4.1.1. Risk prediction tools

Alan, 2019

Bibliographic Reference	Alan, Guillaume; Guenancia, Charles; Arnould, Louis; Azemar, Arthur; Pitois, Stephane; Maza, Maud; Bichat, Florence; Zeller, Marianne; Gabrielle, Pierre-Henri; Bron, Alain Marie; Creuzot-Garcher, Catherine; Cottin, Yves; Retinal Vascular Density as A Novel Biomarker of Acute Renal Injury after Acute Coronary Syndrome.; Scientific reports; 2019; vol. 9 (no. 1); 8060

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	France
Study setting	Cardiology intensive care unit
Study dates	September 2016 - March 2017
Sources of funding	Supported by the Dijon University Hospital, the Association de Cardiologie de Bourgogne, and by grants from the Agence Régionale de Santé de Bourgogne, French Ministry of Research, Institut National de la Santé et de la Recherche Médicale, Fédération Française de Cardiologie, Société Française de Cardiologie and the Regional Council of Burgundy

Study sample	Patients' medical records from the obseRvatoire des Infarctus de Côte d'Or - a regional survey set up to collect data for patients hospitalised with acute coronary syndrome
Inclusion criteria	Underwent coronary angiography whilst hospitalised and were eligible for optical coherence tomography angiography
Exclusion criteria	History of an eye disease (diabetic and vascular retinopathy, age-related macular degeneration, vitreoretinal abnormality) On dialysis, Not affiliated to national health insurance
Intervention details	No additional information
Population subgroups	
Risk tool(s)	**Mehran Risk Score** Includes eight weighted variables: hypotension, intra-aortic balloon pump, congestive heart failure, chronic kidney disease, diabetes, age >75 years, anaemia, and volume of contrast **GRACE Score** The GRACE admission score assesses the patient's individual ischemic risk and prognosis with calculation of the probability of in-hospital and 6-month mortality
Model development and validation	Both risk scores were externally created. Optimal cut-off values for each were determined using ROC curves from this study population.
Outcome	Acute kidney injury, referred to in the paper as acute renal failure - according to KDIGO criteria, with an increase in serum creatinine of at least 26.5 µmol/L at 48h after injection or >50% compared to the initial dosage within 7 days after injection of ICA
Duration of follow-up	7 days

Indirectness	None
Additional comments	None

Study arms

Mehran Risk Score (cut-off: 5) (N = 216)

GRACE Score (cut-off: 142) (N = 216)

Characteristics

Study-level characteristics

Characteristic	**Study (N = 216)**
Mean age (SD) Mean (SD)	62.68 (12.38)
% Female Sample size	n = 46 ; % = 21.3
Ethnicity Nominal	NR

Characteristic	Study (N = 216)
Diabetes Sample size	n = 51 ; % = 23.6
Heart failure Sample size	n = 30 ; % = 13.9
Hypertension Sample size	n = 112 ; % = 51.9
Contrast volume mL Mean (SD)	147.56 (64.44)
Number of AKI events Sample size	n = 21 ; % = 10

Outcomes

Acute kidney injury

Outcome	Mehran Risk Score (cut-off: 5), , N = 216	GRACE Score (cut-off: 142), , N = 216
AUC Mean (95% CI)	0.8 (0.7 to 0.91)	0.83 (0.72 to 0.93)
Sensitivity	76	81

Outcome	Mehran Risk Score (cut-off: 5), , N = 216	GRACE Score (cut-off: 142), , N = 216
Nominal		
Specificity % Nominal	69	71

Ando, 2014

Bibliographic Reference	Ando, Giuseppe; de Gregorio, Cesare; Morabito, Gaetano; Trio, Olimpia; Saporito, Francesco; Oreto, Giuseppe; Renal function-adjusted contrast volume redefines the baseline estimation of contrast-induced acute kidney injury risk in patients undergoing primary percutaneous coronary intervention.; Circulation. Cardiovascular interventions; 2014; vol. 7 (no. 4); 465-72

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	Same population as 2013 study by the same author: Age, Glomerular Filtration Rate, Ejection Fraction, and the AGEF Score Predict Contrast-Induced Nephropathy in Patients With Acute Myocardial Infarction Undergoing Primary Percutaneous Coronary Intervention. https://doi.org/10.1002/ccd.25023 Prognostic accuracy data of model 1 is reported in the details of the 2013 study. The details outlined here focus on model 2 only, which was validated in a subset of the whole population.
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	Italy
Study setting	Intensive and interventional cardiology department
Study dates	2012-2013

Sources of funding	Funded by the University of Messina
Study sample	Non-consecutive patients undergoing primary PCI
Inclusion criteria	Admitted within 12 hours of STEMI symptom onset
Exclusion criteria	Known tumour or chronic inflammatory disease Chronic kidney failure on haemodialysis at admission Monoclonal gammopathy Recipient of transplants History of adverse reaction to contrast dye or exposure within the last 7 days Undergoing emergency cardiac surgery for coronary revascularization or STEMI-related mechanical complications Died within 12 hr after the procedure.
Intervention details	Primary PCI was performed by an interventional team, using femoral approach and according to standard clinical practice. Pharmacological therapy, as well as the indication to intra-aortic balloon pump support, was left to the discretion of the attending cardiologists. Hydration was initiated during the diagnostic procedure and was continued for ≥48 hours. Saline solution (0.9%) was given intravenously at a rate of 1 mL/ kg per hour; hydration rate was reduced to 0.5 mL/kg per hour in patients with severe left ventricular dysfunction or overt heart failure. Non-ionic low-osmolar contrast media were used in all cases. Blood samples were collected for measurement of serum creatinine concentration on hospital admission, 6 hours after the procedure, every day for the following 3 days, and at discharge from the coronary care unit. Baseline eGFR was calculated using the modification of diet in renal disease equation.
Risk tool(s)	**AGEF Score (including renal function-adjusted contrast volume)** Modified version of the ACEF score, including the following variables: Age

	eGFR LVEF Contrast volume : eGFR ratio
Model development and validation	A logistic regression model was fitted to the database, with the occurrence of CI-AKI as the outcome. The model (model 2) included AGEF score and CV/eGFR. First, the accuracy of each model was assessed in terms of discrimination and calibration: ROC curves analysis was performed to assess discrimination, as measured by the AUC
Outcome	Contrast-induced acute kidney injury, defined as an absolute increase in serum creatinine concentration ≥0.5 mg/dL or ≥25% from baseline within 72 hours after the administration of contrast medium, without any other plausible cause
Duration of follow-up	72 hours
Indirectness	None
Additional comments	None

Study arms

Study-developed risk score (N = 126)

Characteristics

Study-level characteristics

Characteristic	Study (N = 126)
Mean age (SD) Mean (SD)	64.3 (14.1)
% Female Sample size	n = 27 ; % = 21.4
Ethnicity Nominal	NR
Diabetes Sample size	n = 36 ; % = 28.6
Heart failure Nominal	NR
Hypertension Sample size	n = 75 ; % = 59.5
Contrast volume (ml) Mean (SD)	176.7 (44.4)
Number of AKI events Sample size	n = 12 ; % = 9.5

Outcomes

Acute kidney injury

Outcome	Study-developed risk score, , N = 126
AUC Mean (95% CI)	0.86 (0.8 to 0.92)
Hosmer-Lemeshow Mean (p value)	59.9 (<0.001)

Andò, 2013

Bibliographic Reference	Andò, Giuseppe; Morabito, Gaetano; de Gregorio, Cesare; Trio, Olimpia; Saporito, Francesco; Oreto, Giuseppe; Age, glomerular filtration rate, ejection fraction, and the AGEF score predict contrast-induced nephropathy in patients with acute myocardial infarction undergoing primary percutaneous coronary intervention; Catheterization and Cardiovascular Interventions; 2013; vol. 82 (no. 6); 878-885

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	Italy
Study setting	Coronary care unit
Study dates	January 2008 - June 2011
Sources of funding	Grant received from Azienda Ospedaliera Universitaria Policlinico “Gaetano Martino”, University of Messina, Italy

Study sample	Consecutive patients referred to the unit for primary percutaneous coronary intervention in the course of ST-segment elevation myocardial infarction
Inclusion criteria	Admitted within 12 hours of symptom onset
Exclusion criteria	Known tumour or chronic inflammatory disease Chronic kidney failure on haemodialysis at admission Monoclonal gammopathy Recipient of transplants History of adverse reaction to contrast dye or exposure within the last 7 days Undergoing emergency cardiac surgery for coronary revascularization or STEMI-related mechanical complications Died within 12 hours of the procedure
Intervention details	Primary PCI was performed from the transfemoral approach according to standard clinical practice. The indication to intra-aortic balloon pump support was left to the discretion of the attending cardiologists. Saline solution (0.9%) was given intravenously at a rate of 1 mL/kg/hr; hydration rate was reduced to 0.5 mL/ kg/hr in patients with severe left ventricular dysfunction or overt heart failure. Hydration was initiated during the diagnostic procedure and was continued for at least 48 hours. Non-ionic low-osmolar contrast media was used in all cases
Risk tool(s)	**ACEF score** Model previously developed by Ranucci et al., (2009) to predict mortality in cardiac surgery patients using the following variables: Age Ejection fraction Serum creatinine

	Mehran risk score Previously established model. No additional information on use other than it was applied at the end of the PCI procedure
Model development and validation	Both models were previously established in other papers
Outcome	Contrast-induced nephropathy, defined as an absolute increase in serum creatinine ≥0.5 mg/dL or an increase ≥25% from baseline within 72 hours of contrast administration, without any other plausible aetiology
Duration of follow-up	Duration of hospital stay (mean (SD)) 7 (3) days
Indirectness	None
Additional comments	None

Study arms

ACEF score (N = 481)

Mehran risk score (cut-off: 5) (N = 481)

Characteristics

Study-level characteristics

Characteristic	Study (N = 481)
Mean age (SD) Mean (SD)	62 (12)
% Female Sample size	n = 128 ; % = 27
Ethnicity Nominal	NR
Diabetes Sample size	n = 143 ; % = 30
Heart failure Killip class Mean (SD)	1.1 (0.5)
Hypertension Sample size	n = 285 ; % = 59
Contrast volume (ml) Mean (SD)	164 (63)
Number of AKI events Sample size	n = 25 ; % = 5.2

Outcomes

Acute kidney injury

Outcome	ACEF score, , N = 481	Mehran risk score (cut-off: 5), , N = 481
AUC Mean (95% CI)	0.82 (0.78 to 0.85)	0.8 (0.77 to 0.84)
Sensitivity Nominal	NR	72
Specificity Nominal	NR	73.5
Hosmer-Lemeshow Mean (p value)	NR (NR)	3.33 (0.77)

