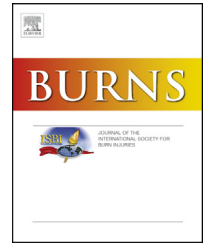


Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/burns

Cell salvage in burn excisional surgery

Rolf K. Gigengack^{a,b,*}, Veerle Verhees^a,
Ankie W.M.M. Koopman-van Gemert^c, Irma M.M.H. Oen^a,
Tjaco M. Ossewaarde^d, Seppe S.H.A. Koopman^e, Stephan A. Loer^b,
Cornelis H. van der Vlies^{b,e,f}

^a Departments of Trauma and Burn Surgery, Maasstad Ziekenhuis, Rotterdam, The Netherlands

^b Department of Anesthesiology, Amsterdam UMC, Location De Boelelaan, Amsterdam, The Netherlands

^c Department of Anesthesiology, Albert Schweitzer Hospital, Dordrecht, The Netherlands

^d Departments of Microbiology, Maasstad Ziekenhuis, Rotterdam, The Netherlands

^e Association of Dutch Burns Centers, Beverwijk, The Netherlands

^f Trauma Research Unit Department of Surgery, Erasmus MC, Rotterdam, The Netherlands

ARTICLE INFO

Article history:

Accepted 26 June 2020

Keywords:

Cell salvage

Burn excisional surgery

Blood

Microbial contamination

Transfusion

ABSTRACT

Background: Hemostasis during burn surgery is difficult to achieve, and high blood loss commonly occurs. Bleeding control measures are limited, and many patients require allogeneic blood transfusions. Cell salvage is a well-known method used to reduce transfusions. However, its evidence in burns is limited. Therefore, this study aimed to examine the feasibility of cell salvage during burn surgery.

Study design and methods: A prospective, observational study was conducted with 16 patients (20 measurements) scheduled for major burn surgery. Blood was recovered by washing saturated gauze pads with heparinized saline, which was then processed using the Cell Saver. Erythrocyte concentrate quality was analyzed by measuring hemoglobin, hematocrit, potassium, and free hemoglobin concentration. Microbial contamination was assessed based on cultures at every step of the process. Differences in blood samples were tested using the Student's t-test.

Results: The red blood cell mass recovered was $29 \pm 11\%$ of the mass lost. Patients' preoperative hemoglobin and hematocrit levels were 10.5 ± 1.8 g/dL and 0.33 ± 0.05 L/L, respectively. The erythrocyte concentrate showed hemoglobin and hematocrit levels of 13.2 ± 3.9 g/dL and 0.40 ± 0.11 L/L thus showing a concentration effect. The potassium level was lower in the erythrocyte concentrate (2.5 ± 1.5 vs. 4.1 ± 0.4 mmol/L, $p < 0.05$). The free hemoglobin level was low (0.16 ± 0.21 μ mol/L). All cultures of the erythrocyte concentrate showed bacterial growth compared to 21% of wound cultures.

Conclusion: Recovering erythrocytes during burn excisional surgery using cell salvage is possible. Despite strict sterile handling, erythrocyte concentrates of all patients showed bacterial contamination. The consequence of this contamination remains unclear and should be investigated in future studies.

© 2020 Published by Elsevier Ltd.

* Corresponding author at: Department of Trauma and Burn Surgery, Maasstadweg 21, 3079 DZ Rotterdam, The Netherlands.
E-mail address: gigengackr@maasstadziekenhuis.nl (R.K. Gigengack).

<https://doi.org/10.1016/j.burns.2020.06.030>

0305-4179/© 2020 Published by Elsevier Ltd.

1. Introduction

Hemostasis during burn excisional surgery is difficult to achieve due to the large wound surface. High blood loss commonly occurs intraoperatively [1–3]. Budny et al. observed a blood loss of >100 mL per 1% body area excised [4]. Bleeding control measures during burn excisional surgery are limited. Topical adrenalin (1 mg in 1000 mL 0.9% NaCl) is a well-known and frequently used technique. Adrenalin induces vasoconstriction, thereby decreasing blood loss. Other techniques include the use of tourniquets and topical tranexamic acid [5]. Nevertheless, many burn patients continue to require allogeneic blood transfusions to maintain an adequate hemoglobin level postoperatively, which has side effects (i.e., hemolysis, immunomodulation, and transfusion-related lung injury) [6].

