Treating Patients With Renal Insufficiency

Zero Contrast PCI

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Columbia University Medical Center
Cardiovascular Research Foundation
Disclosure Statement of Financial Interest

Within the past 12 months, I or my spouse/partner have had a financial interest/arrangement or affiliation with the organization(s) listed below.

<table>
<thead>
<tr>
<th>Affiliation/Financial Relationship</th>
<th>Company</th>
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<tbody>
<tr>
<td>• Grant/Research Support</td>
<td>• NIH/NHLBI, Abbott Vascular,</td>
</tr>
<tr>
<td>• Consulting Fees/Honoraria</td>
<td>Cardiovascular Systems Inc</td>
</tr>
<tr>
<td>• Equity</td>
<td>• Acist Medical, Boston Scientific,</td>
</tr>
<tr>
<td></td>
<td>Cardinal Health, Opsens Medical,</td>
</tr>
<tr>
<td></td>
<td>Shockwave Medical</td>
</tr>
<tr>
<td></td>
<td>• Shockwave Medical</td>
</tr>
</tbody>
</table>
Cardiovascular disease in CKD IV-V/ ESRD

- Accounts for 53% of all deaths with a known cause
- Remains the leading cause of death after renal transplantation
- Exclusion from RCTs has led to a paucity of data making cardiovascular management in this population very challenging

Bhatti and Ali. JAHA 2016;5(8)
Morbidity of Contrast Nephropathy

• Revascularization by PCI in patients with advanced CKD is drastically underutilized.

Dangas et al. AJC 2005; 95:13-19
## “Renalism”

<table>
<thead>
<tr>
<th>Author</th>
<th>Presentation</th>
<th>N</th>
<th>CKD</th>
<th>CKD Invasive</th>
<th>No CKD Invasive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chertow</td>
<td>MI</td>
<td>57,284</td>
<td>26%</td>
<td>25%</td>
<td>47%</td>
</tr>
<tr>
<td>Han</td>
<td>NSTEACS</td>
<td>45,343</td>
<td>14%</td>
<td>48%</td>
<td>74%</td>
</tr>
<tr>
<td>Goldenberg</td>
<td>NSTEACS</td>
<td>13,141</td>
<td>32%</td>
<td>50%</td>
<td>68%</td>
</tr>
<tr>
<td>Szummer</td>
<td>MI</td>
<td>57,477</td>
<td>33%</td>
<td>33%</td>
<td>58%</td>
</tr>
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</table>

## Benefits of PCI in NSTEACS in CKD

N = 15 680

<table>
<thead>
<tr>
<th>eGFR</th>
<th>Strategy</th>
<th>Adjusted OR</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-90</td>
<td>OMT vs PCI</td>
<td>0.63 (0.49-0.81)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>45-60</td>
<td>OMT vs PCI</td>
<td>0.69 (0.51-0.95)</td>
<td>0.020</td>
</tr>
<tr>
<td>30-45</td>
<td>OMT vs PCI</td>
<td>0.68 (0.49-0.94)</td>
<td>0.021</td>
</tr>
<tr>
<td>&lt;30</td>
<td>OMT vs PCI</td>
<td>0.80 (0.52-1.24)</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Entered into model, hypertension, previous angina, previous myocardial infarction, hyperlipidaemia, peripheral vascular disease, cerebrovascular disease, chronic obstructive airways disease, congestive cardiac failure, diabetes mellitus, previous PCI, previous CABG, hemoglobin (g/dl) and peak troponin
Potential Management Strategies

**Experimental**
- DyeVert\(^1\)
- RenalGuard\(^2\)

**Experimental**
- N-acetylcysteine\(^3\)
- Sodium Bicarbonate\(^3\)
- Iso-osmolar contrast\(^4,5\)

---

\(^1\)Catheter Cardiovasc Interv. 2013 Dec 10.
Clinically Validated Strategies
Hemodynamic-guided IV Hydration
Randomized, parallel-group, comparator-controlled, single-blind phase 3 trial

\[ P=0.008 \]
\[ P=0.037 \]
\[ P=0.029 \]
\[ P=0.37 \]

LVEDP guided
Control

LVEDP <13 = 5ml/kg/hr
LVEDP 13-18 = 3ml/kg/hr
LVEDP 18 = 1.5ml/kg/hr

6 Month - Event Rate,\% , N = 396

MAE
Death
MI
Dialysis

Brar et al. Lancet 2014
Intravascular Ultrasound Guidance to Minimize the Use of Iodine Contrast in Percutaneous Coronary Intervention

