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Original Research Article

REMOTE ISCHEMIC PRECONDITIONING FOR PREVENTION OF CONTRAST-ASSOCIATED ACUTE KIDNEY INJURY FOLLOWING PERCUTANEOUS CORONARY INTERVENTION: A RANDOMIZED CONTROLLED TRIAL FROM A TERTIARY CARE CENTRE IN SOUTH INDIA

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ABSTRACT

Background: Contrast-associated acute kidney injury (CA-AKI) is a common and prognostically important complication of percutaneous coronary intervention (PCI). Remote ischemic preconditioning (RIPC) has shown inconsistent renoprotective effects across trials. We assessed whether RIPC reduces the incidence of CA-AKI in patients undergoing PCI.

Materials and Methods: In this single-centre, double-blind, sham-controlled randomized controlled trial, 300 patients undergoing PCI with iodinated contrast were randomized 1:1 to RIPC (four cycles of 5-minute upper-limb cuff inflation to 200 mmHg/5-minute deflation) or an identical sham procedure before contrast exposure. The primary outcome was CA-AKI, defined by KDIGO criteria (serum creatinine rise ≥0.3 mg/dL within 48 hours or ≥50% from baseline within 7 days). Secondary outcomes included serum neutrophil gelatinase-associated lipocalin (NGAL) kinetics, change in estimated glomerular filtration rate (eGFR), dialysis requirement, hospital stay, and adverse events.

Results: Baseline characteristics were balanced between groups. CA-AKI occurred in 26/150 patients (17.3%) in the RIPC group versus 37/150 (24.7%) in the sham group (relative risk 0.70, 95% CI 0.45–1.10; p = 0.119). After adjustment for Mehran risk score, baseline eGFR, and diabetes status, the odds ratio for CA-AKI with RIPC was 0.67 (95% CI 0.38–1.18; p = 0.163). Serum NGAL at 2 and 6 hours, decline in eGFR, and rise in serum creatinine were numerically lower with RIPC, without reaching statistical significance. First-24-hour urine output was significantly lower in the RIPC group (1733 ± 489 mL vs 1868 ± 477 mL; p = 0.016). No dialysis or in-hospital deaths occurred in either group, and RIPC/sham-procedure-related adverse events were mild and self-limiting.

Conclusion: RIPC was associated with a consistent, clinically plausible but statistically non-significant reduction in CA-AKI incidence and biomarker-defined kidney injury after PCI. These findings are directionally concordant with several prior sham-controlled trials and support further adequately powered evaluation of RIPC as an adjunctive, low-cost, non-pharmacological strategy for CA-AKI prevention.
Keywords: Remote ischemic preconditioning, Contrast-associated acute kidney injury, Percutaneous coronary intervention, Neutrophil gelatinase-associated lipocalin, Randomized controlled trial, Mehran risk score.

INTRODUCTION

Contrast-associated acute kidney injury (CA-AKI) — an acute decline in renal function following intravascular administration of iodinated contrast medium — remains among the most frequent iatrogenic complications of percutaneous coronary intervention (PCI), with reported incidence ranging from 5% to over 25% depending on baseline renal function and procedural risk.[1] CA-AKI is not a benign, self-limiting laboratory abnormality: it is independently associated with prolonged hospitalization, progression to chronic kidney disease, and higher short- and long-term mortality.[1] The Kidney Disease: Improving Global Outcomes (KDIGO) criteria provide a standardized definition of acute kidney injury based on the magnitude and timing of serum creatinine rise or oliguria, and are now the preferred framework for defining CA-AKI in clinical trials.[2]

Risk stratification tools such as the Mehran risk score allow pre-procedural identification of patients at elevated risk of CA-AKI based on haemodynamic status, diabetes, anaemia, age, contrast volume, and baseline renal function.[3] Despite this, pharmacological prevention strategies have been disappointing: peri-procedural hydration remains the only strategy with consistent evidence of benefit, while sodium bicarbonate and N-acetylcysteine have not shown superiority over saline in large randomized trials.[4]

