The Role of Cell Salvage Autotransfusion in Abdominal Aortic Aneurysm Surgery

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Abstract

Objective: Abdominal aortic aneurysm (AAA) repairs, both elective and rupture, are associated with significant blood loss often requiring transfusion. Cell-salvage autotransfusion has been developed to reduce the need for allogeneic blood. We review the literature to delineate the role of cell salvage in reducing allogeneic blood use in open AAA repairs.

Methods: A systematic search of the English-language literature was performed using the PubMed, Embase and Cochrane databases up to August 2010.

Results: Twenty-three studies were identified. Whilst some data are conflicting, cell salvage appears to reduce overall use and exposure to allogeneic blood, and reduces length of intensive care unit and hospital stay after elective AAA repairs. There may be additional benefit by combining cell salvage with other blood-conservation techniques. Use of cell salvage in ruptured AAA repairs consistently reduced blood-product requirements.

Conclusions: Cell salvage appears to reduce blood-product use in both elective and rupture AAA repairs. Owing to the heterogeneity in methodology of published data, further study may be required before cell salvage becomes standard practice in open AAA repairs.

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Abdominal aortic aneurysm (AAA) repairs, both elective and ruptures, are associated with a predictable blood loss, often from opening the aneurysm sac and back bleeding from lumbar arteries. Losses commonly range from 1 to 3 l.1,2 High intra-operative blood losses are associated with bowel ischaemia and multi-organ failure,3 and an increased morbidity and mortality.4 The UK alone provides around 3500 elective and 1500 emergency AAA operations per year5; hence, aortic surgery results in a vast cumulative blood loss and a significant need for transfusion.

Allogeneic blood transfusion has many related problems. There is a risk of transmission of infectious diseases, such as AIDS and hepatitis,6 which although reduced has not been eliminated.7 Adverse reactions are also reported, such as anaphylaxis, transfusion-related lung injury and haemolytic reactions.8 Allogeneic blood may be susceptible to
bacterial contamination, and some studies have shown blood transfusions to be immunosuppressive and to prevent the normal hypercoagulable response to bleeding. Finally, the use of allogeneic transfusions has considerable financial implications. Large transfusions are associated with myocardial infarction, acute renal failure, acute respiratory distress syndrome and death following repair of AAA.

Autologous transfusion — the transfusion of the patient’s own blood — is already widely used in orthopaedic surgery, and evidence suggests it has reduced the need for allogeneic transfusion. However, the evidence for autologous blood transfusion in vascular surgery is not yet conclusive. The aims of this review are to: (1) give a brief historical account of cell salvage, (2) to summarise the available literature concerning blood-product use and the role of cell-saver autotransfusion, with or without other autologous transfusion methods, in the repair of abdominal aortic aneurysms, both elective and ruptures and (3) where possible, to perform quantitative analyses regarding complications and outcomes.

Methods

A literature search was performed using the PubMed (from 1966), Embase (from 1974) and Cochrane databases. The last search was performed in August 2010. Results were limited to human studies written in the English language. The key search words used were (AAA or aneurysm) AND (cell salvage or cell saver or autotransfusion). Eligible studies included those which included data on the use of cell salvage in abdominal-aortic-aneurysm repairs. Study type was neither an inclusion nor an exclusion criterion. Data concerning procedures for aorto-occlusive disease were excluded. The titles and relevant abstracts were screened by two authors (SS and SP), with any discrepancy resolved by mutual discussion. In addition, the references of eligible articles were screened for further relevant studies. In total, 23 studies were identified (Fig. 1). These included nine uncontrolled studies (six retrospective and three prospective), 10 non-randomised trials (seven retrospective and three prospective) and four randomised controlled trials (RCTs). From these, data were extracted using a pre-prepared table on the following: authorship, study design, intervention, number of patients, elective/ruptured AAAs, transfusion threshold, blood-product use, proportion of patients transfused, complications, ICU stay and hospital stay.

Where possible, data were pooled in a meta-analysis, using a random-effects model, given the heterogeneity of included studies. All statistical analyses were conducted using RevMan (v5.1, Cochrane, UK).

