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Absolute zero-contrast percutaneous coronary intervention under intravascular ultrasound guidance in chronic kidney disease patients – From despair to hope?

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ABSTRACT

Background: Zero contrast percutaneous coronary intervention (PCI) reduces contrast induced acute kidney injury (CI-AKI), and it improves the outcome of chronic kidney disease (CKD) patients undergoing PCI.
Objectives: We sought to assess the safety and short-term outcomes of 'absolute' zero-contrast PCI under intravascular ultrasound (IVUS) guidance in CKD patients.
Methods: Data from all consecutive CKD patients who were included for absolute zero contrast PCI during the period of June 2020 to March 2021 were included in this analysis. Clinical characteristics, angiographic, IVUS and procedural data, and follow-up data were analyzed.
Results: Totally 42 patients (66 vessels) with the mean age of 69.04 ± 11.9 years, were included for absolute zero-contrast PCI. The mean serum creatinine and estimated glomerular filtration rate (eGFR) were 2.67 ± 1.46 mgs% and 30.67 ± 12.26 ml/min/1.73 m^2 respectively. The most common presentation was acute coronary syndrome (ACS) and the mean left ventricular ejection fraction (LVEF) and SYNTAX score were 43.7 ± 11.9% and 27.7 ± 14.1 respectively. Complex PCI including 14 (21.2%) left main coronary artery (LMCA) PCI (seven LMCA bifurcation PCI) and three chronic total occlusion (CTO) PCI were also done. Technical success was 92.4% without any major complications. Two patients died of non cardiac causes on follow up (3–12 months), and all the remaining were symptom free.
Conclusion: IVUS guided 'absolute' zero-contrast PCI is feasible and safe CKD patients. Even in complex lesion morphologies, the procedure can be completed without any contrast and complications.

1. Introduction

Low-osmolar and *iso*-osmolar iodinated contrast media are commonly used for percutaneous coronary interventions (PCI) and the adverse reactions to them range from mild skin rash/itching to life threatening anaphylaxis [1]. Contrast induced acute kidney injury (CI-AKI) is another serious complication which commonly occurs after PCI, particularly during primary PCI for ST-elevation myocardial infarction (STEMI) and chronic total occlusion (CTO) interventions. One of the major risk factors for CI-AKI is pre-existing renal dysfunction. The incidence of CI-AKI varies between 3.3% and 14.5% in the literature [2]. NCDR-cath PCI registry reported the incidence of CI-AKI as 7.1%, including 0.3% requiring new dialysis, in patients undergoing PCI [3]. A sub study from HORIZONS-AMI found that CI-AKI is associated with higher rates of net adverse cardiac events (NACE) and mortality both at 30 days and 3 years [4]. Besides, CI-AKI is independently associated with higher hospitalization cost of around $10,000 as shown in a study from United States [5]. Contrast volume is one of the easily modifiable risk factors to reduce the incidence of CI-AKI as shown in various models [6]. Indeed, contrast volume to creatinine clearance ratio (CV/CrCl) > 2 has been shown as an independent predictor of CI-AKI in patients with estimated glomerular filtration rate (eGFR) < 30 ml/min/1.73 m^2 [7]. Besides, it has been observed that ultra-low contrast PCI (CV/CrCl < 1) reduces the CI-AKI risk significantly more comparing low contrast PCI (CV/CrCl: 1–3) [8]. Few case series and studies have reported the feasibility and outcome of "Zero-contrast PCI" in advanced CKD patients using Intravascular Ultrasound (IVUS) guidance [9,10]. Most of these studies used final check angiograms, and some did predominantly single

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vessel stenting. In real world, most of the chronic kidney disease (CKD) patients have multivessel disease and many of them may need complex PCI including rotational atherectomy, left main bifurcation and CTO interventions. Hence our study aimed at the feasibility of IVUS guided absolute zero-contrast PCI in CKD patients including those who have complex morphologies.

