Akutes Nierenversagen

Martin Bernardi

ANÄSTHESIE FORUM

ALPBACH

REPETITORIUM

Definition

- Akut auftretende Abnahme der Filtration
  - innerhalb von Stunden bis Tagen
  - prinzipiell rückbildungsfähig
- Prä-, intra-, postrenal
- Nach normaler Nierenfunktion
- CKD (acute on chronic renal failure)

Acute Kidney Disease

Kidney Damage

Renal Failure

Renal Insufficiency

Acute Tubular Necrosis

Acute Renal Failure

Acute Kidney Injury

Acute Renal Impairment

Renal Illness

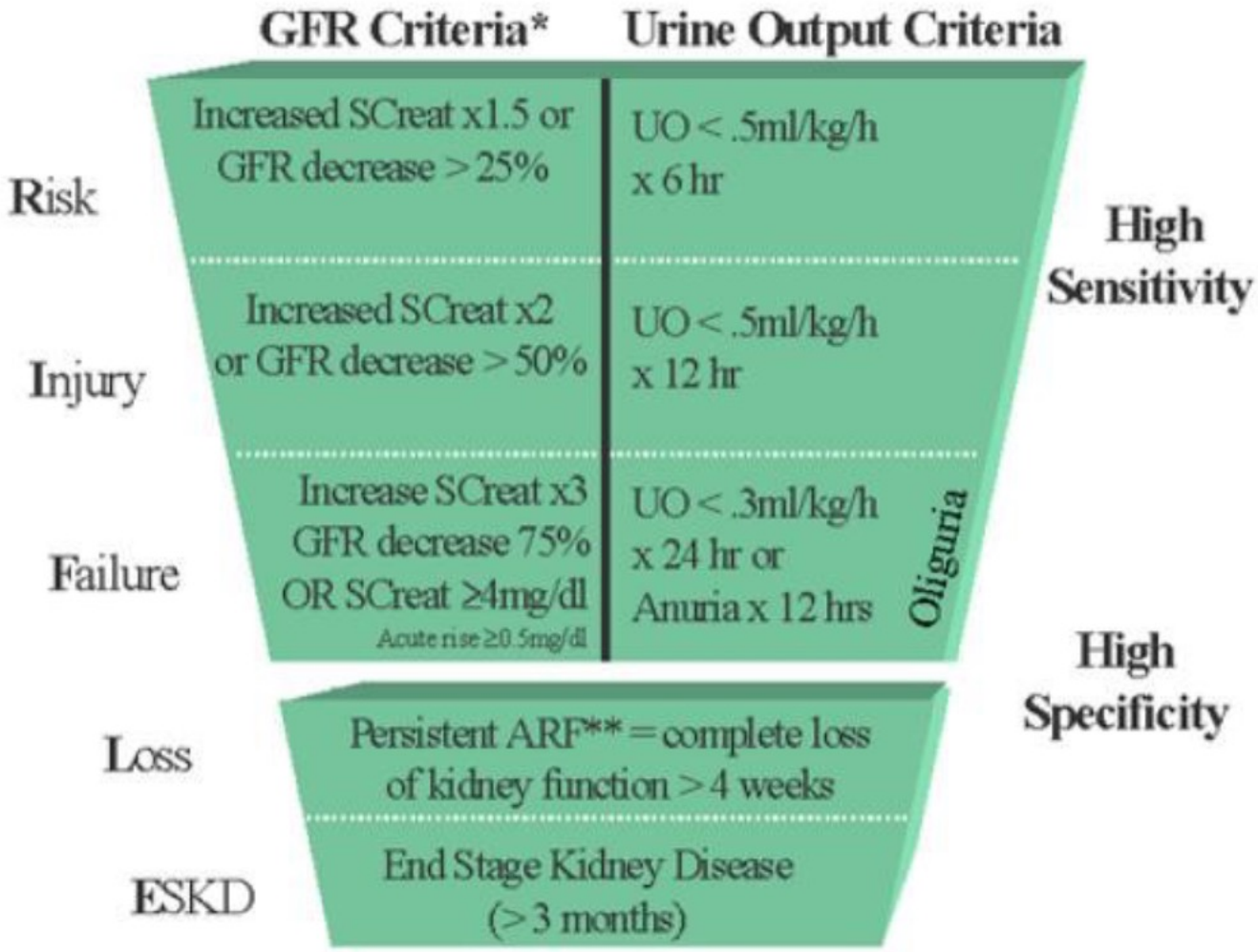
Renal Deficiency

Acute Renal Shutdown

Renal Damage

Kidney Disorder

RIFLE



Bellomo R. et al. Crit Care 2004

AKIN

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Table 2

Classification/staging system for acute kidney injury[a]

Stage	Serum creatinine criteria	Urine output criteria
1	Increase in serum creatinine of more than or equal to 0.3 mg/dl (≥ 26.4 µmol/l) or increase to more than or equal to 150% to 200% (1.5- to 2-fold) from baseline	Less than 0.5 ml/kg per hour for more than 6 hours
2[b]	Increase in serum creatinine to more than 200% to 300% (> 2- to 3-fold) from baseline	Less than 0.5 ml/kg per hour for more than 12 hours
3[c]	Increase in serum creatinine to more than 300% (> 3-fold) from baseline (or serum creatinine of more than or equal to 4.0 mg/dl [≥ 354 µmol/l] with an acute increase of at least 0.5 mg/dl [44 µmol/l])	Less than 0.3 ml/kg per hour for 24 hours or anuria for 12 hours

[a]Modified from RIFLE (Risk, Injury, Failure, Loss, and End-stage kidney disease) criteria [26]. The staging system proposed is a highly sensitive interim staging system and is based on recent data indicating that a small change in serum creatinine influences outcome. Only one criterion (creatinine or urine output) has to be fulfilled to qualify for a stage. [b]200% to 300% increase = 2- to 3-fold increase. [c]Given wide variation in indications and timing of initiation of renal replacement therapy (RRT), individuals who receive RRT are considered to have met the criteria for stage 3 irrespective of the stage they are in at the time of RRT.

Mehta R. et al. Crit Care 2007

KDIGO

Staging of AKI based on the KDIGO Guidelines

Stage	Serum creatinine	Urine output
1	1.5–1.9 times the baseline value OR ≥0.3 mg/dl (≥26.5 mmol/l) increase within 48 hours	<0.5 ml/kg/h for 6–12 h
2	2.0–2.9 times the baseline value	<0.5 ml/kg/h for ≥12 h
3	3.0 times the baseline value OR Increase in serum creatinine to ≥4.0 mg/dl (≥353.6 mmol/l) OR Initiation of renal replacement therapy OR In patients <18 years, decrease in the estimated GFR to <35 ml/min per 1.73 m^2	<0.3 ml/kg/h for ≥24 h OR Anuria for ≥12 h

https://kdigo.org/

Kidney International Supplements (2012) 2

Inzidenz

- 8-16% aller hospitalisierten Patienten
- 30-50% ICU PatientInnen
- Erhöhtes Risiko für CKD
- Erhöhte Lang- und Kurzzeit-Mortalität

Inzidenz

SEVEN-DAY PROFILE PUBLICATION

Intensive Care Med (2015) 41:1411–1423
DOI 10.1007/s00134-015-3934-7

CrossMark

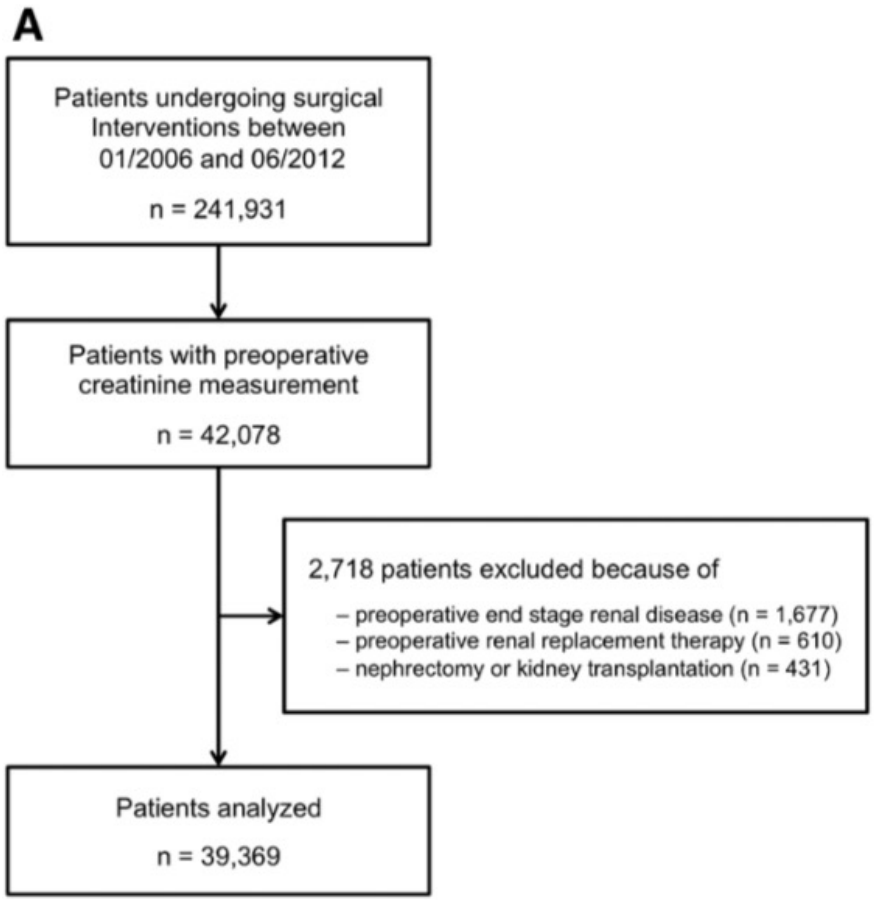
Epidemiology of acute kidney injury in critically ill patients: the multinational AKI-EPI study

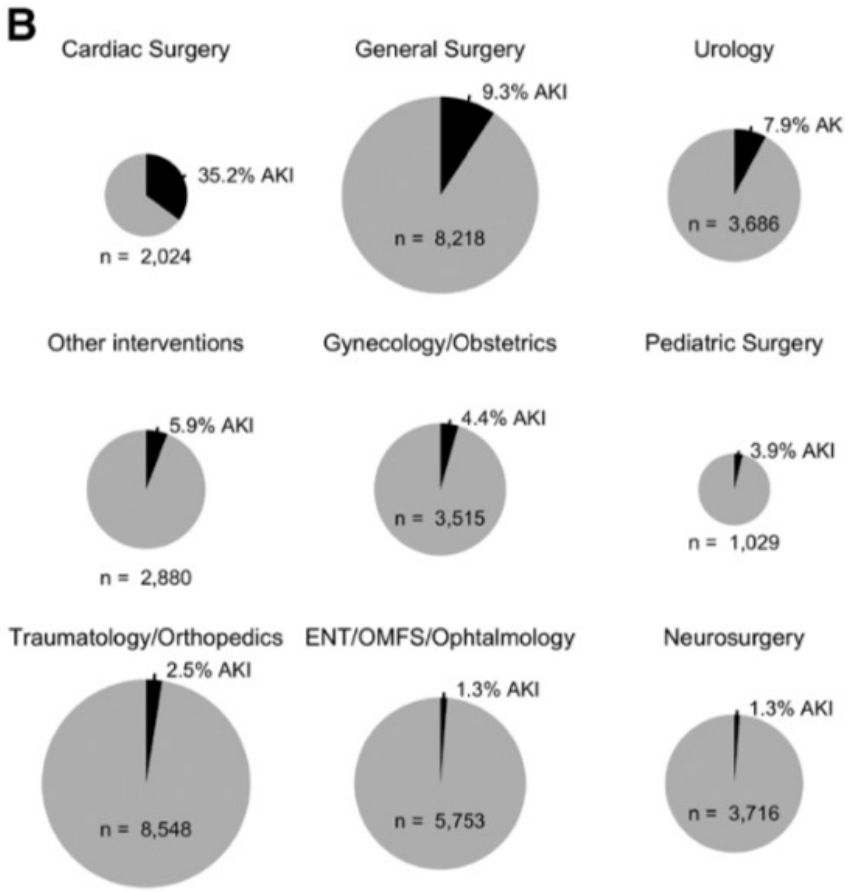
Table 2 Variables at the time of acute kidney injury ($n = 666$)

Etiology of AKI	
Sepsis	271 (40.7 %)
Hypovolemia	227 (34.1 %)
Drug related	96 (14.4 %)
Cardiogenic shock	88 (13.2 %)
Hepatorenal syndrome	21 (3.2 %)
Obstruction of the urine outflow tract	9 (1.4 %)
Predisposing factors for AKI	
Diuretic treatment	216 (32.4 %)
NSAID administration	79 (11.9 %)
Aminoglycoside administration	45 (6.8 %)
Glycopeptide administration	9 (1.4 %)
Amphotericin administration	0 (0 %)
Radiocontrast media administration	14 (2.1 %)

Hoste E. et al. Int Care Med 2015

Inzidenz





Kork F. et al. Anesthesiology 2015

Outcome

- Hohe Mortalität
  - 10-30%
  - 50% im Rahmen MOF
- 50% Restitutio
- 25-50% kompensierte Retention
- 10-15% chronisch dialysepflichtig