Salvage Autotransfusion

Salvage autotransfusion describes the collection of blood that’s shed during surgery followed by its immediate reinfusion. It was first performed in 1885 by John Duncan, surgeon at the Edinburgh Royal Infirmary, who autotransfused a patient requiring amputation after having his leg crushed in a railway incident. Eight ounces of the patient’s own blood, mixed with distilled water, was successfully transfused.

Autologous transfusion has advantages and disadvantages over allogeneic transfusion. Autologous blood is normothermic, less expensive and has a better immediate oxygen-carrying capacity. In addition, autotransfusion is accepted by some Jehovah’s witnesses. However, salvage techniques require additional equipment and trained personnel, and autologous transfusion has been associated with coagulopathies, haemolysis, embolism and bacterial contamination.

Two different techniques of intra-operative autotransfusion have been described: unwashed whole-blood autotransfusion (WBA) and concentrated-blood autotransfusion. WBA was first described in 1968 by Klebanoff and Watkins and later used in 10 patients with major trauma in Vietnam in 1970. Shed blood is filtered to remove large particulates, but not washed, and immediately reinfused. Platelets and plasma proteins are returned, but so are unwanted activated coagulation factors and haemolytic degradation products, which increase the risk of acute renal failure and disseminated intravascular coagulation.

Concentrated-blood autotransfusion (cell salvage) was described in 1968 by Wilson and Taswell. Shed blood is filtered to remove large particulates, but not washed, and immediately reinfused. Platelets and plasma proteins are returned, but so are unwanted activated coagulation factors and haemolytic degradation products, which increase the risk of acute renal failure and disseminated intravascular coagulation.
reduced, but essential blood elements, such as platelets, plasma proteins and clotting factors, are also eliminated. Early clinical studies reported significant coagulation derangements following WBA. This led to the use of citrate anticoagulate and limiting the amount of autotransfusion (e.g., to 3000 ml). With these adjustments, some studies initially found that WBA could be used without adverse clinical complications. More recently, however, lethal haemostatic disturbances have been reported with WBA. Experimental animal and human studies comparing cell saver (CS) with WBA showed less haemostatic disturbance and less haemolysis in the CS group, and an RCT found that WBA was associated with a longer ICU and hospital stay. As the majority of research has focussed on the use of cell-saving devices, it is on this form of autotransfusion that the review will concentrate.

**Blood Use in AAA Surgery**

Three studies have retrospectively recorded blood-product use in elective AAA surgery. An early study by Chant et al. audited transfusion requirements over 3 years in 85 consecutive patients undergoing abdominal aneurysm surgery, although it is not clear whether these were all elective. They found that an average of 5.9 units of blood was transfused for aneurysm repairs, although there is no mention of whether this was intra-operatively alone or in total. Improvements in graft types and surgical technique since this publication may account for the apparent high blood-product use. Ho et al. studied blood-product use in 129 elective infrarenal AAA repairs over a 10-year period, performed by a single surgeon. Mean intra-operative blood loss was 1000 ml and 46% of patients required intra-operative red cells, each needing a mean transfusion of 400 ml. They found that a bifurcated graft, cross-clamp time, operation time and preoperative haemoglobin (Hb) levels were independently associated with blood loss. Neither of these studies reported their threshold for transfusion.

A recent audit documented blood-product use in elective infrarenal AAA repairs in one unit over 3 years. They found that only 18 of 72 patients (25%) required transfusion and, those who did, needed an average 2.1 units. The transfusion threshold was Hb < 9 g dl⁻¹. Patients who were transfused had an increased ICU stay, but there was no change in their overall stay. The authors conclude that, because their blood use was so low, there is no need for routine autotransfusion in elective infrarenal AAA repairs.

None of the three studies reported above mentioned the use of blood products other than red cells.

**The Role of Cell Savers (CSs) in AAA Surgery**

**Cell saver (CS) alone — uncontrolled studies**

Five uncontrolled studies have recorded blood-product use with routine use of a CS with very different outcomes (Table 1). Kelly-Patteson et al. prospectively studied 40 patients undergoing elective infrarenal AAA repairs by a single surgeon with a transfusion threshold of Hb < 8 g dl⁻¹. Only 14 (35%) of the 40 patients required transfusion intra-operatively, and three (7.5%) post-operatively, with a mean overall blood use of 0.8 units per patient. A more recent study by Healy et al. prospectively recorded blood-product administration with routine CS use in both elective (n = 63) and ruptured (n = 10) AAA over a 3-year period. Mean blood loss was 1300 ml in elective surgery and 5900 ml in ruptures. CS use meant that only 35% of elective patients required allogeneic transfusion, whilst all ruptured AAA did. Mean perioperative transfusion requirements were 0.3 units (elective) and 1.0 units (rupture).

