A MINIATURE ARTIFICIAL KIDNEY FOR PERITONEAL DIALYSIS

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Introduction and Aims: We are developing a miniature artificial kidney for peritoneal dialysis, based on the wearable artificial kidney developed within NEPHRON+ (EU FP7). By continuously regenerating dialysate, the device will maintain a large plasma-dialysate concentration gradient, thereby enhancing blood purification while reducing the number of exchanges. Application is envisaged at night as a bedside device. We studied efficacy of regeneration of potassium, phosphate, urea and creatinine removal from peritoneal dialysate by the device and explored whether equilibration at physiological [Ca²⁺], [Mg²⁺] and hypotonic [NaCl] could prevent calcium and magnesium adsorption and net sodium release, respectively.

Methods: In the miniature artificial kidney, spent peritoneal dialysate was pumped (235 mL/min) over a dialyzer and dialysate (100 mL) was recirculated (40 mL/min) over a sorption/electro-oxidation unit in counter current direction for 3 hours. The unit contains polystyrene-divinylbenzene-sulfonate (90 g) and FeOOH (30 g) beads for respectively potassium and phosphate removal. Organic waste (i.e. urea and creatinine) is removed by electro-oxidation (10 graphite electrodes; 3 A) combined with activated carbon (25 g). The sorption/electro-oxidation unit was equilibrated with a solution containing NaCl 95 mM, NaHCO₃ 25 mM, CaCl₂ 1.2 mM and MgCl₂ 0.45 mM.

Results: Cumulative removal of potassium, phosphate, urea and creatinine was 5.3±0.8, 1.7±0.4, 23.2±3.2 and 2.3±0.2 mmol in 3h at an average peritoneal dialysate concentration of 3.1±0.4, 1.2±0.2, 22.2±1.0 and 0.6±0.1 mM, respectively. Cumulative glucose removal was 23.2±3.9 mmol in 3h, primarily by rapid, saturable adsorption to activated carbon (removal 21.1±4.5 mmol in the 1st hour versus 0.5±1.1 mmol in the 3rd hour). Equilibration at [Ca²⁺] 1.2 mM, [Mg²⁺] 0.45 mM and [HCO₃⁻] 5 mM prevented adsorption of these ions. Equilibration at [Na⁺] 120 mM prevented sodium release. Electro-oxidation resulted in release of chlorine by-products, that could be reduced to <0.10 mg/L by activated carbon. Ammonia/-um was generated at a rate of 0.016±0.05 mole per removed mole of urea.

Conclusions: Clinically relevant removal of potassium, phosphate, urea and creatinine from peritoneal dialysate by the miniature artificial kidney was shown in vitro, suggesting that application of the device for peritoneal dialysate regeneration may be worth further exploring. Some glucose is also removed necessitating glucose infusion. Chlorine release complies with AAMI standards. Unfortunately, ammonia/-um is generated due to hydrolysis of urea, albeit at a low amount. Research aimed at increasing efficiency, preventing ammonia/-um release and biocompatibility is warranted.