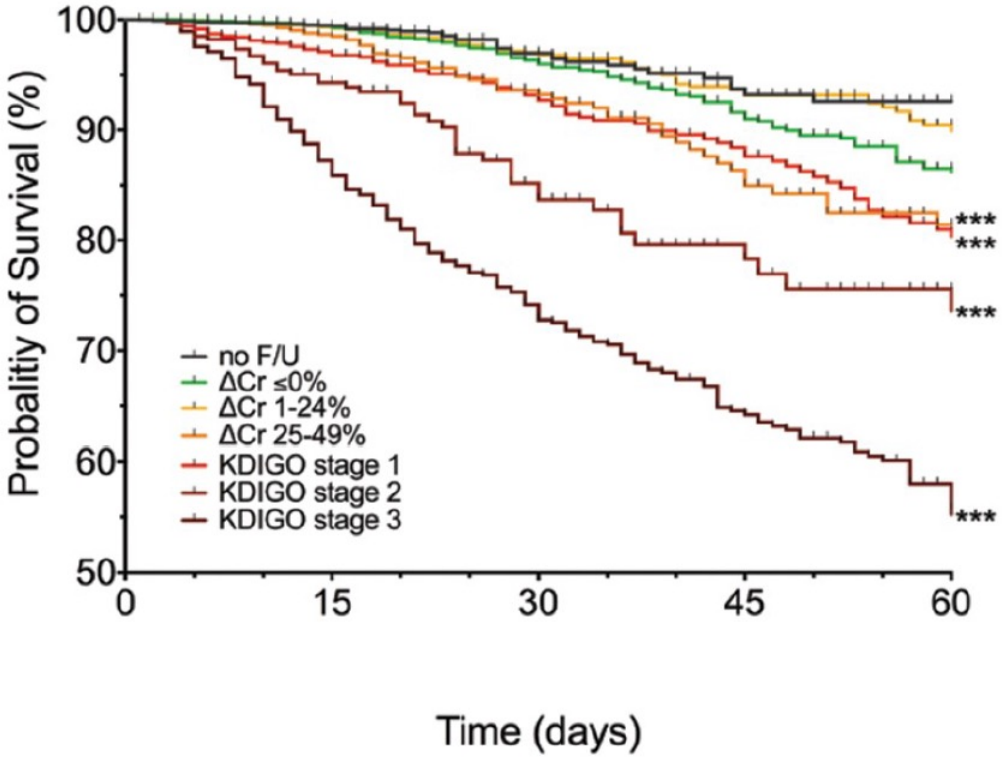
Outcome

ANÄSTHESIE FORUM ALPBACH REPETITORIUM

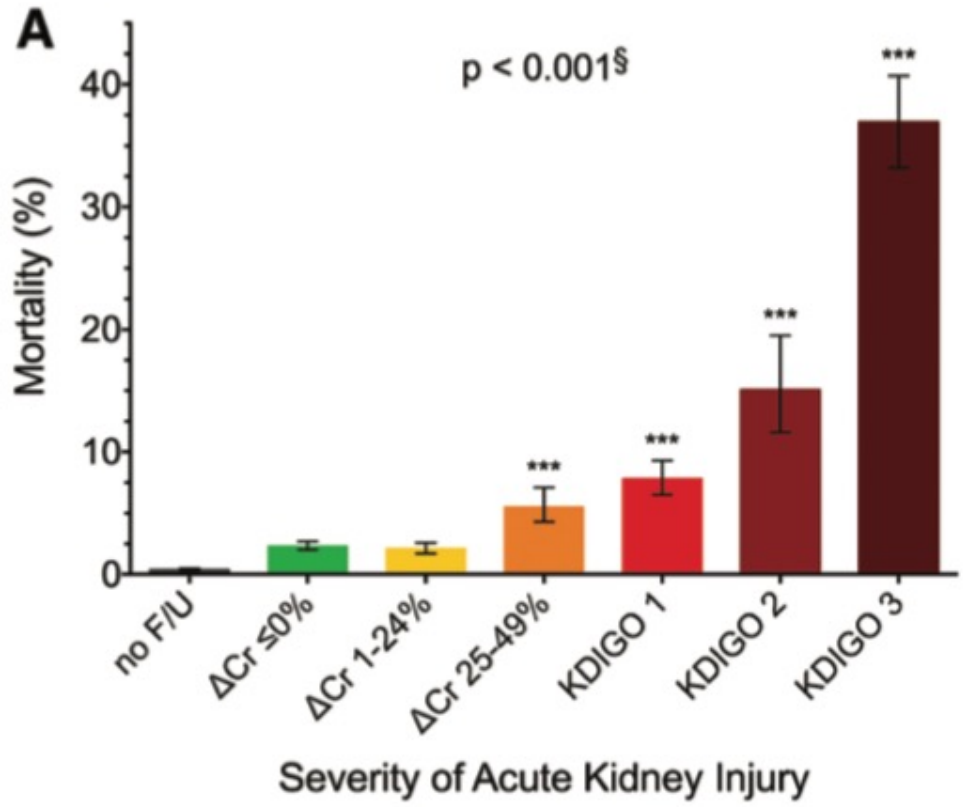
ANESTHESIOLOGY
Trusted Evidence: Discovery to Practice®

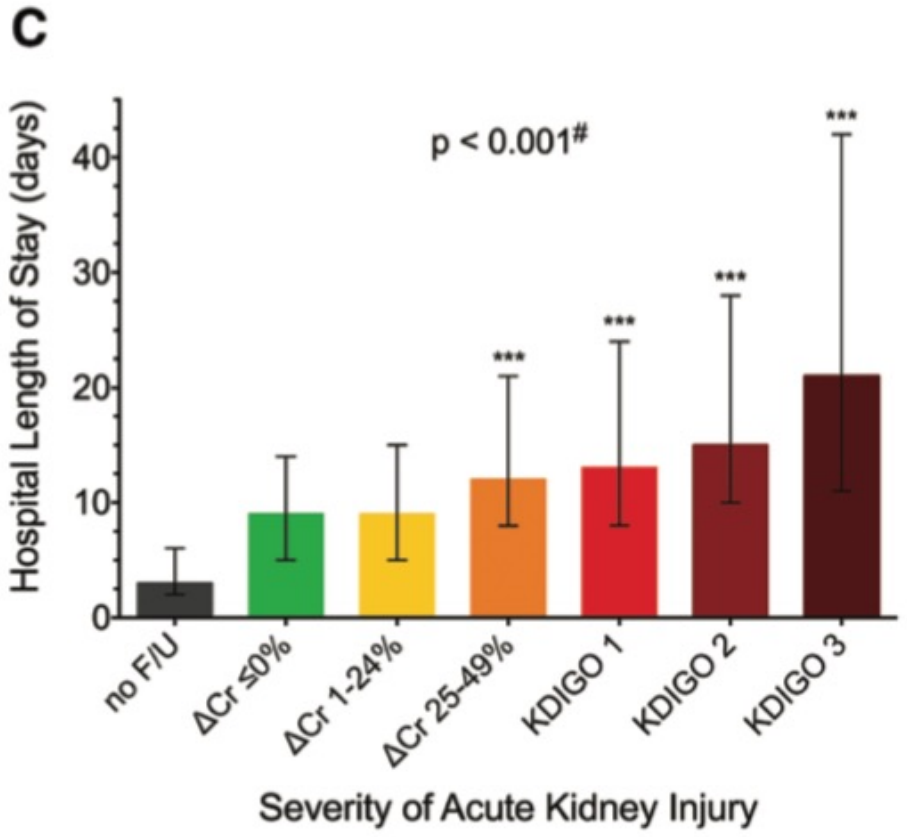
Minor Postoperative Increases of Creatinine Are Associated with Higher Mortality and Longer Hospital Length of Stay in Surgical Patients

Felix Kork, M.D., M.Sc., Felix Balzer, M.D., M.Sc., Claudia D. Spies, M.D., Klaus-Dieter Wernecke, Ph.D., Adit A. Ginde, M.D., M.P.H., Joachim Jankowski, Ph.D., Holger K. Eltzschig, M.D.



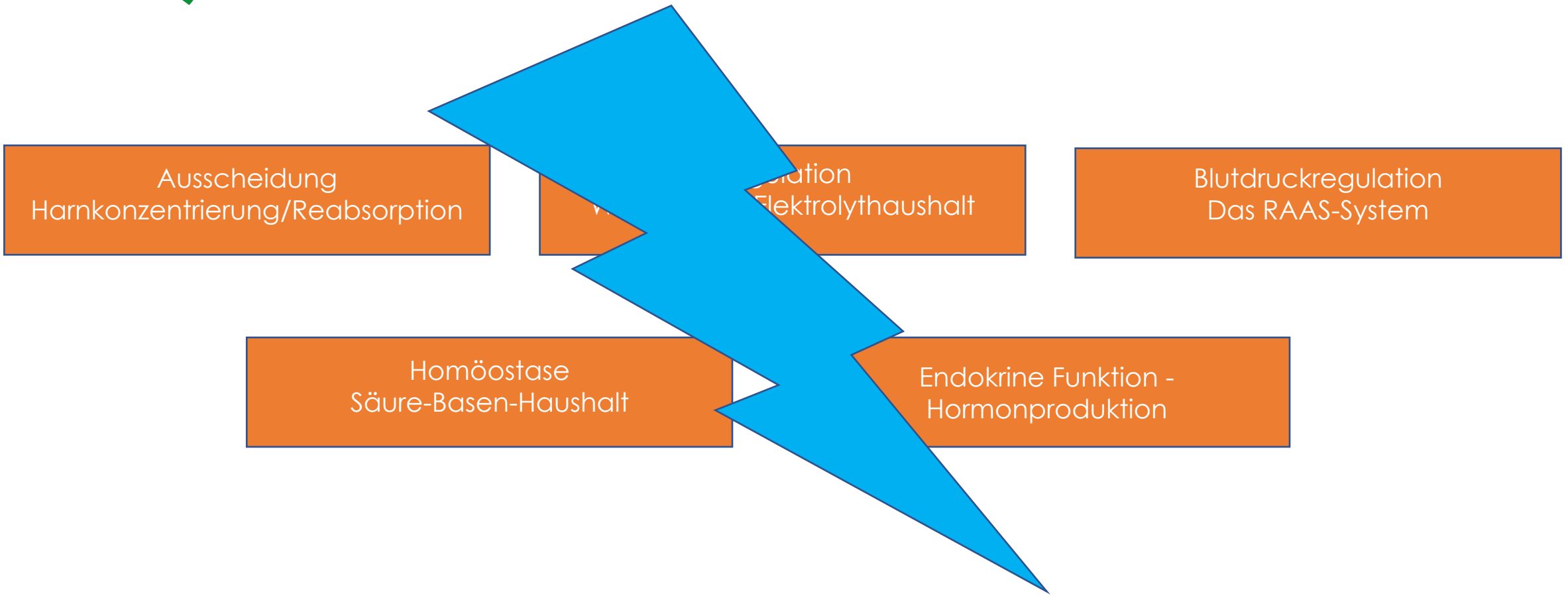
Outcome



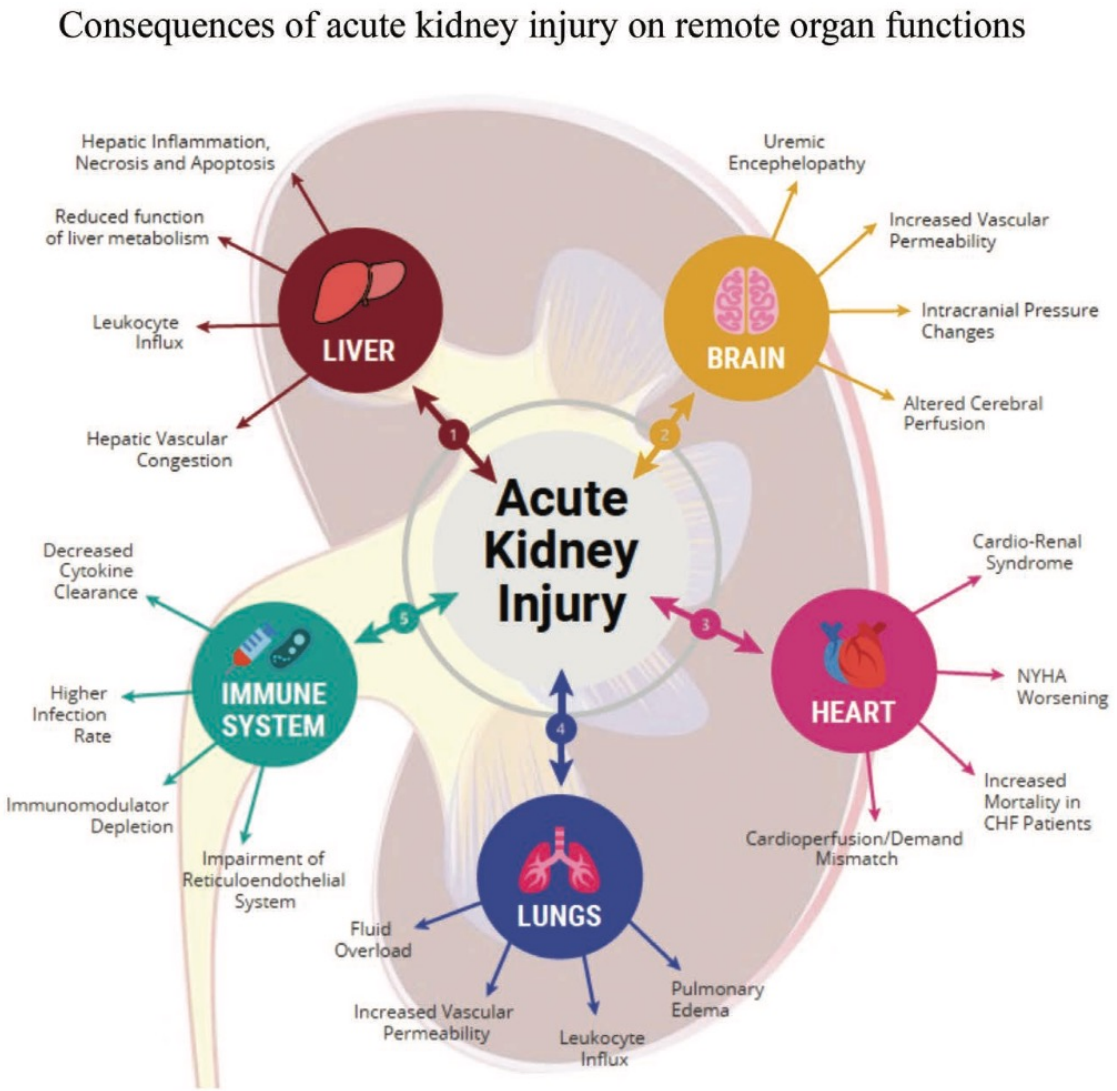


Kork F. et al. Anesthesiology 2015

Folgen

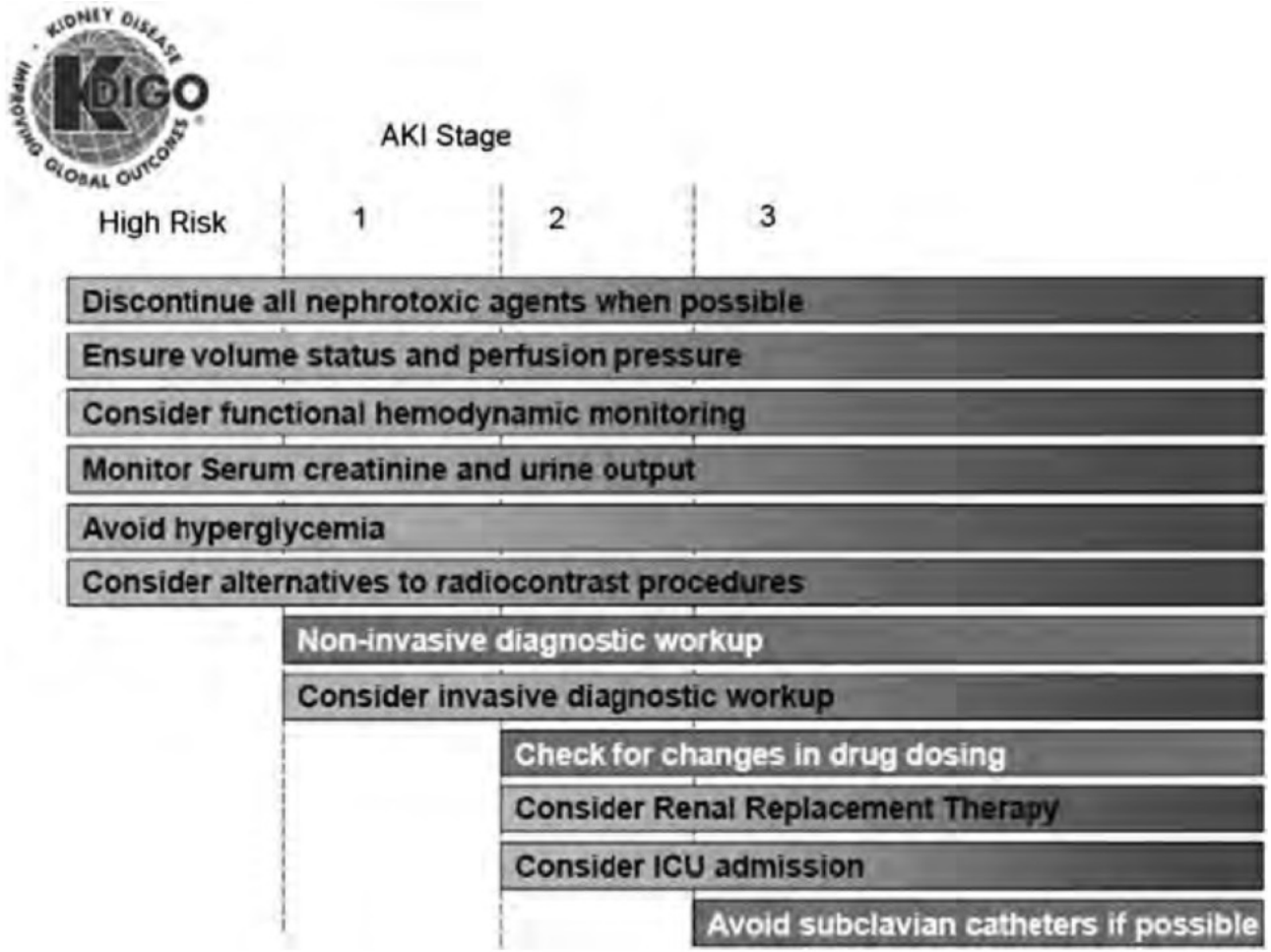

Ausscheidung
Harnkonzentrierung/Reabsorption
lation
lektrolythaushalt
Blutdruckregulation
Das RAAS-System
Homöostase
Säure-Basen-Haushalt
Endokrine Funktion -
Hormonproduktion

