

# Acute kidney injury (AKI); Definitions, implications and mitigation strategies.



# Agenda

## AKI in the Cath Lab

Definitions and susceptibility  
Vulnerability of the kidney  
Increasing incidence of comorbidities  
Increasing incidence of AKI in PCI populations

## Implications of AKI

Short-term AEs  
Longer-term AEs  
Increased readmission rates  
Economic burden  
Benchmark NCDR hospital rates

## Mitigation strategies

Screen for at-risk patients  
Hydration (volume expansion)  
Limit contrast volume in high-risk patients  
Selection of CM

AEs, adverse events  
AKI, acute kidney injury  
CM, contrast media  
PCI, percutaneous coronary intervention  
NCDR, National Cardiovascular Data Registry

# How acute kidney injury after contrast administration is defined

Post-contrast AKI describes a sudden deterioration in renal function that occurs within 48 hours following the intravascular administration of iodinated CM<sup>1</sup>

AKIN suggest a diagnosis of AKI is made if one of the following occurs within 48 hours of a nephrotoxic event such as intravascular iodinated CM exposure:<sup>2</sup>



Absolute SCr increase  
 $\geq 0.3$  mg/dL



Relative increase in SCr  
 $\geq 50\%$  ( $\geq 1.5$ -fold above  
baseline)



Urine output reduced  
to  $\leq 0.5$  mL/kg/hour for  
more than 6 hours

AKI, acute kidney injury  
AKIN, Acute Kidney Injury Network  
CA-AKI, contrast associated AKI  
CI-AKI, contrast-induced AKI  
CIN, contrast-induced nephropathy  
CM, contrast medium/media  
PC-AKI, post-contrast AKI  
SCr, serum creatinine

It has been suggested that the terms CA-AKI<sup>3</sup>, CI-AKI or CIN be reserved for cases where a causal relationship can be shown between the administered CM and the deterioration in renal function<sup>1</sup>

– in clinical practice it is usually difficult to distinguish CI-AKI from PC-AKI<sup>1</sup>

#### References:

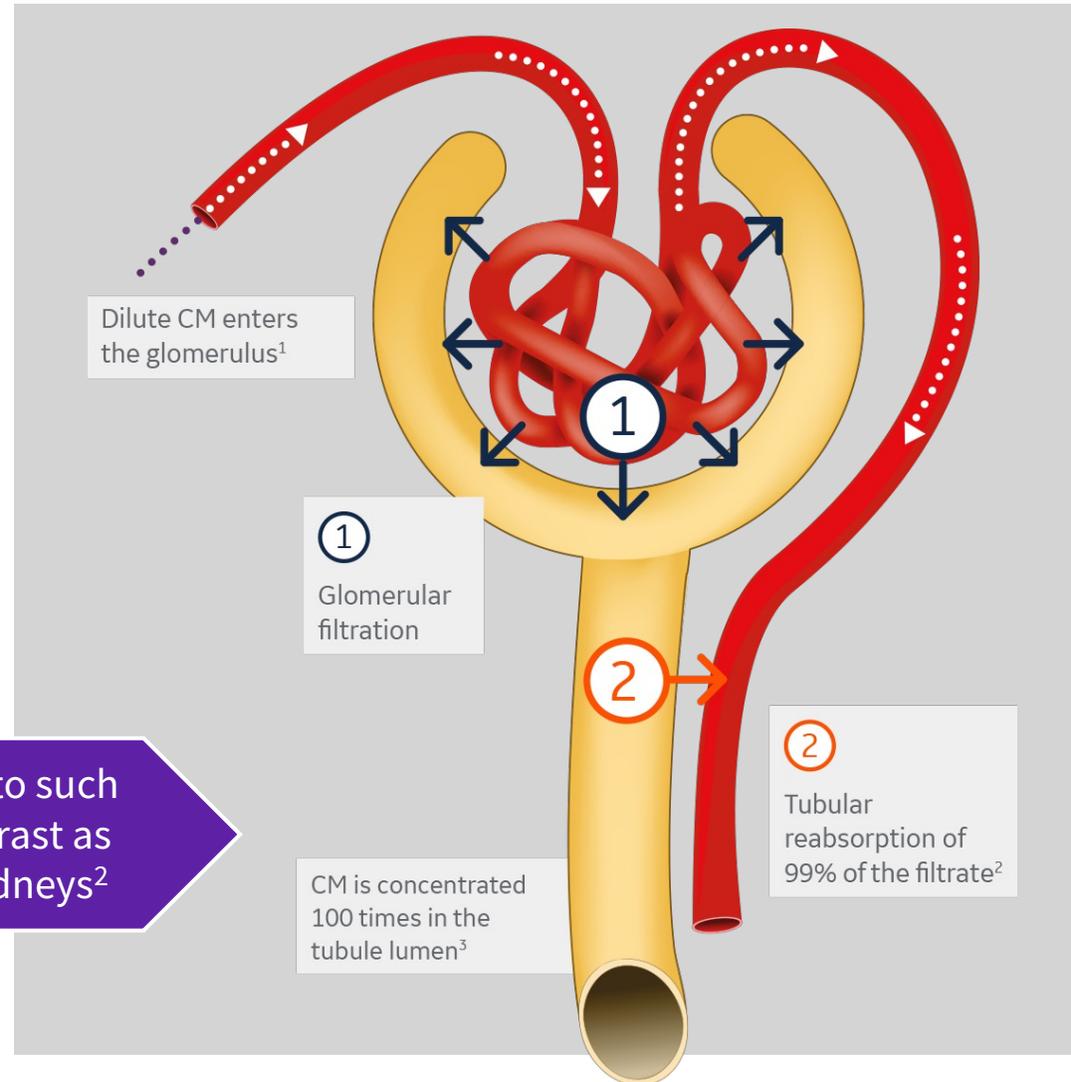
1. van der Molen AJ et al. Eur Radiol. 2018;28(7):2845-2855.
2. Mehta RL et al. Crit Care. 2007;11(2):R31.
3. Mehran, R · Dangas, GD · Weisbord, SD Contrast-associated acute kidney injury. N Engl J Med. 2019; 380:2146-2155

# The kidneys are especially vulnerable to injury from iodinated CM<sup>1,2</sup>

After intravascular injection, CM are diluted in the bloodstream and immediately distributed throughout the extracellular fluid<sup>1</sup>

- ① Being poorly bound to serum albumin, the contrast agent is freely filtered by renal glomeruli<sup>1</sup>
- ② Robust tubular reabsorption of the filtrate leads to a many-fold increase in the luminal CM concentration relative to that in the plasma<sup>2</sup>

No other organ is exposed to such high concentration of contrast as that experienced by the kidneys<sup>2</sup>



