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Case report

Double-kissing crush of the complex left main bifurcation lesions in a patient with acute coronary syndrome and cardiogenic shock

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Abstract Percutaneous coronary intervention of distal unprotected left main bifurcation lesions is technically very challenging, and associated with lower procedural success rate and an increased rate of major adverse cardiac and cerebrovascular events at short- and long-term follow-up, in comparison to coronary artery bypass graft surgery. Herein, we present in detailed a double kissing crush stenting of distal unprotected left main true and complex bifurcation lesion in 69-years old female patient with acute coronary syndrome and cardiogenic shock. Therefore, our patient needed urgent coronary angiography and „ad hoc" percutaneous coronary intervention of the „culprit" lesion due to life-threating condition. This article is focused on advantages of this 2-stent technique over other techniques in the treatment of the distal unprotected left main bifurcation lesions, and point out its limitations as well. Performing double kissing crush stenting in the distal unprotected left main true and complex bifurcation lesions is much more challenging than other stenting technique, but if it is performed by an experienced interventional cardiologist, the efficacy and safety of the procedure exceeds its potential disadvantages, which is of utmost importance for patient benefit.

Key words Acute coronary syndrome, Unprotected left main bifurcation lesion, Double kissing crush, Percutaneous coronary intervention

Introduction

Percutaneous coronary intervention (PCI) of distal unprotected left main (ULM) bifurcation lesions is technically very challenging, and associated with lower procedural success rate and an increased rate of major adverse cardiac and cerebrovascular events (MACCE) at short- and long-term follow-up, in comparison to coronary artery bypass graft surgery (CABG)[1-3]. There are several techniques for this type of lesion, including provisional stenting, T-stenting, T-stenting and small protrusion (TAP), Culotte and double-kissing (DK) Crush stenting[4-5]. Herein, we present a DK-Crush stenting of distal ULM true and complex bifurcation lesion in our patient with acute coronary syndrome and cardiogenic shock. We emphasize advantages of this 2-stent technique over other techniques in the treatment of the distal ULM bifurcation lesions, and point out its limitations as well.

Case Report

A 69-years old female patient was admitted to our hospital due to typical chest pain and dyspnea onset 2 hours ago and ischemic changes on ECG with ST elevation in leads aVR and V1, and horizontal and down-sloping ST depression in all other leads (Figure 1). The patient was hemodynamically unstable with arterial blood pressure (BP) 70/40 mmHg, and therefore, both vasopressor (norepinephrine 2-4 μg/min iv. infusion) and inotropic stimulation (dopamine 2-5 μg/kg/min iv. infusion) were given. The patient was unconscious, intubated, and on mechanical ventilation. Echocardiography findings showed impaired left ventricle function, with ejection fraction (EF) 30%, and hypo-akinesia of medial and apical segments of interventricular septum and anterior wall, and hypokinesia of both lateral and inferior wall. The patients had several comorbidities: arterial hypertension, hyperlipoproteinemia, and poorly regulated insulin-dependent diabetes mellitus (>20 years) with glycated hemoglobin (HbA1C) 7.8%. In the Coronary Care Unit (CCU), the patient was treated with loading dose of dual antiplatelet therapy (aspirin 300 mg and ticagrelor 180 mg) through a nasogastric tube. Due to clinical and ECG signs of acute coronary syndrome (ACS) and hemodynamic instability, the patient was planned for urgent coronary angiography and PCI.
Initial coronary angiogram was performed with the femoral artery approach using standard Judkins tech-

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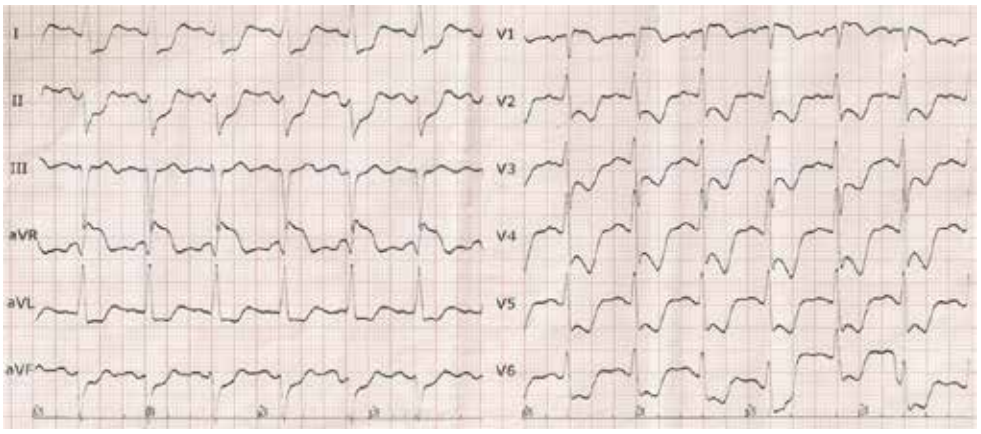

