AKIと補液と腎エコー

東京慈恵医科大学集中治療部　火曜日勉強会
本院ICU　吉田拓生
Doppler ultrasound

- 一般、方法
- 知見
- 実際
- まとめ、私見

AKI-輸液

Contrast Enhanced Ultrasound

- 方法
- 知見
- まとめ、私見

本日の目次
Doppler ultrasound

- 一般、方法
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- 実際
- まとめ、私見

Contrast Enhanced Ultrasound

- 方法
- 知見
- まとめ、私見
ざわざわするフレーズ

「腎不全のリスクが高いから輸液は多めにしよう」
「Cr、BUNが上がってきた、輸液を増やそう」

AKIにとって輸液は薬か？毒か？
A positive fluid balance is associated with a worse outcome in patients with acute renal failure

Didier Payen¹, Anne Cornélie de Pont², Yasser Sakr³, Claudia Spies⁴, Konrad Reinhart³, Jean Louis Vincent⁵ for the Sepsis Occurrence in Acutely Ill Patients (SOAP) Investigators

Critical Care 2008, 12:R74

• 目的: ICU-ARF患者におけるfluid balanceの影響の検討
  ARF: Cr3.5 mg/dL以上 or 尿量500 mL/day以下

• 方法:
  Sepsis Occurrence in Acutely Ill Patients study
  (SOAP study :ヨーロッパ198 施設 ICU、前向き観察研究)よりデータ抽出

• 結果: n= 3147（No ARF n = 2,027 ARF n = 1,120）
Table 4

Mean daily fluid balances and outcome among patients with acute renal failure, stratified by urine output and treatment

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Non-oliguric n = 572</th>
<th>Oliguric n = 548</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean fluid balance, L/24 hours</td>
<td>0.27 ± 1.23</td>
<td>0.62 ± 1.33</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ICU mortality</td>
<td>157 (27.4)</td>
<td>181 (33.0)</td>
<td>0.04</td>
</tr>
<tr>
<td>60-day mortality</td>
<td>181 (32.1)</td>
<td>214 (39.6)</td>
<td>0.01</td>
</tr>
<tr>
<td>ICU stay</td>
<td>4.5 (2.0–11.1)</td>
<td>3 (1.4–8.6)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Hospital stay</td>
<td>12.7 (5.5–21.0)</td>
<td>10.3 (2.3–22.2)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No RRT n = 842</th>
<th>RRT n = 278</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean fluid balance, L/24 hours</td>
<td>0.39 ± 1.21</td>
<td>0.60 ± 1.50</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ICU mortality</td>
<td>214 (25.4)</td>
<td>124 (44.6)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>60-day mortality</td>
<td>259 (31.2)</td>
<td>136 (49.5)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ICU stay</td>
<td>2.9 (1.6–6.9)</td>
<td>8.4 (3.0–19.4)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Hospital stay</td>
<td>10.8 (3.8–24.1)</td>
<td>16 (6.8–34.9)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

- 乏尿
- RRTを要した

→Fluid balance 多め
Table 2

Hazard ratios: results of multivariate Cox regression analysis for 60-day mortality in critically ill patients with acute renal failure

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Hazard ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.02</td>
<td>1.01–1.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SAPS II (per point)</td>
<td>1.03</td>
<td>1.02–1.04</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Heart failure</td>
<td>1.38</td>
<td>1.05–1.81</td>
<td>0.02</td>
</tr>
<tr>
<td>Medical admission</td>
<td>1.68</td>
<td>1.35–2.08</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean fluid balance, L/24 hours</td>
<td>1.21</td>
<td>1.13–1.28</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mechanical ventilation</td>
<td>1.55</td>
<td>1.14–2.11</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Liver cirrhosis</td>
<td>2.73</td>
<td>1.88–3.95</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CI, confidence interval; SAPS II, Simplified Acute Physiology Score II.
Fluid Balance, Diuretic Use, and Mortality in Acute Kidney Injury

Morgan E. Grams,*† Michelle M. Estrella,* Josef Coresh,*‡, Roy G. Brower,* and Kathleen D. Liu§ for the National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome Network


• 目的:
(fluid balance、利尿剤使用)-(重症患者AKI)の関連性を評価

• 方法:
FACTT(Fluid and Catheter Treatment Trial(↓))よりデータ抽出: AKI患者、fluid balance,60日死亡率の検討

多施設RCT、ALI患者1000人に対して制限輸液群 v.s.大量輸液群の検討→死亡率の改善無し。輸液制限群でventilator-free daysが長くなった。
Table 1. Characteristics of FACTT participants with AKI, comparing those randomized to the liberal-fluid strategy with those randomized to the restrictive strategy

<table>
<thead>
<tr>
<th>FACTT Participants with AKI</th>
<th>Liberal Fluid Strategy</th>
<th>Restrictive Fluid Strategy</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n ) % of total study (( n = 500 ) in each arm)</td>
<td>137</td>
<td>169</td>
<td>0.04</td>
</tr>
<tr>
<td>27.4</td>
<td>33.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. | Cumulative fluid balance over the first 7 days by fluid-management group (median values and interquartile range).

- 約3割がAKI

- Average daily fluid balance: 非生存者＞生存者

Table 2. Variables associated with 60-day survival among FACTT participants with AKI

<table>
<thead>
<tr>
<th>FACTT Participants with AKI</th>
<th>Survivors</th>
<th>Nonsurvivors</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n ) (%)</td>
<td>186 (60.8)</td>
<td>120 (39.2)</td>
<td>(&lt;0.001)</td>
</tr>
<tr>
<td>Proportion of days in shock (mean)</td>
<td>19.4</td>
<td>52.0</td>
<td>(&lt;0.001)</td>
</tr>
<tr>
<td>Dialysis within the first 7 days (%)</td>
<td>20.4</td>
<td>42.5</td>
<td>(&lt;0.001)</td>
</tr>
<tr>
<td>Early oliguria (%)</td>
<td>28.5</td>
<td>50.8</td>
<td>(&lt;0.001)</td>
</tr>
<tr>
<td>Average daily fluid balance (mean L per day)</td>
<td>0.3</td>
<td>3.3</td>
<td>(&lt;0.001)</td>
</tr>
<tr>
<td>Average daily furosemide dose (mean mg per day)</td>
<td>73.5</td>
<td>25.6</td>
<td>(&lt;0.001)</td>
</tr>
</tbody>
</table>
Table 3. Relative odds of death by FACTT study day 60 associated with average daily fluid balance and furosemide dose following AKI

