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CASE SERIES
Coronary Heart Disease

Ultra-low contrast, complex left main coronary intervention case series using novel intravascular ultrasound technology

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Background Contrast-induced nephropathy (CIN) in patients with chronic kidney disease (CKD) carries a high morbidity and mortality. Ultra-low contrast percutaneous coronary intervention (ULPCI) has previously been described. Complex left main (LM) ULPCI using two-stent strategy guided by novel intravascular ultrasound (IVUS) co-registration software has not been described. We report a series of complex LM ULPCI using IVUS co-registration.

Case Summaries Five patients with estimated glomerular filtration rate ≤20 mL/min who presented with stable angina or non-ST segment elevation acute coronary syndrome underwent percutaneous coronary intervention (PCI). The patients previously had diagnostic angiography performed as a separate procedure. Successful LM ULPCI was performed in all patients with a provisional and two-stent bifurcation strategies. These were complex procedures, some of which required haemodynamic support and rotational atherectomy.

Discussion This report describes the first ULPCI using a dedicated two-stent LM bifurcation strategy and using rotational atherectomy and IVUS co-registration. This technology facilitated complex PCI in this high-risk patient group with minimal contrast use (≤6 mL) with optimal results and no patients developed acute kidney injury after intervention. The adaptation of ULPCI to daily practice in patients at risk of CIN will improve treatment for this underserved patient group.

Keywords Intravascular ultrasound • Chronic kidney disease • Left main • Bifurcation • Percutaneous coronary intervention • Case report

Introduction

Contrast-induced nephropathy (CIN) is associated with increased morbidity and mortality.[1] Intravascular ultrasound (IVUS)-guided percutaneous coronary intervention (PCI) can reduce contrast volume, and hence CIN risk.[2,3] The technique of ultra-low contrast PCI (ULPCI) has been described.[4,5] However, complex left main (LM) ULPCI with a double kissing (DK) crush strategy guided by IVUS co-registration (Syncvision®, Philips, Eindhoven, Netherlands) has not been reported.[6] We report a case series of complex LM ULPCI in a high-risk patient group using IVUS co-registration. This report included five patients

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Learning points

- Complex distal left main (LM) bifurcation including a double kissing crush strategy with rotational atherectomy in patients with chronic kidney disease (CKD) can be safely performed using minimal contrast.
- The use of intravascular ultrasound with co-registration adds an additional dimension to allow treatment of the most complex LM anatomy in patients with CKD.

with severe LM disease and stage IV chronic kidney disease (CKD) who presented with stable angina or non-ST segment elevation acute coronary syndrome (NSTEACS). All patients had diagnostic angiography performed as a separate procedure at an earlier time. All cases were discussed at the heart team and considered unsuitable for coronary artery bypass graft surgery. The timeline for the procedure is detailed below. Ultra-low contrast percutaneous coronary intervention was undertaken only after careful consideration and planning. Procedures were performed in bi-plane labs (however, also possible in single-plane labs). The steps for ULPCI using IVUS co-registration technique are illustrated in *Table 1* and *Figure 1*. *Table 2* shows the clinical and procedural characteristics of the patients. In all cases, the ULPCI was performed with zero contrast, but 4–6 mL of contrast was used at the end of the procedure to exclude perforation. All cases had a post-procedural IVUS confirming good stent apposition, stent expansion >90% of distal reference vessel area, and no significant edge dissection. There were no procedural complications.

Timeline

(1) Patients with advanced chronic kidney disease presenting with stable angina or non-ST segment elevation acute coronary syndrome
(2) Diagnostic coronary angiogram is performed with minimal use of contrast to obtain the necessary information about the coronary anatomy. All procedures were carried out through the radial artery
(3) Repeated creatinine for all patients following the diagnostic procedure showed no incidence of contrast-induced nephropathy defined as a less 25% rise in its value baseline serum creatinine value
(4) Discussion at the Heart Team meeting to decide the mode of revascularization
(5) Ultra-low contrast percutaneous coronary intervention procedure was performed using the intravascular ultrasound co-registration at a separate time by experienced operators

Case Presentations

Case 1: left main double kissing crush with rotational atherectomy

Clinical details

An 81-year-old male presented to the emergency department (ED) with NSTEACS and acute pulmonary oedema. Past medical history included hypertension, type II diabetes, peripheral vascular disease, and CKD stage IV [estimated glomerular filtration rate (eGFR) 17 mL/min/1.73 m^2]. Electrocardiogram (ECG) showed widespread ischaemia. Echocardiography showed severe left ventricular systolic dysfunction (LVSD) and moderate aortic stenosis (AS). Coronary angiography showed severe calcified distal LM stenosis, severe proximal and mid-left anterior descending artery (LAD), and severe proximal left circumflex (LCx) disease (*Figure 2A and B*). There was no significant right coronary artery (RCA) disease.