Acute Kidney injury



Gumbert et al. Anesthesiology 2020

AKI – was nun…



https://kdigo.org/

Kidney International Supplements (2012) 2,4

Prävention

- Medikamentöse Prävention nicht möglich
- Optimierung der renalen Perfusion
- Euvolämie
- Diuretika nur bei erhaltener Diurese zur Korrektur einer Hypervolämie
  - Hyperhydratation kann eine Nierenschädigung oder Verschlechterung der Nierenfunktion hervorrufen
- Einsatz von Diuretika zur Prävention der AKI ist mangels Wirksamkeit abzuraten
- Kontrastmittelgabe zur radiologischen Diagnostik oder Therapie dringend erforderlich, soll auch bei AKI-(Risiko-)Patienten nicht darauf verzichtet werden

Empfehlungen der Sektionen Niere der DGIIN, ÖGIAIN und DIVI
Med Klin Intensivmed Notfmed 2018

Volumenstatus

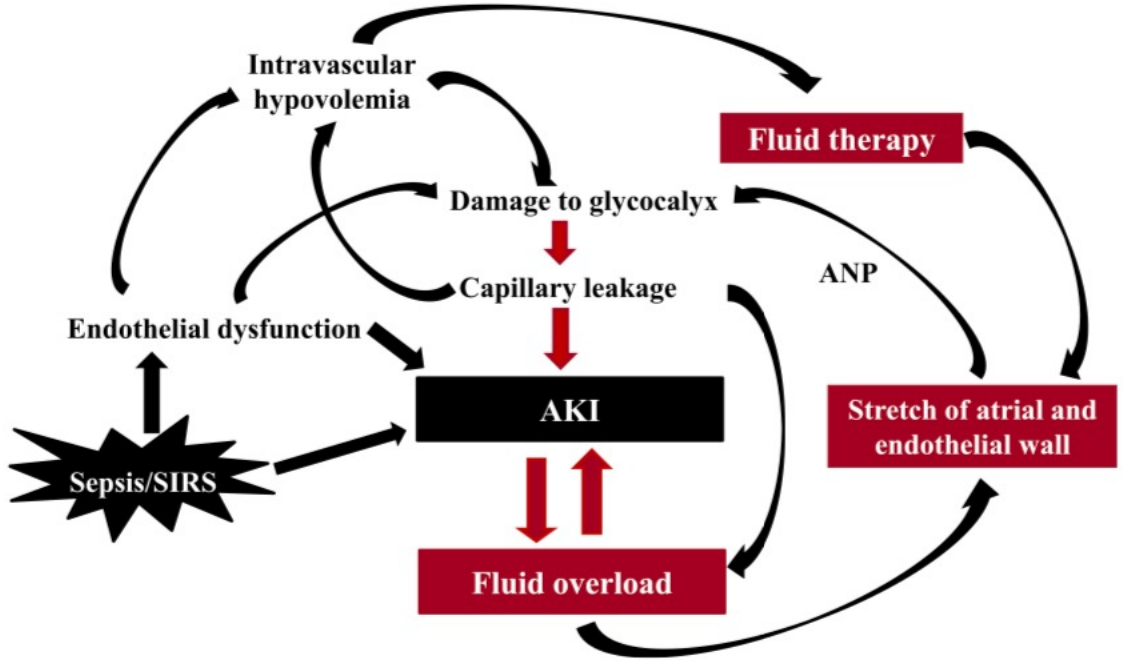


Fig. 1 Interconnected relationship between acute kidney injury and fluid overload. *AKI* acute kidney injury, *ANP* atrial natriuretic peptide, *SIRS* systemic inflammatory response syndrome

Ostermann M et al. Crit Care 2015

Volumentherapie

Patients	Albumin Group	Saline Group	Relative Risk (95% CI)
	no. of deaths/total no.		
Overall	726/3473	729/3460	0.99 (0.91–1.09)
Trauma			
Yes	81/596	59/590	1.36 (0.99–1.86)
No	641/2831	666/2830	0.96 (0.88–1.06)
Severe sepsis			
Yes	185/603	217/615	0.87 (0.74–1.02)
No	518/2734	492/2720	1.05 (0.94–1.17)
ARDS			
Yes	24/61	28/66	0.93 (0.61–1.41)
No	697/3365	697/3354	1.00 (0.91–1.09)

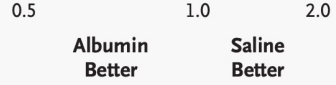
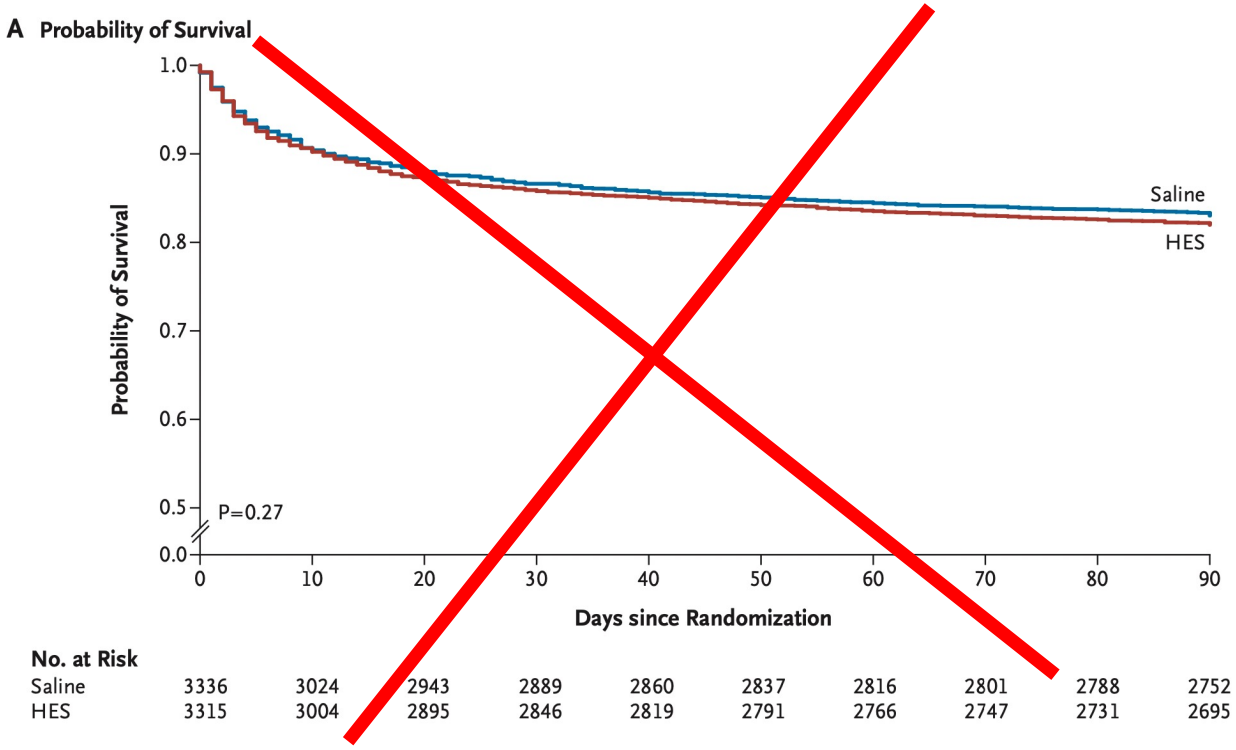


Figure 2. Relative Risk of Death from Any Cause among All the Patients and among the Patients in the Six Predefined Subgroups.

The size of each symbol indicates the relative number of events in the given group. The horizontal bars represent the confidence intervals (CI). ARDS denotes the acute respiratory distress syndrome.



Finfer S et al. NEJM 2004
Myburgh JA et al. NEJM 2012

HES

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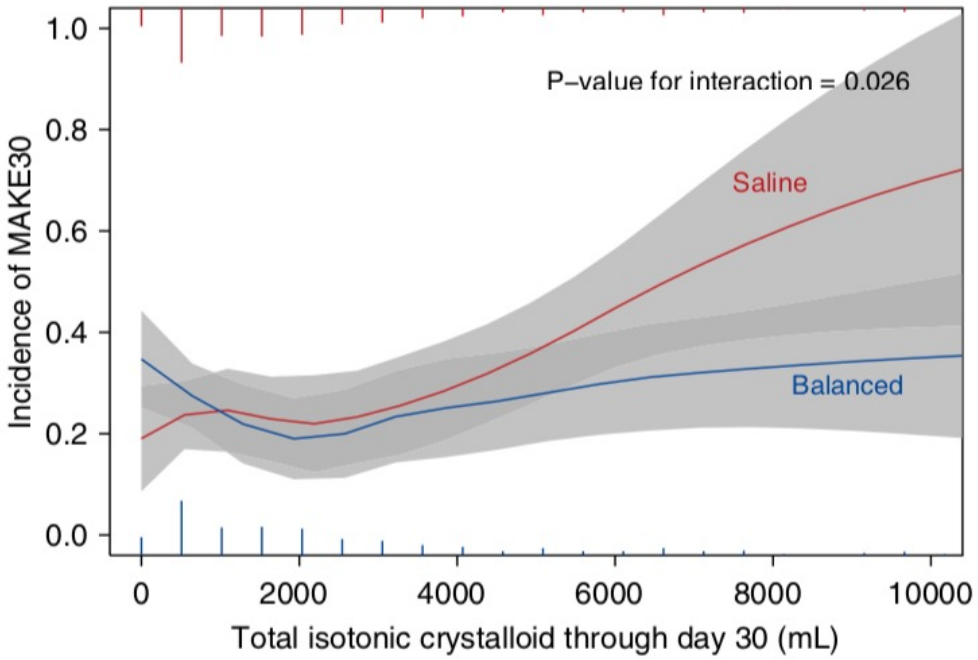
12 January 2018
EMA/4068/2018

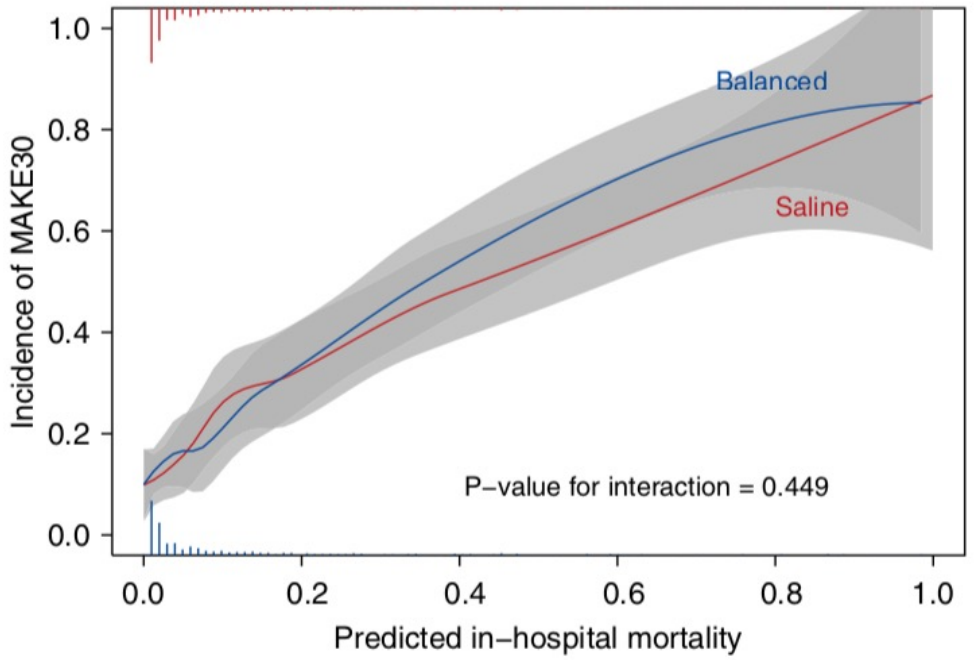
EUROPEAN MEDICINES AGENCY
SCIENCE MEDICINES HEALTH

PRAC recommends suspending hydroxyethyl-starch solutions for infusion from the market

Review finds measures to protect patients have not been sufficiently effective

Volumentherapie





- NaCl 0,9% vs balanciertes Kristalloid
- MAKE30 (in-hospital mortality, receipt of new RRT, or persistent renal dysfunction)