<table>
<thead>
<tr>
<th>Adjustment</th>
<th>Fluid Balance (Post-AKI, in Mean L/Day)</th>
<th>Furosemide Dose (Post-AKI, in Mean 100 mg/Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>P</td>
</tr>
<tr>
<td>None (univariate)</td>
<td>1.73 (1.47 to 2.03)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Full model</td>
<td>1.61 (1.29 to 2.00)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>+Post-AKI fluid balance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+Post-AKI furosemide dose</td>
<td>1.56 (1.25 to 1.95)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Final model</td>
<td>1.61 (1.32 to 1.96)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

^Full model includes adjustment for the following covariates: age, sex, race, fluid-strategy randomization group, catheter randomization group, day first diagnosed with AKI, fluid balance in the 24 hours prior to randomization, enrollment APACHE III score, sepsis as an etiology for ALI, trauma as an etiology for ALI, pneumonia as an etiology for ALI, multiple transfusions as an etiology for ALI, other etiology for ALI, baseline CVP, baseline presence or absence of shock, use of diuretics in the 24 hours prior to randomization, stage of AKI within 2 study days of randomization (AKIN creatinine-based criteria), mean daily CVP, and mean daily presence or absence of shock. The statistically significant covariates in the full model were race, age, day first diagnosed with AKI, and fluid-strategy randomization group.

^Final model includes adjustment for the following covariates: age, race, sex, fluid-strategy randomization arm, catheter randomization arm, enrollment APACHE III score, day first diagnosed with AKI, mean daily CVP, and mean daily presence or absence of shock. The statistically significant covariates in the final model were race, age, day first diagnosed with AKI (with mean fluid balance only), fluid-strategy randomization group (with mean fluid balance only), enrollment APACHE III score, mean daily CVP (with mean furosemide dose only), and mean daily presence or absence of shock.

- 重症度スコア等で調整→OR1.56
- フロセミド使用量に関してはfluid balanceを調整に加えると効果が消える

卵？
An observational study fluid balance and patient outcomes in the randomized evaluation of normal vs. augmented level of replacement therapy trial*

The RENAL Replacement Therapy Study Investigators Crit Care Med 2012; 40: 1753–1760

- 目的: AKIにおけるfluid balanceと予後の関係の検討
- 方法: Renal study（↓）のデータで、fluid balanceと90日死亡率の関係を検討

Randomized Evaluation of Normal versus Augmented Level (RENAL) Replacement Therapy Study

- 多施設 RCT、n=1508、CRRT流量: 40 mL/kg/hr (higher intensity) vs 25 mL/kg/hr (lower intensity)
- 18歳以上、CRRTを要するAKI（輸液負荷に反応せず尿量100ml/6時間以下、BUN 70mg/dl以上、Cr3.4mg/dl以上、pH7.2以下、臨床的に問題となる浮腫あり）
  primary: 90日死亡率  Secondary: ICU死亡率、院内死亡率、人工呼吸器期間、RRT期間、90日時点での透析必要率、臓器不全
Table 1. Baseline characteristics and outcome of patient with a mean daily positive vs. negative fluid balance

<table>
<thead>
<tr>
<th>Baseline Characteristics</th>
<th>Positive Mean Daily Fluid Balance, n = 705</th>
<th>Negative Mean Daily Fluid Balance, n = 748</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>64.5 (14.7)</td>
<td>64.7 (14.9)</td>
<td>.85</td>
</tr>
<tr>
<td>Male</td>
<td>446/705 (63.3%)</td>
<td>491/748 (65.6%)</td>
<td>.34</td>
</tr>
<tr>
<td>Estimated glomerular filtration rate</td>
<td>57.9 (32.7)</td>
<td>55.2 (29.4)</td>
<td>.21</td>
</tr>
<tr>
<td>Mechanical ventilation</td>
<td>548/705 (77.7%)</td>
<td>523/748 (69.9%)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Severe sepsis at baseline</td>
<td>371/705 (52.6%)</td>
<td>348/748 (46.5%)</td>
<td>.02</td>
</tr>
<tr>
<td>Acute Physiology and Chronic Health Evaluation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III score</td>
<td>106.8 (26.7)</td>
<td>98.2 (24.0)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>SOFA cardiovascular</td>
<td>3.0 (1.5)</td>
<td>2.7 (1.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>SOFA respiration (score)</td>
<td>2.8 (1.0)</td>
<td>2.7 (0.9)</td>
<td>.03</td>
</tr>
<tr>
<td>SOFA coagulation (score)</td>
<td>1.0 (1.2)</td>
<td>0.9 (1.1)</td>
<td>.08</td>
</tr>
<tr>
<td>SOFA liver (score)</td>
<td>1.0 (1.2)</td>
<td>0.9 (1.2)</td>
<td>.60</td>
</tr>
</tbody>
</table>

Positive fluid balance ↓ 重症度が高かっただけ？

- 人工呼吸器 7割
- 重症敗血症半数
- 心血管系：半数以上
Figure 4. Cox proportional hazards survival plot with adjustment for treatment group, all Acute Physiology and Chronic Health Evaluation III diagnostic groups, daily use of continuous renal replacement therapy, age, time from intensive care unit to randomization, presence of sepsis, Sequential Organ Failure Assessment (SOFA) respiratory score, SOFA coagulation score, SOFA liver score, SOFA cardiovascular score, SOFA renal score, presence of nonrenal organ failure, international normalized ratio for prothrombin time, activate partial thromboplastin time, platelet count, serum creatinine, $P_{aO_2}/P_{FIO_2}$ ratio, $P_{aco_2}$ days, and clinical diagnosis of significant edema at randomization. The quartile 1 to quartile 4 refer to fluid balance (FB). The broken line refers to patients with a positive mean daily FB, whereas the continuous line refers to patients with a negative mean daily FB. In both groups of patients, there is a significant increase in mortality according to quartile of FB, such that the greater the mean daily FB, the greater the risk of death. $q$, quartile.
思考回路

AKI
↓
腎灌流を良くしたい
↓
輸液
現時点でわかっていること

AKI
↓
腎灌流を良くしたい
↓
輸液 ？ or ×
ここが知りたい

AKI

腎灌流を良くしたい

輸液

？ or ×
Measurement of kidney perfusion in critically ill patients

Antione G Schneider¹,³, Mark D Goodwin², Rinaldo Bellomo¹,³*

This article is one of ten reviews selected from the Annual Update in Intensive Care and Emergency Medicine 2013 and co-published as a series in Critical Care. Other articles in the series can be found online at http://ccforum.com/series/annualupdate2013. Further information about the Annual Update in Intensive Care and Emergency Medicine is available from http://www.springer.com/series/8901.