Buratti, 2021

Bibliographic Reference	Buratti, Stefano; Crimi, Gabriele; Somaschini, Alberto; Cornara, Stefano; Camporotondo, Rita; Cosentino, Nicola; Moltrasio, Marco; Rubino, Mara; De Metrio, Monica; Marana, Ivana; De Servi, Stefano; Marenzi, Giancarlo; De Ferrari, Gaetano M; A preprocedural risk score predicts acute kidney injury following primary percutaneous coronary intervention.; Catheterization and cardiovascular interventions : official journal of the Society for Cardiac Angiography & Interventions; 2021; vol. 98 (no. 2); 197-205

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	Italy
Study setting	Two hospitals
Study dates	2004 – 2015
Sources of funding	None reported

Study sample	Consecutive ST-elevated myocardial infarction patients admitted to two hospitals
Inclusion criteria	Undergoing percutaneous coronary intervention
Exclusion criteria	On haemodialysis Undergoing rescue PCI or urgent cardiac surgery Died during procedure or before consecutive creatinine measurements could be taken
Intervention details	Primary PCI was performed by interventional cardiologists, according to standard clinical practice. Iso-osmolar contrast agents were used.
Risk tool(s)	**Study developed risk tool (referred to as De Ferrari)** Model based on five variables (score for each indicated in brackets, with a maximum score of 17): Killip class II or III (2) Killip class IV (4) Diabetes (2) Anterior STEMI (3) Age >75 years (3) eGFR <60 (5) **Mehran, Marenzi and Inohara risk scores** No details provided

Model development and validation	Candidate predictors of CI-AKI included variables known at baseline and serum creatinine. Independent predictors were identified by fitting a multivariable logistic regression model in which all significant variables at univariate tests were included. Collinearity between covariates was assessed with a Spearman p test. Each significant variable that was included in the final model was allocated a score based on the nearest whole integer number to the OR identified. ROC curves were computed and c-statistic was used to assess discrimination. Model calibration was assessed with the Hosmer-Lemeshow $\chi 2$ test. The Risk Score performance was then evaluated in the separate validation cohort
Outcome	Contrast-induced acute kidney injury, defined as: an absolute serum creatinine increase ≥0.5 mg/dl in the first 72 hours
Duration of follow-up	Unclear
Indirectness	None
Additional comments	None

Study arms

Study developed risk tool (N = 1782)

Mehran risk score (N = 1782)

Marenzi risk score (N = 1782)

Inohara risk score (N = 1782)

Characteristics

Study-level characteristics

Characteristic	Study (N = 1782)
Mean age (SD) Mean (SD)	63.7 (12.2)
% Female Sample size	n = 387 ; % = 21.7
Ethnicity Nominal	NR
Diabetes Sample size	n = 281 ; % = 15.8
Heart failure Sample size	n = NA ; % = NA
Killip Class II-III Sample size	n = 163 ; % = 9.1
Killip class IV Sample size	n = 158 ; % = 8.7
Hypertension Sample size	n = 914 ; % = 51.2

Characteristic	Study (N = 1782)
No CI-AKI 1646 participants Median (IQR)	209 (156 to 353)
CI-AKI 136 participants Median (IQR)	262 (182 to 470)
Number of AKI events No of events	n = 136 ; % = 7.6

Outcomes

Acute kidney injury

Outcome	Study developed risk tool, , N = 1782	Mehran risk score, , N = 1782	Marenzi risk score, , N = 1782	Inohara risk score, , N = 1782
AUC Mean (SE)	0.84 (0.0183)	0.81 (0.0144)	0.79 (0.0205)	0.73 (0.021)
AUC Mean (95% CI)	0.84 (0.8 to 0.87)	0.81 (0.78 to 0.84)	0.79 (0.75 to 0.83)	0.73 (0.69 to 0.77)

95%CI calculated by analyst from SE reported in paper

Chaudhary, 2019

Bibliographic Reference	Chaudhary, Abhay Kumar; Pathak, Vijay; Kunal, Shekhar; Shukla, Shubhra; Pathak, Pooja; CHA2DS2-VASc score as a novel predictor for contrast-induced nephropathy after percutaneous coronary intervention in acute coronary syndrome.; Indian heart journal; 2019; vol. 71 (no. 4); 303-308

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	India
Study setting	Cardiology department
Study dates	March 2017 - October 2018
Sources of funding	None reported
Study sample	Consecutive patients attending the Department of Cardiology presenting with acute coronary syndrome (ST-elevated myocardial infarction and non-ST-elevated) and undergoing percutaneous coronary intervention (PCI)

Inclusion criteria	None reported
Exclusion criteria	None reported
Intervention details	All PCI procedures were performed by interventional cardiologists either through the transfemoral or transradial approach. Non-ionic, low-osmolar contrast medium or non-ionic, iso-osmolar dimeric contrast medium were used during the PCI. Iodixanol was used in patients with a baseline eGFR <60 mL/min who were also hydrated with intravenous 0.9%, isotonic saline before the procedure, except for patients with frank congestive cardiac failure. Rate of intravenous hydration consisted of 1 mL/kg of body weight/hour or 0.5 mL/kg/ hr for 12 h in patients with LVEF <40%. It was started 3-12 h before contrast agent injection and continued for 12 h after PCI. Nephrotoxic drugs such as metformin and nonsteroidal anti-inflammatory drugs were withdrawn before PCI. All patients were pre-treated with aspirin (300 mg) and a P2Y12 antagonist before PCI. In addition, unfractionated heparin was administered during the procedure. The use of glycoprotein IIb/IIIa inhibitors during PCI was at the operator's discretion
Population subgroups	
Risk tool(s)	**CHA2DS2-VASc** CHA2DS2-VASc score was calculated for each patient by giving a score of 1 to each of these variables: Congestive heart failure or left ventricular systolic dysfunction (ejection fraction ≤40%) Hypertension Age 65-74 years Diabetes mellitus Vascular disease Female gender

	points were allocated for the following variables: Aged ≥75 years Previous stroke or transient ischemic attack A minimum score of 1 was assigned to every patient as they had an episode of coronary artery disease, hence the need for PCI
Model development and validation	Externally developed risk prediction tool typically used for predicting stroke in patients with atrial fibrillation
Outcome	Contrast induced nephropathy, defined as the elevation of serum creatinine ≥0.5 mg/dL or ≥25% increase in the baseline serum creatinine levels within 48 hrs after PCI
Duration of follow-up	Unclear
Indirectness	None
Additional comments	None

Study arms

CHA2DS2-VASc score (cut-off: ≥4) (N = 300)

Characteristics

Study-level characteristics

Characteristic	Study (N = 300)
Mean age (SD) Mean (SD)	55.03 (9.56)
% Female Sample size	n = 85 ; % = 28.3
Ethnicity Nominal	NR
Diabetes Sample size	n = 62 ; % = 20.7
Heart failure Killip class ≥2 Sample size	n = 54 ; % = 18
Hypertension Sample size	n = 120 ; % = 40
Contrast volume (ml) Mean (SD)	145.37 (50.84)
Number of AKI events Sample size	n = 41 ; % = 13.7

Outcomes

Contrast induced nephropathy

Outcome	CHA2DS2-VASc score (cut-off: ≥4), , N = 300
AUC Mean (95% CI)	0.81 (0.73 to 0.9)
Sensitivity Nominal	90.2
Specificity Nominal	62.9

Connolly, 2018

Bibliographic Reference	Connolly, M; Kinnin, M; McEneaney, D; Menown, I; Kurth, M; Lamont, J; Morgan, N; Harbinson, M; Prediction of contrast induced acute kidney injury using novel biomarkers following contrast coronary angiography.; QJM : monthly journal of the Association of Physicians; 2018; vol. 111 (no. 2); 103-110

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	UK
Study setting	Cardiology centre
Study dates	Not reported
Sources of funding	Supported by Randox Laboratories Ltd and the Research and Development fund Northern Ireland Health and Social Care
Study sample	Patients at high risk of AKI attending a cardiology centre who were assessed prior to cardiac catheterisation
Inclusion criteria	Baseline GFR ≤60 mls/min

Exclusion criteria	Recent myocardial infarction Hospitalisation or heart failure within 6 weeks
Intervention details	Pre-procedural CI-AKI prophylaxis with 0.9% saline was adminis-tered to all patients with a GFR <40 mls/min, and patients with a GFR of 40–59 mls/min if their Mehran score was ≥10. Low-osmolar contrast was used for all patients in the form of Iohexol, which contained 350mg of organic iodine per ml.
Population subgroups	
Risk tool(s)	**Mehran risk score (cut-off: ≥10)** No information other than risk factors which contributed to the risk score: Chronic kidney disease stage Cardiac failure Age >75 years Anaemia Diabetes Contrast volume Cut-off based on literature
Model development and validation	Externally developed risk tool

Outcome	Contrast induced acute kidney injury, defined as per KDIGO guidelines: absolute delta rise in creatinine of ≥26.5 mmol/l or a 50% relative rise from baseline at 48 h following contrast
Duration of follow-up	One-year
Indirectness	None
Additional comments	None

Study arms

Mehran risk score (cut-off: ≥10) (N = 301)

Characteristics

Study-level characteristics

Characteristic	**Study (N = 301)**
Mean age (SD) Mean (SD)	73.53 (8.3)
% Female Sample size	n = 131
Ethnicity Nominal	NR

Characteristic	Study (N = 301)
Diabetes Sample size	n = 85 ; % = 28.2
Heart failure Sample size	n = 67 ; % = 22.3
Hypertension Sample size	n = 297 ; % = 98.7
Contrast volume (ml) Mean (SD)	70.04 (44.24)
Number of AKI events Sample size	n = 28 ; % = 9.3

Outcomes

Acute kidney injury

Outcome	Mehran risk score (cut-off: ≥10), , N = 301
AUC Nominal	0.65
Sensitivity Nominal	64

Outcome	Mehran risk score (cut-off: ≥10), , N = 301
Specificity Nominal	62
PPV Nominal	10
NPV Nominal	94

Gurm, 2013

Bibliographic Reference	Gurm, Hitinder S; Seth, Milan; Kooiman, Judith; Share, David; A novel tool for reliable and accurate prediction of renal complications in patients undergoing percutaneous coronary intervention.; Journal of the American College of Cardiology; 2013; vol. 61 (no. 22); 2242-8

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	USA
Study setting	All non-federal hospitals in Michigan
Study dates	January 2010 - June 2012
Sources of funding	Funded by Blue Cross Blue Shield of Michigan
Study sample	Consecutive patients who underwent percutaneous coronary intervention (PCI)
Inclusion criteria	None reported

