A comparison of Balsol versus Ringers Lactate as cell saver washing solutions for packed red blood cells as part of priming solution in paediatric elective Cardiac Surgery with Cardio Pulmonary Bypass

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CONTENTS

INDEX

AUTHORS DECLARATION

I, Michelle Swanepoel, declare that the work for the following thesis with the title, A comparison of Balsol versus Ringers Lactate as cell saver washing solutions for packed red blood cells as part of priming solution in paediatric elective Cardiac Surgery with Cardio Pulmonary Bypass (CPB), was undertaken by myself and data was collected by perfusionists. All sections of this paper that use quotes or describe an argument or concept developed by another author have been referenced, including all secondary literature used, to show that this material has been adopted to support my thesis. The research presented in this dissertation has not been submitted to any other tertiary institutions.

The research described in this dissertation was carried out under the supervision of Dr. A. Van Aswegen. The research was conducted in the Department of Anaesthesia, Universitas Hospital, Bloemfontein, South Africa.

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ABSTRACT

Introduction

The need to add Packed Red blood cells (PRBC) to the Cardio Pulmonary Bypass (CPB) circuit prime cause unphysiological acid-base, electrolyte and metabolite values. The main reason why filtering techniques are used prior to paediatric cardiac bypass are to prepare a nearly physiological priming solution. It has become standard practice to wash PRBC before adding it to neonate CPB.

Aim

The aim was to measure and compare pH, electrolytes, metabolites, Haematocrit and Haemoglobin of packed RBC, washed with either Balsol or Ringers Lactate.

Methodology

A series of 20 units of packed RBC's was used and randomised to a Balsol group (control group) and a Ringers lactate group (interventional group) according to a randomisation list. A blood sample was obtained pre and post wash and analysed.

Results

In both groups there was a significant decrease in Potassium (K^+), Sodium (Na^+), Glucose, Haematocrit and Haemoglobin. In the Ringers Lactate group there was a significant increase in Partial pressure of Oxygen (pO_2) and Calcium (Ca^{2+}). In the Balsol group there was a significant increase in pH. There was a statistically significant difference in the percentage change between the two groups for pH, Partial pressure of Carbon dioxide (pCO2), pO_2, Ca^{2+} and Lactate.

Conclusion

The pCO_2, pO_2, Ca^{2+}, Lactate and Bicarbonate (HCO^{3-}) is closer to physiological values in the Ringers Lactate group and the pH, K^+ and Cl^- is closer to physiological values in the Balsol group. Glucose, Na^+, Hct and Hb changed to the same extend in both groups.

(N=250 words)

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LIST OF FIGURES

LIST OF TABLES

LIST OF ABREVIATIONS

ACSS	Autologous cell salvage system
BB-HS	Bicarbonate-buffered hemofiltration solution
BE	Base excess
CAT	Continuous autotransfusion
CPB	Cardiopulmonary Bypass
CS	Cell Saving
DAT	Discontinuous Autotransfusion
Hb	Haemoglobin
Hct	Haematocrit
IQR	Inter quartile range
Ml	Millilitres
mmHg	Millimetres mercury
mmol/L	Millimoles per litre
NaCl	Sodium chloride
$NaHCO_3$	Sodium bicarbonate
pCO_2	Partial pressure of carbon dioxide
pO_2	Partial oxygen pressure
PRBC	Packed red blood cells
RBC	Red blood cells
RL	Ringers Lactate
sO_2	Oxygen saturation
vs.	Versus

LIST OF SCIENTIFIC NOTATIONS

≈	Approximately
°C	Degrees Celsius
µg	Micrograms
µmol/g Hb	Micromoles per gram haemoglobin
Ca^{2+}	Calcium
Cl^{-}	Chloride
HCO_3	Bicarbonate
K^{+}	Potassium
Mg^{2+}	Magnesium
Na^{+}	Sodium
PO_4	Phosphate
△	Change

LIST OF APPENDICES

CHAPTER 1

Introduction

Cardiac Surgery and Extracorporeal Technology have developed considerably since the mid 1950's, but the advent of cardiac surgery performed under extra corporeal circulation gave rise to an enormous demand for homologous blood.

Perceptions of blood transfusions have changed as it has become appreciated that transfusions are not without risk. Stored Red blood cells undergo time dependant metabolic, biochemical and molecular changes which eventually result in irreversible damage, defined as "storage lesions" responsible for many adverse effects of red blood cell transfusion. Improvement in techniques have allowed for a storage period of 42 days for homologous blood. (Offner, 2004)

A study conducted by Koch et al. (2008) examined data from 2872 patients given red blood cell transfusions for coronary artery bypass grafting (CABG) or heart valve surgery or both between 1998 and 2006. The results demonstrate that patients receiving stored blood older than 2 weeks had a significantly increased risk of post-operative complications as well as reduced short term and long term survival.

Although meticulous improvement of surgical skills, extracorporeal circulation and post-operative management have contributed to a marked reduction in morbidity and mortality, the development of cardiac surgery to its present day would not have been possible without homologous blood substitution. (Pillay et al 2015)

Paediatric Cardiopulmonary Bypass (CPB) involves a high ratio of prime volume to patient blood volume. The need to add packed Red Blood cells to the CPB circuit prime may lead to unphysiological acid-base, electrolyte and metabolite values far outside the normal range.

Two Main reasons why Filtering Techniques are used prior to during or at the end of paediatric cardiac bypass are:

1. To prepare a nearly physiological priming solution and therefore avoid potentially harmful acid-base and electrolyte disturbances during initiation of CPB.
2. To impact favourably on the unwanted inflammatory response by eliminating pro-inflammatory mediators. (Osthaus et al 2009)

Massive and Rapid transfusion of RBC's may lead to substantial load of hydrogen ions, Carbon dioxide (CO_2) and potassium associated with haemodynamic instability caused by acid base and electrolyte disorders.
These problems are mainly caused by the preservative solution and worsen during storage. Many different methods have been developed, such as cell saver washing

of RBC's or ultrafiltration of priming fluid in order to reduce these disturbances. (Osthaus et al 2009)

It has also become standard practice to wash donor packed red blood cells before adding it to neonate CPB. (Swindell et al 2007)

At Universitas Hospital Paediatric CPB involves packed Red blood cells washed with Balsol, a balanced electrolyte solution, before adding it to a priming solution.

Aim and Objectives

This was a prospective Randomised Controlled Trail to analyse and compare the quality of Packed Red blood cells that had been washed in a cell saver, with either Balsol or Ringers Lactate, both balanced crystalloid solutions to use as priming for CPB for elective Paediatric Cardiac Surgery. The primary objective of the study was to measure and compare pH, electrolytes, metabolites, Haematocrit (Hct) and Haemoglobin (Hb) of packed red blood cells (PRBC), which was washed with either Balsol or Ringers Lactate. The secondary objective of this study was to determine if any value was influenced negatively or changed at all after packed Red Blood Cells was washed with either Balsol or Ringers Lactate.

CHAPTER 2

LITERATURE REPORT

Autologous Cell Salvage Systems

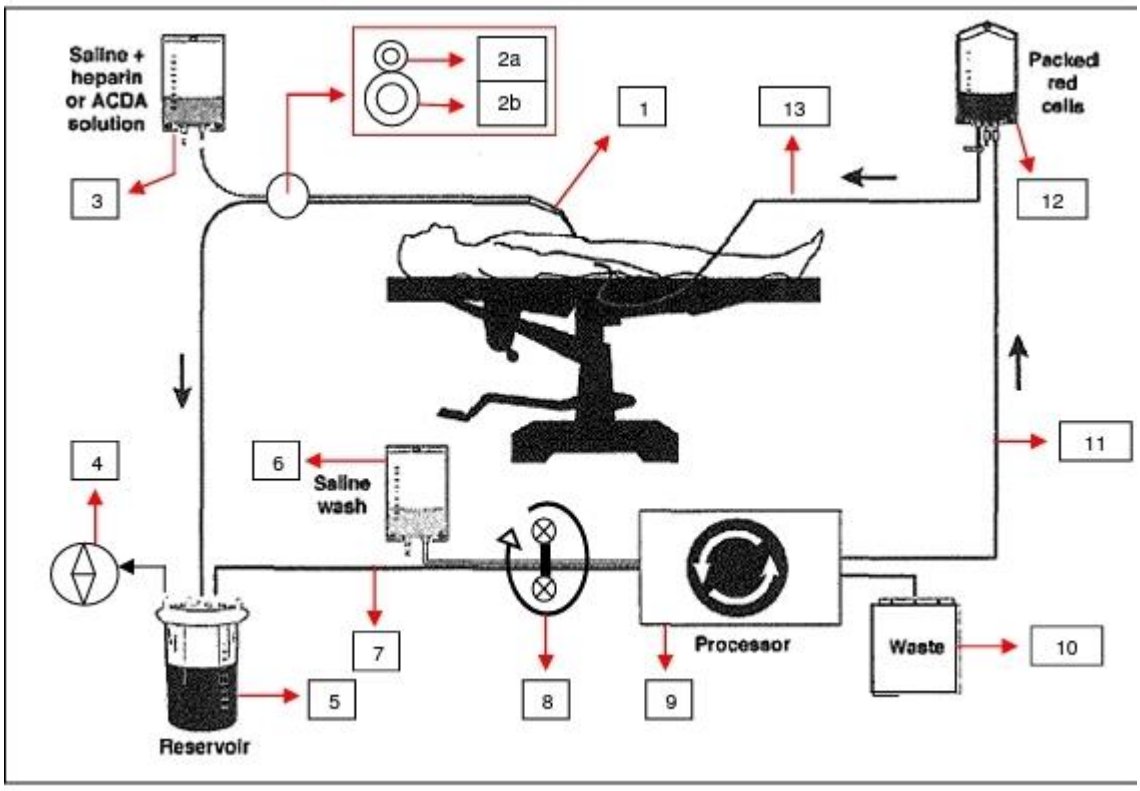

Figure 1: Schematic flow through an autologous cell salvage system

Table 1: Components and function of an Autologous Cell Salvage Systems (ACSS)

Component	Function
1	Represents the suction device.
2	2a and 2b represent a double lumen tube, line 2a carries anticoagulant solution towards the suction device. Line 2b carries anticoagulated blood mixture to a collection reservoir.
3	Represents a bag with the anticoagulant solution. The anticoagulant used is often 30000 international units (IU) of high molecular weight heparin mixed with one litre 0.9% saline. Alternatively acid citrate dextrose solution A (ACD-A) is used.
4	Represents a variable regulated suction device.
5	Represents the collection reservoir that contains a micro-aggregate filter which has a pore size of 20-40µm (microns).
6	Represents the wash solution, usually 0.9% saline that is carried to the centrifugal processor.
7	Represents the line that carries unprocessed filtered blood to the centrifugal processor.
8	Represents a roller pump that controls the rate at which unprocessed blood or wash solution is pumped into the centrifugal processor.
9	Represents the centrifugal processor unit which may be a discontinuous or continuous centrifuge systems.
10	Represents the waste bag that collects effluent from the centrifuge.
11	Represents the processed blood collection line that connects the centrifuge processor to the reinfusion bag. It is also referred to as the reinfusion line.
12	Represents the reinfusion bag that collects the processed re-suspended red blood cells (RBC).
13	Represents a central or peripheral infusion line from the reinfusion bag.

The components of an ACSS are required to accomplish four steps:

1. Collection and anticoagulation of shed blood: proper techniques should be applied in the collecting of shed blood to reduce RBC trauma. The system should be anticoagulated at all times to prevent clotting of blood in the system.
2. Filtering: blood must pass through a filter to remove large particles such as fat and fibrin. This will aid the centrifuging and washing process.
3. Centrifugation: separates low molecular weight and high molecular weight substances, and channels the low molecular weight substances into the waste container. Basically this fractionates RBC from other components of shed blood.

4. Washing: isotonic solution is introduced to carry away remaining activated coagulation factors, free haemoglobin, heparin, and proteolytic enzymes during further centrifugation. Thereafter, the RBC re-suspension can be collected for reinfusion.
   (Pillay, 2015)

CELL SALVAGE PROCEDURE

Installed identically for each case according to SORIN / XTRA operators manual protocol. (SORIN / XTRA operators Manual 2011)

Three Protocols can be used as described in Appendix M

- Popt
- Pstd
- Pfat

Three Phases:-
- Fill phase
- Wash phase
- Empty phase

All protocol except Pfat are carried out through the execution of 3 phases in this sequence.

The intra operative Pstd Protocol is used at Universitas and consists of the following:

First Blood is taken up from extra corporeal circuit (the packed RCB) and treated with an anticoagulant. The anticoagulant used is Sodium Heparin 25 000 IU per 1000ml Balsol / Ringers Lactate. It is then sent into the collection reservoir where it is filtered and stored. Next during the fill phase the system transfers blood from the reservoir into the spinning centrifuge bowl by use of the peristaltic pump. Centrifugation concentrates the RBC into the bowl while supernatant components are expelled to a waste bag.

