ESC European Society of Cardiology
European Heart Journal - Case Reports
doi:10.1093/ehjcr/ytab181

CASE SERIES
Coronary heart disease

Case series of iatrogenic coronary stent avulsion: a rare complication with varied management strategies

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Received 14 December 2020; first decision 8 January 2021; accepted 21 April 2021

Background Coronary stent avulsion is a rare, infrequently reported complication of percutaneous coronary intervention (PCI) with no consensus on management options.

Case summary This case series presents three descriptions of iatrogenic coronary stent avulsions, and three different bailout management strategies. All patients presented with acute coronary syndrome and required PCI. In the first case, a freshly implanted stent was entrapped in a coronary guidewire and avulsed upon withdrawal of the wire into the aortic sinus. In the second case, a staged procedure to implant a new stent was complicated by stent dislodgement and entanglement with a recently implanted stent leading to avulsion of both stents into the aortic sinus and resultant dissection to the coronary arteries. In the third case, following a successful stent implantation, the tip of the coronary guidewire was bound to the proximal edge of the stent resulting in avulsion of the newly implanted stent into the ascending aorta upon retraction of the wire at the end of the procedure. The first two patients were managed percutaneously, and the third surgically. All patients have had acceptable technical and clinical outcomes.

Discussion In the absence of a consensus on best bailout management strategy, we discuss the mechanisms of and the potential management options for this rare, but serious, complication.

Keywords Stent avulsion • Complications • Stent damage • Case series

Learning points

- Iatrogenic avulsion of coronary stent is a very rare complication of percutaneous coronary intervention with only a handful of descriptions in the literature.
- There are essentially only three strategies for management: (i) stent again crushing the avulsed stent *in situ*. (ii) Percutaneous retrieval and re-stenting. (iii) Surgical bailout.
- Interventional cardiologists need to be prepared to tailor the retrieval option based on the anatomy, location of the avulsed stent, and deliverability of retrieval systems.

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Handling Editor: Aref Bin Abdulhak
Peer-reviewers: Felice Gragnano and Alessia Azzano
Compliance Editor: Reshman Amin
Supplementary Material Editor: Anthony Paulo Sunjaya

Introduction

Iatrogenic avulsion of a coronary stent during percutaneous coronary intervention (PCI) is rare.[1] In this complication, deployed stents are displaced from the original implantation site due to interaction with other intracoronary devices such as coronary guidewires, rotational atherectomy burrs, orbital atherectomy crowns, aspiration catheters, or cutting balloons becoming entrapped in part of the stent, with their subsequent removal resulting in the unintentional avulsion of the stent.[1–4] Unsurprisingly, given its infrequent occurrence, there is no consensus as to the best bailout management strategy for this complication.

We describe three cases of iatrogenic stent avulsion of recently implanted (non-endothelialized) coronary stents. Each scenario was managed differently (two percutaneously and one surgically) but all have been associated with acceptable technical and clinical outcomes. This article therefore presents three different options for the management of iatrogenic coronary stent avulsion and reviews the literature on the mechanisms and bailout options of this rare complication.

Timeline

Case presentation

Case 1—partial retrieval and pragmatic percutaneous approach

A 77-year-old gentleman presented with chest pain and was diagnosed with a non-ST-elevation acute coronary syndrome (NSTE-ACS). His background included PCI to the left anterior descending (LAD) and circumflex (Cx) arteries performed approximately a year prior. Examination was unremarkable. His high sensitivity troponin I was raised at 4539 ng/L (<34 ng/L) and his standard 12-lead electrocardiograms were consistent with a threatened posterior infarct with transient anterior ST depression and a dominant R wave in the anterior chest leads. He was loaded with dual anti-platelet therapy (DAPT) with aspirin 300 mg and clopidogrel 600 mg and admitted to the cardiology ward for monitoring.