Semler MW et al. AJRCCM 2017

Volumentherapie

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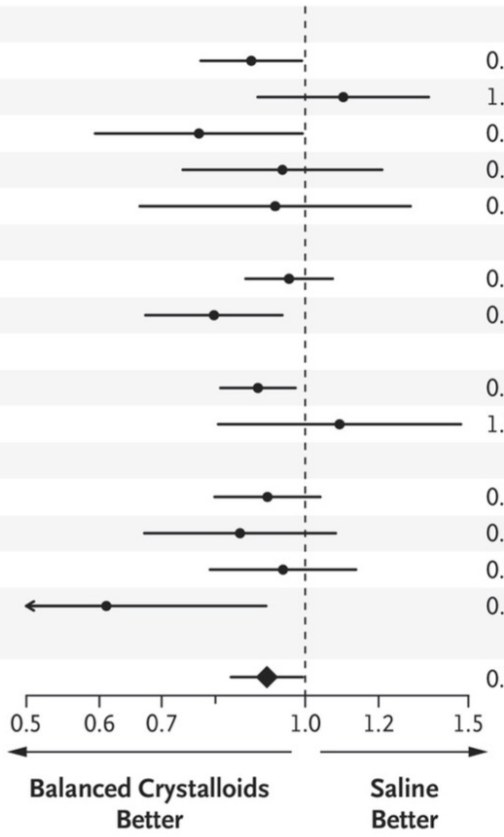
Subgroup	Balanced Crystalloids	Saline	Odds Ratio (95% CI)	P Value	P Value for Interaction
	no. of events/total no. (%)				
Unit					0.27
Medical	615/2735 (22.5)	659/2646 (24.9)	0.87 (0.77–0.99)	0.04	
Cardiac	202/1470 (13.7)	190/1501 (12.7)	1.10 (0.89–1.36)	0.38	
Neurologic	116/1440 (8.1)	141/1377 (10.2)	0.77 (0.59–0.99)	0.04	
Trauma	131/1640 (8.0)	142/1688 (8.4)	0.95 (0.74–1.21)	0.66	
Surgical	75/657 (11.4)	79/648 (12.2)	0.93 (0.66–1.30)	0.66	
Sepsis					0.06
No	744/6775 (11.0)	756/6691 (11.3)	0.96 (0.86–1.07)	0.47	
Yes	395/1167 (33.8)	455/1169 (38.9)	0.80 (0.67–0.94)	0.01	
Traumatic brain injury					0.24
No	1034/7244 (14.3)	1118/7195 (15.5)	0.89 (0.81–0.98)	0.01	
Yes	105/698 (15.0)	93/665 (14.0)	1.09 (0.81–1.47)	0.58	
Categories of kidney function					0.19
Normal	476/5596 (8.5)	514/5561 (9.2)	0.91 (0.80–1.04)	0.16	
Acute kidney injury	315/574 (54.9)	316/537 (58.8)	0.85 (0.67–1.08)	0.18	
Chronic kidney disease	301/1388 (21.7)	307/1360 (22.6)	0.95 (0.79–1.13)	0.55	
Previous renal-replacement therapy	47/384 (12.2)	74/402 (18.4)	0.61 (0.41–0.91)	0.01	
Overall	1139/7942 (14.3)	1211/7860 (15.4)	0.91 (0.83–0.99)	0.04	



Semler MW et al. NEJM 2018

Hyperhydratation

Table 2. ROC Analysis for RRT Requirement After LVAD

	AUC-ROC
Plasma NGAL (pre)	0.83 [0.54–0.95]#
Plasma NGAL (0h)	0.86 [0.66–0.95]#
Serum Cre (pre)	0.70 [0.39–0.90]
Serum Cre (0h)	0.67 [0.33–0.89]
Cre socre	0.77 [0.40–0.95]
TB (pre)	0.44 [0.16–0.77]
TB score	0.78 [0.57–0.91]#
CVP (pre)	0.80 [0.56–0.93]#
CVP at 12h	0.89 [0.70–0.97]#
Urine volume (0–6h)	0.82 [0.51–0.95]#

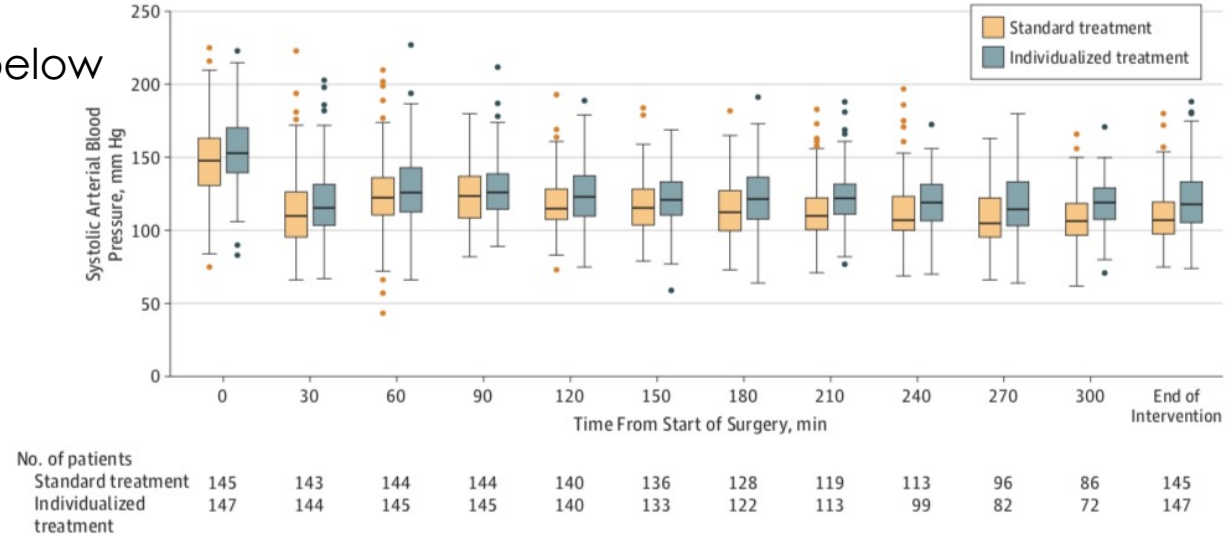
Sumida M et al. Circ J 2014

Perfusionsdruck

JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

Effect of Individualized vs Standard Blood Pressure Management Strategies on Postoperative Organ Dysfunction Among High-Risk Patients Undergoing Major Surgery
A Randomized Clinical Trial

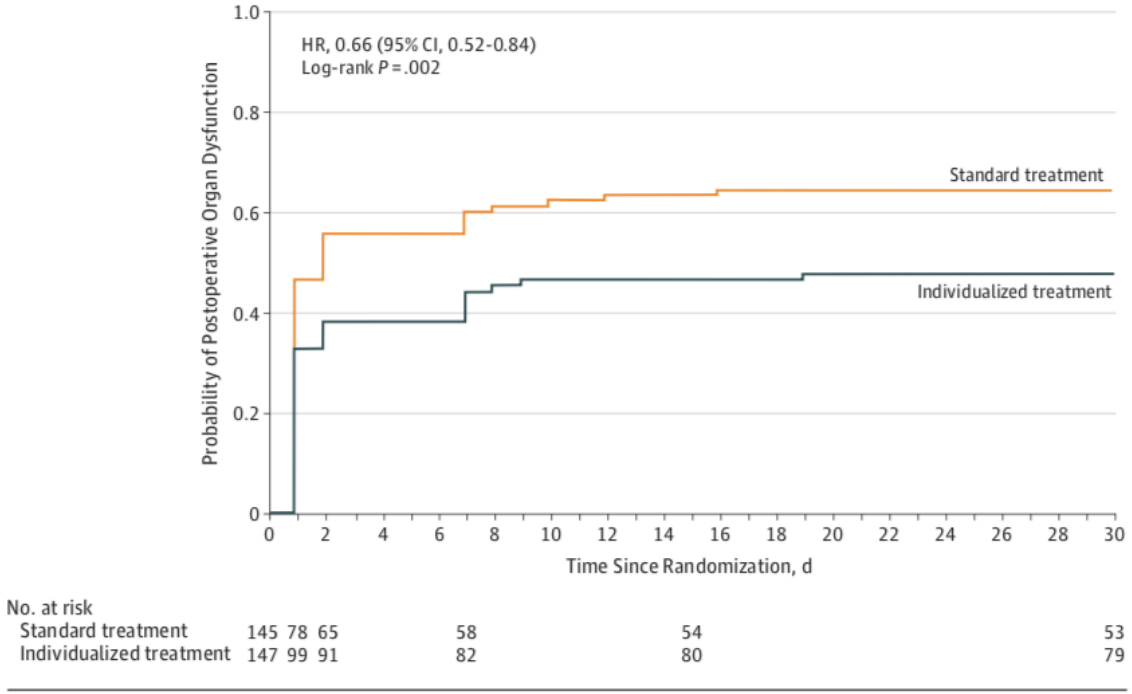
- Standard treatment group
  - ephedrine iv 6-mg boluses for any decrease in SBP below 80 mm Hg or lower than 40% from the patient's reference value
- Individualized treatment group
  - SBP within ±10% of the reference value using a continuous infusion of norepinephrine
- Primary outcome
  - composite of SIRS + at least 1 organ system dysfunction



Futier E et al. JAMA 2017

Perfusionsdruck

Variable	Individualized Treatment (n = 147)	Standard Treatment (n = 145)	Between-Group Absolute Difference, % (95% CI)	Unadjusted Relative Risk (95% CI)	*P* Value	Adjusted Relative Risk (95% CI)[a]	*P* Value
Primary Outcome							
Primary composite outcome, No. (%)[b]	56 (38.1)	75 (51.7)	−14 (−25 to −2)	0.74 (0.57 to 0.95)	.02	0.73 (0.56 to 0.94)	.02



Renal dysfunction (RIFLE stage of risk or higher) occurred in 48 patients (32.7%) in the individualized treatment group and 71 patients (49.0%) in the standard treatment group (absolute risk difference, −16%; 95% CI, −27% to −5%; adjusted relative risk, 0.70; 95% CI, 0.53 to 0.92; *P* = .01). Al-

Conclusions

Among patients predominantly undergoing abdominal surgery who were at increased postoperative risk, management targeting an individualized systolic blood pressure, compared with standard management, reduced the risk of postoperative organ dysfunction.

Futier E et al. JAMA 2017

Vasopressortherapie

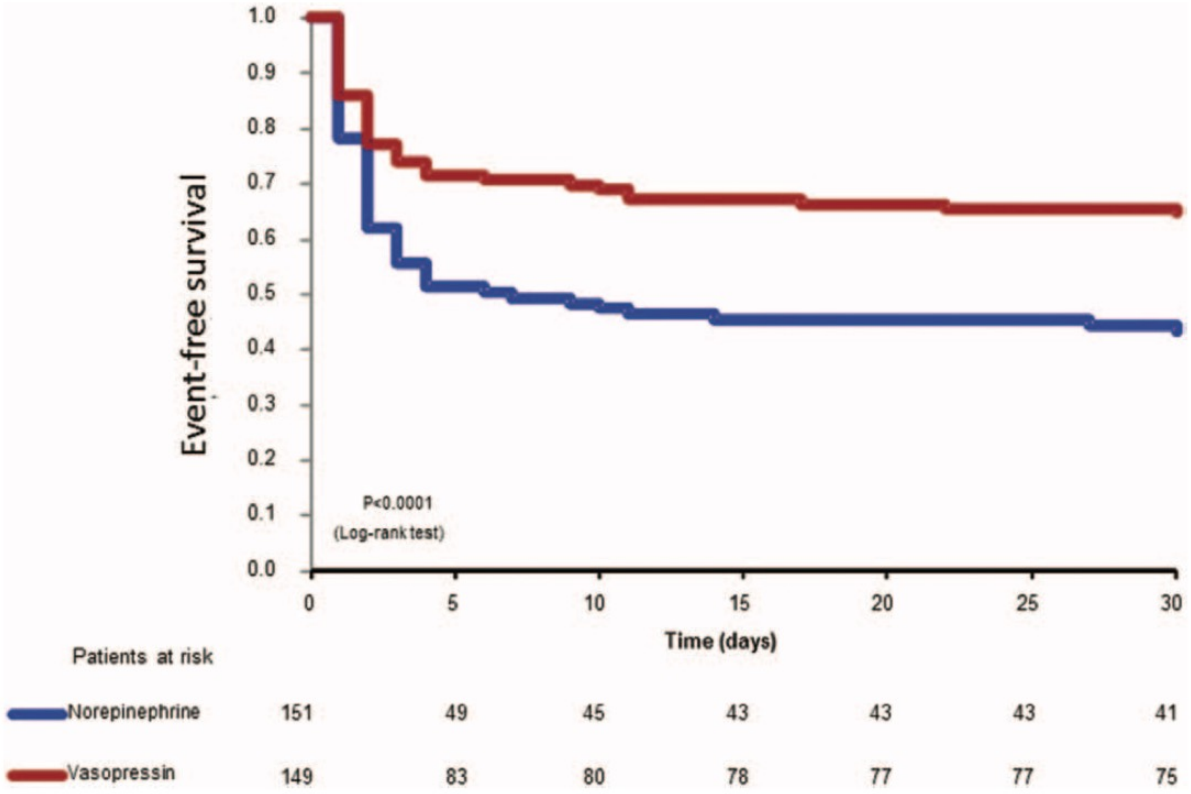
ANÄSTHESIE FORUM ALPBACH REPETITORIUM

CRITICAL CARE MEDICINE

Vasopressin *versus* Norepinephrine in Patients with Vasoplegic Shock after Cardiac Surgery

The VANCS Randomized Controlled Trial

Variable	Norepinephrine (n = 151)	Vasopressin (n = 149)	Unadjusted Odds Ratio or Hazard Ratio or Between-group Difference (95% CI)	*P* Value	Adjusted* Odds Ratio or Hazard Ratio or Between-group Difference (95%CI)	*P* Value
Primary outcome, n (%)	74 (49.0)	48 (32.2)	0.55 (0.38 to 0.80)	0.0014	0.52 (0.36 to 0.75)	0.0005
30-d mortality	24 (15.9)	23 (15.4)	0.99 (0.56 to 1.76)	0.98	1.11 (0.62 to 1.96)	0.73
MV > 48 h	13 (8.6)	8 (5.4)	0.62 (0.26 to 1.49)	0.28	0.62 (0.26 to 1.51)	0.30
Sternal wound infection	15 (9.9)	7 (4.7)	0.46 (0.19 to 1.13)	0.09	0.48 (0.19 to 1.18)	0.11
Reoperation	10 (6.6)	10 (6.7)	0.8 (0.52 to 1.23)	0.31	0.79 (0.51 to 1.22)	0.28
Stroke	4 (2.6)	4 (2·7)	1.03 (0.26 to 4.11)	0.97	1.08 (0.27 to 4.39)	0.91
Acute renal failure	54 (35.8)	15 (10.3)	0.26 (0.15 to 0.46)	< 0.0001	0.26 (0.15 to 0.46)	< 0.0001
Secondary outcomes, n (%)						
Infection	23 (15.2)	16 (10.7)	0.67 (0.34 to 1.33)	0.25	0.71 (0.35 to 1.42)	0.33
Septic shock	13 (8.6)	9 (6.0)	0.68 (0.28 to 1.65)	0.40	0.73 (0.3 to 1.81)	0.50
Atrial fibrillation	124 (82.1)	95 (63.8)	0.38 (0.22 to 0.65)	0.0004	0.37 (0.22 to 0.64)	0.0004
Ventricular arrhythmias	32 (21.2)	27 (18.1)	0.82 (0.46 to 1.46)	0.50	0.8 (0.45 to 1.43)	0.45
Length of ICU stay (d), median (IQR)	6 (4 to 9)	5 (4 to 7)	−2.42 (−4.11 to −0.73)	0.0050	−2.28 (−3.94 to −0.62)	0.0071
Length of hospital stay (d), median (IQR)	13 (10 to 20)	10 (8 to 12)	−3.76 (−6.1 to −1.42)	0.0016	−3.66 (−6.01 to −1.32)	0.0022



Nephrotoxine

- Laufende Medikation regelmäßig evaluieren
- ACE-Hemmer und ATII-Blocker pausieren
- Nephrotoxische Pharmaka absetzen
  - Aminoglykoside: tägl. Einzelgaben
  - Vancomycin: kontinuierliche Infusion
  - Kombination von Vancomycin mit Pipitaz höheres Risiko

Empfehlungen der Sektionen Niere der DGIIN, ÖGIAIN und DIVI
Med Klin Intensivmed Notfmed 2018

Kontrastmittel-assoziiertes AKI

Intensive Care Med (2023) 49:205–215
https://doi.org/10.1007/s00134-022-06966-w

ORIGINAL

Renal outcomes following intravenous contrast administration in patients with acute kidney injury: a multi-site retrospective propensity-adjusted analysis

Michael R. Ehmann[1*], Jonathon Mitchell[1], Scott Levin[1], Aria Smith[1], Steven Menez[2], Jeremiah S. Hinson[1] and Eili Y. Klein[1,3]

Conclusions

Among nearly 14,500 patients who met KDIGO sCr-based criteria for AKI on arrival to the ED, we found no independent association between the administration of CM and persistence of AKI or an increased risk of dialysis initiation within 180 days. Our findings suggest that the recent ACR-NKF consensus recommendations for use of IV CM in patients with stable renal disease may also be applied to patients with pre-existing AKI [16, 17].

