Case Report

Longitudinal Stent Deformation in Undeployed Stents: A Case Series

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Abstract

Longitudinal stent deformation (LSD) is a recently reported problem with newer generation stents. The modification of stent materials and designs to make them more deliverable and conformable, as well as a focused approach in retaining their radial strength, has compromised longitudinal strength in currently available stents. Additionally, enhanced stent radiopacity, improved fluoroscopy, and heightened awareness have led to an increased incidence rate of the potentially under-recognized problem of LSD. Although originally described in deployed stents, LSD is being recognized in undeployed stents too. With available data to suggest an increased rate of adverse cardiac events like stent thrombosis and in-stent restenosis with LSD in deployed stents, an attempt to retrieve an undeployed deformed stent appears justified. We report 3 cases of LSD in undeployed stents and discuss its recognition. We also discuss the retrieval and visual inspection of retrieved stents and the simultaneous completion of coronary interventions via a double guide technique.

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Introduction

Longitudinal stent deformation (LSD) is a rare complication of percutaneous coronary intervention (PCI), with a prevalence of up to 0.097% of the stents deployed in a retrospective analysis.[1] With quantitative coronary angiography, the prevalence of LSD is even higher (1.12%).[2] LSD is increasingly reported with newer generation stents, particularly Promus Element, TAXUS Liberté, and Driver stents, whereas it has not been reported with Firehawk and Orsiro stents. Although typically described in a deployed stent, LSD can be detected in an undeployed stent, especially while the operator is trying to negotiate a complex or calcified lesion or retrieve it into the guide catheter (GC). Such a highly deformed stent can either be judiciously retrieved or be deployed in the coronary/peripheral artery with the attendant risk of adverse vascular events such as stent thrombosis and in-stent restenosis. Here, we describe 3 cases of severe LSD, detected in 3 different categories of stents before deployment, where the retrieval of the deformed stent was attempted via different techniques.

Case Reports

Case # 1

A 45-year-old man presented with recent onset angina

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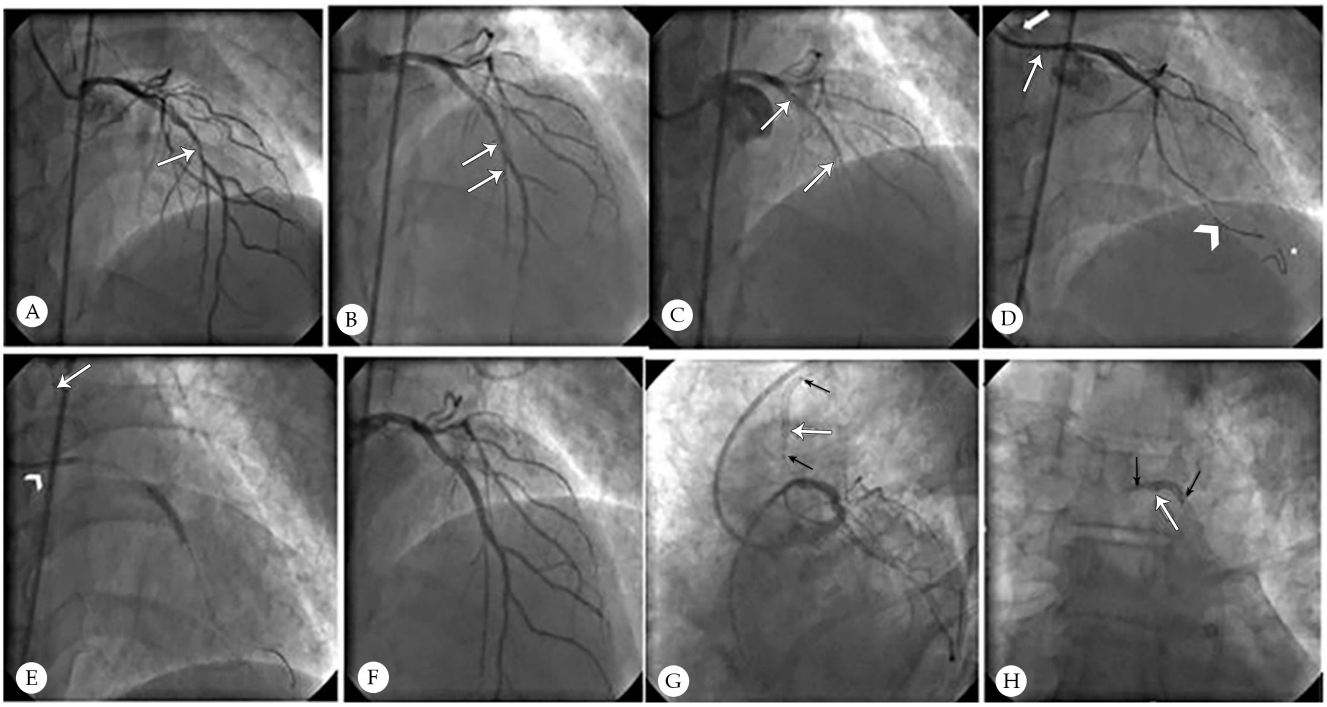