Coronary angiography from the right radial artery (RRA) with an EBU 3.5 6 Fr guide catheter demonstrated the stents in the LAD and Cx. The culprit for his presentation was thought to be the Cx which had a hazy appearance at the ostium (*Figure 1A*). Optical coherence tomography (OCT) of the Cx confirmed a severe stenosis proximally at the inlet to the previously implanted stent. There was also

	Case 1	Case 2	Case 3
Admission (Day 0)	Non-ST-elevation acute coronary syndrome (NSTE-ACS) diagnosed and dual anti-platelet therapy (DAPT) loading undertaken	Anterior ST-elevation myocardial infarction undergoing primary percutaneous coronary intervention (PCI) to left anterior descending artery (LAD) and subsequent admission to coronary care unit	NSTE-ACS diagnosed and DAPT loading undertaken
Day 1	PCI to LAD/circumflex artery (Cx) undertaken Complicated by stent avulsion managed percutaneously with snaring and a crush of protruding stent	Patient stable	Coronary angiography demonstrated triple vessel disease
Day 2	Patient stable	Patient stable	Discussion with patient re: management options [PCI vs. coronary artery bypass grafting (CABG)] reached a decision of undertaking PCI
Days 3–5	Patient discharged	Staged PCI to Cx undertaken. Complicated by avulsion of LAD stent, managed by percutaneous snaring	PCI to LAD/Cx was uncomplicated
Days 6–10		Patient stable, and discharged after 48 h of observation	Patient was stable for 48 h, and therefore discharged awaiting an outpatient staged procedure to the right coronary artery (RCA) chronic total occlusion (CTO)
Days 11–30			Staged PCI to RCA CTO undertaken, complicated by stent avulsion resulting in a referral for a CABG
2–11 months	Rehabilitation	Rehabilitation	Recovery from CABG in cardiac intensive care and subsequent discharge home for rehabilitation
12 month+	Patient well on follow-up with no recurrence of symptoms	Patient well on follow-up with no recurrence of symptoms	Patient well on follow-up with no recurrence of symptoms

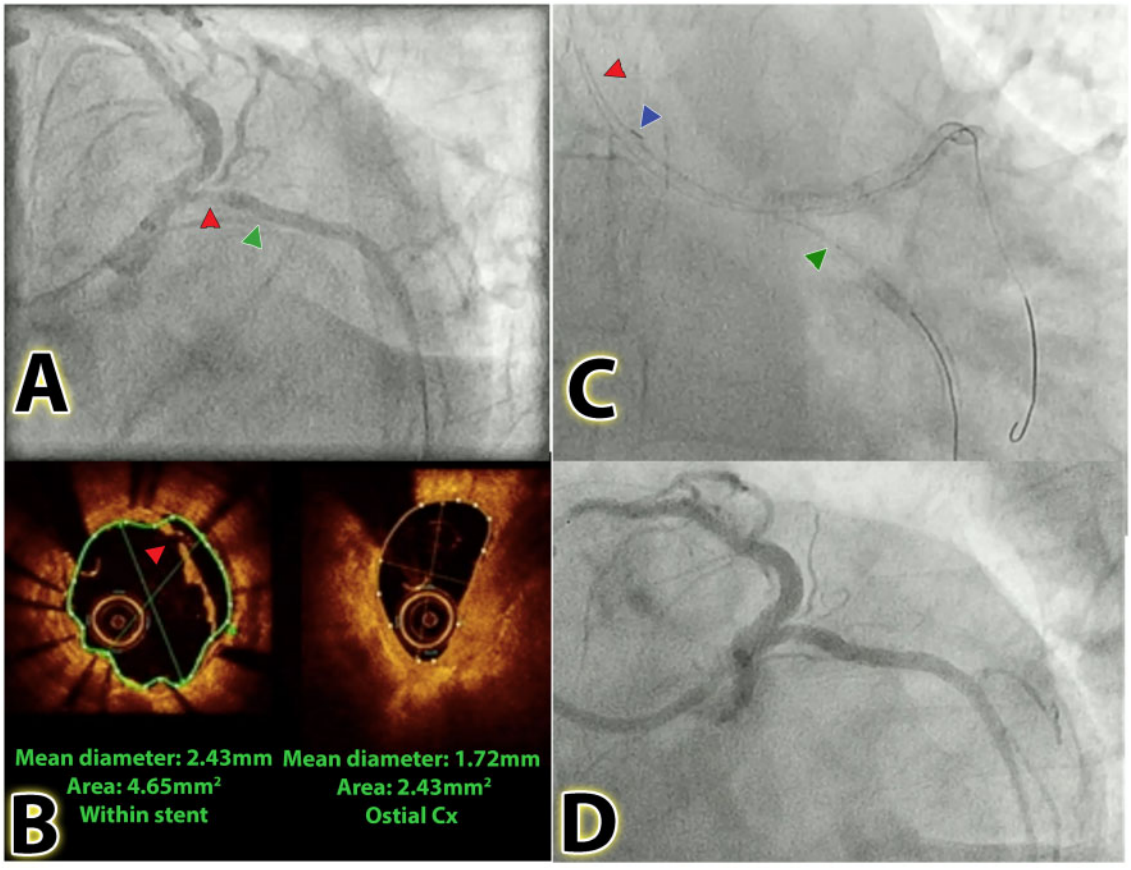
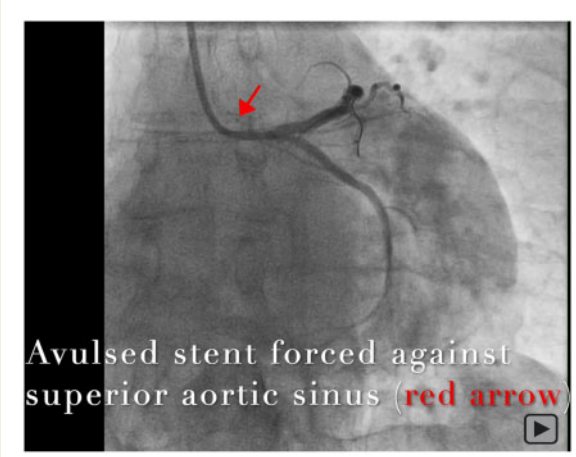