Figure 1. ECG on admission to Coronary Care Unit (CCU): Note the elevation of ST segment of 5.0 mm in lead aVR and 2.0 mm in lead V1 (STaVR > STV1), and horizontally and downsloping depression of ST segment with negative T waves in all other leads. These ECG changes implicates that the culprit lesion is located in the left main (LM), and the patient is at very high-risk for intrahospital mortality due to high amplitude od ST elevation in lead aVR.

nique with 7-French catheters. The culprit lesion was a true bifurcation lesion located in the distal segment of left main (LM) and ostial and proximal segments of both left circumflex artery (LCx) and left anterior descending artery (LAD), with Thrombolysis in Myocardial Infarction (TIMI) 2 flow in both arteries (Figure 2.A). Also, there was a significant stenosis in the medial segment of LAD and distal segment of LCx, as well as in the proximal and medial segments of right coronary artery (RCA) (Figure 2.B,C).

Analyzing the lesion complexity, we emphasized several key characteristics according to EBC consensus document[4,5], which defined our stenting strategy:

1. This was a true bifurcation lesion: 1,1,1 according to Medina classification;
2. The LCx reference diameter was >2.5 mm and it was around 3.0 mm, but it was smaller than LM diameter;
3. There was a significant stenosis at the LCx ostium extending more than 5 mm into the artery;
4. The angle between LAD and LCx was >70 degree (around 90 degree); and
5. Because of significant and long ostial stenosis, we assumed that it would be difficult to access the LCx, and that there was a high-risk of LCx compromise if we first stent the LM towards the LAD.

Therefore, our decision was to perform DK-Crush technique. Culotte stenting was not our first choice due to significant mismatch between the LM and the LCx reference diameters and wide bifurcation angle (>70 degree). After wiring both LAD and LCx with Asahi Sion Blue (Asa-