Next during the wash phase a volume of:

- Saline as per manufacturer recommendation.
- Ringers Lactate - In my Study
- Balsol - In my Study

is washed through the concentrated RBC to remove the free plasma Hemoglobin, anticoagulant and other waste components.

Finally during the empty phase the concentrated RBC, with minimized amounts of waste contaminants are pumped into the RBC bag to be used as directed by the responsible medical practitioner e.g. for priming of CPB circuit in children.

The Pstd mode is designed to achieve a minimum RBC concentration and wash quality in the shortest processing time.

Less time than Popt protocol for a given volume of Blood to process.
In a study conducted by Naumenko et al (2008) they revealed that different centrifuge speeds and washing rates provided different quality of the processed autologous blood.

Thus in this study all settings on the cell saver will be standard for all cases.

Machine: SORIN / XTRA

Standard 225 ml Bowl

Protocol: Pstd

Fill Flow	-	200ml / min
Return Flow	-	250ml / min
Wash Flow	-	250ml / min
Wash Vol	-	1 000ml
Empty Flow	-	350ml / min
Conc Flow	-	300ml / min

BQW (Better Quality Wash) on 2x

<u>BQW Function:</u>

The Blood in the bowl undergoes a series of operations on the basis of a special protocol (accelerations + decelerations of the centrifuge) designed to optimize the wash phase of a cycle.
Twice (Short BQW) – In this state, the BQW cycle will be performed on the RBC's in the bowl up to twice during the wash phase.

HISTORIC OVERVIEW

The first successfully recorded use of cell salvage and autologous transfusion was in 1818 by a British gynaecologist named Dr. James Blundell. Blundell initially became interested in transfusion as a method of treating post-partum haemorrhage after being appalled by his own helplessness to combat fatal haemorrhage during delivery (Blundell, 1818). He transfused a woman afflicted with post-partum haemorrhage, blood soaked swabs were washed in saline and then the mixture was re-infused. This practice in its time was unsurprisingly associated with high mortality. Given the knowledge of haematology in Blundell's era he opposed animal to human transfusion but was an advocate of human to human transfusions. He did, however, report the problems such as rapid coagulation of the blood, infusion of air, and the dark urine passed in some patients (due to incompatible blood types) but maintained that transfusion should be used only in critically ill patients.

In 1874, an English surgeon, William Highmoore, also proposed the use of autotransfusion in his article published in the Lancet in 1974 (Highmoore, 1974). He suggested that the patient's own blood is an overlooked source which can be used to great advantage and advocated intraoperative autotransfusion particularly in the case of post-partum haemorrhage. In 1885, a surgeon Dr. John Duncan performed an amputation of a crushed limb at a late hour, and having no blood donors and only a saline solution as an imperfect alternative, chose to capture and re-infuse approximately eight ounces of a blood mixture collected while amputating the crushed limb. The transfusion of autologous blood proved successful and the patient made a full recovery.

Experimentation with cell salvage and autologous transfusion continued into the next century when it was successfully reported to be used in 1914 by a German, M.J. Theis in the treatment of ruptured ectopic pregnancy (Theis, 1914). Thereafter there were continued reports of autotransfusion employed in procedures including haemothorax, ruptured spleen, and perforating abdominal injuries. In 1943, Arnold Griswald developed the concept of the first cell salvage autotransfusion device (Ashworth and Klein 2010). Suctioned blood was collected in a bottle and then

strained through a cheese cloth before being re-infused. This formed the basic principles on which modern cell salvage devices are designed today. In the 1970's an American military surgeon, Klebanoff in association with Bentley Laboratories developed the first commercially available cell saver machine. The system required patients needing systemic anticoagulation and was associated with a number of complications, such as haemolysis, air embolism, coagulopathy, and renal failure resulting from reinfusion of unfiltered particles (Klebanoff, 1970). As the Bentley system lost favour the Haemonetics Corporation, founded by Jack Lathman in 1971, developed a discontinuous flow centrifuge system that washed salvaged blood with normal saline solution (Haemonetics Historical Timeline 2014) Fresenius later developed an alternative option, the continuous flow centrifuge system.

LITERATURE REVIEW

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Paediatric Cardiopulmonary Bypass (CPB) involves a high ratio of prime volume to patient blood volume. The need to add packed Red Blood cells to the CPB circuit prime lead to unphysiological acid-base, electrolyte and metabolite values far outside the normal range. Preservation of red blood cells in citrate-phosphate – dextrose buffered and saline adenine-glucose-mannitol solutions leads to high glucose levels and acidosis. The increase in potassium and decrease in sodium are due to breakdown of the membrane sodium-potassium pumps at the cold storage temperature of 4ºC with resultant leakage of potassium from cells. (Osthaus et al 2009)

Two main reasons why Filtering Techniques are used prior to during or at the end of paediatric cardiac bypass are to prepare nearly physiological priming solution and therefore avoid potentially harmful acid-base and electrolyte disturbances during initiation of CPB and to impact favourably on the unwanted inflammatory response by eliminating pro-inflammatory mediators. (Osthaus et al 2009)

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Little attention has however been given to the manufacture’s recommendation of 0,9% Saline or Normal Saline as wash solution. Evidence (Awad, Allison, and Lobo 2008) suggests there is nothing “normal” about 0.9% NaCl solution.

Sodium Chloride is only normal in terms of osmolality but it is not a balanced electrolyte solution and has been reported to result in hyperchloremic metabolic acidosis when large volumes are rapidly infused (Chowdhury et al 2012).
It also contributes to unwarranted electrolyte imbalances when used as wash solution, as important ions like potassium, magnesium, calcium and phosphate, that are important for cardiac function are depleted. (Huber et al 2013), (Halpern et al 1996)

Studies were done by Varghese et al (2007) and de Vroege et al (2007) where packed red blood cells were washed with Normal 0.9 % Saline. 57 packed RBC's and 20 packed RBC's respectively. They observed low calcium (Ca^{2+}) plasma levels have been attributed to its uptake by binding to citrate used as conservation media. Levels of potassium (K^+), phosphate (PO_4), glucose, osmolality, protein and lactate dehydrogenase (LDH) were significantly reduced after washing. Sodium (Na^+) concentration was the only electrolyte that significantly increased. Chloride (Cl^-) was not measured.

Table 2: Changes in K^+, Na^+, PO_4, Ca^{2+}, Glucose, osmolality, protein and LDH after processing with CAT and DAT systems (Varghese et al., 2007).

Variable	Before IAT device	After HCS	After CATS (quality mode)	After CATS (emergency mode)
Potassium (mEq L^{-1})	52 (44; 58)	4*† (3; 4)	4*† (3; 5)	17*‡ (14; 20)
Sodium (mEq L^{-1})	92 (87; 95)	154*† (153; 160)	153*† (148; 159)	138*‡ (136; 143)
Phosphate (mEq L^{-1})	37 (36; 39)	16*† (13; 18)	13*† (10; 20)	22*‡ (19; 25)
Calcium (mEq L^{-1})	0·1 (0; 0·2)	0·1 (0; 0·2)	0·1 (0; 0·2)	0·1 (0; 0·2)
Glucose (mg dL^{-1})	369 (353; 404)	132*† (121; 158)	120*† (99; 149)	214*‡ (190; 269)
Osmolality (mEq L^{-1})	304 (298; 310)	287*† (285; 290)	287*† (282; 289)	295*‡ (293; 298)
Protein (g dL^{-1})	0·4 (0·4; 0·5)	0·1*† (0·1; 0·1)	0·1*† (0; 0·1)	0·2*‡ (0·2; 0·3)
LDH (U L^{-1})	429 (376; 520)	11*† (5; 14)	5*†‡ (2; 7)	75*‡ (43; 92)

Values are median (25th, 75th percentile) of measurements with intraoperative autotransfusion devices (IAT; $n = 19$ each).
HCS, Haemonetics Cell Saver; CATS, Continuous Autotransfusion System.
*$P < 0.05$ vs. before IAT device.
†$P < 0.05$ vs. after CATS (emergency mode).
‡$P < 0.05$ vs. after HCS.

Table 3: Changes in pH, pCO_2, pO_2, HCO^{3-}, K^+, Na^+, Ca^{2+}, pO_2, Glucose, lactate and free Hb, before and after cell saver (CS) processing. (de Vroege et al., 2007).

Variable	Before washing ± SD	After washing ± SD
Ph	6.36 ± 0.04	6.36 ± 0.05
pCO_2 (kPa)	8.07 ± 3.59	0.73 ± 0.55 #
pO_2 (kPa)	26.92 ± 9.64	30.9 ± 7.25
$[HCO_3^-]$ (mmol/L)	3.36 ± 1.58	0.45 ± 0.13 #
$[K^+]$ (mmol/L)	47.91 ± 6.78	1.91 ± 0.73 #
$[Na^+]$ (mmol/L)	115.0 ± 6.8	145.0 ± 1.2 #
$[Ca^{2+}]$ (mmol/L)	0 ± 0	0.03 ± 0.08
sO_2 (%)	94.0 ± 8.0	97.0 ± 2.0
Glucose (mmol/L)	14.0 ± 2.5	3.62 ± 0.9 #
Lactate (mmol/L)	16.4 ± 2.1	7.6 ± 2.0 #
Free haemoglobin (g/L)	0.93 ± 0.37	1.03 ± 0.40

SD - Standard deviation
- significant difference compared to baseline values ($P < 0.05$)

In an in vitro setting Huber. et al (2013) washed 10 units of packed red blood cells with either 0,9 % Saline or a bicarbonate buffered hemofiltration solution (BB-HS) using a cell saver. The results of the study reveal, that in the 0,9 % saline group, pH, pCO2 and bicarbonate significantly decreased, in contrast to significant increase in the BB-HS group when compared to the 0,9 % Saline group. Base excess significantly increased in the 0,9 % Saline group in contrast to a significant decrease in the BB-HS group.

Potassium significantly decreased in both groups, whereas Sodium and Calcium significantly increased in both groups, despite 0,9 % Saline being calcium free. Chloride increased in the 0,9 % saline group in contrast to a significant decrease in the BB-HS group. Glucose and lactate decrease significantly in both groups.

Table 4: Changes in measured variables before and after washing with 0.9 % NaCl or BB – HS, (Huber et al., 2013)

Variables measured	Baseline unwashed PRBC Mean ± SD	End of study NaCl Mean ± SD	End of study BB-HS Mean ± SD	P^a
pH	6.71 ± 0.12	6.57 ± 0.12 #	6.85 ± 0.05 #	$p < 0.05$
pCO_2 (mmHg)	94.72 ± 12.39	18.03 ± 7.69 #	157.5 ± 14.46 #	$p < 0.05$
pO_2 (mmHg)	50.76 ± 6.74	62.26 ± 9.29 #	54.8 ± 8.98 #	$p < 0.05$
Bicarbonate (mmol/L)	11.30 ± 2.33	2.22 ± 1.26 #	10.84 ± 1.82 #	$p < 0.05$
Base excess(mmol/L)	-21.64 ± 3.52	-30.15 ± 1.42 #	-7.51 ± 2.49 #	$p < 0.05$
Potassium (mmol/L)	18.35 ± 5.17	2.71 ± 1.18 #	2.50 ± 1.54 #	NS
Sodium (mmol/L)	123.9 ± 4.6	142.2 ± 1.93 #	130.4 ± 1.84 #	$p < 0.05$
Chloride (mmol/L)	114.0 ± 2.50	138.0 ± 3.53 #	103.4 ± 1.35 #	$p < 0.05$
Calcium (mmol/L)	0.16 ± 0.05	0.40 ± 0.07 #	1.06 ± 0.16 #	$p < 0.05$
Glucose (mmol/L)	22.07 ± 2.42	7.69 ± 1.72 #	12.72 ± 1.48 #	$p < 0.05$
Lactate (mmol/L)	15.83 ± 3.67	8.76 ± 2.52 #	7.89 ± 2.23 #	NS
Haemoglobin (g/dL)	22.37 ± 3.66	22.29 ± 2.62	20.43 ± 1.62	NS
Haematocrit (%)	64.27 ± 4.10	66.70 ± 7.43	61.63 ± 5.01	NS
Free haemoglobin (mg/L)	588.5 ± 221.8	656.4 ± 346.8	418.9 ± 241.8 #	$p < 0.05$
LDH (U/L)	67.1 ± 33.4	89.0 ± 71.2	48.8 ± 31.0 #	NS
ATP ($\mu mol.gHb^{-1}$)	4.50 ± 0.63	4.55 ± 0.55	5.15 ± 0.40 #	$p < 0.05$

NS - not significant
LDH - lactate dehydogenase
# $P < 0.05$, end of study vs. baseline
P^a - value at end of study, NaCl vs. BB-HS

A prospective study done by Pillay et al (2015) analysed and compared the quality of residual pump blood post CPB that had been washed with either an unbalanced electrolyte solution (0.9 % Saline) or a balanced electrolyte solution (Balsol)
A series of 40 patients were used. They study concluded that Balsol used for washing residual CPB blood results in a re-suspended RBC concentrate, with an osmolality and electrolyte profile that is superior compared to washing residual CPB blood with 0,9 % Saline solution.