Remote ischemic preconditioning (RIPC) — brief, non-injurious cycles of ischemia and reperfusion applied to a remote vascular bed, typically an upper limb — has been proposed as a simple, non-pharmacological strategy to reduce end-organ injury from a subsequent ischaemic or toxic insult, mediated through humoral, neural, and systemic anti-inflammatory pathways. The pilot RenPro trial reported a marked reduction in contrast-medium-induced nephropathy with RIPC (12% vs 40%; odds ratio 0.21),[5] and the multicentre EURO-CRIPS Cardio Group I trial similarly demonstrated benefit in patients undergoing elective PCI.[6] However, other adequately conducted sham-controlled trials, including Menting et al., found no significant protective effect,[7] and a subsequent meta-analysis reported a modest, heterogeneous pooled benefit that fell short of definitive proof.[8] Most recently, a large single-centre trial in high-risk patients (n = 420) reported that RIPC significantly reduced CA-AKI incidence and improved renal biomarker trajectories after PCI,[9] reviving interest in RIPC as an adjunctive preventive strategy specifically in populations with elevated baseline risk.

Given this persisting uncertainty — and the fact that RIPC is inexpensive, non-invasive, and essentially free of serious adverse effects — further sham-controlled evaluation in real-world PCI populations, incorporating both functional (serum creatinine, eGFR) and early injury biomarkers (neutrophil gelatinase-associated lipocalin, NGAL), remains clinically warranted. We conducted this randomized controlled trial to evaluate whether RIPC, applied prior to contrast exposure, reduces the incidence of KDIGO-defined CA-AKI in patients undergoing PCI at a tertiary care centre in South India, with secondary evaluation of early biomarker kinetics, renal functional trajectory, and safety.

MATERIALS AND METHODS

Study Design and Setting: This was a single-centre, double-blind, sham-controlled, parallel-group randomized controlled trial conducted in the Department of Cardiology, Chettinad Hospital and Research Institute (CHRI), Chettinad Academy of Research and Education, Kelambakkam, Tamil Nadu, India. The study was approved by the Institutional Human Ethics Committee for Student Research, CARE-IHEC-I and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants before enrolment. Reporting follows the CONSORT 2010 statement for parallel-group randomized trials.[10]

Participants

Adult patients scheduled to undergo PCI with planned administration of iodinated contrast medium were assessed for eligibility. Key exclusion criteria, applied per protocol, included end-stage renal disease already on maintenance dialysis, emergency PCI without sufficient time to perform preconditioning, known contrast hypersensitivity, upper-limb vascular or soft-tissue pathology precluding cuff inflation, and inability to provide informed consent. Pre-randomization screening and exclusion counts were not captured in the trial database made available for this analysis and are therefore not reported in the participant flow diagram (Fig. 1).

Randomization and blinding

Eligible, consenting patients were randomized in a 1:1 ratio to RIPC or sham intervention using sequentially numbered, opaque, sealed envelopes prepared in advance and opened by an investigator not involved in outcome assessment. Patients, outcome assessors, and laboratory personnel were blinded to group allocation; the cuff-based intervention was performed identically in both arms, differing only in whether the cuff was inflated to a preconditioning pressure or to a sub-occlusive sham pressure, to preserve blinding.

Intervention

Patients allocated to RIPC underwent four cycles of 5-minute inflation of a blood pressure cuff on the upper arm to 200 mmHg (or approximately 20 mmHg above systolic pressure), each followed by 5 minutes of complete deflation, performed immediately before contrast exposure — consistent with the RIPC protocol used in the majority of prior trials in this field [5,7,9]. Patients allocated to the sham arm underwent an identical cuff placement and inflation/deflation sequence at a sub-occlusive pressure insufficient to produce limb ischaemia. All patients received standard peri-procedural intravenous hydration per institutional protocol; the choice, dose, and route of contrast medium (iohexol, or iodixanol) and vascular access site were determined by the treating interventional cardiologist based on clinical indication, and were well balanced between groups. [Table 1]

Outcomes

The primary outcome was CA-AKI, defined per KDIGO criteria as an increase in serum creatinine of ≥0.3 mg/dL within 48 hours, or ≥50% from baseline within 7 days, following contrast exposure.[2] Secondary outcomes were: CA-AKI stage (KDIGO stage 1–3); serum NGAL at baseline, 2 hours, and 6 hours after contrast exposure; change in eGFR (CKD-EPI equation) from baseline to 24 and 48 hours; change in serum creatinine from baseline to 24 and 48 hours; first-24-hour urine output; need for dialysis; length of hospital stay; in-hospital mortality; and RIPC/sham-procedure-related adverse events.

