

REGENERATION OF ULTRAFILTRATE BY NOVEL SYNTHETIC PYROLYSED CARBON ADSORBENTS.

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Introduction

Acute renal failure patients are admitted to the intensive care unit for many different reasons, such as a trauma, a cardiac insult or severe infection. Management of ICU patients is aimed at restoring the delivery of oxygen to tissues and correcting the underlying reason for the patient's presence on the ward (1). Often this is as a result of reduced functioning of one or more vital organs due to the event the patient has experienced prior to hospitalisation. An assortment of factors such as tissue hypoxia, ischaemia and an exaggerated systemic inflammatory response, which occur during sepsis, all add to the decline in organ function. One of the first organs to fail is often the kidneys. Once renal failure begins the patient's biochemistry will alter quite obviously through the retention of urea, creatinine, potassium, phosphate and other metabolic products.

During the 1970's continuous renal replacement therapy (CRRT), was developed for the treatment of acute renal failure patients. CRRT is described as a continuous extracorporeal blood purification therapy intended to substitute for impaired renal function over an extended period of time. Continuous venovenous hemofiltration (CVVH) is a technique of CRRT, where blood is driven through a porous membrane by a peristaltic pump, via an extracorporeal circuit originating from a vein and terminating in vein. Later this technique was modified, resulting in continuous arteriovenous hemofiltration (CAVH), that is with the blood circuit originating in an artery and terminating in a vein, with the patients own blood pressure driving the circuit. Hemofiltration was designed to remove accumulated metabolic products from the body by slow continuous ultrafiltration through a porous membrane. The hydrostatic pressure of the blood provides the force of filtration and an ultrafiltrate similar to the contents of the Bowman's space in the kidneys is produced. The hemofilter's inability to reabsorb filtered sodium and water, an essential function of the normal kidney, results in a need to replace the fluid and electrolytes from an external source. This replacement fluid is infused into the blood, on its return to the venous system, at rates similar to the filtration rate. This replacement fluid costs about £100/day of treatment.

Ideally in the treatment of these patients, the ability to remove endogenous toxins, which would otherwise be excreted by the healthy kidney, including urea, creatinine and middle molecules are wanted. Novel synthetic carbons were produced by pyrolysing vinylpyridine-divinylbenzene copolymer (SCN) and styrene-divinylbenzene copolymer (SUCS) with defined pore size distribution (0.25 - 0.5mm), have been manufactured by groups in the Ukraine and the UK. These carbons show extremely high biocompatibility due to their high mechanical strength which reduces the formation of fines and the absence of toxic leaching (2). These problems have been observed in comparable materials such as activated carbon and amberlites. By incorporating these types of adsorbents in a cartridge to be used in-line with extracorporeal systems to remove endogenous toxins from the patient's ultrafiltrate, should allow the recycling of 'clean' filtrate back to the patient. This would reduce the need for replacement fluids (3). In addition the system would be of benefit in the treatment of liver failure and sepsis patients. It would also represent substantial cost benefits by allowing the recycling of ultrafiltrate in the ICU and renal units.

Methods & Materials

We report the preliminary findings of a study investigating the potential of polymer based carbon adsorbents for the purpose of ultrafiltrate regeneration. SCN in both oxidised and non-oxidised forms, and SUCS have been used to study the removal of urea (Table 1). A urea solution was passed through a jacketed column containing 6g of carbon adsorbent (flow rate=1ml/min and 37°C). Timed pre and post-column samples were assayed using a standard colorimetric assay and spectrophotometry. A SCN column was run under the same conditions with UFR obtained from intensive care patients with acute renal failure. This allowed initial quantification by SDS-PAGE, standard colorimetric assays and spectrophotometry of urea, creatinine and middle molecules (500D-21000D) removal.

Table 1. Surface characteristics of copolymers used in adsorption study.

	SCN	SCN (4 hours oxidation)	SUCS
BET Surface Area (m ² /g)	950	990	1120
Total CEC* (meq/g)	<0.1	1.8	<0.1

* CEC - Cation Exchange Capacity.

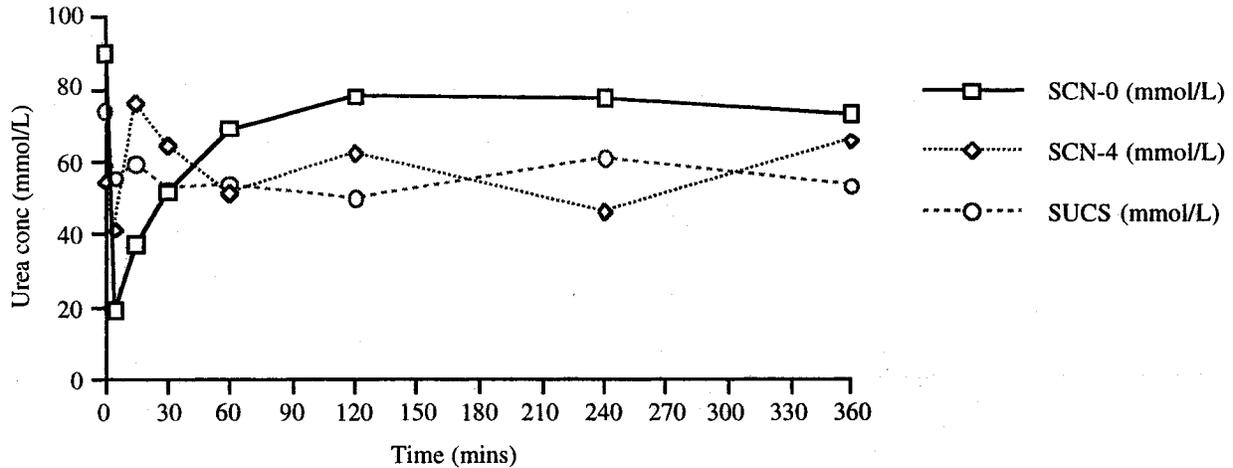


Figure 1 Adsorption of urea from solution by SCN, SCN-4 and SUCS.

Results

Urea was most efficiently removed from solution over the six hour column run by the unoxidised SCN (Figure 1). This carbon was then used in the running of columns perfused with UFR. Middle molecules were efficiently removed from the UFR by the carbons for up to 15 minutes, but with reduced efficiency as the polymers became saturated. Creatinine (400 μ mol/L) was removed effectively for the duration of the column run (6 hours). Urea (20mmol/L) showed saturation kinetics with SCN adsorbing up to 0.033mmol/g.

Discussion

These results demonstrate that with a volume of polymer pyrolysed carbon comparable to the size of hemofiltration cartridge, these adsorbents may offer a novel approach for the regeneration of UFR through the removal of urea, creatinine and middle molecules. This would also give the added benefit of removing a large financial burden from the intensive care unit.

References

- (1) Hinds, C.T. & Watson, D. (1996) In: Intensive Care Medicine - A Concise Textbook. 2nd Ed. 65-108.
- (2) Hughes, R.D. & Williams, R. (1993) Blood Purification 11 (3):163-169.
- (3) Lopukin, Y. N. *et al* (1972) In: Transplantation of endocrine organs in clinic and experiment. Extracorporeal Hemosorption. 69-81.