Procedural details

Access was obtained via 7 Fr right radial approach (RRA). Left main was engaged with an extra backup (EBU) 3.5 7 Fr guide catheter. Both the LAD and LCx were wired. The distal LM was predilated with a 2.5 mm compliant balloon (*Figure 2C*). A Turnpike spiral microcatheter (Teleflex, PA, USA) was used to exchange a workhorse wire to Rotawire Floppy® (Boston Scientific, Natick, MA, USA), and rotational atherectomy was performed in the LM and LAD with a 1.75 mm burr at 160 000 rpm (*Figure 3A*). Intravascular ultrasound co-registration was performed (*Figure 3B*). Left main–LAD IVUS showed disruption in the distal LM calcification (*Figure 3C*). Stent landing zones and vessel size were identified. Intravascular ultrasound of the LCx demonstrated severe ostial disease (*Figure 3D and E*). The mid-LAD was predilated with a 3 mm compliant balloon and stented with 3 mm × 23 mm Xience® (Abbott, MN, USA) drug-eluting stent (henceforth referred to as Xience) (*Figure 4A*). The distal LM was treated with DK crush procedure. The LCx was predilated with 3 mm non-compliant (NC) balloon and stented with 3.5 mm × 28 mm Xience and then crushed with a 4 mm balloon inflated in the proximal LAD–distal LM (*Figure 4B*). The first kissing balloon (KB) inflations were performed after rewiring the LCx stent using 4 and 3.5 mm balloons in the LAD and LCx, respectively (*Figure 4C*). The stent to the LM–LAD (4 mm × 28 mm Xience) was positioned, without contrast, using the floating wire technique to ensure ostial coverage (*Figure 5A*). In this technique, a wire (non-polymer jacketed) is looped in the aortic root, preventing the guide catheter from engaging in the LM, and with forward pressure on the guide the ostium can be identified without contrast.[7,8] Proximal optimization technique (POT) was performed with a 5 mm NC balloon in the LM (*Figure 5B*). The second KB (*Figure 5C*) and a final POT (5 mm NC balloon) were performed. Final IVUS and final angiogram (6 mL contrast) are shown (*Figure 6A–E*) (*Videos 1–3* and Supplementary material online, *Videos S1–S3*).

Table 1 Step by step approach for ultra-low contrast percutaneous coronary intervention using intravascular ultrasound co-registration

- Diagnostic angiogram review: Images reviewed and best working views selected. Display printed still images of the selected views on the image monitor and use as working views. Pick the best working views[a]
- Guide engagement without contrast: Pointers include pressure damping whilst engaging (*Figure 1B*) calcification at the coronary ostium, ECG changes with saline injection, and gentle wire probing to see if the wire follows the course of the vessel
- Wiring: Wire the target vessel(s) using reference roadmaps without contrast (*Figure 1C*)
- Predilatation: If severe stenosis is encountered, predilatation with balloon should be performed to allow IVUS catheter passage
- IVUS: Eagle eye IVUS catheter must be used, since this is the only IVUS catheter compatible with the Syncvision® co-registration system
- Co-registration step 1: Perform Cine acquisition without contrast. Do not change table position or C arm angles after the acquisition. The PTCA wire will act as a marker/guide for the target vessel course (*Figure 1E*)
- Co-registration step 2: Use the Syncvision® software to mark the PTCA wire course with points (one point at the proximal visible part of the guide, second point at the site of the lesion, and a third point at the most distal radiopaque part of the wire). The software will create a continuous line along the target vessel which can be manually edited to make it accurate (*Figure 1D and E*)
- Co-registration step 3: The final step is to perform manual IVUS pull back (1 mm/s) under continuous fluoroscopy. This is the recommended manual pullback speed (*Figure 1F*). Co-registration will be automatically created after the pull back by the software. The IVUS images now will be co-registered to the target artery. Scrolling the trackable marker across the wire will correspond to the cross sectional images in the IVUS (*Figure 1G*)
- *Do not change table position or C arm angles once co-registration has been performed*
- PCI: The PCI can now be done using the IVUS co-registration guidance
- Give contrast injection if:
  (1) Haemodynamic instability
  (2) Chest pain
  (3) ECG changes

AP, •••; ECG, electrocardiogram; IVUS, intravascular ultrasound; LAD, left anterior descending; LAO, Left anterior oblique; LM, left main; PCI, percutaneous coronary intervention; PTCA, percutaneous transluminal coronary angioplasty; RAO, right anterior oblique.
[a]From the diagnostic angiogram (e.g. for LM ostium and mid-LAD: LAO cranial, LM bifurcation: RAO caudal) (*Figure 1A*). The bi-plane lab allow the use of two projections simultaneously (lateral/LAO cranial and AP/RAO caudal) enabling the IVUS co-registration process to be performed quicker than a single-plane mode as the latter require changing the table position/C arm angle to acquire another projection.