Figure 1 (*A*) Coronary angiography (left anterior oblique caudal view) demonstrates existing stent in circumflex artery (green arrow head) and a hazy circumflex artery ostium (red arrow head). (*B*) Optical coherence tomography of the circumflex artery demonstrates neoatheroma with plaque rupture and thrombus (red arrow head) within the existing stent (left), and severe ostial circumflex artery disease (right). (*C*) Avulsed stent is seen protruding into the aortic sinus. The radio-opaque tip of the VersaTurn 0.014″ guidewire (Abbott, IL, USA) is marked with the blue arrow head, the unravelled stent red arrow head, with the newly implanted stent to cover the circumflex artery ostium no longer there (green arrow head). (*D*) End result in left anterior oblique caudal angiographic view demonstrates good end angiographic result.

evidence of neoatherosclerosis within the Cx stent along with evidence of plaque rupture and adherent thrombus (*Figure 1B*). Furthermore, there was concern about the inlet to the LAD stents which appear under-expanded in some angiographic projections. OCT assessment of the LAD revealed an under-expanded proximal LAD stent with inlet disease with a minimum luminal area of 3.7 mm^2, which is considerably less than the accepted OCT reference value of a minimum of 4.5 mm^2 described in the literature.[5,6] A decision was made to treat both the proximal LAD and Cx, and this necessitated a left main (LMS) drug-eluting stent (DES) procedure, with stent sizing determined by both OCT and angiography. The angulated anatomy, and disparity in vessel size meant a double kiss (DK) crush strategy was chosen to address the LMS bifurcation.[7,8]

After preparation of both the LAD and Cx with a scoring balloon (ScoreFlex, OrbusNeich, Hong Kong), a Xience Sierra 3.0 mm × 23 mm DES (Abbott, IL, USA) was implanted without difficulty into the proximal Cx protruding back into the LMS, and overlapping the previously implanted Cx stent distally. This new stent was then 'crushed' in the LMS with a 3.5 semi-compliant balloon as the first step of the DK crush bifurcation strategy.[7,8] In attempting to re-wire the Cx stent (to facilitate the first kiss of DK crush) with a VersaTurn 0.014″ wire (Abbott, IL, USA), the wire became entrapped in the stent and could not be removed.