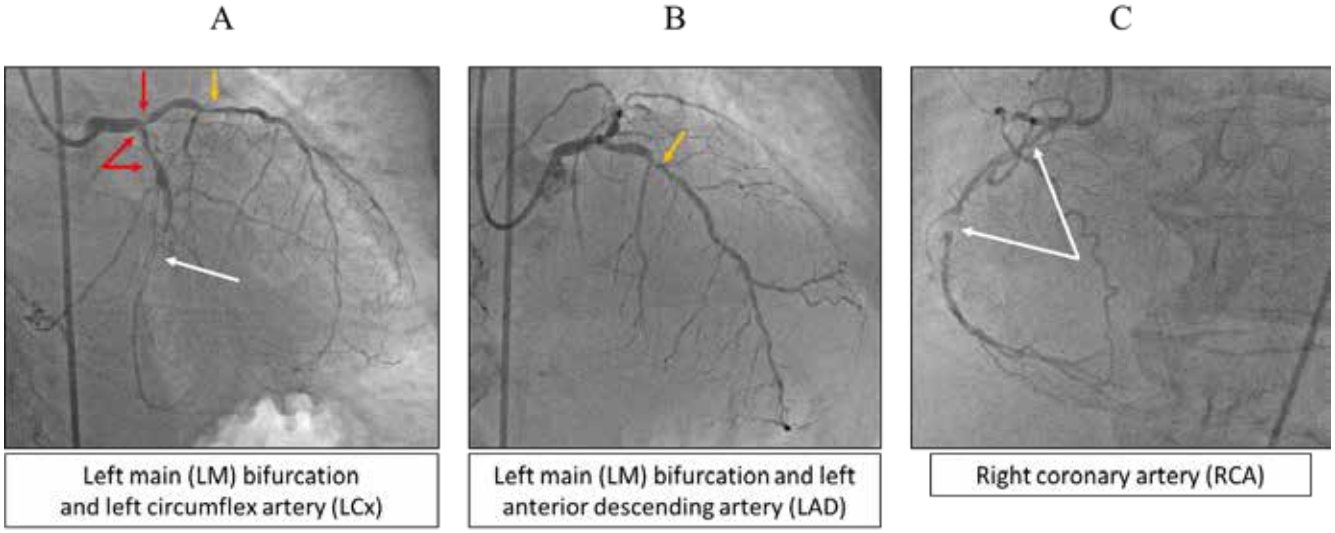

Figure 2. Initial coronary angiogram. A. Postero-anterior (PA) projection with caudal 20 degree angulation shows that the culprit lesion was a true bifurcation lesion located in the distal segment of left main (LM) and ostial and proximal segments of both left circumflex artery (LCx) and left anterior descending artery (LAD), with Thrombolysis in Myocardial Infarction (TIMI) 2 flow in both arteries (red arrows); B. PA projection with cranial 40 degree angulation shows a significant stenosis in the medial segment of LAD (yellow arrow), as well as in the distal segment of LCx (white arrow); and C. Left anterior oblique (LAO) projection 30 degree shows a significant stenosis in the proximal and medial segments of right coronary artery (RCA) (white arrows)

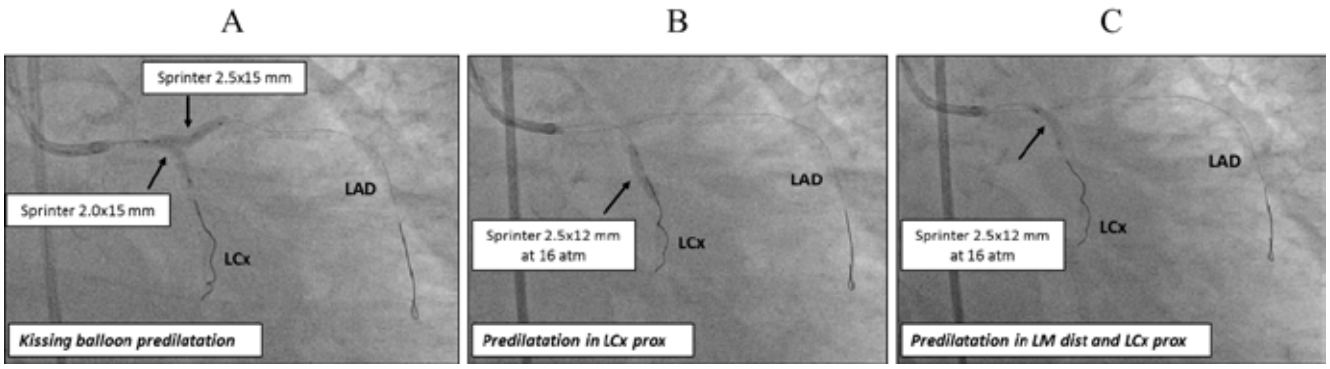

Figure 3. Balloon predilatations of the left main (LM), left anterior descending artery (LAD) and left circumflex artery (LCx). A. Kissing balloon predilatation of the LM bifurcation with 2 semi-compliant (SC) balloons; B. Predilatation in the proximal segment of LCx with SC balloon; C. Predilatation in the ostial segment of LCx and LM with SC balloon.

hi Intecc), kissing balloon predilatation of the LM bifurcation were performed first, with 2 semi-compliant (SC) balloons: Sprinter (Medtronic) 2.5x15 mm in LM-LAD at 14 atm and Sprinter (Medtronic) 2.0x15 mm in LM-LCx at 16 atm (Figure 3A). Additionally, multiple predilatations of LCx were performed in its ostial and proximal segments with SC balloon Sprinter (Medtronic) 2.5x12 mm at 16 atm (Figure 3.B,C). Thrombolysis in myocardial infarction (TIMI) 3 flow was achieved, and arterial BP was increased up to 85/50 mmHg. After that, stenting of the LCx with minimal protrusion in the LM was performed (Figure 4.A,B). Figure 4A shows positioning of the stent in LCx, and in the same time positioning of the SC balloon Sprinter (Medtronic) 3.5x20 mm in the LM towards the LAD. Figure 4B shows implantation of the stent Synergy (Boston Scientific) 3.0x20 mm at 16 atm in the LCx with minimal protrusion in the LM. The next step was removing guidewire and balloon from the LCx, and after that, the SC balloon Sprinter (Medtronic) 3.5x20 mm was inflated in the LM-LAD at 14 atm crushing the proximal part of the stent in the LM (Figure 4C). Additionally, the proximal optimization (POT)-crush in the LM with the same SC balloon at 20 atm was also performed (Figure 4D).