Case 2: left main provisional stenting with multi-vessel disease

Clinical details

An 81-year-old male presented to the outpatient clinic with worsening of ischaemic symptoms and was classified as chronic coronary syndrome (CCS) Class III, despite optimal medical therapy, eGFR was 18 mL/min/1.73 m^2. Echocardiography showed moderate LVSD, coronary angiography showed a critical ulcerated lesion in the LM, severe mid-LAD stenosis, the LCx was dominant showing proximal ulcerated plaque and mid-distal significant stenosis after the second obtuse marginal (OM) branch, there was no significant RCA disease (Supplementary material online, *Figure S1a and b*).

Procedural details

Access was obtained via 7 Fr RRA. Left main was engaged with an EBU3.5 7 Fr guide. Pressure damping was noticed upon guide engagement. The LAD and LCx were wired. The LM was predilated before performing IVUS co-registration. The IVUS identified stent landing zones, the lesion length, and lesion morphology (*Figure 1C*). The ostium of the LAD was free of disease. The LAD was predilated with a 3 mm balloon and stented with 3 mm × 28 mm Xience and overlapped with 4 mm × 33 mm Xience avoiding the ostium of the LAD (Supplementary material online, *Figure S1d and e*). The proximal LAD was post-dilated with a 4.0 mm NC balloon. Left circumflex IVUS co-registration demonstrated a large vessel with significant disease proximally and distally. The distal disease was treated with a drug-eluting balloon because of the potential risk of jailing two sizeable OM branches. A 2.75 mm × 20 mm Sequent Please® (B.Braun, Hessen, Germany) was inflated for 60 s. We then stented the LM–LCx with a 4 mm × 33 mm Xience using the floating wire technique (Supplementary material online, *Figure S1f*). Proximal optimization technique of the LM was performed with 5.0 mm NC balloon. The LAD was re-wired via a distal strut, which was opened with a 3.5 mm Balloon, and a final POT performed in the LM. Final IVUS demonstrated a good result. Check angiogram was performed with 5 mL contrast (Supplementary material online, *Figure S1h* and *Videos S4 and S5*).

Case 3: left main provisional stenting with scoring balloon and intra-aortic balloon pump support

Clinical details

An 86-year-old female presented to the ED with NSTEACS, eGFR was 18 mL/min/1.73 m^2. Echocardiography showed

Table 2 Clinical and procedural characteristics

	Case 1	Case 2	Case 3	Case 4	Case 5
Age	81	81	86	83	79
Sex	Male	Male	Female	Male	Male
Co morbidities	HTN, DM, PVD, CKD IV, TIA	COPD, PN, CKD IV	HTN, DLD, DM, CKD IV, OA	HTN, DM, PVD, CKD IV	HTN, DM, PVD, CKD IV, DVT
Indication	NSTEACS	CCS	NSTEACS	NSTEACS	CCS
Access route	7 Fr Radial	7 Fr Radial	7 Fr Radial	7 Fr Radial	7 Fr Femoral
Vessels treated	LM/LAD/LCx	LM/LADL/Cx	LM/LAD	LM/LAD/LCx	LM/LAD/LCx
eGFR (mL/min/1.73 m^2)	17	18	18	14	20
LVSD	Severe	Moderate	Moderate	Moderate	None
Medina classification of LM	1:1:1	1:0:0	1:1:0	1:1:1	1:1:1
LM bifurcation strategy	• DK crush • *Figures. 2–6* • *Videos 1–3* • Supplementary material online, *Videos S1–S3*	• Provisional • Supplementary material online, *Videos S4 and S5* and *Figure S1*	• Provisional • Supplementary material online, *Figure S2*	• DK crush • Supplementary material online, *Figure S3*	• DK crush • Supplementary material online, *Figure S4*
Adjunctive techniques	Rotational atherectomy		Scoring Balloon		
Haemodynamic support	None	None	IABP	IABP	None
Total contrast volume used at end of procedure (mL)	6	5	5	4	6
Fluoroscopy time (min; s)	54:00	59:12	39:46	47:06	38:08
Time from diagnostic angiography to PCI	3 days	232 days	5 days	6 days	252 days
Time from PCI to discharge	1 day	1 day	1 day	6 days	0 day
Post-procedural CIN	No	No	No	No	No

CCS, chronic coronary syndrome; CIN, contrast-induced nephropathy; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DK, double kissing DM, diabetes mellitus; DVT, deep vein thrombosis; DLD, dyslipidaemia; eGFR, estimated glomerular filtration rate; HTN, hypertension; IABP, intra-aortic balloon pump; LAD, left anterior descending; LCx, left circumflex; LM, left main; LVSD, left ventricular systolic dysfunction; NSTEACS, non-ST segment elevation acute coronary syndrome; OA, osteoarthritis; PCI, percutaneous coronary intervention; PN, peripheral neuropathy; PVD, peripheral vascular disease; TIA, transient ischaemic attack.

moderate LVSD. Coronary angiography showed heavily calcified tight distal LM disease, significant mid-LAD, and mid-LCx disease (Supplementary material online, *Figure S2a*). The RCA had mild to moderate disease. A decision was made for ULPCI with intra-aortic balloon pump (IABP) support.

