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Experience of Intraoperative Cell Salvage in Surgical Correction of Spinal Deformity

A Retrospective Review of 124 Patients

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Abstract: The effect of intraoperative cell salvage (ICS) in surgical correction of spinal deformity remained controversial. This study was to quantitatively demonstrate its effect. In all, 124 patients having ICS in surgical correction of spinal deformity were included. These patients would be divided into 3 groups. Group 1—blood loss less than 15 mL/kg; group 2—between 15 and 37.5 mL/kg; and group 3—more than 37.5 mL/kg. The mean blood loss was 37.2 mL/kg and patients received 872.2 mL salvaged blood on average. The prevalence of intraoperative transfusion of allogenic RBC was 62.9% and the amount averaged 3.4 U. In groups 1 to 3, the prevalence of intraoperative allogenic transfusion was 23.5%, 66.7%, and 100%, respectively. Logistic analysis showed blood loss minus autotransfusion was of significance in predicting intraoperative transfusion, whereas the blood loss or autotransfusion alone was not, implicating an important role of ICS in saving allogenic RBC. The maximum decrease of hemoglobin after operation occurred in the third day, and the magnitude was 45.7 g/L. No severe complications related to ICS were observed. In summary, ICS could decrease the amount of allogenic transfusion in surgical correction of spinal deformity. However, in terms of reducing prevalence of allogenic transfusion, it had a protective effect only in patients with small blood loss.

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Abbreviations: 2,3-DPG = 2,3-disphosphoglycerate, BMI = body mass index, G-6-PD = glucose-6-phosphate dehydrogenase, ICS = intraoperative cell salvage, RBC = red blood cell.

INTRODUCTION

With rapid growth of medical service, the consumption of allogenic red blood cell (RBC) had increased to a huge amount of 107 million units every year,[1] more than 50% of which was transfused in surgical settings.[2] And the cost had escalated from 90 dollars per unit in 1991 to more than 300 dollars per unit in 2000.[3] What is more, despite the development in blood screening, risk of transfusion transmitted disease still existed, and reported to be 1/350,000 for hepatitis B virus, 1/1,800,000 for hepatitis C virus, and 1/2,300,000 for human immunodeficiency virus.[4] In this circumstance, many surgeons were looking for measures that could reduce allogenic transfusion. Intraoperative cell salvage (ICS) was such a technique and had been used extensively for surgical patients.[5,6] Moreover, a systematic review in 2010 confirmed its efficacy. Compared with the control group, the rate of exposure to allogenic transfusion decreased 38% and transfusion of allogenic RBCs was 0.68 unit (U) less.[2]

Intraoperative cell salvage had also been widely used in surgical correction of spinal deformity. Massive blood loss had always been one of the major tissues in surgical correction of spinal deformity. Analysis of 617 patients with spinal deformity showed that the average blood loss was 1.52 mL/kg/level.[7] And a systematic review demonstrated that the averaged blood loss could reach as high as 2639 mL.[8] So it is of no surprise when a survey demonstrated that 78% of orthopedic surgeons would adopt ICS routinely in surgical correction of spinal deformity.[9] However, the effect of ICS might vary in different kinds of surgeries. ICS had been proved to be of no use in vascular surgery.[2] And, as to surgical correction of spinal deformity, its effect remained controversial for the current reports contradicted with each other.[10–17]

This current study retrospectively reviewed patients who had ICS in surgical correction of spinal deformity and predominantly aimed to quantitatively demonstrate its effect.

METHODS

Ethical approval was not necessary in this study for the information involving the privacy of the patients would not be included and presented.

From 2011 January to 2015 October, 155 consecutive patients treated with surgical correction of spinal deformity were reviewed. ICS was used in all patients.

Patients (>10 years old) with spinal deformity who were treated with surgical correction through posterior spinal fusion were included.

Patients were excluded according to the following criteria. Data about baseline and blood transfusion were incomplete or not available. Patients were diagnosed with degenerative scoliosis or neuromuscular scoliosis; anemia or abnormal coagulation function or low platelet; and a history of abnormal coagulation or thrombus.

In all, 124 patients were included. The patients would be divided into 3 groups according to blood loss. Group 1—less

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than 15 mL/kg (<20% of total blood volume); group 2—between 15 and 37.5 mL/kg (20%–50% of total blood volume); and group 3—not less than 37.5 mL/kg (≥50% of total blood volume). The total blood volume was set at 70 mL/kg.[13,15]

The machine used for cell salvage was Jingjing 3000P. The negative pressure was less than 20 kPa to decrease destruction of RBC. When the volume collected was more than 600 to 800 mL, the blood was washed and centrifuged. All salvaged blood would be reinfused into patients.