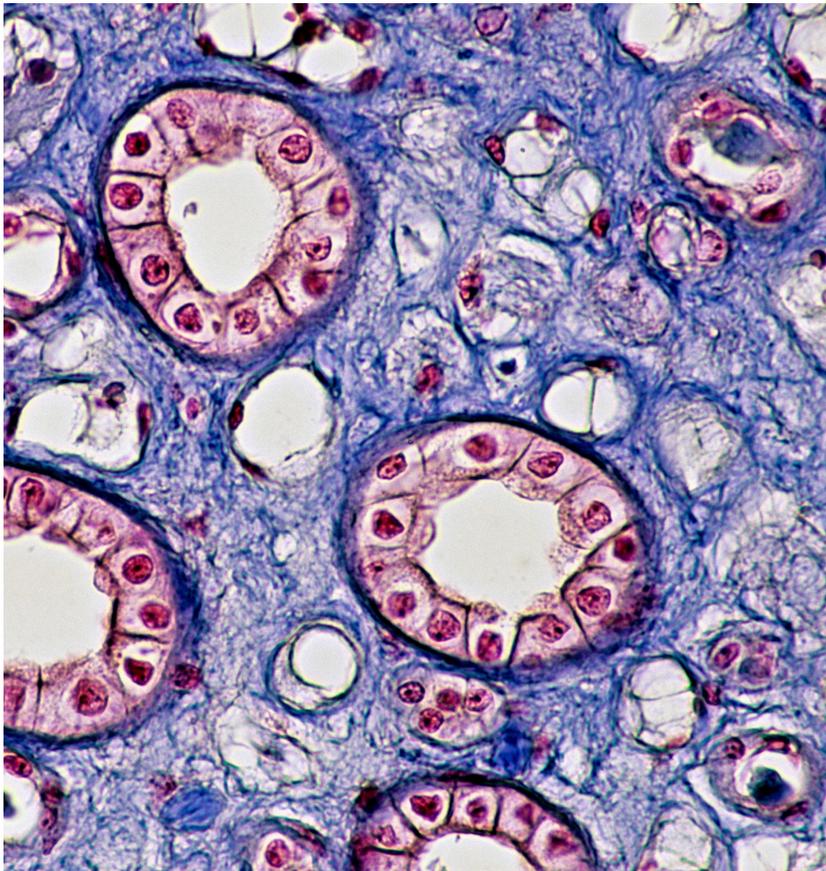
CM, contrast medium/media

#### References:

1. Andreucci M et al. *Drug Healthc Patient Saf.* 2017;9:25-37.
2. Hiremath S, Velez JC. *Curr Opin Nephrol Hypertens.* 2020;29(1):152-160.
3. Berg KJ. *Scand J Urol Nephrol.* 2000;34(5):317-322.

# The kidneys of “high-risk” patients may respond differently<sup>1,2</sup>

Contrast agents are directly toxic to tubular epithelial cells, leading to loss of function and both apoptosis and necrosis<sup>1</sup>



## In healthy patients<sup>2</sup>

- there is a robust tubular repair capability
- exposure to CM may not have any clinical consequences

## In patients with CKD and diabetes mellitus<sup>2</sup>

- the number of functioning nephrons is reduced
- the ability to regenerate tubular epithelial cells is impaired
- routine cardiac procedures can cause CI-AKI that is clinically meaningful

AKI, acute kidney injury  
CI-AKI, contrast-induced AKI  
CKD, chronic kidney disease  
CM, contrast medium/media

### References:

1. Mehran R et al. *N Engl J Med.* 2019;380(22):2146-2155.
2. McCullough PA et al. *J Am Coll Cardiol.* 2016;68:1465-1473.

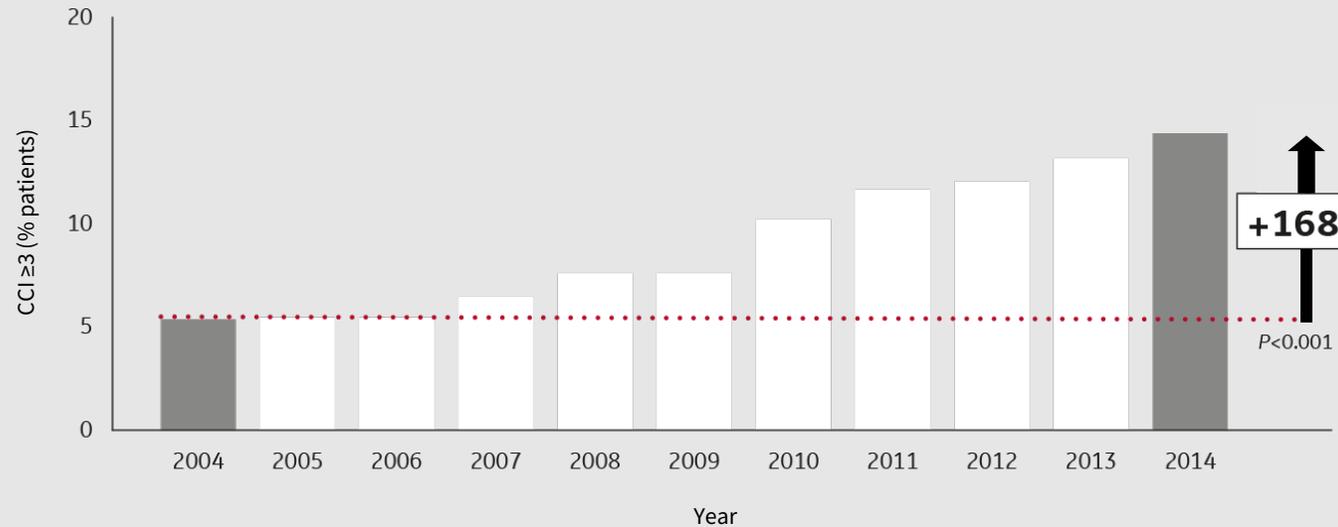
# As patients' comorbidity burden has grown, increasingly complex disease must be addressed<sup>1</sup>

60% of the patients undergoing PCI in contemporary practice have at least one comorbid condition; 1 in 7 have a severe comorbidity burden<sup>1</sup>

The number of patients with severe comorbidity burdens has grown<sup>1\*</sup>

\*Charlson  
Comorbidity  
Index  $\geq 3$

Analysis of  
6,601,526 PCI  
procedures  
undertaken in the  
US from 2004 to  
2014 detailed in  
the NIS dataset



Adapted from Potts J et al. 2018.

n=6,601,526

CCI, Charlson Comorbidity Index  
NIS, Nationwide Inpatient Sample  
PCI, percutaneous coronary intervention