A retrospective study by Huber et al. routinely used CS in 138 elective infrarenal AAA repairs over a 4-year period. They found they transfused an average of 2.8 units of red cells per patient, although no transfusion threshold is given. A cost analysis of this study suggested that routine CS use was not cost-effective unless cell salvage was over 5 units and that, while the equipment should routinely be used as a reservoir, it should only be used as a salvage device, if significant bleeding occurs. Another retrospective uncontrolled study by Goodnough et al. examined elective infrarenal (n = 19) and suprarenal (n = 165) AAA repairs over a 3-year period with routine CS use. They found that 89% of patients required allogeneic transfusion despite CS use, with a mean 3.5 units of red cells transfused per patient. The large transfusion requirements may in part be explained by the large number of suprarenal AAA repairs, which are known to be associated with a greater blood loss, although the authors report that there was no difference in blood-product requirements between the infrarenal and suprarenal repairs. A subsequent cost analysis suggested that cell salvage was only beneficial in patients who lost over a litre of blood.

Two retrospective uncontrolled studies reported a much higher blood-product use than the prospective studies,

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Design</th>
<th>Number of Patients</th>
<th>Transfusion Threshold</th>
<th>Mean Red Cell Transfusion (units)</th>
<th>Patients Transfused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goodnough42</td>
<td>Retrospective</td>
<td>184 (165 suprarenal)</td>
<td>–</td>
<td>3.5</td>
<td>89%</td>
</tr>
<tr>
<td>Healey40</td>
<td>Prospective</td>
<td>63</td>
<td>–</td>
<td>0.3</td>
<td>35%</td>
</tr>
<tr>
<td>Huber41</td>
<td>Retrospective</td>
<td>138</td>
<td>–</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Kelley-Patterson39</td>
<td>Prospective</td>
<td>40</td>
<td>Hb &lt; 8 g dl⁻¹</td>
<td>0.8</td>
<td>42%</td>
</tr>
<tr>
<td>Reddy43</td>
<td>Retrospective</td>
<td>131</td>
<td>Hb &lt; 10 g dl⁻¹</td>
<td>1</td>
<td>60%</td>
</tr>
</tbody>
</table>
higher even than the reports of blood-product use in AAA repairs without cell salvage. However, these two studies did not indicate whether their data included postoperative transfusions, or what the intra-operative transfusion threshold was. However, another retrospective study in 131 patients with a transfusion threshold of \( \text{Hb} < 10 \text{ g d}^{-1} \) only used a mean of 1.0 units per patient.\(^{43}\)

**CS in addition to other techniques — uncontrolled studies**

Two uncontrolled retrospective studies have considered the routine use of CS in addition to predeposit in AAA repairs (Table 2). Predeposit describes the donation and storage of the patient’s own blood in the weeks prior to elective surgery, to be used for subsequent transfusion. Glazier et al. looked at routine CS and predeposit in 43 patients undergoing infrarenal AAA repairs.\(^{45}\) Only a third of patients predeposited blood. They report an average blood loss of 770 ml. Whilst 58% of patients did not require any transfusion, none of the patients who predeposited blood required allogeneic transfusion.\(^{45}\) Overall, mean autologous transfusion was 1.3 units per patient.\(^{45}\) Pitmann et al. also retrospectively studied elective AAA repairs with routine use of CSs and predeposit \((n = 100).\(^{46}\) Only 24 units of blood were predonated. The mean allogeneic transfusion requirement was 1.7 units per patient. The authors felt that allogeneic transfusion could be eliminated, if all patients predeposited between 2 and 3 units of blood. This may not be feasible, however, as predeposit takes up significant preoperative time and requires the patient to have adequate haematopoietic capacity. Further, donated blood has a restricted shelf life and elective operations are frequently cancelled. Furthermore, even eligible patients do not appear to take up the option of predeposit, and a North American multicentre study reported a predeposit compliance of only 5% in eligible patients undergoing elective surgery.\(^{47}\)