Table 5: Statistical summary of the change in post NaCl wash versus the change in post Balsol wash. (Pillay et al, 2015)

Variables measured	Post – wash NaCl Mean ± SD	Post – wash Balsol Mean ± SD	Statistical test	*p* value
pH	0.2 ± 0.1	0.2 ± 0.1	t test (2 group)[1]	= 0.1
pCO_2	-22.25 ± 2.9	-11.25 ± 6.4	t test (2 group)	< 0.001
pO_2	-386.7 ± 68.7	-356.9 ± 65.1	Mann-Whitney test[2]	= 0.03
$[K^+]$	-3.5 ± 0.8	0.4 ± 0.4	t test (2 group)	< 0.001
$[Na^+]$	13.4 ± 3.8	-9.15 ± 2.1	t test (2 group)	< 0.001
$[Cl^-]$	19.7 ± 3.0	-8.6 ± 3.0	t test (2 group)	< 0.001
$[Mg^{2+}]$	-1.4 ± 0.7	0.0065 ± 0.4	Mann-Whitney test	< 0.001
$[Ca^{2+}]$	-0.9 ± 0.1	-0.92 ± 0.1	Mann-Whitney test	= 0.004
$[PO_4^{3-}]$	-0.8 ± 0.3	-0.73 ± 0.19	t test (2 group)	= 0.2
Lactate	-2.9 ± 1.6	-2.77 ± 1.4	t test (2 group)	= 0.8
Glucose	-11.9 ± 2.8	-10.44 ± 2.7	t test (2 group)	= 0.1
Osmolatility	39.3 ± 65.4	-15.95 ± 29	Mann-Whitney test	< 0.001
Albumin	-12.2 ± 4.1	-13.2 ± 3.3	Mann-Whitney test	= 0.8
Total Protein	-20.6 ± 9.3	-20.65 ± 6.4	t test (2 group)	= 0.9
Haematocrit	35.3 ± 5.6	35.25 ± 4.7	Mann-Whitney test	= 0.6
Haemoglobin	11.7 ± 1.9	11.66 ± 1.7	Mann-Whitney test	= 0.6
TCO_2	*	1.33 ± 2.7	NA	NA
Bicarbonate	*	1.68 ± 2.6	NA	NA
Blood Volume	-2144 ± 768.6	-2165 ± 825.4	Mann-Whitney test	=0.9
SID	-8.7 ± 3.1	0.84 ± 3.3	t test (2 group)	< 0.001

*: incalculable by blood gas analyser, NA: not applicable

Halpern et al. (1997) conducted a prospective randomised study to compare 0.9% normal saline with Isolyte S (a balanced multi electrolyte crystalloid solution) when used as wash solution for cell saver autologous blood transfusion.

Table 6: Changes in prewashed systemic blood and washed blood when 0.9% saline and Isolyte S were used as wash solutions, (Halpern et al., 1997)

Variables measured	Prewashed systemic blood Mean ± SD		*p* value	Washed blood averaged Mean ± SD		*p* value	Percent change from prewashed to washed blood		*p* value
	Normal saline	Isolyte S		Normal saline	Isolyte S		Normal saline	Isolyte S	
pH	7.37 ± 0.07	7.43 ± 0.06	NS	7.39 ± 0.09	7.39 ± 0.06	NS	+0.3 ± 0.3	-0.4 ± 0.3	0.001
pCO_2 (mmHg)	31.5 ± 7.0	31.0 ± 6.0	NS	9.3 ± 2.0	10.3 ± 3.5	NS	-69 ± 6.0	-67 ± 9.0	NS
Bicarbonate (meq/L)	13.6 ± 1.6	16 ± 2.4	0.05	4.3 ± 0.8	5.1± 1.4	NS	-69 ± 4.0	-68 ± 7.0	NS
Potassium (meq/L)	3.7 ± 0.4	3.6 ±0.3	NS	1.4 ± 0.3	5.0 ± 0.3	0.0001	-60 ± 10	+41 ± 8.0	0.0001
Ionized calcium (mg/dL)	1.3 ± 0.04	1.2 ± 0.06	NS	0.6 ± 0.1	0.5 ± 0.2	NS	-55 ± 9.0	-59 ± 14	NS
Magnesium (mg/dL)	1.5 ± 0.2	2.1 ± 0.2	0.001	0.6 ± 0.4	3.2 ± 0.2	0.0001	-62 ± 23	+58 ± 21	0.0001
Inorganic phosphorus (mg/dL)	4.3 ± 1.2	3.6 ± 1.3	NS	1.3 ± 0.7	2.1 ± 0.7	0.05	-69 ± 8.0	-37± 14	0.005
Sodium (meq/L)	150.0 ± 4.0	151.0 ± 8.0	NS	153.0 ± 2.0	147.0 ± 7.0	0.05	+2.3 ± 3.0	-3.0 ± 1.0	0.001
Chloride (meq/L)	125.0 ± 10	116.0 ± 6.0	0.05	143.0 ± 8.0	104.0 ± 10	0.0001	+14 ± 4.4	-10 ± 5.0	0.0001
Lactic acid (mmol/L)	2.7 ± 1.6	2.9 ± 2.0	NS	1.3 ± 1.0	1.3 ± 1.1	NS	-54 ± 11	-57 ± 15	NS
Glucose (mg/dL)	113 ± 38	104 ± 31	NS	23 ± 6.0	23 ± 15	NS	-79 ± 5.0	-79 ± 11	NS
Total protein (g/dL)	4.2 ± 0.7	4.6 ± 0.6	NS	0.8 ± 0.4	1.2 ± 0.7	NS	-79 ± 6	-74 ± 12	NS
Albumin (mg/dL)	2.3 ± 0.4	2.3 ± 0.2	NS	0.5 ± 0.2	0.6 ± 0.3	NS	-79 ± 6.0	- 73 ± 12	NS
Haemoglobin (g/dL)	15.8 ± 1.2	16.3 ± 1.3	NS	15.5 ± 1.7	15 ± 1.8	NS	-2.0 ± 8.0	-7.0 ± 12	NS
Haematocrit (%)	47 ± 5.0	49 ± 5.0	NS	46 ± 5.0	44 ± 5.0	NS	-2.0 ± 9.0	-9.0 ± 12	NS

CHAPTER 3

MATERIALS AND METHODOLOGY

INTRODUCTION

This was a prospective Randomised Controlled Trail to analyse and compare the quality of Packed Red blood cells that had been washed in a cell saver, with either Balsol or Ringers Lactate, both balanced crystalloid solutions to use as priming for CPB for elective Paediatric Cardiac Surgery. The primary objective of the study was to measure and compare pH, electrolytes, metabolites Hct and Hb of packed RBC, which was washed with either Balsol or Ringers Lactate. The secondary objective of this study was to determine if any value was influenced negatively or changed at all after packed Red Blood Cells was washed with either Balsol or Ringers Lactate.

This study was conducted at Universitas Hospital Bloemfontein. The study included 20 children who were undergoing elective cardiac surgery who met the inclusion criteria, and whose parents gave informed consent to participate in the study. Patients were equally divided into a Balsol control group (n=10) and a Ringers Lactate interventional group (n=10) according to a randomisation list provided by the department of Biostatistics.

Inclusion criteria

- All paediatric cases under 12 years of age
- Packed Red Blood Cells according to blood bank regulations
- All paediatric elective Cardiac Surgery cases with the use of Cardiac Pulmonary Bypass

The data collection resulted in 240 measurements per group, which included pre and post cell saver processing. Similar previous studies have shown that a sample size of 40 is adequate to compare the control to the interventional group (de Vroege et al., 2007; Varghese et al., 2007; Huber et al., 2013; Pillay et al., 2015). The number of patients recruited and the sample size for this study is 20 patients. This sample size was approved by the Department of Biostatistics.

Under optimal conditions with full lists running roughly 2-3 paediatric cardiac cases are done with CPB per week. Due to cancelation of lists at Universitas Hospital because of a lack of Anaesthetic consultants the sample size for this study has been reduced to 20. Due to above mentioned circumstances 20 cases was done in roughly 22 weeks.

Before commencement of this study, ethical approval was obtained from the University of the Free State Ethics committee (Appendix A). The department of cardiothoracic surgery and the department of Perfusion granted permission for the study to be conducted. Approval was obtained from the Free State Department of Health (Appendix B) and Prof. BSJ Diedericks (Appendix C).

Patients who met the inclusion criteria were recruited in the cardiac ward at Universitas hospital. A Letter of information, assent form and consent form, drawn up by the researcher in English, Afrikaans and Sesotho was presented to all patients and parents who volunteered to participate in the study. They were informed that their right to participate their children in the trial was entirely voluntary and that they were entitled to withdraw at any point without affecting their child's medical treatment. They were also informed that all information used in the trial would remain confidential and that any data reported in scientific journals or published would not include information identifying their children as a patient in the study. (Appendix D, E and F). Parents who were willing to let their children participate signed the consent form. All patients recruited to the study were under the consultant care of the surgeon and anaesthetist, who confirmed that the patient required surgery with CPB and Cell saving.

METHODOLOGY

When the patient was brought into theatre consent was checked and verified with the patient's parent/s. The perfusionists washed the packed red blood cells according to the protocol of the study and randomisation list.

Cell salvage was achieved using the following settings:

Machine: SORIN / XTRA

Standard 225 ml Bowl

Protocol: Pstd

Fill Flow	-	200ml / min
Return Flow	-	250ml / min
Wash Flow	-	250ml / min
Wash Vol	-	1 000ml
Empty Flow	-	350ml / min
Conc Flow	-	300ml / min

Better Quality Wash (BQW) on 2x

<u>BQW Function:</u>

The Blood in the bowl undergoes a series of operations on the basis of a special protocol (accelerations + decelerations of the centrifuge) designed to optimize the wash phase of a cycle.

The cell saver was installed identically for every case. The balanced solutions used for the interventional group was Ringers Lactate and for the control group Balsol.

Blood sampling and analysis;

A sample of blood (1ml) was obtained from all the included units of packed Red blood cells before washing in the cell saver for pre wash analysis via Bloodgas machine.

In the control group Balsol was used as wash solution and in the interventional group Ringers Lactate was used as wash solution.

After processing, a blood sample (1ml), was taken for post wash analysis.

Clinical data which was be recorded for every pre and post wash sample is shown in Table 7.

Table 7: Summary of the variables that was measured before and after processing of packedu red blood cell's using the cell saver.

pH
pCO_2
pO_2
Potassium $[K^+]$
Sodium $[Na^+]$
Chloride $[Cl^-]$
Calcium $[Ca^{2+}]$
Lactate
Glucose
Bicarbonate $[HCO^{3-}]$
Haematocrit
Haemoglobin

This data was used to compare Balsol vs Ringers Lactate.

The Radiometer ABL 90 FLEX blood gas analyser (Appendix G) report results for the measured variables in a specific range (Appendix H). In the samples the blood gas analyser reports results below the reference range of the electrode, the lower reference range was taken as the result to make a statistical analysis. The ABL 90 Flex bloodgas analyser is a cassette based analyser which can deliver 17 parameters (Appendix H) from a sample of 65ul blood in 35 seconds. It ensures standardised mixing of a blood sample in 7 seconds, using safePICO syringes or capillary tubes, with the built in sample mixer. Automatic quality control with dedicated QC solutions is built into the analyser which also runs continuous system analysis checks and takes automated corrective actions when necessary. The data collection sheet and data collected for the Balsol control group and Ringers lactate interventional group are listed in Appendix I and Appendix J respectively.

Statistical analysis

Statistical analysis was performed by the Department of Biostatistics, UFS. Variables were summarised by medians and interquartile ranges due to skew distributions. Changes from pre to post within groups were analysed using signed rank tests. The two groups were compared regarding changes using Mann-Whitney tests. P-values<0.05 were considered statistically significant.

CHAPTER FOUR

RESULTS

Statistical summary of data

The statistical summary for the variables measured in the Ringers Lactate interventional group are shown in Table 8 as medians and inter quartile ranges pre and post wash. The change and % change are also shown. Variables with p values < 0.05 was statistically significant.

Table 8: Statistical summary for the variables measured in the Ringers Lactate interventional group.

