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Imaging-guided percutaneous coronary intervention with ultra-low contrast angiographic control for patients at extreme risk of contrast induced nephropathy

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The occurrence of contrast induced nephropathy (CIN) remains one of the gravest complications of percutaneous coronary intervention (PCI) and is related to increased morbidity and mortality [1, 2]. In select cases renal replacement therapy is required, increasing the rate of major adverse events [3]. Minimizing contrast administration and optimal fluid management are effective in prevention [4], but in select patients a minimal quantity of contrast may lead to CIN. Since indicated the first feasibility reports [5–7], the concept of intravascular ultrasound (IVUS) guided PCI has become appealing for patients at risk of CIN. Presented herein, is a series of IVUS-guided PCI cases with ultra-low contrast volume angiographic control.

The procedure protocol is as follows. Hydrophobic guidewires are placed in main vessel and major sidebranches. Intraluminal position is IVUS-verified. "Dry-cine" positioning of IVUS and ultrasound imaging are co-registered to select optimal strategy. The effect of main vessel stenting is assessed with control IVUS pullbacks. Should a side branch compromise be suspected, the vessel is re-wired and physiological assessment is performed. In order to achieve optimal imaging quality, HD-IVUS is the preferred imaging modality. Post-procedural transthoracic echocardiography is performed to exclude pericardial effusion. Bail-out contrast administration is acceptable yet remains the last resort. Thus, this protocol admits the administration of a minimal quantity of contrast media mixed 1:1 with saline for post-procedural ultra-low contrast angiographic verification only, at the operator's discretion. The acceptable quantity of contrast is calculated from MDRD estimated glomerular filtration rate (eGFR) as follows: x mL of contrast = eGFR/2. The maximum quantity actually administered per patient in the following case series was 4 mL.

Patient 1. A 72-year-old male with chronic kidney disease (CKD) stage 4 was admitted with non-ST-segment elevation myocardial infarction (NSTEMI). Echocardiography showed moderate left ventricular systolic dysfunction (left ventricular ejection fraction [LVEF] 42%), eGFR was 20.9 mL/min/1.73 m^2). Coronary angiography showed multivessel disease (MVD), with diffuse lesions in left anterior descending artery (LAD), obtuse marginal branches (OM1, OM2) and significant aorto-ostial in right coronary artery (RCA) (Fig. 1A, B). Within 24 h CIN had developed, with oliguria and an eGFR drop to 16 mL/min/1.73 m^2. This was treated with hydration. The patient was qualified for coronary artery bypass grafting (CABG). Due to scarce venous material the RCA was not grafted and qualified for "zero contrast" PCI. The artery was wired with a hydrophobic wire. IVUS confirmed diffuse significant stenosis originating in the ostium (Fig. 1C, D). Dry cine of the IVUS sensor was acquired at plaque origin. Direct stenting with a 3.5 × 29 sirolimus eluting stent was performed with post-dilation of the ostium. Control IVUS pullback confirmed proper deployment and apposition of the stent. One control contrast injection was performed (4 mL saline and 4 mL of contrast) to confirm the findings of IVUS (Fig. 1E, G). Further in-hospital stay was uneventful. The patient was discharged on the second day post-PCI with no signs of CIN.