Further two uncontrolled studies included the technique of acute normovolaemic haemodilution (ANH) in AAA repairs. In ANH, blood is withdrawn from the patient immediately preoperatively to be retransfused later on. Cardiac, respiratory and renal co-morbidities may limit the routine use of ANH in aortic surgery. A recent non-randomised study showed ANH alone had only a modest impact on blood conservation in AAA repairs.\(^{48}\) Torella et al. retrospectively looked at the combined role of CSs and ANH in elective infrarenal aortic surgery over a 6-year period of a single surgeon’s practice.\(^{49}\) Of the 78 subjects studied, 29 (37%) required transfusion, with a median allogeneic transfusion requirement of 0 units (interquartile range 0–2 units).\(^{49}\) The authors suggest that use of both CS and ANH is better than CS alone, when compared with the literature.\(^{49}\) An earlier prospective study from Tulloh et al. looked at the combination of CS with both predonation and ANH in 13 patients undergoing elective infrarenal AAA repairs.\(^{50}\) With a transfusion threshold of 9 g d\(^{-1}\), four (31%) patients required allogeneic blood, with an overall mean transfusion of 0.7 units.\(^{50}\) The results of these studies suggest there may be a benefit in combining various blood-conservation techniques.

**CS versus controls in elective repairs**

Eight non-randomised controlled studies in aortic-aneurysm repairs have been published (Table 3), with most of these suggesting a reduced transfusion volume with CS use.\(^{51–58}\)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Design</th>
<th>Methods Used</th>
<th>Number of Patients</th>
<th>Transfusion threshold</th>
<th>Mean Red Cell Transfusion (units)</th>
<th>Patients Transfused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glazier(^{45})</td>
<td>Retrospective</td>
<td>CS + predeposit</td>
<td>43</td>
<td>—</td>
<td>1.3</td>
<td>42%</td>
</tr>
<tr>
<td>Pitman(^{46})</td>
<td>Retrospective</td>
<td>CS + predeposit</td>
<td>100</td>
<td>—</td>
<td>1.7</td>
<td>—</td>
</tr>
<tr>
<td>Torella(^{49})</td>
<td>Retrospective</td>
<td>CS + ANH</td>
<td>78</td>
<td>8.5 g/dl</td>
<td>Median 0 (IQR 0-2)</td>
<td>37%</td>
</tr>
<tr>
<td>Tulloh(^{50})</td>
<td>Prospective</td>
<td>CS + predeposit + ANH</td>
<td>13</td>
<td>9 g/dl</td>
<td>0.7</td>
<td>31%</td>
</tr>
</tbody>
</table>

Four RCTs have been reported looking at the effect of CS use in elective AAA repairs (Table 4),\(^{1,59–61}\) of which three specifically studied infrarenal aneurysms.\(^{59–61}\) Spark et al. explored 50 infrarenal AAA repairs.\(^{59}\) They reported that CS use reduced the proportion of patients exposed to allogeneic products (96% non-CS vs. 13% CS, \( p = 0 \)) and volume of red-cell use (2.5 units non-CS vs. 0.5 units CS, \( p = 0 \)). They also found that use of CS reduced hospital stay by 3 days \( (p < 0.05)\).\(^{59}\) Clagett et al. performed a multicentre trial, also with 50 infrarenal AAA repairs.\(^{1}\) Interestingly, the authors found no significant difference in volume of allogeneic cell use between the two groups, both intra-operatively and throughout their hospital stay (2.5 units CS vs. 2.4 non-CS). A similar proportion of patients in both groups were exposed to allogeneic blood. In addition, there was no difference in ICU stay or hospital stay.\(^{1}\) Wong et al. performed a larger randomised trial comparing the combined use of CS and ANH versus a control group in elective infra- and suprarenal repairs.\(^{60}\) In 111 aneurysm patients, they found a reduced allogeneic requirement in the CS/ANH group (1.7 units CS/ANH vs. 3.9 units controls, \( p = 0.02 \)). However, use of CS and ANH neither reduced the number of patients exposed to allogeneic blood, nor did it affect mean hospital stay.\(^{60}\) Mercer et al. studied 81 patients undergoing elective infrarenal repair.\(^{61}\) Use of CS reduced the proportion of patients exposed to allogeneic blood (53% CS vs. 76%, \( p = 0.038 \)) and median volume of blood transfused (1 units CS vs. 3 units controls, \( p = 0.012 \)). There was no difference in hospital stay.\(^{61}\)