VARIABLES MEASURED	PRE-WASH		POST WASH		CHANGE (POST - PRE)	% CHANGE (POST - PRE)	p
	MEDIAN	(IQR)	MEDIAN	(IQR)	MEDIAN	MEDIAN	VALUE
pH	6.75	6.75 - 6.80	6.75	6.75 - 6.79	0	0	1
pCO2	76.8	74.1 - 81.5	12	12 - 12	-64.8	-84.4	<0.01
PO2	42.6	34.9 - 47.7	51.5	42.9 - 59.2	10.1	24.2	<0.01
K+	14	11.4 - 18.1	5.05	5 - 5.1	-8.95	-63.7	<0.01
Na+	131	127 - 137	123	122 - 123	-8.5	-6.4	<0.01
Cl-	70	70 - 113	70	70 - 70	0	0	0.25
Ca2+	0.4	0.4 - 0.4	1.27	1.25 - 128	0.87	218	<0.01
Lactate	31	31 - 31	22.5	21 - 24	-8.5	-27.4	0.01
Glucose	47	46 - 47	11.4	9.5 - 12	-35	-75.7	<0.01
HCO3-	9	7.8 - 9	17	17 - 17	9.2	118	1
Hct	65	63.2 - 68.3	50.2	47.4 - 53.8	-13.3	-20.5	<0.01
Hb	21.2	20.6 - 22.3	16.4	15.5 - 17.5	-4.4	-20.7	<0.01

p values <0.05 were considered statistically significant.

The statistical summary for the variables measured in the Balsol control group are shown in Table 9 as medians and inter quartile ranges pre and post wash. The change and % change are also shown. Variables with p values < 0.05 was statistically significant.

Table 9: Statistical summary for the variables measured in the Balsol control group.

VARIABLES MEASURED	PRE-WASH		POST WASH		CHANGE (POST - PRE)	% CHANGE (POST - PRE)	p
	MEDIAN	(IQR)	MEDIAN	(IQR)	MEDIAN	MEDIAN	VALUE
pH	6.75	6.75 - 6.78	7.01	6.97 - 7.05	0.26	3.85	<0.01
pCO2	90.05	65.7 - 94.7	84.4	77.4 - 89	-2	-2.18	0.85
PO2	42.9	32.5 - 48.4	42.65	35.5 - 47.7	2	5.08	0.49
K+	14.4	12.7 - 18.1	3.95	3.9 - 4	-10.5	-71.85	<0.01
Na+	131	127 - 133	123	123 - 123	-7.5	-5.72	<0.01
Cl-	70	70 - 118	107	107 - 108	36.5	52.14	0.08
Ca2+	0.4	0.4 - 0.4	0.4	0.4 - 0.4	0	0	*
Lactate	31	31 - 31	31	31 - 31	0	0	*
Glucose	47	44 - 47	10.4	8.2 - 12.5	-34.1	-76.59	<0.01
HCO3-	7.85	7.2 - 8.45	15.15	13.75 - 16.2	7.75	92.37	0.13
Hct	61.5	59 - 67.1	50.2	47.8 - 54	-13.4	-19.78	<0.01
Hb	20.05	19.3 - 21.9	16.4	15.6 - 17.6	-4.35	-19.79	<0.01

p values <0.05 were considered statistically significant.

The Statistical summary of the % change in post Ringer Lactate wash vs the %change in post Balsol wash are shown in table 10 as medians. Variables with p values < 0.05 was statistically significant.

Table 10: Statistical summary of the% change in post Ringers Lactate wash versus the %change in post Balsol wash.

VARIABLES MEASURED	% CHANGE BALSOL MEDIAN	% CHANGE RINGERS LACTATE MEDIAN	p VALUE
pH	3.85	0	<0.01
pCO_2	-2.18	-84.37	<0.01
PO_2	5.08	24.2	0.01
K^+	-71.85	-63.7	0.3
Na^+	-5.72	-6.4	0.34
Cl^-	52.14	0	0.1
Ca^{2+}	0	217.5	<0.01
Lactate	0	-27.41	<0.01
Glucose	-76.59	-75.74	0.82
HCO_3^-	92.37	117.94	0.16
Hct	-19.78	-20.47	0.76
Hb	-19.79	-20.73	0.76

Changes in pH

There was no change in pH after washing with Ringers Lactate in contrast with the significant increase in pH after Balsol wash ($p< 0.01$). There was a significant difference in the percentage change between the two groups after washing ($p< 0.01$)

Changes in pCO_2

There was a significant decrease in pCO_2 with the Ringers Lactate wash. The pCO_2 also decreased after the Balsol wash but not statistically significant. There is a significant difference in the percentage change between the two groups after washing ($p<0.01$)

Changes in pO_2

There was no change in pO_2 in the Balsol group and a significant increase in the Ringers Lactate group post wash ($p< 0.01$). There was also a significant difference in the percentage change between the two groups after washing (p 0.01)

Changes in K^+

There was a significant decrease in K^+ in both the Ringers Lactate and Balsol groups post wash ($p<0.01$) but the difference in percentage change between the two groups were not statistically significant.

Changes in Na^+

There was a significant decrease in Na^+ in both groups post wash ($p<0.01$) but the difference in the percentage change between the two groups were not statistically significant.

Changes in Cl^-

There was no changes in Cl^- in the Ringers Lactate group post wash and an increase in Cl^- in the Balsol group post wash but not statistically significant.

Changes in Ca^{2+}

There was a significant increase in Ca^{2+} in the Ringers Lactate group post wash ($p<0.01$) but there was no change in the Balsol group post wash. There was a significant difference in the percentage change between the two groups post wash ($p<0.01$).

Changes in Lactate

There was a significant decrease in Lactate in the Ringers Lactate group post wash (p 0.01) but there was no change in the Balsol group post wash. There was a significant difference in the percentage change between the two groups post wash ($p<0.01$).

Changes in Glucose

There was a significant decrease in glucose within the Balsol and Ringers Lactate groups post wash ($p<0.01$) but the difference in percentage change between the two groups post wash was not statistically significant.

Changes in HCO_3

There was an increase in both the Balsol and Ringers Lactate groups post wash but not statistically significant. The difference in percentage change between the two groups post wash was also not statistically significant

Changes in Hct and Hb

There was a significant decrease in Hct and Hb in both the Ringers Lactate and Balsol groups post wash ($p<0.01$) but the difference in the percentage change between the two groups were not statistically significant.

CHAPTER 5

DISCUSSION

Introduction

Allogenic blood is a scarce and lifesaving resource, but its prescription is also not without risk. Stored red blood cells undergo time dependant metabolic, biochemical and molecular changes which eventually result in irreversible damage, defined as storage lesions responsible for many adverse effects of RBC transfusions (Offner, 2004.). The introduction of autologous cell salvage systems to cardiac surgery has decreased the demand for the scarce and precious allogenic blood resource, as well as its associated risks. Manufactures of autologous cell salvage systems recommend the use of 0.9% NaCl for the processing of salvaged blood. A study conducted by Shaw et al. (1997), revealed that patients receiving exclusively normal saline on the day of surgery had higher mortality, major complications, postoperative infections, renal failure requiring dialysis, blood transfusions, longer ventilation time and more electrolyte disturbances than those receiving balanced crystalloid solutions. Patients undergoing cardiac surgery with CPB are also at higher risk for electrolyte depletion (Polderman and Girbes, 2004).

This was a prospective Randomised Controlled Trail to analyse and compare the quality of Packed Red blood cells that had been washed in a cell saver, with either Balsol or Ringers Lactate, both balanced crystalloid solutions to use as priming for CPB for elective Paediatric Cardiac Surgery. The primary objective of the study was to measure and compare pH, electrolytes, metabolites Hct and Hb of packed RBC, which was washed with either Balsol or Ringers Lactate. The secondary objective of this study was to determine if any value was influenced negatively or changed at all after packed Red Blood Cells was washed with either Balsol or Ringers Lactate.

In this investigation a services of 20 units of packed RBC’s was used (N=20) and was randomised to a Balsol group (control group) and a Ringers lactate group (interventional group) according to a randomisation list that was provided by the department of Biostatistics Procedure that was done was Elective Paediatric Cardiac Surgery with CPB at Universitas Hospital in Bloemfontein.

Discussion

In this study there was no change in pH after washing with Ringers Lactate in contrast with the significant increase in pH after Balsol wash ($p< 0.01$). There was a significant difference in the percentage change between the two groups after washing ($p< 0.01$). In a study conducted by de Vroege et al. (2007), 20 RBC units with a mean age of 36 days were washed with 0.9% NaCl and there was no change in pH (6.36 ± 0.05). In an animal study conducted by Halpern et al. (1996), washing blood with 0.9% NaCl and re-infusing blood after every wash cycle resulted in a significant decrease in pH. Halpern et al. (1997), conducted a similar animal study to compare washing blood with either 0.9% NaCl or Isolyte S and re-infused washed blood after every wash cycle. They found that pH increased with 0.9% NaCl by 0.3% in the mean averaged washed blood when compared to the mean prewashed systemic blood. In a study conducted by Huber et al. (2013), ten units of packed RBC with a mean age of 9 days were washed with either 0.9% NaCl or BB-HS. The results revealed a significant decrease and increase in pH from baseline after washing with 0.9% NaCl and BB-HS respectively, with pH being significantly higher at the end of washing with BB-HS. In a study conducted by Pillay et al. (2015), 40 patient's residual CPB pump blood was washed with either 0.9% NaCl or Balsol. Both groups significantly increased the pH.

Also in the study conducted by Pillay et al. (2015) there was a highly significant decrease in pCO_2 within the NaCl group below the detectable range of the electrode (< 6mmHg), and a less pronounced but significant decrease in pCO_2 within the Balsol group after washing. In contrast there was a significant increase in HCO_3 within the Balsol group after washing. After washing PRBC with 0.9% NaCl, de Vroege et al. (2007), observed a significant decrease of ≈ 90% in both pCO_2 and HCO_3. Huber et al. (2013), observed a significant decrease (≈80%) and increase (≈70%) in pCO_2 from baseline after washing PRBC with 0.9% NaCl and BB-HS respectively, with pCO_2 being significantly higher at the end of washing with BB-HS. Huber et al. (2013) also revealed a significant decrease (≈80%) in HCO_3 from baseline after washing with 0.9% NaCl and a less pronounced but significant decrease (≈4%) in HCO_3 after washing with BB-HS.

In the present study there was a significant decrease in pCO_2 within the Ringers Lactate group with a less pronounced decrease in pCO_2 in the Balsol group after washing. The difference in percentage change between the Balsol and Ringers Lactate groups post wash revealed that pCO_2 significantly decreased in the Ringers Lactate group when compared to the Balsol group. There was an increase in HCO_3 post wash within the Ringer Lactate and Balsol groups probably because Balsol contains 27 mmol/L of HCO_3 and Ringers Lactate contains 28 mmol/L.

In the present study there was no change in pO_2 in the Balsol group and a significant increase in the Ringers Lactate group post wash ($p< 0.01$). There was also a significant difference in the percentage change between the two groups after washing (p 0.01). In a study conducted by Pillay et al. (2015) there was a highly significant decrease in pO_2 within the NaCl and Balsol groups after washing and a significant difference in the change between groups after washing. In contrast after washing PRBC with 0.9% NaCl de Vroege et al. (2007), reported a non-significant increase in pO_2. Huber et al. (2013), reported a significant increase in pO_2 at the end of washing with 0.9% NaCl and a significant but marginal increase after washing with BB-HS.

In a study conducted by Polderman and Girbes, (2004), it was revealed that 34% patients requiring CPB developed a significant moderate hypokalaemia ($K^+ < 3.6$ mmol/L) despite receiving on average 16mmol/L of potassium from cardioplegia and potassium infusion supplementation (10.1 ± 4.7 mmol/hr) during surgery. In a study by Pillay et al. (2015) they reported a highly significant decrease in K^+ within the NaCl group after washing and a highly significant increase in K^+ within the Balsol group after washing. In the present study there was a significant decrease in both the Ringers Lactate and Balsol groups post wash ($p<0.01$) but the difference in percentage change between the two groups were not statistically significant. Vargese et al. (2007), and de Vroege et al. (2007), both reported that potassium was significantly reduced when washing PRBC with 0.9 % NaCI. Huber et al. (2013), also reported significantly reduced potassium with both 0.9 % NaCI and BB-HS. Swindell et al. (2007), demonstrated that washing irradiated PRBC resulted in CPB circuits for neonates and infants having lower potassium loads than circuits that received unwashed blood.

Immediately after CPB serum potassium was significantly lower in the washed blood group compared to the unwashed group. Swindell and co-workers also reported washing blood resulted in 4 patients becoming hypokalaemic during CPB, but commented that it was easier to manage that hyperkalaemia. In the present study there was also a significant decrease in both the Ringers Lactate and Balsol groups post wash ($p<0.01$) even though the contents of Balsol and Ringers Lactate contain K^+ of 4.0 and 5 mmol/L respectively. The difference in percentage change between the two groups were not statistically significant.