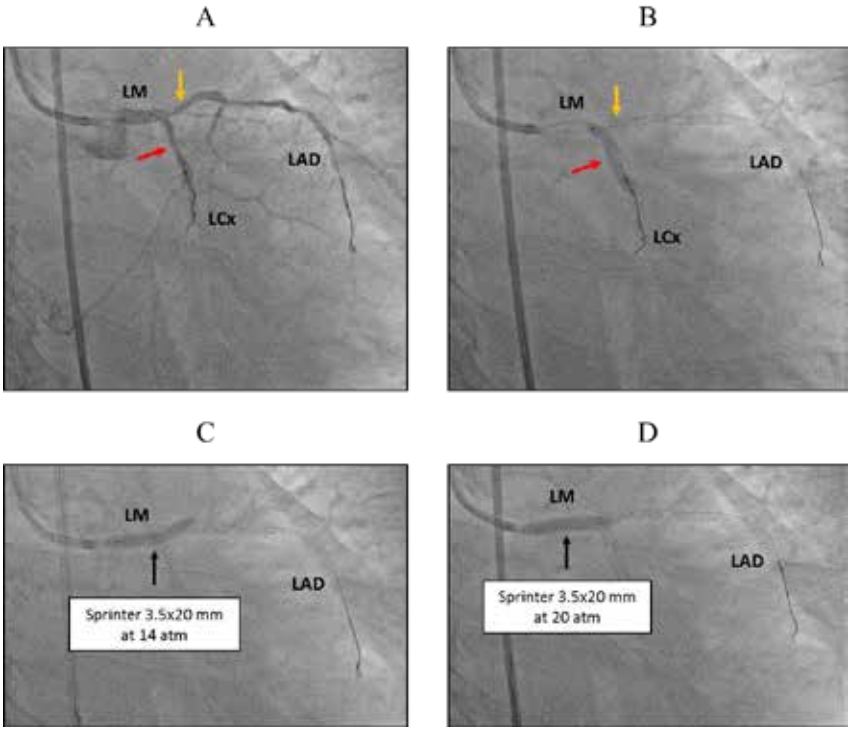

Figure 4. A. Positioning of the stent Synergy (Boston Scientific) 3.0x20 mm (red arrow) in the left circumflex artery (LCx) with minimal protrusion in the left main (LM), and in the same time positioning of the uninflated semi-compliant (SC) balloon Sprinter (Medtronic) 3.5x20 mm (yellow arrow) in the LM towards the left anterior descending artery (LAD); B. Implantation of the stent Synergy (Boston Scientific) 3.0x20 mm at 16 atm (red arrow) in the LCx with minimal protrusion in the LM. The uninflated SC balloon Sprinter (Medtronic) 3.5x20 mm (yellow arrow) is located in the LM towards the LAD; C. After removing guidewire and balloon from the LCx, the crush of the proximal part of the implanted stent in the LM was performed with SC balloon Sprinter (Medtronic) 3.5x20 mm in the LM-LAD at 14 atm; and D. The proximal optimization (POT)-crush in the LM was performed with the same SC balloon at 20 atm.