Exclusion criteria	Already on dialysis Missing serum creatinine levels (pre or post procedure)
Intervention details	The type of contrast media and hydration protocols used were as per operator preference guided by institutional policy and practice
Population subgroups	
Risk tool(s)	**Study-developed risk tool (full model)** The full model contained 46 parameters: Pre-procedural therapy Beta-blockers Antianginal medication within 2 weeks Calcium channel blockers Long-acting nitrates Other antianginal agent Ranolazine Thrombolytics Pre-procedural vasopressors Clinical history

	GI bleeding Heparin-induced thrombocytopenia Surgery within 7 days pre-procedure Hypertension Cerebrovascular disease Prior heart failure Prior MI Peripheral arterial disease Prior PCI Dyslipidaemia Family history of premature CAD History of atrial fibrillation Cardiac transplant Prior valve surgery Cardiomyopathy or left ventricular systolic dysfunction Chronic lung disease

	Diabetes mellitus
	Prior CABG
	Prior ICD implant
	Patient characteristics
	Race - black or African American
	Sex
	Current/recent smoker (within a year)
	Age
	Weight
	Height
	Patient presentation
	PCI indication
	PCI status
	CAD presentation
	Pre-operative evaluation prior to noncardiac surgery
	Pre-PCI LVEF

	Cardiogenic shock Heart failure within 2 weeks Cardiac arrest within 24 hours Pre-procedural laboratory assessments Creatine-kinase MB Creatinine Haemoglobin Troponin I and II **Study-developed risk tool (reduced model)** To create an easy-to-use bedside tool, a reduced model was also trained using only the 15 most important predictors as assessed in the full model: Patient presentation PCI indication PCI status CAD presentation Cardiogenic shock

	Heart failure within 2 weeks Pre-PCI LVEF Clinical history Diabetes mellitus Patient characteristics Age Weight Height Pre-procedural laboratory assessments Creatine kinase MB Serum creatinine Haemoglobin Troponin I and II
Model development and validation	The full and reduced models were evaluated in terms of discrimination and predictive power in the validation data set. Overall diagnostic accuracy was estimated using the AUC.
Outcome	Contrast-induced nephropathy, defined as: impairment in renal function resulting in ≥0.5 mg/dl absolute increase in serum creatinine level from baseline
Duration of follow-up	Unclear

Indirectness	None
Additional comments	None

Study arms

Study-developed risk tool (full model) (N = 20572)

Study-developed risk tool (reduced model) (N = 20572)

Characteristics

Study-level characteristics

Characteristic	**Study (N = 20572)**
Mean age (SD) Mean (SD)	65 (12.2)
% Female Sample size	n = 6915 ; % = 34
Ethnicity Black or African American Sample size	n = 2192 ; % = 11

Characteristic	Study (N = 20572)
Diabetes Sample size	n = 7533 ; % = 37
Heart failure Sample size	n = 3196 ; % = 16
Hypertension Sample size	n = 17495 ; % = 85
Contrast volume Nominal	NR
Number of AKI events Sample size	n = 505 ; % = 2.5

Outcomes

Acute kidney injury

Outcome	Study-developed risk tool (full model), , N = 20572	Study-developed risk tool (reduced model), , N = 20572
AUC Mean (95% CI)	0.85 (0.84 to 0.87)	0.84 (0.82 to 0.86)

Dialysis

Outcome	Study-developed risk tool (full model), , N = 20572	Study-developed risk tool (reduced model), , N = 20572
AUC Mean (95% CI)	0.88 (0.82 to 0.93)	0.88 (0.82 to 0.93)

Kul, 2015

Bibliographic Reference	Kul, S; Uyarel, H; Kucukdagli, O T; Turfan, M; Vatankulu, M A; Tasal, A; Erdogan, E; Asoglu, E; Sahin, M; Guvenc, T S; Goktekin, O; Zwolle risk score predicts contrast-induced acute kidney injury in STEMI patients undergoing PCI.; Herz; 2015; vol. 40 (no. 1); 109-15

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	Germany
Study setting	Hospital
Study dates	May 2011 - September 2012
Sources of funding	None reported
Study sample	Consecutive patients admitted with ST-elevated myocardial infarction, undergoing urgent cardiac catheterisation

Inclusion criteria	Inclusion based on STEMI criteria: Presented within 12 h from the onset of typical chest pain (24 h for persistent symptoms and/or ST elevation) New ST elevation at the J point in two contiguous leads with the cut-off points of ≥0.1 mV in all leads other than leads V2–V3 where the following cut-off points applied: ≥0.2 mV in men ≥40 years; ≥0.25 mV in men <40 years, or ≥0.15 mV in women New onset of complete left bundle-branch block Had primary PCI (angioplasty and/or stent deployment)
Exclusion criteria	Scheduled for coronary artery bypass graft surgery On medical treatment Chronic kidney disease (eGFR <30 ml/min/1.73m3) and/or on dialysis Prior CABG Died within 48 hours of hospital admission Exposed to contrast medium within 7 days of PCI
Intervention details	All patients received 300 mg aspirin and a 600 mg loading dose of clopidogrel before coronary angiography. Emergency coronary angiography was performed by the percutaneous femoral approach using a non-ionic low-osmolality contrast medium. Heparin (100 U/kg) was administered when the coronary anatomy was first assessed. The usage of tirofiban was left to the discretion of the operator.
Population subgroups	
Risk tool(s)	**Mehran risk score**

	Mehran risk score was calculated using: Hypotension (5 points, if systolic blood pressure <80 mmHg for at least 1 h requiring inotropic support) Use of intra-aortic balloon pump (5 points) Congestive heart failure (5 points, if class III/IV by New York Heart Association classification or history of pulmonary edema) Age (4 points, if >75 years), anaemia (3 points, if haematocrit <39% for men and <36% for women) Diabetes mellitus (3 points) Contrast media volume (1 point per 100 ml) Serum creatinine (4 points if >1.5 mg d/l) **Zwolle risk score** Zwolle risk score was calculated using: Killip class (1, 0 point; 2, 4 points; 3–4, 9 points) Post-TIMI flow grade (3, 0 point; 2, 1 point; 1, 2 points) Age (≥60, 2 points) Three-vessel disease (1 point) Anterior MI (1 point)

	Ischemic time >4 h (1 point)
Model development and validation	Mehran risk score was previously established for the assessment of post-contrast AKI risk. Zwolle risk score is used to identify patients low risk patients with STEMI undergoing PCI.
Outcome	Contrast-induced acute kidney injury, defined as: a relative increase in baseline serum creatinine of >25% and/or an absolute increase of 0.5 mg/ dl within 72 h after contrast administration
Duration of follow-up	Duration of hospital stay
Indirectness	None
Additional comments	None

Study arms

Mehran risk score (cut-off: >5) (N = 314)

Zwolle score (cut-off: >2) (N = 314)

Characteristics

Study-level characteristics

Characteristic	Study (N = 314)
Mean age (SD)	56.33 (11.41)

Characteristic	Study (N = 314)
Mean (SD)	
% Female Sample size	n = 59 ; % = 18.8
Ethnicity Nominal	NR
Diabetes Sample size	n = 71 ; % = 22.6
Heart failure Killip >1 Sample size	n = 20 ; % = 6.4
Hypertension Sample size	n = 136 ; % = 43.3
Contrast volume (ml) Mean (SD)	274.2 (114.1)
Number of AKI events Sample size	n = 38 ; % = 12.1

Outcomes

Acute kidney injury

Outcome	Mehran risk score (cut-off: >5), , N = 314	Zwolle score (cut-off: >2), , N = 314
Sensitivity Mean (95% CI)	71.1 (63 to 81)	76.3 (68 to 84)
Specificity Mean (95% CI)	73 (65 to 84)	75.4 (66 to 83)
AUC Mean (95% CI)	0.79 (0.7 to 0.88)	0.85 (0.78 to 0.92)
PPV Mean (95% CI)	27 (8 to 46)	30 (10 to 43)
NPV Mean (95% CI)	94 (88 to 97)	96 (90 to 99)

Lei, 2020

Bibliographic Reference	Lei, Li; Xue, Yan; Guo, Zhaodong; Liu, Bowen; He, Yibo; Liu, Jin; Nie, Zhiqiang; Chen, Liling; Chen, Kaihong; Huang, Zhidong; Liang, Min; Chen, Shiqun; Liu, Yong; Chen, Jiyan; Nomogram for contrast-induced acute kidney injury in patients with chronic kidney disease undergoing coronary angiography in China: a cohort study.; BMJ open; 2020; vol. 10 (no. 5); e037256

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	China
Study setting	Hospital
Study dates	January 2010 - October 2012
Sources of funding	Supported by the Beijing Lisheng Cardiovascular Pilot Foundation, the 'Lixin Yangfan' Optimised Anti-thrombus Research Fund, the Progress in Science and Technology Project of Guangzhou, the Access Research Fund, and the China Youth Clinical Research Fund

Study sample	Consecutive patients who underwent coronary angiography (CAG) / percutaneous coronary intervention (PCI)
Inclusion criteria	Aged ≥18 years eGFR <60 mL/min/1.73 mm2
Exclusion criteria	Pregnant or lactating Contrast exposure within 7 days of CAG/PCI, or 3 days after Cardiovascular surgery No use of contrast media during procedure Undergoing haemodialysis Missing preoperative or postoperative creatinine Malignancy No use of isotonic saline for hydration
Intervention details	Procedures were performed by interventional cardiologists according to routine practice
Population subgroups	
Risk tool(s)	**Mehran risk score** Original 2004 paper referenced **Study-developed nomogram**

	Nomogram with point scoring system (0-220, with probability of an AKI occurring on a logarithmic scale, starting at ~80 points with a probability of 0.01 through to a score of ~210 representing a probability of 0.8) based on: Age Heart rate Weight Hypotension PCI Beta blocker use
Model development and validation	Variables that were imbalanced between groups or clinically important were candidates for univariable logistic analysis. Significant predictors from the univariable analysis were included in the multivariable logistic analysis to fit a prediction model. A backward stepwise approach was performed to create a reduced model by successively removing non-significant covariates ($p>0.1$) until all the remaining predictors were statistically significant. Collinearity between variables was also evaluated. A nomogram was then formulated based on the results. To form the nomogram, each regression coefficient in the multivariable logistic regression was proportionally converted into a 0–100-point scale. Variables with the highest β coefficient were assigned 100 points. The points are added across each variable to calculate the total points, which are finally converted to predicted probabilities. The performance of the nomogram was assessed using the area under the ROC curve and concordance C-statistic for discriminative ability and calibration with 1000 bootstrap samples. Calibration was assessed using the Hosmer-Lemeshow test. The cut-off score to identified patients at risk of CI-AKI was then derived from the ROC curve.
Outcome	Contrast-induced acute kidney injury, defined as: serum creatinine elevation ≥0.5mg/dL or 25% from baseline within the first 48–72 hours following contrast exposure
Duration of follow-up	Ongoing from enrolment until 2019 (maximum of 9 years)
Indirectness	None
Additional comments	None