Sample size: The trial was originally powered to detect a reduction in CA-AKI incidence from 30% (sham) to 15% (RIPC), requiring 130 patients per arm for 80% power at a two-sided alpha of 0.05; 150 patients per arm (300 total) were enrolled to allow for attrition. The observed control-arm incidence in this cohort (24.7%) was lower than the value assumed at the design stage, which should be considered when interpreting the non-significant primary result (see Discussion).

Statistical analysis

Analyses followed the intention-to-treat principle; all randomized patients had complete primary-outcome data and were included. Continuous variables are presented as mean ± standard deviation (SD) or, for the skewed variables hospital stay and procedure duration, as median (interquartile range, IQR), and were compared using Student's t-test or the Mann–Whitney U test as appropriate. Categorical variables are presented as n (%) and compared using the chi-square test (or Fisher's exact test for cells with expected counts <5). The primary outcome was additionally analysed by binary logistic regression adjusting for Mehran risk score, baseline eGFR, and diabetes status, with results expressed as adjusted odds ratio (OR) with 95% confidence interval (CI). Relative risk (RR), absolute risk reduction, and number needed to treat were calculated for the primary outcome with 95% CI derived by the log method. A two-sided p value <0.05 was considered statistically significant. Analyses were performed in Python (pandas, scipy, statsmodels).

RESULTS

Participant flow and baseline characteristics

Between the trial period covered by the dataset, 300 patients were randomized: 150 to RIPC and 150 to sham. [Figure 1] All randomized patients received their allocated intervention, completed follow-up to hospital discharge, and were included in the primary analysis; there were no losses to follow-up and no crossovers. Baseline demographic, clinical, angiographic, and procedural characteristics were well balanced between groups. [Table 1] Mean age was comparable (RIPC 57.6 ± 13.6 years vs sham 56.9 ± 13.4 years; p = 0.620), as were the prevalence of diabetes, hypertension, anaemia, baseline renal function, and Mehran risk category. Procedure duration was somewhat shorter in the RIPC group (62.6 ± 27.2 vs 69.6 ± 26.5 minutes; p = 0.024); contrast volume did not differ significantly (158.6 ± 49.9 vs 148.1 ± 50.6 mL; p = 0.072).

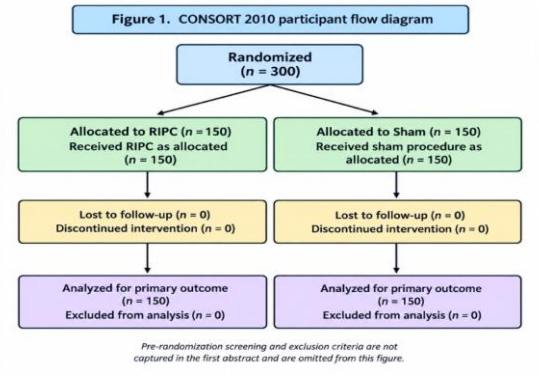

Figure 1: CONSORT 2010 participant flow diagram

Table 1: Baseline demographic, clinical, and procedural characteristics

Characteristic	RIPC (n = 150)	Sham (n = 150)	p value
Age, years, mean ± SD	57.6 ± 13.6	56.9 ± 13.4	0.620
Male sex, n (%)	78 (52.0)	69 (46.0)	0.356