2. Methods

2.1. Study design and population

Our study was a prospective single-centre observational study which was done during the period of June 2020 to February 2021. PCI was planned in acute coronary syndrome (ACS) patients and in patients with stable ischemic heart disease (SIHD) when anyone of the following were present (i) angiographically significant coronary stenosis (angiographic diameter stenosis ≥70% in non-left main coronary artery (non-LMCA) and ≥50% in LMCA), (ii) IVUS measured minimal luminal area (MLA) of <6 mm2 in LMCA lesions, or (iii) Fractional flow reserve ≤ 0.8. Patients with CKD were considered for IVUS guided absolute zero-contrast PCI when they had met the following criteria (Fig. 1): (1) eGFR < 30 ml/min/1.73 m^2; (2) Serum creatinine > 1.5 mgs% or eGFR < 45 ml/min/1.73 m^2 (Stage 3b, 4, and 5 CKD) **and** any of the following criteria (a) Age > 75 years. (b) Left ventricular ejection fraction (LVEF) < 35%. (c) Diabetes mellitus. (d) Recent hypotension or shock. Patients who underwent coronary angiogram at other centres were taken for procedure within 24 h after reaching our centre if they had ACS or after 7 days if they had SIHD. Nevertheless, all the patients who underwent coronary angiogram (Ultra low contrast, i.e., Total contrast volume < eGFR) at our centre were taken for PCI on ad hoc basis.

2.2. Procedures

Baseline clinical characteristics, laboratory investigations, echocardiography and electrocardiographic (ECG) findings were noted for all the patients. Two hours prior to the initiation of the procedure, all patients were hydrated with 0.9% normal saline at a dose of 1 ml/kg/hr (if EF < 40%) or 2 ml/kg/h (if EF ≥ 40%) and hydration was continued at the same dose for 8 h after the procedure. When the procedure was started on urgent basis, hydration was started as soon as possible and it was continued after the procedure for 8 h. Though all the patients received statins as a part of CAD management, none of them were administered other medications with the aim of reducing CI-AKI. Since the procedures were planned as "Absolute zero-contrast PCI," patients and their care takers were specifically debriefed about the non-availability of final angiogram, and informed consent was obtained