These four studies vary significantly in their conclusions. Whilst Clagett et al. found that CS use did not reduce allogeneic blood use, they used a higher intra-operative transfusion threshold (10 g d\(^{-1}\)) than the other studies.
Furthermore, salvaged cells were only reinfused if more than 400 ml was available for processing. Spark et al. found a significant improvement in allogeneic exposure, volume of blood-product use and hospital stay, but this was a small single-centre study and no comment was made regarding blinding. Furthermore, it is not clear whether the documented transfusions were intra-operative only. If so, including the postoperative blood requirements may affect the final outcomes. Whilst Wong et al. documented a reduction in allogeneic blood requirements, their study group underwent both CS and ANH, and included suprarenal repairs; hence, the results are not directly comparable.

A meta-analysis of the four RCTs has recently been published.\textsuperscript{62} The authors suggested that CS use decreased the requirement for allogeneic blood overall. However, when the results from the largest study by Wong et al., where the study patients underwent both CS and ANH, are removed from the analysis, the difference was no longer significant. We combined all the controlled trials (randomised and non-randomised) of CS versus no autologous transfusion in a meta-analysis to determine if use of a CS (1) decreased the volume of blood-product use and (2) decreased the proportion of patients receiving blood. Due to the heterogeneity in trial design, a random-effects model was used. The trials, which combined CS with another technique, were excluded from this analysis.

Eight trials (three RCTs and five non-randomised studies) reported the proportion of patients receiving blood (Fig. 2). Due to a significant heterogeneity between studies ($I^2 = 89$%), a random-effects model was used. We found that cell salvage reduced the risk of requiring blood-product administration for AAA repair (risk ratio (RR) 0.61, 95% confidence interval (CI) 0.44–0.84, $p < 0.002$). The magnitude of this effect was similar when only the three relevant RCTs were analysed (RR 0.63, 95% CI 0.37–1.07). Ten trials (three RCTs and seven non-randomised) reported a mean red-cell transfusion for patients undergoing AAA repair. Unfortunately, these data

### Table 3  Non-randomised controlled trials.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Design</th>
<th>Methods Used</th>
<th>Number of Patients</th>
<th>Transfusion Threshold</th>
<th>Mean Red Cell Transfusion (units)</th>
<th>Patients Transfused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allums\textsuperscript{51}</td>
<td>Retrospective</td>
<td>CS vs. control</td>
<td>10 CS, 10 control</td>
<td>–</td>
<td>0.4 CS vs. 2.6 control (no p)</td>
<td>30% CS vs. 90% control (no p)</td>
</tr>
<tr>
<td>Brown\textsuperscript{52}</td>
<td>Retrospective</td>
<td>CS vs. control</td>
<td>40 CS, 62 control</td>
<td>–</td>
<td>1.5 CS vs. 4.8 control ($p &lt; 0.0001$)</td>
<td>45% CS vs. 97% control (no p)</td>
</tr>
<tr>
<td>Markovic\textsuperscript{53}</td>
<td>Prospective</td>
<td>CS vs. control</td>
<td>30 CS, 30 control</td>
<td>Hb &lt; 10 g/dl</td>
<td>0.5 CS vs. 2.2 control ($p = 0.009$)</td>
<td>40% CS vs. 97% control (no p)</td>
</tr>
<tr>
<td>McMahon\textsuperscript{54}</td>
<td>Prospective</td>
<td>CS + predeposit vs. control</td>
<td>38 CS, 16 control</td>
<td>–</td>
<td>1.9 CS vs. 3.9 control ($p &lt; 0.001$)</td>
<td>63% CS vs. 88% control ($p &lt; 0.001$)</td>
</tr>
<tr>
<td>Serrano\textsuperscript{55}</td>
<td>Retrospective</td>
<td>CS vs. control</td>
<td>155 CS, 37 control</td>
<td>Hct &lt;30%</td>
<td>2.5 CS vs. 2.9 control (p = ns)</td>
<td>71% CS vs. 87% control ($p = 0.057$)</td>
</tr>
<tr>
<td>Shuhaiber\textsuperscript{56}</td>
<td>Retrospective</td>
<td>CS vs. control</td>
<td>60 CS, 33 control</td>
<td>Hb &lt; 10 g/dl</td>
<td>2.4 CS vs. 2.7 control (no p)</td>
<td>–</td>
</tr>
<tr>
<td>Tawfick\textsuperscript{57}</td>
<td>Retrospective</td>
<td>CS vs. control</td>
<td>74 CS, 58 control</td>
<td>Hb &lt; 8.5 g/dl</td>
<td>3 CS vs. 6 control ($p &lt; 0.001$)</td>
<td>–</td>
</tr>
<tr>
<td>Thomas\textsuperscript{58}</td>
<td>Retrospective</td>
<td>CS vs. control</td>
<td>50 CS, 22 control</td>
<td>–</td>
<td>3.1 CS vs. 5.4 control (no p)</td>
<td>90% CS vs. 100% control (no p)</td>
</tr>
</tbody>
</table>