Attempts were made to free the wire with a small balloon then a Corsair (Asahi, Japan) microcatheter, but these were unsuccessful. Forceful retraction of the guidewire through the microcatheter caused the wire to fracture but also inadvertent avulsion the newly implanted stent from the Cx. The stent 'unravelled'. Its distal portion remained in the proximal Cx, but the stent became stretched and deformed, being pulled through the LMS, with part of the stent apparatus protruding into the aortic sinus (*Figure 1C*). Filaments of the fractured wire remained entrapped in the portion of the avulsed stent that protruded into the aorta. The EBU guide and intracoronary wires were removed. The access was upgraded to a 7 Fr sheath, and a 7 Fr JR4 catheter was used to introduce a three-loop retrieval system (EN Snare, Merit, UT, USA). This allowed removal of the



Video 1 Once the left main stent bifurcation stenting in Case 1 was complete, the avulsed stent that protruded into the aorta was forced against the superior aortic sinus wall using the tip of the guide catheter which was fixed in the coronary with a balloon. This allowed for shortening of the protruded segment back into the left main stent.

entrapped fractured wire filaments from the deformed avulsed stent that protruded into the aorta. Despite the disruption of the stent apparatus and obvious trauma to the proximal left coronary artery, Thrombolysis in Myocardial Infarction III flow persisted.

A pragmatic decision was taken to continue with PCI to the LMS this time employing a mini-crush technique to the bifurcation.[9] A 7 Fr EBU 3.5 guide was reintroduced to the LMS ostium. Wires were advanced without trouble to both the LAD and Cx. Pre-dilatation of both the LAD and Cx was achieved with 1:1 sized NC balloons. Next, a new Xience Sierra 3.0 mm × 23 mm DES (Abbott, IL, USA) was implanted into the Cx, with minimal protrusion of the proximal stent into the LMS. This was then followed by the 'mini-crush' of the new stent and the implantation of a second Xience Sierra 3.5 mm × 15 mm DES (Abbott, IL, USA) from the LAD back to the ostium of the LMS. This LAD/LMS stent crushed the intracoronary portion of the deformed avulsed stent against the wall of the LMS coronary artery. After post-dilatation with a 4.5 mm non-compliant balloon, and kissing balloon post-dilatation of the LMS bifurcation, the end result within the coronaries was angiographically satisfactory (*Figure 1D*). Once the LMS bifurcation stenting was complete, the avulsed unravelled stent that protruded into the aorta was forced against the superior aortic sinus wall using the tip of the guide catheter which was fixed in the coronary by an inflated semi-compliant balloon (*Video 1*) (a technique which has previously been described in the literature for protruding stent apparatus[10]). The procedure was optimized by Intravascular Ultrasound (IVUS) with a 5.0 mm non-compliant balloon to the LMS. The stent is fully expanded and opposed to the LMS (*Video 1*). The patient was discharged on the same DAPT regimen given on admission, which was felt to be sufficient in the context of the technical outcome. Indeed, the patient has been followed up for 24 months with no recurrence of symptoms.

Case 2—complete percutaneous retrieval

A 73-year-old man presented to our cardiac centre with an anterior ST-elevation myocardial infarction accompanied by chest pain. He had a background history of hypertension, smoking history, and hyperlipidaemia. Following a brief unremarkable examination and DAPT loading with aspirin 300 mg and prasugrel 60 mg, he underwent immediate angiography demonstrating three-vessel coronary artery disease with the culprit lesion located in the LAD (*Figure 2A*). He underwent successful stenting to the proximal LAD with a Xience Sierra 3.0 mm × 33 mm DES (Abbott, IL, USA). The proximal most stent struts of this stent protruded back across the ostium of the Cx. Post-procedure, the patient was admitted to the coronary care unit for observation and after discussion with the patient a plan to perform staged PCI to the Cx and right coronary artery (RCA) was reached.