After transfusion of salvaged blood, if hemoglobin was still less than 70 g/L or if anemic symptoms developed, such as systolic blood pressure less than 100 mm Hg, tachycardia with heart rate greater than 100 beats/min, or a reduced urine output of less than 30 mL/h, even after initial fluid challenge with 500 mL saline, with a hemoglobin level between 70 and 80 g/L.

Usually, hemoglobin would increase by 5 to 10 g/L with 1 unit of allogenic RBC. With autologous or allogenic transfusion, the level of hemoglobin would be kept above 70 g/L during the operation.

All statistical analyses were performed with the help of SPSS version 22.0. The Student *t* test or chi-square test was performed to compare variables between groups. Regression analyses were conducted to identify predictors of transfusion of allogenic RBC. All statistical tests were 2-tailed, and a *P* value <0.05 was deemed significant.

RESULTS

Demographic Description

In all, 124 patients were included. The diagnosis was idiopathic scoliosis in 80 patients, congenital scoliosis in 12 patients, congenital kyphosis in 8 patients, and lumbar kyphosis due to ankylosing spondylitis in 24 patients.

The demographic data of these patients were shown in Table 1. These patients had a mean age of 23.7 years and weighed 45.7 kg, with a body mass index (BMI) of 19.1 kg/m^2. The preoperative Cobb angle was 70.7° in idiopathic scoliosis, 47.7° in congenital scoliosis, and 83.8° in congenital kyphosis. And the correction rate was 74.1%, 87.4%, and 62.1%, respectively. The preoperative lumbar lordosis (T12-S1) was 5.0° in ankylosing spondylitis and the correction was 23.4°°. The average operation time was 315.7 minutes and the number of screws was 14.7. No patient had anemia preoperatively, with the average hemoglobin being 133.4 g/L (Table 1).

The number of patients was 34 (27.4%), 54 (43.5%), and 36 (29.0%) in the 3 groups. The age, BMI, and preoperative hemoglobin were similar between different groups. Patients in group 3 weighed less than those in group 1 and had larger preoperative Cobb angle and number of screws. The difference of operation time was of significance among different groups (Table 1).

The average blood loss was 37.2 mL/kg, accounting for 53.1% of total blood volume. The salvaged blood was 19.8 mL/kg or 872.2 mL per patient, and the recycle rate was 53.2%. The blood loss was 10.9, 27.6, and 76.4 mL/kg in the 3 groups. The volume of salvaged blood increased with the blood loss, but the recycle rate did not (Table 2).

Prevalence and Predictors of Transfusion of Allogenic RBC

The prevalence of transfusion of allogenic RBC was 62.9% intraoperatively, 17.7% postoperatively, and 68.0% perioperatively. In groups 1 to 3, the prevalence of allogenic transfusion during operation was 23.5%, 66.7%, and 100%, respectively. The difference was significant, with the odds ratio (OR) of group 2/1 and 3/2 being 6.5 ($P = 0.01$) and 9.0 ($P = 0.03$). Postoperatively, no patients in group 1 needed transfusion of allogenic RBC. In group 2 and group 3, 11.1% and 38.9% of patients had transfusion of allogenic RBC, and the OR of group 3/2 was 5.1 ($P = 0.05$) (Table 3).

Regression analysis was used to explore predictors of transfusion of allogenic RBC intraoperatively. Univariate analysis showed that low weight, blood loss, volume of autotransfusion, blood loss minus autotransfusion, ratio of autotransfusion/blood loss, division of group, and preoperative Cobb angle were correlated with intraoperative transfusion of allogenic RBC, whereas diagnosis, age, BMI, preoperative hemoglobin, or number of screws was not. Multivariate analysis demonstrated that, weighed by age, body weight, preoperative hemoglobin, diagnosis, operative time (OR 1.02, $P = 0.03$) and blood loss minus autotransfusion (OR 1.15, $P = 0.04$) were still predictors of intraoperative transfusion of allogenic RBC