In previous investigations by Varghese et al. (2007), de Vroege et al. (2007), Huber et al. (2013), and Swindell et al (2007), all reported significant increases in sodium after washing PRBC with 0.9 % NaCI solution. The animal study conducted by Halpern et al. (1996), demonstrated that continuous washing with 0.9 % NaCI and re-infusion of blood resulted in a significant increase in mean washed blood average sodium and compared to baseline systemic values. Halpern et al. (1997), also demonstrated a significantly higher sodium level in the mean washed blood average when 0.9% NaCI was used as a wash solution compared to Isolyte S.

The results of the study conducted by Pillay et al. Report a highly significant increase in sodium within the NaCI group after washing and a highly significant decrease in sodium within the Balsol group after washing. There was also a highly significant difference in the change between groups after washing. The results of the present study showed that there was a significant decrease in Na^+ in both groups post wash ($p<0.01$) but the difference in the percentage change between the two groups were not statistically significant.

Huber et al. (2013), reported after washing PRBC with 0.9% NaCI and BB-HS there was a significant increase and decrease in Cl^- from baseline respectively, with Cl^- being significantly lower after washing with BB-HS. The animal study conducted by Halpern et al. (1997), also demonstrated that after washing with 0.9 % NaCl and Isolyte S, Cl^- increased and decreased respectively in mean washed blood average, with Cl^- being significantly higher in 0.9 % NaCl group. Halpern et al. (1996), also reported that continuous washing with 0.9 % NaCl and reinfusion of blood resulted in a significant increase in the mean washed blood average chloride as compared to baseline systemic values.

It my studied the results showed that there was no changes in Cl^- in the Ringers Lactate group post wash and an increase in Cl^- in the Balsol group post wash but not statistically significant.

In the present study there was a significant increase in Ca^{2+} in the Ringers Lactate group post wash ($p<0.01$) but there was no change in the Balsol group post wash. There was a significant difference in the percentage change between the two groups post wash ($p<0.01$). Both 0.9 % NaCl and Balsol solutions used in a study conducted by Pillay et al are calcium and phosphate free. The results of that study revealed there was a highly significant decrease in ionized Ca^{2+} within the NaCl and Balsol groups after washing and a significant difference in the change between groups after washing. Animal studies conducted by Halpern et al. (1996), demonstrated that washing with 0.9% NaCl resulted in significant reduction in ionized Ca^{2+} and PO_4.

Halpern et al. (1997), also reported in an animal study after washing with 0.9 % NaCl and Isolyte S, ionized calcium decreased in the washed blood average with no significant difference between solutions. Humber et al. (2013), reported after washing PRBC with 0.9 % NaCl and BB-HS that calcium significantly increased from baseline with both solutions. The increase being significantly greater with BB – HS.

In the present study there was a significant decrease in Lactate in the Ringers Lactate group post wash (p 0.01) but there was no change in the Balsol group post wash. There was a significant difference in the percentage change between the two groups post wash ($p<0.01$). Halpern et al. (1996), Pillay et al. (2015) and de Vroege et al. (2007) Huber et al. (2013) and Swindell et al. (2007), also observed a similar significant decrease in the lactate load after washing PRBC.

In my study it showed that there was a significant decrease in glucose within the Balsol and Ringers Lactate groups post wash ($p<0.01$) but the difference in percentage change between the two groups post wash was not statistically significant. Varghese et al. (2007) and de Vroege et al. (2007), and Pallay et al. (2015) also observed similar significant decreases after washing PRBC. Huber et al. (2013), reported a significant decrease in glucose from baseline after washing with PRBC with o.9 % NaCl and BB – HS, with glucose being significantly higher after washing with BB – HS.

In the study reported by Pillay et al. (2015) the results showed a highly significant increase in haematocrit and Haemoglobin within the NaCl and Balsol groups after washing. In contrast in the present study there was a significant decrease in Hct and Hb in both the Ringers Lactate and Balsol groups post wash ($p<0.01$) but the difference in the percentage change between the two groups were not statistically significant.

LIMITATIONS

Firstly, processed blood was not transfused immediately to the patients and no in vivo observations could be made in terms of acid-base, osmolality and electrolyte changes. Secondly, the re-suspended RC concentrate may have also undergone time dependant changes in the interim between being processed re-transfusion, which were not investigated. Thirdly, other important variables like strong ion difference, osmolality, magnesium and phosphate were not measured due to financial and logistical constraints. Finally, due to cancelation of lists at Universitas Hospital because of a lack of Anaesthetic consultants the sample size for this study has been reduced to 20.

STRENGHTS

The strength of this study lay in the use of two solutions which is both balanced crystalloid solutions with patients not exposed to unbalanced solutions.

CHAPTER 6

CONCLUSION

The results of this prospective Randomised controlled trial are summarised in Table 11 and Table 12.

Table 11: Ringers Lactate Interventional Group

VARIABLE	PRE-WASH	POST-WASH	P- VALUE
pCO_2	76.8	12	<0.01
K^+	14	5.05	<0.01
Na^+	131	123	<0.01
Lactate	31	22.5	<0.01
Glucose	47	11.4	<0.01
Hct	64.95	50.2	<0.01
Hb	21.2	16.4	<0.01
pO_2	42.6	51.45	<0.01
Ca^{2+}	0.4	1.27	<0.01

$p < 0.05$ is statistically significant

Table 12: Balsol Control Group

VARIABLE	PRE-WASH	POST-WASH	P- VALUE
K^+	14.4	3.95	<0.01
Na^+	131	123	<0.01
Glucose	47	10.4	<0.01
Hct	61.5	50.2	<0.01
Hb	20.05	16.4	<0.01
pH	6.75	7.01	<0.01

$p < 0.05$ is statistically significant

There was also a statistically significant difference ($p < 0.05$) in the % change between the 2 groups after washing for pH, pCO_2, pO_2, Ca^{2+} and Lactate.

In conclusion the profile for pCO_2, pO_2, Ca^{2+}, Lactate and HCO_3^- is closer to physiological values in the Ringers Lactate interventional group and pH, K^+ and Cl^- is closer to physiological values in the Balsol group. Glucose, Na^+, Hct and Hb changed to the same extend in both balanced crystalloid solutions Ringers Lactate and Balsol.

RECOMMENDATIONS

From the results of this investigation it is recommended that a balanced crystalloid solution such as Ringers Lactate or Balsol is used as washing solutions employed with cell saving machines for processing of packed RBC and residual pump blood in cardiac surgery rather than an unbalanced crystalloid solution like Normal Saline. It is recommended that further investigations be conducted to address the limitations found in this investigation. It is also recommended that the use of balanced electrolyte solutions with cell saver in other specialities such as vascular, orthopaedic and neurosurgery be investigated.

CHAPTER SEVEN

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APPENDIX A

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS·UV
HEALTH SCIENCES

IRB nr 00006240
REC Reference nr 230408-011
IORG0005187
FWA00012784

09 January 2018

M SWANEPOEL
DEPT OF ANAESTHESIOLOGY
FACULTY OF HEALTH SCIENCES
UFS

Dear M Swanepoel

HSREC 149/2017 (UFS-HSD2017/1414)
PRINCIPAL INVESTIGATOR: M SWANEPOEL
PROJECT TITLE: A COMPARISON OF BALSOL VERSUS RINGERS LACTATE AS CELL SAVER WASHING SOLUTIONS FOR PACKED RED BLOOD CELLS AS PART OF PRIMING SOLUTION IN PAEDIATRIC ELECTIVE CARDIAC SURGERY WITH CARDIO PULMONARY BYPASS (CPB)

CONDITIONAL APPROVAL

1. You are hereby kindly informed that the Health Sciences Research Ethics Committee (HSREC) reviewed the above research project. Research may not be conducted before the following condition(s) has/have been met and the HSREC grants final approval for the project:

   1.1. *Permission from Free State Department of Health must be submitted before final approval will be granted.*

   Dr A Van Aswegen was not involved in the review of this project

   PLEASE NOTE: Upon receipt of the updated documentation/other request(s) from the HSREC in RIMS, the project will be re considered.

2. Kindly use the **HSREC NR** as reference in correspondence to HSREC Administration.

3. The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 46) (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite); Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines; Constitution of the HSREC of the Faculty of Health Sciences.

Yours faithfully

PROF WJ STEINBERG
VICE CHAIR: HEALTH SCIENCES RESEARCH ETHICS COMMITTEE

Health Sciences Research Ethics Committee
Office of the Dean: Health Sciences
T: +27 (0)51 401 7795/7794 E: ethicsfhs@ufs.ac.za
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YUNIVESITHI YA FREISTATA

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Health Sciences Research Ethics Committee

02-Aug-2018

Dear Dr Michelle Swanepoel

Ethics Number: UFS-HSD2017/1414

Ethics Clearance: **A comparison of Balsol versus Ringers Lactate as cell saver washing solutions for packed red blood cells as part of priming solution in paediatric elective cardiac surgery with cardio pulmonary bypass (CPB)**

Principal Investigator: **Dr Michelle Swanepoel**

Department: **Anaesthesiology (Bloemfontein Campus)**

SUBSEQUENT SUBMISSION APPROVED

With reference to your recent submission for ethical clearance from the Health Sciences Research Ethics Committee. I am pleased to inform you on behalf of the HSREC that you have been granted ethical clearance for your request as stipulated below:

- *Amendment to sample size*

The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite), Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this request for ethical clearance and we wish you continued success with your research.

Yours Sincerely

Dr. SM Le Grange
Chair : Health Sciences Research Ethics Committee

Health Sciences Research Ethics Committee
Office of the Dean: Health Sciences
T: +27 (0)51 401 7795/7794 | E: ethicsfhs@ufs.ac.za
IRB 00006240; REC 230408-011; IORG0005187; FWA00012784
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APPENDIX B

health
Department of Health
FREE STATE PROVINCE

27 March 2018

Dr. M Swanepoel
Dept. of Anaesthesiology
Faculty of Health Science
UFS

Dear Dr M Swanepoel

Subject: A comparison of Balsol versus Ringers Lactate as cell saver washing solutions for packed red blood cells as part of priming solution in Paediatric elective cardiac surgery with cardiopulmonary bypass.

- Please ensure that you read the whole document. Permission is hereby granted for the above – mentioned research on the following conditions:
- Serious Adverse events to be reported to the Free State department of health and/ or termination of the study
- Ascertain that your data collection exercise neither interferes with the day to day running of Universitas Hospital nor the performance of duties by the respondents or health care workers.
- Confidentiality of information will be ensured and please do not obtain information regarding the identity of the participants.
- **Research results and a complete report should be made available to the Free State Department of Health on completion of the study (a hard copy plus a soft copy).**
- Progress report must be presented not later than one year after approval of the project to the Ethics Committee of the University of Free State and to Free State Department of Health.
- Any amendments, extension or other modifications to the protocol or investigators must be submitted to the Ethics Committee of the University of Free State and to Free State Department of Health.
- **Conditions stated in your Ethical Approval letter should be adhered to and a final copy of the Ethics Clearance Certificate should be submitted to** sehee.ars@fshealth.gov.za **before you commence with the study**
- No financial liability will be placed on the Free State Department of Health
- Please discuss your study with the institution manager/CEOs on commencement for logistical arrangements
- Department of Health to be fully indemnified from any harm that participants and staff experiences in the study
- Researchers will be required to enter in to a formal agreement with the Free State department of health regulating and formalizing the research relationship (document will follow)
- You are encouraged to present your study findings/results at the Free State Provincial Health research day
- Future research will only be granted permission if correct procedures are followed see http://nhrd.hsrc.ac.za

Trust you find the above in order.
Kind Regards

Dr D Motau
HEAD: HEALTH
Date: 29/03/18

Head : Health
PO Box 227, Bloemfontein 9300
4th Floor Executive Suite, Brandwag House, 205 Maitland and Harvey Road, Bloemfontein
Tel (051) 448 1148 Fax (051) 430 1560 e-mail khuseni@fshealth.gov.za/shikoba@fshealth.gov.za
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APPENDIX C

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS·UV HEALTH SCIENCES GESONDHEIDSWETENSKAPPE

Department of Anaestehsiology
Faculty of Health Sciences
University of the Free State
Bloemfontein
9321
Tel 051 4053071
Cell 082 827 0024
Email: chellys83@gmail.com

Dear Prof Diedericks

This is a prospective randomized controlled trial with the aim to determine according to Blood gas analysis which crystalloid Balsol versus Ringers lactate are closest to physiological values when used to wash packed Red Blood cells with, in a cell saver, for Paediatric elective Cardiac Surgery procedures under Cardio Pulmonary Bypass.