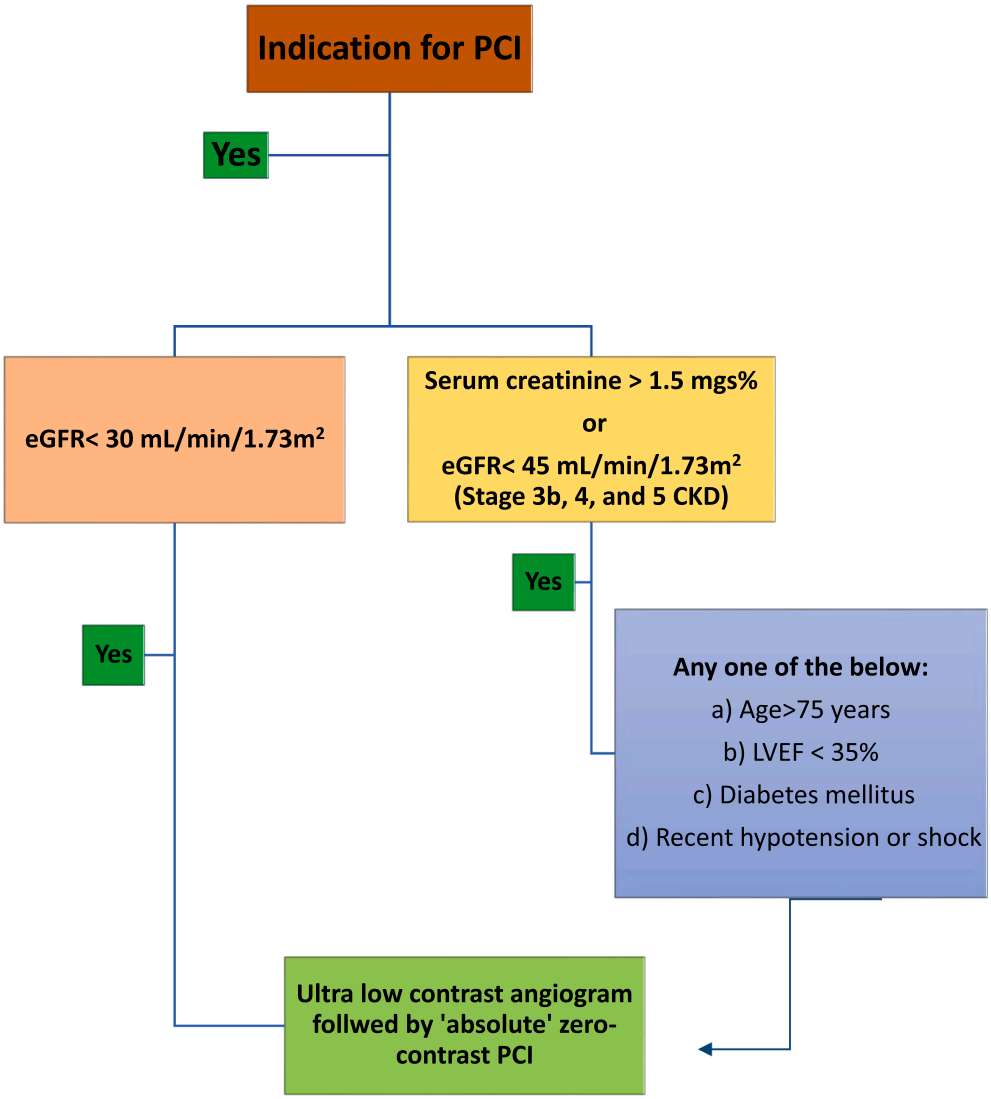

Fig. 1. Selection of patients for IVUS guided 'absolute' zero-contrast PCI. IVUS: Intravascular ultrasound; PCI: Percutaneous coronary intervention.

before procedure. All the procedures were done by a single operator with an experience of 200 LMCA PCI and 150 CTO PCI per year. Procedural techniques, hardware selection and stenting strategy (particularly in bifurcation lesions) were left to the operator's discretion. Boston scientific iLAB ultrasound imaging system with Polaris software, OptiCross™ 6 (40 MHz) and OptiCross™ HD coronary imaging catheters (60 MHz) were used for IVUS runs. In general, lesion preparation with rotational atherectomy was done when the IVUS detected calcium arc was >180° along with calcium length ≥5 mm. Blood transfusion was planned if the post procedure haemoglobin was <8 gms%. After discharge, all the patients were followed up with ECG, echocardiogram and renal function tests at one week and 3 months. The study was approved by the institute's human research committee.

2.3. Zero-contrast PCI protocol

Initial coronary angiogram was performed using low-osmolar or *iso*-osmolar iodinated contrast (total contrast volume in ml was less than the eGFR in mL/min/1.73 m^2) and 5F or 6F catheters. Femoral access was preferred in most cases so that radial artery would be preserved for future dialysis and also larger sized catheters could be used for multiple marker wires. After coronary angiography, guiding catheter engagement was done, which was confirmed by passing the guidewire and identifying the wire course along the main vessel. We kept the angiogram as a roadmap, and the same fluoroscopic projection was used while passing the guidewire. Additional wires (hydrophobic or hydrophilic) were inserted into the significant side branches to silhouette the main vessel along with major side branches (Supplementary Fig. 1). One guidewire was placed in aorta as marker wire to locate the left main or right coronary ostium in aorto-ostial stenting (floating wire technique). After the creation of "metallic silhouette," IVUS runs across the main vessel and side branches (In LMCA PCI and when side branch stenting was planned) were done to measure the lesion length, proximal and distal reference vessel diameters, calcium arc and length and to identify the proximal and distal landing zones. Then lesion preparation was done using semi-compliant/non-compliant balloons, scoring/ cutting balloons and rotational atherectomy, according to the lesion morphology. Repeat IVUS run was done after lesion preparation, if needed, particularly in heavily calcified lesions. Stent size was selected according to the IVUS measurements and it was positioned fluoroscopically at the landing zones. Proximal and distal landing zones were identified initially in the IVUS run by the distances from the nearest side branch (SB) marker wires (Supplementary Fig. 2). Then fluoroscopically the landing zones were recognised using the above distance measurements from the SB marker wires. After stent deployment, post IVUS run was done to detect edge dissection, stent underexpansion, malapposition and geographical miss and to measure minimal stent areas (MSA). All the major side branches were screened during this main vessel IVUS run. When the SB ostial area appeared inadequate by visual estimation, guidewire recrossing followed by IVUS measurement of SB ostium was done (Particularly in Left main – LAD cross over stenting). Post-dilatation was done if needed, and finally serial echocardiographic screening was done to rule out pericardial effusion (Supplementary Fig. 3). The entire procedure was planned without using any contrast. When the patient developed severe angina, significant ECG changes or pericardial effusion, check angiogram using minimal contrast was done to identify complications.