**Reference:**

1. Potts J et al. *Am J Cardiol.* 2018;122(5):712-722.

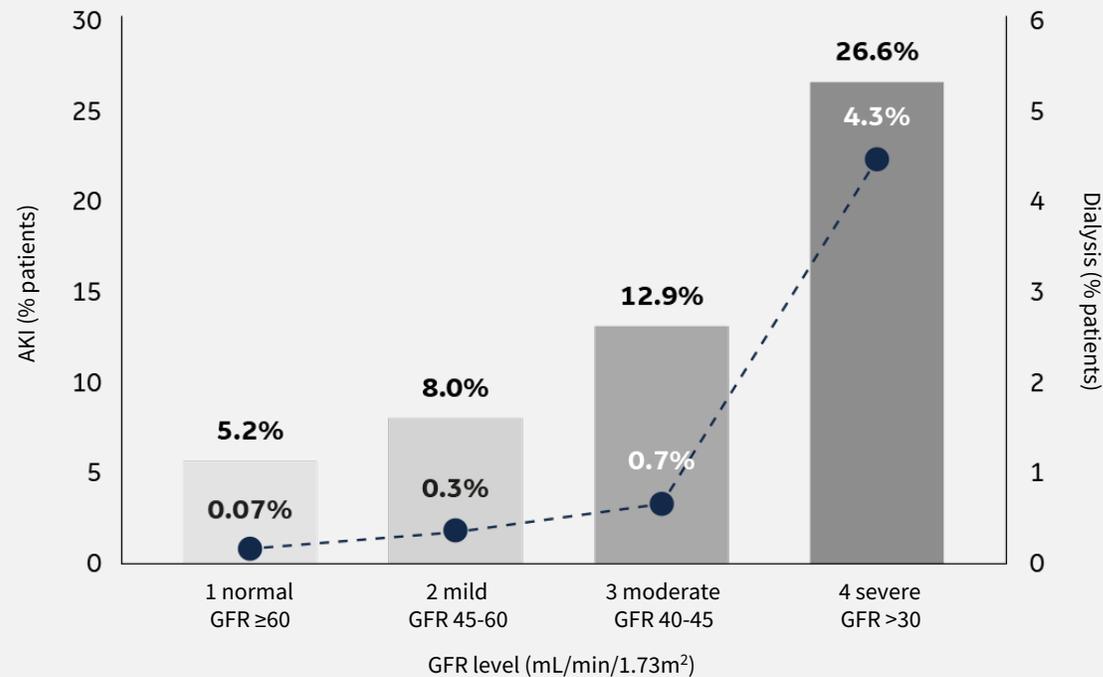
# Patients with baseline renal insufficiency are at increased risk of AKI

A large national cohort study of post-PCI patients found AKI developed in 7.1% of patients, 0.3% of whom required acute dialysis<sup>1</sup>

The incidence of AKI sharply increases as CKD progresses and eGFR worsens<sup>1</sup>

Data from 985,737 consecutive patients at 1,253 sites participating in the NCDR CathPCI Registry<sup>®</sup> from June 2009 through June 2011

AKI was defined as an absolute increase of  $\geq 0.3$  mg/dL or  $\geq 1.5$ -fold relative increase in SCr



Adapted from Tsai TT et al. 2014.

● AKI-D

AKI, acute kidney injury  
AKI-D, AKI dialysis  
CKD, chronic kidney disease  
eGFR, estimated GFR  
GFR, glomerular filtration rate  
NCDR, National Cardiovascular Data Registry  
PCI, percutaneous coronary intervention  
SCr, serum creatinine

The CathPCI Registry is a registered trademark of NCDR

Reference:

1. Tsai TT et al. *JACC Cardiovasc Interv.* 2014;7(1):1-9.

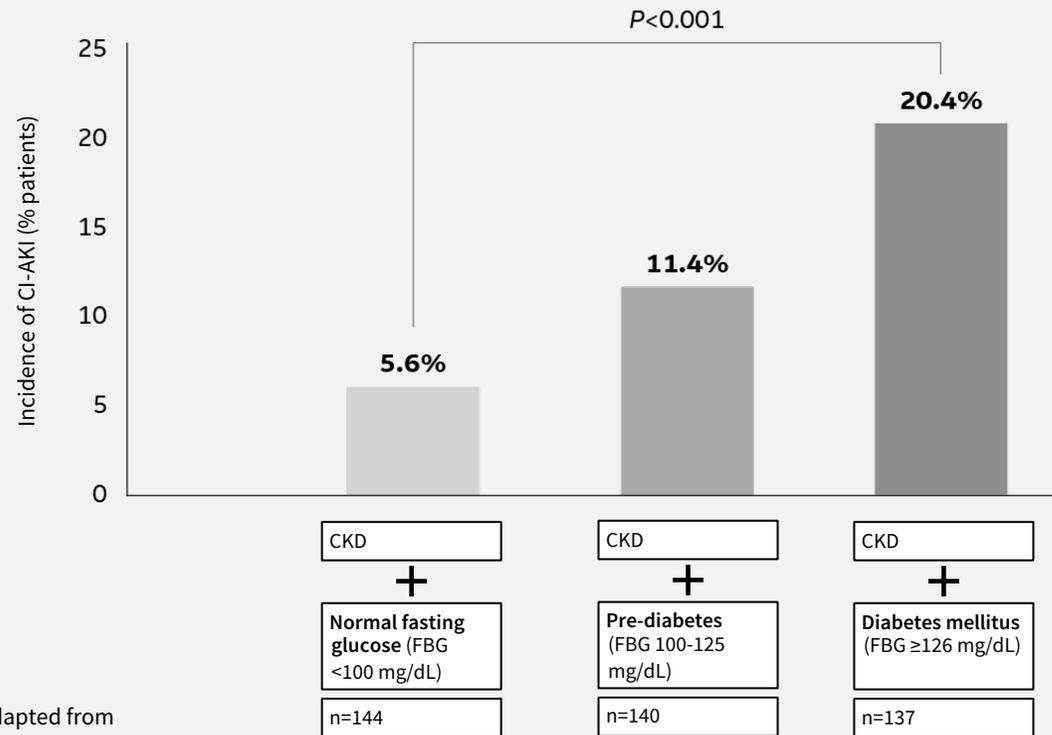
# As risk factors increase, so the incidence of CI-AKI tends to increase<sup>1</sup>

CKD and diabetes are principal risk factors for CI-AKI<sup>2</sup>

CKD patients who also have diabetes mellitus are at increased risk for developing CI-AKI<sup>1</sup>

Single center, prospective cohort study of 421 patients with CKD (91% stage 3) referred for non-emergency diagnostic coronary angiography

CI-AKI was defined as an increase of  $\geq 25\%$  in SCr within 48 hours



Adapted from Toprak O et al. 2007.