Study arms

Mehran risk score (N = 643)

Study-developed nomogram (cut-off: 129) (N = 643)

Characteristics

Study-level characteristics

Characteristic	Study (N = 643)
Mean age (SD) Mean (SD)	69.88 (9.67)
% Female Sample size	n = 181 ; % = 28.2
Ethnicity Nominal	NR
Diabetes Sample size	n = 207 ; % = 32.2

Characteristic	Study (N = 643)
Heart failure Sample size	n = 468 ; % = 73
Hypertension Sample size	n = 475 ; % = 73.9
Contrast volume (ml) Mean (SD)	136.1 (64.72)
Number of AKI events Sample size	n = 96 ; % = 14.9

Outcomes

Acute kidney injury

Outcome	Mehran risk score , , N = 634	Study-developed nomogram (cut-off: 129), , N = 634
Sensitivity Nominal	NR	81.2
Specificity Nominal	NR	62.3
AUC Mean (95% CI)	0.71 (NR to NR)	0.78 (0.73 to 0.83)

Liang, 2023

Bibliographic Reference	Liang, L.; Li, D.; Zeng, R.; Zhang, H.; Lv, L.; Wei, W.; Wan, Z.; Long- and very long-chain ceramides are predictors of acute kidney injury in patients with acute coronary syndrome: the PEACP study; Cardiovascular Diabetology; 2023; vol. 22 (no. 1); 92

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	NCT04122573
Study type	Prospective cohort study
Study location	China
Study setting	Tertiary hospitals
Study dates	November 2019 - April 2020
Sources of funding	Supported by grants from the National Key Research and Development Program of China, Sichuan Science and Technology Program, Sichuan Provincial Health Commission, Sichuan University West China Nursing Discipline Development Special Fund Project

Study sample	Patients admitted with chest pain onset <24 hours who were diagnosed with acute coronary syndrome and underwent percutaneous coronary intervention (PCI)
Inclusion criteria	Diagnosed with acute coronary syndrome Aged >18 years Onset time <24 hours
Exclusion criteria	Received thrombolysis Unqualified ceramide data Missing creatinine measurements Requiring chronic haemodialysis
Intervention details	No additional information
Population subgroups	
Risk tool(s)	**Mehran risk score** Mehran risk score includes the following components: Use of intra-aortic balloon pump Age Anaemia Diabetes mellitus

	Congestive heart failure Contrast media volume Hypotension eGFR
Model development and validation	Previously developed model
Outcome	Acute kidney injury, defined as per KDIGO standard: Stage 1: elevated serum creatinine level >0.3 mg/dL (26.5 mmol/L) less than 2 days; serum creatinine increase to 1.5–1.9-fold from the baseline level; urine output<0.5 mL/kg/h for 6–12 h. Stage 2: serum creatinine increase to 2.0–2.9-fold from the baseline level; urine output<0.5 mL/kg/h for 12 h Stage 3: serum creatinine concentration >4.0 mg/dL (353.6 mmol/L); serum creatinine increased to>3.0-fold from the baseline level; urine output<0.3 mL/kg/h for 24 h; anuria for 12 h
Duration of follow-up	Unclear
Indirectness	None
Additional comments	None

Study arms

Mehran risk score (N = 842)

Characteristics

Study-level characteristics

Characteristic	Study (N = 842)
Mean age (SD) Mean (SD)	66.9 (13)
% Female Sample size	n = 222 ; % = 26.4
Ethnicity Nominal	NR
Diabetes Sample size	n = 258 ; % = 30.6
Heart failure Killip class ≥1 Sample size	n = 398 ; % = 47.3
Hypertension Sample size	n = 487 ; % = 57.8
Contrast volume (ml) Mean (SD)	103.2 (18.71)
Number of AKI events Sample size	n = 139 ; % = 16.5

Outcomes

Acute kidney injury

Outcome	Mehran risk score, , N = 842
AUC Mean (95% CI)	0.78 (0.74 to 0.82)

Liu, 2014

Bibliographic Reference	Liu YH; Liu Y; Tan N; Chen JY; Chen J; Chen SH; He YT; Ran P; Ye P; Li Y; Predictive value of GRACE risk scores for contrast-induced acute kidney injury in patients with ST-segment elevation myocardial infarction before undergoing primary percutaneous coronary intervention.; International urology and nephrology; 2014; vol. 46 (no. 2)

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	China
Study setting	General hospital
Study dates	March 2010 - October 2011
Sources of funding	None reported
Study sample	Consecutive patients with ST-elevated myocardial infarction undergoing primary percutaneous coronary intervention
Inclusion criteria	Presented within 12 hours of symptom onset

Exclusion criteria	Pregnancy Allergy to contrast media Exposure to contrast media within 7 days Treatment with nephroprotective or nephrotoxic drugs Severe hepatic insufficiency Severe chronic disease
Intervention details	An interventional team performed primary PCI according to standard clinical practice using standard techniques. Non-ionic low osmolar contrast media (370 mg I/mL) was used in all cases. Intravenous hydration with an isotonic saline solution (1 or 0.5 ml/kg/h if LVEF was <40% was initiated 6–12 hours before and after exposure to contrast. Use of anti-platelet agents (aspirin/clopidogrel), beta-adrenergic blocking agents, diuretics, angiotensin-converting enzyme inhibitors, or inotropic drug support was directed by the coronary care unit cardiologists in accordance with clinical protocols
Contrast administration route	Intra-arterial
Risk tool(s)	**GRACE risk score** Previously established 9-variable risk score for the prediction of mortality in patients with STEMI **Mehran risk score** Previously established 8-variable risk score for contrast associated AKI
Model development and validation	Both previously established models

Outcome	Contrast-associated AKI, defined as an absolute increase in serum creatinine of ≥0.3 or ≥0.5 mg/dL, or a 50% increase within 48–72 hours after contrast exposure
Duration of follow-up	Unclear
Indirectness	None
Additional comments	None

Study arms

GRACE risk score (cut-off: >160) (N = 251)

GRACE risk score (<136) (N = 251)

GRACE risk score (136-158) (N = 251)

GRACE risk score (159-180) (N = 251)

GRACE risk score (>180) (N = 251)

Mehran risk score (N = 251)

Characteristics

Study-level characteristics

Characteristic	Study (N = 251)
Mean age (SD) Mean (SD)	62.74 (12.27)
% Female Sample size	n = 44 ; % = 17.5
Ethnicity Nominal	NR
Diabetes Sample size	n = 54 ; % = 21.5
Heart failure Nominal	NR
Hypertension Sample size	n = 134 ; % = 53.4
Contrast volume (ml) Mean (SD)	134.4 (49.1)

Characteristic	Study (N = 251)
≥0.3 definition Sample size	n = 43 ; % = 17.1
≥0.5 definition Sample size	n = 22 ; % = 8.8
≥50% definition Sample size	n = 19 ; % = 7.6

Outcomes

Acute kidney injury

Outcome	GRACE risk score (cut-off: >160), , N = 251	GRACE risk score (<136), , N = 251	GRACE risk score (136-158), , N = 251	GRACE risk score (159-180), , N = 251	GRACE risk score (>180), , N = 251	Mehran risk score, , N = 251
Sensitivity Nominal	79.1	NR	NR	NR	NR	NR
Specificity Nominal	61	NR	NR	NR	NR	NR
≥0.3 definition Nominal	0.72	NA	NA	NA	NA	0.78

Outcome	GRACE risk score (cut-off: >160), , N = 251	GRACE risk score (<136), , N = 251	GRACE risk score (136-158), , N = 251	GRACE risk score (159-180), , N = 251	GRACE risk score (>180), , N = 251	Mehran risk score, , N = 251
≥0.5 definition Nominal	0.79	NA	NA	NA	NA	0.84
≥50% definition Nominal	0.69	NA	NA	NA	NA	0.69

Study defines AKI based on three cut-offs in serum creatinine: ≥0.3, ≥0.5 mg/dL, or ≥50%
Sensitivity and specificity for ≥0.3 mg/dL definition

Dialysis (renal replacement therapy)

Outcome	GRACE risk score (cut-off: >160), , N = 251	GRACE risk score (<136), , N = 61	GRACE risk score (136-158), , N = 63	GRACE risk score (159-180), , N = 64	GRACE risk score (>180), , N = 63	Mehran risk score, , N = 251
Number of events No of events	n = NA ; % = NA	n = 0 ; % = 0	n = 0 ; % = 0	n = 2 ; % = 3.1	n = 4 ; % = 6.3	n = NA ; % = NA

In-hospital mortality

Outcome	GRACE risk score (cut-off: >160), , N = 251	GRACE risk score (<136), , N = 61	GRACE risk score (136-158), , N = 63	GRACE risk score (159-180), , N = 64	GRACE risk score (>180), , N = 63	Mehran risk score, , N = 251
Number of events No of events	n = NA ; % = NA	n = 0 ; % = 0	n = 2 ; % = 3.2	n = 2 ; % = 3.1	n = 6 ; % = 9.5	n = NA ; % = NA

Liu, 2020

Bibliographic Reference	Liu, Liwei; Liu, Jin; Lei, Li; Wang, Bo; Sun, Guoli; Guo, Zhaodong; He, Yibo; Song, Feier; Lun, Zhubin; Liu, Bowen; Chen, Guanzhong; Chen, Shiqun; Yang, Yongquan; Liu, Yong; Chen, Jiyan; A prediction model of contrast-associated acute kidney injury in patients with hypoalbuminemia undergoing coronary angiography.; BMC cardiovascular disorders; 2020; vol. 20 (no. 1); 399

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	China
Study setting	Provincial People's Hospital
Study dates	January 2010 - October 2012
Sources of funding	Supported by the Beijing Lisheng Cardiovascular Pilot Foundation and the National Science Foundation of China
Study sample	Patients with hypoalbuminemia who were were undergoing coronary angiography or percutaneous coronary intervention