The MOZART (Minimizing cOntrast utilizAtion With IVUS Guidance in coRonal angioplasT) Randomized Controlled Trial

CONCLUSIONS Thoughtful and extensive use of IVUS as the primary imaging tool to guide PCI is safe and markedly reduces the volume of iodine contrast compared with angiography-alone guidance. The use of IVUS should be considered for patients at high risk of contrast-induced acute kidney injury or volume overload undergoing coronary angioplasty. (Minimizing cOntrast utilizAtion With IVUS Guidance in coRonal angioplasT) [MOZART]; NCT01947335 (J Am Coll Cardiol Intv 2014;7:1287-93) © 2014 by the American College of Cardiology Foundation.

<table>
<thead>
<tr>
<th>Primary endpoint</th>
<th>Angiography-guided (n=42)</th>
<th>IVUS-guided (n=41)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total contrast volume, ml</td>
<td>71.4 ± 35.9</td>
<td>22.9 ± 12.5</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Ultra-low contrast angiography

Risk -Adjusted
Crude

• Contrast volume/eGFR ratio ≤ 1
• eGFR <15 contrast diluted
• Projections
  – RCA – LAO/Cranial
  – LCA – AP/Cranial and AP/Caudal
• LVEDP used to guide hydration

Ultra-low contrast angiography
ULCA

Standard of Care

CKD V
eGFR – 16mg/dL

9cc contrast

77cc contrast
Physiological Guidance

FFR/iFR with pullback used to confirm ischemia in:
- intermediate lesions
- poor visualization

FFR pullback across ambiguous lesion
# Ultra-low contrast angiography

<table>
<thead>
<tr>
<th>Clinical Characteristics</th>
<th>Ultra-Low Contrast (n=51)</th>
<th>Standard (n=50)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>eGFR</td>
<td>20.2 ± 13.0</td>
<td>21.6 ± 7.0</td>
<td>0.51</td>
</tr>
<tr>
<td>Age</td>
<td>65.3 ± 13</td>
<td>67.3 ± 13</td>
<td>0.45</td>
</tr>
<tr>
<td>Male, %</td>
<td>72</td>
<td>72</td>
<td>0.95</td>
</tr>
<tr>
<td>African American, %</td>
<td>16</td>
<td>12</td>
<td>0.56</td>
</tr>
<tr>
<td>Hypertension, %</td>
<td>90</td>
<td>90</td>
<td>1.0</td>
</tr>
<tr>
<td>Diabetes Mellitus, %</td>
<td>67</td>
<td>60</td>
<td>0.37</td>
</tr>
<tr>
<td>Dyslipidemia, %</td>
<td>74</td>
<td>90</td>
<td>0.04</td>
</tr>
<tr>
<td>Peripheral arterial disease, %</td>
<td>14</td>
<td>18</td>
<td>0.56</td>
</tr>
<tr>
<td>Congestive Heart Failure, %</td>
<td>34</td>
<td>44</td>
<td>0.30</td>
</tr>
<tr>
<td>LVEF</td>
<td>46 ± 18</td>
<td>44 ± 17</td>
<td>0.71</td>
</tr>
<tr>
<td>Previous MI, %</td>
<td>40</td>
<td>34</td>
<td>0.53</td>
</tr>
<tr>
<td>Previous PCI, %</td>
<td>32</td>
<td>30</td>
<td>0.88</td>
</tr>
<tr>
<td>Previous CABG, %</td>
<td>12</td>
<td>12</td>
<td>0.97</td>
</tr>
<tr>
<td>Active Smoker, %</td>
<td>8</td>
<td>4</td>
<td>0.41</td>
</tr>
<tr>
<td>Former Smoker, %</td>
<td>51</td>
<td>42</td>
<td>0.42</td>
</tr>
</tbody>
</table>
Outcomes

<table>
<thead>
<tr>
<th>Clinical Characteristics</th>
<th>Ultra-Low Contrast (n=51)</th>
<th>Standard (n=50)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast Volume</td>
<td>13.5 ± 6.5</td>
<td>39.9 ± 47.6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Post-angiography</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIN</td>
<td>0</td>
<td>8</td>
<td>0.04</td>
</tr>
<tr>
<td>GFR</td>
<td>19.6 ± 11.9</td>
<td>22.3 ± 8.0</td>
<td>0.18</td>
</tr>
<tr>
<td>RRT</td>
<td>0</td>
<td>8</td>
<td>0.04</td>
</tr>
<tr>
<td>Follow-up</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GFR</td>
<td>22.1 ± 13.6</td>
<td>15.1 ±15.0</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Bhatti & Ali. TCT 2019; #30, 09/25/19 1:45, Rm 209
## Predictors of Renal Replacement Therapy

