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REVIEW

Perioperative Blood Management in Posterior Instrumented Fusion for Adolescent Idiopathic Scoliosis: Original Study and Short Review of the Literature

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Background: The potential hazards of allogeneic blood transfusion are well established in literature. Few things are known, however, about the results of combining different blood saving techniques and their results in avoiding allogeneic blood transfusion (ABT) in scoliosis surgery.

Aim: To report specific results about utilization of preoperative autologous blood donation (PABD) and intraoperative blood-saver (BLDS) in conjunction, aiming to minimize the need for ABT.

Materials and methods: Between 1989 and 2012, 107 patients underwent posterior instrumented fusion (PIF) for adolescent idiopathic scoliosis (AIS) correction. Retrospective evaluation was conducted. Patients were classified into two groups, according to the method utilized: group A with only allogeneic blood transfusion (ABT) and group B where PABD with BLDS intraoperatively was applied. Hematocrit and hemoglobin values were evaluated preoperatively, postoperatively, and at discharge. The variables we examined included also gender, age, levels fused and number of predeposited blood units, required transfused blood units (TBU), as well as ABT rates between the two groups.

Results: More than 70% of the transfusions in both groups were needed intraoperatively. In group A, an average of 2.4 units per patient was transfused and ABT reached 76%. In contrast, in group B an average of 4.5 units per patient was transfused but ABT rate was only 7.3%, while the rest 92.7% was autologous blood. However, the wasted autologous blood reached 24.9%.

Conclusions: Our results demonstrated that PABD with intraoperative cell salvage (CS) is associated with statistically significant ABT rates decrement but the combination of these methods cannot assure ABT avoidance.

BACKGROUND

Posterior instrumented fusion (PIF) surgery for adolescent idiopathic scoliosis (AIS) is unfavorably associated with substantial blood loss.[1-3] Allogeneic blood transfusion (ABT) emerges as a fundamental necessity in this situation. Nevertheless, ABTs are associated with significant increase of perioperative morbidity.[4] Transmission of viral diseases (HBV, HCV and HIV), as well as effects on the immunological function are considered responsible for transfusion-related acute lung injury (TRALI), postoperative bacterial infections and hemolytic transfusion reactions.[3,4] The above are the major adverse effects of ABT, which is also considered to have a remarkable impact on socioeconomics being related to significant costs.[5]

ABT avoidance represents thus a veritable requisiteness. Various techniques have emerged in recent years in this field.[5] Preoperative assessment of hemoglobin (Hb) levels, abdominal compression prevention with proper patient positioning, hypotensive anesthesia and conduction of assiduous intraoperative hemostasis, as well as pharmacologic agents utilization may be implemented by spine surgeons.[5,6]

Preoperative autologous blood donation (PABD) and intraoperative blood salvage with Cell-Saver systems are pioneer methods for blood conservation in scoliosis surgery.[6,7] Effectiveness of these techniques in ABT potentiality decrement has been extensively studied in current literature.[2,3,8-11] However, none of these studies reported any particular results about utilization of these techniques in conjunction, in terms of altering ABT rates.

The aim of the present study was to publish specific results concerning the use of PABD in combination with intraoperative cell salvage (CS) in patients treated for AIS with posterior instrumented fusion, enrolling a relatively wide population size. Particular emphasis is put on ABT potentiality and perioperative blood management, as well as the percentage of autologous blood wasted. A short review of the literature regarding PABD and intraoperative CS utilization was conducted in parallel.

MATERIALS AND METHODS

Population characteristics

The patients recruited in this study were diagnosed with AIS, with indication for PIF, completing all current indications. All operations were performed by the same senior spine surgeon. Patients were duly informed about the study aims and scope and gave written consent to participate. Approvals from the Hospital Institutional Review Board and local ethics committee were also obtained. Moreover, all aspects of this study were in accordance with the ethical principles stated in the Declaration of Helsinki.