Figure 1. The angiographic images show LSD in an undeployed stent and its management. The AP cranial view shows: A) tubular 90% stenosis in the LAD (arrow), B) an in situ semi-compliant balloon for pre-dilation (arrows), C) failure to negotiate a TAXUS Liberté Stent (arrows) across the lesion, and D) the lodging of the deformed stent (the white block arrow) at the tip of the first GC (disengaged from the LM) on a Zinger support guidewire still across the lesion (asterisk). The LCA was engaged with a second GC (the line arrow), and a second coronary wire (arrowhead) was used to cross the lesion in the occluded LAD. E) Stenting with a 3 m × 28 mm drug-eluting stent through the second GC (arrowhead) while the first guide with the deformed stent on the 'GC' was parked in the aorta (block arrow). F) The final angiogram shows good results. G) The LAO caudal view shows a longitudinally deformed TAXUS Liberté Stent lodged at the GC tip (white block arrow). It is far from the proximal balloon marker within the guide (black line arrow within the guidewire), but it is still crimped on the balloon at the distal end (black line arrow). H) The AP view shows that the whole system is retrieved through the descending aorta.
LSD, Longitudinal stent deformation; AP, Anteroposterior; GC, Guide Catheter; LM, Left main coronary artery; LCA, Left coronary artery; LAD, Left anterior descending coronary artery; LAO, Left anterior oblique

and an elevated troponin level and was diagnosed as non–ST-elevation acute coronary syndrome. Two-dimensional echocardiography showed a left ventricular ejection fraction of 45%. Coronary angiography revealed 90% stenosis in the left anterior descending, for which PCI was planned. The left coronary artery was engaged with a 6F Judkins Left-4 Launcher GC. The lesion was crossed with a Zinger Support Guidewire and adequately pre-dilated with a 2.5 mm × 15 mm semi-compliant balloon at 12 atm. Then, a 3.0 mm × 28 mm paclitaxel-eluting TAXUS Liberté Stent was attempted, but it failed to negotiate the lesion despite multiple attempts. While being manipulated, the stent was deformed at the proximal edge by the guide tip. Attempts to retrieve the stent into the GC proved unsuccessful due to deformation and longitudinal compression, although the stent balloon was partially within the guide. The patient started having chest pain due to abrupt vessel closure. GC *en bloc* with the deformed stent was disengaged from the left coronary artery, and the coronary wire was kept across the lesion. Another GC, an Extra Back-Up 3.5 6F Launcher, was used to engage the left coronary artery through the contralateral femoral access. A second Zinger support coronary guidewire was employed to cross the lesion in the occluded left anterior descending using the first wire as a roadmap. After the confirmation of the wire position, the lesion was re-dilated, and the first wire was removed. Subsequently, a 3.0 × 28 mm drug-eluting stent (DES) was deployed at 14 atm. The final angiogram showed no residual stenosis with thrombolysis in myocardial infarction (TIMI) grade III flow (Figure 1 A-H). Accidently, the coronary wire through the deformed stent was pulled out during manipulation. The deformed stent, along with the GC, was taken into the iliac artery. During the attempts to retrieve it into the introducer sheath, the stent became completely dislodged off the balloon and embolized into a small branch of the superficial femoral artery, from where it could not be retrieved.