2.4. Definitions

Technical success was defined as successful stenting of the vessels without using any contrast (Absolute zero contrast PCI). Low-contrast PCI was defined as the ratio of contrast volume to eGFR (CV/eGFR) between 1 and 3 and Ultra-low contrast PCI was defined as CV/eGFR ratio <1. Procedural success was defined as technical success without in-hospital mortality. IVUS criteria for optimal stenting was defined as following: (1) MSA > 80% of mean stent area (When proximal and distal reference lumen areas were available) or MSA > distal reference lumen area (When only distal reference lumen area was available) in non LMCA vessels, (2) Stent area >7 mm^2 at polygon of confluence and >8 mm^2 at proximal LMCA in LMCA PCI, and (3) no significant edge dissection/ malapposition. Significant edge dissection was defined as dissection with circumference >60°, >2 mm length or involving media/adventitia and significant malapposition was defined as >0.4 mm distance between stent and adjacent wall and >1 mm length. CI-AKI was defined as an increase in serum creatinine by ≥0.3 mg/dl within 48 h of contrast medium exposure or a ≥50% increase within seven days (KIDGO working group definition) [11].

3. Results

3.1. Clinical and angiographic characteristics

Totally 42 patients (consisting of 66 vessels) underwent IVUS guided zero-contrast PCI during this study period. The mean age of the population was 69.04 ± 11.9 years (Table 1) and 8 (19%) of them were ≥80 years. Most of our cohort had moderate to severe CKD and the most

Table 1
Baseline clinical characteristics.

Baseline characteristics	Overall group (n = 42)*
Age (mean ± SD) (years)	69.04 ± 11.9
Male	41 (97.6%)
Hypertension	38 (90.5%)
Diabetes mellitus	34 (81%)
Dyslipidemia	27 (64.3%)
Previous PCI	14 (33.3%)
Previous CAD	18 (42.9%)
Previous CVA	2 (4.8%)
Initial hospital presentation	12(28.6%)
	26 (61.9%)
	3 (7.1%)
	1 (2.4%)
SIHD	
NSTEMI/Unstable angina	
STEMI (Non culprit lesions)	
STEMI (Culprit lesions)	
LVEF (mean ± SD) (Percentage)	43.7 ± 11.9
LVEF (%)	
>50	11 (26.2%)
31–50	22(52.4%)
≤30	9(21.4%)
Serum creatinine (mg/dL) (mean ± SD)	2.67 ± 1.46
eGFR (mL/min/1.73 m^2) (mean ± SD)	30.67 ± 12.26
BMC2 CIN risk (%) (mean ± SD)	17.3 ± 11.6
BMC2 dialysis risk (%) (mean ± SD)	2.3 ± 1.5
MedicationsAspirin	
Thienopyridine	20 (47.6%)
Statins	12 (28.5%)
Beta blockers	32 (76.2%)
ACE inhibitors/ ARBs	8 (19%)
Sulfonylurea	15 (35.7%)
Metformin	30 (71.4%)
DPP4 inhibitors	26 (61.9%)
Alpha glucosidase inhibitors	12 (28.6%)
	13 (30.9%)

Data are represented as numbers (Percentage) or mean ± Standard deviation. ACE: Angiotensin converting enzyme; ARB: Angiotensin receptor blocker; BMC: Blue Cross Blue Shield of Michigan Cardiovascular Consortium; CIN: Contrast induced nephropathy; CAD: Coronary artery disease; CVA: Cerebro-vascular accident; DPP4: Dipeptidyl peptidase-4; eGFR: estimated glomerular filtration rate; LVEF: left ventricular ejection fraction; NSTEMI: non-ST-elevation myocardial infarction; PCI: Percutaneous coronary intervention; SIHD: Stable ischemic heart disease; STEMI: ST-elevation myocardial infarction.