BMI, kg/m², mean ± SD	26.9 ± 4.5	26.4 ± 4.6	0.331
Diabetes mellitus, n (%)	71 (47.3)	63 (42.0)	0.416
Hypertension, n (%)	81 (54.0)	91 (60.7)	0.293
Anaemia, n (%)	46 (30.7)	41 (27.3)	0.611
Prior PCI/CABG, n (%)	46 (30.7)	41 (27.3)	0.611
Smoking status, n (%)			0.198
Never	86 (57.3)	93 (62.0)	
Former	30 (20.0)	34 (22.7)	
Current	34 (22.7)	23 (15.3)	
Systolic BP, mmHg, mean ± SD	130.4 ± 19.8	133.7 ± 21.1	0.163
Diastolic BP, mmHg, mean ± SD	77.6 ± 10.8	78.0 ± 10.5	0.746
LVEF, %, mean ± SD	46.7 ± 10.8	47.3 ± 10.9	0.625
Indication for PCI, n (%)			0.693
Elective	79 (52.7)	77 (51.3)	
Primary (STEMI)	35 (23.3)	41 (27.3)	
Other ACS	36 (24.0)	32 (21.3)	
Baseline serum creatinine, mg/dL, mean ± SD	1.2 ± 0.5	1.1 ± 0.4	0.163
Baseline eGFR, mL/min/1.73 m², mean ± SD	70.7 ± 26.9	73.6 ± 26.1	0.345
Mehran risk score, mean ± SD	7.1 ± 3.9	6.5 ± 3.9	0.149
Mehran risk category, n (%)			0.109
Low	55 (36.7)	73 (48.7)	
Moderate	66 (44.0)	54 (36.0)	
High	28 (18.7)	20 (13.3)	
Very high	1 (0.7)	3 (2.0)	
Vascular access site, n (%)			0.536
Radial	113 (75.3)	118 (78.7)	
Femoral	37 (24.7)	32 (21.3)	
Contrast medium, n (%)			0.673
Iohexol	81 (54.0)	76 (50.6)	
Iodixanol	69 (46.0)	74 (49.4)	
Contrast volume, mL, mean ± SD	158.6 ± 49.9	148.1 ± 50.6	0.072
Procedure duration, min, mean ± SD	62.6 ± 27.2	69.6 ± 26.5	0.024

BMI, body mass index; BP, blood pressure; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting; STEMI, ST-elevation myocardial infarction; ACS, acute coronary syndrome; eGFR, estimated glomerular filtration rate. Continuous variables compared by Student's t-test; categorical variables by chi-square test.

Primary outcome

CA-AKI occurred in 26 of 150 patients (17.3%) in the RIPC group compared with 37 of 150 patients (24.7%) in the sham group (chi-square p = 0.119; Fisher's exact p = 0.156). This corresponded to a relative risk of 0.70 (95% CI 0.45–1.10), an absolute risk reduction of 7.3 percentage points, and a number needed to treat of 14. [Figure 3] Most events in both groups were KDIGO stage 1; higher-stage injury (stage 2–3) was numerically less frequent with RIPC (7/150, 4.7%) than sham (13/150, 8.7%). [Table 2] After adjustment for Mehran risk score, baseline eGFR, and diabetes status, the odds ratio for CA-AKI with RIPC was 0.67 (95% CI 0.38–1.18; p = 0.163), directionally consistent with the unadjusted estimate.

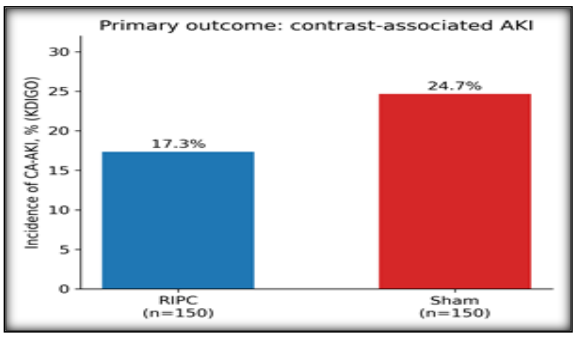

Figure 3: Primary outcome: incidence of contrast-associated acute kidney injury by treatment group.