- Risiko bei isoosmolaren Kontrastmittel sehr gering
- Wichtige diagn. Untersuchungen od. Interventionen nicht verzögern

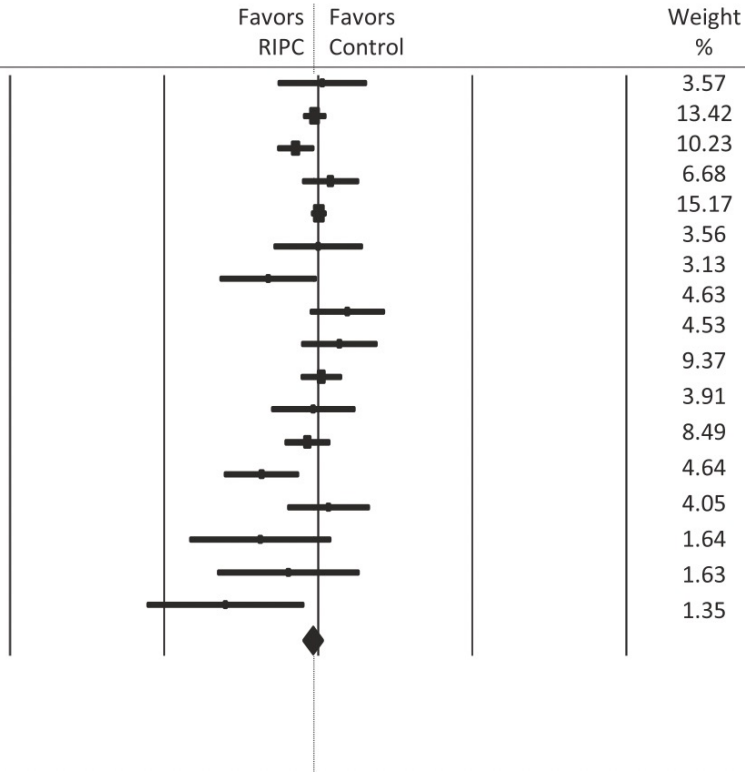
Rozenbaum Z et al. Nephron 2018
Goto Y et al. Crit Care 2019
Ehmann M et al. ICM 2023

Prävention – Remote ischemic preconditioning

Effects of RIPC on Incidence of IR-AKI	RIPC Group No. of Events	RIPC Group Total	Control Group No. of Events	Control Group Total	RR (95%CI)	Weight %
Pınaud et al 2016	13	50	12	49	1.062(0.539-2.093)	3.57
Hu et al 2016	68	101	71	100	0.948(0.788)1.141	13.42
Zarbock et al 2015	45	120	63	120	0.714(0.536-0.952)	10.23
Meybohm et al 2015	42	692	35	693	1.202(0.777-1.859)	6.68
Hausenloy et al 2015	287	749	293	772	1.010(0.888-1.147)	15.17
Gallagher et al 2015	12	43	12	43	1.000(0.507-1.973)	3.56
Candilio et al 2015	9	89	19	89	0.474(0.227-0.990)	3.13
Murphy et al 2014	17	31	11	31	1.545(0.872-2.739)	4.63
Mouton et al 2014	16	34	12	35	1.373(0.768-2.454)	4.53
Hong et al 2014	70	644	66	636	1.047(0.762-1.439)	9.37
Young et al 2012	13	48	14	48	0.929(0.490-1.761)	3.91
Pedersen et al 2012	27	54	30	51	0.850(0.598-1.209)	8.49
Zimmerman et al 2011	12	59	28	59	0.429(0.242-0.759)	4.64
Choi et al 2011	14	38	12	38	1.167(0.624-2.183)	4.05
Venugopal et al 2010	4	38	10	40	0.421(0.144-1.229)	1.64
Rahman et al 2010	5	80	8	82	0.641(0.219-1.875)	1.63
Ali et al 2007	3	41	12	41	0.250(0.076-0.821)	1.35
Subtotal(95%CI)		2911		2927	0.905(0.783-1.045)	
Total events	657		708			

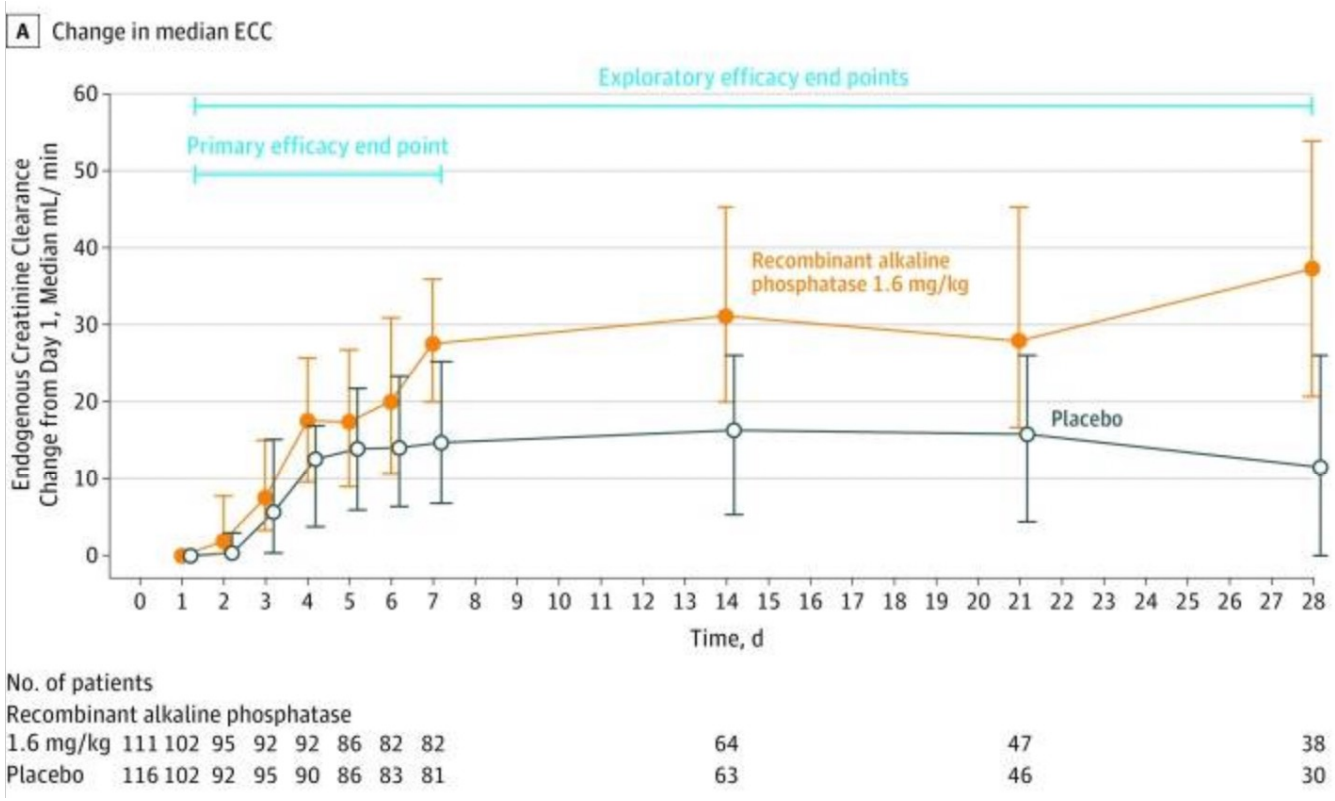
Heterogeneity: Tau^2=0.031; Q=29.819; df=16; (P=0.019); I^2=46%

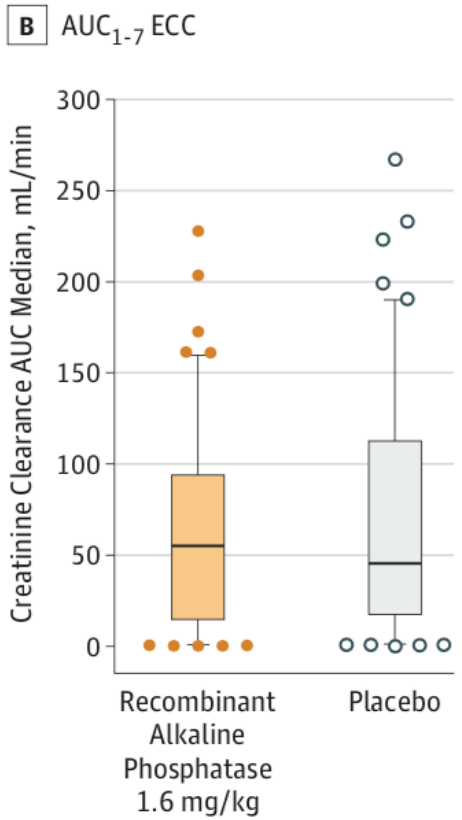
Test for overall effect: Z=--1.362, (P=0.173)



Hu J et al. Crit Care 2016

Prävention – Alkalische Phosphatase





Pickkers P et al. JAMA 2018

Prävention – Care bundles

- High-risk Patient:innen
- Renoprotektive Maßnahmen
  - Vermeidung von nephrotox. Substanzen
  - Keine ACEI/ARB für 48h
  - Vermeiden von Hyperglykämie
  - Engmaschiges SCr & UO Monitoring
  - Erweitertes hämodynamisches Monitoring
  - Optimierter Volumenstatus
  - KM-Alternativen

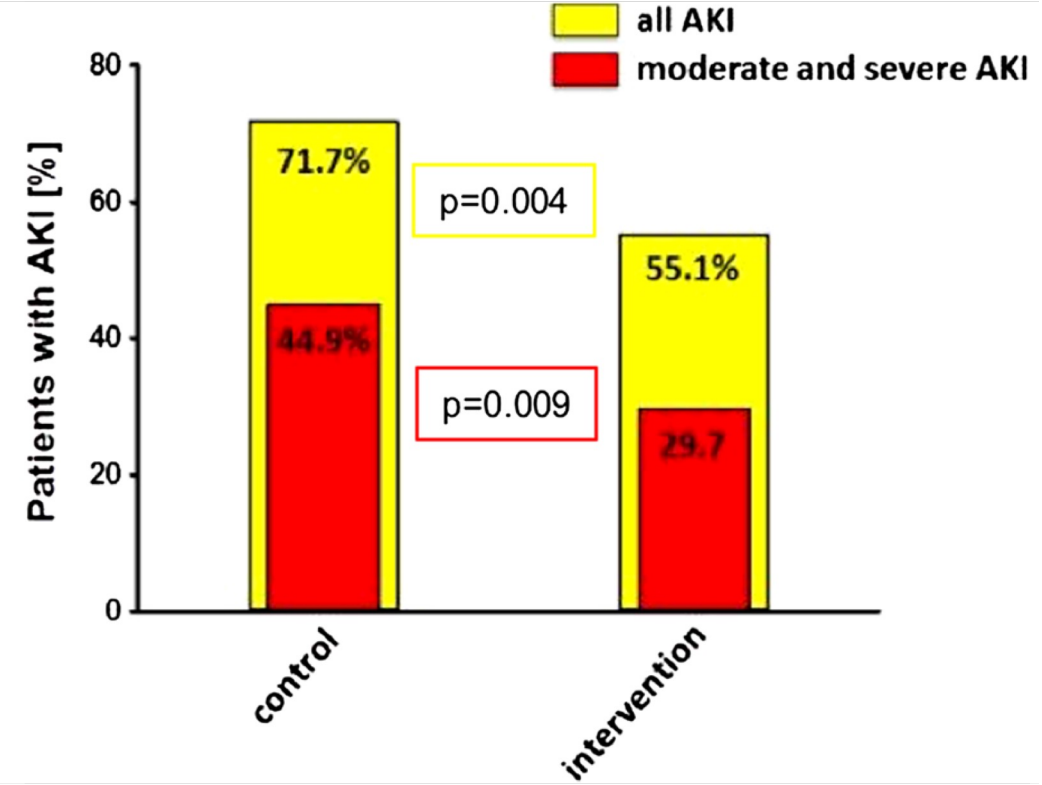


Fig. 2 Occurrence of cardiac surgery-associated AKI. Rate of CSA-AKI in control and intervention groups

Meersch M et al. ICM 2017

Prävention – Care bundles

ANÄSTHESIE FORUM
ALPBACH
REPETITORIUM

Intensive Care Med (2017) 43:1551–1561
DOI 10.1007/s00134-016-4670-3

Prevention of Cardiac Surgery–Associated Acute Kidney Injury by Implementing the KDIGO Guidelines in High-Risk Patients Identified by Biomarkers: The PrevAKI-Multicenter Randomized Controlled Trial

Zarbock, Alexander MD[*]; Küllmar, Mira MD[*]; Ostermann, Marlies MD[†]; Lucchese, Gianluca MD[†]; Baig, Kamran MD[†]; Cennamo, Armando MD[†]; Rajani, Ronak MD[†]; McCorkell, Stuart MD[†]; Arndt, Christian MD[‡]; Wulf, Hinnerk MD[‡]; Irqsusi, Marc MD[§]; Monaco, Fabrizio MD[‖]; Di Prima, Ambra Licia MD[‖]; García Alvarez, Mercedes MD[¶]; Italiano, Stefano MD[¶]; Miralles Bagan, Jordi MD[¶]; Kunst, Gudrun MD[#]; Nair, Shrijit MD[#]; L'Acqua, Camilla MD[**]; Hoste, Eric MD[††]; Vandenberghe, Wim MD[††]; Honore, Patrick M. MD[‡‡]; Kellum, John A. MD[§§]; Forni, Lui G. MD[‖‖]; Grieshaber, Philippe MD[¶¶]; Massoth, Christina MD[*]; Weiss, Raphael MD[*]; Gerss, Joachim PhD[##]; Wempe, Carola PhD[*]; Meersch, Melanie MD[*]

Author Information

Anesthesia & Analgesia: August 2021 - Volume 133 - Issue 2 - p 292-302
doi: 10.1213/ANE.0000000000005458

SEVEN-DAY PROFILE PUBLICATION

CrossMark

Prevention of cardiac surgery-associated AKI by implementing the KDIGO guidelines in high risk patients identified by biomarkers: the PrevAKI randomized controlled trial

Melanie Meersch[1], Christoph Schmidt[1], Andreas Hoffmeier[2], Hugo Van Aken[1], Carola Wempe[1], Joachim Gerss[3] and Alexander Zarbock[1*]