Case # 2

A 70-year-old diabetic man presented with a 2-week history of rest angina. Electrocardiography showed QS complexes in lead V_1-V_2. Echocardiography revealed hypokinesia in the anterior wall with preserved wall thickness and a left

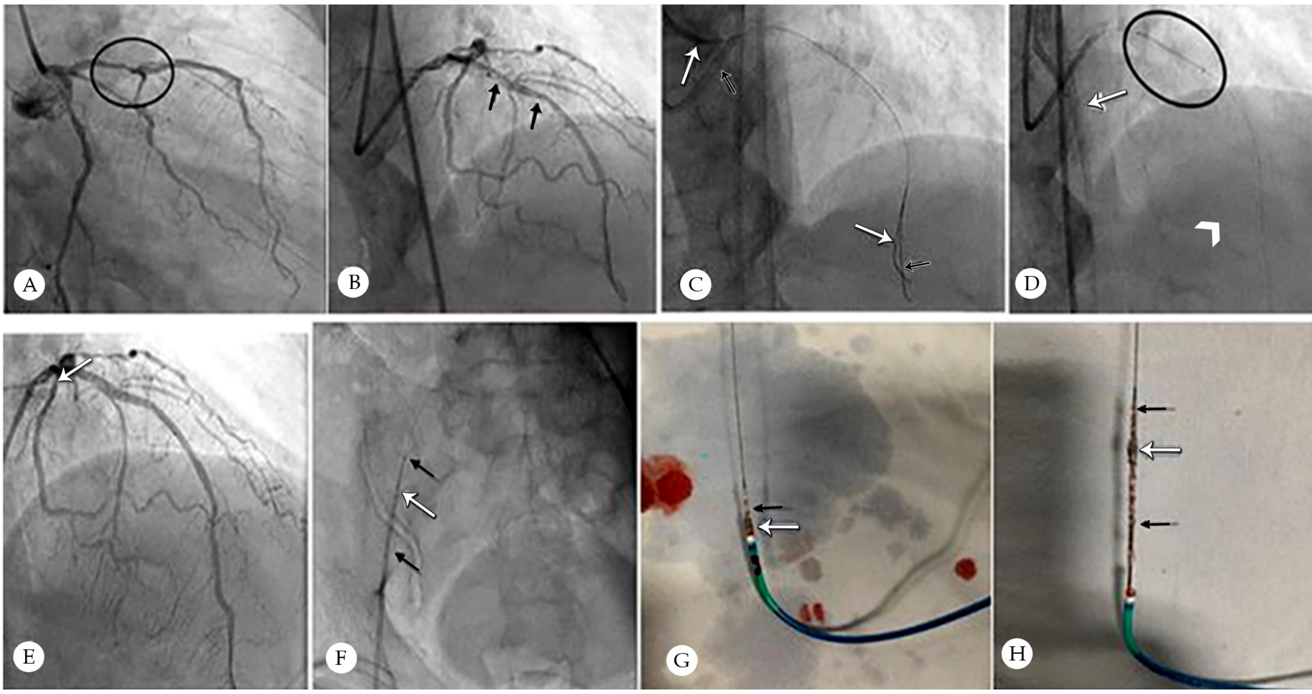

Figure 2. The angiographic images show LSD in an undeployed stent and its retrieval. A) The RAO/caudal view of the LAD shows eccentric and calcified stenosis (90%) (circle). B) The AP cranial view here was obtained after the pre-dilation of the lesion with an in situ semi-compliant balloon (black arrows). C) Following the failure to cross the lesion, the deformed Firehawk Stent (white block arrow), which was lodged at the tip of the first GC and was disengaged from the LM, was pulled back with the first coronary guidewire in situ (white line arrow). The LM was engaged with a second GC (black block arrow), and a second coronary guidewire (black line arrow) was used to cross the lesion in the LAD. D) After the removal of the first wire, stenting was accomplished with a 3 mm × 22 mm drug-eluting stent (circle) through the second GC. The first GC, along with the deformed stent, was parked in the descending aorta (white arrow). E) The final angiogram in the AP cranial view shows no residual stenosis. F) The deformed Firehawk Stent (white arrow) on the balloon (black arrows) with the whole system is retrieved through the femoral sheath. G) The retrieved deformed stent (white block arrow) did not enter the GC. H) The longitudinally deformed stent (white arrow) is on the balloon (black arrows).
LSD, Longitudinal stent deformation; RAO, Right anterior oblique; LAD, Left anterior descending artery; AP, Anteroposterior; LM, Left main; GC, Guide Catheter