A recognized method to reduce allogeneic transfusions during high blood loss surgery is cell salvage [7,8], which can be performed using a Cell Saver, an autologous red blood cell recovery system. The device collects and washes red blood cells; processes blood; and removes plasma, debris, and harmful substances such as free hemoglobin. After processing, the erythrocyte concentrate can safely be re-administered to the patient [8,9]. Cell salvage is a cost-effective technique and beneficial in surgery with an expected blood loss of >1000 mL [7,9]. However, the use of cell salvage is complex during burn excisional surgery when compared to other high blood loss surgeries. Specifically, collecting blood is more challenging during cell salvage.

During burn excisional surgery, blood loss is more diffusely distributed over the wound surface as compared to blood loss in other types of surgery. Furthermore, hemolysis is a risk when using cell salvage during burn excisional surgery. Erythrocytes are damaged by air-contact, shear forces by suction pressure and frequent skimming of the surface by collecting small volumes of blood with suction tubes [7,8,10–12]. These factors decrease the possibility of retrieval of erythrocytes during burn excisional surgery.

The use of cell salvage during burn excisional surgery has been considered controversial due to the risk of infection [13]. The literature regarding its safety and effectiveness is limited. Jeng et al. found that the bacterial load in the erythrocyte concentrate is similar to that of cell salvage in elective vascular surgery [14]. However, no data on bacteremia or sepsis can be found in the literature. Bacterial contamination of the erythrocyte concentrate appears to be routine, as approximately 30% of units show bacterial contamination in other forms of surgery [15]. To reduce the bacterial load, some authors advocate the addition of antibiotics to erythrocyte concentrates [8,10,14,16]. Despite the common use of cell salvage, the impact of bacteria in the erythrocyte concentrate remains unknown [13,15].

Therefore, this study aims to investigate the feasibility and the areas for improvement of cell salvage during burn excisional surgery using blood-saturated gauze washed in heparin-saline solution. Furthermore, we tested bacterial contamination in the processed erythrocyte concentrate.

2. Materials and methods

This prospective observational study was conducted at the Maastad Hospital, one of three burn centers in the Netherlands, which treats more than 200 burn patients annually. The Institutional Research Ethics Board of Maastad Hospital Rotterdam approved the present study (L2017123). All participants provided written informed consent.

2.1. Population

All consecutive patients admitted from January 2018 to July 2018 scheduled for burn excisional surgery were eligible for inclusion. Inclusion criteria were an expected blood loss of >500 mL and age of >18 years. Patients with an active infection (bacterial growth in a blood culture) or with a history of immunodeficiency disorder were excluded. In total, 16 patients were included in this study for a total of 20 procedures. All patients received perioperative antibiotic prophylaxis (gentamicin 7 mg/kg) once or tobramycin (5 mg/kg) in case of allergy.

2.2. Surgical technique

Full-thickness or deep dermal wounds that were unlikely to heal within 14–21 days were excised using sharp instruments. After the initial excision, dressings soaked in adrenaline were applied to the wound surface to control and absorb blood loss. When total excision was completed, the wound surface was covered using a split skin graft.

2.3. Procedure

To investigate the quality of the erythrocyte concentrate, patients' blood samples were compared with those taken from the erythrocyte concentrate. Hemoglobin, hematocrit, and potassium levels were measured. Hemolysis was determined by measuring the free hemoglobin level in the finished product. Free hemoglobin levels were measured using spectrophotometry. The normal value in our laboratory of free hemoglobin is <5.3 $\mu\text{mol/L}$ to determine hemolysis.