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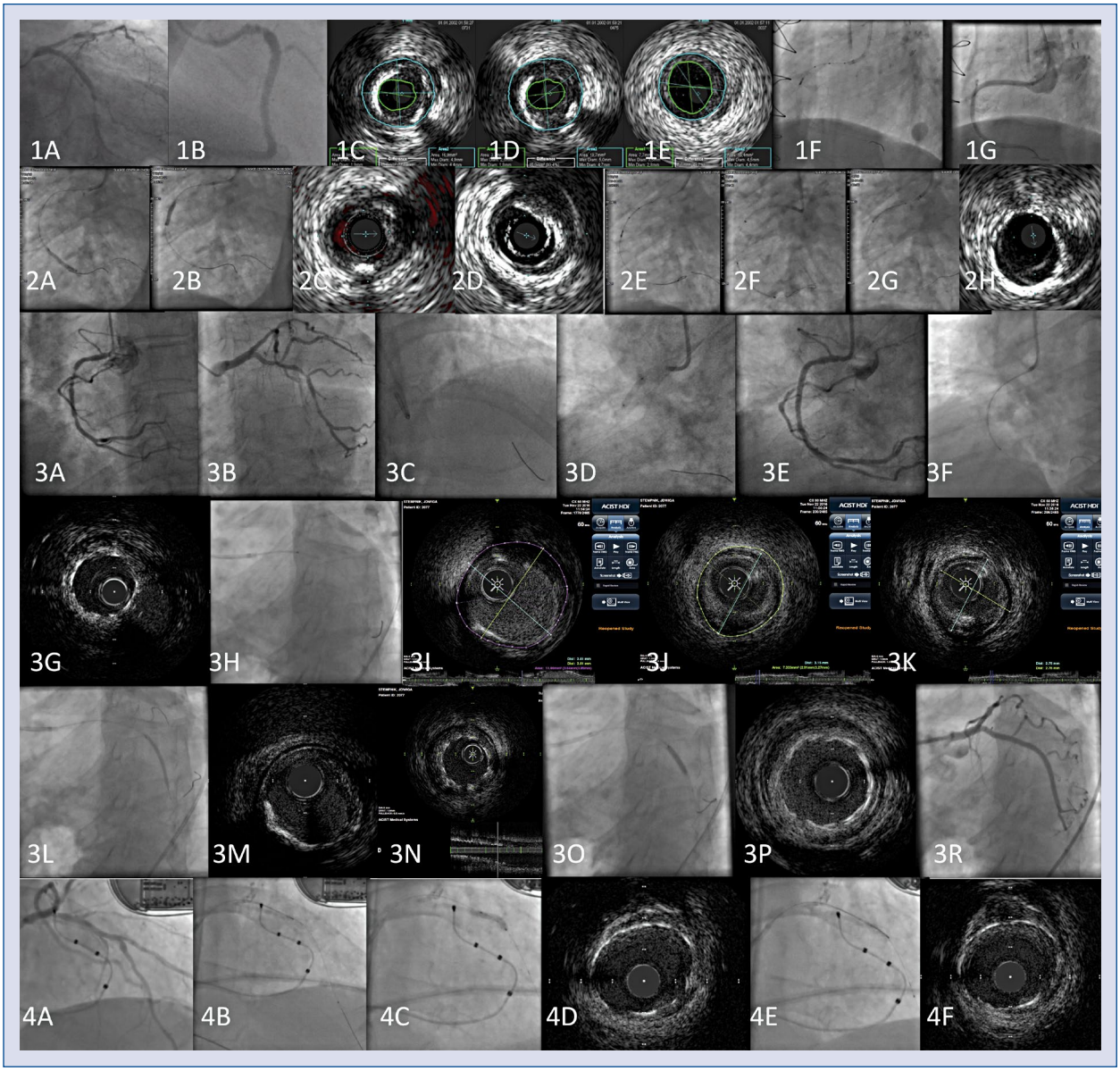

Figure 1. Intravascular ultrasound-guided percutaneous coronary intervention. **1A–G.** Case 1; **2A–H.** Case 2; **3A–R.** Case 3; **4A–F.** Case 4.

Patient 2. A 74-year-old female, with numerous comorbidities (diabetes, stage IV CKD — eGFR on admission 26 mL/min/1.73 m^2, Leriche syndrome), was admitted after an NSTEMI complicated with pulmonary edema. Echocardiography revealed an LVEF of 48% with no valvular disease. The patient was initially qualified for CABG, however after re-assessment (dubious ostial left main lesion, diffuse critical stenoses of the RCA) the patient was qualified for IVUS-guided PCI. The significance of ostial left main lesion was excluded (minimal lumen area [MLA] 8.8 mm^2). As IVUS catheter introduction to the RCA was impossible, numerous predilations were performed (Fig. 2A, B). IVUS pullback revealed diffuse, calcified lesions with a dissection in mid-RCA (Fig. 2C, D). A "mother and child" catheter was introduced to the distal part of the vessel and 3 everolimus eluting stents (EES) were implanted (3.5 × 38; 3.5 × 33; 4.0 × 28; Fig. 2E, F). Control IVUS pullback showed stent underexpansion in the mid and distal RCA. Post-dilation with 3.0 and 4.0 non-compliant balloon resulted in an optimal IVUS result (Fig. 2G, H). However, the patient presented with chest pain. Control echo showed good contractility and no pericardial effusion. A single contrast injection was performed (4 mL of contrast mixed with 4 mL of saline), confirming optimal PCI result, identifying 2 small

(< 1 mm) occluded side branches of the RCA. Further in-hospital stay was uneventful and the patient was released 4 days after the procedure.