TABLE 1. Demographic Description

	Total	Group 1	Group 2	Group 3
No.	124	34	54	36
Age, yrs	23.7 ± 1.7	28.1 ± 4.1	23.5 ± 2.6	19.9 ± 2.0
F/M	52/72	16/18	18/36	18/18
Weight, kg	45.7 ± 1.2	49.6 ± 2.5	45.1 ± 1.9	42.8 ± 1.9*
BMI, kg/m^2	19.1 ± 0.4	19.8 ± 0.9	18.9 ± 0.7	18.7 ± 0.7
Hb, g/L)	133.4 ± 1.7	134.6 ± 4.0	131.1 ± 2.3	135.6 ± 3.3
Hct	0.40 ± 0.01	0.40 ± 0.01	0.39 ± 0.01	0.40 ± 0.01
Time, min	315.7 ± 16.3	235.6 ± 12.9	299.5 ± 21.9*	415.8 ± 32.6†
Screws	14.7 ± 0.5	12.8 ± 0.8	14.2 ± 0.8	17.1 ± 1.1†
Pre-Cobb,°	70.7 ± 4.1 (80)	50.8 ± 4.8 (18)	63.4 ± 5.1 (34)	92.3 ± 6.0 (28)†
Post-Cobb,°	18.3 ± 3.3 (80)	3.9 ± 3.3 (18)	11.1 ± 3.3 (34)	36.3 ± 5.8 (28)†

Only patients with adolescent idiopathic scoliosis were included and the number in the bracket represents number of patients.

BMI = body mass index, F/M = female/male ratio, Hb = hemoglobin, Hct = hematocrit, No. = number of patients, Post-Cobb = postoperative Cobb angle, Pre-Cobb = preoperative Cobb angle, screws = number of screws, time = operation time.

*Indicates a significant difference compared with group 1.

†Indicates a significant difference compared with both group 1 and group 2.

TABLE 2. Blood Loss and Autotransfusion

	Total	Group 1	Group 2	Group 3
Blood loss, mL/kg	37.2 ± 5.3	10.9 ± 0.7	27.6 ± 1.2*	76.4 ± 14.1†
Autotransfusion, mL/kg	19.8 ± 2.1	7.3 ± 0.6	16.5 ± 1.2*	36.5 ± 5.2†
Autotransfusion, mL	872.2 ± 87.2	364.7 ± 38.8	753.7 ± 61.6*	1529.2 ± 207.3†

*Indicates a significant difference compared with group 1.
†Indicates a significant difference compared with group 1 and group 2.

(Table 4). This analysis implicated an important role of ICS in saving allogenic RBC.

The Amount of Transfusion of Allogenic RBC

The amount of transfusion of allogenic RBC was 3.4 U intraoperatively, 0.4 U postoperatively, and 3.9 U perioperatively. The amount of transfusion of allogenic RBC intraoperatively was 0.6, 3.1, and 6.8 U in the 3 groups, and the difference was of significance (Table 3).

Change of Hemoglobin

The average hemoglobin before operation was 133.4 g/L. Within 6 hours after operation, the hemoglobin decreased by 22.2 g/L. The hemoglobin continued to decrease until 72 hours after operation, and the magnitude was 45.7 g/L. From the fourth day after operation, the hemoglobin started to increase, and it was 98.3 g/L on the seventh day after operation (Figure 1).

Transfusion Other Than Allogenic RBC

Transfusion of other blood products was predominantly frozen fresh plasma. Among the patients, 38.7% (48/124) needed transfusion of frozen fresh plasma, and the amount was 235.5 mL.

Complications

No complications related to transfusion of allogenic or autologous RBC, such as fever, allergy, coagulopathy, hematuria, and acute renal failure, were observed in this cohort. In all, 108 patients had mild electrolyte disturbance that could be easily corrected. Four patients had prolonged wound healing without infection.

TABLE 3. Prevalence and Amount of Transfusion of Allogenic RBC

	Total	Group 1	Group 2	Group 3
Prevalence of allogenic transfusion, %				
Intraoperative	62.9	23.5	66.7*	100†
Postoperative	17.7	0	11.1	38.9†
Perioperative	68.0	23.5	74.1*	100*
Amount of allogenic transfusion, mL				
Intraoperative	3.44 ± 0.49	0.59 ± 0.29	3.09 ± 0.67*	6.75 ± 0.85†
Postoperative	0.42 ± 0.12	0	0.30 ± 0.18	0.89 ± 0.29†
Perioperative	3.86 ± 0.53	0.59 ± 0.29	3.39 ± 0.67*	7.64 ± 0.93†

RBC = red blood cell.
*Indicates a significant difference compared with group 1.
†Indicates a significant difference compared with group 1 and group 2.

