arrow) in the proximal LAD (Figure 4A). The D1 was wired using a Whisper MS (Abbott) guidewire with additional support provided by a steerable Venture Wire Control (VWC) microcatheter (black arrow) (Figure 4B). Lesion crossing with the VWC catheter was achieved in about two minutes, without any device-related complications. Balloon delivery proved

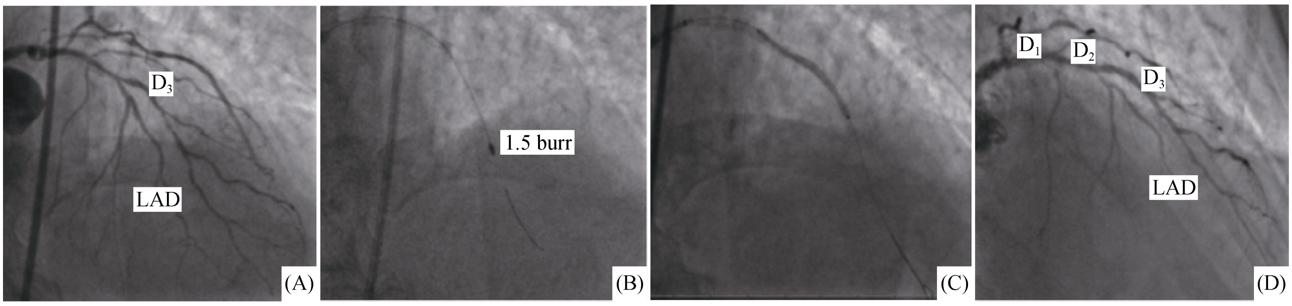


Figure 3. Percutaneous coronary intervention of the left anterior descending and third diagonal branch stenosis. A Sion blue wire was placed in the distal D3 side branch and exchanged with a rota wire through a Fine cross microcatheter (A & B). The distal LAD was not treated given its relatively small calibre (A). The disease in the distal LMS and proximal to mid-LAD was de-bulked using a 1.5mm rota bur (B). A Resolute Onyx 2.5 × 38 mm DES was deployed from the mid-LAD extending into the D3, post-dilated with a 2.75 × 15 mm NC balloon (C). A good angiographic result was obtained (3D). D: diagonal; DES: drug-eluting stent; LAD: left anterior descending; LMS: left main stem; NC: non-compliant.