After obtaining approval from ethics committee and relevant authorities data will be collected. Data collection will take approximately 6 months (Jan – Jun 2018) and analysis plus minus 1 month (Jul – Aug 2018).

Blood gas analysis are done routinely on post wash samples thus the routine Blood gas analysis will be no extra cost. Only pre wash analysis will be an extra cost of R5 278, 80. I will apply to the Post graduate committee for funding.

Analysis will be done with a point of care device. No parental consent needed because no information regarding the patient will be collected and because Balsol and Ringers lactate are both standardized solutions used to wash packed Red Blood Cells with.

With your permission I would like to initiate the study as soon as I get HREC and FSDoH approval. If you have any further queries regarding any aspect of the study please do not hesitate to contact me.

Sincerely yours,

Dr M Swanepoel
Registrar
Department of Anaesthesiology
University of the Free State

Permission granted
2017 10 17

KONSULTANTE/CONSULTANTS: Prof BJS Diedericks, C Lamacraft, CL Odendaal, AM Kachelhoffer, Drs NA Pearson, MG Sanekal, J Lammer, RP Mosidi, A Theron, N van der Westhuizen, H Noeth
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YUNIBESITHI YA FREISTATA

APPENDIX D

CONSENT TO PARTICIPATE IN RESEARCH

You have been asked to participate in a research study.

You have been informed about the study by ..... .

You may contact Michelle Swanepoel at 0828270024 any time if you have questions about the research.

You may contact the Secretariat of the Health Sciences Research Ethics Committee, UFS at telephone number (051) 4017794/5 if you have questions about your rights as a research subject.

Your child's participation in this research is voluntary, and they will not be penalized or lose benefits if you refuse for them to participate or decide to terminate participation.

If you agree to participate, you will be given a signed copy of this document as well as the participant information sheet, which is a written summary of the research.

The research study, including the above information has been verbally described to me. I understand what my child's involvement in the study means and I voluntarily agree for my child to participate.

_____	_____
Signature of Participant (Parent/Guardian)	Date
_____	_____
Signature of Witness	

ASSENT FORM

Hereby I give permission to participate in the research study as described to me by .....

I understand the research involves the following. The blood that I will receive during my operation will be washed with two different salt water solutions. Both salt water solutions is good to wash the blood with and the researcher just want to see which one is the best to wash the blood with.

....

(Signature of participant) *(Date)*

....

(Signature of witness) *(Date)*

INFORMATION DOCUMENT

Study title : A comparison of Balsol versus Ringers Lactate as cell saver washing solutions for packed red blood cells as part of priming solution in paediatric elective Cardiac Surgery with Cardio Pulmonary Bypass (CPB)

I, Dr. Michelle Swanepoel from the Free State Department of Anaesthesia and Dr. A. Van Aswegen from the Free State Department of Neurosurgery, are doing research which entails the following. Open heart surgery in children involves the use of an enormous amount of bank blood. It has become standard practise to wash the bank blood before using it, to was out all the storage lesions. In this study we will wash with two different salt water solutions which is both effective and safe. Research is just the process to learn the answer to a question. In this study we want to learn which one of the salt water solutions are the best to wash the blood with.

Invitation to participate: We are asking for your permission to include your child in this research study.

The subject will be given pertinent information on the study while involved in the project and after the results are available.

Participation is voluntary, and refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled; the subject may discontinue participation of their child at any time without penalty or loss of benefits to which the subject is otherwise entitled.

Confidentiality: Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law.
Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Health Sciences Research Ethics Committee.

If results are published, this may lead to individual/cohort identification.

Contact details of researcher(s) – for further information/reporting of study-related adverse events.
Dr. M. Swanepoel
Cell no 0828270024
Email chellys83@gmail.com

Contact details of HSREC Secretariat and Chair – for reporting of complaints/problems.
Tel nr (051) 401 7794

APPENDIX E

TOESTEMMING TOT DEELNAME AAN NAVORSING

U is versoek om u kind aan 'n navorsingstudie deel te neem.

U is oor die studie ingelig deur .....

U kan Michelle Swanepoel enige tyd kontak by 0828270024 indien u vrae oor die navorsing het

U kan die Sekretariaat van die Gesondheidswetenskappe Navorsingsetiekkomitee, UV by telefoonnommer (051) 4017794/5 kontak indien u enige vrae het oor u regte as 'n proefpersoon.

U kind se deelname aan hierdie navorsing is vrywillig, en sal nie gepenaliseer word of voordele verbeur as u weier om u kind te laat deelneem of besluit om deelname te staak nie.

As u instem vir deelname van u kind, sal 'n ondertekende kopie van hierdie dokument sowel as die deelnemerinligtingsblad, wat 'n geskrewe opsomming van die navorsing is, aan u gegee word .

Die navorsingstudie, insluitend die bogenoemde inligting is verbaal aan my beskryf. Ek begryp wat my kind se betrokkenheid by die studie beteken en ek stem vrywillig in om my kind te laat deelneem.

_____ _____

Handtekening van deelnemer (Ouer/ Voog) Datum

_____ _____

Handtekening van getuie Datum

TOESTEMMING VORM

Hiermee gee ek toestemming om deel te neem aan die navorsing studie soos aan my beskryf deur .....

Ek verstaan die navorsing behels die volgende. Die bloed wat aan my gegee gaan word gedurende my operasie gaan gewas word met twee verskillende soorte sout water oplossings. Beide sout water oplossings is goed om bloed te was. Die navorser wil net sien watter oplossing is die beste om die bloed te was.

....

(Hantekening van deelnemer) *(Datum)*

....

(Handtekening van getuie) *(Datum)*

INLIGTINGSDOKUMENT

Studietitel: n Vergelyking tussen Balsol en Ringers Laktaat as n sel beskermende was oplossing vir gepakte rooi bloed selle as deel van die inspuit oplossing in pediatriese elektiewe kardiale chirurgie met kardio pulmonale omleiding.

Ek, Michelle Swanepoel van die Vrystaat Narkose Departement en Dr. A. Van Aswegen van die Vrystaat Neurochirurgie departement, is besig om navorsing te doen oor die volgende.Ope hart chirurgie in kinders behels die gebruik van massiewe hoeveelhede bank bloed. Dit is n standaard prosedure om bank bloed te was voor dit toegedien word aan die kind om al die stoor letsels uit te was. In hierdie studie gaan ons met twee verskillende soorte sout water oplossings was wat altwee effektief en veilig is. Navorsing is slegs die proses waardeur die antwoord op 'n vraagstuk verkry word. In hierdie studie wil ons n antwoord kry oor watter een van die twee sout water oplossings die beste resultate gee

Uitnodiging om deel te neem: Ons vra toestemmimg om u kind by die navorsing studie in te sluit.

Die proefpersoon se ouers sal pertinente inligting oor die studie ontvang tydens betrokkenheid by die projek en agterna wanneer die resultate beskikbaar is.

Deelname is vrywillig, en weiering om u kind te laat deelneem sal geen boete of verlies van voordele waarop die deelnemer andersins geregtig is behels nie; die proefpersoon se ouers kan hom/haar te eniger tyd aan deelname onttrek sonder boete of verlies van voordele waarop die proefpersoon andersins geregtig is.

Vertroulikheid: Daar sal gepoog word om persoonlike inligting vertroulik te hou. Volkome vertroulikheid kan nie gewaarborg word nie. Persoonlike inligting kan bekend gemaak word as die wet dit vereis.
Organisasies wat u navorsingsrekords mag ondersoek en/of kopieer vir kwaliteitsversekering en data-analise sluit groepe soos die Gesondheidswetenskappe Navorsingsetiekkomitee.

As resultate gepubliseer word kan dit lei tot individuele/groepsidentifikasie.

Kontakbesonderhede van navorser(s) – Vir verdere inligting/rapportering van studieverwante newe-effekte.
Dr. M. Swanepoel
Sel nr 0828270024
Epos chellys83@gmail.com

Kontakbesonderhede van GWNEK Sekretariaat en Voorsitter – vir rapportering van klagtes/probleme

Tel nr (051) 4017794

APPENDIX F

Tumelo ya honka karolo nyakisisong (resecheng)

O kopiloe honka ngwana hao karolong nyakisisong (resecheng).

O hlaloseditswe ka nyakisiso ke …….

O ka fumana Michelle Swanepoel ho 0828270024 ka nako efeng le efeng ha o nale dipotso mabapi le nyakisiso.

O ka fumana motsamaise wa lefapa la bophelo komiteng ya boitswaro ya nyakisiso (reseche) yunivesity ya freistata (UFS) ho 051 4017794/5 ha o nale dipotso mabapi le di tokelo tsa hao jwalo ka mon'ka karolo nyakisisong.

Hon'ka karolo ya ngwana hao nyakisisong ena e etsoa ka boithaopo, me hankeke bao kahlola kapo wa lahleheloa ke melemo ha o hana hore a nke karolo kapo o emisa honka karolo.

Ha o dumela hore ngwana hao a nke karolo, o tla fuwa pampiri e saenilweng la leqhepe lena homoho le pampiri ya tsebiso ya mon'ka karolo e eleng kakaretso ya nyakisiso.

Thuto ya nyakisiso le boitsebiso bona e fanwe ka molomo ho nna.

Kea utlwisisa hore karolo ya ka le ya ngwanaka thutong yena ke eng me ke dumela ka boithaopo hore ngwanaka a nke karolo.

……. …….

(Mosaeno wa mon'ka karolo) (Letsatsi)

…… ……

(Mosaeno wa mopaki) (Letsatsi)

Foromo ya tumelo

Kamoo ke fana ka tumelo ya ho nka karolo nyakisisong (resecheng) jwale ka ke hlaloseditswe ke Dr Michelle Swanepoel. Kea utlwisisa hore nyakisiso e amana le tse latelang.

Madi a ke tlo a fuwang ka nako ya opereishene ya ka a tla hlatsuwa ka metsi a letswai a mabedi a fapanang. Bobedi ba metsi a letswai a lukile ho hlatswa madi empa motho a etsang nyakisiso o batla ho bona feela ke efeng e hlatswang madi hantle haholo.

……. …….

(Mosaeno wa mon'ka karolo) (Letsatsi)

…… …….

(Mosaeno wa mopaki) (Letsatsi)

Leqhepe la boitsebiso

Sehlooho sa thuto: Ho bapisoa Balsol le Ringers lactate jwalo ka motsoako o hlatswang le ho boloka lisele tsa madi mo di-opereisheneng tsa bana tsa pelo.

Nna, Dr Michelle Swanepoel wa lefapha la bophelo mo freistata wa barobatsi le Dr A. Van Aswegen wa lefapha la bophelo mo freistata wa bongaka ba hloho re etsa nyakisiso e amanang le tse latelang.

Opereishene ya dipelo tse buleilweng baneng e hloka madi a mangata haholo. Ho bilwe tlwaelo ho hlatswa madi a tswang storong pele ga o sebediswa, ho tlosa ditsila tse beileng teng ka nako ya storo. Thutong ena re tla hlatswa ka mesti a letswai (motsoako) e mebedi e fapanang, me bobedi ba tsona boa sebetsa hape bo sireletsehile. Nyakisiso ke tsela ya ho ithuta karabo ho tswa potsong e itseng. Thutong ena re batla ho ithuta hore ke efeng ya motsoako o sebetsang hantle haholo ho hlatswa madi.

Memo ya honka karolo:

Re kopa tumelo ya hao ho kenya ngwana hao thutong ena ya nyakisiso. Mon'ka karolo o tla fuwa botsebiso bo bohlokoa mabapi le thuto ka nako ya reseche le kamora liphello di ba teng.

Hon'ka karolo ke ka boithaopo, le ho hana ha ho tsamaisane le kahlolo kapo ho lahleheloa ke melemo se mokodi a di tswanetsweng, mokodi a la emisa honka karolo nako engwe le engwe kantle ho kahlolo kapo ho lahleheloa ke melemo tse mokodi a di tswanetsweng.

Lekunutung:

Ho tla etswa bonete hore ditaba tsa motho di beiwa lekunutung. Lekunutu le feletsweng ha le kgone ho netefatswa. Ditaba tsa motho di senoleloa ha ho hlokoa ke melao. Mafapha a ka hlahlobang kapo a kopiletsa ditaba tsa hao tsa nyakisiso ho netefatsa tsobotsi a tswana le lefapha la bophelo komiteng ya boitswaro ba reseche (nyakisisong). Ha liphello di hatisoa e ka lateloa ka boitsebahatso ba motho mong kapa batho.