Inclusion and Exclusion Criteria

Inclusion criteria: (i) Clinical diagnosis of AIS, (ii) PIF indications completed, (iii) operation performed by the senior spine surgeon in the hospital.

Exclusion criteria: (i) disc herniation, (ii) vertebral fractures, (iii) other types of scoliosis, (iv) previous spinal surgery or revision surgery, (v) hemostatic disturbances, (vi) AIS corrected from other spine surgeons in the hospital.

Methods and study design

A total of 107 patients were subjected to PIF for AIS in two different institutions from the same senior spine surgeon (A.G.C.) between 1989 and 2012. PIF is the standard surgical treatment for scoliosis. Indications for PIF were curves larger than 50°, with thoracic rib hump and/or lumbar prominence, with affected pulmonary function.[24] All-pedicle screw constructs were used since they have shown superior radiographic correction versus hook and hybrid constructs.[25]

An age and number of levels fused match was performed between the two groups except for 21 patients thus finally 86 were included. All patients were retrospectively studied and allocated to two groups: group A (25 patients) which received only ABT (control group), and group B (61 patients) where PABD was performed in conjunction with intraoperative CS. PABD was based on a weekly collecting schedule, with one month duration, collecting and processing a total of 3.6 blood units on average per patient. CS was only intraoperatively performed and not postoperatively. Specialized in CS systems manipulation medical personnel postoperative absence, as well as no postoperative drainage recruitment excluded the possibility of postoperative CS system utilization. Furthermore, type and technical characteristics of the analogous device recruited for CS featured a significant differentiation among the patients. Initial purpose was to mobilize the same CS system for all patients. However, technical issues as approval of each individual Social Security Funds instituted a remarkable obstacle in this aim. Social Security Funds approval was obtained, also the commercial features of utilized CS system. As a consequence, CS systems were not used for all patients. Moreover, different commercial types on terms of label and model of CS system were utilized for patients in group B. Etiologies as particularly low BMI and distant residence place constituted a fundamental impediment in PABD wide implementation.

Surgical Procedure

Patients were preoperatively prone positioned, with subsequent middle incision and posterior spine elements exposure. Pedicle screw insertion and prebent rods positioning instituted the subsequent steps. Correction maneuvers were performed when necessary. Rods stabilization and transverse rods positioning were done after satisfactory correction was achieved. Wound suture was performed. No postoperative drainage was done. Meticulous hemostasis was undertaken in all surgical stages.

Intraoperative blood management was co-decided by anesthesiologist and spine surgeon. Transfusion limit was determined at Hb level of 9 g/dl. Postoperative hemodynamic evaluation revealed an Hb level of 10 g/dl on average. Patients were mainly mobilized in postoperative day 2, and discharged on postoperative day 15 on average.

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Statistical analysis

Statistical analysis of data was performed with version 23.00 (SPSS Inc, Chicago, IL). Continuous variables were presented as mean ± standard deviation (SD) and categorical variables as percentages. The Student's *t*-test for independent samples and the Mann-Whitney test were used for statistical analysis of continuous parameters when normal distribution was present and absent, respectively. Analysis of variance (ANOVA) and post-hoc Bonferroni test were used for assessment of between-group differences. In contrast, population differentiation evaluation was conducted with Wilcoxon test. Logistic regression was also performed in order to identify particular potential predictors of intraoperative hemorrhage volume.

RESULTS

Demographic and surgical characteristics of the two groups are shown in **Table 1**. A slight statistically significant difference between these baseline parameters was observed only for BMI demonstrating the comparability of the two groups.