ventricular ejection fraction of 40%. Coronary angiography through the right radial route revealed a moderately calcified left anterior descending with proximal, eccentric, and discrete stenosis (90%). Additionally, the proximal right coronary artery was cut off, and the proximal left circumflex had 60% stenosis. The patient refused coronary artery bypass grafting and opted for PCI. Due to intense spasms in the radial artery, a transfemoral approach was selected for PCI. The left coronary artery was engaged with an Extra Back-Up 3.5 6F Launcher GC, and the lesion in the left anterior descending was crossed with a 0.014″ Balanced Middleweight Guidewire. Pre-dilation with a 2.5 mm × 15 mm semi-compliant balloon at 16 atm pressure dilated the lesion well, although multiple inflations were required because of calcification. A 3 mm × 23 mm rapamycin-eluting Firehawk Stent (MicroPort Corp, Shanghai, China) was attempted, but it failed to negotiate the lesion. While the GC was being manipulated, the stent became deformed and compressed at the proximal edge. Fluoroscopy helped identify longitudinal shortening in the stent. Due to its deformity, the stent was lodged at the GC tip in the left main coronary artery, and any attempt to retrieve it would deform it further. Consequently, this GC system was parked in the aorta, and coronary intervention was completed as in the first case with a second GC from the contralateral access using a 3 × 12 mm sirolimus-eluting stent with good angiographic results. The deformed stent, together with its GC, was carefully brought down to the femoral sheath under fluoroscopic guidance and smoothly removed through the 6F sheath. The retrieved stent was utterly deformed and shortened proximally on visual examination, although it was still on the balloon at the distal edge (Figure 2 A-H).

Case # 3

A 56-year-old man presented with recent onset angina. Electrocardiography showed ST-segment depression in leads V_1 to V_5. Two-dimensional echocardiography revealed mild hypokinesia in the left anterior descending territory with a left ventricular ejection fraction of 45%. Coronary angiography through the right radial route illustrated a moderately calcified left anterior descending with a diffuse lesion, causing stenosis (a maximum of 90%). Further, the proximal left circumflex showed 80% stenosis, the first obtuse marginal exhibited a calcified lesion with 99% stenosis, and the right coronary artery demonstrated