Some days later, the patient returned to the catheterization laboratory where he had uncomplicated PCI to the RCA with a Xience Sierra 3.5 mm × 28 mm DES. Following this, attempts were made to treat the Cx. Through a 6 Fr EBU 3.5 guide catheter, a Sion Blue (Asahi, Japan) wire was placed in the atrioventricular (AV) Cx and a second Sion Blue was placed in the first obtuse marginal (OM) branch (*Figure 2B*). The AV Cx was treated with an Agent drug-eluting balloon, and the OM was prepared with a semi-compliant balloon. Next, a Xience Sierra 2.5 mm × 38 mm DES (Abbott, IL, USA) was advanced into the OM branch, but resistance was felt as the stent crossed the proximal struts of the previously implanted LAD stent. Upon attempting to retract the stent it was dislodged from the balloon catheter. Furthermore, the dislodged stent was now entangled within the recently implanted LAD stent which was avulsed from the LAD. This stent was deformed with its distal portion remaining in the LAD but the proximal half of the stent being distorted and stretched through the LMS and protruding back into the aortic sinus from the LMS ostium. The proximal part of the LAD stent which was now in the aortic root was bound to the dislodged Xience Sierra 2.5 mm × 38 mm DES (*Figure 2C*).

At this stage, the guide catheter and wires were removed. The RRA access and EBU 3.5 guide catheter were upgraded to 7 Fr, and a three-loop snare (EN Snare) was introduced to remove the dislodged stent from the aortic root (*Figure 2D*). However, the dislodged stent and the avulsed deformed previously implanted LAD stent apparatus were bound together, and so when the snare was retracted the LAD stent apparatus was removed 'en bloc' with the dislodged Cx stent (Supplementary material online, *Figure S1*). The LAD and LMS were extensively dissected (*Figure 2E*) after the stent removal. Both the LAD and OM were rewired and re-stented using an IVUS-guided DK crush bifurcation technique.[7] The end result was excellent (*Figure 2F*) and the patient's post-procedural recovery period was uncomplicated.

Case 3—surgical retrieval and coronary artery bypass grafting

A 56-year-old gentleman presented with chest pain and was diagnosed with an NSTE-ACS associated with a high sensitivity troponin I rise of 2387 ng/L (<34 ng/L). His background history was significant for hypertension and hyperlipidaemia, and his examination was

