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ORIGINAL STUDY

The role of peri-operative cell salvage in instrumented anterior correction of thoracolumbar scoliosis : A case-controlled study

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Anterior scoliosis surgery is associated with potentially high blood loss, usually requiring allogenic transfusion either intra- or post-operatively.
Blood loss in this type of surgery has been shown to correlate with surgical and anaesthetic techniques. In our centre the development of specific anaesthetic techniques as well as the routine use of cell salvage has dramatically reduced the rates of allogenic blood transfusion.
Specific indications for the use of the cell saver in anterior scoliosis surgery have not been well defined. Previous studies have commented on the benefit from re-infusion of salvaged autologous blood for orthopaedic patients in general, whilst others have shown a negligible advantage specifically in anterior thoraco-lumbar fusion surgery.
We carried out a retrospective study of 137 consecutive patients, all of whom underwent instrumented anterior scoliosis correction between March 1999 and September 2004. A study group consisting of 104 patients in whom a cell saver was used was compared with a control group consisting of 33 patients who underwent anterior instrumentation without cell saver. There was no significant difference in the mean ages, extent of surgery and male to female ratio between groups.
In the control group 39.4% of patients required allogenic blood transfusion, versus 6.7% in the study group ; the difference is statistically significant ($p < 0.0001$).
A significant difference was also noted in post-operative haemoglobin values. The mean post-operative haemoglobin was 9.6 g/dl in the control group, versus 10.2 g/dl in the study group ($p = 0.007$).
Our experience confirms that re-infusion of salvaged autologous blood in anterior scoliosis surgery has a role in the minimisation of postoperative anaemia and allogenic transfusion requirements in this type of surgery.

Keywords : autologous blood transfusion ; cell saver ; scoliosis ; anterior spinal fusion.

INTRODUCTION

Although allogenic blood transfusion in the UK is considered safe, much work has been published regarding the complications of blood transfusion in

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surgical patients, and this has led to effective measures to minimise peri-operative blood loss.

Orthopaedic surgery in general and spinal surgery in particular have occasionally been associated with dramatic blood loss requiring transfusion of blood components.

Advances in instrumentation and implant technology have allowed the spinal surgeon to produce constructs of increasing size, requiring extensive dissection.

A number of options are available to reduce the requirements of allogenic blood, and these are well documented in literature.

In addition to hypotensive anaesthesia, meticulous attention to haemostasis, careful tissue handling and short operating time, these options include preoperative autologous donation, haemodilution, intra-operative cell salvage, post-operative re-infusion of drained blood and intra-operative administration of tranexamic acid.

Previous studies have been made adopting several of the above strategies, and whilst some centres will adopt a strategy incorporating a number of these measures to aid in allogenic blood conservation, there has been little evidence that a particular measure in isolation is beneficial.

Most studies examining blood loss in spinal deformity patients have focussed on posterior approach corrections, and if anterior approach patients are available these represent only a small number of the total population.

To our knowledge, analysis of blood loss in a sufficiently large population of patients undergoing exclusively anterior instrumented spinal deformity correction surgery has not been published to date.

The objective of this study was therefore to investigate the impact of cell salvage in isolation on allogenic blood transfusion requirements in patients undergoing surgical correction of spinal deformity exclusively through an anterior approach.

METHODS

We examined the consecutive records of patients undergoing anterior scoliosis deformity correction at our institution between March 1999 and September 2004.

The Royal Orthopaedic Hospital is a tertiary referral centre for Orthopaedics, with a dedicated team of spinal surgeons who perform about 2000 spinal procedures per year.

Some patients underwent combined approach surgery, however in all cases the anterior instrumentation was performed initially and for the purposes of this study, this episode was treated in isolation.

The records allowed data collection for patient demographics, pre-operative and postoperative haematocrit and haemoglobin levels, as well as extent of surgery and extent of blood loss. Blood bank records were also reviewed to ensure no allogenic blood units were unaccounted for.

Use of the cell saver was introduced in our institution in December 2000. This allowed us to analyse a "control" cohort of patients in whom cell salvage was not used between March 1999 and October 2000.

We allowed a "grace period" of 4 months after introduction of the cell saver, and the study cohort of patients included the period from April 2001 to October 2004.

The "study" cohort all had intra-operative cell salvage performed by the Dideco Electa (Sorin Group, Modena, Italy) cell saver or The Baylor Rapid Autologous Transfusion (BRAT ; COBE Co, Denver, USA) by an experienced technician in accordance with the manufacturer's recommendations.

Anaesthesia

A brief outline of the anaesthetic approach is given below.