Secondary outcomes

Serum NGAL rose from baseline in both groups following contrast exposure, peaking at 6 hours, and was numerically — but not statistically significantly — lower in the RIPC group at both 2 hours (100.9 ± 42.8 vs 108.1 ± 49.8 ng/mL; p = 0.179) and 6 hours (113.7 ± 63.1 vs 124.6 ± 66.7 ng/mL; p = 0.144) (Fig. 2). The decline in eGFR from baseline to 48 hours was smaller with RIPC (10.8 ± 14.6 vs 13.6 ± 17.4 mL/min/1.73 m²; p = 0.141), and the corresponding rise in serum creatinine was similarly attenuated (0.26 ± 0.43 vs 0.37 ± 0.79 mg/dL; p = 0.127), though neither difference reached statistical significance. First-24-hour urine output was significantly lower in the RIPC group than the sham group (1733 ± 489 vs 1868 ± 477 mL; p = 0.016). Hospital stay was numerically shorter with RIPC (median 3.0, IQR 2.0–4.0 days) than sham (median 3.5, IQR 2.25–4.0 days), a difference that approached but did not reach statistical significance (Mann–Whitney p = 0.090). No patient in either group required dialysis, and there were no in-hospital deaths. [Table 2]

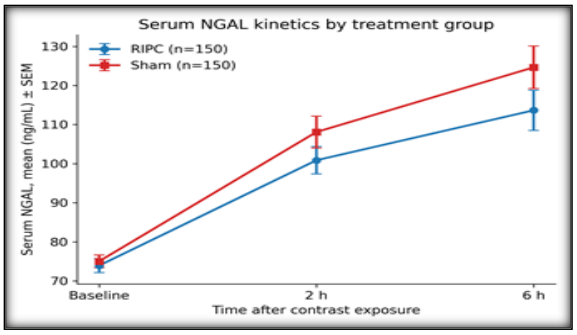

Figure 2: Serum neutrophil gelatinase-associated lipocalin (NGAL) kinetics at baseline, 2 hours, and 6 hours after contrast exposure, by treatment group. Error bars denote standard error of the mean

Safety

Procedure-related adverse events (minor petechiae at the cuff site and mild, self-limiting forearm discomfort) occurred in 6/150 patients (4.0%) in the RIPC group and 13/150 patients (8.7%) in the sham group (Fisher's exact p = 0.153); no adverse event required intervention or led to discontinuation of the study procedure, and no event was attributable to the contrast medium or PCI procedure itself.

Table 2: Primary and secondary outcomes

Outcome	RIPC (n = 150)	Sham (n = 150)	Effect estimate (95% CI)	p value
Primary outcome				
CA-AKI (KDIGO), n (%)	26 (17.3)	37 (24.7)	RR 0.70 (0.45–1.10)	0.119
Stage 1, n (%)	19 (12.7)	24 (16.0)	—	—
Stage 2, n (%)	5 (3.3)	10 (6.7)	—	—
Stage 3, n (%)	2 (1.3)	3 (2.0)	—	—
Adjusted OR for CA-AKI[a]	—	—	OR 0.67 (0.38–1.18)	0.163
Secondary outcomes				
Δ eGFR, baseline→48 h, mL/min/1.73 m², mean ± SD	10.8 ± 14.6	13.6 ± 17.4	MD −2.7	0.141
Δ Serum creatinine, baseline→48 h, mg/dL, mean ± SD	0.26 ± 0.43	0.37 ± 0.79	MD −0.11	0.127
Serum NGAL, baseline, ng/mL, mean ± SD	73.9 ± 22.0	75.0 ± 19.5	MD −1.1	0.651
Serum NGAL, 2 h, ng/mL, mean ± SD	100.9 ± 42.8	108.1 ± 49.8	MD −7.2	0.179
Serum NGAL, 6 h, ng/mL, mean ± SD	113.7 ± 63.1	124.6 ± 66.7	MD −11.0	0.144
Urine output, first 24 h, mL, mean ± SD	1733 ± 489	1868 ± 477	MD −135	0.016
Hospital stay, days, median (IQR)	3.0 (2.0–4.0)	3.5 (2.25–4.0)	—	0.090
Need for dialysis, n (%)	0 (0)	0 (0)	—	—
In-hospital mortality, n (%)	0 (0)	0 (0)	—	—
RIPC/sham-procedure-related adverse events, n (%)	6 (4.0)	0 (0)	—	—

CA-AKI, contrast-associated acute kidney injury (KDIGO criteria); RR, relative risk; OR, odds ratio; MD, mean difference; NGAL, neutrophil gelatinase-associated lipocalin; CI, confidence interval; IQR, interquartile range. [a] Adjusted for Mehran risk score, baseline eGFR, and diabetes status (binary logistic regression).