Direct collection (suction) of the shed blood from the wound surface was impossible due to the diffuse nature of blood loss. Thus, a new approach was used to collect the shed blood: dressings were used on the wound surface to absorb the shed blood. The duration of gauze application to the wound varied with a time frame of 20–30 min. All gauze pads were weighed before use and before washing to determine the estimated blood loss. Saturated dressings were washed with heparinized saline to the discretion of the researcher (1L 0.9% NaCl + heparin 5000 IE) in order to extract the blood from the dressing. Subsequently the heparinized saline was processed using factory standard settings with a 125 mL bowl of the Cell Saver (Haemonetics Cell Saver 5+; Haemonetics Corporation, Braintree, USA). All bowls were considered full before processing. Gauze handling was performed by a researcher following a strict sterile protocol. Thus, maximum measures were carried out to ensure sterile handling of the gauze pads in order to minimize bacterial contamination.

In order to investigate the microbial contamination of the erythrocyte concentrate, blood cultures (bottles) were taken from the blood collection reservoir, after washing, and after applying a micro aggregate blood transfusion filter (40 μm). These were compared to microbial swab cultures of the burn wound (with the intention to obtain samples of the whole wound) taken before the incision. After taking cultures and measurements, the finished erythrocyte concentrate was discarded and not transfused to the patients.

2.4. Statistical analysis

All data were analysed using the SPSS statistical analysis package (IBM Corporation, Armonk, USA). Baseline characteristics were described as counts and percentages (dichotomous variables), medians and interquartile range (continuous variables, non-normal distribution), or means and standard deviations (continuous variables, normal distribution). Red blood cell mass lost was calculated by the patients' hematocrit \times volume of blood loss, and the red blood cell mass recovered was calculated by the hematocrit of the erythrocyte concentrate \times volume of erythrocyte concentrate. The percentage of recovered red blood cell mass was calculated by red blood cell mass recovered/red blood cell mass lost \times 100. Differences in patient laboratory results and the results of the erythrocyte concentrate were tested using a Student's t-test to evaluate the concentration effect of the cell saver. Using a Pearson correlation, the relation between the volume of processed fluids and the percentage of recovered erythrocytes was determined. Furthermore, the correlation between the preoperative hematocrit and hematocrit of the erythrocyte concentrate was determined.

3. Results

3.1. Erythrocyte concentrate quality

Table 1 presents the main characteristics of the subjects included in the study. In total, 16 patients were included in 20 procedures. The mean age was 53 ± 16 years, 11 patients had a flame-related injury, and 5 had a scalding-related injury. Prior to the surgical procedure, all patients received one dose of

prophylactic intravenous antibiotics: 15 patients received gentamicin and 1 patient received tobramycin due to allergy to gentamicin. The median blood loss estimated by weight measurement was 1830 (1053–2676) mL with a minimum of 600 mL and a maximum blood loss of 4100 mL. The mean volume of recovered erythrocyte concentrate was 421 ± 181 mL. The mean recovered red blood cell mass was 172 ± 96 mL and the mean percentage of recovered red blood cell mass was $29 \pm 11\%$. The percentage of recovered blood shows a weak negative correlation with the volume of blood loss ($r^2 = 0,367$, $P < 0.05$).

As shown in Table 2, patients' preoperative hemoglobin and hematocrit levels were 10.5 ± 1.8 g/dL and 0.33 ± 0.05 L/L, respectively. In the erythrocyte concentrate, hemoglobin and hematocrit levels were respectively 13.2 ± 3.9 g/dL and 0.40 ± 0.11 L/L, showing a concentration effect. No significant correlation was observed between preoperative hematocrit and the hematocrit of the erythrocyte concentrate. The potassium level was lower in the finished product as compared to the preoperative values (2.5 ± 1.5 mmol/L vs. 4.1 ± 0.4 mmol/L). The free hemoglobin level of the erythrocyte concentrate was low (0.16 ± 0.21 $\mu\text{mol/L}$). In total, a mean volume of 5279 ± 1773 mL fluid was processed through the cell saver. The volume of fluids processed, and the volume of recovered blood were positively correlated ($r^2 = 0.607$, $P < 0.05$).