Procedure details

Access was obtained via 7 Fr RRA. The LM was engaged with an EBU3.5 7 Fr guide catheter. After wiring the LAD and LCx, LM was predilated with 2 mm balloon, a 3.5 mm NC balloon and a 3.5 mm AngioSculpt® RX (Philips, Eindhoven, Netherlands) scoring balloon. Intravascular ultrasound demonstrated calcium disruption in the distal LM (Supplementary material online, *Figure S2b*) with no significant ostial LCx disease (Supplementary material online, *Figure S2c*). A 6 Fr Guideliner V3® (Teleflex) was used for additional guide support. The mid-LAD was stented with 3 mm × 18 mm Xience followed by treating the LM with a provisional single stent (3.5 mm × 33 mm Xience) into the LAD overlapping the mid-LAD stent using the floating wire technique(Supplementary material online, *Figure S2d*). Left main POT was performed with 5 mm NC balloon (Supplementary material online, *Figure S2e*) and the proximal LAD was post-dilated with 4 mm NC balloon and the mid-LAD was post-dilated with a 3.5 mm NC. Intravascular ultrasound showed a good result in the LM (Supplementary material online, *Figure S2f*) and LAD (Supplementary material online, *Figure S2g*). Final angiogram was performed using 5 mL of contrast (Supplementary material online, *Figure S2h*).

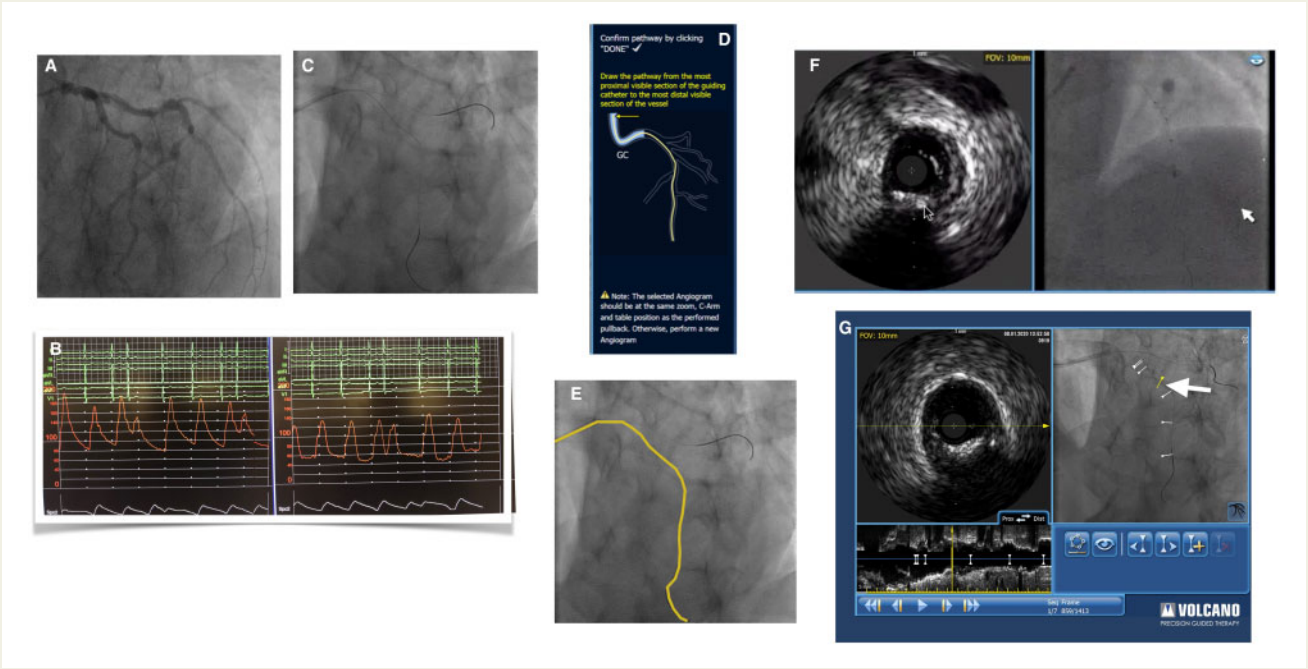


Figure 1 (*A*) Previous angiogram image displayed. (*B*) Change in pressure waveform on right panel upon guide catheter engagement. (*C*) Left anterior descending artery wired using the previous angiogram as a roadmap. (*D* and *E*) Percutaneous transluminal coronary angioplasty wire used to mark vessel course. (*F*) Intravascular ultrasound pull back performed. (*G*) Intravascular ultrasound co-registration performed by the software, yellow marker (white arrow) corresponds to intravascular ultrasound image.