AKI, acute kidney injury  
CI-AKI, contrast-induced AKI  
CKD, chronic kidney disease  
FBG, fasting blood glucose  
KDIGO, Kidney Disease: Improving Global Outcomes  
SCr, serum creatinine

#### References:

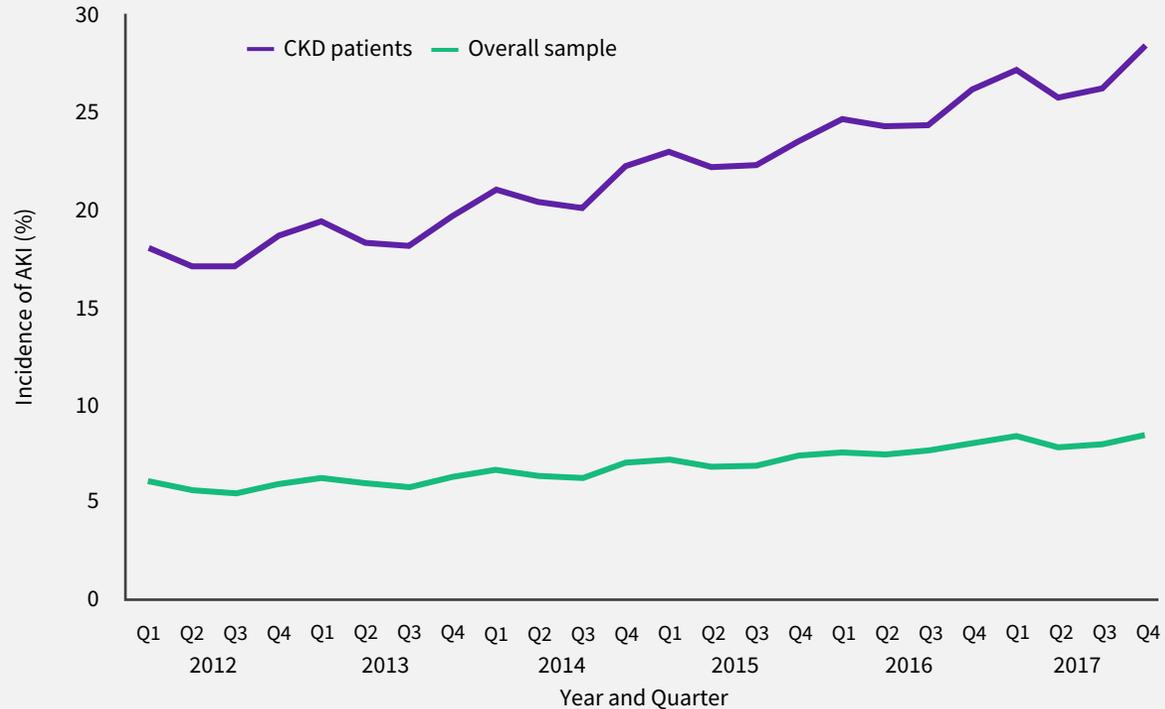
1. Toprak O et al. *Nephrol Dial Transplant*. 2007;22(3): 819-826.
2. KDIGO AKI Work Group. *Kidney Int Suppl*. 2012;2:1-138.

# The incidence of post-procedure AKI in Cath Lab patients continues to grow<sup>1</sup>

Not only are vulnerable patient populations growing, so too is the complexity of procedures being performed<sup>2</sup>

The incidence of AKI among cardiac catheterization and PCI patients is increasing in the United States<sup>1</sup>

Premier Healthcare Database analysis of 2,763,681 patients undergoing coronary angiography/PCI procedures in 749 US hospitals during 2012–2017



Adapted from Prasad A et al. 2020.

AKI, acute kidney injury  
CKD, chronic kidney disease  
PCI, percutaneous coronary intervention

#### References:

1. Prasad A et al. *Catheter Cardiovasc Interv.* 2020;96(6):1184-1197.
2. Keuffel E et al. *J Med Econ.* 2017;21(4):356-364.

# CI-AKI is associated with poor short-term outcomes.<sup>1</sup>

CI-AKI is a powerful independent predictor of adverse outcomes and mortality after primary PCI in STEMI<sup>1</sup>

## Impact of CI-AKI on 30-day outcomes after PCI in STEMI<sup>1</sup>

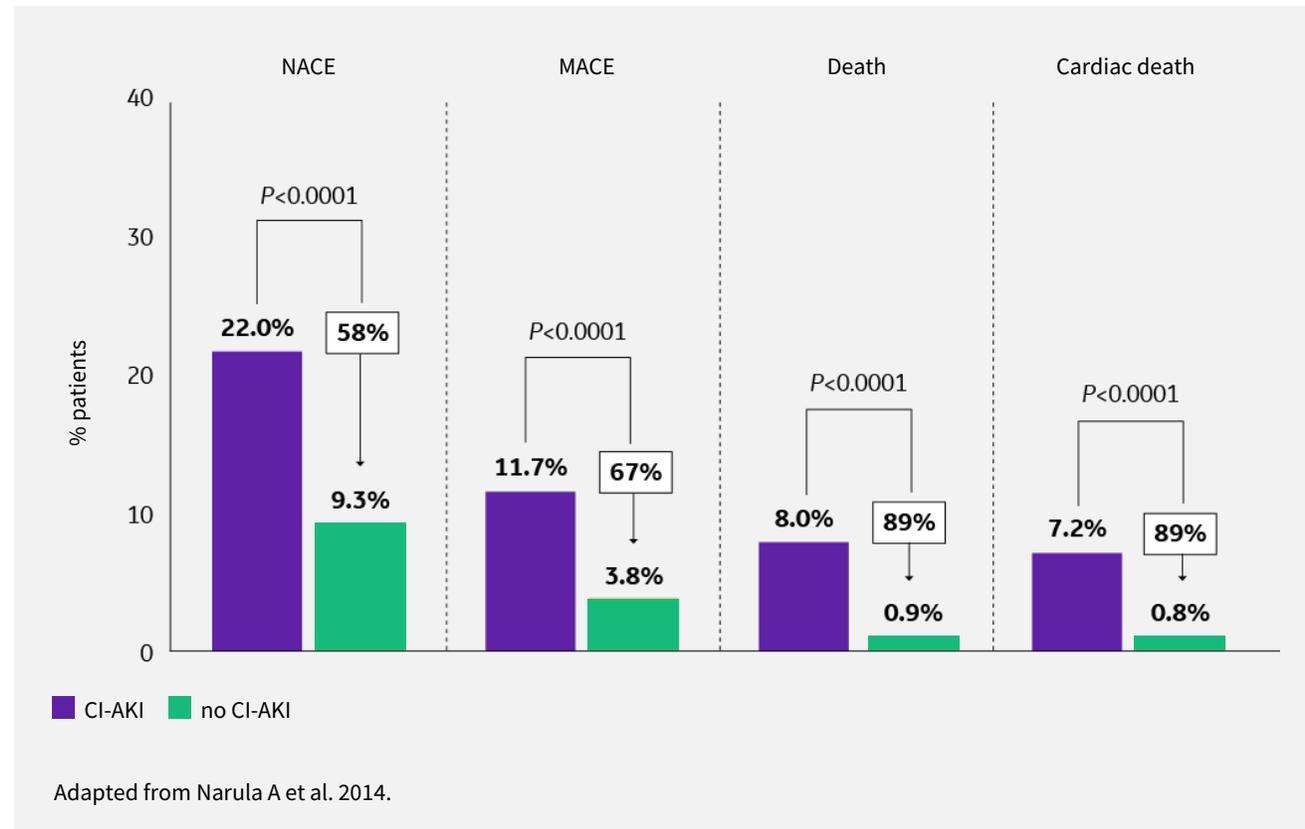
Prospective, open-label, randomized study of 3,602 STEMI patients undergoing PCI