Mabapi le boitsebiso bo bong/litlaleho nyakisisong kopana ho:

Dr M Swanepoel

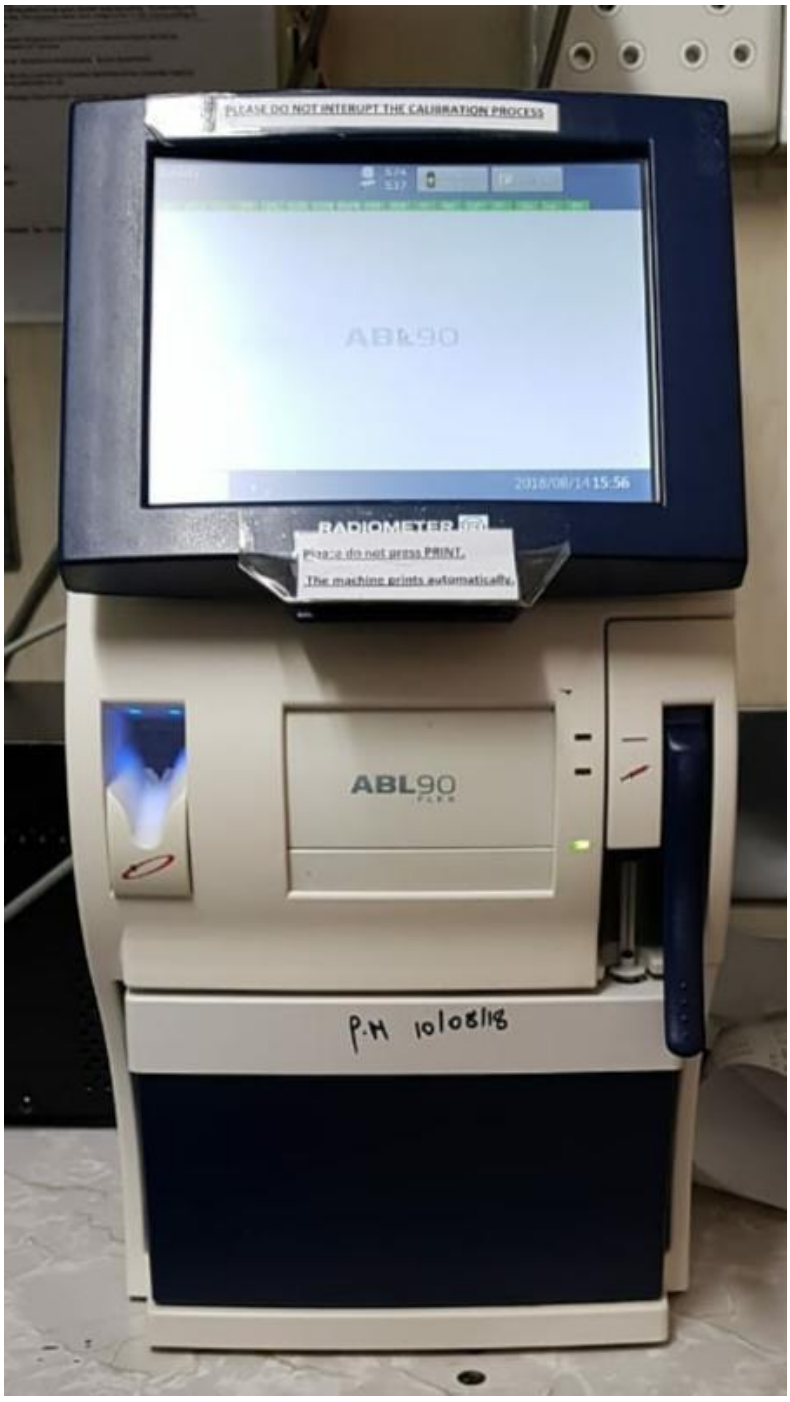
Nomoro: 0828270024

Email: chellys83@gmail.com

Mabapi lelitlaleho le litletlebo kopana le motsamaise le modula sitilo sa HSREC ho:

Nomoro ya mogala: 0514017794

APPENDIX G


PLEASE DO NOT INTERUPT THE CALIBRATION PROCESS
ABL90
2018/08/14 15:56
RADIOMETER
Please do not press PRINT.
The machine prints automatically.
ABL90
P.H 10/08/18

APPENDIX H

Measured parameters

Blood

For the numerical format (that depends on the individual ranges) see chapter 8: *Parameters* in the ABL90 FLEX reference manual.

Parameter	Unit	Range of indication	Reportable range (default)
pH	pH scale	6.3-8.0	6.750-7.850
pCO_2	mmHg; Torr	5-250	12.0-110
	kPa	0.67-33.3	1.60-14.7
pO_2	mmHg; Torr	0-800	26.0-550
	kPa	0-107	3.47-73.3
*c*tHb	g/dL	–0.48-27.7	0*)-27
	g/L	–4.8-277	0*)-270
	mmol/L	–0.30-17.2	0*)-16.8
sO_2	%	–2-102	0*)-100*)
	fraction	–0.02-1.02	0.00*)-1.00*)
FO_2Hb	%	–2-103	0*)-100*)
	fraction	–0.02-1.03	0.00*)-1.00
*F*COHb	%	–2-103	0*)-100*)
	fraction	–0.02-1.03	0.00*)-1.00*)
*F*MetHb	%	–2-103	0*)-100*)
	fraction	–0.02-1.03	0.00*)-1.00*)
*F*HHb	%	–2-102	0*)-100*)
	fraction	–0.02-1.02	0.00*)-1.00*)
*F*HbF	%	–25-121	0*)-100*)
	fraction	–0.25-1.21	0.0*)-1.00*)
cK^+	mmol/L; meq/L	0.5-25	1.5-10.5
cNa^+	mmol/L; meq/L	7-350	115-190
cCa^{2+}	mmol/L	0.2-9.99	0.40-2.70
	meq/L	0.4-19.98	0.80-5.40
	mg/dL	0.8-40.04	1.60-10.82
cCl^-	mmol/L; meq/L	7-350	70-160
*c*Glu	mmol/L	0-60	0-47
	mg/dL	0-1081	0-847
*c*Lac	mmol/L; meq/L	–0.1-31	–0.1-31
	mg/dL	–1-279	–1-279
*c*tBil	µmol/L	–20-1000	0*-690
	mg/dL	–1.2-58.5	0*-40.3
	mg/L	–12-585	0*-403

*) The values are for the analyzer with the activated "Out-of-range suppression"

APPENDIX I

DATA COLLECTION SHEET

Bloodgas analysis:

Sample nr

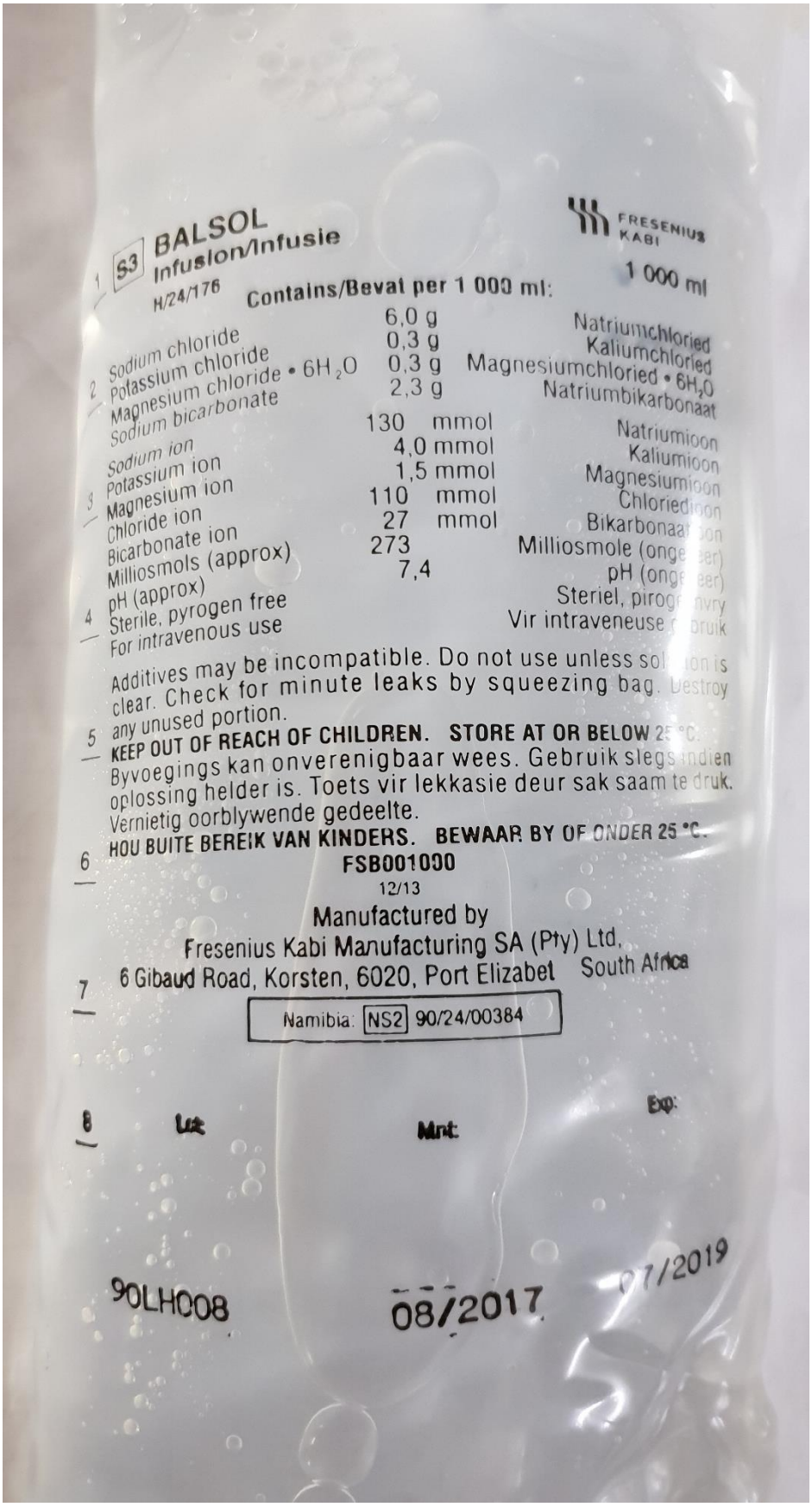
Sample type

	Normal Values	Pre-wash	Post-wash
Ph	7.35 – 7.45		
p CO_2	35 – 45 mm Hg		
P O_2	75 – 100 mm Hg		
Potassium [K^+]	3.5 – 5.0 mmol/L		
Sodium [Na^+]	135 – 145 mmol/L		
Chloride [Cl^-]	95 – 105 mmol/L		
Calcium [Ca^{2+}] Total	2 – 2.6 mmol/L		
Lactate	0		
Glucose	3.6 – 6.1 mmol/L		
Bicarbonate [HCO^{3-}]	18– 22 mmol/L		
Hematocrit	36 - 52%		
Hemoglobin	12 – 17 g/dL		