DISCUSSION

As the techniques advanced, surgical correction of spinal deformity become much more common. One of the major problems was massive blood loss. To decrease allogenic transfusion, many spinal centers routinely used ICS, and there had been several reports. However, controversy still remained about its efficacy. First of all, the effect of ICS varied in different surgical settings. Patients would benefit from ICS in cardiac surgery, whereas it was not this case in vascular surgery.[2] Moreover, we should be aware that neither the conclusion from cardiac surgery or vascular surgery could be used in spine surgery directly. In addition to application of materials for hemostasis, such as gelfoam and cotton, the surgical field was mainly bone and the operation was ''violent,'' which might result in severe destruction of RBCs and activation of white blood cells, and subsequent release of cytokine.[18–21] This might impact the efficacy of ICS. Secondarily, reports about ICS in surgical correction of spinal deformity had inconsistent results, and few of them focused on quantitative analysis of its effect.[10–17] To settle down these issues and provide more information for clinic decision, this current study reviewed the application of ICS in surgical correction of spinal deformity in our team.

Usually, according to the guideline by American Association of Blood Banks (AABB),[22] indications of ICS included anticipated blood loss more than 20% of total blood volume, prevalence of transfusion of allogenic RBCs greater than 10%, and the average amount more than 1 U. In this current study, the blood loss was 37.2 mL/kg (53.1% of total blood volume). Among the patients, 62.9% need allogenic transfusion and

TABLE 4. Predictors of Intraoperative Transfusion of Allogenic RBC

Risk Factors	OR	95% CI	*P*
Weight	0.94	0.89, 0.99	0.04
Time	1.02	1.01, 1.03	<0.01
Blood loss	1.14	1.07, 1.23	<0.01
Autotransfusion	1.17	1.07, 1.29	<0.01
Blood loss−autotransfusion	1.26	1.10, 1.44	<0.01
Autotransfusion/blood loss	0.04	0.01, 0.77	0.03
Group	10.3	3.24, 32.99	<0.01
Cobb angle	1.07	1.02, 1.13	<0.01

CI = confidence interval, OR = odds ratio, RBC = red blood cell.

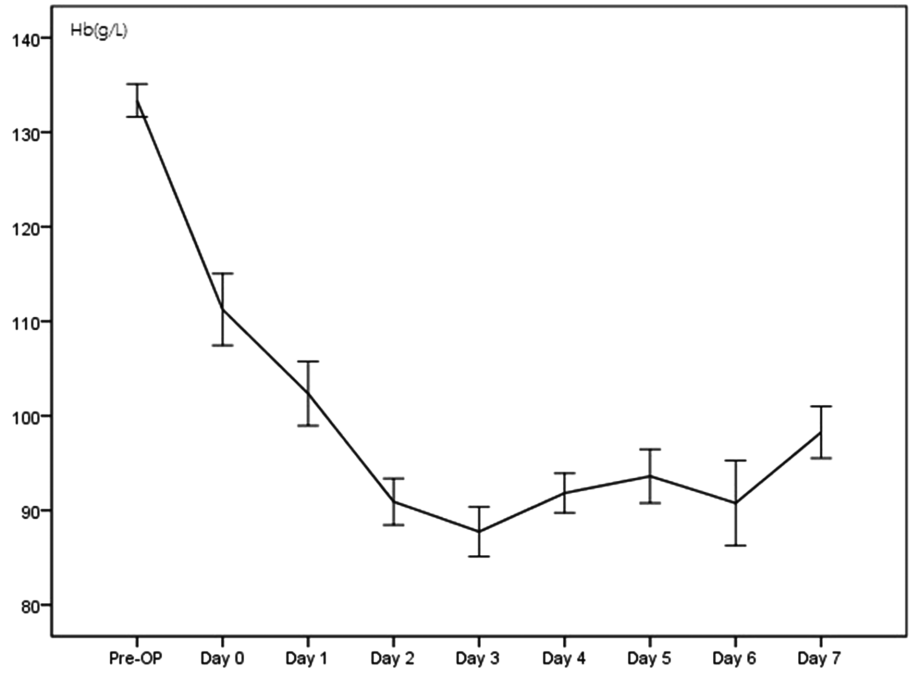

FIGURE 1. Change of postoperative hemoglobin.

the amount averaged 3.4 U. These data indicated that, generally, ICS was appropriate for surgical correction of spinal deformity.