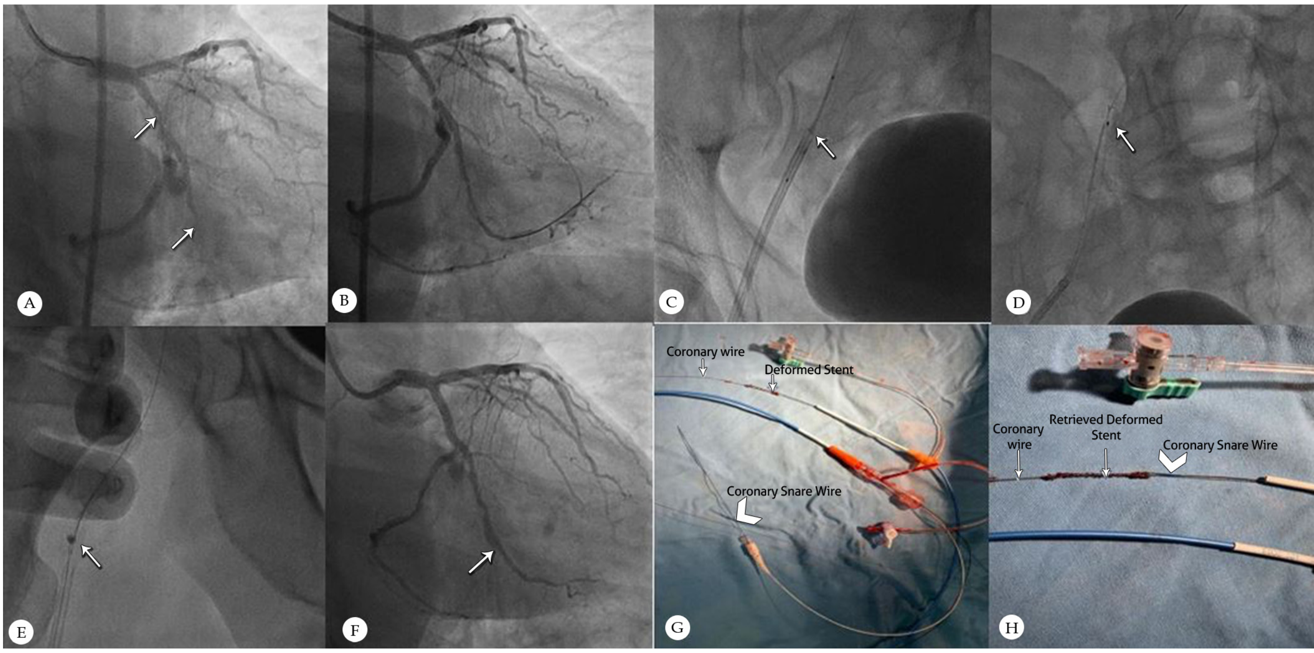

Figure 3. The angiographic images show LSD in an undeployed stent and its retrieval using a snare. The RAO/caudal view shows: A) significant stenosis in the LCX-OM_1 with critical stenosis in the distal OM_1 (white line arrows). B) This angiographic image shows post-lesion pre-dilation with a 2.5 mm × 15 mm semi-compliant balloon. C) The GC with a longitudinally deformed Orsiro Stent (2.5 mm × 33 mm), which is lodged at the tip, is brought into the femoral sheath (white arrow). D) A snare was used to grasp the deformed stent. E). The stent was pulled back through the femoral sheath *en bloc*. F) The final angiography after the stenting of the proximal LCX shows brisk TIMI grade 3 flow in the LCX- OM_1. G & H) The retrieved longitudinally deformed stent (white block arrow) is on the balloon.
LSD, Longitudinal stent deformation; RAO, Right anterior oblique; LCX, Left circumflex artery; OM, Obtuse marginal artery; GC, Guide catheter; TIMI, Thrombolysis in myocardial infarction

plaques. The patient opted for PCI. The transfemoral approach was selected due to tortuosity in the subclavian and innominate arteries. After the engagement of the left coronary artery with an Extra Back-Up 3.5 6F Launcher GC, the lesion in the left anterior descending was crossed with a 0.014″ Balanced Middleweight Guidewire. After adequate pre-dilation, the lesion was stented with a 2.5 mm × 40 mm DES and a 3 mm × 40 mm DES, followed by post-dilatation, which achieved good results. The calcified lesion in the left circumflex–the first obtuse marginal was crossed with a Fielder FC Guidewire and pre-dilated with a 2.0 mm × 15 mm semi-compliant balloon, followed by a 2.5 mm × 15 mm semi-compliant balloon, at 14 atm. A 2.5 × 33 mm Orsiro Stent (BIOTRONIK, Berlin, Germany) was attempted, but it could not negotiate the lesion in the obtuse marginal. During the attempts to retrieve the stent into the GC, the stent was deformed and visibly shortened longitudinally over the balloon and was not retrievable into the GC. This deformed stent and the GC assembly were carefully brought down to the iliac artery under fluoroscopic guidance. Afterward, a coronary snare was introduced through the same GC into the iliac artery distal to the partially dislodged stent. The snare loop was passed over the distal tip of the stent-loaded coronary wire, and the stent was grasped. Next, the whole system was pulled out *en bloc* with the femoral sheath. On visual examination, the retrieved stent was completely deformed and shortened proximally, although it was still on the balloon at its distal edge (Figure 3 A-H).

These cases illustrate the management of a patient with a deformed undeployable stent. The first 2 cases demonstrate the use of the double guide technique to prioritize the emergent coronary intervention, followed by the retrieval of a deformed stent. The third case depicts the method of retrieving a deformed stent by snaring in the iliac artery. The stent that we lost in the first case was possibly retrievable by snaring as was used in the third case. All 3 patients were in good condition at a minimum follow-up of 2 years.