Case 4: left main double kissing crush with intra-aortic balloon pump support

Clinical details

An 82-year-old male presented to the ED with NSTEACS. Estimated glomerular filtration rate was 14 mL/min/1.73 m^2. Echocardiography showed moderate LVSD. Coronary angiography showed severe distal LM, severe LAD, and severe mid-LCx disease (Supplementary material online, *Figure S3a and b*). The patient developed chest pain and widespread ischaemia on the ECG whilst transferring to the cath lab (Supplementary material online, *Figure S3c*, top). In view of this we decided to place IABP with ultrasound guidance before commencing PCI. Post-IABP insertion there was immediate improvement of ischaemic changes seen on ECG monitoring (Supplementary material online, *Figure S3c*, bottom).

Procedural details

Access was obtained via 7 Fr RRA. Left main was engaged with an EBU3.5 7 Fr guide catheter. The LM was predilated with a 3 mm balloon and IVUS co-registration was performed in both the LAD and LCx (Supplementary material online, *Figure S3d*). The mid-LAD was stented with 3 mm × 48 mm Xience. The mid-LCx was stented with 2.5 mm × 18 mm Xience (Supplementary material online, *Figure S3e*). The distal LM was treated with a DK crush procedure with all steps as described in Case 1 (LAD–LM 4 mm × 28 mm Xience, LCx 3.5 mm × 33 mm Xience). Final angiogram performed using 4 mL of contrast (Supplementary material online, *Figure S3g*) Final IVUS is shown in *Figure 3F–H*.

Case 5: left main double kissing crush

Clinical details

A 79-year-old male presented with worsening symptoms of CCS Class III despite optimal medical therapy, eGFR was 20 mL/min/1.73 m^2. Echocardiogram showed preserved LV function. Coronary angiography showed severe distal LM stenosis, severe mid-LAD stenosis, and severe ostial LCx stenosis (Supplementary material online, *Figure S4a–c*).

Procedural details

Access was obtained via 7 Fr RRA. Left main was engaged with EBU3.5 7 Fr guide catheter. After predilatation of the LM with a 2.5 mm balloon, IVUS co-registration was performed of LAD and LCx. The mid-LAD was stented with 2.5 mm × 33 mm Xience, then DK crush was performed in the same steps as described in Case 1 (LCx stent 3 mm × 33 mm Xience/LM–LAD stent 3.5 mm × 28 mm Xience). Proximal optimization technique 5 mm balloon LM (Supplementary material online, *Figure S4*).

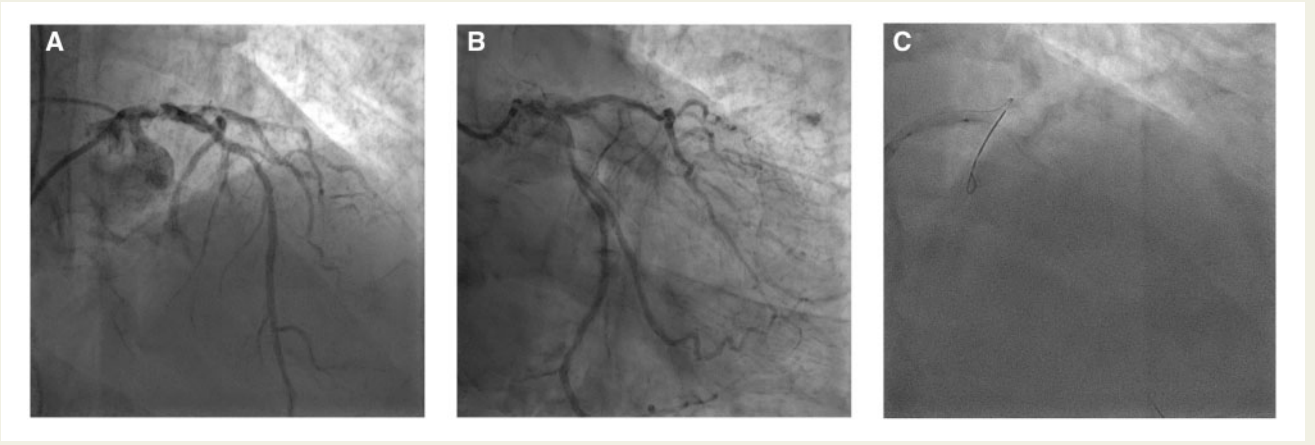


Figure 2 (*A* and *B*) Angiogram demonstrating severe calcified distal left main, severe mid-left anterior descending and mid-left circumflex disease. (*C*) Left main predilated with 2.5 mm balloon.