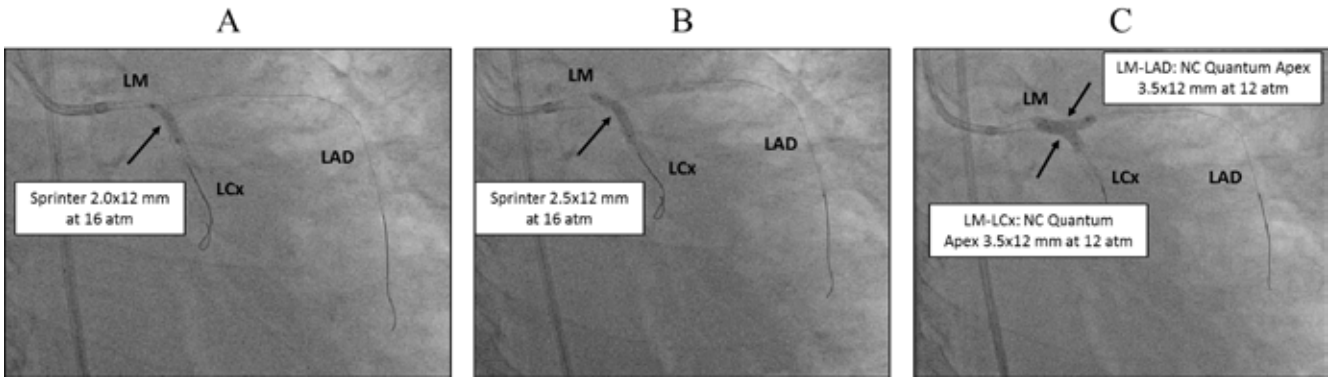

Figure 5. A. and B. After rewiring of the left circumflex artery (LCx) through the proximal strut of the crushed stent, LCx strut dilatation was performed with semi-compliant (SC) balloons Sprinter (Medtronic) 2.0x12 mm and Sprinter (Medtronic) 2.5x12 mm, both at 16 atm; C. First kissing balloon inflation (KBI) was performed with 2 non-compliant (NC) balloons: NC Quantum Apex (Boston Scientific) 3.5x12 mm in LM-LAD at 12 atm and NC Quantum Apex (Boston Scientific) 3.5x12 mm in LM-LCx at 12 atm. LM - left main; LAD - left anterior descending artery

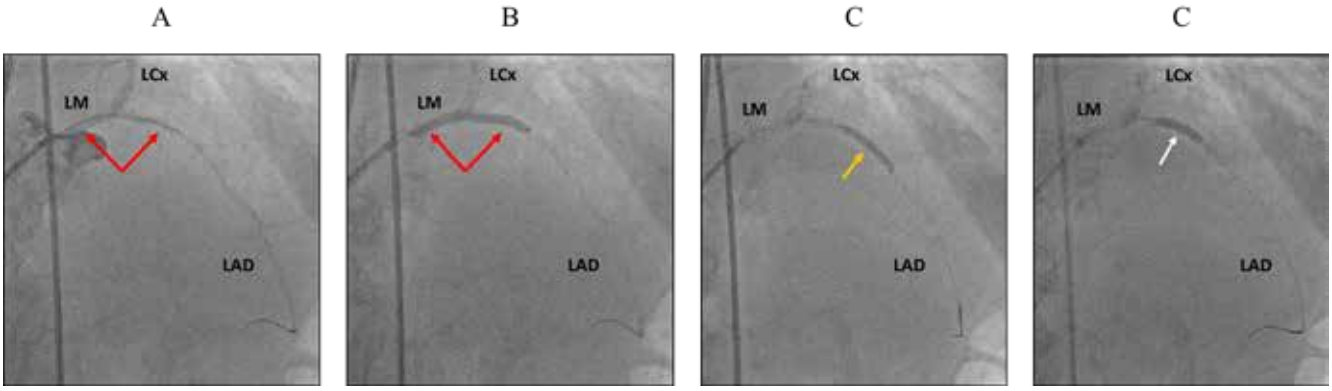

Figure 6. A. Positioning of the stent CID (Alvimedica) 3.5x38 mm (red arrows) from the left main (LM) ostium towards the proximal segment of left anterior descending artery (LAD), after removing the guidewire from the LCx; B. Implantation of the stent CID (Alvimedica) 3.5x38 mm (red arrows) from the LM ostium towards the proximal segment of LAD at 14 atm; C. Another stent Promus Premier (Boston Scientific) 3.0x20 mm (yellow arrow) was implanted in the medial segment of LAD at 14 atm; and D. Postdilatation between two stents in the LAD with non-compliant (NC) balloon Quantum Apex (Boston Scientific) 3.5x12 mm at 16 atm (white arrow). LCx - left circumflex artery

After rewiring of the LCx through the proximal strut of the crushed stent with Asahi Sion Blue (Asahi Intecc), LCx strut dilatation was performed with SC balloons Sprinter (Medtronic) 2.0x12 mm and Sprinter (Medtronic) 2.5x12 mm, both at 16 atm (Figure 5.A,B). First kissing balloon inflation (KBI) was performed with 2 non-compliant (NC) balloons: NC Quantum Apex (Boston Scientific) 3.5x12 mm in LM-LAD at 12 atm and NC Quantum Apex (Boston Scientific) 3.5x12 mm in LM-LCx at 12 atm (Figure 5C). Then, after removing the guidewire and balloon from the LCx, stent CID (Alvimedica) 3.5x38 mm was implanted from the LM ostium towards the proximal segment of LAD at 14 atm (Figure 6.A,B). Additionally, another stent Promus Premier (Boston Scientific) 3.0x20 mm was implanted in the medial segment of LAD at 14 atm, and postdilatation between two stents in the LAD with NC balloon Quantum Apex (Boston Scientific) 3.5x12 mm at 16 atm was performed (Figure 6.C,D).