Critical Care 2013, 17:220

・ベッドサイドで行え、
・簡単で、
・合併症がない、
診断ツールとして
・Doppler ultrasound(主にはresistive index、以下RI)
・Contrast-enhanced ultrasound(以下CEUS)
が紹介。
Doppler ultrasound

- 一般、方法
- 知見
- 実際
- まとめ、私見

Contrast Enhanced Ultrasound

- 方法
- 知見
- まとめ、私見

AKI-輸液
Doppler ultrasound

- 一般、方法
- 知見
- 実際
- まとめ、私見

Contrast Enhanced Ultrasound

- 方法
- 知見
- まとめ、私見

半定量評価
Resistive Index

AKI-輸液
半定量評価

Table 1 Colour-Doppler for a semi-quantitative evaluation of intra-renal vascularisation [1]

<table>
<thead>
<tr>
<th>Stage</th>
<th>Quality of renal perfusion by colour-Doppler</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Unidentifiable vessels</td>
</tr>
<tr>
<td>1</td>
<td>Few vessels in the vicinity of the hilum</td>
</tr>
<tr>
<td>2</td>
<td>Hilar and interlobar vessels in most of the renal parenchyma</td>
</tr>
<tr>
<td>3</td>
<td>Renal vessels identifiable until the arcuate arteries in the entire field of view</td>
</tr>
</tbody>
</table>

血管同定できず

腎門部に血管が数本しか見えない

腎実質の大半で腎門部血管、葉間血管が確認できる

視野全体で弓状動静脈まで同定可能

半定量評価
Resistive Index

• Step 1
  コンベックスプローブで腹部エコー走査

• Step 2
  後側方アプローチで腎長軸像を描出
• Step 3
カラードプライで腎内血管を描出
• Step 4 葉間動脈 or 弓状動脈を同定
• Step 4  葉間動脈 or 弓状動脈を同定
• Step 5

最小のDoppler gate (2–5 mm)でパルスドプラーゲートを切り、反射波が起こらないように調整する。
ノイズを含まない程度にgainを最大に設定する。
• Step 6
3〜5個の同じ形の波を描出
• Step 7
収縮期の最高速度、拡張期の最低速度を測定
• Step 8
各波でRI測定
・Step 9
3〜5回の平均をとる

・Step 10
対照として対側も測定

\[
RI = \frac{(\text{peak systolic velocity} - \text{minimum diastolic velocity})}{\text{peak systolic velocity}}
\]

\[
RI = \frac{0.39 - 0.16}{0.39} = 0.589
\]
RI 値 一般

・正常値 0.7より低い : 0.58 (±0.05) 〜 0.64 (±0.04)

・60歳以上、4歳未満だと0.7より高いこともある

・左右差は5%未満

・不整脈（特に心房細動）の影響は未検討

RI 値 変動因子

生理学的にRIを左右する因子
・血管コンプライアンス
・糖尿病、高血圧
・血管抵抗
・脈圧
・腎血流量
・心拍数
・O2, CO2
・年齢

病的にRIを左右する因子
・間質圧
・尿管圧
・腹腔内圧
・人工呼吸器管理（PEEP）

Doppler ultrasound

- General, Method
- Knowledge
- Actual
- Summary, Personal Opinion

Contrast Enhanced Ultrasound

- Method
- Knowledge
- Summary, Personal Opinion
Doppler-based renal resistive index for prediction of renal dysfunction reversibility: A systematic review and meta-analysis

Sebastien Ninet, MD, David Schnell, MD, Antoine Dewitte, MD, Fabrice Zeni, MD, PhD, Ferhat Meziani, MD, PhD, Michael Darmon, MD, PhD

• 目的：
AKI、短期のreversibility予測に関するRIの検討 (systematic review)

• 方法：
Pubmed, Cochrane databases(1985～2013)で検索

• 対象：
RI計測、AKIのreversibility, mechanismに関する研究
小児、腎移植患者は除外
Table 1
Characteristics of included studies

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>France</td>
<td>France</td>
<td>France</td>
<td>France</td>
</tr>
<tr>
<td>Multicenter study</td>
<td>No</td>
<td>Yes (n = 3)</td>
<td>Yes (n = 2)</td>
<td>No</td>
</tr>
<tr>
<td>Prospective design</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Setting</td>
<td>ICU</td>
<td>ICU</td>
<td>ICU</td>
<td>ICU</td>
</tr>
<tr>
<td>Population</td>
<td>MV</td>
<td>MV + shock</td>
<td>60% MV</td>
<td>Cardiac surgery</td>
</tr>
<tr>
<td>Adults</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>n</td>
<td>51</td>
<td>35</td>
<td>58</td>
<td>65</td>
</tr>
<tr>
<td>Persistent AKI prevalence</td>
<td>43%</td>
<td>37%</td>
<td>31%</td>
<td>9%</td>
</tr>
<tr>
<td>AKI prevalence</td>
<td>69%</td>
<td>74%</td>
<td>43%</td>
<td>28%</td>
</tr>
</tbody>
</table>

MV indicates mechanical ventilation.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>France</td>
<td>France</td>
<td>UK</td>
<td>USA</td>
<td>Japan</td>
</tr>
<tr>
<td>Multicenter study</td>
<td>No</td>
<td>Yes (n = 3)</td>
<td>Yes (n = 2)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Prospective design</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Setting</td>
<td>ICU</td>
<td>ICU</td>
<td>ICU</td>
<td>Ward</td>
<td>Ward</td>
</tr>
<tr>
<td>Severe sepsis</td>
<td>MV</td>
<td>AKI</td>
<td>AKI</td>
<td>AKI</td>
<td>AKI</td>
</tr>
<tr>
<td>Adults</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Mixed</td>
</tr>
<tr>
<td>n</td>
<td>94</td>
<td>69</td>
<td>57</td>
<td>91</td>
<td>40</td>
</tr>
<tr>
<td>Persistent AKI prevalence</td>
<td>30%</td>
<td>13%</td>
<td>35%</td>
<td>67%</td>
<td>40%</td>
</tr>
<tr>
<td>AKI prevalence</td>
<td>55%</td>
<td>30%</td>
<td>60%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
RI上昇 - persistent AKI

Cutoff point 0.71[16] ～0.80[19, 27]

※Persistent AKI詳細に関しては後述

Fig. 3. (A) Summary of sensitivity for persistent AKI in patients with elevated RI or PI. (B) Summary of specificity for persistent AKI in patients with elevated RI or PI.
Fig. 4. (A) Summary of positive likelihood ratios for persistent AKI in patients with elevated RI or PI. (B) Summary of negative likelihood ratio for persistent AKI in patients with elevated RI or PI.