16.1% developed CI-AKI

MACE: death, re-infarction, target vessel revascularization for ischaemia, or stroke

NACE: a combination of major bleeding or MACE

CI-AKI: increase in SCr  $\geq 0.5$  mg/dL or  $\geq 25\%$  from baseline within 48 hours of CM exposure



AKI, acute kidney injury  
CI-AKI, contrast-induced AKI  
CM, contrast medium/media  
MACE, major adverse cardiac events  
MI, myocardial infarction  
NACE, net adverse clinical events  
PCI, percutaneous coronary intervention  
SCr, serum creatinine  
STEMI, ST-segment elevation MI

### Reference:

1. Narula A et al. *Eur Heart J*. 2014; 35(23): 1533-1540.

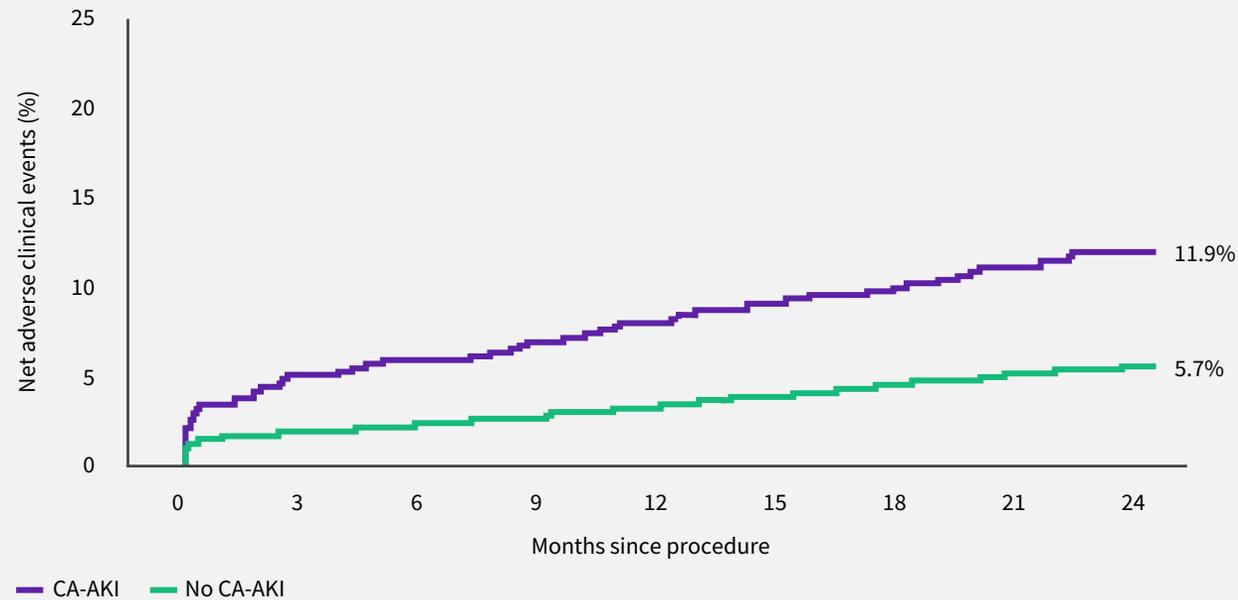
# Significant morbidity and mortality may persist after hospital discharge<sup>1,2</sup>

## Cumulative incidence of adverse events post-discharge, by presence of in-hospital AKI<sup>2</sup>

Prospective, multicenter registry study of 7,412 PCI patients

CA-AKI was defined as a post-PCI SCr increase of >0.5 mg/dL or a relative increase of ≥25% compared with pre-PCI

Primary endpoint: 2-year rate of NACE: All-cause mortality, MI, definite or probable stent thrombosis, or major bleeding



Adapted from Mohebi R et al. 2022.

AKI, acute kidney injury  
CA-AKI, contrast-associated AKI  
PCI, percutaneous coronary intervention  
NACE, net adverse clinical events  
MI, myocardial infarction  
PCI, percutaneous coronary intervention  
SCr, serum creatinine