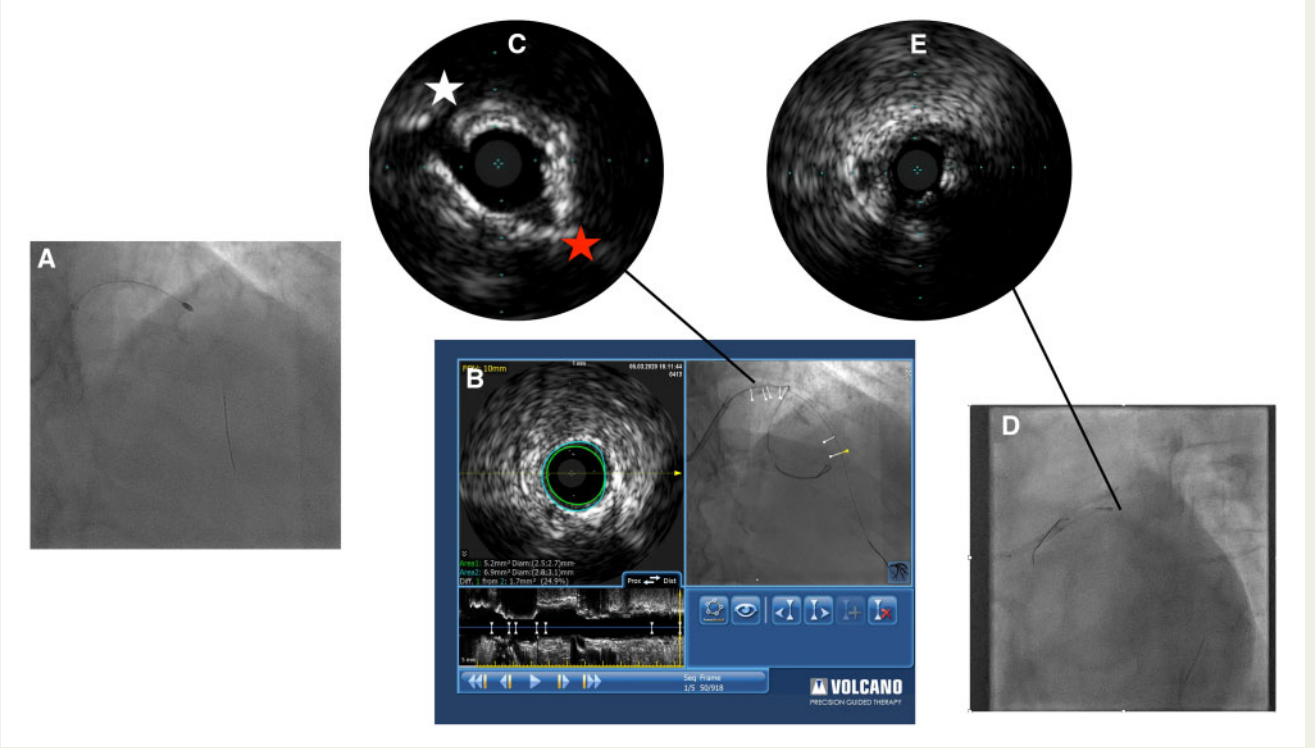


Figure 3 (*A*) Rotational atherectomy of left main–left anterior descending performed with 1.75 mm burr. (*B*) Co-registered intravascular ultrasound of left anterior descending–left main demonstrating distal landing zone in left anterior descending. (*C*) Intravascular ultrasound of left anterior descending ostium, wire seen in left circumflex (white star) disruption of calcium (red star) following rotational atherectomy. (*D* and *E*) Intravascular ultrasound of left circumflex demonstrating severe proximal disease.

Discussion

To the best of our knowledge, this report demonstrates the first description of ULPCI using complex DK crush technique and IVUS co-registration technology. Most previously described LM ULPCI case series were done in a smaller number using a provisional approach and there is only one description of ULPCI LM with two stents performed as a T-stent.[4,9,10] The novelty in our

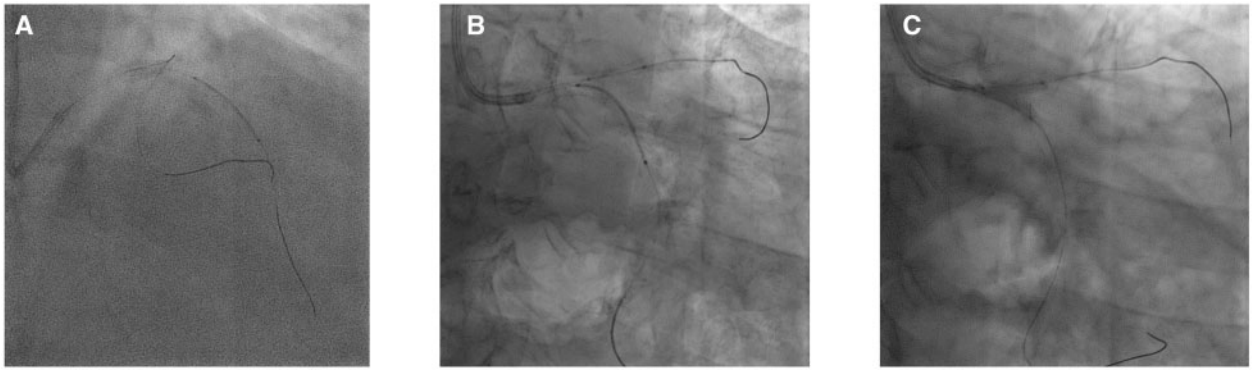


Figure 4 (*A*) Stenting of the mid-left anterior descending. (*B*) Positioning of left circumflex stent with a balloon in left anterior descending for the crush. (*C*) First kissing balloon inflation.