Anaesthesia was induced by intravenous propofol 2-3 mg/kg, and the patient was intubated with a size 7.0 to 8.0 armoured endotracheal tube by using remifentanil 2-4 mcg/kg. One-lung ventilation was achieved with use of either bronchial blocker or double-lumen tube. All patients received thoracic epidural after induction of anaesthesia, but without muscle relaxants, and a single dose of 10 ml levobupivacaine 0.25% given into the epidural space. If somato-sensory evoked potentials (SSEP's) were used, then the levobupivacaine was replaced by epidural diamorphine 0.25-0.50 mg in saline.

Routine monitoring included continuous ECG, pulse oximetry, end-tidal CO2, invasive blood pressure, central venous pressure (CVP), neuromuscular transmission (Datex-Ohmeda), urine output, and blood gases. Anaesthesia was maintained either by total intravenous anaesthesia (TIVA, Asena®, pump, Alaris, San Diego, USA) or nitrous oxide / oxygen with sevoflurane ; If on the other hand the patient was being monitored by SSEPs then TIVA alone was used.

All patients received continuous remifentanil infusion 0.1-0.5 mcg/kg/min to maintain systolic blood pressure between 60 to 80 mmHg and intravenous crystalloid or colloid to maintain CVP (3-5 mmHg) and urine output (0.5 ml/kg/hr). Positive end-expiratory pressure (PEEP) was not used as this is associated with increased bleeding. Body temperature was maintained between 36-37° Celsius by hot air blankets ("Bair Hugger" patient warming system).

If venous oozing was deemed by the operating surgeon to be significant, then an aprotinin bolus of 10,000 units/kg was given and maintained with a continuous infusion rate of 5,000 units/kg/hr.

Frequent saline wash into the wound was encouraged, and all swabs washed in saline. Suction catheter levels were maintained between 100 to 150 mmHg negative pressure to prevent red cell damage. In the event of an appropriate quantity of recovered blood from suction and swab wash, this was re-infused by the anaesthetist at the time of surgery or immediately after. As our hospital has no on-site blood bank, all patients underwent cross matching for 2 units of allogenic blood for use in the event of emergency, however if this blood was not used after 72 hours it was returned to the blood bank. All surgeries in both groups were performed by one or more of the senior surgical authors. Peri-operative blood loss was estimated by a combination of salvaged blood and swab wash and weights.

The indications for post-operative allogenic transfusion were determined by a range of factors, with operative blood loss of greater than 1 litre and fall in postoperative haemoglobin to below 7 g/dl being the most significant.

All patients were commenced on ferrous sulphate 200mg bd for a period of 2 to 3 months postoperatively.

Data was analysed by use of appropriate commercially available statistical analysis software (*Analyse-it Software, Ltd. http://www.analyse-it.com/ ; 2007*).

RESULTS

A total of 137 patients were included in the study.

The control group consisted of 33 patients undergoing anterior scoliosis correction, of whom 23 were female and 10 were male whilst the study group consisted of 104 patients – 86 females and 18 males – undergoing the same surgery.

The male:female ratio was 1:2.3 in the control group and 1:4.7 in the study group.

The average ages were identical in both groups (mean 16.4 years).

The extent of surgery in terms of spinal levels fused was also identical between the two groups. It is clear therefore that in terms of male:female ratio, mean age and extent of surgery, the two groups are statistically similar and therefore comparable.

Table I shows patient demographic data.

As expected, pre-operative haemoglobin and haematocrit levels were also statistically similar, allowing a baseline for comparison.

In the control group 13 patients (n = 33) or 39.4% underwent post-operative allogenic transfusion. A total of 21 units were transfused in this group ; in those patients receiving allogenic transfusion, the average amount transfused was thus 1.6 units.

If we examine the group as a whole, this gives a mean of 0.6 allogenic units per patient (95% C.I 0.3 to 0.9).

In the study group 7 patients (n = 104) or 6.7% underwent post-operative allogenic transfusion. A total of 14 units were transfused in this group ; in the 7 patients receiving transfusion, the average transfused was thus 2 units. In the study group as a whole this gives an average of 0.1 allogenic unit per patient (95% CI 0.0 to 0.2).

This difference in allogenic transfusion requirements between the two groups is statistically significant ($p < 0.0001$). This data is shown in table II.

Within the study group, the mean pre-operative haematocrit was 0.41.

Mean post-operative haematocrit values were 0.285 in the control group and 0.294 in the study group ; the difference is statistically not significant ($p = 0.06$).

In those patients who underwent allogenic transfusion, the rise in haematocrit was small. In the study group this amounted to a mean haematocrit of 0.31 post-transfusion, equating to a mean rise of 0.015.