### References:

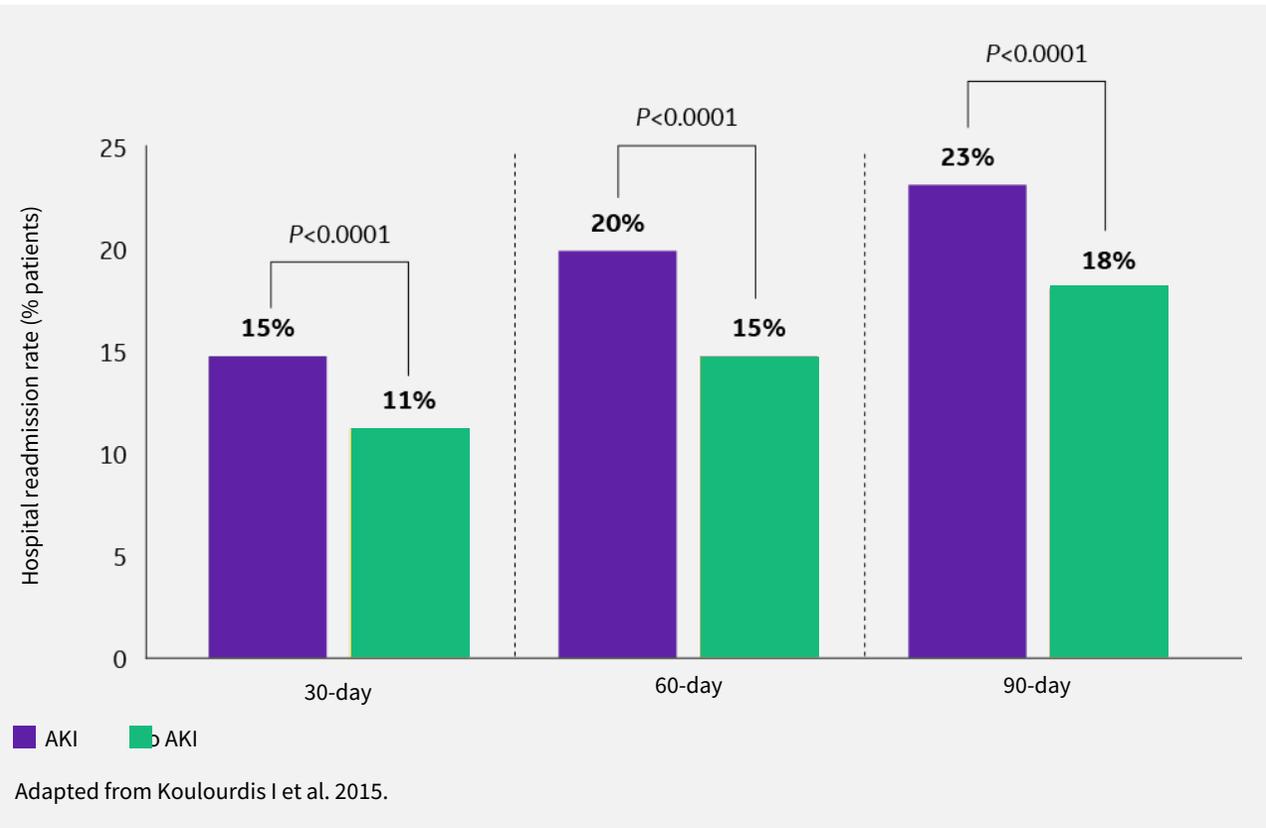
1. Valle JA et al. *Circ Cardiovasc Interv.* 2017;10(4):e004439.
2. Mohebi R et al. *JACC Cardiovasc Interv.* 2022;15(7):753-766.

Post-PCI AKI should be recognized as a significant risk factor not only for in-hospital adverse events but also after hospital discharge<sup>1</sup>

# Survivors of hospital-acquired AKI experience higher odds of early hospital readmission

Hospital readmission rates among patients with and without AKI during the index hospitalization<sup>1</sup>

Retrospective cohort study of adults discharged from a tertiary acute-care facility from October 2000 through September 2007



AKI, acute kidney injury

The development of AKI during hospitalization might be an unrecognized, albeit important, care-related determinant of hospital readmissions<sup>1</sup>

Reference:

1. Koulourdis I et al. *Am J Kidney Dis.* 2015;65(2):275-282.

# The economic burden of hospital-acquired AKI is high<sup>1,2</sup>

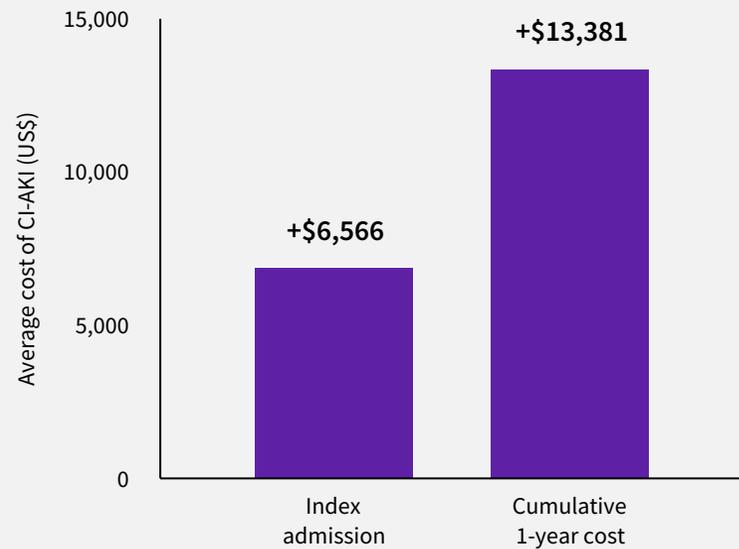
Data from the 2012 NIS was used to compare hospitalization costs and LOS for patients with and without AKI<sup>1</sup>

n=29,763,649 adult hospitalizations without ESRD  
Adapted from Silver SA et al. 2017.

	Impact on LOS	Impact on hospitalization cost
AKI	+ 3.2 days	+ \$7,933
AKI-D	+ 11.5 days	+ \$42,077

## Additional healthcare cost associated with CI-AKI (adjusted for baseline characteristics)

*Retrospective analysis of Medicare data (January 1, 2016 to December 31, 2020) for 509,039 patients undergoing PCI*



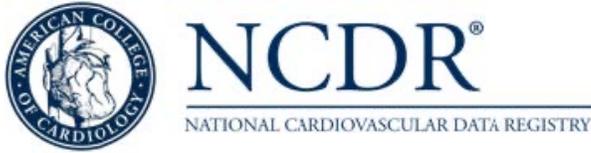
Adapted from Griffiths RI et al. 2023.

AKI, acute kidney injury  
AKI-D, AKI dialysis  
CI-AKI, contrast-induced AKI  
ESRD, end-stage renal disease  
LOS, length of stay  
NIS, National Inpatient Sample  
PCI, percutaneous coronary intervention

### References:

1. Silver SA et al. *J Hosp Med.* 2017;12(2):70-76.
2. Griffiths RI et al. *Am Heart J.* 2023;262:20-28.

# Reviewing benchmarked data can help inform best practice



In-hospital AKI rate is an important quality metric in the NCDR CathPCI Registry<sup>®1</sup>

## Executive Summary

CathPCI Registry

National Outcomes Report (999997) compared to rolling four quarters (R4Q) for US Hospitals ending 2014Q3

Section II: Quality Metrics - to support self assessment and quality improvement at the provider, hospital, and/or healthcare system level

### PCI in-hospital risk adjusted AKI (all patients)

My Hospital	US Hospital 50th percentile	US Hospitals 90th percentile
	6.13	2.85

Your hospital's PCI in-hospital risk-adjusted AKI rate for all patients adjusted using the NCDR risk adjustment model

AKI, acute kidney injury  
NCDR, National Cardiovascular Data Registry  
PCI, percutaneous coronary intervention

The CathPCI Registry is a registered trademark of NCDR

#### Reference:

1. The CathPCI Registry. <https://cvquality.acc.org/NCDR-Home/registries/hospital-registries/cathpci-registry> (accessed July 1, 2025).