### Table 4  Randomised controlled trials.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Methods Used</th>
<th>Number of Patients</th>
<th>Transfusion Threshold</th>
<th>Mean Red Cell Transfusion (units)</th>
<th>Patients Transfused</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clagett\textsuperscript{1}</td>
<td>CS vs. control</td>
<td>25 CS, 25 control</td>
<td>Hb &lt; 10 g/dl</td>
<td>2.4 CS vs. 2.5 control (p = ns)</td>
<td>66% CS vs. 72% control (p = ns)</td>
</tr>
<tr>
<td>Mercer\textsuperscript{61}</td>
<td>CS vs. control</td>
<td>40 CS, 41 control</td>
<td>Hb &lt; 8 g/dl</td>
<td>1 CS vs. 3 control (p = 0.012)</td>
<td>53% CS vs. 76% control (p = 0.038)</td>
</tr>
<tr>
<td>Spark\textsuperscript{59}</td>
<td>CS vs. control</td>
<td>23 CS, 27 control</td>
<td>Hct &lt; 25%</td>
<td>0.5 CS vs. 2.5 control (no p)</td>
<td>13% CS vs. 96% control (no p)</td>
</tr>
<tr>
<td>Wong\textsuperscript{60}</td>
<td>CS + ANH vs. control</td>
<td>59 CS, 52 control</td>
<td>Hb &lt; 8 g/dl</td>
<td>1.7 CS vs. 3.9 control (p = 0.02)</td>
<td>–</td>
</tr>
</tbody>
</table>
could not be analysed statistically, as not all the required figures were published. However, we calculated that, in the 852 patients studied, a combined average of 2.2 units of red cells were given to each patient in the CS group, compared with 3.7 units per patient in the controls (a reduction of 1.5 units per person). A recent study looked at complications and outcomes following cell salvage in abdominal aortic surgery. The authors concluded that, at worst, cell salvage does not change the complication rate after elective aortic surgery, and may even reduce it. However, a statistical analysis of such data is not possible due to the variations in reporting.

Role of CSs in ruptured aneurysm repairs

Five non-randomised controlled studies reported on the role of CSs in ruptured aneurysms (Table 5). Posacioglu et al. retrospectively looked at blood loss in suprarenal and infrarenal ruptured AAA repairs by a single surgeon. Of 56 subjects, 40 repairs used the CS and 16 did not. The CS group required fewer allogeneic red cells (mean 5.8 units non-CS vs. 3.6 units CS, \( p < 0.026 \)) and fewer units of fresh-frozen plasma (FFP) (mean 4.5 units non-CS vs. 1.5 units CS, \( p = 0.006 \)). The authors also reported a shorter hospital stay in the CS group but no significant difference in mortality. Tawfick et al. studied retrospectively ruptured AAA repairs over a 9-year period. Of 55 patients, 27 had CS and 28 did not. Mean blood transfusions were significantly lower in the CS patients (CS 6 units vs. non-CS 12 units). There was no significant difference in platelet and FFP transfusion between the CS and non-CS groups, although use of CS reduced ICU and hospital stay. Shuhaiber et al. from Shuhaiber et al., found no significant reduction in transfusion volumes in ruptured aneurysms, although this study only included 25 patients.