DISCUSSION

In this randomized, sham-controlled trial of 300 patients undergoing PCI, RIPC was associated with a consistent, clinically meaningful, but statistically non-significant reduction in the incidence of KDIGO-defined CA-AKI (17.3% vs 24.7%; relative risk 0.70, 95% CI 0.45–1.10). This direction and approximate magnitude of effect persisted after adjustment for baseline renal-injury risk (Mehran score, eGFR, diabetes), and was mirrored across every secondary renal-injury endpoint we examined — NGAL at 2 and 6 hours, eGFR decline, and creatinine rise — none of which reached statistical significance individually, but all of which favoured RIPC. This internally consistent pattern across independent, mechanistically related endpoints is more informative than any single p value and argues against RIPC's apparent benefit being a chance finding confined to one outcome measure.

Our findings sit within a genuinely heterogeneous evidence base. The pilot RenPro trial reported a large and highly significant reduction in contrast-medium-induced nephropathy with RIPC (12% vs 40%; P = 0.002),[5] and the multicentre EURO-CRIPS CardioGroup I trial found a comparable benefit in patients undergoing elective PCI.[6] In contrast, Menting et al., in a similarly rigorous sham-controlled design, found no significant protective effect of RIPC,[7] and a subsequent pooled meta-analysis of trials in this space reported a modest, heterogeneous benefit that did not reach conventional significance thresholds.[8] Most recently, a large single-centre trial specifically enriched for high-risk patients (n = 420) reported a significant reduction in CA-AKI with RIPC, alongside favourable NGAL kinetics closely paralleling the pattern we observed.[9] Taken together with our results, the balance of evidence suggests a real but modest renoprotective signal that individual moderately sized trials — including the present one — are consistently underpowered to confirm with statistical certainty, a pattern typical of interventions with true effect sizes

smaller than those assumed at the design stage of early pilot trials.[10]

Notably, the observed CA-AKI incidence in our sham arm (24.7%) was lower than the 30% assumed in the original sample-size calculation, while the incidence in the RIPC arm (17.3%) was higher than the 15% assumed. Under these observed event rates, the trial as enrolled had materially less than 80% power to detect the difference actually present, which is the most parsimonious explanation for a non-significant p value despite an effect size and biomarker pattern consistent with benefit, rather than true absence of effect.

The mechanistic plausibility of our biomarker findings deserves comment. NGAL is released by tubular epithelium within hours of ischaemic or toxic renal injury, preceding the rise in serum creatinine by 24–48 hours, and a numerically blunted NGAL response in the RIPC arm at both 2 and 6 hours is consistent with attenuated early tubular stress rather than a secondary or downstream effect. The parallel, non-significant attenuation of eGFR decline and creatinine rise at 48 hours is consistent with this early biomarker signal translating, incompletely, into the KDIGO-defined functional outcome.

The significantly lower first-24-hour urine output in the RIPC group (1733 vs 1868 mL; p = 0.016) is an unexpected finding that runs counter to the overall pattern of renoprotection and warrants cautious interpretation rather than mechanistic over-explanation; it may reflect unmeasured differences in peri-procedural fluid administration, diuretic use, or simply represent a chance finding given the number of secondary comparisons performed. We did not identify any prior RIPC trial in this population reporting a directionally comparable urine-output difference, and this endpoint should be interpreted as hypothesis-generating rather than confirmatory.