3.2. Microbiology

Table 3 shows an overview of microorganisms obtained from the wound and erythrocyte cultures. For example, the wound cultures of 9 out of 16 patients showed growth of *Staphylococcus aureus*, while 15 of the 20 erythrocyte concentrate cultures showed *S. aureus* growth. So, the predominant microorganism was *S. aureus*. Hereafter, *Enterococcus faecalis* (9/20 cultures with growth) and *S. epidermidis* (9/20 cultures with growth) were the most predominant microorganisms in the final erythrocyte concentrate. Preoperative wound cultures showed bacterial growth in 21% of patients. In contrast, all cultures obtained during the washing process showed bacterial growth. Most of the microorganisms found in the preoperative wound cultures were also present in the final erythrocyte concentrate.

Table 1 – Baseline characteristics.

n	16
Age (mean \pm SD)	53 ± 16
Etiology	
- Flame (n)	11
- Scalding (n)	5
%TBSA (mean \pm SD)	16 ± 7 %
Preoperative antibiotics	
- gentamicin (n)	15
- tobramycin (n)	1
n	20
Estimated blood loss (median (25–75%))	1830 (1053–2676) ml
Mean volume processed (mean \pm SD)	5279 ± 1773 ml
Volume erythrocyte concentrate (mean \pm SD)	412 ± 181 ml
Percentage retrieved (percentage)	25 %
Volume heparinized saline (mean \pm SD)	4300 ± 1431 ml

4. Discussion

This study investigated the feasibility of using a cell salvage technique in burn excisional surgery as a blood-saving method. Recovering shed erythrocytes is feasible. Despite strict sterile handling, the erythrocyte concentrates of all patients showed bacterial contamination. The consequence of this contamination remains unclear and should be investigated in future studies.

The blood retrieval method combined with the use of cell salvage is effective in recovering erythrocytes during burn excisional surgery. Hemoglobin and hematocrit levels (13.2 g/dL and 40 L/L, respectively,) of the finished product were higher than the preoperative values, indicating the effectiveness of the cell salvage procedure. The reported hematocrit level in the literature ranged from 41% to 50%, which is comparable to our results [8,10,17]. The Cell Saver has a hemolysis sensor

Table 2 – Laboratory results.

	Pre-operative patient	Erythrocyte concentrate
n	20	20
Hemoglobin g/dL	10.5 ± 1.8	13.2 ± 3.9*
Hematocrit L/L	0.33 ± 0.05	0.40 ± 0.11*
Potassium mmol/L	4.1 ± 0.4	2.5 ± 1.5*
Free hemoglobin μmol/L		0.16 ± 0.21

* p < 0.05 pre-operative vs. Cell Saver blood.

controlling the wash procedure, thereby reducing the fraction of free hemoglobin in the finished product [8]. As expected, the fraction of free hemoglobin was low in our study.

The percentage of red blood cell mass recovered using cell salvage was 29%. This was lower than that reported in other studies. The reported efficiency ranged from 43% to 50% in burn excisional surgery [14,18] and up to 58% in aortic surgery when using swab washing [19]. The lower efficiency in this study can be partially explained by the differences in the blood retrieval methods. In both burn excisional studies, suction directly on the wound surface was used in combination with a collection bag, in contrast to our protocol in which gauze pads were used to recover blood. Our current surgical procedure makes it impossible to use the methods used in other studies. Additionally, erythrocyte damage could have developed due to direct mechanical damage using gauze pads, in combination with air and non-endothelial tissue contact and manual manipulation of the dressings [8]. Moreover, a substantial volume of blood might have remained in the gauze based on the color after washing, and a small negative correlation between the volume of blood loss and the recovered erythrocyte concentrate. Finally, some blood was clotted before contact with the heparinized saline.