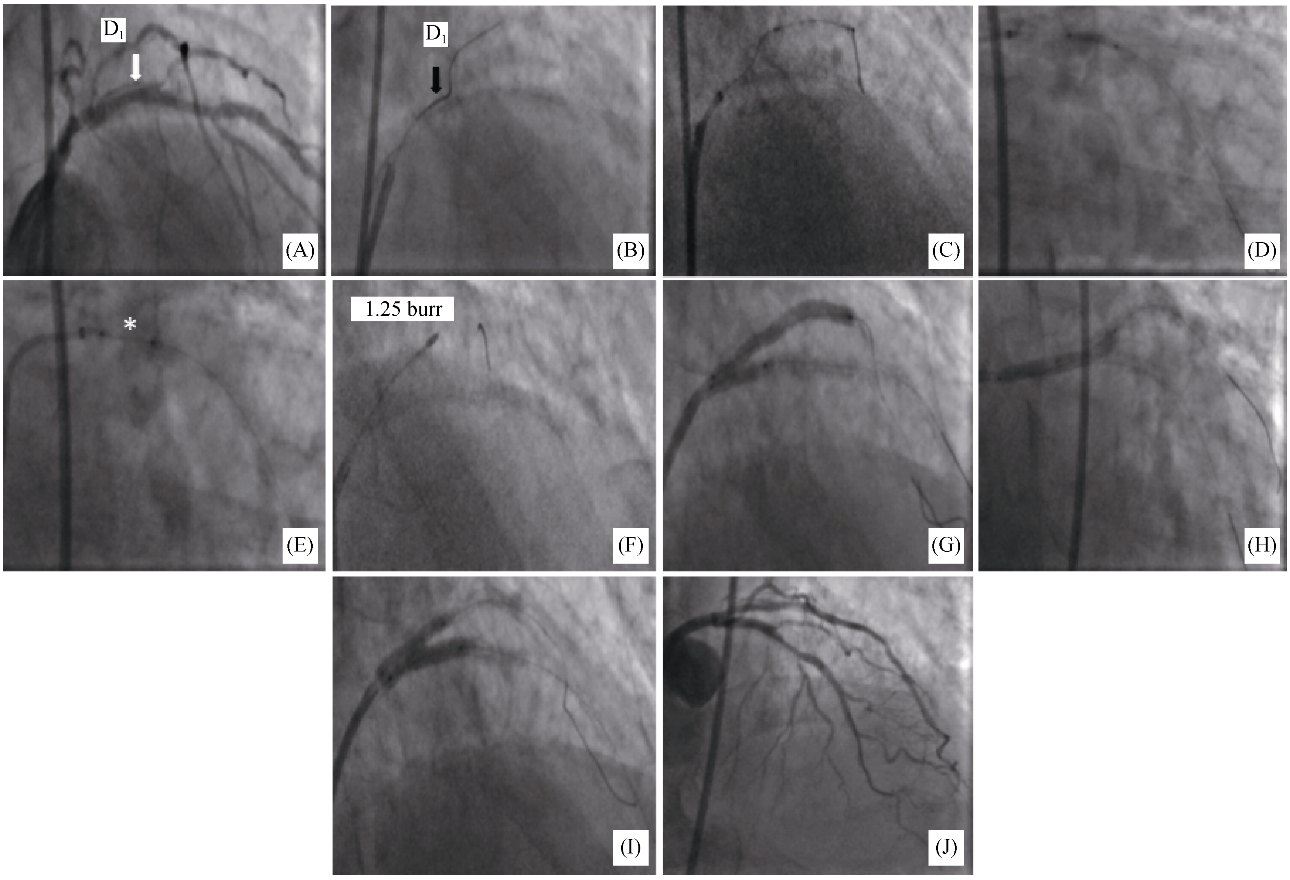


Figure 4. Percutaneous coronary intervention of first diagonal, proximal left anterior descending and left main stem stenosis. There was evidence of a dissection (white arrow) in the proximal LAD (A). The high rising D1 was wired using a Whisper MS wire with additional support provided by a steerable VWC micro-catheter (black arrow) (B). Balloon delivery proved difficult due to the awkward angulation of this vessel and significant vascular calcification. A Guideliner extension catheter was used (C) and a series of balloon dilatations performed (C, D). Rotational atherectomy with 1.25 burr used (F) to de-bulk the undilated (white asterisk, E) segment of D1 disease. A Resolute Onyx 2.75 × 38 mm DES was deployed in the D1 (G). The disease in the LMS was dilated using a 2.5 × 15mm balloon. A further Resolute Onyx 3.0 × 34 mm DES was deployed from the ostium of the LMS into the previously deployed stent in the mid-LAD (H). The D1 was then re-wired using a Pilot 50 wire. The stent struts were dilated using a 1.5 × 12 mm followed by 2.5 × 12 mm balloon. The diagonal stent was post dilated using a 3.0 × 20 mm NC balloon. The LMS stent was post dilated using a 3.5 × 20 mm NC balloon. A final simultaneous kissing inflation was performed at the bifurcation using a 3.5 × 20 mm NC balloon in the LMS into LAD and 3.0 × 20 mm NC balloon in the LMS into D1 (I). A good final angiographic result (J) was obtained. D: diagonal; DES: drug-eluting stent; LAD: left anterior descending; LMS: left main stem; NC: non-compliant; VWC: venture wire control.