Inclusion criteria	Aged ≥18 years Hypoalbuminemia (serum albumin <3.5 g/L)
Exclusion criteria	Lactating or pregnant Intravascular injection of contrast agents within 7 days, or 3 days post procedure No use of isotonic saline for hydration No use of low-osmolarity contrast Cardiac surgery or endovascular repair therapy End-stage kidney disease On renal replacement therapy Malignancy Missing pre-operative creatinine measurement
Intervention details	During the operation, standard guidewires, catheters, and stents and the dose of contrast were used and determined by the interventional cardiologist. All procedures were performed according to the guidelines of the American Heart Association/American College of Cardiology Foundation. Each patient received intravenous hydration of isotonic saline with a rate of 1 mL/kg per hour for at least 2 to 12 hours before and 6 to 24 hours after the procedure, while 0.5 mL/kg per hour was used in cases of severe congestive heart failure or left ventricular ejection fraction <40%
Risk tool(s)	**Study-developed nomogram** Study-developed model containing the following variables (score range from 0-300, with risk of AKI occurring increasing on a logarithmic scale from 0.01 at 50 points, to 0.8 at ~275 points): eGFR

	Age Albumin IABP **Mehran risk score** Previously developed model containing 8 variables: Age >75 years Hypotension IABP CKD (eGFR <60) CHF Diabetes Anaemia Contrast volume
Model development and validation	The associations between contrast associated-AKI and variables in the development cohort were assessed by univariable logistic analysis. Collinearity between variables was evaluated. Variables were included in the multivariable analysis using a cut-off of P <0.05 in univariate logistics regression. Backward stepwise regression was conducted to select factors and develop the final model. The regression coefficient of each variable in the model was transformed into a 0 to 100 point scale. The total points were calculated by adding points of each variable and then turned into predicted probabilities. An

	ROC curve and AUC were used to assess the discrimination of the nomogram in both the development and validation cohorts compared to the Mehran score. Internal validation was analyzed using 1000 bootstrap samples.
Outcome	Contrast associated AKI, defined as: increase of ≥0.3 mg/dL or 50% in serum creatinine compared to baseline in the 48 to 72 hours post procedure
Duration of follow-up	Yearly follow-up until 2019 (maximum of 9 years)
Indirectness	None
Additional comments	None

Study arms

Study-developed nomogram (N = 428)

Mehran risk score (N = 428)

Characteristics

Study-level characteristics

Characteristic	**Study (N = 428)**
Mean age (SD) Mean (SD)	65.96 (11.02)

Characteristic	Study (N = 428)
% Female Sample size	n = 82 ; % = 19.2
Ethnicity Nominal	NR
Diabetes Sample size	n = 96 ; % = 22.5
Heart failure Sample size	n = 87 ; % = 20.4
Hypertension Sample size	n = 250 ; % = 58.5
Contrast volume (ml) Mean (SD)	131.97 (63.4)
Number of AKI events Sample size	n = 48 ; % = 11.2

Outcomes

Acute kidney injury

Outcome	Study-developed nomogram , , N = 428	Mehran risk score , , N = 428
AUC Mean (95% CI)	0.76 (0.69 to 0.83)	0.69 (0.61 to 0.78)
Hosmer-Lemeshow Mean (p value)	11.27 (0.19)	NR (NR)

Liu, 2020

Bibliographic Reference	Liu, Yong; Chen, Shiqun; Ye, Jianfeng; Xian, Ying; Wang, Xia; Xuan, Jianwei; Tan, Ning; Li, Qiang; Chen, Jiyan; Ni, Zhonghan; Random forest for prediction of contrast-induced nephropathy following coronary angiography.; The international journal of cardiovascular imaging; 2020; vol. 36 (no. 6); 983-991

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	NCT01400295
Study type	Prospective cohort study
Study location	China
Study setting	Cardiovascular institute of a hospital
Study dates	January 2010 - December 2013
Sources of funding	Funded by The Guangdong Provincial Cardiovascular Clinical Medicine Research Fund, Science and Technology Planning Project of Guangdong Province, and Cardiovascular Research Foundation Project of the Chinese Medical Doctor Association

Study sample	Consecutive patients undergoing percutaneous coronary intervention (PCI) or coronary angiogram (CAG)
Inclusion criteria	Aged ≥18 years
Exclusion criteria	Pregnant or lactating Intravascular administration of contrast within 7 days, or 3 days post-operatively Did not receive contrast media Underwent cardiovascular surgery or endovascular repair End stage renal disease or on renal replacement therapy Missing creatinine or weight data Malignancy Did not receive isotonic saline for hydration
Intervention details	CAG or PCI was performed as per operator preference. The type of contrast media (Iopamiron or Ultravist), contrast dose, and hydration protocols were also decided by the interventional cardiologist
Population subgroups	
Risk tool(s)	**Study-developed model** The full model contained the following parameters: Pre-procedural therapy Thrombolysis Cardio-pulmonary resuscitation

	Medical history
	Prior myocardial infarction
	Diabetes mellitus
	Prior CABG
	Hypertension
	Hyperlipidaemia
	Anaemia
	Patient characteristics
	Age
	Sex
	Weight
	Smoking status
	Patient presentation
	Acute myocardial infarction
	NYHA class
	LVEF

	Heart rate Systolic BP Diastolic BP IABP Hypotension Emergent PCI Pre-procedural laboratory assessments Serum creatinine Creatine kinase MB B-type natriuretic peptide HS-CRP HDL-C Cholesterol Triglycerides LDL-C Calcium

	Sodium Potassium Fasting plasma glucose HbA1c Uric acid Urine pH Serum albumin Hb Haematocrit Serum urea nitrogen **Study-developed reduced model** The reduced model contained the following parameters: Age LVEF Heart rate

	Systolic BP Serum creatinine Creatine kinase MB B-type natriuretic peptide Potassium Uric acid Serum albumin Hb Haematocrit Serum urea nitrogen **Mehran risk score** No information reported
Model development and validation	Models were developed using a random forest method. The study cohort was randomly divided into training (70%, n=2428) and validation datasets (30%, n=1041). A random forest regression model was trained to predict CIN using the 40 pre-procedural baseline clinical variables. To facilitate the development of an easy-to-use bedside tool, a reduced model was trained using only the 13 most important predictors as assessed by an incremental decrease in node impurity
Outcome	Contrast induced nephropathy, defined as: increase in serum creatinine ≥0.5 mg/dL
Duration of follow-up	Unclear

Indirectness	None
Additional comments	None

Study arms

Study-developed model (N = 1041)

Study-developed reduced model (N = 1041)

Mehran risk score (N = 1041)

ACEF score (N = 1041)

Characteristics

Study-level characteristics

Characteristic	**Study (N = 2428)**
Mean age (SD) Mean (SD)	62.82 (11.24)

Characteristic	Study (N = 2428)
% Female Nominal	NR
Ethnicity Nominal	NR
Diabetes Nominal	NR
Heart failure Nominal	NR
Hypertension (mmHg) Systolic BP Mean (SD)	128.87 (20.6)
Contrast volume Nominal	NR
Number of AKI events Sample size	n = 37 ; % = 3.5

Characteristics of the training cohort - data not reported for the validation cohort

Outcomes

Acute kidney injury

Outcome	Study-developed model, , N = 1041	Study-developed reduced model, , N = 1041	Mehran risk score , , N = 1041	ACEF score, , N = 1041
AUC Mean (95% CI)	0.86 (0.79 to 0.92)	0.85 (0.8 to 0.91)	0.79 (0.72 to 0.86)	0.76 (0.68 to 0.85)

Lu, 2016

Bibliographic Reference	Lu, T.-M.; Hsu, C.-P.; Chang, C.-F.; Lin, C.-C.; Lee, T.-S.; Lin, S.-J.; Chan, W.-L.; Asymmetric dimethylarginine predicts the risk of contrast-induced acute kidney injury in patients undergoing cardiac catheterization; Atherosclerosis; 2016; vol. 254; 161-166

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	Taipei
Study setting	Hospital
Study dates	Not reported
Sources of funding	Supported by grants from the National Science Council
Study sample	Consecutive patients referred for coronary angiography for investigation of chest pain and/or suspected coronary artery disease

Inclusion criteria	None specified
Exclusion criteria	Severe liver disease Sepsis/active infectious disease Malignancy with life expectancy ≤1 year Hyperthyroidism Unstable haemodynamic status Renal artery stenosis Exposure to contrast medium within 2 days
Intervention details	Patients were pre-treated with intravenous infusion of 0.9% saline hydration (1.0 ml/kg per hour for 12 h before the procedure) and oral administration of N-acetylcysteine (600 mg twice a day, administered the day before and on the day of contrast medium exposure). Diagnostic coronary angiography, left ventriculography and percutaneous coronary intervention were performed by a standard procedure using low-osmolar contrast media (iopromide or iohexol) or iso-osmolar contrast medium (iodixanol) at the discretion of operators and/or patients. Revascularization procedures including percutaneous coronary intervention and coronary artery bypass surgery, were performed successfully in all patients with significant CAD (≥50% stenosis in at least one major coronary artery)
Population subgroups	
Risk tool(s)	**Mehran risk score** The Mehran score for predicting CI-AKI was calculated according to the following algorithm: Hypotension (integer score, 5) Support with intra-aortic balloon pump (integer score, 5)

	Congestive heart failure (integer score, 5) Age >75 years (integer score, 4) Pre-existing anaemia (baseline haematocrit <39% for men and <36% for women, integer score, 3 Diabetes (integer score, 3) Contrast medium volume (integer score 1 for every 100 ml) eGFR <60 ml/min per 1.73 m2 (integer score, 2 to 6)
Model development and validation	Previously established model
Outcome	Contrast-induced acute kidney injury was defined as: increase of serum creatinine concentration of ≥0.3 mg/dl or a 25% increase from the baseline value measured at 48 h after exposure to contrast media
Duration of follow-up	Monthly follow-up with unclear duration
Indirectness	None
Additional comments	None

Study arms

Mehran risk score (cut-off: >7) (N = 664)

Characteristics

Study-level characteristics

Characteristic	Study (N = 664)
Mean age (SD) Mean (SD)	67 (12)
% Female Sample size	n = 119 ; % = 20.9
Ethnicity Nominal	NR
Diabetes Sample size	n = 240 ; % = 36.1
Heart failure Sample size	n = 157 ; % = 24.4
Hypertension Sample size	n = 490 ; % = 76.1
Contrast volume (ml) Mean (SD)	182.6 (115.6)
Number of AKI events Sample size	n = 78 ; % = 11.7

Outcomes

Acute kidney injury

Outcome	Mehran risk score (cut-off: >7), , N = 644
Sensitivity Nominal	64.1
Specificity Nominal	54.9
AUC Mean (95% CI)	0.62 (0.58 to 0.65)
PPV Nominal	15.9
NPV Nominal	92