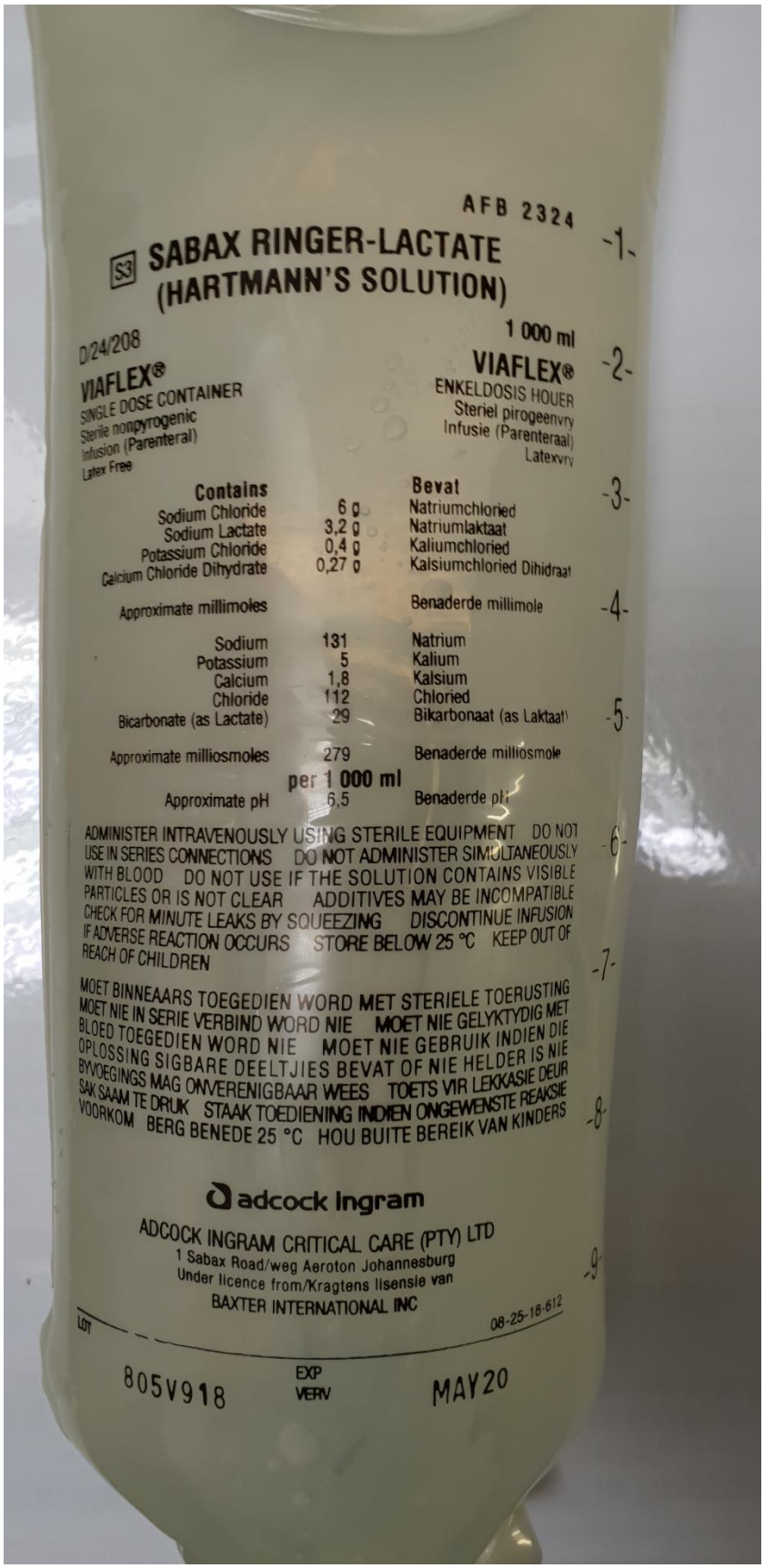
APPENDIX J

PASIENT NR.	UM NR	WASH 1 = RINGERS 2 = BALSOL	WASH	Ph	p CO2	P O2	K+	Na+	Cl-	Ca2+	LACTATE	GLUCOSE	HCO3-	HCT	Hb
1	734063	1	PRE	6,75	85,8	50,6	21,6	127	70	0,4	31	43		71,7	23,4
1	734063	1	POST	6,75	12	64,1	5,1	124	70	1,29	31	8,7		54,8	17,9
2	739478	2	PRE	6,75	89	48,4	19,8	127	70	0,4	31	44		68,8	22,4
2	739478	2	POST	6,97	89,7	47,6	3,9	124	107	0,4	31	8,4		50,1	16,4
3	738429	2	PRE	6,75	65,7	45,8	11,5	136	118	0,4	31	47	7,5	59	19,3
3	738429	2	POST	7,04	74,1	51,4	3,8	122	106	0,4	31	7,8	16,3	47,8	15,6
4	537982	1	PRE	6,75	80,9	34,9	13,1	132	70	0,4	31	46		63,3	20,7
4	537982	1	POST	6,75	12	43,7	5,1	123	70	1,27	22	12,7		49,7	16,2
5	559839	1	PRE	6,8	66,6	39,8	8	138	122	0,4	31	47	7,8	57,3	18,7
5	559839	1	POST	7,1	72,3	42,9	3,8	123	107	0,4	31	11,1	17	47,4	15,5
6	746383	2	PRE	6,85	18,5	136	13,7	131	124	0,4	31	47	6,9	55,1	18
6	746383	2	POST	6,96	85,7	31,8	5,1	123	107	0,4	31	18,4	13	54	17,6
7	740437	1	PRE	6,84	68,4	47,7	15,4	128	113	0,4	31	35	9	59	19,3
7	740437	1	POST	6,84	12	59,2	5,1	124	70	1,27	21	6,9		50,2	16,4
8	746557	2	PRE	6,75	95,4	67,8	19,6	129	70	0,4	31	45		71,9	23,5
8	746557	2	POST	6,92	97,5	47,7	4	123	106	0,4	31	11,3	12,9	57,2	18,7
9	743745	1	PRE	6,75	76,3	63,6	19	127	70	0,4	31	47		69,8	22,8
9	743745	1	POST	6,75	12	82,4	5	123	70	1,3	24	9,5		43,8	14,3
10	748228	2	PRE	6,75	98,3	40	15,1	131	70	0,4	31	47		60,6	19,8
10	748228	2	POST	7,05	82	42,3	3,9	124	107	0,4	31	6,9		36,2	11,8
11	720535	2	PRE	6,75	91,1	32,5	16,3	131	70	0,4	31	47		62,1	20,2
11	720535	2	POST	7,01	86,4	35,5	3,9	123	107	0,4	31	10,2	15,7	39,2	12,8
12	687823	1	PRE	6,75	84	31,7	14,9	130	70	0,4	31	47		66,4	21,7
12	687823	1	POST	6,75	12,2	35,7	5	122	70	1,25	23	12		50,2	16,4
13	746724	2	PRE	6,78	85,2	38,4	18,1	123	114	0,4	31	39	8,7	67,1	21,9
13	746724	2	POST	7,07	77,4	40,1	4	123	108	0,4	31	8,2	16,3	49,2	16
14	747708	1	PRE	6,75	74,1	45,4	18,1	127	70	0,4	31	47		63,2	20,6
14	747708	1	POST	6,75	12	58,8	5,1	123	70	1,28	23	11		43,9	14,3
15	729641	1	PRE	6,83	74,3	36,6	11,4	134	117	0,4	31	46	9	63,5	20,7
15	729641	1	POST	6,79	12	45,4	5,1	120	70	1,23	20	17,1		51,3	16,7
16	748491	2	PRE	6,81	61,8	47,6	12,7	133	121	0,4	31	47	8,2	60,9	19,9
16	748491	2	POST	7,1	68,1	52	4	122	107	0,4	31	15,1	16,1	58	18,9
17	728859	1	PRE	6,75	81,5	46,2	8,6	137	70	0,4	31	47		66,8	21,8
17	728859	1	POST	6,75	12	57,5	5	122	70	1,27	21	12		53,8	17,5
18	643458	2	PRE	6,75	94,7	31,5	12,8	135	70	0,4	31	47		58,5	19,1
18	643458	2	POST	6,99	89	32,5	3,9	123	108	0,4	31	12,5	14,5	50,3	16,4
19	744315	2	PRE	6,75	92,7	30,5	10,5	127	70	0,4	31	39		63,3	20,6
19	744315	2	POST	7,01	83,1	43	4	123	108	0,4	31	10,6	14,6	51,2	16,7
20	721517	1	PRE	6,75	77,3	33,4	11,8	137	70	0,4	31	47		68,3	22,3
20	721517	1	POST	6,75	12	38,8	5	122	70	1,28	21	11,7		57,8	18,9

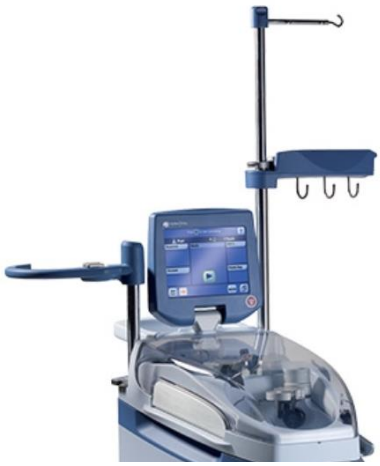
APPENDIX K


S3 BALSOL
Infusion/Infusie
H/24/176
FRESENIUS KABI
Contains/Bevat per 1 000 ml:
1 000 ml
Sodium chloride 6,0 g Natriumchloried
Potassium chloride 0,3 g Kaliumchloried
Magnesium chloride • 6H2O 0,3 g Magnesiumchloried • 6H2O
Sodium bicarbonate 2,3 g Natriumbikarbonaat
Sodium ion 130 mmol Natriumioon
Potassium ion 4,0 mmol Kaliumioon
Magnesium ion 1,5 mmol Magnesiumioon
Chloride ion 110 mmol Chlorieduoon
Bicarbonate ion 27 mmol Bikarbonaat ion
Milliosmols (approx) 273 Milliosmole (onge eer)
pH (approx) 7,4 pH (onge eer)
Sterile, pyrogen free Steriel, pirog nvry
For intravenous use Vir intraveneuse g bruik
Additives may be incompatible. Do not use unless sol ion is clear. Check for minute leaks by squeezing bag. Destroy any unused portion.
KEEP OUT OF REACH OF CHILDREN. STORE AT OR BELOW 25 °C.
Byvoegings kan onverenigbaar wees. Gebruik slegs indien oplossing helder is. Toets vir lekkasie deur sak saam te druk. Vernietig oorblywende gedeelte.
HOU BUITE BEREIK VAN KINDERS. BEWAAR BY OF ONDER 25 °C.
FSB001000
12/13
Manufactured by
Fresenius Kabi Manufacturing SA (Pty) Ltd,
6 Gibaud Road, Korsten, 6020, Port Elizabet South Africa
Namibia: NS2 90/24/00384
Lot:
Mnf:
Exp:
90LH008
08/2017
07/2019

APPENDIX L


AFB 2324
S3 SABAX RINGER-LACTATE
(HARTMANN'S SOLUTION)
-1-
D/24/208
1 000 ml
VIAFLEX®
SINGLE DOSE CONTAINER
Sterile nonpyrogenic
Infusion (Parenteral)
Latex Free
VIAFLEX®
ENKELDOSIS HOUER
Steriel pirogeenvry
Infusie (Parenteraal)
Latexvry
-2-
Contains
Bevat
-3-
Sodium Chloride 6 g Natriumchloried
Sodium Lactate 3,2 g Natriumlaktaat
Potassium Chloride 0,4 g Kaliumchloried
Calcium Chloride Dihydrate 0,27 g Kalsiumchloried Dihidraat
Approximate millimoles Benaderde millimole
-4-
Sodium 131 Natrium
Potassium 5 Kalium
Calcium 1,8 Kalsium
Chloride 112 Chloried
Bicarbonate (as Lactate) 29 Bikarbonaat (as Laktaat)
-5-
Approximate milliosmoles 279 Benaderde milliosmole
per 1 000 ml
Approximate pH 6,5 Benaderde pH
ADMINISTER INTRAVENOUSLY USING STERILE EQUIPMENT DO NOT USE IN SERIES CONNECTIONS DO NOT ADMINISTER SIMULTANEOUSLY WITH BLOOD DO NOT USE IF THE SOLUTION CONTAINS VISIBLE PARTICLES OR IS NOT CLEAR ADDITIVES MAY BE INCOMPATIBLE CHECK FOR MINUTE LEAKS BY SQUEEZING DISCONTINUE INFUSION IF ADVERSE REACTION OCCURS STORE BELOW 25 °C KEEP OUT OF REACH OF CHILDREN
-6-
-7-
MOET BINNEAARS TOEGEDIEN WORD MET STERIELE TOERUSTING MOET NIE IN SERIE VERBIND WORD NIE MOET NIE GELYKTYDIG MET BLOED TOEGEDIEN WORD NIE MOET NIE GEBRUIK INDIEN DIE OPLOSSING SIGBARE DEELTJIES BEVAT OF NIE HELDER IS NIE BYVOEGINGS MAG ONVERENIGBAAR WEES TOETS VIR LEKKASIE DEUR SAK SAAM TE DRUK STAAK TOEDIENING INDIEN ONGEWENSTE REAKSIE VOORKOM BERG BENEDE 25 °C HOU BUITE BEREIK VAN KINDERS
-8-
adcock ingram
ADCOCK INGRAM CRITICAL CARE (PTY) LTD
1 Sabax Road/weg Aeroton Johannesburg
Under licence from/Kragtens lisensie van
BAXTER INTERNATIONAL INC
-9-
08-25-18-612
LOT
805V918
EXP
VERV
MAY20

APPENDIX M



Operating Protocols

INTRA-OPERATIVE FACTORY PROTOCOLS

Popt

Designed to obtain:
- Very high Hct[1]
- Excellent supernatant removal[2]
- Good processing speed[2]

Achieved by:
- Two step filling at different flow rates and automated stand-by
- Dual RBC detector technology for optimal bowl filling (active for XTRA BOWL 55 and XTRA BOWL 225)

Pstd

Designed to obtain:
- High processing speed (with XTRA BOWL 225)[2]
- Good hematocrit[2]
- Good wash quality[2]

Achieved by:
- One-step automatic filling
- Possibility to adjust flows (filling, washing, emptying)
- High wash and empty flows

Pfat

Designed to obtain:
- Removal of fat particles
- Excellent supernatant removal
- Good Hematocrit

Achieved by:
- Newly designed fat removal phase
- High wash flows