### Multivariable Predictors

<table>
<thead>
<tr>
<th>Clinical Characteristics</th>
<th>Hazard Ratio</th>
<th>95% Confidence Interval</th>
<th>P</th>
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<tbody>
<tr>
<td>ULCA</td>
<td>0.40</td>
<td>0.18-0.86</td>
<td>0.02</td>
</tr>
<tr>
<td>LVEF</td>
<td>0.97</td>
<td>0.95-0.99</td>
<td>0.003</td>
</tr>
<tr>
<td>African American</td>
<td>2.93</td>
<td>1.25-6.85</td>
<td>0.01</td>
</tr>
<tr>
<td>Pre-angio eGFR</td>
<td>0.91</td>
<td>0.86-0.96</td>
<td>0.003</td>
</tr>
</tbody>
</table>
Minimal Contrast Angiography - CABG

No femoral artery arteriogram

Single AP Caudal of LCA given LIMA

LIMA Angiography

Guidewire guidance to identify LIMA  
LIMA angiography

NOT FOR MEDICAL USE

SVG Angiography

Guide wire guidance to identify SVG

SVG angiography

- Median contrast volume 13.5ml [IQR, 10.5, 17.8]

Zero Contrast PCI

First Description of PCI without Radio-contrast utilization

Imaging- and physiology-guided percutaneous coronary intervention without contrast administration in advanced renal failure: a feasibility, safety, and outcome study

Ziad A. Ali¹,²*, Keyvan Karimi Galougahi¹, Tamim Nazif¹,², Akiko Maehara¹,², Mark A. Hardy³, David J. Cohen⁴, Lloyd E. Ratner³, Michael B. Collins¹,², Jeffrey W. Moses¹,², Ajay J. Kirtane¹,², Gregg W. Stone¹,², Dimitri Karmpaliotis¹,², and Martin B. Leon¹,²

¹Division of Cardiology, Center for Interventional Vascular Therapy, New York Presbyterian Hospital and Columbia University, New York, NY, USA; ²Cardiovascular Research Foundation, New York, NY, USA; ³Department of Surgery, New York Presbyterian Hospital and Columbia University, New York, NY, USA; and ⁴Division of Nephrology, New York Presbyterian Hospital and Columbia University, New York, NY, USA

Received 21 December 2015; revised 10 January 2016; accepted 3 February 2016

Zero contrast PCI

Prior ultra low contrast Angiogram

Prx Ref (4.5x4.4mm)

Dist Ref (4.5x4.4mm)

Guide-wire coronary silhouette

FFR 0.76 CFR 1.2

Zero contrast PCI

- 93% stent expansion
- FFR 0.91 (no ischemia)
- CFR 3.9 (no slow flow)

Angiography

- 68 year-old male IDDM (EF 55%), CKD V (Cr 3.8, GFR 13) who presents with progressive angina and SOB for 5 months.

- Has been having increasing medical therapy over that time, now on Carvedilol 12.5mg BID, Amlodipine 7.5mg OD (intolerant to nitrates).

- Primary cardiologist referred for coronary angiography to Columbia University Cardio-renal Center
Minimal Contrast Angiography

Pre-angiography LVEDP guides hydration

LVEDP <13 = 5ml/kg/hr
LVEDP 13-18 = 3ml/kg/hr
LVEDP 18 = 1.5ml/kg/hr
Confirmation of Catheter Engagement

Baseline EKG

Intracoronary injection of 10cc 0.9% NaCl
Ultra-low Contrast Angiography

- CV/eGFR < 1
- GFR 13 ➔ Absolute contrast limit 13mL
- US guided groin access with micropuncture
- RCA 2.9mL
Angiography

AP/CAU 3.1mL

AP/Cr 3mL

Total Contrast 9mL
Multi-vessel disease?
• RCA iFR 1.00
• Cx iFR 1.00
• LAD iFR 0.87
LAD Pullback

- iFR pullback shows discrete lesion
IVUS Co-registration

At the distal reference, dry cine angiogram is recorded

IVUS measures distal reference EEL-EEL 2.8mm
Imaging-guided Stent Sizing

Distal to Proximal 29.6mm

Proximal reference 4.1mm

Distal reference 2.8mm
Stent Deployment

Distal reference IVUS cine used as roadmap for co-registration

2.5x30 DES deployed at 12 atmospheres
PCI Optimization

Proximal 3.5x15 NC@18 atm

Distal 2.5x15 NC@18 atm
Imaging-guided Optimization

Distance to MSA 9.1mm

Proximal reference 6.31mm²
MSA 2.61mm²
Distal reference 3.5mm²
Targeted Optimization