common clinical presentation was ACS. Out of 42 patients 21 patients (50%) were in CKD stage 3b, 10 patients (23.8%) were in CKD stage 4 and 7 patients (16.7%) were in CKD stage 5. The initial hospital presentation was non-STEMI/unstable angina in 26 (61.9%) patients, SIHD in 12(28.6%) patients and STEMI in 4 (9.5%) patients. Out of 4 STEMI cases, 1 case underwent both culprit vessel and non-culprit PCI in the same setting and the remaining 3 patients underwent non-culprit vessel revascularisation as zero-contrast PCI after 3–5 days of culprit vessel PCI. Only 1 patient was already on haemodialysis and all the remaining patients were not on any renal replacement therapy. Severe left ventricular (LV) systolic dysfunction (LV ejection fraction $\leq$ 30%) was seen in 9 (21.4%) patients and mild to moderate LV systolic dysfunction (LV ejection fraction 31–50%) was present in 22 (52.4%) patients.

Totally 8 patients had undergone coronary angiogram at other centres and 3 of them underwent absolute zero-contrast PCI at our centre after 7 days. The remaining 5 patients had ACS and they underwent procedure within 24 h after reaching our centre. The mean SYNTAX I score of our cohort was 27.7 ± 14.1 and 27 patients (64.3%) had SYNTAX I score > 23. In-stent restenosis was seen six patients involving 8 (12.1%) vessels (Table 2). Single vessel, 2-vessel and 3-vessel disease were seen in 7 (16.7%) patients, 10 (23.8%) patients and 25 (59.5%) patients respectively.

3.2. Procedural characteristics

PCI was done in 66 vessels with the mean of 1.6 ± 0.7 vessels per patient (Table 3). Totally 14 cases underwent LMCA PCI including 7 cases of LMCA bifurcation PCI. Moreover, one of these patients underwent LAD-diagonal bifurcation PCI along with LMCA bifurcation PCI. Single vessel, 2-vessel and 3-vessel PCI were done in 22 patients, 16 patients and 4 patients respectively. Apart from LMCA PCI, left anterior descending artery (LAD), left circumflex (LCX) and right coronary artery (RCA) PCI were done in 17, 18 and 17 vessels respectively. We used femoral approach for all patients except 2 cases, in whom right radial access was used. Similarly, 7F guiding catheter was used for all vessels except 3 vessels where 6F catheter was used. We used multiple guidewires to silhouette the main vessel and its major branches. The mean number of guidewires per vessel was 2.72 ± 0.7 and the most commonly used guidewire was Fielder-FC. IVUS criteria for optimal stenting were achieved in 75.8% of non LMCA PCI and 100% of LMCA PCI. IVUS showed some calcium in 51 vessels and 19 of them had >180° calcium arc. Ostial positioning of the stent was planned in 37 vessels and it was successful in 34 vessels (91.8%) using the metallic silhouette technique. Balloon angioplasty with drug eluting balloon without stenting was done in 4 vessels with in-stent restenosis. In total, 3 vessels (2 RCA and 1 LAD) with CTO were successfully stented using antegrade wire escalation technique and the lesions were crossed with Fielder FC in 2 vessels and Gaia second in 1 vessel.

Table 2
Coronary angiographic and IVUS characteristics.

Angiographic and IVUS data	Overall group*
Number of PCI vessels (n)	66
Number of vessels involved per patient (mean ± SD)	1.6 ± 0.7
SYNTAX-I score(mean ± SD)(n = 42)	27.7 ± 14.1
SYNTAX-I score	
<23	15 (35.7%)
23–32	13 (31%)
>32	14 (33.3%)
SYNTAX-II score (mean ± SD) (n = 42)	45 ± 12.7
IVUS lesion length (mm)	37.2 ± 19.9
MLA of non-LMCA vessels (mm^2) (n = 66)	2.6 ± 0.76
MLA of LMCA (mm^2) (n = 14)	6.36 ± 2.6
MLA of POC (mm^2) (n = 14)	6.08 ± 1.64
LMCA diameter (mm) (n = 14)	4.54 ± 0.33
Calcium arc (n = 66)	
≥180°	19 (28.8%)
<180°	32 (48.5%)
No calcium	15 (22.7%)

Data are represented as numbers (Percentage) or mean ± Standard deviation (SD). n varied in a few cases and is specified accordingly. IVUS: Intravascular ultrasound; LMCA: left main coronary artery; MLA: minimal luminal area; PCI: Percutaneous coronary intervention; POC: polygon of confluence; SYNTAX: Synergy between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery.