RANDOMIZED CONTROLLED TRIALS

Biomarker-guided Intervention to Prevent Acute Kidney Injury After Major Surgery

The Prospective Randomized BigpAK Study

Göcze, Ivan MD[*]; Jauch, Dominik MD[†]; Götz, Markus MD[*]; Kennedy, Pascal[*]; Jung, Bettina MD[‡]; Zeman, Florian[§]; Gnewuch, Carsten MD[¶]; Graf, Bernhard M. MD[‖]; Gnann, Wolfgang[**]; Banas, Bernhard MD[‡]; Bein, Thomas MD[‖]; Schlitt, Hans J. MD[*]; Bergler, Tobias MD[‡]

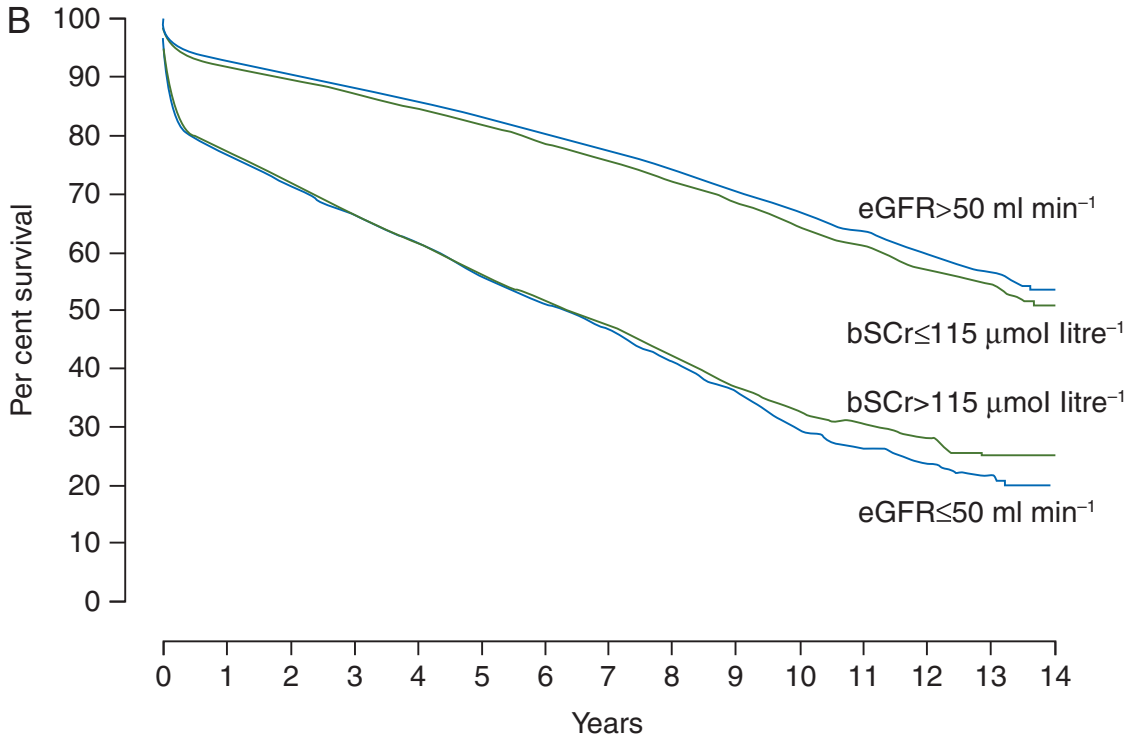
Präoperative Risikofaktoren

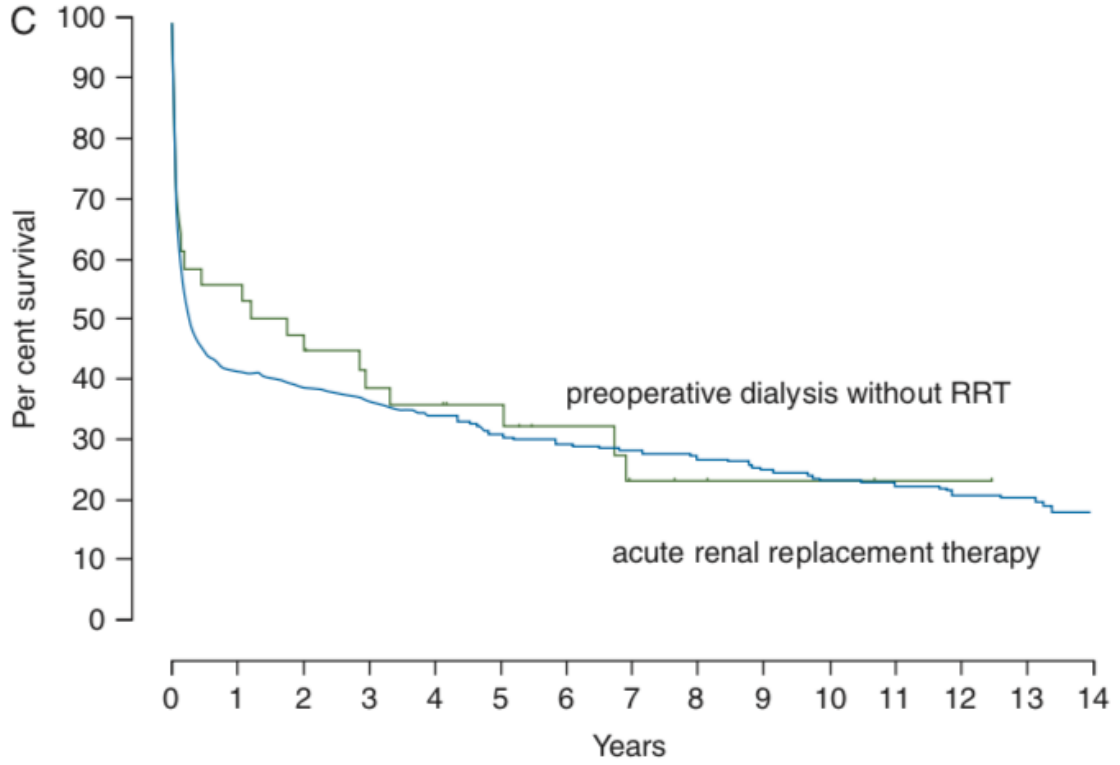
- Nierenfunktion beeinflusst Kurz- und Langzeitüberleben
- Erhöhtes präoperatives Serumkreatinin ist ein unabhängiger Risikofaktor

Variables	Univariate		Multivariate			
			Short-term survival (≤150 days)		Long-term survival (>150 days)	
	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Preoperative risk factors						
bSCR (μmol litre^{-1})	1.29 (1.26–1.32)	<0.0001				
$bSCr_{high}$ (μmol litre^{-1})	2.61 (2.43–2.80)	<0.0001	1.59 (1.38–1.83)	0.0027	1.46 (1.32–1.62)	<0.0001
eGFR (ml min^{-1})	0.97 (0.975–0.978)	<0.0001				
$eGFR_{low}$ (ml min^{-1})	2.86 (2.67–3.06)	<0.0001				
CKD Stage 1 (ml min^{-1})	1					
Stage 2	1.94 (1.72–2.19)	<0.0001				
Stage 3	3.83 (3.42–4.30)	<0.0001				
Stage 4	7.89 (6.70–9.30)	<0.0001				
Stage 5	8.32 (6.84–10.12)	<0.0001				
Female	1.20 (1.12–1.29)	<0.0001			0.87 (0.79–0.95)	0.0024
Age (yr)	1.06 (1.05–1.06)	<0.0001	1.04 (1.03–1.05)	<0.0001	1.05 (1.05–1.06)	<0.0001
BMI (kg m^{-2})	0.97 (0.97–0.98)	<0.0001				
Congestive heart failure	2.00 (1.85–2.17)	<0.0001	1.42 (1.22–1.65)	0.0002		
Diabetes	1.59 (1.48–1.71)	<0.0001			1.37 (1.25–1.50)	<0.0001
Angina pectoris (absence of)	1		1			
Angina, stable	0.76 (0.70–0.82)	<0.0001	0.70 (0.58–0.83)	<0.0001		
Angina, unstable	0.96 (0.88–1.05)	0.3984	1.21 (1.02–1.44)	0.0289		
Infarction	1.25 (1.17–1.35)	<0.0001				
LVEF >50%	1				1	
LVEF 30–50%	1.49 (1.39–1.60)	<0.0001			1.27 (1.17–1.39)	<0.0001
LVEF <30%	2.44 (2.18–2.74)	<0.0001			1.65 (1.42–1.92)	<0.0001
Atrial fibrillation	1.96 (1.81–2.13)	<0.0001			1.52 (1.38–1.69)	<0.0001
PAOD	1.47 (1.37–1.57)	<0.0001			1.20 (1.10–1.30)	<0.0001
COPD	1.55 (1.42–1.70)	<0.0001			1.40 (1.25–1.56)	<0.0001
History of CKD	2.76 (2.48–3.06)	<0.0001			1.30 (1.12–1.51)	0.0006
EuroSCORE	1.20 (1.19–1.21)	<0.0001				
Logistic EuroSCORE	1.07 (1.035–1.039)	<0.0001				
Medications						
Diuretics	1.90 (1.78–2.04)	<0.0001			1.27 (1.16–1.38)	<0.0001
ACE-inhibitors	1.19 (1.11–1.28)	<0.0001				

Bernardi MH et al. Br J Anaesth 2015

Präoperative Risikofaktoren





Bernardi MH et al. Br J Anaesth 2015

Perioperative Risikofaktoren

ANÄSTHESIE FORUM ALPBACH REPETITORIUM

Duration from end of surgery to metabolic panel draw (hour)

2

Pre-operative serum creatinine (mg/dl)

1,1

Post-operative serum creatinine (mg/dl)

1,3

Post-operative serum albumin (mg/dl)

2,6

Post-operative BUN (mg/dl)

45

Post-operative serum potassium (mmol/L)

4,4

Post-operative serum sodium (mmol/L)

135

Post-operative serum bicarbonate (mmol/L)

21

Original Investigation FREE

March 8, 2022

Predictive Accuracy of a Perioperative Laboratory Test–Based Prediction Model for Moderate to Severe Acute Kidney Injury After Cardiac Surgery

Sevag Demirjian, MD[1]; C. Allen Bashour, MD[2]; Andrew Shaw, MB[2]; et al

» Author Affiliations | Article Information

JAMA. 2022;327(10):956-964. doi:10.1001/jama.2022.1751

	Result	Probability
1	$AKI^{2/3}$ in 3 days	46.6%
2	$AKI^{2/3}$ in 14 days	41.9%
3	AKI^{D} in 3 days	37.2%
4	AKI^{D} in 14 days	41%

https://riskcalc.org/AKIpostCardiacSurgery/

Demirjian S et al. JAMA 2022

Postoperative Früherkennung

EJA

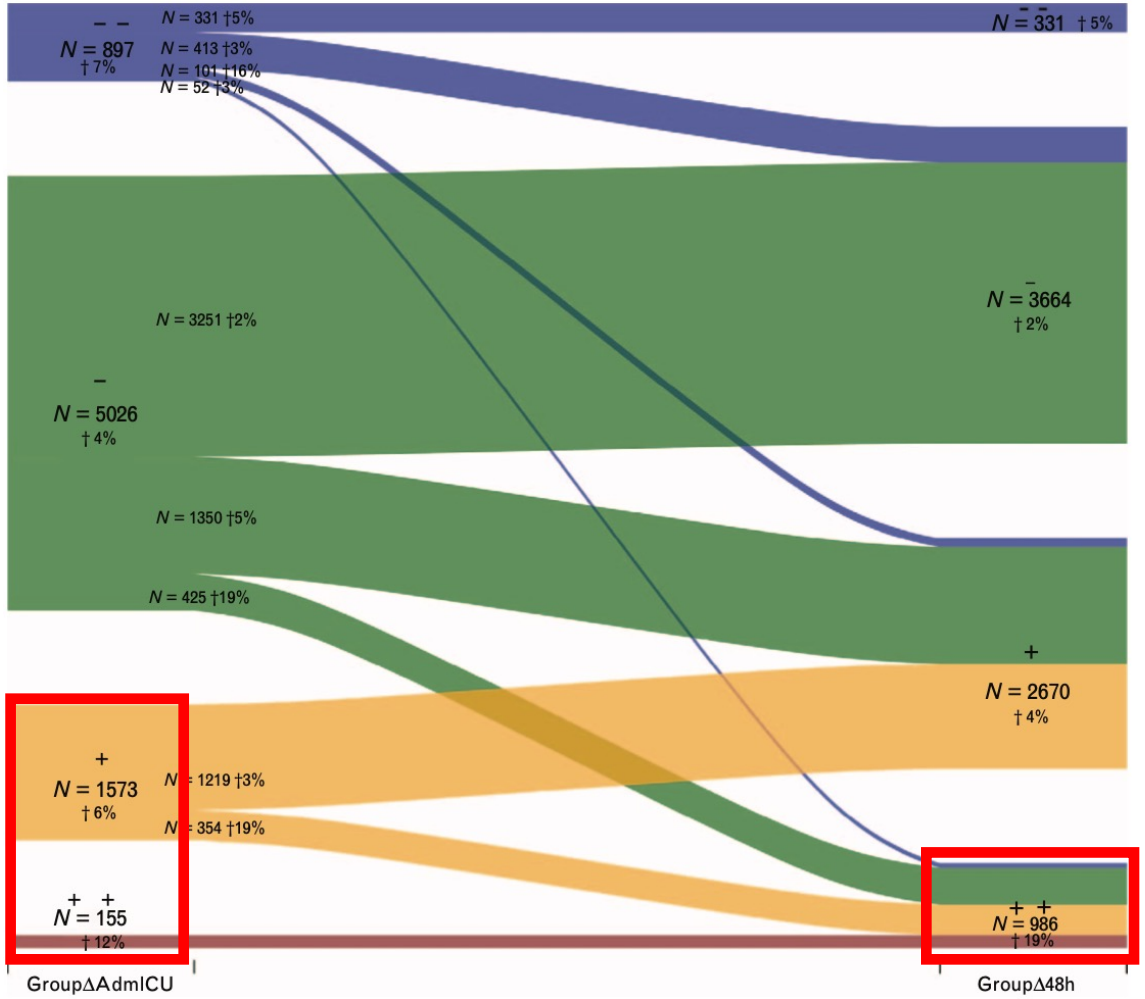
Eur J Anaesthesiol 2020; **37**:898–907

ORIGINAL ARTICLE

Very early changes in serum creatinine are associated with 30-day mortality after cardiac surgery

A cohort study

Martin H. Bernardi, Robin Ristl, Thomas Neugebauer, Michael J. Hiesmayr, Wilfred Druml and Andrea Lassnigg