Targeted optimization is performed of the distal segment of stent

2.75x15 NC balloon deployed at 20 atmospheres
Post PCI-Physiology D1

IVUS confirms expansion, apposition and absence of protrusion, dissection
Post PCI-Physiology LAD

iFR®
Distal
0.93
Completion of PCI procedure

Post-PCI LVEDP guides hydration

If post-procedure there are;

a) Symptoms
b) EKG Changes
c) New effusion

Limited angiography is performed.

TTE to rule out new effusion

LVEDP <13 = 5ml/kg/hr
LVEDP 13-18 = 3ml/kg/hr
LVEDP 18 = 1.5ml/kg/hr

Brar et al. POSEIDEN. Lancet 2014
PCI, physiology, IVUS, and follow-up data

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guide wires</td>
<td>3 [3, 4]</td>
</tr>
<tr>
<td>Lesion length (mm)</td>
<td>22 [16, 38]</td>
</tr>
<tr>
<td>Number of stents</td>
<td>1 [1, 1]</td>
</tr>
<tr>
<td>Total stent length (mm)</td>
<td>22 [16, 38]</td>
</tr>
<tr>
<td>Stent diameter (mm)</td>
<td>3 [3, 3.5]</td>
</tr>
<tr>
<td>Pre-dilation</td>
<td>25 (81)</td>
</tr>
<tr>
<td>Post-dilation</td>
<td>30 (97)</td>
</tr>
<tr>
<td>Minimal stent area (mm²)</td>
<td>6.8 [5.9, 8.3]</td>
</tr>
</tbody>
</table>
Pre-specified criteria for angiography

Post-procedure;

a) Symptoms
b) EKG Changes
c) CFR <1.8
d) Ischemic FFR
e) New effusion
Acute Clinical Outcomes

- No patient received contrast during PCI

<table>
<thead>
<tr>
<th>PCI, physiology, IVUS, and follow-up data</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Procedure time (min)</td>
<td>72 [61, 119]</td>
</tr>
<tr>
<td>Fluoroscopy time (min)</td>
<td>20 [16, 35]</td>
</tr>
<tr>
<td>Radiation dose (mGy)</td>
<td>1154 [538, 1932]</td>
</tr>
<tr>
<td>Follow-up (days)</td>
<td>79 [33, 207]</td>
</tr>
<tr>
<td>Follow-up eGFR (mL/min/1.73 m²)</td>
<td>18 [14, 22]</td>
</tr>
<tr>
<td>Change in eGFR (mL/min/1.73 m²)</td>
<td>-0.2 [-1.4, 1.8]</td>
</tr>
</tbody>
</table>

| Renal replacement therapy | 0 (0) |
| Stent thrombosis          | 0 (0) |
| Revascularization         | 0 (0) |
| MI                        | 0 (0) |
| Death                     | 0 (0) |
# Propensity Matched Analysis (6-months)

1:1 Propensity matching according to Mehran criteria for CIN Risk

<table>
<thead>
<tr>
<th>Event</th>
<th>Zero Contrast (n=40)</th>
<th>Standard (n=29)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast Nephropathy</td>
<td>0 (0%)</td>
<td>17 (58%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Renal Replacement Rx, n (%)</td>
<td>0 (0%)</td>
<td>8 (27%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MACE</td>
<td>0 (0%)</td>
<td>6 (20%)</td>
<td>0.02</td>
</tr>
<tr>
<td>Stent Thrombosis</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Repeat Revascularization</td>
<td>0 (0%)</td>
<td>3 (10%)</td>
<td>0.06</td>
</tr>
<tr>
<td>Myocardial Infarction</td>
<td>0 (0%)</td>
<td>1 (3.4%)</td>
<td>0.40</td>
</tr>
<tr>
<td>Death</td>
<td>0 (0%)</td>
<td>2 (6.9%)</td>
<td>0.16</td>
</tr>
</tbody>
</table>