Persistent AKI

Random Effects Model

Pooled Positive LR = 4.91 (2.44 to 9.87)
Coef-Q = 42.66; df = 8 (P = .00001)
Inconsistency (I-square) = 81.2%
Tau-squared = 0.8312

Random Effects Model

Pooled Negative LR = 0.21 (0.11 to 0.41)
Coef-Q = 24.23; df = 8 (P = .0021)
Inconsistency (I-square) = 67.0%
Tau-squared = 0.5604
Doppler ultrasound
- 一般、方法
- 知見
- 実際
- まとめ、私見

Contrast Enhanced Ultrasound
- 方法
- 知見
- まとめ、私見

AKI-輸液

AKI診断
AKI予後予測
モニタリング
治療
Diagnostic accuracy of Doppler renal resistive index for reversibility of acute kidney injury in critically ill patients


- 目的: persistent AKI or transient AKIをRIで予測できるか
- デザイン: prospective observational study

- 対象:
  単施設、ICU、人工呼吸器導入72時間以内

- 除外:
  18歳未満、妊婦、AKI回復途中、CCr≤30ml/min
  腎血管狭隘、腎後性、利尿剤投与、不整脈
方法

挿管後、なるべく早くRI測定
右腎のみ、弓状動脈か葉間動脈を同定
3ヶ所平均測定

AKI: 初日にAKI判定→3日後にtransient AKI or persistent AKIか判定

定義:

AKI: AKIN分類(下図)
persistent AKI: Cr値の上昇継続、乏尿
transient AKI: 腎低灌流に伴うAKI, 3日以内に回復(Cr値が半分 or ベース値)

AKIN分類

<table>
<thead>
<tr>
<th>ステージ</th>
<th>糸球体濾過量(GFR)</th>
<th>尿量</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>血清Cr値上昇≥0.3mg/dlまたは血清Cr値上昇150〜200%（基礎値の1.5〜2倍）</td>
<td>6時間以上にわたって0.5mL/kg/時間以下</td>
</tr>
<tr>
<td>2</td>
<td>血清上昇&gt;200〜300%（基礎値の2〜3倍）</td>
<td>12時間以上にわたって0.5mL/kg/時間以下</td>
</tr>
<tr>
<td>3</td>
<td>血清Cr値上昇&gt;300%（基礎値の&gt;3倍）または血清Cr上昇0.5mg/dlを伴って血清Cr≥4mg/dL</td>
<td>24時間以上にわたって0.3mL/kg/時間以下または12時間以上にわたって無尿</td>
</tr>
</tbody>
</table>

Renal replacement therapyを受けた場合はステージ3とする。
Table 1 Characteristics of patients without acute kidney injury (AKI), with transient AKI, or with persistent AKI

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>All patients (n = 51)</th>
<th>No AKI (n = 16)</th>
<th>Transient (n = 13)</th>
<th>Persistent (n = 22)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender</td>
<td>37 (73%)</td>
<td>11 (69%)</td>
<td>9 (69%)</td>
<td>17 (77%)</td>
<td>0.80</td>
</tr>
<tr>
<td>Age (years)</td>
<td>62 (48–72)</td>
<td>53 (42–54)</td>
<td>55 (47–70)</td>
<td>71 (62–75)</td>
<td>0.01</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26 (23–28)</td>
<td>26 (22–27)</td>
<td>24 (23–26)</td>
<td>27 (26–29)</td>
<td>0.009</td>
</tr>
<tr>
<td>Knaus C or D [24]</td>
<td>27 (53%)</td>
<td>8 (50%)</td>
<td>7 (54%)</td>
<td>12 (54%)</td>
<td>0.08</td>
</tr>
<tr>
<td>LOD score at ICU admission [23]</td>
<td>7 (5–9)</td>
<td>6 (4–6)</td>
<td>6 (4–7)</td>
<td>9 (8–11)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Time between MV and inclusion</td>
<td>1 (1–1)</td>
<td>1 (1–1)</td>
<td>1 (1–1)</td>
<td>1 (1–1)</td>
<td>0.99</td>
</tr>
<tr>
<td>Baseline creatinine (µmol/l)</td>
<td>88 (75–97)</td>
<td>82 (70–97)</td>
<td>90 (73–99)</td>
<td>88 (78–105)</td>
<td>0.47</td>
</tr>
<tr>
<td>Risk factors for AKI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate chronic kidney disease³</td>
<td>6 (12%)</td>
<td>0 (0%)</td>
<td>2 (14%)</td>
<td>4 (18%)</td>
<td>0.77</td>
</tr>
<tr>
<td>Sepsis</td>
<td>35 (69%)</td>
<td>10 (67%)</td>
<td>9 (64%)</td>
<td>16 (73%)</td>
<td>0.85</td>
</tr>
<tr>
<td>History of hypertension</td>
<td>27 (53%)</td>
<td>4 (25%)</td>
<td>7 (54%)</td>
<td>16 (73%)</td>
<td>0.02*</td>
</tr>
<tr>
<td>Diabetes</td>
<td>21 (41%)</td>
<td>5 (31%)</td>
<td>6 (46%)</td>
<td>10 (46%)</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Resistive index                          | 0.77 (0.71–0.82)      | 0.71 (0.66–0.77) | 0.71 (0.62–0.77)   | 0.82 (0.81–0.89)    | <0.0001*|

• N=51、60歳前後、BMI 25強、Sepsis 7割前後

• RI: (no AKI, transient AKI) < (persistent AKI)
Fig. 1 Scatterplot of the Doppler sonography renal resistive index ($RI$) in the three groups of patients according to renal function, namely, absence of acute kidney injury ($AKI$), presence of pre-renal, or persistent AKI. The dotted line represents a RI of 0.795

- $RI > 0.795$
- Persistent AKI 陽性的中率: 89%
- 陰性的中率: 87%
目的:
RI, シスタチンCでAKI発生予測(72時間以内)の検討

デザイン:
prospective observational study

対象:
2施設、18歳以上、重症敗血症、重症外傷、1時間以上MAP65mmHg以上で安定

除外:
片腎、腎結石、慢性腎不全、腎動脈狭窄
方法:
入院後12時間以内にRI測定
右腎のみ
弓状動脈か葉間動脈を同定
安定した3つの wave pulse を描出
両腎3か所ずつ描出し、平均値算出
左右差>0.05の時は除外(片側閉塞性の可能性)