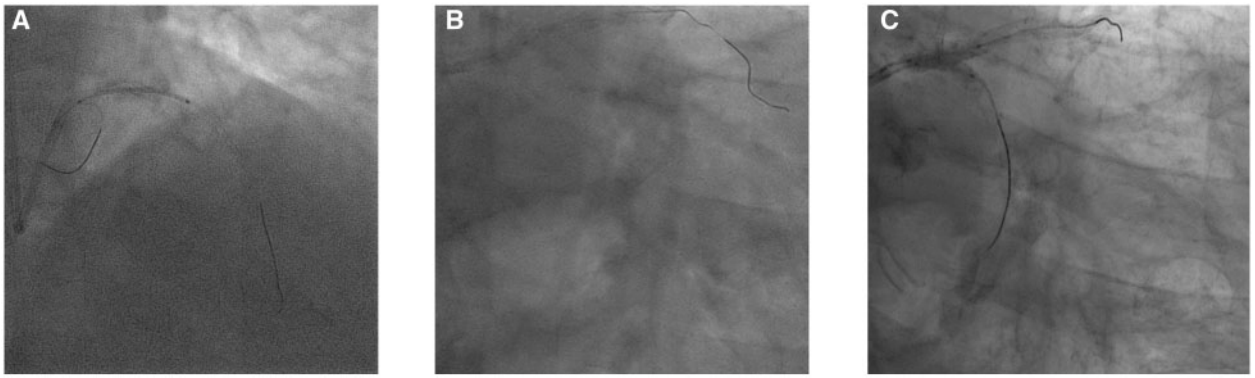


Figure 5 (*A*) Stenting of the left anterior descending to left main ostium with floating wire technique. (*B*) Second kissing balloon inflation. (*C*) Proximal optimization technique of the left main.

report lies in two main aspects. First, the use of Syncvision® IVUS co-registration technology for ULPCI which facilitated accurate positioning for balloon dilatation and stenting. Second, a complex DK crush strategy for LM bifurcation ULPCI was performed in three out of five cases as dictated by the coronary anatomy. The spectrum of the complexity of the cases described in the current report, including rotational atherectomy and mechanical haemodynamic support sets a new benchmark for LM ULPCI. Observational studies suggest that CKD patients with multivessel disease who undergo revascularization have better survival than those who receive medical therapy.[11,12] The recent ischaemia CKD trial concluded that patients with advanced CKD and moderate or severe ischaemia with stable coronary artery disease did not benefit from an initial invasive strategy, however, patients with intolerable angina were excluded in this study and nearly 50% of patients in the study had no angina.[13] In our series, the two patients with CCS were symptomatic despite optimal medical therapy. Nevertheless, patients with advanced CKD with NSTEACS and CCS with refractory angina, who are not a surgical candidates are often turned down by the cardiologists on the basis of CIN and renal failure risk. We did not repeat the coronary angiogram when patients underwent PCI. In the two cases of CCS there was a delay between diagnostic angiography and PCI due to the coronavirus pandemic. We decided against repeating the angiogram since it is unlikely that these patients will develop significant new disease, moreover the vessels with significant disease which are the target for PCI are all assessed with IVUS during the PCI. This series demonstrates that even in very unstable high-risk patients it is possible to perform complex intervention using minimal contrast. The benefit of ULPCI is to reduce the risk of CIN; however, the occurrence of acute kidney injury post-procedure is multifactorial and controlling for other