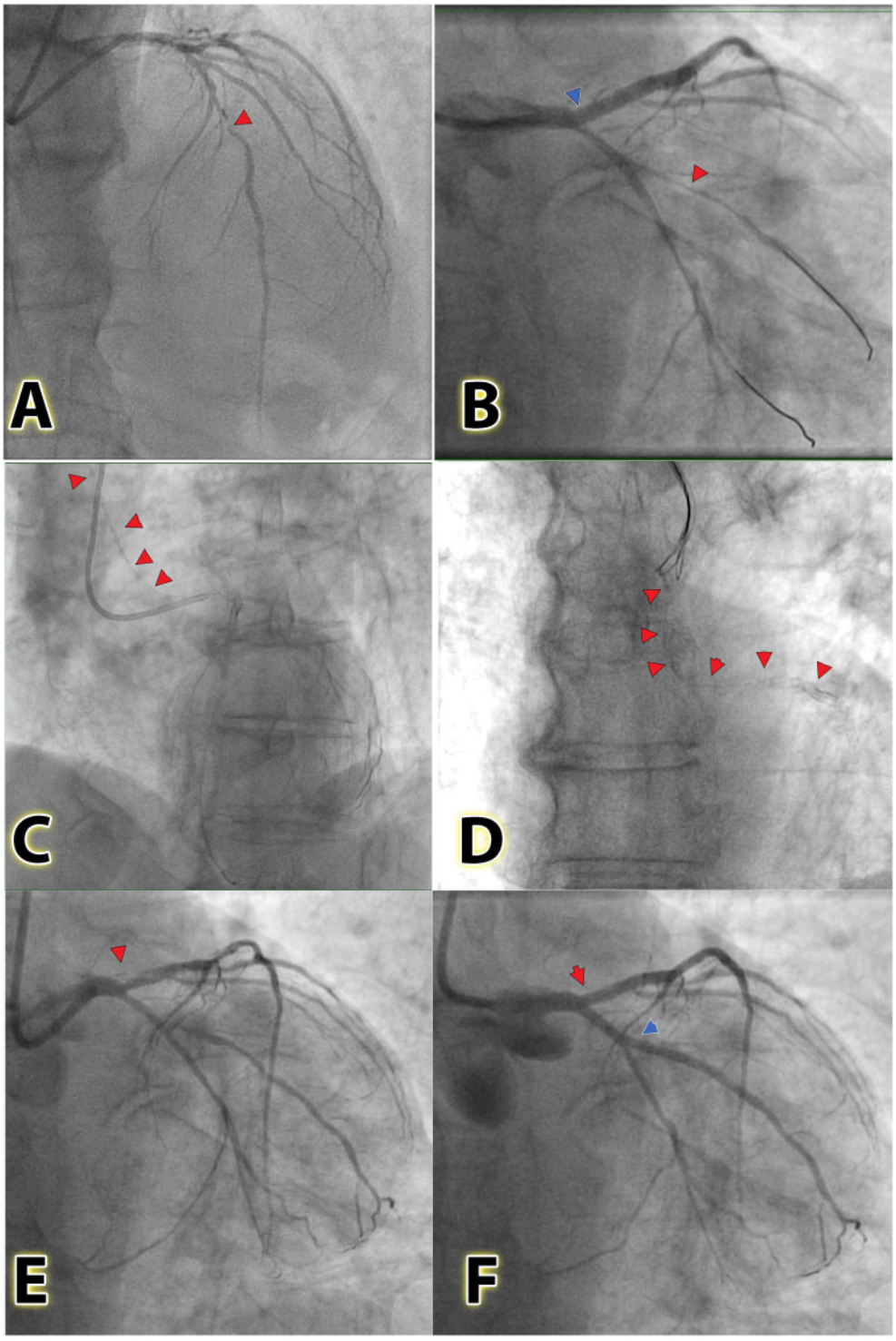


Figure 2 (*A*) Severe left anterior descending artery disease, marked with a red arrow, triggered a percutaneous coronary intervention to the left anterior descending artery (postero-anterior cranial view). (*B*) Patient returned after 4 days for a staged procedure to a severe lesion in the obtuse marginal branch of the circumflex artery (red arrow head, postero-anterior caudal view) with guidewires inserted into both the atrioventricular circumflex artery and obtuse marginal branches. The previously implanted prox-mid-left anterior descending artery stent is patent and indicated with the blue arrow head. (*C*) Attempts to deliver a stent to the obtuse marginal were met with resistance. On withdrawal the stent was stripped from the delivery catheter. The image demonstrates an avulsed and unravelled left anterior descending artery stent in the ascending aorta with the stripped stent hanging on the end of the unravelled left anterior descending artery stent (red arrow heads). (*D*) A three-loop retrieval system was utilized to extract the stent (marked with red arrow heads, postero-anterior view), (*E*) leaving behind a dissected left anterior descending artery implicating the distal left main stent (red arrow heads, postero-anterior caudal view). (*F*) Final angiographic postero-anterior caudal view demonstrating good result in the left main stent-left anterior descending artery (red arrow) and circumflex artery (blue arrow).