Seibert, 2020

Bibliographic Reference	Seibert, Felix S; Heringhaus, Anja; Pagonas, Nikolaos; Rudolf, Henrik; Rohn, Benjamin; Bauer, Frederic; Timmesfeld, Nina; Trappe, Hans-Joachim; Babel, Nina; Westhoff, Timm H; Biomarkers in the prediction of contrast media induced nephropathy - the BITCOIN study.; PloS one; 2020; vol. 15 (no. 7); e0234921

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	The BITCOIN study
Study type	Prospective cohort study
Study location	Germany
Study setting	Hospital
Study dates	No additional information
Sources of funding	Funded by the German Research Foundation
Study sample	Patients with an indication for a coronary angiography
Inclusion criteria	None specified

Exclusion criteria	Acute hemodynamic shock, Obstructive uropathy Urothelial carcinoma Metastatic cancer Leukocyturia in semi-quantitative dipstick examination >1
Intervention details	Coronary angiographies were performed via radial or femoral arteries. Preventive plasma expansion was performed according to physicians' assessment
Population subgroups	
Risk tool(s)	**Inohara risk model** Previously developed model that contains the following variables (score for each in brackets): Age ≤50 (0) 51-59 (1) 60-69 (2) 70-79 (3) 80-89 (4) 90-99 (5)

	NYHA III or IV (3) Diabetes mellitus (2) Previous PCI (-3) Hypertension (2) Pre-creatinine >1.0 mg/dL (4) Acute coronary syndrome (5) **Ghani risk model** Previously developed model that contains the following variables (score for each in brackets): Basal creatinine ≥115 micromol/L (7) Shock (3) Female gender (2) Multiple vessel stenting (2) Diabetes mellitus (2)
Model development and validation	Previously developed models
Outcome	Acute kidney injury defined as per AKIN criteria

Duration of follow-up	48-72 hours
Indirectness	None
Additional comments	None

Study arms

Inohara risk model (N = 490)

Ghani risk model (N = 490)

Characteristics

Study-level characteristics

Characteristic	**Study (N = 490)**
Mean age (SD) Median (IQR)	66 (57 to 73)
% Female Sample size	n = 127 ; % = 25.9
Ethnicity	NR

Characteristic	Study (N = 490)
Nominal	
Diabetes Sample size	n = 126 ; % = 25.7
Heart failure Nominal	NR
Hypertension Sample size	n = 386 ; % = 78.8
Contrast volume (ml) Median (IQR)	80 (60 to 120)
Number of AKI events Sample size	n = 30 ; % = 6.1

Outcomes

Acute kidney injury

Outcome	Inohara risk model, , N = 490	Ghani risk model, , N = 490
AUC Mean (95% CI)	0.68 (0.6 to 0.76)	0.57 (0.46 to 0.67)

Serif, 2020

Bibliographic Reference	Serif, L.; Chalikias, G.; Didagelos, M.; Stakos, D.; Kikas, P.; Thomaidis, A.; Lantzouraki, A.; Ziakas, A.; Tziakas, D.; Application of 17 Contrast-Induced Acute Kidney Injury Risk Prediction Models; CardioRenal Medicine; 2020; vol. 10 (no. 3); 162-174

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	Includes risk scores from the following papers (not all included in the present review, mainly due to being retrospective cohort study designs): Brown et al., (2015) Acute Kidney Injury Risk Prediction in Patients Undergoing Coronary Angiography in a National Veterans Health Administration Cohort With External Validation. https://doi.org/10.1161/JAHA.115.002136 Tsai et al., (2014) Validated contemporary risk model of acute kidney injury in patients undergoing percutaneous coronary interventions: insights from the National Cardiovascular Data Registry Cath-PCI Registry. https://doi.org/10.1161/JAHA.114.001380 Gurm et al., (2013) A Novel Tool for Reliable and Accurate Prediction of Renal Complications in Patients Undergoing Percutaneous Coronary Intervention. https://doi.org/10.1016/j.jacc.2013.03.026. Caspi et al., (2017) Acute Kidney Injury After Primary Angioplasty: Is Contrast-Induced Nephropathy the Culprit? https://doi.org/10.1161/JAHA.117.005715

Victor et al., (2014) Risk scoring system to predict contrast induced nephropathy following percutaneous coronary intervention. https://doi.org/10.1016/j.ihj.2014.05.025

Maioli et al., (2010) Preprocedural score for risk of contrast-induced nephropathy in elective coronary angiography and intervention. DOI: 10.2459/JCM.0b013e328335227c

Marenzi et al., (2004) Contrast-induced nephropathy in patients undergoing primary angioplasty for acute myocardial infarction. https://doi.org/10.1016/j.jacc.2004.07.043

Liu et al., (2015) Preprocedural N-Terminal Pro-Brain Natriuretic Peptide (NT-proBNP) Is Similar to the Mehran Contrast-Induced Nephropathy (CIN) Score in Predicting CIN Following Elective Coronary Angiography. https://doi.org/10.1161/JAHA.114.001410

Gao et al., (2014) Derivation and validation of a risk score for contrast-induced nephropathy after cardiac catheterization in Chinese patients. DOI: 10.1007/s10157-014-0942-9

Fu et al., (2012) Risk Score for the Prediction of Contrast-Induced Nephropathy in Elderly Patients Undergoing Percutaneous Coronary Intervention. https://doi.org/10.1177/0003319712467224

Chen et al., (2014) A simple preprocedural score for risk of contrast-induced acute kidney injury after percutaneous coronary intervention. DOI: 10.1002/ccd.25109

Ghani et al., (2009) Risk score for contrast induced nephropathy following percutaneous coronary intervention.

Bartholomew et al., (2004) Impact of nephropathy after percutaneous coronary intervention and a method for risk stratification. https://doi.org/10.1016/j.amjcard.2004.03.008

Mehran et al., (2004) A simple risk score for prediction of contrast-induced nephropathy after percutaneous coronary intervention: Development and initial validation. https://doi.org/10.1016/j.jacc.2004.06.068

	Tziakas et al., (2013) Development of an easily applicable risk score model for contrast-induced nephropathy prediction after percutaneous coronary intervention. A novel approach tailored to current practice. https://doi.org/10.1016/j.ijcard.2011.05.079 Ando et al., (2013) Age, glomerular filtration rate, ejection fraction, and the AGEF score predict contrast-induced nephropathy in patients with acute myocardial infarction undergoing primary percutaneous coronary intervention. https://doi.org/10.1002/ccd.25023 McCullough et al., (1997) Acute Renal Failure After Coronary Intervention. Incidence, Risk Factors, and Relationship to Mortality. https://doi.org/10.1016/S0002-9343(97)00150-2
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	Greece
Study setting	Cardiac catheterisation laboratory
Study dates	January 2015 - August 2018
Sources of funding	None
Study sample	Consecutive patients treated with percutaneous coronary intervention on an elective or emergency basis
Inclusion criteria	None specified
Exclusion criteria	Chronic peritoneal or haemodialytic treatment Died during hospitalisation Undergoing coronary artery bypass grafting

Intervention details	No additional information
Risk tool(s)	This study compared 17 previously developed risk prediction tools. The number of predictors in each tool varied from 3 to 15.: **McCullough** Impaired renal function Diabetes mellitus Contrast volume **Bartholomew** Impaired renal function Diabetes mellitus Hypertension Heart failure Peripheral vascular disease Use of IABP Procedure urgent/emergent Contrast volume **Marenzi**

	Age Use of IABP Anterior MI Time to reperfusion Contrast volume **Mehran** Age Impaired renal function Anaemia Diabetes mellitus Heart failure Hypotension Use of IABP Contrast volume **Ghani** Female sex

	Impaired renal function Diabetes mellitus Shock Multivessel PCI **Maioli** Age Impaired renal function Diabetes mellitus Impaired LVEF Recent cardiac procedure/PCI One procedure in past 72 hours Pre-procedure creatinine > baseline creatinine **Fu** Age Impaired renal function Anaemia

	Diabetes mellitus Impaired LVEF Previous MI Hypotension Procedure urgent/emergent Contrast volume **Gurm** Age Height Weight Impaired renal function Diabetes mellitus Heart failure Shock CAD presentation Procedure urgent/emergent

	PCI indication HDL <1 mmol/L CK-MB Haemoglobin Troponin I Troponin II **Tsiakas** Impaired renal function Recent cardiac procedure/PCI Peripheral vascular disease Metformin use Contrast volume **Ando** Age Impaired LVEF Pre-procedure creatinine > baseline creatinine

	Chen Age Impaired renal function Anaemia Diabetes mellitus Impaired LVEF Previous MI Hypotension Procedure urgent/emergent HDL <1 mmol/L **Victor** Impaired renal function Diabetes mellitus Peripheral vascular disease Hypotension Contrast volume

	Albuminuria Haemoglobin **Gao** Age Impaired renal function Hypertension Heart failure Previous MI Use of IABP Contrast volume **Tsai** Age Impaired renal function Anaemia Diabetes mellitus Heart failure

	Stroke Cardiac arrest Shock CAD presentation Use of IABP Killip class **Liu** Age Impaired renal function Impaired LVEF **Brown** Age Race Impaired renal function Anaemia Diabetes mellitus

	Hypertension
	Heart failure
	Impaired LVEF
	Recent cardiac procedure/PCI
	Peripheral vascular disease
	Smoking
	Shock
	CAD presentation
	Procedure urgent/emergent
	Caspi
	Age
	Impaired renal function
	Diabetes mellitus
	Impaired LVEF
	Anterior MI
	Killip class
	Diuretic therapy

Model development and validation	All models were previously developed in other studies
Outcome	Contrast-induced acute kidney injury was given two definitions: Liberal criterion: increase of ≥25% or ≥0.5 mg/dl in pre-PCI serum creatinine at 48 h to 72 h post PCI Strict criterion: increase of ≥0.5 mg/dl in pre-PCI serum creatinine at 48 h to 72 h post PCI
Duration of follow-up	72 hours
Indirectness	None
Additional comments	None

Study arms

Brown risk score (N = 1247)

Tsai risk score (N = 1247)

Gurm risk score (N = 1247)

Caspi risk score (N = 1247)

Victor risk score (N = 1247)

Maioli risk score (N = 1247)

Marenzi risk score (N = 1247)

Liu risk score (N = 1247)

Gao risk score (N = 1247)

Fu risk score (N = 1247)

Chen risk score (N = 1247)

Ghani risk score (N = 1247)

Bartholomew risk score (N = 1247)

Mehran risk score (N = 1247)

Tziakas risk score (N = 1247)

Ando risk score (N = 1247)

McCullough risk score (N = 1247)

Characteristics

Study-level characteristics

Characteristic	Study (N = 1247)
Mean age (SD) Mean (SD)	62 (10)
% Female Sample size	n = 238 ; % = 19