Perioperative blood management featured a remarkable differentiation in the two groups. The patients in group A received allogeneic blood and 76% of them needed transfusion (mean 2.4 units). However, there were six patients (24%) who didn't need any kind of transfusion. 71.7% of the allogeneic blood transfusions (1.7 units) was needed intraoperatively, whereas the remainder 28.3% (0.7 units) postoperatively **(Fig. 1)**. In contrast, all patients in group B were transfused but ABT was not required for the majority of them since 92.7% of the blood transfusions was autologous. These patients received on average 4.5 blood units, being transfused with 3.5 units (76.9%) intraoperatively and one unit postoperatively (23.1%) but allogeneic blood was only 7.3% of the total transfusion requirements. Intraoperative CS accomplished an average re-transfusion of 372.6 ml of blood. Considering that 300 ml blood is quantitatively equal with one blood unit, intraoperative CS was associated with intraoperative re-transfusion of 1.3 blood units, which is 28.1% of total transfused blood quantity **(Fig. 2)**.

Table 1. Baseline demographic and surgical characteristics of studied patients

Variable	Group A	Group B	p value
Enrolled patients	25 (29.1%)	61 (70.9%)	-
Gender			
Males	9 (36%)	12 (19.7%)	0.109
Females	16 (64%)	49 (80.3%)	
Age (yrs)	15.8±2.24	16.5±2.35	0.054
BMI	18.25±3.27	19.68±2.74	**0.034**
Operation duration (min)	287.5±68.38	275.51±64.97	0.455
Number of levels fused	10.16±3.02	9.62±1.85	0.14
Hospitalization duration (days)	18.24±15.52	16.75±9.79	0.596

Statistically significant p values are shown in bold.
Level of significance was defined at p=0.05.

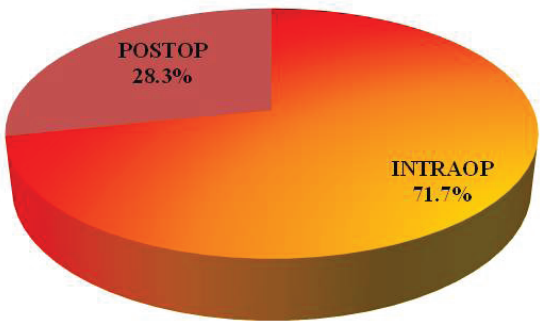

Figure 1. Group A - Transfusion requirements.

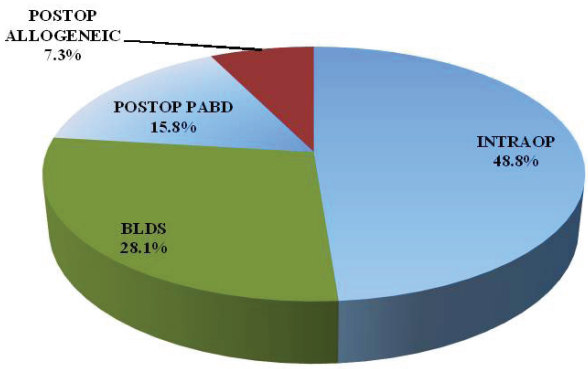

Figure 2. Group B - Transfusion requirements.

In group A, 76% of the patients were transfused and all the transfusions were allogeneic blood. On the contrary, in group B all patients required transfusion but only 7.3% was ABT, while the rest 92.7% was autologous blood transfusions. Therefore, combination of PABD with intraoperative CS was capable of important ABT rates decrease. However, elimination of ABT requirements was not possible **(Fig. 3)**. Moreover, the wasted autologous blood reached 24.9%, since out of a total of 229 autologous blood units that were collected with PABD method 57 were not transfused.

Impact of PABD and CS in hemodynamic condition was studied measuring the Hct and Hb levels. These indexes were calculated preoperatively, postoperatively, and at discharge of patients. Preoperatively, Hct level was 39.8 in group A and 35.3 in group B. In addition, preoperative Hb levels were 13.1±1.7 and 11.6±1.1, respectively. This difference was statistically significant for these two variables ($p<0.001$). Hb levels differentiation among the different chronic intervals is presented in **Fig. 4**. Hct and Hb levels were similar between the two groups postoperatively and at discharge.