Patient 3. A 75-year-old male with hypertension and diabetes was admitted with Canadian Cardiovascular Society (CCS) III angina. Echocardiography showed very good LVEF with no valvular disease. Coronary angiography revealed MVD with critical RCA lesions, significant circumflex artery (Cx) lesions and diffuse LAD lesions (LAD FFR 0.89). Ad hoc RCA PCI with 1 EES was performed (Fig. 3A–E). After the procedure (130 mL of contrast media) CIN was diagnosed and treated with i.v. fluids (creatinine levels 113 → 147 → 117 μmol/L). The patient qualified for a second stage procedure. On readmission (after 3 months) deterioration of renal function was observed (eGFR 28 mL/min/1.73 m^2) with no improvement after 6 days of hydration. The patient qualified for IVUS--HD assessment of the RCA and IVUS-HD guided zero contrast Cx PCI. IVUS-HD of RCA showed optimal effect of prior PCI (Fig. 3F, G). Cx was wired with a hydrophobic wire. IVUS showed diffuse obstructive CAD (Fig. 3H–K). OM1 was wired. Balloon angioplasty with a 2.5 × 30 mm catheter was performed (Fig. 3L). IVUS pullback showed good dilation of the vessel with no significant dissection. Two EES were implanted (2.5 × 23, 3.0 × 30) and, due to some malposition in IVUS (Fig. 3M, N), post dilated with a 3.0 non-compliant balloon (Fig. 3O). IVUS-HD control showed optimal effect (Fig. 3P). Injection of 3.5 mL of contrast showed optimal effect of PCI (Fig. 3R). The patient was discharged after 2 days.

Patient 4. An 80-year-old male with ischemic systolic heart failure and CKD (eGFR 20 mL/ /min/1.73 m^2), after numerous PCIs, after CRT-D implantation, was readmitted due to acute heart failure and electrical storm. Myocardial infarction was excluded. Echocardiographic assessment revealed an LVEF of 20% and a significantly dilated left ventricle (LVEDD 78 mm). The patient was treated medically, requiring bilateral thoracentesis. After stabilization, due to recurrent ventricular tachycardia (VT), the patient was scheduled for coronary angiography. Significant LAD restenosis was observed (Fig. 4A). After the procedure, further deterioration of renal function occurred (creatinine level 202 → 287 μmol/L) — treated with i.v. fluids. The patient was discussed by the Heart Team and qualified for zero contrast PCI. LAD was wired with a hydrophobic wire. As this was restenosis, an additional side branch wiring was not necessary. IVUS confirmed the presence of significant restenosis with MLA of 2.2 mm^2 (Fig. 4B). High-pressure dilation of the restenosis with a non-compliant 3.0 balloon was performed, followed by 3.0 paclitaxel eluting balloon inflations (Fig. 4C). Control IVUS revealed proper stent apposition and lumen dilation (postprocedural MLA of 4.5 mm^2, Fig. 4D–F). No recurrence of VT was observed. The creatinine titers returned to prior levels (207 μmol/L).

The patients were observed for a follow-up period of 12 months. Patients no. 1–3 had uncomplicated follow-up, not requiring further revascularization and/or renal replacement therapy. Patient no. 4 had recurrent episodes of acute heart failure and subsequently died after 3 months and 9 days from index procedure, also with no need for further revascularization or renal replacement therapy.

This primary experience shows, that significant experience in both PCI and IVUS can result in safe and effective IVUS-guided PCI procedures. The acceptance of ultra-low contrast quantity of contrast for final assessment may facilitate the introduction of these procedures in centers aiming to implement a similar protocol for patients at extreme risk of contrast induced nephropathy.

Conflict of interest: None declared

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