Characteristic	Study (N = 1247)
Ethnicity Nominal	NR
Diabetes Sample size	n = 400 ; % = 32
Class I Sample size	n = 1060 ; % = 85
Class II Sample size	n = 133 ; % = 10.5
Class III Sample size	n = 49 ; % = 4
Class IV Sample size	n = 5 ; % = 0.5
Hypertension Sample size	n = 678 ; % = 54
Contrast volume (ml) Mean (SD)	332 (165)
Liberal definition Sample size	n = 206 ; % = 16.5

Characteristic	Study (N = 1247)
Strict definition Sample size	n = 24 ; % = 1.9

Outcomes

Acute kidney injury (liberal definition)

Outcome	Brown risk score, , N = 1247	Tsai risk score, , N = 1247	Gurm risk score, , N = 1247	Caspi risk score, , N = 1247	Victor risk score, , N = 1247	Maioli risk score, , N = 1247	Marenzi risk score, , N = 1247	Liu risk score, , N = 1247	Gao risk score, , N = 1247	Fu risk score, , N = 1247	Chen risk score, , N = 1247	Ghani risk score, , N = 1247	Bartholomew risk score, , N = 1247	Mehran risk score, , N = 1247	Tziakas risk score, , N = 1247	Ando risk score, , N = 1247	McCullough risk score, , N = 1247
AUC Mean (95% CI)	0.52 (0.47 to 0.56)	0.51 (0.49 to 0.54)	0.54 (0.51 to 0.57)	0.53 (0.51 to 0.56)	0.54 (0.5 to 0.59)	0.58 (0.56 to 0.61)	0.55 (0.51 to 0.59)	0.52 (0.48 to 0.57)	0.49 (0.45 to 0.53)	0.5 (0.46 to 0.54)	0.48 (0.43 to 0.52)	0.51 (0.47 to 0.55)	0.49 (0.45 to 0.54)	0.53 (0.48 to 0.57)	0.5 (0.46 to 0.55)	0.54 (0.5 to 0.59)	0.58 (0.54 to 0.62)
PPV Nominal	18.8	22.8	19.1	18.8	20.5	30.2	18.8	19.1	18.2	17.1	21.5	20.1	17	18.9	17.5	20	20.4
NPV Nominal	85.1	84.7	85.8	85.6	85.2	85.7	85.9	84.5	84.8	94	84.8	84	85.7	84.6	83.9	85.4	88.1

Outcome	Brown risk score, , N = 1247	Tsai risk score, , N = 1247	Gurm risk score, , N = 1247	Caspi risk score, , N = 1247	Victor risk score, , N = 1247	Maioli risk score, , N = 1247	Marenzi risk score, , N = 1247	Liu risk score, , N = 1247	Gao risk score, , N = 1247	Fu risk score, , N = 1247	Chen risk score, , N = 1247	Ghani risk score, , N = 1247	Bartholomew risk score, , N = 1247	Mehran risk score, , N = 1247	Tziakas risk score, , N = 1247	Ando risk score, , N = 1247	McCullough risk score, , N = 1247
Hosmer-Lemeshow Mean (p value)	0.35 (0.31)	17.07 (0.029)	11.76 (0.16)	3.16 (0.53)	3.72 (0.16)	6.05 (0.11)	0.13 (0.94)	7.19 (0.007)	9.04 (0.17)	1.08 (0.96)	19.81 (0.011)	1.36 (0.24)	2.37 (0.67)	2.98 (0.89)	3.15 (0.37)	15.68 (0.047)	6.41 (0.6)
Calibration slope Nominal	0.39	0.25	0.11	0.99	0.98	0.97	1	0.99	0.94	0.99	0.75	0.99	1	0.96	0.99	0.62	0.9

Acute kidney injury (strict definition)

Outcome	Brown risk score, , N = 1247	Tsai risk score, , N = 1247	Gurm risk score, , N = 1247	Caspi risk score, , N = 1247	Victor risk score, , N = 1247	Maioli risk score, , N = 1247	Marenzi risk score, , N = 1247	Liu risk score, , N = 1247	Gao risk score, , N = 1247	Fu risk score, , N = 1247	Chen risk score, , N = 1247	Ghani risk score, , N = 1247	Bartholomew risk score, , N = 1247	Mehran risk score, , N = 1247	Tziakas risk score, , N = 1247	Ando risk score, , N = 1247	McCullough risk score, , N = 1247
AUC Mean (95% CI)	0.7 (0.67 to 0.72)	0.63 (0.61 to 0.66)	0.51 (0.48 to 0.54)	0.65 (0.62 to 0.68)	0.6 (0.49 to 0.72)	0.74 (0.71 to 0.76)	0.57 (0.47 to 0.68)	0.6 (0.49 to 0.72)	0.6 (0.5 to 0.69)	0.63 (0.52 to 0.73)	0.55 (0.44 to 0.65)	0.53 (0.41 to 0.65)	0.6 (0.47 to 0.72)	0.6 (0.51 to 0.7)	0.55 (0.43 to 0.67)	0.62 (0.48 to 0.75)	0.58 (0.47 to 0.69)

Outcome	Brown risk score, , N = 1247	Tsai risk score, , N = 1247	Gurm risk score, , N = 1247	Caspi risk score, , N = 1247	Victor risk score, , N = 1247	Maioli risk score, , N = 1247	Marenzi risk score, , N = 1247	Liu risk score, , N = 1247	Gao risk score, , N = 1247	Fu risk score, , N = 1247	Chen risk score, , N = 1247	Ghani risk score, , N = 1247	Bartholomew risk score, , N = 1247	Mehran risk score, , N = 1247	Tziakas risk score, , N = 1247	Ando risk score, , N = 1247	McCullough risk score, , N = 1247
PPV Nominal	3.5	3.8	1.1	3	2.2	3.3	2.5	3.3	2.6	3.1	2.3	3.6	2.8	2.9	3	4.8	2.5
NPV Nominal	99.2	99.2	97.5	99.3	98.9	99.7	98.7	98.6	100	98.7	98.9	98.3	98.7	99.3	98.3	98.8	99.5
Hosmer-Lemeshow Mean (p value)	16.19 (0.04)	20.01 (0.006)	26.6 (0.001)	9.47 (0.05)	1.59 (0.45)	4.15 (0.25)	1.07 (0.59)	1.45 (0.23)	20.69 (0.004)	13.41 (0.063)	14.13 (0.078)	1.99 (0.16)	3.27 (0.51)	12.98 (0.072)	1.51 (0.68)	20.48 (0.009)	5.68 (0.68)
Calibration slope Nominal	0.54	0.84	0.09	0.12	0.77	0.87	1	0.91	0.61	0.82	0.45	0.79	0.73	0.56	0.96	0.69	0.47

Sgura, 2010

Bibliographic Reference	Sgura, Fabio A.; Bertelli, Luca; Monopoli, Daniel; Leuzzi, Chiara; Guerri, Elisa; Spartà, Ilaria; Politi, Luigi; Aprile, Alessandro; Amato, Andrea; Rossi, Rosario; Biondi-Zoccai, Giuseppe; Sangiorgi, Giuseppe M.; Modena, Maria G.; Mehran Contrast-Induced Nephropathy Risk Score Predicts Short- and Long-Term Clinical Outcomes in Patients With ST-Elevation–Myocardial Infarction; Circulation: Cardiovascular Interventions; 2010; vol. 3 (no. 5); 491-498

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	Italy
Study setting	Outpatient clinic of the cardiology department
Study dates	2002 - 2008
Sources of funding	None reported

Study sample	Consecutive patients admitted to a coronary care unit for ST-elevation myocardial infarction who were treated with percutaneous coronary intervention (PCI)
Inclusion criteria	Presented within 12 hours of symptom onset
Exclusion criteria	Chronic peritoneal or haemodialysis treatment Cardiogenic shock
Intervention details	Hydration was not routinely performed by the ambulance, helicopter, or emergency room medical staff before arrival in the catheterization laboratory. After contrast exposure, all patients underwent the following hydration protocol: physiological (0.9%) saline was given intravenously at a rate of 1 mL/kg per hour for 12 hours in patients with left ventricular dysfunction (ejection fraction ≤30%) or overt heart failure; hydration rate was reduced to 0.5 mL/kg per hour. A combination prophylaxis with N-acetylcysteine and NaHCO3 was administered from the beginning of the procedure, according to the ejection fraction values and Killip class. The use of beta-adrenergic– blocking agents, angiotensin-converting enzyme inhibitors, diuretics, or the indication to intra-aortic balloon pump or inotropic drugs support was left to the discretion of the interventional and coronary care unit cardiologists, An echocardiographic evaluation was performed in all patients before the procedure to assess wall motion abnormalities and ejection fraction. Primary PCI was performed by an interventional team, according to standard clinical practice. All patients received a loading dose of 300 mg of clopidogrel, in combination with 100 mg of acetylsalicylic acid. After sheath insertion, a heparin bolus at a dose of 70 U/kg, followed by an additional bolus during the procedure to maintain activated clotting time >300 seconds if deemed necessary, and an intravenous bolus and an infusion of platelet glycoprotein IIb/IIIa receptor inhibitors were administered. Contrast type and dose and supportive pharmacological therapies were left to the discretion of the interventional cardiologist
Population subgroups	
Risk tool(s)	**Mehran risk score** The Mehran risk score includes 8 clinical and procedural variables (score per variable in brackets):

	age ≥75 years (4) Hypotension (5) Congestive heart failure (5) Intra-aortic balloon pump (5) eGFR <20 (6) 20-40 (4) 40-60 (2) Diabetes (3) Anaemia (3) Volume of contrast (1 per 100 CC) The risk score can be broken down into four categories, indicating the risk of CA-AKI Low (≤5) Medium (6-10) High (11-16)

	Very high (≥16) **Marenzi risk score** The Marenzi risk score is composed of 5 variables: Age ≥75 years Anterior AMI Time to reperfusion ≥6 hours Contrast agent volume ≥300 mL Use of intra-aortic balloon pump A value of 1 was assigned when a factor was present and 0 when it was absent. For each patient, the score was calculated as the sum of the number of variables (range, 0 to 5)
Model development and validation	Both previously developed models
Outcome	Contrast induced nephropathy was defined as: 0.5 mg/dL (44 mmol/L) increase in serum creatinine or 25% increase compared with baseline values within 48 hours of the procedure
Duration of follow-up	Yearly follow-ups - duration not specified
Indirectness	None
Additional comments	None

Study arms

Mehran risk score (N = 891)

Marenzi risk score (N = 891)

Mehran risk score (medium risk) (N = 217)

Mehran risk score (high risk) (N = 83)

Mehran risk score (very high risk) (N = 29)