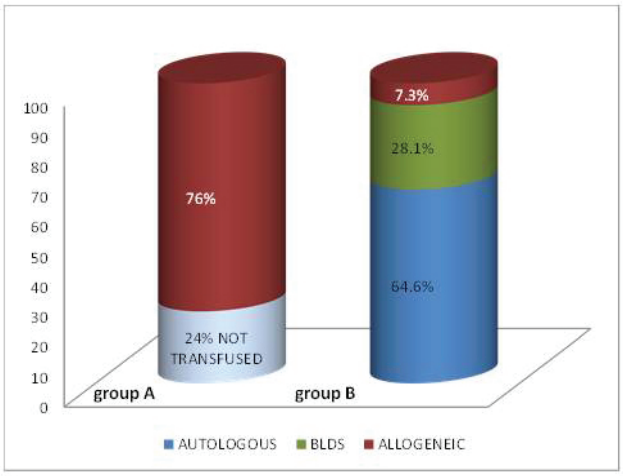

Figure 3.

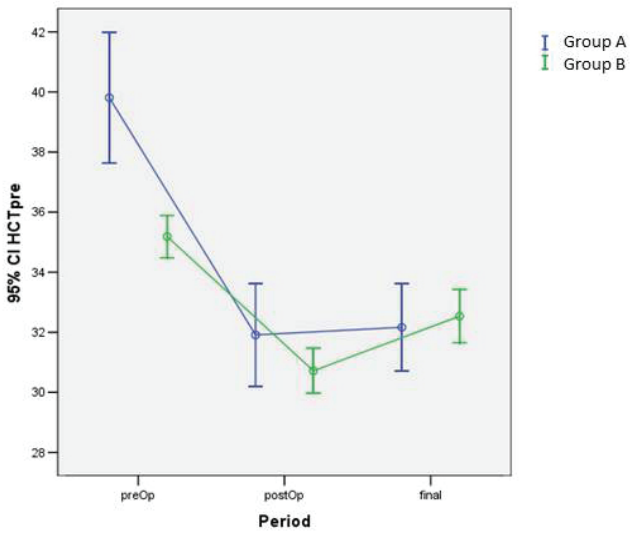

Figure 4.

DISCUSSION

Blood loss constitutes a noteworthy surgical issue in scoliosis surgery.[2] Perioperative blood management is therefore of substantial importance. ABT is associated with potential hazardous complications and, thus, ABT avoidance with blood conservation methods recruitment should institute a fundamental priority.[5]

PABD and intraoperative CS with Cell-saver systems are widely utilized for blood conservation in PIF for AIS in recent years.[3,9,10,12] However, much controversy exists in current literature about these methods' safety and efficacy, in terms of decreasing ABT potentiality.

PABD favorable impact on reducing ABT rates remains still controversial **(Table 2)**. Sanpera et al.[10] retrospectively studied 37 patients, concluding that PABD implementation resulted in more significant transfusion potentiality intraoperatively, which is in accordance with our study. In addition, a worth mentioning portion of autologous blood was not utilized. In our study, 57 of the 229 predonated autologous blood units were wasted, representing 24.9% of the collected autologous blood. PABD was thus theorized to be downgraded in terms of cost-effectiveness.[10] This thesis was also advocated from other studies, demonstrating that PABD is associated with considerably high intraoperative transfusion rates and significant procedure costs.[8,13,14] On the contrary, Ridgeway et al. prospectively studied 45 patients, stating that PABD is related to remarkable decrement of ABT potentiality.[8] Boniello et al. reported the same conclusion, speculating also that PABD is not primarily culpable for preoperative Hct levels abatement.[9] Moreover, conjunction of PABD with other blood conservation techniques may further decrease the ABT rates.[15]