difficult due to the awkward angulation of this vessel and significant calcification. A Guideliner extension catheter was used and a series of pre-dilatations performed using a 1.0 × 15 mm, 1.25 × 10 mm, 2.0 × 15 mm and finally 2.5 × 12 mm semi-compliant balloon (Figure 4C & D). Although the flow into this vessel improved, there was an undilatable segment of disease in the proximal portion (white asterisk) (Figure 4E). We therefore elected to proceed to rotational atherectomy to de-bulk this segment of disease. A Fine Cross micro-catheter was placed in the diagonal SB. This was used to exchange the Whisper MS wire to a rota wire. The lesion was de-bulked using a 1.25 mm rota burr (Figure 4F). A further balloon dilatation was performed using a 2.5 × 20 mm semi-compliant balloon. A Resolute Onyx 2.75 × 38 mm DES was deployed in the diagonal artery (4G). The disease in the LMS was dilated using a 2.5 × 15 mm balloon. A further Resolute Onyx 3.0 × 34 mm DES was deployed from the ostium of the LMS into the previously deployed stent in the mid-LAD (4H). The diagonal artery was then re-wired using a Pilot 50 wire (Abbott). The stent struts were dilated using a 1.5 × 12 mm followed by 2.5 × 12 mm balloon. The diagonal stent was post dilated using a 3.0 × 20 mm NC balloon. The LMS stent was post-dilated using a 3.5 × 20 mm NC balloon. A final simultaneous kissing inflation was performed at the bifurcation using a 3.5 × 20 mm NC balloon in the LMS into LAD and 3.0 × 20 mm NC balloon in the LMS into diagonal artery (Figure 4I). A good final angiographic result (Figure 4J) was obtained.

Case 2. An 86-year-old lady, with previous coronary artery bypass grafting in 2010 [left internal mammary artery (LIMA) to LAD and saphenous vein graft (SVG) to Cx], paroxysmal atrial fibrillation and moderate to severe aortic stenosis with moderate left ventricular systolic dysfunction was admitted in our centre due to typical stable angina CCS class III over the last three months. Diagnostic coronary angiography demonstrated patent LIMA to LAD, occluded SVG to Cx, and blocked dominant RCA not grafted. She was subsequently discussed in our multidisciplinary Heart Team meeting and it was decided to consider PCI to Cx and transfemoral transcatheter aortic valve implantation.

A 7F AL1 GC gave good support (Figure 5). There was evidence of two severe calcified lesions proximally (white arrows) in a big angulated Cx (Figure 5A). Wiring the Cx proved very difficult, due to significant vessel angulation and calcification. The use of the SwiftNinja microcatheter (Merit Medical, West Jordan, UT, USA) enabled us selective Cx catheterisation (Figure 5B) and wiring with a Gaia 1st wire (Asahi) (Figure 5C). We then exchanged to a Corsair microcatheter (Asahi) which crossed 2/3 of the proximal Cx lesion facilitated by an anchoring LAD technique