入院初日、3日目にAKI判定(AKIN分類)
<table>
<thead>
<tr>
<th>Data</th>
<th>Overall</th>
<th>Sepsis</th>
<th>Polytrauma</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>58</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>Age, y</td>
<td>44 (24–58)</td>
<td>54 (34–65)</td>
<td>32 (20–50)</td>
</tr>
<tr>
<td>Sex, M/F, n</td>
<td>40/18</td>
<td>17/11</td>
<td>23/7</td>
</tr>
<tr>
<td>SAPS II</td>
<td>32 (15–45)</td>
<td>41 (27–47)</td>
<td>25 (15–37)</td>
</tr>
<tr>
<td>Mechanical ventilation, n (%)</td>
<td>35 (60)</td>
<td>15 (54)</td>
<td>20 (67)</td>
</tr>
<tr>
<td>MAP, mmHg</td>
<td>80 (70–87)</td>
<td>79 (71–83)</td>
<td>81 (70–90)</td>
</tr>
<tr>
<td>Arterial lactate, mmol/L</td>
<td>2.2 (1.6–4.7)</td>
<td>2.5 (1.6–5.2)</td>
<td>2.1 (1.6–3.6)</td>
</tr>
<tr>
<td>Catecholamine, n (%)</td>
<td>33 (57)</td>
<td>16 (57)</td>
<td>17 (57)</td>
</tr>
<tr>
<td>Norepinephrine, n (%)</td>
<td>29 (50)</td>
<td>14 (50)</td>
<td>15 (50)</td>
</tr>
<tr>
<td>Norepinephrine dose, µg/kg per min</td>
<td>0.13 (0.07–0.39)</td>
<td>0.17 (0.09–0.53)</td>
<td>0.08 (0.04–0.28)</td>
</tr>
<tr>
<td>Epinephrine, n (%)</td>
<td>4 (7)</td>
<td>2 (7)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Epinephrine dose, µg/kg per min</td>
<td>0.26 (0.16–0.47)</td>
<td>0.24 (0.15–0.34)</td>
<td>0.4 (0.17–0.6)</td>
</tr>
<tr>
<td>ICU mortality, n (%)</td>
<td>8 (14)</td>
<td>5 (18)</td>
<td>3 (10)</td>
</tr>
</tbody>
</table>

- N=58
- 30歳～50歳付近
- 6割が昇圧剤を要する
FIG. 1. Distribution of patients according to renal function upon inclusion and evolution throughout the study period.

Day3: stage 0～1: 40人 stage2～3: 18人
### Table 2. Characteristics of the patients on D1 according to the AKI stage on D3

<table>
<thead>
<tr>
<th></th>
<th>AKI 0–1</th>
<th>AKI 2–3</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, n</td>
<td>40</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>35 (22–51)</td>
<td>58 (50–69)</td>
<td>0.0024</td>
</tr>
<tr>
<td>SAPS II</td>
<td>24 (14–40)</td>
<td>51 (35–58)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Sepsis, n (%)</td>
<td>17 (43)</td>
<td>11 (61)</td>
<td>0.3</td>
</tr>
<tr>
<td>MAP, mmHg</td>
<td>80 (72–90)</td>
<td>77 (66–83)</td>
<td>0.08</td>
</tr>
<tr>
<td>Arterial lactate, mmol/L</td>
<td>1.8 (1.6–2.8)</td>
<td>4.0 (1.9–10.8)</td>
<td>0.0011</td>
</tr>
<tr>
<td>Catecholamine, n (%)</td>
<td>18 (45)</td>
<td>15 (83)</td>
<td>0.015</td>
</tr>
<tr>
<td>Mechanical ventilation, n (%)</td>
<td>19 (48)</td>
<td>16 (89)</td>
<td>0.0071</td>
</tr>
<tr>
<td>SCr, μmol/L</td>
<td>72 (60–92)</td>
<td>124 (85–191)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SCr clearance, mL/min per m²</td>
<td>109 (67–148)</td>
<td>24 (16–60)</td>
<td>0.0012</td>
</tr>
<tr>
<td>Urine output, mL/h</td>
<td>54 (37–88)</td>
<td>42 (7–52)</td>
<td>0.075</td>
</tr>
<tr>
<td>SCys, mg/L</td>
<td>0.68 (0.57–0.78)</td>
<td>1.23 (0.85–2.02)</td>
<td>0.0002</td>
</tr>
<tr>
<td>SCys clearance, mL/min per m²</td>
<td>125 (105–157)</td>
<td>57 (32–93)</td>
<td>0.0002</td>
</tr>
<tr>
<td>UCys, mg/L</td>
<td>0.09 (0.04–0.5)</td>
<td>3.32 (0.1–14.7)</td>
<td>0.0008</td>
</tr>
<tr>
<td>RI</td>
<td>0.66 (0.62–0.70)</td>
<td>0.80 (0.72–0.82)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Values are median (interquartile range), unless otherwise stated. SAPS II indicates Simplified Acute Physiology Score II.

Day3のAKI予後不良⇒Day1のRI高値
TABLE 3. Comparison of ROC curve for RI, SCr, SCys, and UCys as predictors of AKI 2-3 on D3

<table>
<thead>
<tr>
<th></th>
<th>Cutoff value</th>
<th>Odds ratio (95% CI)</th>
<th>Univariate logistic regression $P$</th>
<th>AUC</th>
<th>Multivariate logistic regression $P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCr</td>
<td>107 $\mu$mol/L</td>
<td>1.04 (1.01–1.06)</td>
<td>0.0016</td>
<td>0.826</td>
<td>NS</td>
</tr>
<tr>
<td>Creatinine clearance D1</td>
<td>—</td>
<td>0.95 (0.91–0.99)</td>
<td>0.0088</td>
<td>0.897</td>
<td>NS</td>
</tr>
<tr>
<td>SCys</td>
<td>0.8 mg/L</td>
<td>11.34 (1.86–69.32)</td>
<td>0.0086</td>
<td>0.837</td>
<td>NS</td>
</tr>
<tr>
<td>Cystatin C clearance D1</td>
<td>—</td>
<td>0.97 (0.95–0.99)</td>
<td>0.0012</td>
<td>0.836</td>
<td>NS</td>
</tr>
<tr>
<td>UCys</td>
<td>1.28 mg/L</td>
<td>1.34 (0.996–1.81)</td>
<td>0.0534</td>
<td>0.761</td>
<td>NS</td>
</tr>
<tr>
<td>Renal RI</td>
<td>0.707</td>
<td>13.90 (3.24–59.59)</td>
<td>0.0004</td>
<td>0.910</td>
<td>0.0004</td>
</tr>
<tr>
<td>Sepsis vs. polytrauma</td>
<td>NA</td>
<td>0.47 (0.15–1.47)</td>
<td>0.1932</td>
<td>0.593</td>
<td>NS</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; NA, not applicable; NS, not significant; SAPS II, Simplified Acute Physiology Score II.