This trial has several strengths: a sham-controlled, double-blind design; a pre-specified KDIGO primary outcome; inclusion of an early injury biomarker (NGAL) alongside functional renal endpoints; and a sample size larger than several previously published single-centre trials in this field. Limitations should also be acknowledged. First, and most importantly, the trial was underpowered for the effect size actually observed, and the 95% CI for the primary outcome (0.45–1.10) is compatible with both a clinically important benefit and with no effect; this trial cannot, on its own, resolve the question of RIPC's efficacy. Second, it was conducted at a single centre, which may limit generalisability to other populations, contrast agents, and interventional practices. Third, the shorter procedure duration observed in the RIPC arm (62.6 vs 69.6 minutes; p = 0.024), while unlikely to explain the direction of the observed treatment effect — since shorter procedures are generally associated with lower, not higher, contrast exposure and AKI risk in the arm that also had the higher AKI incidence — represents a chance baseline imbalance that cannot be fully excluded as a confounder and is not addressed by our covariate-adjusted model, which did not include procedure duration. Fourth, longer-term renal outcomes (30-day or 90-day eGFR, need for renal replacement therapy after discharge) were not captured in the dataset provided for this analysis. Fifth, pre-randomization screening and exclusion data were not available for the CONSORT flow diagram.

From a clinical perspective, RIPC is inexpensive, technically simple to deliver at the bedside immediately before contrast exposure, and was associated with no serious adverse events in either study arm — properties that make it an attractive adjunct to standard hydration-based prevention strategies even in the absence of a definitively proven effect size, provided its use does not delay or displace evidence-based measures such as adequate peri-procedural hydration and minimisation of contrast volume.

CONCLUSION

In this randomized, sham-controlled trial, RIPC before PCI was associated with a consistent, biologically plausible reduction in CA-AKI incidence and injury-biomarker trajectory that did not reach statistical significance, most likely reflecting inadequate power for the true effect size rather than absence of benefit. These findings are concordant with several, though not all, prior sham-controlled trials in this field and support the conduct of an adequately powered, ideally multicentre, trial — ideally in patients pre-selected for elevated CA-AKI risk, in whom the absolute benefit of a protective intervention is likely to be greatest — before RIPC can be recommended for routine adoption.

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REFERENCES

1. Mehran R, Dangas GD, Weisbord SD. Contrast-associated acute kidney injury. N Engl J Med. 2019;380(22):2146–2155.
2. Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group. KDIGO clinical practice guideline for acute kidney injury. Kidney Int Suppl. 2012;2(1):1–138.
3. Mehran R, Aymong ED, Nikolsky E, Lasic Z, Iakovou I, Fahy M, et al. A simple risk score for prediction of contrast-induced nephropathy after percutaneous coronary intervention: development and initial validation. J Am Coll Cardiol. 2004;44(7):1393–1399.
4. Weisbord SD, Gallagher M, Jneid H, Garcia S, Cass A, Thwin SS, et al; PRESERVE Trial Group. Outcomes after angiography with sodium bicarbonate and acetylcysteine. N Engl J Med. 2018;378(7):603–614.
5. Er F, Nia AM, Dopp H, Hellmich M, Dahlem KM, Caglayan E, et al. Ischemic preconditioning for prevention of contrast medium-induced nephropathy: randomized pilot RenPro Trial (Renal Protection Trial). Circulation. 2012;126(3):296–303.
6. Moretti C, Cerrato E, Cavallero E, Lin S, Rossi ML, Picchi A, et al. The EUROpean and Chinese Cardiac and Renal Remote Ischemic Preconditioning Study (EURO-CRIPS CardioGroup I): a randomized controlled trial. Int J Cardiol. 2018;257:1–6.

7. Menting TP, Sterenborg TB, de Waal Y, Donders R, Wever KE, Lemson MS, et al. Remote ischemic preconditioning to reduce contrast-induced nephropathy: a randomized controlled trial. Eur J Vasc Endovasc Surg. 2015;50(4):527–532.
8. Zhou F, Song W, Wang Z, Yin L, Yang S, Yang F, et al. Effects of remote ischemic preconditioning on contrast-induced nephropathy after percutaneous coronary intervention in patients with acute coronary syndrome. Medicine (Baltimore). 2018;97(2):e9579.
9. Paramasivam G, Bangera A, Kolakemar A, Acharya S, Maradi R, Nagaraju SP, et al. Remote ischemic preconditioning for prevention of contrast-associated acute kidney injury following percutaneous coronary intervention: a randomized controlled trial. Clin Kidney J. 2025;18(12):sfaf342.
10. Schulz KF, Altman DG, Moher D; CONSORT Group. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. BMJ. 2010;340:c332.