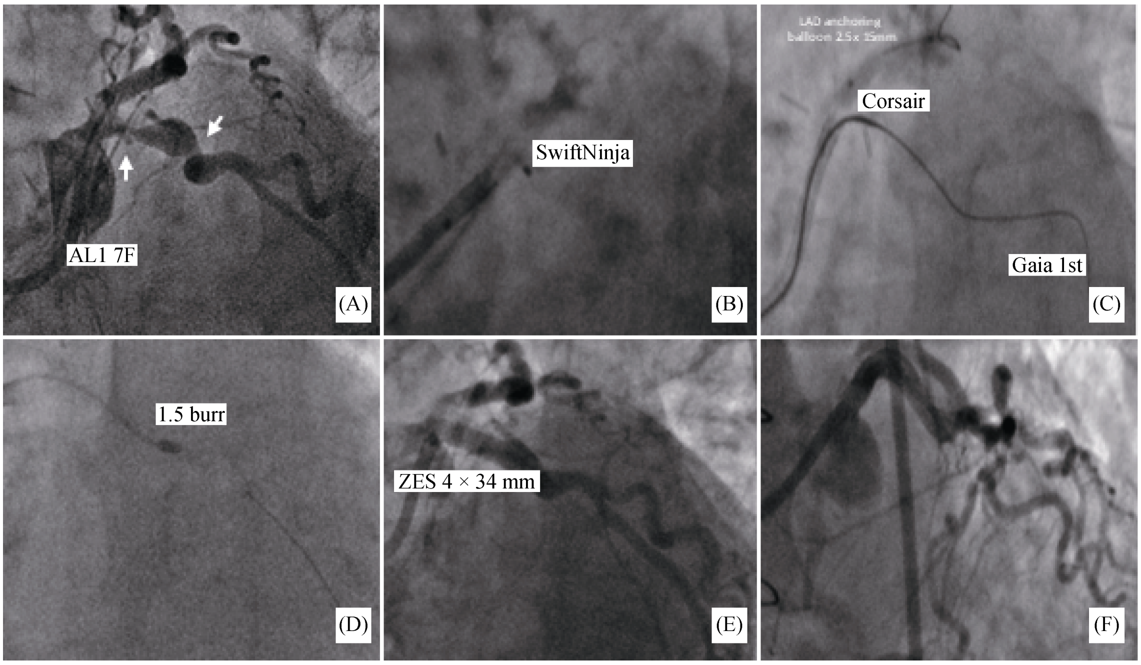


Figure 5. Percutaneous coronary intervention of proximal and mid circumflex stenosis. 7F AL1 GC gave good support. Evidence of two severe calcified lesions (white arrows) in a big angulated Cx non-grafted vessel (A). SwiftNinja microcatheter enabled selective Cx catheterisation (B) and wiring with a Gaia 1st wire (C). Exchanged to a Corsair microcatheter which crossed 2/3 of the proximal Cx lesion facilitated by anchoring technique (C). Rotational atherectomy with 1.5 burr to modify both lesions (D). Following balloon predilation, a ZES 4 × 34 mm was implanted (E) with excellent angiographic result (F). Cx: circumflex; ZES: zotarolimus-eluting stent.

(Figure 5C). Rotational atherectomy with 1.5 burr to modify both Cx lesions (Figure 5D). Following balloon predilation, a ZES 4 × 34 mm was implanted (Figure 5E) and post dilated with a 4.0 × 15 mm NC balloon with excellent angiographic result (Figure 5F). A 12-month course of clopidogrel in addition to lifelong rivaroxaban was recommended.

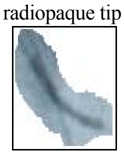
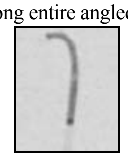
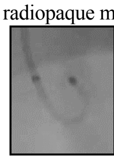
Heavily calcified coronary stenosis has traditionally represented a very challenging scenario for octogenarians PCI. This was mostly due to the difficulty in adequately dilating these lesions and/or to the inability to deliver and implant stents appropriately, which is often associated with high rates of procedural complications and suboptimal long-term clinical outcomes.[11] Furthermore, the octogenarians have a higher prevalence of tortuous coronary anatomy, making lesion access very difficult.[1–3] Thanks to dedicated steerable coronary micro-catheters and to other adjunctive devices like rotational atherectomy, the vessel and lesions access has become feasible and the treatment of most fibrotic and heavily calcified stenoses predictable and safe[12] as we described in our two cases.

The VWC steerable micro-catheter was an extremely useful adjunct in our case to access the D1 (Figure 4). It is a low profile, 6F compatible, flexible, torqueable, support catheter with a mechanically activated atraumatic deflectable tip that can bend up to 90° to steer the guidewire in the desired direction and is available in rapid exchange or over-the wire (OTW) versions. The flexible three-layered coiled torque shaft provides precise controlled torque translation from proximal rotating hub to distal tip, allowing this to be precisely directed. The VWC catheter system can be used with all approved 0.014" guidewires (Table 1).[13,14] In our first case (Figure 4B), the distal radio-opaque tip of the catheter was deflected to the desired angle to allow guidewire advancement to the target vessel/lesion and to provide simultaneous support for lesion crossing. Following successful lesion negotiation, the VWC catheter was returned to its straight configuration and removed.