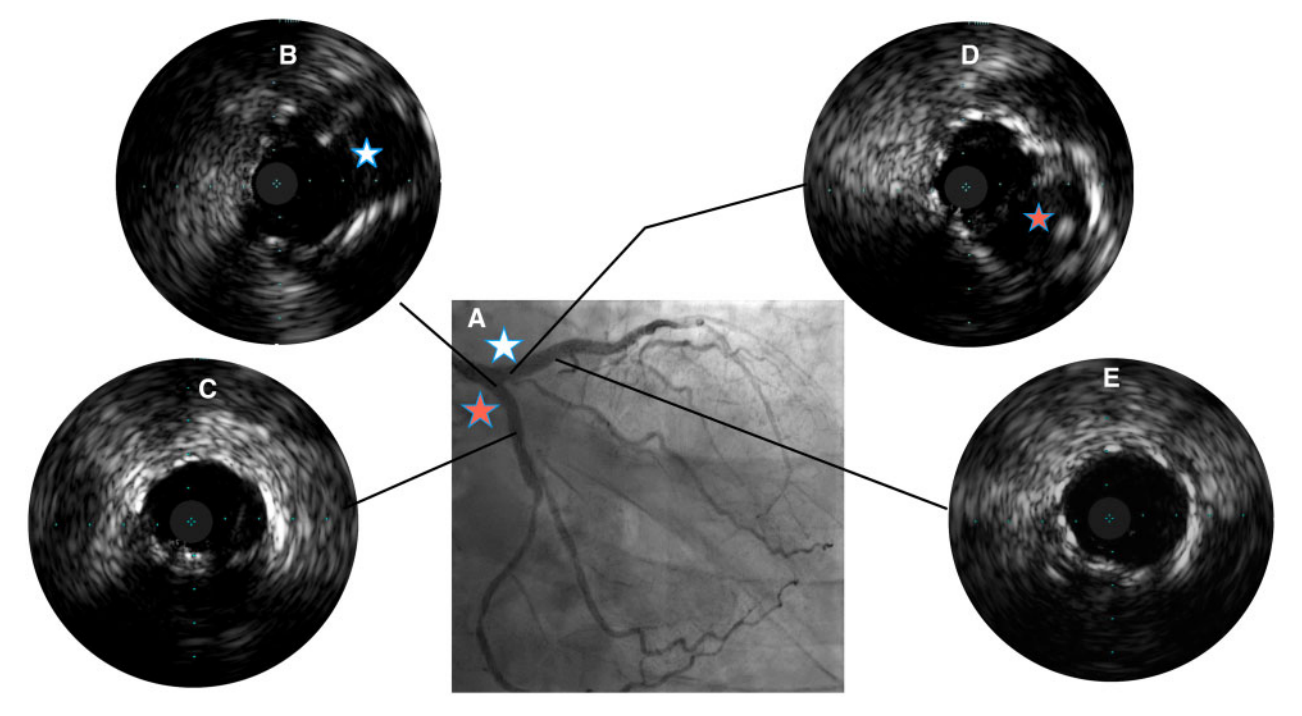
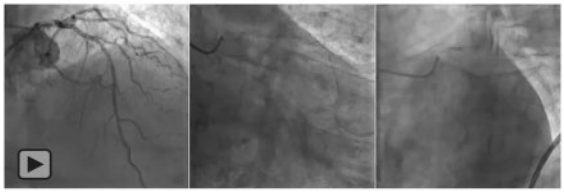
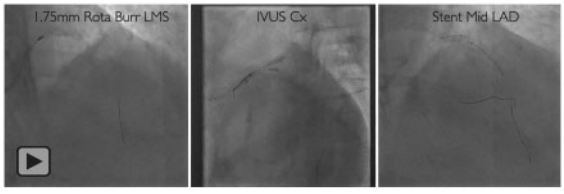


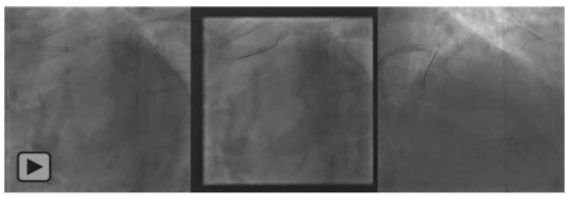
Figure 6 (*A*) Final angiogram. (*B*) Intravascular ultrasound left circumflex–left main, left anterior descending ostium seen with (white star) clearing of struts. (*C*) Intravascular ultrasound of Proximal Cx showing good stent expansion. (*D*) Intravascular ultrasound left anterior descending–left main, left circumflex ostium at the distal left main seen with clearing of struts (red star). (*E*) Intravascular ultrasound of mid showing good stent expansion.



Video 1 Case 1. Angiogram demonstrates severe calcified left main disease and severe proximal and mid-left anterior descending disease.



Video 3 Case 1. Rotational atherectomy of left main–left anterior descending with 1.75 mm rota burr. Intravascular ultrasound of left circumflex. Stenting of mid-left anterior descending.



Video 2 Case 1. Left circumflex and left anterior descending wired using previous angiogram as a roadmap. Balloon dilatation of left main to allow passage of intravascular ultrasound catheter.

factors (e.g. hydration, haemodynamic stability) is of paramount importance.[14] When performing this technique, few points should be taken into consideration. First, there is a learning curve for doing this technique and early cases may take longer time to perform. Second, it is important to start with the simpler lesions to gain enough experience and familiarity before contemplating any complex cases. Third, patients should have a follow-up to assess renal function 3–5 days after intervention. Finally, patient safety during the procedure must override any planned ultra-low contrast use (i.e. use contrast if the clinical situation mandates).

Conclusion

The use of IVUS with co-registration adds an additional dimension to perform ULPCI, reduces the risk of CIN, and can be used to perform complex LM bifurcation stenting with good results.

Lead author biography

Dr Billal Patel is an Interventional Cardiologist at Lancashire Cardiac Centre (Blackpool, UK). His special interests include ultra-low contrast PCI, intracoronary imaging, left main bifurcations, and mentorship for trainees and education. Research interests include coronary physiology and microvascular dysfunction.

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 series including images and associated text has been obtained from the patients in line with COPE guidance.

Conflict of interest: B.P. reports receiving speaker fees for Philips. All other authors declared no conflict of interest.

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