Harnausscheidung

ANÄSTHESIE FORUM ALPBACH REPETITORIUM

A

Risk for AKI

Urine Output (mL/kg/hr)	1	2	3	4	5	6	7	8	9	10	11	12
≥.9	1.703 (1.315, 2.206) 968/3678	1.701 (1.313, 2.205) 936/3565	1.675 (1.292, 2.173) 909/3479	1.676 (1.292, 2.174) 892/3405	1.676 (1.29, 2.176) 871/3319	1.692 (1.303, 2.198) 860/3247	1.716 (1.321, 2.229) 846/3151	1.719 (1.323, 2.235) 823/3042	1.744 (1.341, 2.269) 797/2915	1.792 (1.377, 2.332) 776/2764	1.869 (1.434, 2.436) 749/2562	1.914 (1.467, 2.498) 712/2375
≥.8	1.69 (1.305, 2.189) 958/3648	1.703 (1.314, 2.207) 930/3537	1.696 (1.307, 2.2) 904/3434	1.698 (1.308, 2.203) 883/3348	1.7 (1.309, 2.208) 858/3239	1.722 (1.325, 2.237) 844/3143	1.76 (1.354, 2.287) 830/3037	1.783 (1.371, 2.32) 804/2902	1.773 (1.361, 2.31) 760/2730	1.788 (1.372, 2.331) 737/2586	1.894 (1.451, 2.472) 709/2384	1.976 (1.512, 2.583) 675/2195
≥.7	1.675 (1.293, 2.17) 943/3611	1.708 (1.317, 2.214) 920/3495	1.702 (1.312, 2.208) 890/3373	1.712 (1.318, 2.222) 864/3263	1.723 (1.326, 2.24) 836/3115	1.719 (1.322, 2.236) 807/2988	1.749 (1.344, 2.276) 778/2825	1.794 (1.376, 2.338) 756/2691	1.833 (1.405, 2.392) 714/2484	1.872	1.971	2.082
≥.6	1.679 (1.296, 2.176) 935/3573	1.704 (1.314, 2.21) 909/3451	1.724 (1.328, 2.239) 873/3282	1.729 (1.33, 2.248) 831/3115	1.769 (1.359, 2.302) 795/2893	1.775 (1.362, 2.313) 757/2721	1.801 (1.379, 2.351) 715/2508	1.855 (1.418, 2.427) 686/2348	1.961 (1.493, 2.574) 640/2113			
≥.5	1.708 (1.317, 2.213) 922/3491	1.731 (1.334, 2.247) 887/3322	1.777 (1.367, 2.31) 832/3033	1.78 (1.367, 2.319) 774/2802	1.868 (1.429, 2.44) 717/2495	1.877 (1.434, 2.457) 668/2286	1.99 (1.514, 2.614) 609/2007	2.055 (1.559, 2.71) 563/1819	2.224 (1.679, 2.947) 513/1587			
≥.4	1.774 (1.367, 2.301) 900/3328	1.83 (1.407, 2.382) 839/3041	1.92 (1.47, 2.508) 737/2548	1.964 (1.498, 2.575) 661/2250	2.117 (1.607, 2.79) 578/1858	2.197 (1.661, 2.907) 521/1634	2.448 (1.837, 3.261) 461/1351	2.74 (2.045, 3.672) 431/	3.09 (2.283, 4.184) 374/962	3.393 (2.476, 4.65) /823	3.675 (2.648, 5.101) 287/692	3.637 (2.602, 5.085) 258/613
≥.3	1.884 (1.449, 2.451) 835/2932	2.077 (1.59, 2.714) 730/2439	2.227 (1.688, 2.936) 563/1728	2.442 (1.838, 3.246) 478/1401	2.823 (2.101, 3.793) 396/1049	3.132 (2.305, 4.255) 338/846	3.81 (2.757, 5.267) 281/641	4.6 (3.269, 524) 235/ 93	5.069 (3.479, 7.385) 186/375	5 898 (3. 8.819) 15 /301	6.941 (4.497, 10.713) 133/231	7.461 (4.736, 11.754) 120/203
≥.2	2.161 (1.649, 2.831) 654/2112	2.455 (1.855, 3.25) 487/1431	3.052 (2.248, 4.144) 315/795	3.595 (2.597, 4.974) 249/571	4.786 (3.346, 6.844) 191/384	5.727 (3.886, 8.441) 157/295	7.039 (4.579, 10.823) 122/210	7.4 (4.643, 12.078) 92/154	8.368 (4.801, 14.584) 67/106	1 314 (6.677, 26.548) 54/76	13.148 (5.945, 29.078) 43/56	15.326 (6.427, 36.546) 39/49
≥.1	2.355 (1.77, 3.135) 395/1192	3.163 (2.283, 4.383) 220/562	3.05 (2.117, 4.392) 130/326	3.252 (2.162, 4.892) 96/226	3.587 (2.268, 5.673) 69/159	4.708 (2.824, 7.849) 59/118	5.593 (3.161, 9.895) 49/88	7.329 (3.826, 14.038) 41/65	7.513 (3.491, 16.166) 30/47	14.84 (5.253, 41.928) 25/32	20.875 (4.236, 102.877) 18/20	36.99 (4.382, 312.244) 16/17

Color scale: 35, 30, 15, 10, 5, 0

Risk for 30-day mortality

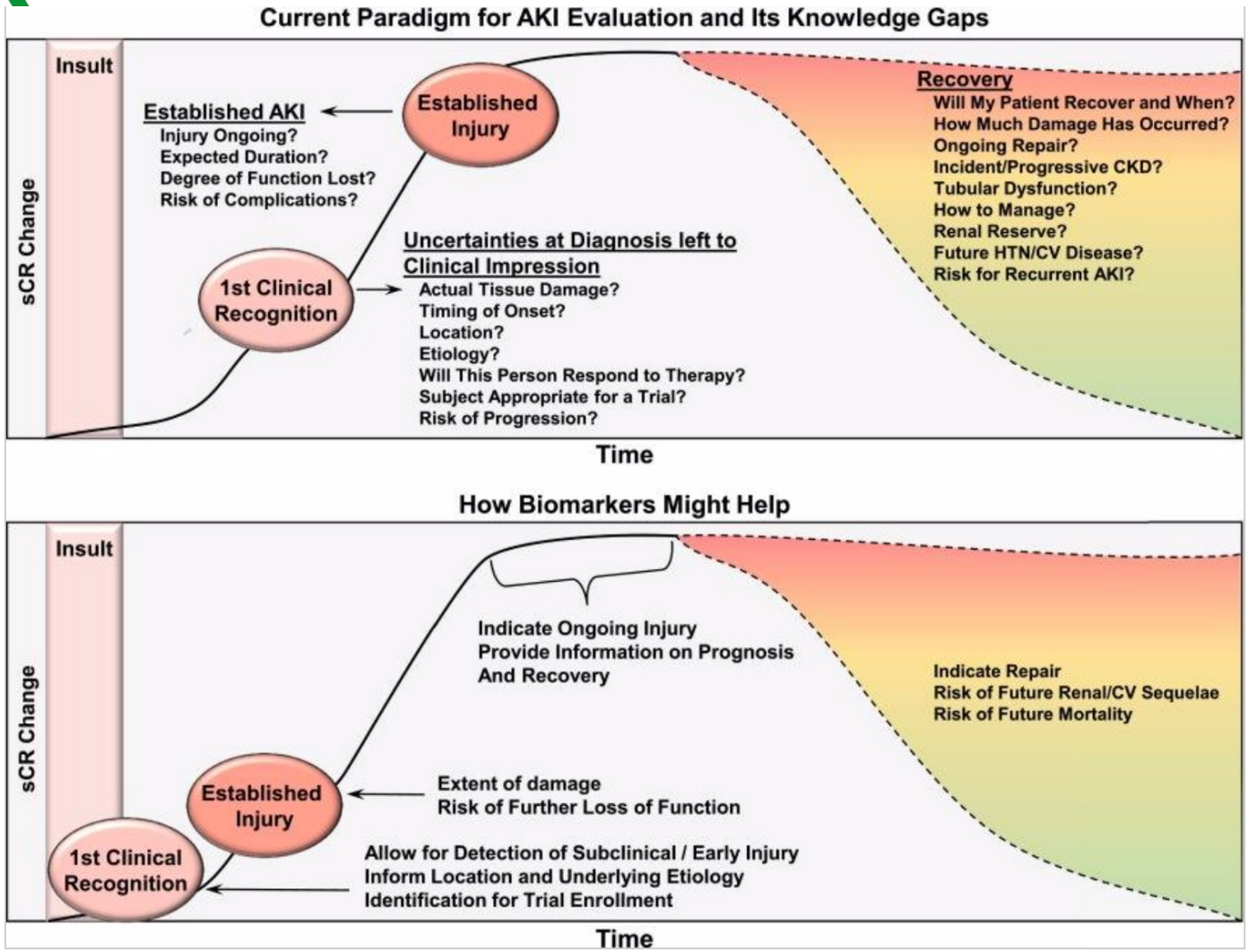
	1	2	3	4	5	6	7	8	9	10	11	12
≥.9	1.202 (0.644, 2.244) 105/3678	1.197 (0.638, 2.246) 100/3565	1.197 (0.636, 2.254) 97/3479	1.173 (0.622, 2.213) 95/3405	1.126 (0.592, 2.141) 90/3319	1.069 (0.56, 2.041) 85/3247	1.061 (0.553, 2.034) 83/3151	1.029 (0.535, 1.978) 80/3042	1 (0.516, 1.939) 75/2915	1.045 (0.537, 2.031) 74/2764	1.141 (0.585, 2.226) 71/2562	1.217 (0.621, 2.384) 68/2375
≥.8	1.188 (0.634, 2.226) 103/3648	1.194 (0.635, 2.245) 99/3537	1.129 (0.598, 2.131) 94/3434	1.112 (0.585, 2.111) 91/3348	1.097 (0.574, 2.096) 86/3239	1.061 (0.554, 2.032) 82/3143	1.075 (0.559, 2.067) 80/3037	1.047 (0.542, 2.025) 75/2902	1.037 (0.532, 2.021) 70/2730	1.052 (0.537, 2.059) 68/2586	1.17 (0.594, 2.306) 65/2384	1.252 (0.636, 2.463) 65/2195
≥.7	1.2	1.207	1.121	1.113	1.115	1.077 (0.559, 2.074)	1.122 (0.579, 2.174)	1.099 (0.564, 2.138)	1.124 (0.573, 2.205)	1.109 (0.563, 2.184)	1.181 (0.594, 2.351)	1.305 (0.651, 2.614)
≥.6						1.208 (0.623, 2.342)	1.2 (0.613, 2.349)	1.153 (0.583, 2.28)	1.221 (0.611, 2.44)	1.224 (0.607, 2.466)	1.229 (0.598, 2.524)	1.358 (0.658, 2.803)
≥.5						1.384 (0.707, 2.712)	1.468 (0.732, 2.945)	1.322 (0.648, 2.694)	1.366 (0.66, 2.827)	1.407 (0.664, 2.983)	1.539 (0.714, 3.318)	1.556 (0.718, 3.374)
≥.4	1.281 (0.68, 2.413) 99/3328	1.264 (0.664, 2.406) 86/3041	1.372 (0.713, 2.642) 78/2548	1.543 (0.79, 3.013) 71/2250	1.83 (0.906, 3.698) 61/1858	1.881 (0.922, 3.839) 57/1634	1.94 (0.923, 4.076) 47/1351	1.815 (0.856, 3.851) 43/1 82	1.986 (0.919, 4.294) 40/962	2.109 (0.941, 4.725) 3 823	2.454 (1.068, 5.639) 31/692	2.535 (1.094, 5.872) 30/613
≥.3	1.39 (0.729, 2.65) 88/2932	1.401 (0.724, 2.711) 71/2439	1.81 (0.904, 3.625) 61/1728	2.148 (1.044, 4.42) 52/1401	2.362 (1.109, 5.031) 45/1049	2.734 (1.277, 5.856) 42/846	3.307 (1.518, 7.208) 37/641	3.5 (1.57 43) 32/ 3	3.607 (1.524, 8.537) 26/375	4 353 (1.95 12.069) 2 301	5.576 (2.124, 14.64) 21/231	5.705 (2.131, 15.276) 20/203
≥.2	1.658 (0.848, 3.242) 71/2112	1.865 (0.93, 3.738) 53/1431	2.607 (1.239, 5.487) 41/795	3.174 (1.49, 6.763) 38/571	4.154 (1.868, 9.238) 33/384	4.961 (2.175, 11.319) 30/295	6.473 (2.784, 15.048) 26/210	7.7 (3.165, 18.858) 23/154	836 (3.027, 21.156) 19/106	(3.664, 32.042) 16/76	16.434 (4.763, 56.7) 15/56	11.978 (3.36, 42.702) 14/49
≥.1	1.8 (0.885, 3.659) 47/1192	3.06 (1.408, 6.649) 32/562	3.069 (1.36, 6.927) 24/326	4.494 (1.923, 10.502) 23/226	8.207 (3.125, 21.551) 19/159	10.745 (3.667, 31.483) 17/118	14.166 (4.586, 43.756) 16/88	19.279 (6.055, 61.382) 16/65	30.801 (8.672, 109.391) 15/47	43.341 (11.188, 167.897) 14/32	44.654 (7.957, 250.594) 10/20	65.256 (9.747, 436.907) 10/17

Color scale: 60, 50, 40, 30, 20, 10, 0

Bsp.:
Harnmenge:
<0.3ml/kg/h seit 9 Stunden

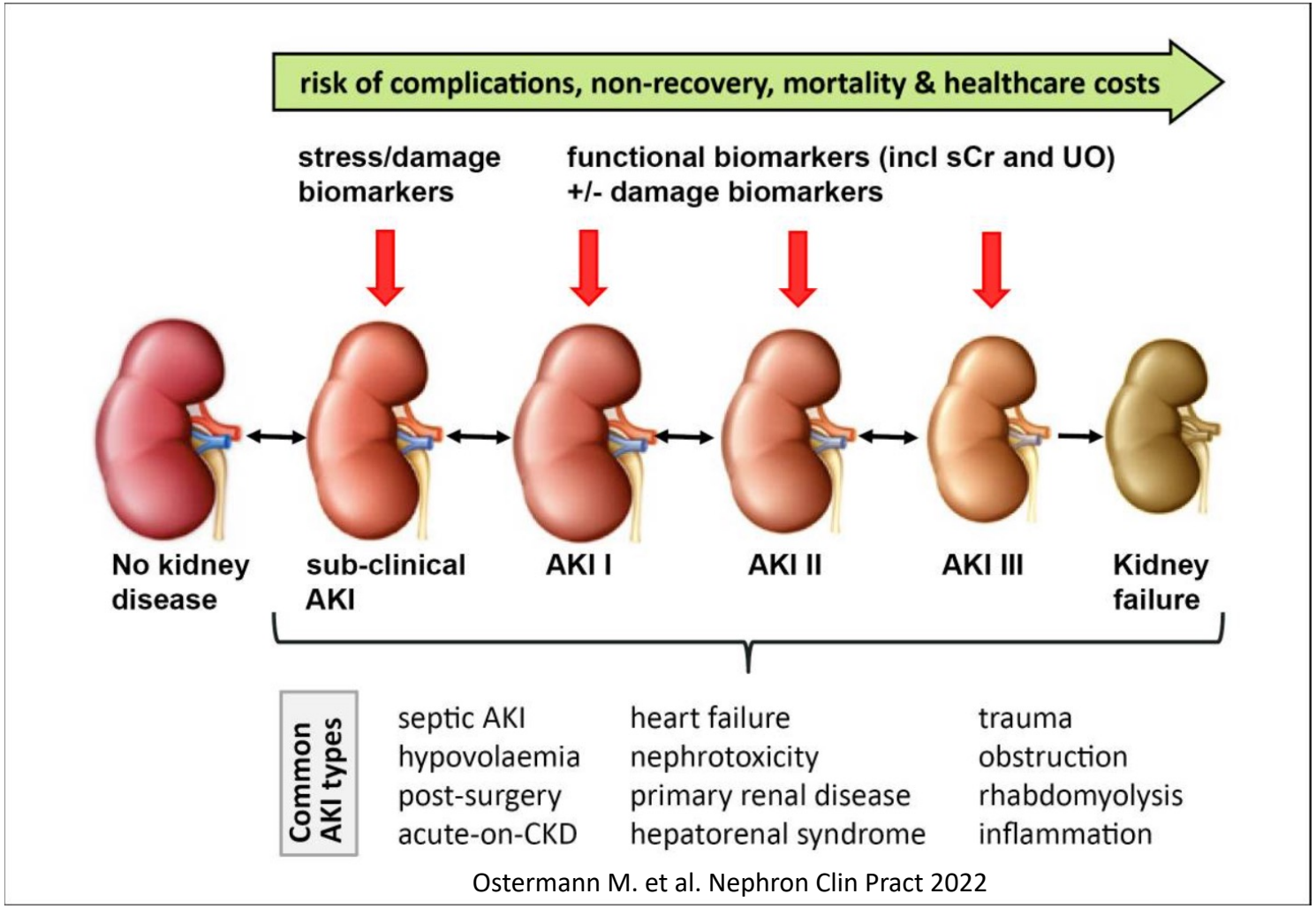
Engoren M et al. Ann Thorac Surg 2017; 103(4):1229-37