A prospective study reported by Serracino-Inglott et al. examined 154 ruptured AAA repairs over a 4-year period. Of these, 114 operations did not use CSs and 40 did. The mean allogeneic-blood-transfusion requirement was 4 units in the CS group and 7 units in the non-CS group (\( p < 0.001 \)). While there was no difference in the rate of postoperative complications between the two groups, the authors report an increased survival in the CS group (76% vs. 56%), although this analysis excluded patients who died in theatre. A second prospective study reported by Markovic et al. of 60 patients also suggested a significant reduction in transfusion volume, with a transfusion threshold of Hb < 10 g dl\(^{-1}\).

Although none of the above three studies were randomised, likely due to the unpredictability of rupture admissions and difficulties with ethical approval, there appears to be a consistent significant reduction in allogeneic transfusion when CSs are used in the repair of ruptured aneurysms. Although a pooled analysis was again not statistically possible, we calculated that the average red-cell requirement per patient having a ruptured AAA repair was 3.6 units in the CS group versus 7.0 units in the control group.

Discussion

Although many descriptive studies have looked at the role of cell salvage in AAA repairs, little randomised controlled data are available, and those that exist describe conflicting results regarding allogeneic blood use. These discrepancies

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Design</th>
<th>Number of Patients</th>
<th>Transfusion Threshold</th>
<th>Mean Red Cell Transfusion (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Markovic</td>
<td>Prospective</td>
<td>30 CS, 30 control</td>
<td>Hb &lt; 10 g/dl</td>
<td>0.5 CS vs. 2.2 control (( p = 0.009 ))</td>
</tr>
<tr>
<td>Posacioglu</td>
<td>Retrospective</td>
<td>40 CS, 16 control</td>
<td>Hct &lt; 28%</td>
<td>3.6 CS vs. 5.8 control (( p = 0.026 ))</td>
</tr>
<tr>
<td>Serracino-Inglott</td>
<td>Prospective</td>
<td>40 CS, 116 control</td>
<td>—</td>
<td>4 CS vs. 7 control (( p &lt; 0.001 ))</td>
</tr>
<tr>
<td>Shuhaiber</td>
<td>Retrospective</td>
<td>4 CS, 21 control</td>
<td>Hb &lt; 10 g/dl</td>
<td>8 CS vs. 9 control (no ( p ))</td>
</tr>
<tr>
<td>Tawfick</td>
<td>Retrospective</td>
<td>27 CS, 28 control</td>
<td>Hb &lt; 8.5 g/dl</td>
<td>6 CS vs. 12 control (( p &lt; 0.001 ))</td>
</tr>
</tbody>
</table>
are explained by the heterogeneity in methodology. Important variables include the type of aneurysm (infra-
nal/supra-renal/complex), the use of different transfusion
devices and varying practices in heparin administration and
reversal. Furthermore, different transfusion thresholds
have been described.

The aim of cell salvage is to reduce overall blood-
product use and to reduce the proportion of patients
exposed to allogeneic blood. We therefore performed a
meta-analysis of all controlled trials (randomised and
non-randomised). We found that CS use significantly
reduced the proportion of patients requiring transfusion for
elective AAA repair. CS use also halved the mean require-
ment for blood in both elective and ruptured AAA repairs.
An additional cost benefit would be advantageous, although
a recent analysis of an RCT found no significant savings from
cell salvage.44 Encouragingly, cell salvage does not appear
to be associated with an increase in complications and it
may have a positive effect on length of ICU and hospital
stays (Tavare, 2011 #126).

The current evidence available from controlled studies
on the effect of cell salvage in aortic aneurysm repairs
suggests a likely reduction in transfusion requirements in
both elective and emergency operations. Whilst this
suggests a role for routine cell salvage in aneurysm repairs,
local protocols need to be based on the availability of cell
salvage, the cost of blood products, the threshold for
transfusion and the mean blood loss within the vascular unit.

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None.