Intraoperative CS with Cell-saver institutes a well-established method for blood conservation in AIS surgery.[7] The overwhelming majority of literature reports advocate that Cell-saver intraoperative recruitment is associated with a remarkable decrement in intraoperative blood transfusion potentiality **(Table 3)**.[2,3,11,16-19] Postoperative clinical outcomes are not unfavorably affected with Cell-saver utilization.[17] Oliveira et al. argued that CS utilization was

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Table 2. PABD utilization outcomes in the relevant recent literature

Authors	Year	Number of patients	Ailment - Surgical Treatment	Conclusion
Moran et al.	1995	116	97 cases - idiopathic scoliosis 19 cases - spinal deformity of other etiology	PABD in combination with other blood conservation techniques significantly decreased ABT requirement
Ridgeway et al.	2003	45	Scoliosis surgery	PABD is effective in terms of safety and reducing ABT requisites
Bess et al.	2006	123	AIS surgery	The majority of patients were transfused at a high Hct (>30) or wasted one autologous unit minimum, demonstrating that guidelines for PABD utilization should be reviewed
Boniello et al.	2016	125	Posterior spinal fusion for AIS	PABD is not fundamentally responsible for preoperative Hct levels decrement, being also associated with remarkably lower ABT potentiality
Kelly et al.	2016	418	Adult spinal deformity surgery	PABD is not associated with ABT rates decrement, leading also to increased perioperative transfusion potentiality
Sanpera et al.	2016	37	AIS surgery	PABD is related to significant procedure costs and redundant blood transfusions

Table 3. CS recruitment reports in the literature

Authors	Year	Number of patients	Ailment - Surgical Treatment	Conclusion
Bowen et al.	2010	54	Posterior spinal fusion for Idiopathic Scoliosis	Intraoperative CS is associated with decreased ABT rates, especially in conditions of long operation duration and significant intraoperative hemorrhage
Carless et al.	2010	75 RCTs	Adult elective cardiac and orthopaedic surgeries	CS is capable of reducing ABT possibility, featuring alongside not a negative effect in clinical outcomes
Ersen et al.	2012	45	Posterior spinal fusion for AIS	Intraoperative CS is related to decreased perioperative ABT potentiality
Akgül et al.	2014	33	AIS surgery	Intraoperative CS recruitment is not capable of ABT rates reduction in surgical treatment of AIS
Carey et al.	2015	167	Posterior spinal fusion for AIS	Intra- and postoperative CS is correlated with significantly lower perioperative transfusion potentiality
Liu et al.	2017	562 (7 studies)	Scoliosis surgery	Intraoperative CS remarkably decreases peri- and post-operative ABT in scoliosis surgery, being also associated with enhanced Hct and Hb levels in the first postoperative day
Oliveira et al.	2017	42	Posterior arthrodesis with instrumentation for AIS	CS effectively decreased ABT rates, being also cost-effective

associated with significantly lesser cost, in contrast to ABT.[3] Liu et al. published a meta-analysis on intraoperative CS outcomes, concluding that Hct and Hb levels were remarkably increased on the first postoperative day, demonstrating thus that intraoperative CS mainly contributed to patients hemodynamic stabilization. In addition, intraoperative CS is not related to intraoperative transfusion complications rate increment.[2] Akgül et al. were the only researchers to claim that Cell-saver utilization was not correlated with ABT rates decrement.[12] The limited number of patients enrolled may be responsible for this differentiation.

In our study, PABD implementation (in conjunction with intraoperative CS) was found to have a significant impact on preoperative Hct and Hb values. The patients in group B were subjected to PIF with lower preoperative Hct and Hb values in comparison with group A, increasing thus the possibility of intraoperative hemodynamic imbalance. Intraoperative transfused blood unit number was significantly higher in group B, even with the additional utilization of intraoperative CS, demonstrating that this imbalance with subsequent required transfusion occurred more frequently in group B. In contrast, Hct and Hb levels reflected postoperatively and at discharge were similar to those of the control group. Furthermore, it was also concluded that PABD in conjunction with intraoperative CS is capable of significantly decreasing the ABT rates. Nevertheless, absolute elimination was not accomplished, indicating a relative insufficiency.