1-year Clinical Outcome

**ULCA + ZPCI vs ULCA**
HR: 1.42 [95% CI: 0.61, 3.30], \( P = 0.41 \)

**ULCA + ZPCI vs Standard**
HR: 0.40 [95% CI: 0.21, 0.75], \( P = 0.0032 \)

**ULCA vs Standard**
HR: 0.29 [95% CI: 0.13, 0.65], \( P = 0.0013 \)

*Indirect comparison

**Number at risk:**
- ULCA + ZPCI*: 82
- ULCA: 51
- Standard Angiography: 50

*Indirect comparison

Rahim & Ali. TCT 2019; #32, 09/25/19 2:15, Rm 209
Zero-contrast Rota-PCI

Prior ULCA angiogram

Prior low contrast angiogram

2.75x38 DES

Galougahi and Ali. CCI. 2017;90(4):E85-E89
Zero-contrast CTO-PCI

Prior ULCA angiogram

Metallic Silhouette

Reverse CART and Crossing

Zero contrast Vein Graft PCI

Zero contrast CHIP PCI

<table>
<thead>
<tr>
<th>Prior ULCA angiogram</th>
<th>Metallic Silhouette</th>
<th>Final Kissing Balloon</th>
</tr>
</thead>
</table>

Rahim and Ali. EuroPCR 2017
Zero contrast PCI: Step-by-Step

What's Next?
OCT Co-registration Guided Zero Contrast PCI

• First Report
• Co-registration
• Automatic measures

Optical coherence tomography-guided percutaneous coronary intervention in pre-terminal chronic kidney disease with no radio-contrast administration

Keyvan Karimi Galoughi1,2, Adrian Zalewski3, Martin B. Leon1,4, Dimitri Karmpaliotis3,5, and Ziad A. Ali1,4,6

1Division of Cardiology, Center for Interventional Vascular Therapy, New York Presbyterian Hospital and Columbia University, New York, NY, USA; 2Sydney Medical School Foundation, University of Sydney, Australia; and 3Cardiovascular Research Foundation, New York, NY, USA

A 67-year-old man with advanced chronic kidney disease (CKD) (creatinine = 4.5 mg/dL, eGFR = 13 mL/min/1.73 m²) not requiring haemodialysis presented with progressive angina. Diagnostic angiography with ultra-low radio-contrast volume (12 mL, contrast volume/eGFR ratio <1) revealed significant stenosis in the left anterior descending (LAD) artery (Panel A). The lesion was haemodynamically significant (fractional flow reserve: 0.77). Post-angiography, the renal function remained stable. A staged percutaneous coronary intervention (PCI) was performed without utilizing radio-contrast medium. Previous angiographic images were used to guide catheter engagement and guidewire placement in the LAD and diagonal arteries, thus creating a metallic silhouette of the artery (Panel B). Repeat physiological assessment confirmed haemodynamic significance [FFR: 0.78, coronary flow reserve (CFR): 1.4]. Optical coherence tomography (OCT) with angiographic co-registration (Optis, St Jude Medical, MA) was performed using a mixture of saline and colloidal infusate to displace blood (Panels C and D). Proximal (Panel E) and distal (Panel G) reference diameters determined by measuring the distance between respective external elastic laminae and minimal luminal area (Panel F) were used for selection of the pre-dilation balloon and stent sizes. An automated angiographic co-registered OCT pullback was used to guide the PCI (Panels H and I: G: distal reference = white bar). Co-registered OCT was repeated to determine minimal stent area (Panels J and K) and to guide post-dilation. Post-procedure FFR improved to 0.93 and CFR to 3.0. Post-PCI renal function remained stable. This case highlights the feasibility of radio-contrast free OCT-angiographic co-registration guided PCI to prevent contrast-induced nephropathy and requirement for renal replacement therapy in selected extremely high-risk patients with near-end-stage CKD.

Conflict of interest: D.K. has served as a speaker or a member of the speaker’s bureau for Abbott: Vascular, Boston Scientific and Medtronic. Z.A.A. is a speaker for and holds grant support from St Jude Medical.

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Non-contrast Solutions

Pre-PCI OCT – Contrast vs Saline
Non-contrast Solutions

Pre-PCI OCT – Contrast vs Solution X
Zero contrast revascularization

- Vessel anatomy based on non-contrast CT-CAC
Zero Contrast Revascularization

- DynaCT/CT-CAC coregistration to fluoroscopy
Zero Contrast Revascularization

66 year old female with previous history of HTN, HLD, DM, CAD, CKD stage 5 presented with shortness of breath and central chest pressure on exertion. Remote history of anaphylaxis to contrast medium during CTA.

eGFR\text{ml/min/1.73}\text{m}^2 = 15
Creatinine = 4.07 mg/dl
Clinical Impact

In patients with advanced CKD who require revascularization, PCI may safely be performed without contrast using imaging and physiological guidance with high procedural success and without complications.