# Clinical recommendations

Screen for patient risk<sup>1-5</sup>



Administer periprocedural hydration<sup>1-5</sup>



Limit contrast volume in high-risk patients<sup>1-5</sup>



Consider the risks and benefits of the contrast media<sup>1,3,5</sup>



## References:

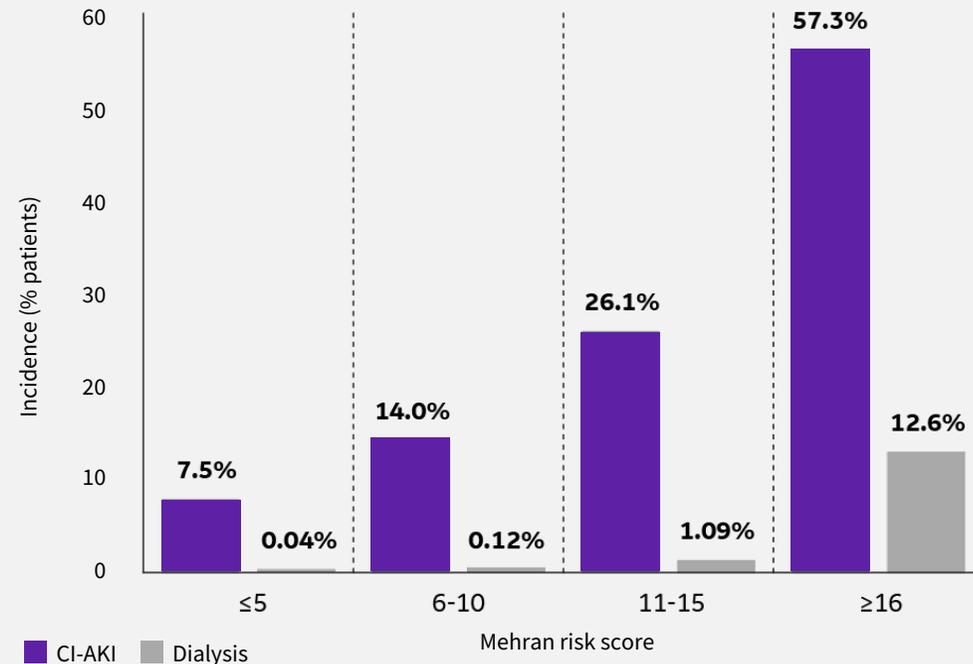
1. Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group. *Kidney Int Suppl.* 2012;2:1-138.
2. Lawton JS et al. *J Am Coll Cardiol.* 2022;79(2):e21-e129.
3. McCullough PA et al. *J Am Coll Cardiol.* 2016;68:1465-1473.
4. Naidu SS et al. *Catheter Cardiovasc Interv.* 2021;98(2):255-276.
5. Ronco F et al. *Rev Cardiovasc Med.* 2020;21(1):9-23.

# Screening for patient risk – Mehran

Several investigators have looked at the use of risk scores to guide preventive strategies, the most comprehensive of which is the Mehran risk score<sup>1</sup>

## Mehran risk score for CI-AKI<sup>2</sup>

Variable	Points
Hypotension	5
Intra-aortic balloon pump	5
Chronic heart failure	5
Age >75 years	4
Anemia	3
Diabetes	3
Contrast media volume	1 for each 100 mL
Serum creatinine >1.5 mg/dl	4
or eGFR <60 ml/min//1.73 m <sup>2</sup>	2 for 40-60 4 for 20-40 6 for <20



Adapted from Mehran R et al. 2004.

ACS, acute coronary syndrome  
AKI, acute kidney injury  
CI-AKI, contrast-induced AKI  
eGFR, estimated glomerular filtration rate

### Reference:

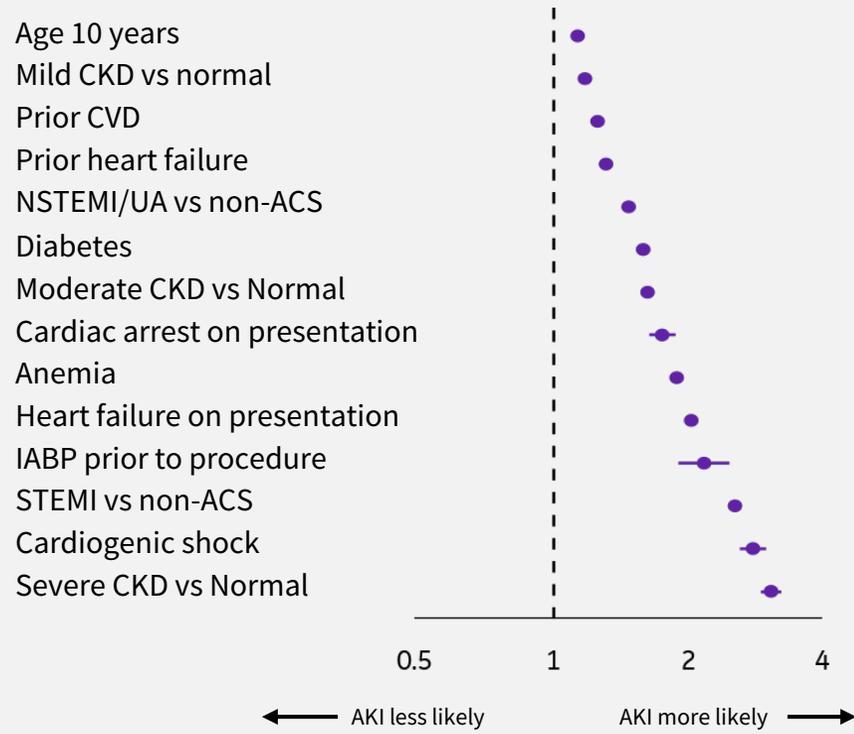
1. Azzalini L et al. *Can J Cardiol.* 2016;32(2):247-255.
2. Mehran R et al. *J Am Coll Cardiol.* 2004;44:1393-1399.
3. Abellás-Sequeiros RA et al. *J Cardiol.* 2016;67(3):262-267.