One of the advantages of ICS was that some of patients could be free of the risk of allogenic transfusion and the related complications might be reduced. In the randomized controlled study by Liang et al[14] in 2014, 110 patients with a medium blood loss (696.8 vs 767.4 mL; $P = 0.27$) were included, and patients with ICS were shown to have smaller risk of allogenic transfusion (14.5% vs 32.7%; $P = 0.03$). In our study, the blood loss was 10.9 mL/kg in group 1, and with ICS, the risk of intraoperative allogenic transfusion of RBC was 23.5% and most of the patients would not need allogenic transfusion. Additionally, the multivariate analysis demonstrated that, weighed by age, weight, preoperative level of hemoglobin, diagnosis and operative time, and blood loss minus autotransfusion still had a significant effect, whereas the blood loss or autotransfusion alone did not. This showed that the ''net blood loss'' of RBC, other than the ''blood loss,'' was correlated with the risk of allogenic transfusion, implicating an important role of ICS in terms of reducing prevalence of allogenic transfusion.

However, with the amount of blood loss increasing, this protective effect might be limited. In the study published by Miao et al[13] in 2014, patients had massive blood loss (2138 vs 2135 mL; $P = 0.84$) and the result indicated that the risk of allogenic transfusion was similar (58/60 vs 59/60). Our research observed that prevalence of transfusion of allogenic RBC climbed up as the blood loss increased. Patients in group 2 had blood loss of 27.6 mL/kg and the prevalence was 66.7%. In group 3, all patients need intraoperative transfusion of allogenic RBC.

Another benefit of ICS was claimed to be its potential effect of preserving sources of RBC. As far as we know, there were 7 studies focusing on this topic.[10–15,17] Two studies draw the conclusion that ICS could not decrease the amount of transfusion of allogenic RBC.[15,17] However, results from these 2 studies might be misleading. One applied ICS on the grounds of predonated autologous blood, which had been proved to be effective.[15] In the other study, the Cobb angle differed significantly between groups, and data of blood loss were not provided.[17] The inherent vice of these 2 studies made the results uncertain. On the other hand, there were 5 studies in support of application of ICS.[10–14] In 1 study, some of the patients had predonated autologous blood, and the measure was the total amount of transfusion, including autologous and allogenic RBC.[10] Another study had significantly less blood loss in patients with ICS (13.2 vs 27.6 mL/kg; $P < 0.01$).[11] After excluding these 2 studies, the other 3 studies were of good quality and draw similar conclusion that application of ICS could decrease the amount of transfusion of allogenic RBC.[12–14] So, according to the existing clinical evidence, we believed that ICS could decrease the amount of transfusion of allogenic RBC. Our study showed the salvaged blood was 16.3 mL/kg on average.

A controversial issue was whether the salvaged RBC functioned as the allogenic RBC. Limited by retrospective design of this current study, we could not provide related information. However, Che et al[18] demonstrated that the salvaged blood did not had higher level of free hemoglobin, whereas the salvaged RBC had higher activity of 2,3-DPG (2,3-disphosphoglycerate) and G-6-PD (glucose-6-phosphate dehydrogenase), and also a similar level of phosphatidylserine (PS) when compared with venous blood, indicating good oxygen-carrying, antioxidant capacities and little effect on RBC senescence. Another study by Buchta et al[23] showed that 10 days after transfusion, 78.9% of salvaged RBCs were still found in circulation. These studies provided strong evidence of perfect performance of salvaged RBC. In our study, prevalence and amount of postoperative allogenic transfusion was not high, even in patients in group 3. To some extent, this indicated a continuous function of salvaged RBC from another perspective.

The preoperative hemoglobin was 133.4 g/L, and it decreased to its lowest value in the third day after operation (87.7 g/L). Thus, to better avoid postoperative allogenic transfusion, we recommend preoperative hemoglobin should be 45 g/L higher than trigger point of allogenic transfusion. This result was similar with that published by van Popta et al.[24]

No complications related with ICS were observed in this cohort. However, cases of coagulopathy were reported by several authors. Thus, as to complications of ICS, a systematic review of large-sample patients was needed.

There exist several limitations in this current study. First of all, because ICS was adopted routinely by our team, a control group was lacking. However, as mentioned above, we predominantly aimed to demonstrate the effect of ICS. Secondly, as a retrospective research, we failed to gain the sample of salvaged blood and related analysis was impossible. The effect of ICS on change of hemoglobin, inflammation, and coagulation was not provided either.

CONCLUSIONS

Intraoperative cell salvage could decrease the amount of allogenic transfusion in surgical correction of spinal deformity. However, in terms of reducing prevalence of allogenic transfusion, it had a protective effect only in patients with small blood loss. No severe complications related to ICS were observed.

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