After second rewiring with Asahi Sion Blue (Asahi Intecc) of the LCx through the distal strut of the crushed stent, final KBI was performed in the same way as the first one with the higher pressure in the balloon located in the LCx atm (Figure 7A). After that, the POT with NC Quantum Apex (Boston Scientific) 4.5x12 mm at 14 atm, and additionally flaring with the same NC balloon at 20 atm were performed in the ostial segment of LM, in order to improve optimal stent expansion and strut apposition in the artery (Figure 7.B,C).

Figure 8 shows the final angiogram with good result and TIMI 3 flow in both LAD and LCx arteries. Arterial BP was increased up to 110/70 mmHg immediately after PCI, with vasopressor (norepinephrine 2-4 µg/min iv. infusion) and without inotropic stimulation for the next several days. Maximal value of high-sensitive troponin T was 9372 ng/L, while brain natriuretic peptide was >5000 pg/ml.

However, 400 ml of contrast agent was used for the intervention in this patient with cardiogenic shock, and therefore, contrast-induced nephropathy occurred. Seventy-two hours after PCI, serum creatinine level increased from 86 up to 272 µmol/L, while estimated glomerular filtration rate (eGFR) decreased from 58 up to 15 ml/min/1.73 m^2. The patient was received 6 hemodialysis for the next 6 days. Fourteen days after PCI, serum creatinine level decreased up to 108 µmol/L, while eGFR increased up to 48 ml/min/1.73 m^2. The patient was hemodynamically stable, with arterial BP of 110/70 mmHg, without

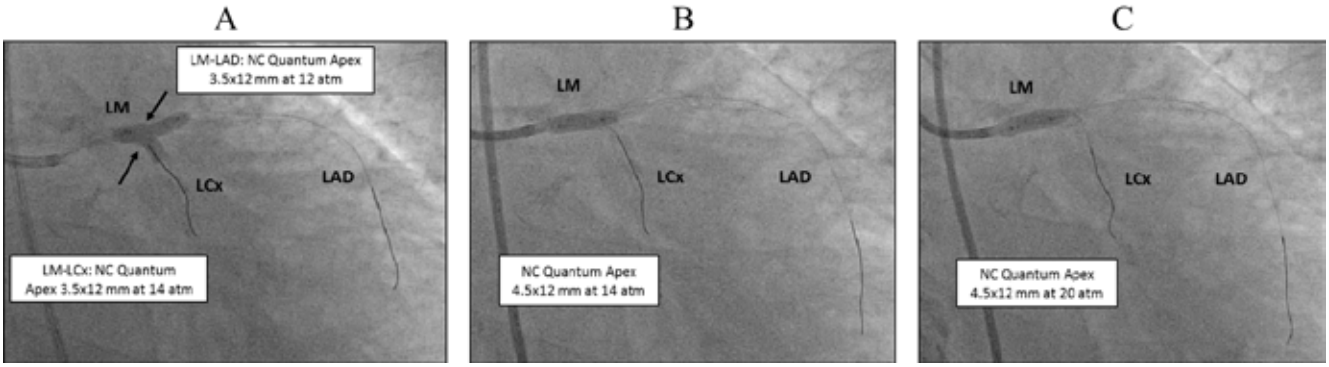

Figure 7. A. Final kissing balloon inflation (KBI) was performed with 2 non-compliant (NC) balloons: NC Quantum Apex (Boston Scientific) 3.5x12 mm in LM-LAD at 12 atm and NC Quantum Apex (Boston Scientific) 3.5x12 mm in LM-LCx at 14 atm; B. The proximal optimization (POT) in the LM with NC Quantum Apex (Boston Scientific) 4.5x12 mm at 14 atm; and C. Flaring with the same NC balloon at 20 atm were performed in the ostial segment of LM, in order to improve optimal stent expansion and strut apposition in the artery. LM - left main; LAD - left anterior descending artery; LCx - left circumflex artery