Table 3
Procedural characteristics.

Procedural data	Overall group*
Number of vessels treated with zero-contrast PCI(n)	66
Approach (n = 66)	
Femoral	64 (97%)
Radial	2 (3%)
Guide Catheter (n = 66)	
7F	63 (95.5%)
6F	3 (4.5%)
Number of wires per vessel (mean ± SD)	2.72 ± 0.7
Number of IVUS runs per vessel (mean ± SD)	2.95 ± 0.95
Microcatheters used	5 (7.6%)
Guide extensions used	5 (7.6%)
Cutting balloons used	17 (25.8%)
OPN balloon used	2 (3%)
Stenting done	62 (93.9%)
Drug eluting balloon alone	4 (6.1%)
Number of stents per vessel (mean ± SD)	1.48 ± 0.8
Stent length (mm)	40.5 ± 24.0
LMCA PCI	14 (21.2%)
LMCA bifurcation PCI (n = 42)	7 (16.7%)
Rotational atherectomy	4 (6.1%)
CTO PCI	3 (4.5%)
ISR PCI	8 (12.1%)
Minimal stent area non-LMCA (mm^2) (mean ± SD) (n = 66)	6.29 ± 1.98
Minimal stent area LMCA (mm^2) (mean ± SD) (n = 14)	12.2 ± 2.5
Minimal stent area POC (mm^2) (mean ± SD) (n = 14)	11.03 ± 2.15
Procedure time (min) (mean ± SD)	76.8 ± 33.1
Fluoroscopy time (min) (mean ± SD)	36.3 ± 17.7
Radiation dose (mGy) (mean ± SD)	3379.3 ± 1839.9
Technical success	61 (92.4%)
Procedure completed with "ultra low contrast"	5 (7.6%)
Peak/48-hour creatinine (mean ± SD) (mg/dL)	2.66 ± 1.43

Data are represented as numbers (Percentage) or mean ± Standard deviation (SD). CTO: Chronic total occlusion; ISR: In-stent restenosis; IVUS: Intravascular ultrasound; LMCA: left main coronary artery; PCI: Percutaneous coronary intervention; POC: Polygon of confluence.

3.3. Outcomes

Technical success was achieved in 61 vessels (92.4%) and the remaining cases (7.6%) were completed with ultra-low volume contrast. Only 1 patient developed mild pericardial effusion which was managed conservatively and 4 patients (9.5%) required blood transfusion. Among the four patients who required blood transfusion, two had undergone LMCA bifurcation stenting; one patient had undergone rotational atherectomy, and the final patient had undergone multivessel PCI in the same setting. Moreover, multiple IVUS runs were required in all four cases in view of complex PCI. The blood transfusion rate was relatively high because of low haemoglobin reserve in this cohort and it was not related to complications.

Though 5 (11.9%) patients developed CI-AKI as per KDIGO definition (Maximum 1.4 mgs%) elevation, none of them required dialysis and all patients were hemodynamically stable after procedure. Mean serum creatinine level on 1 week and 1 month follow-up was 2.56 ± 1.28 mgs % and 2.57 ± 1.25 mgs% respectively. On follow-up (3–12 moths), 2 patients died of non-cardiac causes (One patient had B/L pneumonia with respiratory failure and another 1 had massive ischemic stroke) and all the remaining patients are stable without any symptoms. None of

these patients developed stent thrombosis or required target lesion/vessel revascularisation.