Discussion

LSD, a rare complication of PCI, is being increasingly reported with newer generation stents, possibly due to changes in stent designs and strut thickness for better conformability and trackability in tortuous and complex coronary lesions. Higher radio-opacity and better fluoroscopy may also increase the detection rate of stent deformation.[3] LSD is mainly reported with the Promus Element Stent and the TAXUS Liberté Stent, and to some extent with the Driver Stent. In a retrospective analysis by Williams P et al,[1] LSD occurred in 0.86% of Promus Element stents and 0.097% of all stent types. Although LSD has been reported with many stents, there is no previous report of LSD in Firehawk and Orsiro stents. Nonetheless, a mechanical testing study has revealed that longitudinal strength is lower in the Firehawk Stent than in the XIENCE Xpedition stent.[4] Similarly, third-generation stents with ultrathin struts like Orsiro may be more prone to deformation by any mechanical stress.

LSD, as described in a deployed stent, occurs at the stent edges, especially the proximal edge, usually by compression from the GC tip. Still, it can occur anywhere along the stent length or the distal edge due to the passage of secondary devices (eg, a post-dilation balloon). In a study by Rhee et al,[2] factors associated with higher chances of LSD included ostial lesions, severe calcification, left main coronary artery lesions, the use of secondary devices, adjunctive plain old balloon angioplasty, bifurcation treatment, and the use of intravascular ultrasound or optical coherence tomography.

Although typically described in a deployed stent, LSD can be detected in an undeployed stent as described in our case series. LSD occurred due to GC-induced deformation of the proximal stent edge while we were trying to negotiate the lesion with a deep-seated GC. Another contributing factor was severe calcification in the proximal portion of the left anterior descending in the second case. The detection of LSD in an undeployed coronary stent is challenging; nonetheless, fluoroscopically is indicated by the separation and shortening of the stent away from balloon markers at the edges. To the best of our knowledge, there is only 1 reported case of LSD detected just before the deployment of a stent from our institution only.[5] Our 3 cases are novel insofar as they represent the detection of LSD in an undeployed stent, followed by attempted/successful retrieval. Although LSD can occur with any stent, a stent with low longitudinal strength in a calcified lesion like ours is more prone to deformation.

An unrecognized, hence, untreated LSD in a deployed stent has been shown to increase the risk of stent thrombosis and in-stent restenosis. Indeed, the consequences can be serious, more so if the stent is deployed in the left main coronary artery or bifurcation. Even after management with post-dilatation, metal overload and non-uniform drug distribution due to deformation remain a concern. In a longitudinal study of 1000 patients by Pitney et al,[6] LSD occurred in 1.8%. The authors also reported a 6-month major adverse cardiovascular event rate of 36% and an in-stent restenosis rate of 29%. LSD in a deployed stent could lead to incomplete plaque coverage and diminished drug delivery, predisposing to stent thrombosis and in-stent restenosis.[7-9] In severe accordion-like longitudinal deformation, coronary artery bypass grafting may be required to retrieve the stent and manage the primary coronary lesion.[10]

Despite the current paucity of data, the serious consequences associated with LSD in a deployed stent underscore the need for the recognition of LSD and the planning of potential treatment strategies. If LSD is recognized before stent deployment, the retrieval of the stent potentially reduces the associated cardiovascular events; however, the risk of vascular injury or stent embolization in the process must be considered as happened in our first case. Nevertheless, a careful removal under fluoroscopy is possible either by a simple pull back into the sheath or by the use of other techniques like snaring through the same guide as in our third case. Notably, the urgency to treat the primary lesion remains a challenge in such a situation. One alternative to overcome this challenge is the use of the double guide technique, as used in our first 2 cases, to complete the coronary intervention on priority, followed by the retrieval of the undeployed stent without risking the loss of access to the pre-dilated vessel. This technique can be easily adapted in an emergency, mainly if the patient develops active ischemia. The second GC ensures procedural safety and offers itself for stent retrieval later using different techniques such as snaring if required.[11]

To the best of our knowledge, there are no published reports of completing the primary procedure, followed by the retrieval of an undeployed longitudinally deformed stent, via the double guide technique, which also permits a visual examination for LSD.