Among the limitations of our study are the different commercial types, regarding label and model, of CS system that were utilized for patients. Technical issues as approval of each individual Social Security Funds established the commercial features of utilized CS system. Also, the retrospective character of the study resulted in slight differences at the postoperative treatment of the patients such as exact mobilization date, frequency of Hct check and the volume of intravenous N/S used.

The establishment of particular predictive factors of intraoperative blood loss institutes a realistic necessity. Nevertheless, there is a remarkable differentiation among relevant studies in the literature. Ialenti et al. retrospectively studied 340 patients, concluding that sex, operation duration, as well as preoperative kyphosis represent significant predictors of intraoperative blood loss.[20] Kwan et al. also speculated that a number of attending surgeons may be remarkably associated with intraoperative hemorrhage volume. Two-surgeon strategy was concluded to be related to shorter intraoperative times, lesser intraoperative blood loss and ABT rates.[21] Moreover, preoperative Hb level and estimated intraoperative hemorrhage have been reported to institute autonomous predictive factors of transfusion requirement.[22] Miri et al. also concluded that operation duration, age at surgery, number of fused levels and mean intraoperative Systolic Blood Pressure designate additional predictors of intraoperative blood loss in lumbosacral surgeries.[23]

To our best knowledge, this is the first study in the literature to report particular outcomes of recruitment of PABD in conjunction with intraoperative CS in PIF surgery for AIS. Our results demonstrated that PABD with CS intraoperatively is associated to statistically significant ABT rates decrement, in comparison with the control group. However, this combination was not capable of perfect ABT requisites elimination. Design of further studies with wider population sizes and alongside cost-effectiveness assessment is essential in order to identify the especial impact of PABD in combination with intraoperative CS utility in perioperative blood management of patients subjected to PIF for AIS.

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Периоперационный контроль за кровью в время заднего инструментального спондилодеза при лечении подросткового идиопатического сколиоза: авторское исследование и краткий обзор литературы

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Введение: Потенциальные опасности аллогенного переливания крови хорошо представлены в литературе. Однако мало что известно о результатах совместного применения различных методов сохранения крови и о результатах в предотвращении аллогенного переливания крови (АПК) при операции сколиоза.

Цель: Сообщить о конкретных результатах использования предоперационного аутологичного донорства крови (ПАДК) и интраоперационной реинфузии крови (ИРК) с целью минимизации потребности в АПК.

Материалы и методы: В период с 1989 по 2012 год 107 пациентам была проведен задний инструментальный спондилодез (ЗИС) для коррекции подросткового идиопатического сколиоза (ПИС). Проведена ретроспективная оценка. Пациенты были разделены на две группы, в соответствии с используемым методом: группа А с только аллогенным переливанием крови (АПК) и группа В, где применялись ПАДК с ИРК во время операции. Показатели гематокрита и гемоглобина были измерены до операции, после операции и при выписке. Переменные, которые нами были измерены, включали также пол, возраст, уровни спондилодеза, количество предварительно выделенных единиц крови, необходимые переливающиеся единицы крови (ПЕК), а также частота АПК между этими двумя группами.

Результаты: Более 70% переливаний в обеих группах были необходимы во время операции. В группе А было перелито в среднем 2,4 единицы на одного пациента, а АПК - 76%. В отличие от этого, в группе В в среднем 4,5 единицы на одного пациента было перелито, но показатель АПК составлял всего 7,3%, а остальные 92,7% были аутологичной. Однако потерянная аутологичная кровь достигла 24,9%.

Заключение: Наши результаты показали, что ПАДК с интраоперационной реинфузией крови (ИРК) ассоциируется со статистически значимым снижением частоты АПК, но комбинация этих методов не может обеспечить избежание АПК.

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