4. Discussion

In our study on absolute zero-contrast PCI, we included all patients with CKD irrespective of their high-risk clinical features and lesion morphologies. Around 19% of our patients were ≥80 years with the maximum age of 92 years. Furthermore, our cohort had other high-risk characteristics like ACS (71.4%), severe LV systolic dysfunction (21.4%), multi vessel disease (83.3%), LMCA disease (33.3%), CTO (4.5%) and highly calcified lesions (28.8%). In spite of the complex cases, we achieved a technical success rate of 92.4% without any in-hospital mortality. Another similar study showed good success rate, albeit with minimal contrast for final check angiogram, and they reported 10% incidence of AKI after procedure (Defined as ≥0.5 mgs% rise in serum creatinine) [11]. Nevertheless, we followed 'Absolute zero-contrast PCI' protocol and the incidence of AKI (Defined as ≥0.3 mgs % rise in serum creatinine) was 11.9%. Indeed 4 out of 5 patients who developed AKI in our study had only 0.3–0.4 mgs% rise and none required renal replacement therapy. Most of our patients underwent PCI through femoral approach and hence the possibility of atheromatous embolization induced AKI cannot be ruled out [12]. Moreover, most of our patients (80.9%) underwent ad hoc PCI after ultra-low contrast angiogram (mean contrast volume/eGFR was 0.47) in view of ACS with ongoing angina (71.4%), reflecting the real-world clinical scenario. On the contrary, most of the previous studies had selected their patients as staged PCI after few days of coronary angiogram and hence they had lower rate of CI-AKI [10,11].

Patients with CKD are at very high risk of cardiovascular events and cardiovascular deaths account for nearly 40–50% of all deaths that occur in stage 4 and stage 5 CKD [13,14,15]. They often present with multi-vessel disease and complex lesion morphologies and Coronary artery bypass grafting (CABG) carries 4.5-fold elevated risk of AKI compared to PCI in these patients [16]. MOZART trial showed that IVUS guided PCI reduces the dose of contrast agent significantly without any difference in the in-hospital and 4 months outcome (death, myocardial infarction, unplanned revascularization, or stent thrombosis) comparing conventional angiogram guided PCI [17]. Furthermore, the incidence of CI-AKI (Defined as ≥0.5 mgs% rise in serum creatinine) was also lower in IVUS guided PCI group (7.3%) with the median contrast use of 20 ml. Our group would have had only 2.3% incidence of CI-AKI if we had applied the same definition of CI-AKI as that of MOZART group.

Another study which compared ultra-low contrast PCI with conventional PCI also showed decreased incidence of CI-AKI and no difference in the mortality, target vessel failure or stent thrombosis [18]. It was an all-comers study without any angiographic exclusion criteria and they achieved the success rate of 88%. The mean procedure time of our study (76.8 min) is more than that of MOZART trial (48 min). The reason could be that we followed absolute zero-contrast protocol unlike the MOZART trial where mean 20 ml of contrast was used to guide the procedure.

Though both radial and femoral accesses are feasible for zero-contrast PCI, femoral access allows preservation of the radial arteries for future dialysis. Moreover, larger guiding catheters can be used (>7F) in femoral approach which can give better support and larger lumen for multiple wires and IVUS runs. In addition, many CKD patients have heavily calcified vessels which often need rotational atherectomy or higher profile balloons (cutting balloon, OPN and intra vascular lithotripsy) for lesion preparation. Hence, we preferred femoral access. During procedure we checked activated clotting time (ACT) every 30 min and the catheter was flushed with saline every 10 min to avoid clot formation. In presence of multiple wires and balloons, clot formation inside the catheter is very common and when the scenario compels for check angiogram this clot may embolize into the coronaries. Hence it is important to flush the catheter frequently even if the ACT is maintained above 300 s.

We used "metallic silhouette" technique in all our cases as mentioned previously. Though other methods like "Marker wire technique" are described in the literature for stent positioning, we preferred metallic silhouette technique because it is simpler and more reliable [19]. Aorto-ostial positioning of the stent requires "floating wire" technique to locate the ostium and we did most of our LMCA PCI (12 cases) from the ostium. Once metallic silhouette is created, IVUS run should be done before pre-dilatation, whenever possible, to confirm the guidewire position inside the true lumen. However, in arteries with heavy calcification, pre-dilatation with smaller sized balloons is required to facilitate the IVUS run. In such cases, operator experience is extremely important to identify the subintimal position of guidewire, particularly when rotational atherectomy is planned. Since the blood flow across the vessel cannot be measured, particular attention should be given for the ECG changes and patient's symptoms during rotational atherectomy. In scenarios where two overlapping stents are required to cover the lesions, repeat IVUS run should be done after the first stent deployment, whenever possible. This method helps to perfectly select the second stent length, which is measured from the first stent edge to the proximal/distal landing zones.

