Removing the harmful molecules that accumulate in blood during storage

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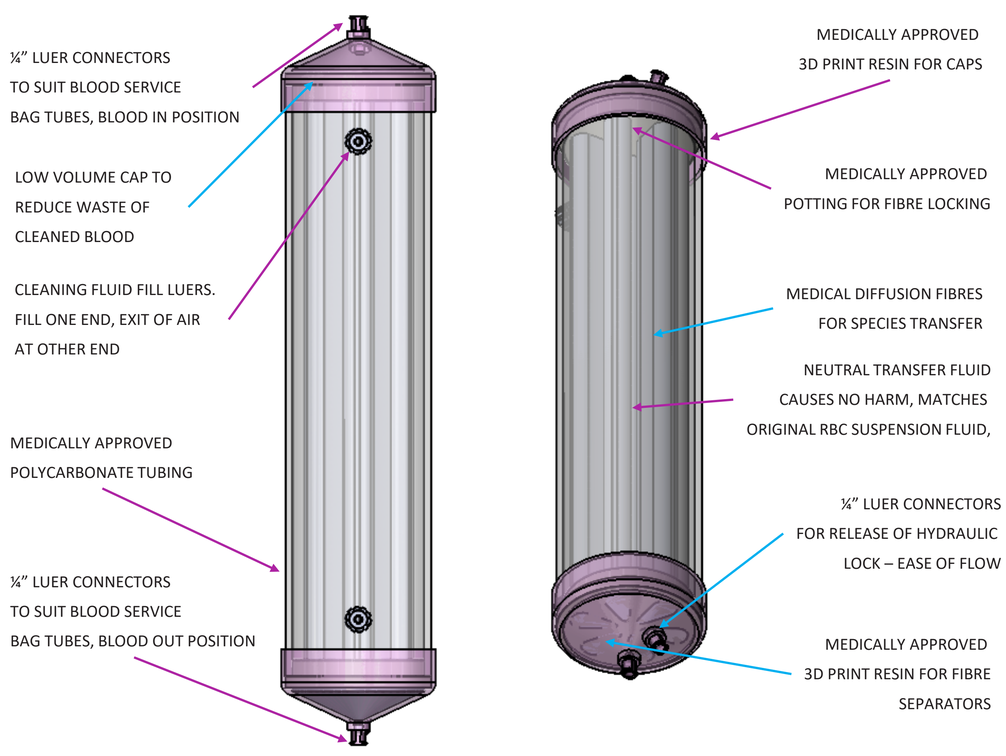
Motivation

Potentially harmful contaminants including potassium ions, free haemoglobin, and free haem accumulate during red cell concentrate (RCC) storage. Such species can have directly adverse impacts on health and may facilitate development of infection. Currently, the UK and EU limit RCC shelf life to 35 days; the North American limit is 42 days. Potassium concentrations over 40mmol/litre have been reported at the end of shelf life. The risks are highest for neonatal patients, and vulnerable patients in intensive care. There is strong, and increasing, motivation to find ways for reducing the concentrations of harmful species. It would be a bonus to restore the concentration of species depleted during storage and to reduce the proportion of misshapen cells which are less able to pass through capillaries.

There is also concern that removing the plasticiser DEHP from blood bags may reduce shelf life. There is evidence that DEHP has adverse health impacts [1] and its use in blood bags is being phased out.

Novel device for reducing concentrations of harmful species

The device illustrated in the figure consists of a vertical cylinder full of extracting liquid and containing an array of microporous hollow fibres sealed at the top and bottom. The pores are small enough to retain the red cells, but large enough to allow the harmful species to diffuse through. RCC to be treated drip into the top of the device, flow though the hollow fibres, and exit at the bottom. Harmful species diffuse through the fibres into the extracting liquid. The extractant is sealed into the cylinder so there is no net flow to or from the blood. The design ensures that blood haematocrit is the same at exit as in the feed. The device has no moving parts, and does not require any services such as water, gas, or electricity. The efficacy varies little with drip rate, so that automated control is not needed.



Time expired study

The Welsh Blood Service (WBS) supplied 11 units of dated blood containing potassium ion concentrations between 28 and 58 mmol/litre, free haemoglobin between 41 and 615 mmol/litre, creatinine between 32 and 53 µmol/l and urea between 1.75 and 4.9 mmol/L. Theory shows that the proportion of contaminants removed is independent of inlet concentration, but depends on the volume of blood processed, the volume of extractant, and the mass transfer coefficients for each species. Table 1 gives proportions of species removed using SAGM (saline-adenine-glucose-mannitol) extractant. The device was sized to remove >80% of potassium from one unit of blood in an hour. Measurements were made independently by Haemair and WBS.

Component	Haemair Measurement	WBS Measurement
Potassium ions	83%	84%
Free Haemoglobin	39%	43%
Creatinine	72%	
Urea	60%	

Table 1. Removal of potentially harmful components from RCC

At the same time, normal concentrations of sodium (150 mmol/L) and osmolarity (330 mmol/L) were restored. Haemoglobin, Haematocrit, and pH were unchanged.

We also measured red cell morphology to assess the impact of passing RCC through the fibres. Table 2 gives proportions of normally shaped red cells measured using light microscopy and confocal microscopy.

Measurement	Normal before	Normal after	Significance
Light microscopy	51.73 ± 7.9%	65.06 ± 4.47%	p = 0.23
Confocal microscopy	43.88 ± 9.04%	62.64 ± 7.84%	p = 0.425

Table 2. Change in red cell morphology after passage through device

The results indicate that morphology might be improved after passing red cells through the device.

Implications

The simple device can remove a significant fraction of harmful species from RCC. This could potentially reduce risks in blood transfusion and extend the shelf life. It opens the possibility of adding compounds to RCC that may improve cell flexibility and extend component shelf life, but would need to be removed before transfusion to a patient. Such added compounds could be removed shortly before transfusion.

References

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