Biomarker



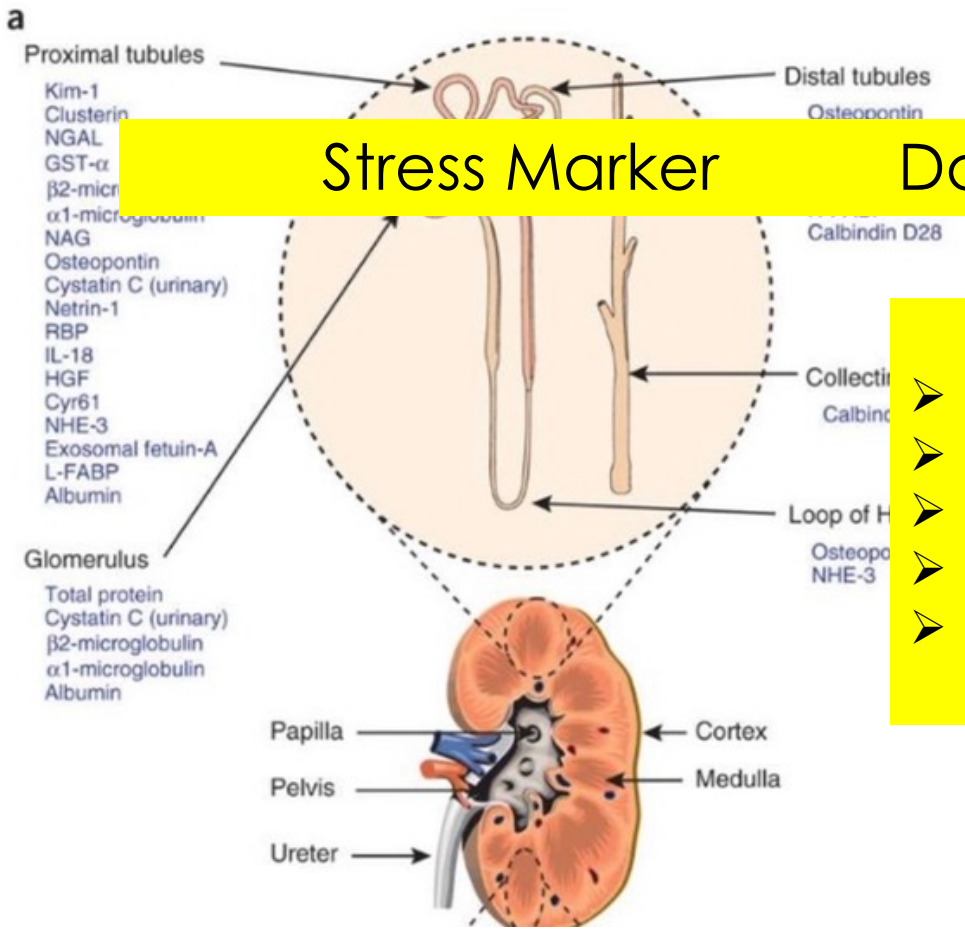
Malhotra, Siew CJASN 2017

Biomarker



Ostermann M. et al. Nephron Clin Pract 2022

Biomarker



Stress Marker Damage Marker Functional Marker

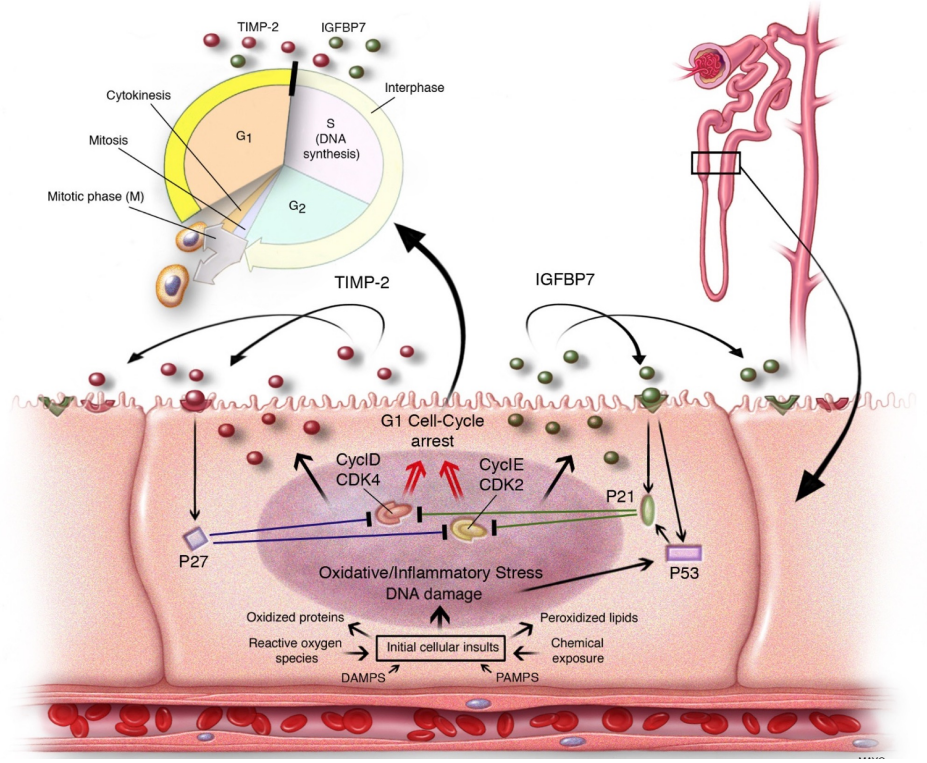
- Risk assessment
- Prediction
- Diagnosis
- Severity
- Recovery

AKI biomarker	Biological role	Source	Stress marker[a]	Damage marker[b]	Functional marker[c]	Risk assessment	Prediction of AKI	Diagnosis of AKI	Severity of AKI	Kidney recovery
Alanine aminopeptidase; alkaline phosphatase; γ-glutamyl transpeptidase	Enzymes located on the brush border villi of the proximal tubular cells; released into urine after tubular damage	Coca et al,[2] 2008		Urine				X	X	
Calprotectin	Cytosolic calcium-binding complex; derived from neutrophils and monocytes; detectable in urine in intrinsic AKI	Charlton et al,[3] 2014; Heller et al,[4] 2011		Urine				X		
C-C motif chemokine ligand 14	Pro-inflammatory chemokine; released into urine following stress or damage of tubular cells	Hoste et al,[5] 2020		Urine						X
Chitinase 3-like protein 1	39 kDa intracellular protein of glycoside hydrolase family; expressed by endothelial cells, macrophages, and neutrophils	De Loor et al,[6] 2016		Urine and plasma				X		
Cystatin C	13 kDa cysteine protease inhibitor produced by nucleated human cells; freely filtered	Coca et al,[2] 2008; Ho et al,[7] 2015; Ravn et al,[8] 2019			Plasma			X	X	
Dickkopf-3	38 kDa stress-induced, kidney tubular epithelia-derived glycoprotein; secreted into urine under tubular stress conditions	Schunk et al,[9] 2019	Urine			X	X			
α glutathione S-transferase	Cytoplasmic enzyme in proximal tubule	Koyner at al,[10] 2010		Urine				X		
										X
Hepcidin	2.78 kDa peptide hormone predominantly produced in hepatocytes; freely filtered	Ho et al,[7] 2015		Urine and plasma				X	X	
Tissue metalloproteinase-2; insulin-like growth factor binding protein-7	Metalloproteinases released during cell cycle arrest	Kashani et al,[12] 2013; Ostermann et al,[13] 2018; Joannidis et al,[14] 2019	Urine				X	X	X	
	atory cytokine; released tubular damage	Coca et al,[2] 2008; Ho et al,[7] 2015		Urine			X	X		
	coprotein produced by l; released into urine after	Coca et al,[2] 2008; Ho et al,[7] 2015; Koyner et al,[10] 2010		Urine			X	X	X	
	lipid chaperone; freely bed in proximal tubule; er tubular cell damage	Ho et al,[7] 2015		Urine and plasma				X		
	stranded non-coding lividual microRNAs are pecially in association with osis and fibrosis	Fan et al,[15] 2019		Urine and plasma				X		
	tubular epithelial cells, lls and podocytes; released	Moledina et al,[16] 2017		Urine					X	
	enzyme; released into urine	Charlton et al,[3] 2014		Urine				X		
	ypes: (1) monomeric 25 oduced by neutrophils and cluding tubular cells; (2) protein produced by erodimeric 135 kDa protein cells	Coca et al,[2] 2008; Ho et al,[7] 2015; Charlton et al,[3] 2014		Urine and plasma				X	X	
	related molecule minimally al tubular cells of normal kidneys; released into urine after tubular cell damage	Ramesh et al,[17] 2010		Urine				X		
Osteopontin	Glycoprotein expressed in tubular cells and interstitial infiltrating cells in areas of tubulointerstitial damage	Lorenzen et al,[18] 2011		Plasma				X	X	
Proenkephalin A	Endogenous polypeptide hormone in adrenal medulla, nervous system, immune system and renal tissue; freely filtered	Legrand et al,[19] 2019			Plasma			X	X	X
Retinol binding protein	21 kDa glycoprotein; synthesized by liver; filtered by glomeruli and reabsorbed by proximal tubules; released into urine following tubular damage	Charlton et al,[3] 2014		Plasma						
Tumor necrosis factor	Pro-inflammatory cytokine; released after tubular damage	Ho et al,[7] 2015		Plasma				X		

Bonventre J. Nat Biotechnol 2010
Ostermann M. et al. JAMA 2020

TIMP2*IGFBP7

- IGFBP7 – insulin-like growth factor-binding protein 7
- TIMP-2 – tissue inhibitor of metalloproteinases-2
  - „Cell cycle arrest“ Biomarkers
  - Identifikation von Hochrisikopatient:innen



Biomarker

- Eventuell frühere Risikoerkennung
  - Frühzei
  - Redukt
  - Hilfestellung bei Entscheidung zum Start/Stop einer RRT

Derzeit nicht empfohlen!

Bagshaw SM. Nephron 2015
Berdugo MA et al. J Med Econ 2019
Meersch M et al. Intensive Care Med 2017

Indikationenen Nierenersatztherapie

Urgent indications (in the absence of contraindications to RRT)	Severe hyperkalemia unresponsive to medical measures for potassium removal (e.g., K^+ ≥6.0 mmol/l, rapidly rising, or cardiac toxicity) Severe acidemia and metabolic acidosis (e.g., pH ≤7.2 or serum bicarbonate ≤12 mmol/l despite normal or low arterial pCO_2) Refractory hypoxemia due to fluid overload (e.g., diuretic-resistant pulmonary edema) Symptoms or complications attributable to uremia (e.g., pericarditis, encephalopathy) Concomitant intoxication with a dialyzable drug/toxin
Relative indications (in the absence of life-threatening complications of AKI)	Advanced nonkidney organ dysfunction worsened or exacerbated by excessive fluid accumulation (i.e., impaired respiratory function) Anticipated solute burden (e.g., tumor lysis syndrome; rhabdomyolysis; intravascular hemolysis) Need for large volume fluid administration (i.e., nutrition, medications or blood products)
Relative contraindications	Low likelihood for benefit (i.e., futile prognosis) Patient receiving palliative care and/or approaching end-of-life High likelihood of nonrecovery of kidney function in patient who is not a candidate for long-term dialysis

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Nierenersatztherapie Early vs. Late

Feature	ELAIN [36]	AKIKI [17]	IDEAL-ICU [33]	STARRT-AKI [18▪▪]
Country	Germany	France	France	Multi-National
No. of sites	1	31	24	168
No. of participants	231	620	488[a]	3019
Setting/population	Mixed medical/surgical ICU (94.8% surgical)	Mixed medical/surgical ICU (79.7% medical)	Mixed medical/surgical ICU (septic shock)	Mixed medical/surgical ICU
ARR for sample size calculation	18%	15%	10%	6%
Control group mortality	55%	55%	55%	44%
Interventions:				
Early (accelerated)	KDIGO stage 2 (within 8 h)	KDIGO stage 3 (within 6 h)	RIFLE-failure (within 12 h)	KDIGO stage 2 (within 12 h)
Delayed (conservative)	KDIGO stage 3 (within 12 h)	Specific criteria/ emergent indications	Specific criteria 48–60 h after eligibility or emergent indications	Specific criteria/ emergent indications
Actual inter-arm time difference in RRT initiation (h)	19.5	55	44	25
Received RRT in delayed	90.8%	51.0%	62.0%	61.8%
RRT modality	CRRT	Physician discretion (initial IHD 55%)	Physician discretion	Physician discretion
SOFA score at enrollment	~16.0	~10.9	~12.3	~11.7
Primary endpoint	90-day mortality	60-day mortality	90-day mortality	90-day mortality
Early (accelerated)	39.3%	48.5%	58.0%	43.9%
Delayed (conservative)	54.7%	49.7%	54.0%	43.7%
Effect estimate	HR, 0.66 (95% CI 0.45–0.97)	HR, 1.03 (95% CI 0.82–1.29)	RR, 1.08[b] (95% CI 0.90–1.30)	RR, 1.00 (95% CI 0.93–1.09)
Kidney recovery	RRT dependence at 90 days	RRT dependence at 60 days	RRT dependence at 90 days	RRT dependence at 90 days
Early (accelerated)	53.6%	2.0%	2.0%	10.4%
Delayed (conservative)	38.7%	5.0%	3.0%	6.0%
Effect estimate	OR, 0.55 (95% CI 0.32–0.93)	RR, 0.53[b] (95% CI 0.20–1.41)	RR, 0.83[b] (95% CI 0.28–2.46)	RR, 1.74 (95% CI 1.24–2.43)
Adverse events	Aggregate	CRBSI	Indication for emergent RRT[c]	Aggregate
Early (accelerated)	75.0%	10.0%	–	23.0%
Delayed (conservative)	68.5%	3.0%	17%	16.5%
Effect estimate	RR, 1.18[b] (95% CI 0.86–1.61)	RR, 1.35[b] (95% CI 1.08–1.68)	–	RR, 1.40 (95% CI 1.21–1.62)

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Danke für die Aufmerksamkeit!

Martin Bernardi

ANÄSTHESIE FORUM

ALPBACH

REPETITORIUM