When post-operative haemoglobin levels were compared, the difference was significant ($p = 0.007$). In the control group the mean post-op haemoglobin was 9.6/dl versus 10.2/dl in the study group . This information is described in the boxplot in figure 1.

Table I. — Patient demographic data

	Control n = 33	Study n = 104	*p*-value
Male:Female	1:2.3	1:4.7	
Mean age (years)	16.4	16.4	
Mean number of levels fused	5.1	5.1	
Pre-op haemoglobin (g/dl)	13.41	13.52	0.63
Pre-op haematocrit	0.39	0.41	0.06

Table II. — Transfusion results

	Control n = 33	Study n = 104	*p*-value
Number requiring transfusion (%)	13 (39.4)	7 (6.7)	
Total units transfused	21	14	
Overall mean units transfused (95% CI)	0.6 (0.3 – 0.9)	0.1 (0.0 – 0.2)	< 0.001
Transfusion trigger (g/dl)	8.23	8.10	

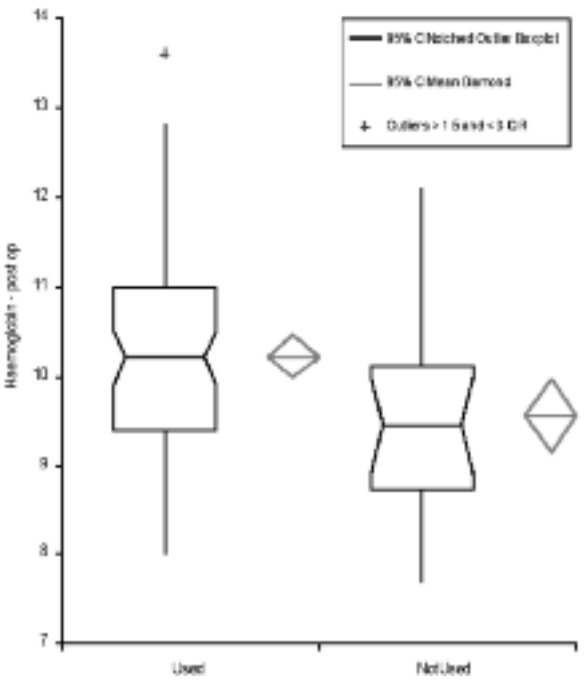

Fig. 1. — Boxplot of post-operative haemoglobin values in study group (left) and control group (right). This difference is significant $p = 0.007$.

The mean haemoglobin level of patients undergoing transfusion, or the so-called transfusion trigger, was 8.23 g/dl in the control group and 8.10 g/dl in the study group.

In terms of peri-operative blood loss for the entire cohort, the mean volume of estimated blood loss was 766 ml (290-1790 ml).

In terms of describing a relationship between extent of surgery and transfusion requirement, there did not appear to be any correlation between the two variables.

In the control group the correlation coefficient was 0.25 whilst in the study group it was 0.19.

None of the patients suffered major postoperative complications.

DISCUSSION

This study confirms the beneficial role of peri-operative cell salvage in anterior spinal deformity surgery. This type of surgery is associated with significant, occasionally life-threatening haemorrhage.

Patients undergoing this type of surgery usually belong to the paediatric population, however we included a number of young adults in this study. Nevertheless this does not detract from the fact that these are predominantly adolescent patients with complex spinal deformity. All these patients underwent anterior instrumentation only.

There are a number of published studies describing the effects of blood conservation strategies on posterior approach to spinal deformity correction, but there is a lack of published work on blood conservation in patients undergoing anterior spinal

deformity correction. Notwithstanding this lack of data, our transfusion rates compare favourably with those already published.

Meert *et al* in 2002 published their study on 107 patients undergoing spinal fusions. The overall transfusion rate in their cohort was 59%. They concluded that low body weight and neuromuscular scoliosis were predictors for increased allogenic transfusion (*9*).

In their study on 150 patients in 1992, Behrman and Keim showed that intra-operative cell salvage had the effect of reducing allogenic and pre-donated autologous blood transfusion requirement (*2*). All their surgeries were via a posterior approach, and the extent of surgery was perhaps not quite as great as those performed today ; the patients underwent either scoliosis correction by Harrington rods or lumbar decompression and fusion.

In a study by Laing *et al* in 1993, 27 children underwent spinal deformity corrections amounting to 34 operations. There was no blood conservation strategy employed. Twelve surgeries involved the anterior approach although not all of these were instrumented (*5*). The mean volume of blood transfused in these 12 patients was 0.8 unit per patient. The authors also commented that blood loss in patients undergoing posterior surgery was higher on average that those undergoing anterior surgery.