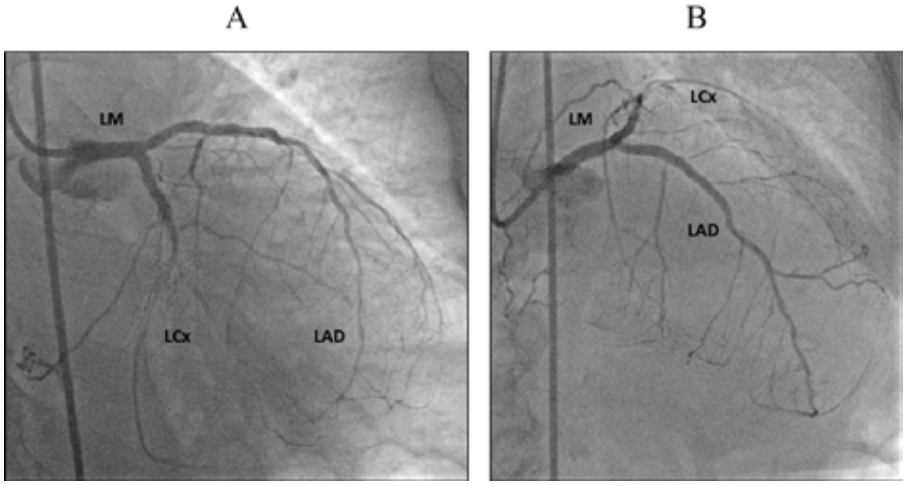

Figure 8. Final coronary angiogram shows good result and TIMI 3 flow in both left anterior descending (LAD) and left circumplex (LCx) arteries. A. Postero-anterior (PA) projection with caudal 20 degree angulation; and B. PA projection with cranial 40 degree angulation. Significant stenosis in the distal segment of LCx, as well as in the proximal and medial segments of right coronary artery (RCA) did not treat during index procedure. LM – left main

vasopressor and inotropic stimulation. Therefore, she was discharged from our hospital, and planned for outpatient visit 1 month later.

Discussion

The present case demonstrates detailed approach to the DK-Crush technique for stenting of distal ULM true bifurcation lesion in hemodynamically unstable patient with acute coronary syndrome and cardiogenic shock. Therefore, our patient needed urgent coronary angiography and „ad hoc" PCI of the „culprit" lesion due to life-threating condition. Current European Society of Cardiology (ESC) guidelines recommend PCI as an alternative to CABG surgery in selected patients with ULM coronary artery disease[6]. Previous studies and registries have been demonstrated that 1-stent strategy with drug-eluting stent (DES) placement (especially new-generation DES) for ostial or body/shaft lesions of the ULM was non-inferior in comparison to CABG in terms of long-term MACCE[7-12]. However, the majority of patients with ULM coronary artery disease have involvement of the distal bifurcation, which is associated with worse long-term outcomes after stenting compared with ostial/shaft lesions treatment[8,13]. In DELTA-2 registry, 85% of patients had involvement of the distal ULM bifurcation which was treated with provisional stenting in majority of cases, while 2-stent strategy was performed in only 20% of them[6]. In this registry, PCI of ULM was associated with lower risk for cerebrovascular events, but with higher risk for target vessel revascularization (TVR), in comparison to CABG at long-term follow-up[9]. However, there were no differences in death and myocardial infarction (MI) between PCI DELTA 2 cohort and CABG DELTA 1 cohort[8-9]. Similarly, in the recent EXCEL (Evaluation of XIENCE Versus Coronary Artery Bypass Surgery for Effectiveness of Left Main Revascularization) trial, 80% of patients had distal ULM bifurcation lesion with low or intermediate SYNTAX (Synergy Between Percutaneous Coronary Intervention With Taxus and Cardiac Surgery) scores ($\leq$32), which were also treated most commonly with provisional stenting using new-generation DES (everolimus-eluting stent, XIENCE, Abbott Vascular)[12]. In this trial, PCI of ULM with

new-generation DES was non-inferior to CABG with respect to composite rate of death, MI or stroke at long-term follow-up, but TVR rate at 30 days was higher with PCI[12]. Contrary, in the NOBLE (Nordic-Baltic-British Left Main Revascularization Study) trial, in which around 80% of patients also had distal ULM bifurcation lesion and treated with provisional stenting using first-generation DES, PCI of ULM was associated with a higher composite rate of death, MI, stroke, or repeat revascularization at 5 years than CABG[11]. Therefore, PCI of distal ULM bifurcation lesion remains a matter of debate[14].