Despite its use from 2008 in the market, in 2017 Teleflex subsidiary Vascular Solutions recalled VWC catheters after discovering a manufacturing defect that could cause coronary embolisms. The company concluded that there is a potential for excess material used to manufacture the catheter to be present within the inner lumen of the distal catheter tip. It is possible that the excess material may separate from the catheter during a procedure, posing a potential risk of an embolism to the patient.[15]

Therefore, use of different microcatheters (steerable or angled tip) is mandatory for such angulated vessels/lesions. SuperCross™ Microcatheter (Vascular Solutions, Inc., Minneapolis, Minnesota 55369, USA) is an OTW catheter, which provides support in tortuous anatomy and gaining SB access (Table 1). It is intended to be used in conjunction with steerable guidewires to access discrete regions of the coronary and/or peripheral vasculature. Dual coil design provides excellent torque response, flexibility, pushability and kink resistance. Embedded platinum/tungsten coil provides enhanced visibility along the entire angled tip. Full-length lumen facilitates sub-selective delivery of contrast or therapeutic agents. It may be used to facilitate placement

Table 1. Steerable and angle tip microcatheters.

	Venture wire control	SuperCross	SwiftNINJA
Type of microcatheter	Steerable Available in RX, and OTW	Fixed curve OTW	Steerable OTW
Tip of microcatheter	Deflects up to 90°*	Angled in 45°, 90° and 120°*	Deflects up to 180°*
Guidewire compatibility	0.014"	0.014"	0.014"
Guide catheter compatibility	6F	6F	6F
Working length in cm	145 (RX), 140 (OTW)	130 and 150	125
RX segment length in cm	30	n/a	n/a
Radiopacity	8 mm radiopaque tip length 	Along entire angled tip 	Two radiopaque markers 
Hydrophilic coating length in cm	Distal 24 (RX), distal 45 (OTW)	Distal 80	Distal 80
Inner diameter	0.018" (0.46 mm)	Distal 0.017" (0.43 mm) Proximal 0.018" (0.46 mm)	0.021" (0.54 mm)
Distal portion outer diameter	2.2F (0.74 mm)	2.4F (0.71 mm)	2.4F (0.80 mm)

*Curve angle is the angle of movement relative to its straight axis i.e. the bend angle; RX: rapid exchange; OTW: over-the-wire.

and exchange of guidewires and other interventional devices. Hydrophilic coating is present on the distal 80 cm for angled tip versions and 40 cm for the straight and flexible tip versions. It is available in multiple tip configurations (straight, flexible and angled 45°, 90° 120°, 90° XT tip versions designed to direct wire placement in bifurcated vessels).

The steerable microcatheter SwiftNINJA, which has a remote-controlled flexible tip manipulated using a dial in the handgrip, was recently developed and delivered to the market (Table 1). This device enables the user to change the angle of the microcatheter tip manually and makes selective catheterisation easier as demonstrated in our second case. It can also be used for coil embolization. It is currently the most advanced and only 180° articulating coronary and peripheral vascular microcatheter on the market today.[16] Unlike any other support catheter, can manipulate the distal tip. This manipulation of the distal tip can be useful in peripheral intervention, particularly below the knee, but also in complex coronary interventions, as demonstrated in our case described. The SwiftNINJA™ has a steering dial located proximally on the grip, which enables the operator to have optimal control of the direction of the 2.4F steerable tip, up to 180° in opposing directions. Once the desired direction of the steerable tip is determined, the steering dial can be locked with the dial stopper to maintain the intended curve shape.

In conclusion, PCI in octogenarians can be challenging due to adverse coronary vasculature. The use of steerable microcatheters may turn procedural failure into success.

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