Absolute zero-contrast PCI of CTO is a technically challenging procedure and we crossed three CTO vessels using antegrade approach. After lesion crossing, distal wire position should be confirmed by entering into the side branches. It is important to keep the roadmap of distal side branches which are seen filling through collaterals. After guidewire and microcatheter crossing, lesion can be dilated with smaller sized balloons to facilitate the IVUS run and then IVUS run should be done to confirm the wire position in true lumen. IVUS guided proximal cap puncture may help in avoiding the subintimal entry. Both antegrade and retrograde CTO PCI have been done successfully in few case reports [20,21].

We achieved IVUS criteria for adequate stent expansion in 75.8% cases in spite of the presence of complex lesions. Comparing the study by Ziad Ali et al. [10], where the predetermined target MSA was achieved in 87% cases, our cohort had lesser percentage of adequate stent expansion. The reason being, we included more complex cases like heavily calcified vessels, LMCA bifurcation PCI, etc. Similar to our study, many other studies on image guided PCI had also documented stent underexpansion ranging from 23% to 46% [22,23,24]. IVUS/OCT defined stent under-expansion is one of the strongest predictors of device oriented clinical outcomes. However, the IVUS criteria for absolute expansion >5.5 mm^2 is dependent on the reference vessel diameters and the relative expansion criteria (MSA > 80% of average reference lumen area) does not consider the vessel tapering [22].

Although absolute zero-contrast PCI is feasible is most of the cases, it needs extremely skilled operators and catheterisation laboratories with intra-coronary imaging facilities. Moreover, the benefit of this procedure should be contemplated against the risk of prolonging the procedure time in ACS where rapid revascularisation is of paramount importance. Operator skills and experience play crucial role in this scenario.

Finally, the debate continues to find out the better option between 'absolute zero-contrast PCI' and 'ultra-low contrast PCI' for revascularisation in CKD patients. Given the wealth of information from the ultra-low contrast check angiogram, is it worth avoiding that? There are no randomised controlled trials between ultra-low contrast PCI and zero-contrast PCI to prefer one over the other. Any dynamic change in the renal function during acute myocardial infarction (AMI) is associated with long term outcome. There is a graded independent association between the severity of AKI during AMI and long-term mortality after discharge. Even transient AKI during AMI is associated increased long-term mortality comparing patients without AKI with the adjusted hazard ratio of 1.2 [25]. In our study we have shown that the incidence of CI-AKI is lower than the incidence reported in MOZART trial after applying the same definition for CI-AKI. Hence, we believe that absolute zero-contrast PCI is the preferred option when it is done under expert hands. The major drawback of IVUS guided absolute zero-contrast PCI is

that we cannot quantify the final distal flow, particularly in ACS. Conventionally the final TIMI flow is considered as a strong predictor of long-term mortality after PCI in acute coronary syndromes [26,27] and hence further studies on absolute zero-contrast PCI with long-term follow-up is needed.

We acknowledge the limitations of our study. Our study was an observational study without any control group. A randomized controlled trial between 'ultra-low contrast PCI' and 'absolute zero-contrast PCI' will help to identify the outcome differences between the two similar procedures. Similarly, comparison between 'routine contrast guided PCI' and 'absolute zero-contrast PCI' will throw light on the mortality benefit of this technique. Secondly our study was conducted in a single centre with limited number of patients. Larger studies involving multiple centres are needed before accepting 'absolute zero-contrast PCI' as a standard practice. Finally, as mentioned previously, the long-term outcomes are not known even though the short-term outcomes appear strikingly better.

5. Conclusion

Coronary revascularisation is frequently denied in CKD patients and elderly patients with borderline renal function and low LVEF, in fear of CI-AKI. IVUS guided absolute zero-contrast PCI is feasible and safe in these high-risk patients and even complex PCI can be performed successfully without major complications.

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All the authors state that they have nothing to disclose.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcha.2022.101052.

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