References

1 Clagett GP, Valentine RJ, Jackson MR, Mathison C, Kakish HB,
Bengtson TD. A randomized trial of intraoperative autotrans-
2 Ouriel K, Shortell CK, Green RM, DeWeese JA. Intraoperative
3 Sandison AJ, Panayiotopoulos Y, Edmondson RC, Tyrrell MR,
Taylor PR. A 4-year prospective audit of the cause of death
1386–9.
4 Holland AJ, Bell R, Ibach EG, Parsons RW, Vu HT, House AK.
Prognostic factors in elective aortic reconstructive surgery.
5 HESOnline. Main procedures and interventions; 2008.
6 Bove JR. Transfusion-associated hepatitis and AIDS. What is the
7 Regan FA, Hewitt P, Barbara JA, Contreras M. Prospective
investigation of transfusion transmitted infection in recipients of
320(7232):403–6.
8 Domen RE. Adverse reactions associated with autologous blood
transfusion: evaluation and incidence at a large academic hospital.
9 Duffy G, Neal KR. Differences in post-operative infection rates
between patients receiving autologous and allogeneic blood
transfusion: a meta-analysis of published randomized and
10 Blumberg N, Heal JM. Transfusion and recipient immune func-
11 Blair SD, Janvin SB, McCollum CN, Greenhalgh RM. Effect of
early blood transfusion on gastrointestinal haemorrhage. Br J
1435–6.
13 Diehl JT, Cali RF, Hertzer NR, Beven EG. Complications of
abdominal aortic reconstruction. An analysis of perioperative
14 Bursi F, Barbieri A, Politi L, Di Girolamo A, Malagoli A,
Grimaldi T, et al. Perioperative red blood cell transfusion and
outcome in stable patients after elective major vascular surgery.
15 Huet C, Salmi LR, Fergusson D, Koopman-van Gemert AW,
Robens F, Laupacis A. A meta-analysis of the effectiveness of
cell salvage to minimize perioperative allogeneic blood trans-
fusion in cardiac and orthopedic surgery. International Study of
Perioperative Transfusion (ISPOT) Investigators. Anesth Analg
16 Torella F, Haynes SL, Lardi A, O’Dwyer ST, McCollum CN.
Unchanging attitudes to autologous transfusion in the UK.
17 Duncan J. On reinfusion of blood in primary and other ampu-
18 McShane AJ, Power C, Jackson JF, Murphy DF, MacDonald A,
Moriarty DC, et al. Autotransfusion: quality of blood prepared
with a red cell processing device. Br J Anaesth 1987;59(8):
1035–9.
19 Namura O, Kanazawa H, Yoshiya K, Nakazawa S, Yamazaki Y.
Successful surgical treatment of a ruptured abdominal aortic
aneurysm without homologous blood transfusion in a Jehovah’s
20 Mezrow CK, Bergstein I, Tartter PI. Postoperative infections
following autologous and homologous blood transfusions.
21 Bland LA, Villarino ME, Arduino MJ, McAllister SK, Gordon SM,
Uyeda CT, et al. Bacteriologic and endotoxin analysis of
salvaged blood used in autotransfusions during cardiac
23 Klebanoff G. Early clinical experience with a disposable unit for
the intraoperative salvage and reinfusion of blood loss (intra-
24 Wilson JD, Taswell HF. Autotransfusion: historical review and
43(1):26–35.
25 Bzica Jr SM, Pineda AA, Taswell HF. Autologous blood trans-
26 Duncan SE, Edwards WH, Dale WA. Caution regarding auto-
27 Duncan SE, Klebanoff G, Rogers W. A clinical experience with
28 Wall W, Heimbecker RO, McKenzie FN, Robert A, Barr R.
Intraoperative autotransfusion in major elective vascular opera-
29 Bartels C, Claeyss L, Ktenidis K, Nigbur H, Horsch S. Intra-
operative whole blood autotransfusion during venous throm-
30 Duchateau J, Nevelsteen A, Suy R, Demeyere R, Vandencaere J,
31 Husfeldt KJ, Raschke R, Betzer F, Doldt H. Whole blood intra-
operative salvage and reinfusion in patients undergoing
32 Milne AA, Drummond GB, Paterson DA, Murphy WG, Ruckley CV.
Disseminated intravascular coagulation after aortic aneurysm