Day3 AKI stage 2～3の予測
• RI: 0.707→AUCが0.909
Doppler ultrasound
• 一般、方法
• 知見
• 実際
• まとめ、私見

Contrast Enhanced Ultrasound
• 方法
• 知見
• まとめ、私見

AKI-輸液

AKI診断
AKI予後予測
モニタリング
治療
Early detection of postoperative acute kidney injury by Doppler renal resistive index in cardiac surgery with cardiopulmonary bypass

G. Bossard, P. Bourgoin, J. J. Corbeau, J. Huntzinger and L. Beydon*


• 目的: 心臓外科術後（人工心肺あり）、RI、AKI発生予測検討
• デザイン: prospective observational study

• 対象:
  （60歳以上、動脈炎、頸動脈狭窄50%以上、弁膜症手術、術前IABP使用）うち2つを有する患者
• 除外:
  
  CCr < 30ml/min、腎動脈狭窄、緊急手術、腎毒性治療あり、非洞調律
• 方法: MAP65mmHgが得られてから測定
Fig 2 Resistance index before and after the operation in subjects who underwent preoperative RRI assessment. Horizontal marks represent the mean of the nearby data points.

- AKI群
  術前→術後RI上昇

- RI:
  No AKI < AKI
術後AKIの予測
RI 0.74→感度0.94、特異度0.89
Doppler ultrasound

• 一般、方法
• 知見
• 実際
• まとめ、私見

Contrast Enhanced Ultrasound

• 方法
• 知見
• まとめ、私見

AKI-輸液

AKI診断
AKI予後予測
モニタリング
治療
Renal Perfusion Assessment by Renal Doppler During Fluid Challenge in Sepsis

David Schnell, MD1,2; Laurent Camous, MD1,3; Stéphane Guyomarç’h, MD4; Jacques Duranteau, MD, PhD5; Emmanuel Canet, MD1; Pierre Gery, MD4; Anne-Sylvie Dumenil, MD5; Fabrice Zeni, MD, PhD4; Elie Azoulay, MD, PhD1; Michael Darmon, MD, PhD4,6

(Crit Care Med 2013; 41:1214–1220)

• 目的: 輸液反応性とRIを評価
• デザイン: prospective observational study

• 対象:
  3施設ICU、心拍出量モニタリングされている人工呼吸器患者、
  輸液負荷が必要な患者

除外:
18歳未満、妊婦、AKI回復途中、CCr≤30ml/min、腎血管狭窄、
不整脈
• 方法:
輸液負荷が必要とされた人工呼吸器患者
輸液負荷(生食500ml 30分)前、負荷後にRI測定

• 定義:
AKI: AKIN分類に基づく
persistent AKI: Cr値の上昇継続、乏尿
transient AKI: 腎低灌流に伴うAKI, 3日以内に回復

• 輸液反応性判定:
大動脈血流量が10%以上増加したときに反応性ありとする（経食道エコーで測定）
Figure 2. Scatterplot of the relationship between changes in stroke volume before (T0) and after (T1) fluid challenge (FC) and changes in renal resistive index (RI). Stroke volume was not correlated with RI changes after FC ($r^2 = 0.04, p = 0.25$).

- 輸液反応性と RIの変化
→相関は低い
・輸液負荷前、反応性の有無でRI有意差なし

Figure 1. Boxplot showing the resistive index (RI) before and after fluid challenge (FC) in FC responders (dark gray) and nonresponders (light gray). The Doppler-based renal RI was not modified by the FC in nonresponders (0.72 [0.67–0.75] before and 0.71 [0.67–0.75] after FC, \( p = 0.62 \)) or responders (0.70 [0.65–0.75] before and 0.72 [0.68–0.74] after FC, \( p = 0.11 \)).

・輸液反応群、非反応群いずれでも輸液負荷前後でRI有意差なし（ただし反応性なしの群ではわずかにRI上昇）
AKIありはRI高値
0.66 [0.65–0.70] v.s. 0.72 [0.69–0.76]  p=0.05
TABLE 2. Response to Fluid Challenge and Resistance Index Variations According to Renal Status

<table>
<thead>
<tr>
<th>Characteristics before FC (T0)</th>
<th>No AKI, n = 9</th>
<th>Transient AKI, n = 13</th>
<th>Persistent AKI, n = 13</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean arterial pressure (mm Hg)</td>
<td>77 (73–81)</td>
<td>77 (73–81)</td>
<td>68 (64–78)</td>
<td>0.09</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>115 (95–122)</td>
<td>113 (92–133)</td>
<td>120 (99–127)</td>
<td>0.89</td>
</tr>
<tr>
<td>Stroke volume (mL)</td>
<td>54 (41–69)</td>
<td>39 (27–64)</td>
<td>41 (27–102)</td>
<td>0.51</td>
</tr>
<tr>
<td>Resistive index</td>
<td>0.66 (0.65–0.70)</td>
<td>0.71 (0.70–0.73)</td>
<td>0.76 (0.67–0.80)</td>
<td>0.06</td>
</tr>
</tbody>
</table>

• AKI予測

RI: Transient AKI < persistent AKI (ただしp=0.06)
Doppler ultrasound

- General, methods
- Knowledge
- Actual
- Summary, personal opinion

Contrast Enhanced Ultrasound

- Methods
- Knowledge
- Summary, personal opinion

AKI-輸液

AKI診断
AKI預後予測
モニタリング
治療
Doppler resistive index to reflect regulation of renal vascular tone during sepsis and acute kidney injury

Antoine Dewitte\textsuperscript{1,2,*}, Julien Coquin\textsuperscript{1,3}, Bertrand Meyssignac\textsuperscript{1}, Olivier Joannès-Boyau\textsuperscript{1}, Catherine Fleureau\textsuperscript{1}, Hadrien Roze\textsuperscript{1,3}, Jean Ripoche\textsuperscript{2}, Gérard Janvier\textsuperscript{1,3}, Christian Combe\textsuperscript{2,4} and Alexandre Ouattara\textsuperscript{1,3}

Critical Care 2012, 16:R165

• 目的: AKIの有無とMAP(平均動脈圧)-敗血症患者RIの検討
• デザイン: prospective observational study

• 対象:
  単施設ICU、重症敗血症(診断から24時間以内)
• 除外:
  18歳未満、妊娠、AKI回復途中、CCr\leq 30ml/min、腎血管狭窄、腎後性、ACE阻害薬、NSAIDs、肝硬変、エピネフリンorドブタミンを要する（心原性の要素）
### Table 2 Characteristics of patients according to acute kidney injury