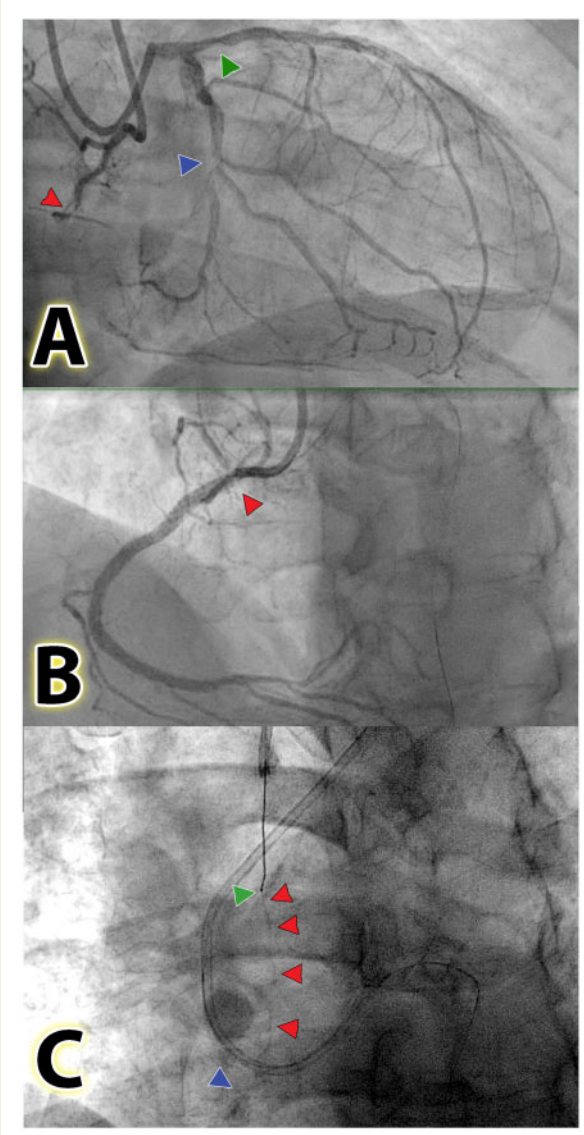


Figure 3 (*A*) Dual catheter angiography (postero-anterior caudal view) demonstrating severe disease in the circumflex artery (blue arrowhead) and the left anterior descending artery (green arrow head) with a chronic total occlusion to the right coronary artery (red arrow head). (*B*) After chronic total occlusion percutaneous coronary intervention, attempts to withdraw the guidewire were faced with resistance as the interface between the proximal stent edge and the wire tip (red arrow head, left anterior oblique cranial view). (*C*) Partially avulsed right coronary artery stent can be seen in the ascending aorta (red arrow heads, postero-anterior view) outside the right coronary artery ostium (blue arrow head) entangled on the tip of the guidewire (green arrow head).

unremarkable. He was admitted to our cardiology unit for monitoring and started on DAPT with aspirin 300 mg and clopidogrel 600 mg. He underwent coronary angiography which demonstrated triple vessel coronary artery disease which included proximal LAD disease, mid-Cx disease and a chronic total occlusion (CTO) of the mid-RCA. Treatment options were discussed with the patient, and he opted to undergo PCI in preference to coronary artery bypass grafting (CABG). The treatment of the LAD and Cx were uncomplicated. A staged procedure to treat the RCA CTO was undertaken as an outpatient.

The CTO PCI procedure to the RCA was planned in accordance with a hybrid algorithm approach using bi-radial access (7 Fr RRA, 6 Fr left radial artery).[11] Dual coronary injections in the LMS (VL 3.5 6 Fr) and the RCA (AL 0.75 7 Fr) confirmed the presence of the RCA occlusion, and defined the proximal cap, length, and potential retrograde options (*Figure 3A*). The occlusion was crossed easily anterogradely with a Pilot 200 guidewire (Abbott, IL, USA) through a Corsair (Asahi, Japan) microcatheter. The Pilot 200 was subsequently exchanged for a Sion Blue guidewire (Asahi, Japan). On this wire, the lesion was prepared and the vessel was treated with overlapping Xience Sierra 3.0 mm × 33 mm DES (Abbott, IL, USA) (*Figure 3B*). Upon withdrawal of the Sion blue wire resistance was felt when the wire tip reached the proximal stent edge. Attempts to withdraw the guide catheter and the wire resulted in avulsion of the proximal stent which became deformed and stretched with the distal stent remaining in the RCA but the more proximal stent apparatus 'unravelling' back into the ascending aorta (*Figure 3C*).

There were concerns about retrieving the stents with a snare, as a long length of stent had been implanted into an angulated and calcified vessel. After an informed discussion between the patient and the treating team we agreed to refer for surgical management. The patient subsequently underwent CABG with a left internal mammary artery graft to the LAD, and two venous grafts to the RCA and Cx. As part of the procedure, the protruding unravelled stent was retrieved from the ascending aorta. The postoperative outcome was uncomplicated and the patient was discharged home well.

Discussion

Iatrogenic avulsion of a coronary stent is a rare complication of PCI that has only been described in a handful of published case reports. In the three procedures described in this series, the stents avulsed were recently implanted and were not endothelialized. The likelihood is that the stents were malapposed to the coronary wall or had been deformed (as in the planned DK crush procedure, Case 1) making them prone to be caught by or avulsed by other PCI equipment during the same or an early staged procedure. In our patients, two stents were caught and avulsed by the guidewire, whereas a third was caught by a stent catheter. A number of other mechanisms of coronary stent avulsion have been reported including stents being caught on and avulsed by cutting balloons,[3,12,13] an aspiration catheter,[2] orbital atherectomy burr, a guide extension catheter,[4] another stent,[14] or a snare meant for retrieving another piece of equipment.[1] These cited case reports do not exclusively describe the avulsion of 'freshly' implanted stents since some of these stents were more than 6 months old.