The finished product in all patients tested positive for microorganisms with a large variety of species. Most microorganisms belong to normal skin flora. *S. aureus*, *S. epidermidis*, and *E. faecalis* were the most prevalent microorganisms. The high number of growth in cultures was surprising, as only 21% of the preoperative wound cultures showed bacterial growth. Normally, during cell salvage, the bacterial load will substantially decrease [16]. Several factors could have contributed to the high microbial load before washing. First, wound cultures could have been an underestimation of the wound flora as the culture could have missed parts of the wound surface. Second, bacterial contamination could have taken place in the deeper layers of skin exposed during the excisional surgery. Third, the product might be contaminated during the washing procedure due to air- and body contact by the operator, despite the strict sterile handling. However, this possibility is unlikely because the results show only one *Candida utilis*. Finally, two studies reported bacterial contamination in burn excisional surgery with 43.6 and 75% of samples testing positive for microbial infection [10,14]. This difference can partially be explained by our method in which gauze pads are positioned on the patient for a prolonged period of time, thereby increasing the risk of bacterial contamination.

The extent in which this bacterial infection is harmful to the patient is unknown. Bacterial contamination is not an absolute

Table 3 – Number of cultures showing growth for a microorganism.

Micro-organism	Wound culture	After filter
n	16 patients	20 procedures
<i>Staphylococcus aureus</i>	9	15
<i>Enterococcus faecalis</i>	2	9
<i>Staphylococcus epidermidis</i>		9
<i>Citrobacter koserii</i>	1	5
<i>Morganella morganii</i>	1	3
<i>Pseudomonas aeruginosa</i>	2	3
<i>Acinetobacter baumannii</i>	1	
<i>Streptococcus mitis/oralis</i>		3
<i>Bacillus cereus group</i>		2
<i>Escherichia coli</i>		2
<i>Hemolytic streptococcus G</i>		2
<i>Candida utilis</i>		1
<i>Corynebacterium striatum</i>		1
<i>Enterobacter cloacae complex</i>		1
<i>Enterococcus casselglaucus</i>		1
<i>Enterococcus faecium</i>		1
<i>Enterococcus gallinarum</i>		1
<i>Granulicatella adiacens</i>		1
<i>Klebsiella pneumonia</i>		1
<i>Proteus mirabilis</i>		1
<i>Staphylococcus caprae</i>		1
<i>Staphylococcus haemolyticus</i>		1
<i>Stenotrophomonas maltophilia</i>		1
<i>Streptococcus gallolyticus</i>		1

contraindication for cell salvage. However, reinfusing contaminated erythrocyte concentrate can trigger sepsis by introducing infective agents and toxins [13]. All patients received antibiotic prophylaxis of gentamicin or tobramycin, resulting in adequate antibiotic coverage during the first 24 h postoperatively. Two studies in dogs show a protective effect of antibiotics and show no adverse effect of transfusing contaminated blood [20]. Nevertheless, whether the effectiveness of prophylactic antibiotics is sufficient when transfusing infected erythrocyte concentrate in humans remains unclear, as humans have a lower tolerance to bacteremia than dogs [20]. Our data indicates that an antibiotic regimen based on wound cultures may not reflect the antibiotics required for patients. Additional research is essential to explore the safety of transfusing contaminated erythrocyte concentrate.

The use of cell salvage by Cell Saver is cost-effective. A standard red blood cell concentrate costs 220 euros. On average, the cell saver produced 412 ml erythrocyte concentrate or a red blood cell mass of 172 mL, which is comparable to

a standard red blood cell concentrate (0.58 L/L × 280 mL = 162 mL). The Cell Saver[®] package with all necessities costs 200 euros, saving 20 euros.

This study has some limitations and strengths. This is a small prospective study. Despite the small group, we can conclude that we have a reasonable doubt on the safety of cell salvage and other measures should be taken to reduce bacterial contamination. Although all blood cultures showed bacterial growth, quantitative data with regard to colony forming units/mL are lacking. Several studies show a beneficial effect of adding antibiotics to the washing process on microbial contamination. However, in this study, no antibiotics were added to the washing process. Furthermore, the finished product was not transfused to patients to investigate the response. Before beginning this study, the safety issues surrounding the transfusion of salvaged blood were unsure and we decided not to transfuse in this study. We could consider transfusion after optimization of this protocol and further minimize the bacterial contamination. A well-considered decision, based on future results, must be made if transfusion of salvaged erythrocytes during burn excisional surgery is to be undertaken.