<table>
<thead>
<tr>
<th></th>
<th>No AKI (n = 42)</th>
<th>Transient AKI (n = 24)</th>
<th>Persistent AKI (n = 28)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean arterial pressure, mm Hg</td>
<td>78 (67-86)</td>
<td>70 (65-87)</td>
<td>70 (65-87)</td>
<td>0.4</td>
</tr>
<tr>
<td>Heart rate, beats per minute</td>
<td>92 (78-105)</td>
<td>90 (83-120)</td>
<td>96 (79-117)</td>
<td>0.5</td>
</tr>
<tr>
<td>Fluid balance on inclusion day, mL</td>
<td>1,585 (837-2,612)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1,725 (1,205-3,002)</td>
<td>2,650 (1,556-3,487)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.01</td>
</tr>
<tr>
<td>Norepinephrine dose, µg/kg per minute</td>
<td>0.18 (0.06-0.37)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.29 (0.11-0.45)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.48 (0.20-0.78)&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>0.01</td>
</tr>
<tr>
<td>Cardiac index, L/minute per m²</td>
<td>3.1 (2.3-4.6)</td>
<td>3.3 (2.3-3.8)</td>
<td>3.1 (2.4-4.2)</td>
<td>1</td>
</tr>
<tr>
<td>Blood lactate, mEq/L</td>
<td>1.2 (0.9-2.0)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.5 (1.0-2.9)</td>
<td>2.4 (1.3-3.9)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.02</td>
</tr>
<tr>
<td>Hematocrit, percentage</td>
<td>30 (27-33)</td>
<td>31 (28-38)</td>
<td>29 (25-32)</td>
<td>0.3</td>
</tr>
<tr>
<td>PaO₂/FiO₂ ratio</td>
<td>240 (140-320)</td>
<td>240 (140-305)</td>
<td>180 (120-260)</td>
<td>0.1</td>
</tr>
<tr>
<td>Serum creatinine at inclusion, µmol/L</td>
<td>69 (45-81)&lt;sup&gt;a,c&lt;/sup&gt;</td>
<td>160 (98-196)&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>191 (134-243)&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>FeNa, percentage</td>
<td>0.5 (0.2-1)&lt;sup&gt;a,c&lt;/sup&gt;</td>
<td>1.5 (0.6-2.4)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.7 (0.6-6.7)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.008</td>
</tr>
<tr>
<td>FeU, percentage</td>
<td>28 (16-39)</td>
<td>36 (31-45)</td>
<td>31 (12-46)</td>
<td>0.2</td>
</tr>
<tr>
<td>Resistance index</td>
<td>0.72 (0.68-0.75)&lt;sup&gt;a,c&lt;/sup&gt;</td>
<td>0.75 (0.72-0.79)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.77 (0.70-0.80)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Results are expressed as median (interquartile range). FeNa, fractional excretion of sodium, was calculated as [[(urine sodium/plasma sodium)/(urine creatinine/plasma creatinine)] × 100. FeU, fractional excretion of urea, was calculated as [[(urine urea/plasma urea)/(urine creatinine/plasma creatinine)] × 100. P value refers to between-group comparisons (Kruskal-Wallis one-way analysis of variance with post hoc analysis). <sup>a</sup>P <0.05 compared with persistent acute kidney injury (AKI) group. <sup>b</sup>P <0.05 compared with no AKI group. <sup>c</sup>P <0.05 compared with transient AKI group. PaO₂/FiO₂, arterial partial pressure of oxygen/fraction of inspired oxygen.

- **RI:**
  - No AKI - transient AKI: p<0.05
  - No AKI - persistent AKI: p<0.05
Figure 1 Relationship between resistive index (RI) and mean arterial pressure (MAP) in patients without acute kidney injury (AKI).

- AKI なし群
RIとMAP
負の相関関係

Figure 2 Relationship between resistive index (RI) and mean arterial pressure (MAP) in patients with acute kidney injury (AKI).

- AKIあり群
相関関係なし

Correlations were assessed by using Spearman correlation coefficient.
Doppler ultrasound

- 一般、方法
- 知見
- 実際
- まとめ、私見

Contrast Enhanced Ultrasound

- 方法
- 知見
- まとめ、私見

AKI-輸液

習得

AKI診断
AKI予後予測
モニタリング
治療
 Resistive Index or color-Doppler semi-quantitative evaluation of renal perfusion by inexperienced physicians: results of a pilot study

D. SCHNELL 1, 2, M. REYNAUD 3, M. VENOT 1, A.-L. LE MAHO 4, M. DINIC 3, M. BAULIEU 3, G. DUCOS 1, J. TERREAUX 3, F. ZENI 3, E. AZOULAY 1, F. MEZIANI 2, J. DURANTEAU 4, M. DARMON 3, 5

Minerva Anestesiol 2014;80:1273-81

• 目的: RI、半定量評価を用いた腎灌流評価、熟練-非熟練間の差異検討

• デザイン: prospective observational study

• 対象:
  3施設、ICU、人工呼吸器患者(導入から48時間以内)

• 除外:
  18歳未満、妊婦、AKI回復途中、CCr≤30ml/min、腎血管狭窄、腎後性、不整脈
方法：
• 熟練者：腎エコー評価の5年以上の経験あり
• 非熟練者：腎エコーの経験なし

• 非熟練者：腎エコーによる腎灌流評価に関して半日のtraining sessionを受ける

• Training session
  1時間の講義
  2-3時間のハンズオン：腎臓の同定、腎臓内の血管をドプラーやで同定、半定量評価、RI計算
Grade Renal perfusion

- 0  Unidentifiable vessels
- 1  Few vessels visible in the vicinity of the hilum
- 2  Hilar and interlobar vessels visible in most of the renal parenchyma
- 3  Renal vessels identifiable until the arcuate arteries in the entire field of view

RI計測
右腎、3波で計測、平均値算出

AKI定義: AKIN分類
Table II.—Main patient characteristics according to renal function at inclusion.

<table>
<thead>
<tr>
<th>Renal perfusion at inclusion</th>
<th>All patients N.=69</th>
<th>Patients without AKI N.=48</th>
<th>Patients with AKI N.=21</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI (junior operator)</td>
<td>0.69 (0.63-0.76)</td>
<td>0.67 (0.62-0.72)</td>
<td>0.76 (0.66-0.82)</td>
<td>0.04</td>
</tr>
<tr>
<td>RI (senior operator)</td>
<td>0.70 (0.64-0.74)</td>
<td>0.70 (0.64-0.74)</td>
<td>0.75 (0.69-0.81)</td>
<td>0.01</td>
</tr>
<tr>
<td>Semiquantitative grade (junior)</td>
<td>2 (2-3)</td>
<td>3 (2-3)</td>
<td>2 (1-2)</td>
<td>0.002</td>
</tr>
<tr>
<td>Semiquantitative grade (senior)</td>
<td>2 (2-3)</td>
<td>3 (2-3)</td>
<td>2 (1-2)</td>
<td>0.004</td>
</tr>
</tbody>
</table>

• AKIの有無: RI、半定量評価いずれも有意差あり
Figure 3.—Boxplot of Doppler-sonography renal resistive index (RI) values according to semi-quantitative color-Doppler grade.