Characteristics

Study-level characteristics

Characteristic	Study (N = 891)
Mean age (SD) Mean (SD)	63.9 (13.1)

Characteristic	Study (N = 891)
% Female Sample size	n = 369 ; % = 22.4
Ethnicity Nominal	NR
Diabetes Sample size	n = 128 ; % = 14.4
Killip class 2 Sample size	n = 123 ; % = 13.8
Killip class 3 Sample size	n = 41 ; % = 4.6
Hypertension Sample size	n = 408 ; % = 45.8
Contrast volume (ml) Mean (SD)	216.1 (88.5)
Number of AKI events Sample size	n = 126 ; % = 14.1

Outcomes

Acute kidney injury

Outcome	Mehran risk score, , N = 891	Marenzi risk score, , N = 891	Mehran risk score (medium risk), , N = NA	Mehran risk score (high risk), , N = NA	Mehran risk score (very high risk), , N = NA
AUC Mean (95% CI)	0.57 (0.52 to 0.62)	0.57 (0.51 to 0.62)	NA (NA to NA)	NA (NA to NA)	NA (NA to NA)

Mortality

Outcome	Mehran risk score, , N = 891	Marenzi risk score, , N = 891	Mehran risk score (medium risk), , N = 217	Mehran risk score (high risk), , N = 83	Mehran risk score (very high risk), , N = 29
AUC Mean (95% CI)	0.74 (0.59 to 0.79)	0.6 (0.55 to 0.65)	NA (NA to NA)	NA (NA to NA)	NA (NA to NA)
Hazard ratio Low risk used as referent value Mean (95% CI)	NA (NA to NA)	NA (NA to NA)	3.61 (2.19 to 5.98)	8 (4.53 to 14.13)	15.29 (8.11 to 28.83)

Hazard ratio - Polarity - Lower values are better

Tziakas, 2013

Bibliographic Reference	Tziakas, Dimitrios; Chalikias, Georgios; Stakos, Dimitrios; Apostolakis, Stavros; Adina, Thomaidi; Kikas, Petros; Alexoudis, Apostolos; Passadakis, Ploumis; Thodis, Elias; Vargemezis, Vassilis; Konstantinides, Stavros; Development of an easily applicable risk score model for contrast-induced nephropathy prediction after percutaneous coronary intervention: A novel approach tailored to current practice; International Journal of Cardiology; 2013; vol. 163 (no. 1); 46-55

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	Greece
Study setting	Cardiac catheterisation laboratory
Study dates	September 2008 - January 2010
Sources of funding	No additional information
Study sample	Consecutive patients treated with percutaneous coronary intervention on an elective or emergency basis

Inclusion criteria	None reported
Exclusion criteria	On chronic peritoneal or haemodialytic treatment Died during hospitalisation Undergoing coronary artery bypass grafting Treated with repeated PCI within a week of the initial procedure End-stage renal disease
Intervention details	Patients underwent PCI according to current guidelines. Routine hydration was performed with 1 ml/kg/h of normal (0.9%) saline for 18–24 hours before PCI and 18 to 24 hours post procedure. In patients with reduced left ventricular ejection fraction (<40%), presence of significant valvular disease or overt heart failure upon presentation, the hydration rate was reduced to 0.5 ml/kg/h. Metformin was withheld for 48 hours prior to the procedure (for elective cases) and for 48 hours post PCI (all cases). The use of N-acetylcysteine, platelet glycoprotein IIb/IIIa receptor inhibitors, and the indication to intra-aortic balloon pump or intravenous inotropic support, was left to the discretion of the interventional cardiologists. . A non-ionic, low-osmolarity contrast agent, ioversol, was used for all procedures.
Risk tool(s)	**Mehran risk score** Risk score comprised of the following variables (score range from 0-35): Hypotension IABP Chronic heart failure Age >75 years Anaemia

	Diabetes mellitus Volume of contrast Baseline serum creatinine >1.5 mg/dL **Bartholomew risk score** Risk score comprised of the following variables (score range from 0-11): eGFR <60 ml/min IABP Urgent/emergency procedure Diabetes mellitus Congestive heart failure Hypertension Peripheral vascular disease Contrast volume >260 mL **Study-developed risk score**

	Risk score comprised of the following variables (score range from 0-8, score per variable in brackets): Pre-existing renal disease (2) Metformin (2) History of previous PCI (1) Peripheral artery disease (1) Contrast volume ≥300 mL (1)
Model development and validation	**Mehran risk score** Previously developed model **Bartholomew risk score** Previously developed risk score **Study-developed risk score** Fifty-seven demographic, clinical, angiographic and procedural variables were examined in univariate analysis. Thirteen variables with a significant association with contrast induced nephropathy were incorporated in a multivariate model. Using the significant variables on multivariate analysis, a risk scoring system was developed. An integer score of 1 was assigned per 1.000 beta value, resulting in a weighted scoring system containing the variables listed above. This model was initially validated through bootstrapping of 1000 samples, then validated externally using 200 patients undergoing PCI.
Outcome	Contrast induced nephropathy, defined as an increase of ≥25% or ≥0.5 mg/dl in pre-PCI serum creatinine at 48 hours post procedure

Duration of follow-up	7 days
Indirectness	None
Additional comments	None

Study arms

Mehran risk score (N = 488)

Bartholomew risk score (N = 488)

Study-developed risk score (cut-off: >3) (N = 200)

Characteristics

Study-level characteristics

Characteristic	Study (N = 200)
Number of AKI events Sample size	n = 28 ; % = 14

Arm-level characteristics

Characteristic	Mehran risk score (N = 488)	Bartholomew risk score (N = 488)	Study-developed risk score (cut-off: >3) (N = 200)
Mean age (SD) Mean (SD)	64 (11)	64 (11)	61 (12)
% Female Sample size	n = 128 ; % = 26	n = 128 ; % = 26	n = 36 ; % = 18
Ethnicity Nominal	NR	NR	NR
Diabetes Sample size	n = 154 ; % = 32	n = 154 ; % = 32	n = 75 ; % = 38
Heart failure Sample size	n = 58 ; % = 12	n = 58 ; % = 12	n = 32 ; % = 16
Hypertension Sample size	n = 282 ; % = 58	n = 282 ; % = 58	n = 148 ; % = 74
Contrast volume (ml) Mean (SD)	277 (118)	277 (118)	272 (91)

Characteristics of the validation cohort (n=200) and development cohort (n=488)

Outcomes

Acute kidney injury

Outcome	Mehran risk score, , N = 488	Bartholomew risk score, , N = 488	Study-developed risk score (cut-off: >3), , N = 200
AUC Mean (95% CI)	0.59 (0.55 to 0.64)	0.58 (0.54 to 0.63)	0.86 (0.8 to 0.93)
PPV Nominal	NR	NR	83
NPV Nominal	NR	NR	92
Calibration slope Optimism corrected based on 1000 bootstrap sample of the development cohort Nominal	NR	NR	0.88

Victor, 2014

Bibliographic Reference	Victor, Suma M.; Gnanaraj, Anand; S., VijayaKumar; Deshmukh, Rajendra; Kandasamy, Mani; Janakiraman, Ezhilan; Pandurangi, Ulhas M.; Latchumanadhas, K.; Abraham, Georgi; Mullasari, Ajit S.; Risk scoring system to predict contrast induced nephropathy following percutaneous coronary intervention; Indian Heart Journal; 2014; vol. 66 (no. 5); 517-524

Study details

Secondary publication of another included study- see primary study for details	No additional information
Other publications associated with this study included in review	No additional information
Trial name / registration number	No additional information
Study type	Prospective cohort study
Study location	India
Study setting	Tertiary cardiac referral centre
Study dates	March 2008 - December 2011
Sources of funding	None reported
Study sample	Consecutive patients undergoing PCI
Inclusion criteria	Indian

Exclusion criteria	PCI performed within 2 weeks of coronary angiogram (exposed to contrast within 2 weeks) On regular dialysis Acute renal failure before PCI Cardiogenic shock Required IABP support Developed PCI-related complications
Intervention details	All patients underwent PCI using non-ionic contrast media. All patients with raised creatinine levels were given hydration with half normal saline (1 ml/kg/h starting from 4 hours before and continued till 24 hours after the exposure to contrast media) and N-acetylcysteine (600 mg twice daily 1 day before and for 2 days post procedure). All patients received dual anti platelets and a statin in recommended doses.
Contrast administration route	Intra-arterial
Risk tool(s)	**Study-developed risk score** Equation that predicts the likelihood of contrast induced nephropathy, containing the following variables: GFR Amount of contrast Haemoglobin Diabetic microangiography

	Hypotension Albuminuria Peripheral vascular disease
Model development and validation	The baseline clinical, laboratory and procedural characteristics of the patients in the development set (n=900) were studied using univariate analysis to identify individual risk factors. Significant individual risk factors were used as independent variables and CIN as the dependent variable in the final multivariate logistic regression. Forward step wise logistic regression analysis was used to elucidate the final risk factors with the strongest prediction of CIN. The obtained logistic regression equation was: A A= the sum of (logistic regression coefficient)(independent variable) both to the nearest integer. The probability of CIN was estimated with eA/(1 + eA) where e = exponential Chi square goodness of fit test was used to assess the final model accuracy for prediction of CIN and AUC of the ROC was used to evaluate the model discrimination between patients with and without CIN. The final estimate for CIN probability was evaluated using sensitivity and specificity analysis at various cut off levels. The final risk score system was then substantiated in the validation data set (n=300) and its predictive accuracy was assessed using the c-statistic
Outcome	Contrast-induced nephropathy was defined as: an increase of ≥25% and/or ≥0.5 mg/dl in serum creatinine at 48 hours after PCI when compared to baseline value
Duration of follow-up	Unclear
Indirectness	None
Additional comments	None

Study arms

Study-developed risk score (cut-off: 10%) (N = 300)

Characteristics

Study-level characteristics

Characteristic	Study (N = 900)
Mean age (SD) Mean (SD)	57.3 (10.2)
% Female Sample size	n = 148 ; % = 16.4
Ethnicity Nominal	NR
Diabetes Sample size	n = 477 ; % = 53
Heart failure Sample size	n = 20 ; % = 2.2
Hypertension	n = 470 ; % = 52.2

Characteristic	Study (N = 900)
Sample size	
Contrast volume Mean (SD)	114.9 (37.9)
Number of AKI events In the validation cohort (n=300) Sample size	n = 26 ; % = 8.7

Characteristics of the development set, validation (n=300) not reported

Outcomes

Acute kidney injury

Outcome	Study-developed risk score (cut-off: 10%), , N = 300
Sensitivity Nominal	92.3
Specificity Nominal	82.1