Also in 1993, Simpson *et al* published a retrospective review which included a total of 23 children and young adult patients undergoing anterior spinal fusion. All their patients underwent a programme of pre-donation, and the study design discriminated between those patients undergoing surgery with cell salvage and those without. However true comparison with our work cannot be made as Simpson *et al* did not differentiate between the anterior and posterior approach patients.

Nevertheless the authors concluded that with the employment of a pre-donation programme, intra-operative salvage was of little benefit (*19*).

Moran *et al* in 1995 published a large series of 116 adolescent patients undergoing spinal deformity correction who participated in autologous predonation (*10*). Eighty six patients underwent posterior correction only, whilst 15 patients underwent some form of anterior surgery varying from soft tissue release to instrumentation. Cell salvage was used in these cases although its effect on overall outcome was unclear. Once again differentiation by surgical approach was not clearly made, although the overall allogenic transfusion rate was 11% and mean estimated blood loss was 1200 ml (range 100 to 8840 ml).

Some studies have directed focus to the cost implications involved. This is increasingly important in the climate of health rationing and pressure on blood stocks. In the UK the cost of a unit of allogenic blood varies between NHS trusts but is in the region of £ 120 per unit.

Reitman *et al* in 2004 published work examining the cost-benefit outcome of the cell saver (*13*). Notably the 102 adult patients included in the study had a mean age of 48 and were undergoing lumbar spine fusion by the postero-lateral approach. Most underwent 1 or 2 level fusions. Autologous predonation was also performed in some patients. Reitman *et al* concluded that use of the cell saver added to operative time which in turn was related to increased blood loss. They surmised that the cell saver was neither useful nor cost-effective for elective lumbar fusions.

Most recently, Verma *et al* published their results on 70 idiopathic scoliosis patients undergoing corrective surgery (*21*). This study comprised a number of patients in whom anterior surgery was performed but these were all as part of a combined approach. Indeed the 8 patients undergoing anterior surgery alone were excluded from the study. The authors used a combination of blood conservation measures including autologous pre-donation, acute normovolaemic haemodilution, and intra-operative cell salvage and concluded that it was quite reasonable to expect complete avoidance of allogenic transfusion in these elective patients.

Some studies have described abnormalities of platelet function in idiopathic scoliosis although the clinical relevance of this is uncertain. There is however a well documented increased risk of blood loss in patients undergoing surgery for neuromuscular scoliosis. This may be concurrent with the fact that these patients require more extensive surgery, indeed our study included a fair proportion of these patients, however Edler *et al* (*3*) described an almost

7 times higher risk in neuromuscular patients of losing more than 50% of their blood volume during posterior approach surgery.

This study has shown that during anterior instrumentation of spinal deformity the use of intra-operative cell salvage alone can result in significantly reduced allogenic transfusion rates. For patients who are unable to enrol in alternative blood conservation techniques, this provides a clinically valuable tool.

The additional finding of higher postoperative haemoglobin values is also useful ; changes in haematocrit results are rather more equivocal.

The eradication of allogenic transfusion in this type of surgery remains a laudable aim. The preservation of blood stocks and avoidance of associated risks such as allergic, haemolytic and infective complications are just a part of this.

There is much evidence to suggest that immune status can be preserved or even enhanced by autologous transfusion. Both the number and activity of polymorphonuclear leucocytes increase after administration of autologous blood and furthermore cellular immunity is not suppressed as it is with allogenic transfusion (*4*).

Multi-level anterior spinal deformity surgery is perhaps the most fraught of surgeries. Meticulous technique coupled with hypotensive anaesthesia and cell salvage may not be enough to prevent allogenic transfusion. The limited use of aprotinin (*Trasylol*, Bayer AG) in some selected patients may or may not have impacted on outcome. Although aprotinin was available at our institution from 1998 onwards, it has not been used since early 2008 following recent studies linking it to an increased risk of myocardial infarction, renal failure and death in patients undergoing cardiac surgery (*8,16*), which have led to its complete withdrawal as of May 2008. To this day, none of our patients have suffered the serious complications described above, and this may be due to the fact that much lower doses are used (10,000 units/kg bolus, 5,000 units/kg/hr infusion) when compared to cardiac surgery. Current guidelines have recommended the use of tranexamic acid, however we find this to be less effective at eliminating capillary ooze than aprotinin. Data in this regard continue to be analysed.

Importantly none of the patients in our series required intra-operative allogenic transfusion.

In our study, some patients who received allogenic transfusion did so a number of days after surgery, and the decision to transfuse may have been made notwithstanding actual requirement. The retrospective transfusion trigger for these patients in both groups appears inordinately high and this demonstrates the importance of all team members being aware of the transfusion policy.

Nevertheless due to a lack of published studies we are unable to draw definitive conclusions. Our series may serve as a baseline for future studies.

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