Although provisional stenting is currently recommended for most non-LM bifurcation lesions, a recent study by Chen et al. showed a worse outcome at 1-year follow-up with this 1-stent strategy of distal ULM true bifurcation lesion compared with DK-Crush 2-stent strategy[13,15-19]. This result was driven by higher rates of target vSessel MI and definite or probable stent thrombosis (ST), as well as rates of target lesion revascularization (TLR), especially at the LCx ostium, in the provisional group compared with DK-Crush group[13]. Similar findings were observed in the DKCRUSH-III trial in which DK-Crush stenting was superior to another 2-stent Culotte strategy in the treatment of distal ULM true bifurcation lesions, also driven by lower rates of definite or probable ST, as well as rates of TVR and TLR, especially at the LCx ostium, as in DK-CRUSH V trial[15,20]. This increased 3-year rate of ST in the Culotte group led to a more frequent MI and cardiac deaths, especially in patients with complex distal ULM bifurcation lesion with wide bifurcation angle (≥70%), and SYNTAX score ≥23[20-21]. There are several reasons for the superiority of DK-Crush over both provisional and Culotte stenting in the treatment of distal ULM true bifurcation lesions. First, DK-Crush with first KBI immediately after balloon crush provides better stent expansion at the LCx ostium[13,15,20]. Second, final KBI and POT with NC balloon at high pressure during DK-Crush stenting further improves stent expansion and strut apposition at both LAD and LCx ostium, as well as in the ULM[15,20]. Therefore, DK-Crush ensures fully coverage of the LCx ostium with less metal overlap and stent distortion, resulting in lower rates of in-stent restenosis, TLR and TVR, as well as ST and target vessel MI, in comparison to Culotte stenting[15,20]. Additionally, it has been demonstrated that DK-Crush stenting of distal ULM bifurcation lesion with wide angle ≥70% was associated with much better efficacy in terms of MACCE and better safety in terms of ST, compared with Culotte stenting[15,20]. Regarding provisional approach of the distal ULM true bifurcation lesion, bail-out LCx stenting through ULM stent cells may be difficult or result in imprecise placement, incomplete stent expansion and strut apposition, or edge dissection[13]. According to previous findings, the European Society of Cardiology (ESC) recommends DK-Crush stenting as a preferred strategy for the treatment of distal ULM true bifurcation lesion (Class of Recommendation IIB, Level of Evidence B)[6].

However, DK-Crush is a very complex technique with many steps, and therefore, requires additional procedural time and large amount of contrast dose usage[22]. This could be very unfavorable in patients with cardiogenic shock due to renal hypoperfusion resulting in higher risk for contrast-induced nephropathy which is a well-known strong predictor of in-hospital morbidity and mortality[23]. Therefore, it is necessary to take into account both benefit and risk for DK-Crush stenting in these patients, and this benefit-risk ratio largely depends on the operator skill and experience[22].

Performing DK-Crush in distal ULM true and complex bifurcation lesions is much more challenging than Culotte and/or provisional stenting, but if the PCI is performed by an experienced interventional cardiologist, the efficacy and safety of the procedure exceeds its potential disadvantages, which is of utmost importance for patient benefit.

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Sažetak

"Double-Kissing Crush" tehnika kompleksne bifurkacione lezije na glavnom stablu leve koronarne arterije kod pacijenta sa akutnim koronarnim sindromom i kardiogenim šokom

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Perkutana koronarna intervencija bifurkacione lezije glavnog stabla leve koronarne arterije je tehnički veoma izazovna i zahtevna procedura, i udružena je sa manjim periproceduralnim uspehom i većom učestalošću neželjenih kardiovaskularnih i cerebrovaskularnih događaja tokom kratkoročnog i dugoročnog perioda praćenja, u poredjenju sa aorto-koronarnom bajpas operacijom srca. U ovom radu detaljno objašnjavamo "double kissing crush" stent tehniku lečenja prave i kompleksne bifurkacione lezije glavnog stabla leve koronarne arterije kod 69-godišnje bolesnice sa akutnim koronarnim sindromom koji je komplikovan kardiogenim šokom. Zbog toga je našoj bolesnici bila potrebna hitna koronarna angiografija i „ad hoc" perkutana koronarna intervencija lezije odgovorne za nastanak ovog životno-ugrožavajućeg stanja. Ovaj rad je fokusiran na prednosti "double kissing crush" stent tehnike u odnosu na druge tehnike u lečenju bifurkacione lezije glavnog stabla leve koronarne arterije, ali takodje ukazuje i na njena postojeća ograničenja. Izvođenje ove stent tehnike u lečenju prave i kompleksne bifurkacione lezije glavnog stabla leve koronarne arterije mnogo je zahtevnije od ostalih tehnika stentiranja, ali ako je izvodi iskusan interventni kardiolog, efikasnost i bezbednost ove tehnike prevazilazi njene potencijalne nedostatke, što je od najveće važnosti za dobrobit pacijenta.

***Ključne reči**: Akutni koronarni sindrom, Bifurkaciona lezija glavnog stabla, Double kissing crush stent tehnika, Perkutana koronarna intervencija*