For future research, improvements of our protocol are required. For example, to improve the percentage of salvaged erythrocytes, more research is needed to determine the correct ratio of heparinized saline and shed blood, as our data suggests that there is a relationship between the total volume processed by the cell saver and the percentage of recovered blood. Also, no conclusions can be drawn regarding the optimal heparin concentration in heparinised saline. Furthermore, quantitative measurement of the bacterial load should be performed. To further decrease the bacterial load, the washing process could be performed under the plenum to reduce contamination via air, and antibiotics could be added to the erythrocyte concentrate to reduce the bacterial load, as proven by Lenzen and Perez-Ferrer et al. [10,21] Gentamicin (8 mg/L) and vancomycin (40 mg/L) would eradicate all bacteria found in the blood cultures of this study. A new emerging alternative to reduce microbial load could be phototherapy, which shows promising results [22]. Finally, to further minimize the bacterial load in the finished erythrocyte concentrate a leukocyte reduction filter could be used instead of a micro-aggregate filter [16].

5. Conclusion

This study investigated the feasibility of using cell salvage in burn excisional surgery as a blood-saving method. Recovering erythrocytes during burn excisional surgery using cell salvage is possible, and the erythrocyte concentrate is of good quality and cost-effective. Despite the strict sterile handling, the erythrocyte concentrates of all patients showed bacterial contamination with consequences that remain unclear, this should be investigated in future studies.

Authors' contributions

RG was responsible for drafting the manuscript, drafting the design, and performing the statistical analysis and

finalization. VV contributed to the inclusion of patients and reviewed the manuscript. AKG, JK, and SL contributed to the design and analysis and reviewed the manuscript. IO contributed to inclusion and reviewed the manuscript. CV contributed to the design and reviewed the manuscript.

Disclaimers

No disclaimers to mention.

Funding

We received funding (3750 euros) from Stichting Coolsingel for all necessities of the Cell Saver.

Conflict of interest

None of the authors have conflict of interest.

REFERENCES

- [1] Butts CC, Bose K, Frotan MA, Hodge J, Gulati S. Controlling intraoperative hemorrhage during burn surgery: a prospective, randomized trial comparing NuStat[®] hemostatic dressing to the historic standard of care. *Burns* 2017;43:374–8, doi:http://dx.doi.org/10.1016/j.burns.2016.08.026.
- [2] Sterling JP, Heimbach DM. Hemostasis in burn surgery—a review. *Burns* 2011;37:559–65, doi:http://dx.doi.org/10.1016/j.burns.2010.06.010.
- [3] Hart DW, Wolf SE, Beauford RB, Lal SO, Chinkes DL, Herndon DN. Determinants of blood loss during primary burn excision. *Surgery* 2001;130:396–402, doi:http://dx.doi.org/10.1067/msy.2001.116916.
- [4] Budny PG, Regan PJ, Roberts AH. The estimation of blood loss during burns surgery. *Burns* 1993;19:134–7, doi:http://dx.doi.org/10.1016/0305-4179(93)90036-8.
- [5] Posluszny JA, Gamelli RL. Anemia of thermal injury: combined acute blood loss anemia and anemia of critical illness. *J Burn Care Res* 2010;31:229–42, doi:http://dx.doi.org/10.1097/BCR.0b013e3181d0f618.
- [6] Palmieri TL, Holmes JH, Arnoldo B, Peck M, Potenza B, Cochran A, et al. Transfusion requirement in burn care evaluation (TRIBE): a multicenter randomized prospective trial of blood transfusion in major burn injury. *Ann Surg* 2017;266:595–602, doi:http://dx.doi.org/10.1097/SLA.0000000000002408.
- [7] Sikorski Ra, Rizkalla Na, Yang Ww, Frank Sm. Autologous blood salvage in the era of patient blood management. *Vox Sang* 2017;112:499–510, doi:http://dx.doi.org/10.1111/vox.12527.
- [8] Koopman-van AWMM. Autotransfusion: therapeutic principles, efficacy and risks. In: Kochhar Puneet, editor. *Blood Transfus. Clin. Pract.*. InTech; 2012. p. 205–22, doi:http://dx.doi.org/10.5772/35754.
- [9] Ashworth A, Klein AA. Cell salvage as part of a blood conservation strategy in anaesthesia. *Br J Anaesth* 2010;105:401–16, doi:http://dx.doi.org/10.1093/bja/aeq244.
- [10] Lenzen C. Intraoperative blood salvage in bacterial contaminated surgical site — an in vitro study. *Transfus Med Hemother* 2006;33:314–23, doi:http://dx.doi.org/10.1159/000092259.

