Dynamic contrast-enhanced ultrasound identifies microcirculatory alterations in sepsis-induced acute kidney injury

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BACKGROUND: Microcirculatory slow flow combined with plugged capillaries is a hallmark of sepsis-induced AKI. The primary objective of our study was to use CEUS imaging to investigate microbubble kinetics in a porcine model of sepsis-induced AKI. As a second objective, we assessed the effect of fluid resuscitation on the CEUS parameters and its relation with LSI and Cytocam-IDF changes that occurred during the recovery of systemic hemodynamics.

METHODS: Experiments were conducted on fully instrumented and anesthetized 13 female pigs. While the auricular vein was used for anesthesia and fluid infusion, the left femoral artery was cannulated for monitoring arterial pressure, the swan-ganz catheter was inserted in pulmonary artery through the right jugular vein. The catheter in the right femoral vein was used for fluid resuscitation.

RESULTS: Plugged capillaries could be quantified by decreased peak enhancement and an increased ratio of the final plateau intensity to peak enhancement. Reduced intrarenal blood flow could be estimated by measuring the microbubble transit times between the interlobar arteries and capillary vessels in the renal cortex. LSI analysis confirmed that these CEUS parameters were related to cortical renal hypoperfusion. Cortical microcirculatory perfusion declined by further administration of fluids during resuscitation. Sublingual microcirculation measured by IDF in a fixed area showed decreased functional capillary density associated with plugged sublingual capillary vessels that persisted during and after fluid resuscitation.

CONCLUSION: These results confirmed the feasibility of dynamic CEUS imaging to visualize and quantify renal microcirculatory hypoperfusion by identifying the sepsis-induced plugging of microcirculatory capillary vessels. We also demonstrated that Cytocam-IDF could be used to easily detect sepsis-induced plugging of microcirculatory capillary vessels in one fixed sublingual area. In addition, our results demonstrated that microcirculatory alteration associated with sepsis-induced AKI persisted despite fluid resuscitation and successfully normalized systemic hemodynamic variables.
Keywords: acute kidney injury, sepsis, ceus, microcirculation

Figure 1

\[ TiC \text{ analysis} \]

Figure 2

\[ \text{Hemodynamic variables} \]

Figure 3
Bubble kinetics

Figure 4

CEUS overview
Figure 5

\[ \Delta \text{Time of arrival (s)} \]

\[ t_0 \quad t_1 \quad t_2 \]

$dT$ from the artery to ROI's

Figure 6

\[ \text{Median flux (a.u.)} \]

\[ t_0 \quad t_1 \quad t_2 \]

$LSI$

Figure 7
Cytocam example

Figure 8

Cytocam results