In those cases described within the literature, new stents were implanted where old stents were completely avulsed out of the coronary artery.[1,2,4,13] Where part of the avulsed stent remained within the coronary vasculature, one group successfully crushed the remaining part against the wall of the coronary artery with a high-pressure balloon and deployed another stent across it to establish definitive

coronary patency.[3] One case reported surgical intervention as the bailout strategy of choice.[12] Finally, a case where the avulsed stent embolized into the brachial artery utilized a combination of percutaneous implantation of new stents in the coronary artery and a surgical extraction of the retracted stent from the brachial artery.[14]

Beyond these single case descriptions cited, there are no other published reports on iatrogenic coronary stent avulsion. This makes it difficult for operators to agree on a consensus for bailout strategies. There are essentially only three strategies for management. (i) Stent again crushing the deformed and avulsed stent in place against the coronary wall. (ii) Percutaneous retrieval of the avulsed stent and then re-stenting. (iii) Surgical bailout. In our case series, we describe all of these potential management strategies. In Case 1, we successfully retrieved wire filaments from the aorta with a snare, then stented the remainder of the avulsed stent against the coronary artery wall. In Case 2, the whole of the avulsed stent was retrieved with a snare, and then the coronary artery was re-stented. In both cases, a three-loop retrieval system was deployed to retrieve the protruding part of the stents from the ascending aorta. In Case 3, a decision was made to pursue a surgical treatment option to retrieve the stent, as concern was raised about the uncertainty of percutaneous retrieval of the avulsed stent in an angulated and calcified RCA. The choice of bailout strategy will likely depend upon a number of factors. Percutaneous solutions would obviously be favourable, but sometimes unattainable. Ideally any avulsed deformed stent apparatus would be snared and removed completely allowing a definitive stenting procedure to be undertaken. Snaring may be impossible in some instances depending upon the position of the avulsed stent or the availability/deliverability of retrieval systems. However, often management decisions are more nuanced, for example, in Case 1 snaring of the retained avulsed stent was considered after the fractured wire filaments were removed successfully, but there was concern that the snare could inadvertently 'drive' the protruding deformed stent back into the LMS ostium, making a bad situation even worse. As a result we chose to re-stent; crushing the deformed avulsed stent against the coronary wall. Furthermore, sometimes anatomical considerations such as those considered in Case 3 will dictate strategy. Due to the length of stent, tortuosity and calcification of the vessel, there were concerns that percutaneous retrieval of the avulsed stent may not be achievable, or worse harmful. We were unable to rewire the RCA and so crushing the deformed avulsed stent was not an option. As a result we decided that definitive cardiothoracic management was the best strategy.

Interventional cardiologists need to be aware of the range of options available for the management of this rare, but serious, complication and be prepared to tailor the bailout management strategy based on the anatomy, location of the avulsed stent, and deliverability of retrieval systems.

Conclusion

Iatrogenic avulsion of coronary stent is a very rare complication of PCI with only a handful of descriptions in the literature. Interventional cardiologists need to be aware of the possible mechanisms that lead to this complication and be aware of the different management strategies both percutaneously and surgically. It remains unknown what the best management option is, but that will likely be influenced by anatomy, equipment deliverability/availability, and operator experience.

Lead author biography

Dr Majd B. Protty is a Wales Clinical Academic Track (WCAT) registrar in Cardiology at Cardiff University and the Wales deanery. He is currently enrolled on a PhD programme at Cardiff University funded by a Wellcome Trust GW4CAT Fellowship. The focus of his research is on inflammation, thrombosis, and haemostasis as it relates to patients suffering from coronary artery disease.

Supplementary material

Supplementary material is available at *European Heart Journal - Case Reports* online.

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that written consent for submission and publication of this case report including images and associated text has been obtained from the patient in line with COPE guidance.

Conflict of interest: None declared.

Funding: None received.

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