The Mehran score was more recently validated in a contemporary cohort of ACS patients; the CI-AKI rate predicted by the model closely approximated the observed rate<sup>3</sup>

# Screening for patient risk – NCDR model

Data from the large NCDR cohort were assessed to understand the incidence, predictors, and outcomes of AKI post-PCI<sup>1</sup>

## NCDR risk model for post-contrast AKI<sup>1</sup>



Focusing on pre-procedure variables to best estimate the periprocedure risk of AKI, can enhance the patient consent process and risk/benefit evaluations<sup>1</sup>

ACS, acute coronary syndrome  
AKI, acute kidney injury  
CKD, chronic kidney disease  
CVD, cardiovascular disease  
IABP, intra-aortic balloon pump  
MI, myocardial infarction  
NCDR, National Cardiovascular Data Registry  
NSTEMI, non-ST-segment elevation MI  
PCI, percutaneous coronary intervention  
STEMI, ST-segment elevation MI  
UA, unstable angina

### Reference:

1. Tsai TT et al. *JACC Cardiovasc Interv.* 2014;7(1):1-9.

Adapted from Tsai TT et al. 2014.

# Administering periprocedural hydration

Data from the large NCDR cohort were assessed to understand the incidence, predictors, and outcomes of AKI post-PCI

## Two commonly referenced hydration protocols<sup>1-3</sup>

	Clinical practice guidelines	Hemodynamic-guided fluid administration
Name	ACCF/AHA/SCAI Practice Guidelines for PCI	POSEIDON Trial Hydration Protocol
Type	Normal saline (isotonic crystalloid)	Sliding scale hydration based on intracardiac pressure measurement (LVEDP)
Preprocedure	Intravenous administration: 1-1.5 mL/kg/h for 3-12 hours	Bolus infusion at 3 mL/kg for 1 hour
Intraprocedure and Postprocedure	Post procedure: Intravenous administration: 1-1.5 mL/kg/hr for 6-24 hours	5 mL/kg/h for LVEDP <13 mm Hg 3 mL/kg/h for LVEDP 13-18 mm Hg 1.5 mL/kg/h for LVEDP >18 mm Hg Continued 4 hours postprocedure
Reference	Levine GN et al. <i>JACC</i> 2011;24:e44-e122	Brar SS et al. <i>Lancet</i> 2014;383:1814-1823

ACCF, American College of Cardiology Foundation  
 AHA, American Heart Foundation  
 AKI, acute kidney injury  
 LVEDP, left ventricular end diastolic pressure  
 PCI, percutaneous coronary intervention  
 NCDR, National Cardiovascular Data Registry  
 SCAI, Society for Cardiovascular Angiography and Interventions

### References:

1. Levine GN et al. *J Am Coll Cardiol.* 2011;58(24):e44-122.
2. Brar SS et al. *Lancet.* 2014;383(9931):1814-1823.
3. ClinicalTrials.gov Identifier: NCT01218828.  
<https://clinicaltrials.gov/ct2/show/NCT01218828>  
 (accessed July 1, 2025).
4. Tsai TT et al. *JACC Cardiovasc Interv.* 2014;7(1):1-9.

**Focusing on pre-procedure variables to best estimate the periprocedure risk of AKI, can enhance the patient consent process and risk/benefit evaluations<sup>4</sup>**

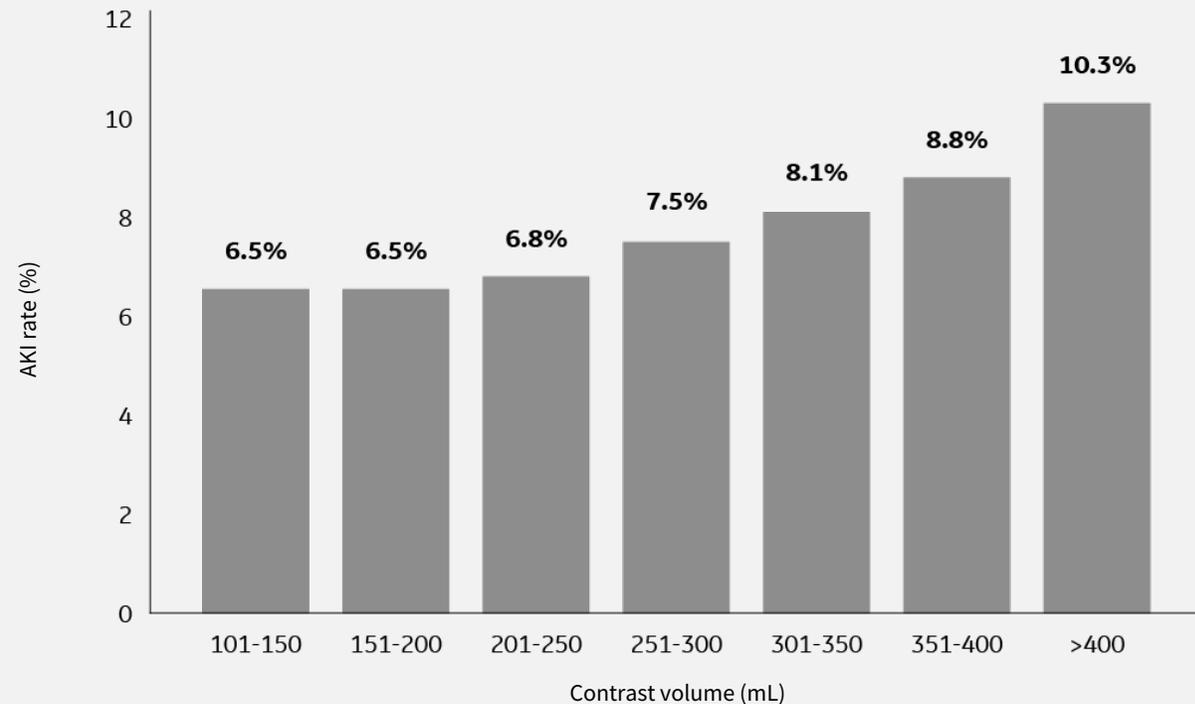
# Limiting contrast volume in high-risk patients

Evidence suggests that there is a nearly linear relationship between the magnitude of contrast reduction and the expected reduction in AKI<sup>1</sup>

## Relationship between increasing contrast volume and AKI<sup>2</sup>

Cross-sectional study using the NCDR CathPCI Registry<sup>®</sup> to identify in-hospital care for PCI in the US

Participants included 1,349,612 patients who underwent PCI performed by 5,973 physicians in 1,338 hospitals from June 2009 through June 2012



Adapted from Amin AP et al. 2017.

AKI, acute kidney injury  
NCDR, National Cardiovascular Data Registry  
PCI, percutaneous coronary intervention

The CathPCI Registry is a registered trademark of NCDR

### References:

1. Gurm HS et al. *J Invasive Cardiol.* 2016;28(4):142-146.
2. Amin AP et al. *JAMA Cardiol.* 2017;2(9):1007-1012 (+online supplementary content).



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