- [11] Yazer MH, Waters JH, Elkin KR, Rohrbaugh ME, Kameneva MV. A comparison of hemolysis and red cell mechanical fragility in blood collected with different cell salvage suction devices. *Transfusion* 2008;48:1188–91, doi:http://dx.doi.org/10.1111/j.1537-2995.2008.01670.x.
- [12] Waters JH, Williams B, Yazer MH, Kameneva MV. Modification of suction-induced hemolysis during cell salvage. *Anesth Analg* 2007;104:684–7, doi:http://dx.doi.org/10.1213/01.ane.0000255208.96685.2e.
- [13] Klein AA, Bailey CR, Charlton AJ, Evans E, Guckian-Fisher M, McCrossan R, et al. Association of Anaesthetists guidelines: cell salvage for peri-operative blood conservation 2018. *Anaesthesia* 2018;73:1141–50, doi:http://dx.doi.org/10.1111/anae.14331.
- [14] Jeng JC, Boyd TM, Jablonski KA, Harviel JD, Jordan MH. Intraoperative blood salvage in excisional burn surgery: an analysis of yield, bacteriology, and inflammatory mediators. *J Burn Care Rehabil* 1998;19:305–11, doi:http://dx.doi.org/10.1097/00004630-199807000-00006.
- [15] Waters JH. Indications and contraindications of cell salvage. *Transfusion* 2004;44:40S–4S, doi:http://dx.doi.org/10.1111/j.0041-1132.2004.04176.x.
- [16] Waters JH, Tuohy MJ, Hobson DF, Procop G. Bacterial reduction by cell salvage washing and leukocyte depletion filtration. *Anesthesiology* 2003;99:652–5, doi:http://dx.doi.org/10.1097/0000542-200309000-00021.
- [17] Serrick CJ, Scholz M, Melo A, Singh O, Noel D. Quality of red blood cells using autotransfusion devices: a comparative analysis. *J Extra Corpor Technol* 2003;35:28–34.
- [18] Samuelsson A, Björnsson A, Nettelblad H, Sjöberg F. Autotransfusion techniques in burn surgery. *Burns* 1997;23:188–9, doi:http://dx.doi.org/10.1016/s0305-4179(97)86848-9.
- [19] Haynes SL, Bennett JR, Torella F, McCollum CN. Does washing swabs increase the efficiency of red cell recovery by cell salvage in aortic surgery? *Vox Sang* 2005;88:244–8, doi:http://dx.doi.org/10.1111/j.1423-0410.2005.00631.x.
- [20] Dzik WH, Sherburne B. Intraoperative blood salvage: medical controversies. *Transfus Med Rev* 1990;4(3):208–35, doi:http://dx.doi.org/10.1016/S0887-7963(90)70266-0.
- [21] Perez-Ferrer A, Gredilla-Díaz E, de Vicente-Sánchez J, Navarro-Suay R, et al. Vancomycin added to the wash solution of the cell-saver. Effect on bacterial contamination. *Rev Esp Anestesiol Reanim* 2017;64:185–91, doi:http://dx.doi.org/10.1016/j.redar.2016.10.002.
- [22] Gwynne PJ, Gallagher MP. Light as a broad-spectrum antimicrobial. *Front Microbiol* 2018;9:119, doi:http://dx.doi.org/10.3389/fmicb.2018.00119.