- 半定量  RIの相関
  Color-Doppler grade ↓ - RI ↑
Persistent AKI

Cutoff: RI=0.75

Color-Doppler grade 1  78%-100%
Figure 2.—Bland-Altman plot of the mean of two resistive index (RI) values obtained by a senior and a junior operator, respectively; against the difference between the two values.\(^{19}\)

概ね、誤差がy軸+/-双方向に均等に分布

→2測定値間の差は偶然誤差の要素大きい

加算誤差:
上限:+0.105
下限:-0.107

非熟練者による評価はおおむね妥当
ちなみにお、
Intrarenal Resistive Index after Renal Transplantation


• 目的: 移植片機能に関するRIの有用性評価
• デザイン: prospective observational study

• 対象: 単施設、片腎移植患者
• 除外: 水腎症、腎動脈狭窄、腎周囲液体貯留
• 方法: 術前、3、12、24か月後に生検＋RI測定 or 急性の機能不全
  生検＋RI測定
D ≥50% Reduction in Estimated GFR

- 3か月時点 RI 0.8以上
   腎機能↓
   死亡率↑
Doppler ultrasound
• 一般、方法
• 知見
• 実際
• まとめ、私見

Contrast Enhanced Ultrasound
• 方法
• 知見
• まとめ、私見
• 178cm 85kg BMI 27
• 脳外科患者
• 測定当日: BUN/Cr: 13/0.6 尿量1500ml/日
初回施行（吉田）
178cm 85kg BMI 27 腦外科患者
測定当日：BUN/Cr: 13/0.6 尿量1500ml/日

半定量評価: Grade 1〜2
• Restive Index
  \[0.16 \div (0.57-0.16) = 0.39\]

• 呼吸変動が大きく、動脈にパルスドプララーのgateを合わせるのが難しかった
• 所要時間15分ぐらい
• 息止め、もしくは呼吸の影響が読みやすい患者でないと難しい印象
Doppler ultrasound
• 一般、方法
• 知見
• 実際
• まとめ、私見

Contrast Enhanced Ultrasound
• 方法
• 知見
• まとめ、私見

AKI-輸液
まとめ

- RIの正常値は0.7付近
- AKI発生時、RI値は高めとなる
- RI高値は、3日後AKI的な予後を予測することができる

- RI値と相関する血行動態パラメーターは不明
- RI値を改善させる事を治療目標にすべきが不明
- RI値を改善させる手段が不明
私見

・既存の研究は元のCCr\(\leq 30\)ml/min、不整脈、利尿剤使用を除外し、特定のpopulation（敗血症、人工呼吸器、CABG）のみの検討で注意が必要。
・一般化するには、まだまだ研究の蓄積が必要

・描出は難しくないが、呼吸動作が大きいと計測が難しい

・数少ない、AKIの短期予後を予測できる数値としての価値は高い
・現状で臨床で使える状況は、ICU在室か退室かの判断に迷う状況ぐらいか
Doppler ultrasound

- General, method
- Knowledge
- Reality
- Summary, personal opinion

Contrast Enhanced Ultrasound

- Method
- Knowledge
- Summary, personal opinion
Doppler ultrasound

- 一般、方法
- 知見
- 実際
- まとめ、私見

Contrast Enhanced Ultrasound

- 方法
- 知見
- まとめ、私見
Contrast-enhanced ultrasound

- 撹拌生食(micro bubbleがcontrast agent)の急速静注：右左シャント（奇異性塞栓、卵円孔開存、肺動静脈瘻）の証明手段として使われてきた
- 近年、脳虚血合併症の可能性が指摘されている

- 小さく殻が安定、肺循環を超える、適切な半減期を持つcontrast agentが開発中→現在、第2世代

Critical Care 2011, 15:157
Figure 2. Optical microscopic view of microbubbles in rabbit blood (courtesy of Bracco SpA).
Figure 4. Example of destruction refilling sequences obtained in a 60-year-old male patient 1 hour after coronary artery bypass surgery.
Each panel of the figure is divided in two; the left side shows contrast specific images and the right side standard B-mode images. (a) After the destruction flash (left), no signal is detectable in the contrast-specific image (that is, all the microbubbles have been destroyed). (b) Five seconds after destruction (left), partial replenishment of the main arteries with contrast can be noticed. (c) Ten seconds post-destruction (left), the kidney is fully replenished with contrast. No significant changes are observed in B-mode images (a-c, right).

- 左写真: コントラストエコー
- a→b→c: 静注直後→5秒後→10秒後
• Mean transit time (mTT) Relative blood volume (rBV)

Perfusion index (= rBV/mTT)
Doppler ultrasound

- 一般、方法
- 知見
- 実際
- まとめ、私見

Contrast Enhanced Ultrasound

- 方法
- 知見
- まとめ、私見

AKI-輸液
Contrast-enhanced ultrasonography to evaluate changes in renal cortical microcirculation induced by noradrenaline: a pilot study

Antoine G Schneider¹,³, Mark D Goodwin², Anthony Schelleman², Michael Bailey³, Lynne Johnson² and Rinaldo Bellomo¹,³,⁴*

Critical Care 2014, 18:653

・目的: CEUS-腎灌流の変化(血圧上昇)の関連性検討
・デザイン: prospective observational study

・対象:
  24時間以上昇圧剤が必要と考えられた人
・除外:
  頭蓋内圧亢進、EF30％以下、虚血性心疾患、心室性不整脈、
  大動脈瘤・解離、末期腎不全、RRT施行中、同意取得不可、
  60mmHg or 80mmHgが目標血圧として不適切、COIあり
Figure 2 Overall results. MAP, mean arterial pressure.

- PI: 3056 → 4101  P = 0.38
Figure 3 Perfusion indices patient per patient. (a) Raw data (arbitrary units). (b) Percentage change from baseline. Grey bars are for patients (Pt) with chronic hypertension (Pt 5, 7 and 10). MAP, mean arterial pressure.

- 個人のレベルでは大きな変化を示している人もいる
- 未知の要素に関してさらなる検討が必要
まとめ、私見

・灌流を知りたい、という問いに対し直感的で理解しやすい検査である

・治療目標になりうるか、どうすれば治療できるか、の手前段階であり、まだまだ実臨床で使用は難しい

・安全性への懸念はあり、市場に出回ってからも動向に注意が必要
全体 まとめ

・現状、輸液はAKIの治療手段にはなり得ない

・腎灌流を知りたい、という動機の元、研究が進められている

・文献数としてはRIに関する文献が多く、腎エコーの領域では引き続き、話題の中心になるだろう

・研究対象としての余地を感じる