Conclusion

Longitudinal stent deformation is an uncommon and under-recognized complication of PCI using current generation stents. Usually detected in deployed coronary stents, longitudinal stent deformation can be occasionally detected in an undeployed stent. In addition to the strategies aimed at reducing its occurrence and optimizing treatment in the deployed stent, bail-out options such as the retrieval of undeployed/undeployable deformed stents may potentially avoid adverse clinical consequences reported with longitudinal stent deformation. The double guide technique is a readily available approach to manage such a complication.

Learning Points

1. Longitudinal stent deformation can be induced by the guide catheter tip before stent deployment. Gentle manipulation of the guide catheter with coaxial alignment during the withdrawal of the stent is essential to prevent further stent deformation.

2. If a deformed stent is lodged at the guide catheter tip, disengage the GC with a deformed stent *en bloc* from the left main while maintaining the first coronary wire in position across the lesion. This not only serves as a marker for rewiring the lesion in case of abrupt vessel closure using a double guide but also may help maintain vessel patency.

3. Appropriately prioritize the stenting of the lesion using the second guide catheter rather than try to retrieve the stent first by removing the guide catheter assembly as the latter approach risks abrupt vessel closure and failure to rewire the lesion.

References

1. Williams PD, Mamas MA, Morgan KP, El-Omar M, Clarke B, Bainbridge A, Fath-Ordoubadi F, Fraser DG. Longitudinal stent deformation: a retrospective analysis of frequency and mechanisms. EuroIntervention 2012;8:267-274.
2. Rhee TM, Park KW, Lee JM, Lee MS, Jeon KH, Kang HJ, Koo BK, Rhew JY, Cha KS, Bae JH, Han KR, Park SH, Park WJ, Rha SW, Oh SK, Kwon HM, Seung KB, Ahn T, Kim SH, Kim HS. Predictors and long-term clinical outcome of longitudinal stent deformation: insights from pooled analysis of Korean multicenter drug-eluting stent cohort. Circ Cardiovasc Interv 2017;10:e005518.
3. Barragan P, Garitey V, Mouneimne K, Rieu R. Longitudinal compression behaviour of coronary stents: a bench-top comparative study. EuroIntervention 2014;9:1454-1462.
4. Yue X, Guo J, Zhang J, Cao C, Zhang Z, Shen D, Tang J, Zhang J. Evaluation of mechanical performances of stents with 38 mm length in long lesion. Biomed Res Int 2020;2020:2594161.
5. Vijayvergiya R, Sharma P, Gupta A, Goyal P, Panda P. Longitudinal stent deformation during coronary bifurcation stenting. Cardiovasc Revasc Med 2016;17:143-145.
6. Pitney M, Pitney K, Jepson N, Friedman D, Nguyen-Dang T, Matthews J, Giles R, Taylor D. Major stent deformation/pseudofracture of 7 Crown Endeavor/Micro Driver stent platform: incidence and causative factors. EuroIntervention 2011;7:256-262.
7. Daoyuan Si, Yaliang Tong, Bo Yu, Yuquan He, Guohui Liu. In-stent restenosis and longitudinal stent deformation: a case report. BMC Cardiovasc Disord 2020;20:24.
8. Guler A, Guler Y, Acar E, Aung SM, Efe SC, Kilicgedik A, Karabay CY, Barutcu S, Tigen MK, Pala S, İzgi A, Esen AM, Kirma C. Clinical, angiographic and procedural characteristics of longitudinal stent deformation. Int J Cardiovasc Imaging 2016;32:1163-1170.
9. Mamas MA, Williams PD. Longitudinal stent deformation: insights on mechanisms, treatments and outcomes from the Food and Drug Administration Manufacturer and User Facility Device Experience database. EuroIntervention 2012;8:196-204.
10. Cheng ST, Su CW, Liau CS, Ko YL. Accordion stent deformation upon retrieval of a side-branch protective guidewire. Acta Cardiol Sin 2015;31:568-571.
11. Trehan VK, Jain G, Kathuria S, Pandit BN. Retrieving a deformed stent during transradial intervention: an alternative femoral approach using guide catheter shortening. Indian Heart J 2013;65:323-326.