Intra-operative cell salvage for cesarean delivery: a retrospective study using propensity score matched analysis

Xi Wu, Shang-Long Yao, Jing Wu, Cheng-Ying Li, Lei-Ming Xia

Department of Anesthesiology, Institute of Anesthesiology and Critical Care Medicine, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei 430022, China.

Abstract

Background: Obstetric hemorrhage is a major cause of maternal death during cesarean delivery. The objective of this retrospective observational study was to evaluate the efficacy and safety of intra-operative cell salvage (IOCS) in cesarean section.

Methods: We included a total of 361 patients diagnosed with central placenta previa who underwent cesarean section from May 2016 to December 2018. In this study, 196 patients received autologous transfusion using IOCS (IOCS group) and 165 patients accepted allogeneic blood transfusion (ABT group). Propensity score matched analysis was performed to balance differences in the baseline variables between the IOCS group and ABT group. Patients in the IOCS group were matched 1:1 to patients in the ABT group.

Results: After propensity score matching, 137 pairs of cases between the two groups were successfully matched and no significant differences in baseline characteristics were found between the IOCS group and ABT group. Patients in the IOCS group were associated with significantly shorter length of hospital stay, compared with ABT group (8.9 ± 4.1 days *vs.* 10.3 ± 5.2 days, $t = -2.506$, $P = 0.013$). The postoperative length of hospital stay was 5.3 ± 1.4 days for patients in the IOCS group and 6.6 ± 3.6 days for those in the ABT group ($t = -4.056$, $P < 0.001$). The post-operative hemoglobin level in the IOCS group and ABT group was 101.3 ± 15.4 and 96.3 ± 16.6 g/L, respectively, which were significantly different ($t = 2.615$, $P = 0.009$). Allogeneic red blood cell transfusion was significantly lower at 0 unit (range: 0–11.5 units) in the IOCS group when compared with 2 units (range: 1–20 units) in the ABT group ($P < 0.001$).

Conclusions: This retrospective observational study using propensity score matched analysis suggested that IOCS was associated with shorter length of postoperative hospital stay and higher post-operative hemoglobin levels during cesarean delivery.

Keywords: Allogeneic; Blood salvage; Cesarean section; Hemorrhage

Introduction

With the increasing rate of cesarean sections, the prevalence of placenta previa is continuing to rise.[1] Placenta previa is characterized as the placenta overlying the internal os of the cervix.[2] Women with placenta previa are prone to hemorrhage and at increased risk for adverse maternal and perinatal complications.[3,4] Obstetric hemorrhage is a major cause of maternal death and blood conservation is critical for cesarean delivery.[5] Blood is a costly and scarce resource which also carries potential risks of infection and adverse reactions.[6] Allogeneic blood transfusion (ABT) is associated with mistransfusion from ABO-incompatible transfusion, acute allergic reactions, infection transmission, and alloimmunization.[7] Several blood conservation techniques have been increasingly used for red cell salvage which lowers demand for heterologous blood transfusion and conserves the blood supply.[8]

Pre-operative autologous blood donation (PAD) may induce iatrogenic anemia and result in a self-defeating cycle of blood donation.[9] PAD is unavailable in an emergency and was reported not reasonable for the great majority of all parturient women with placenta previa.[10] Acute normovolemic hemodilution (ANH) may lead to cardiac failure and placental insufficiency, which has limited application in obstetrics.[11] Intra-operative cell salvage (IOCS) is a blood conservation strategy for collection of blood loss from the surgical site, filter, centrifugation, and autologous blood re-infusion.[12] It was concluded that IOCS is more valuable and effective in cesarean section than the former two techniques (PAD and ANH).[8] IOCS has been widely applied in various types of

Access this article online

Quick Response Code:

Website: www.cmj.org

DOI: 10.1097/CM9.0000000000000620

Correspondence to: Dr. Lei-Ming Xia, Department of Anesthesiology, Institute of Anesthesiology and Critical Care Medicine, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430022, China
E-Mail: xia834@126.com

Chinese Medical Journal 2020;133(2)

Received: 04-12-2019 **Edited by:** Yi Cui

surgeries, such as vascular, obstetric, orthopedic, cardiac, and cerebral surgery.[13] A cost-effectiveness analysis found that IOCS is economically reasonable for parturient at high-risk of hemorrhage.[14] However, studies on the application of IOCS in cesarean delivery are limited in the mainland of China. The aim of this study was to evaluate the efficacy and safety of IOCS in cesarean section for women with central placenta previa.

Methods

Ethical approval

This retrospective study was approved by the Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology (No. S125). Written informed consent was waived, given the analysis was based on electronic medical record database with anonymous selection.

Patients and study design

Perioperative patient data were accessed from DoCare anesthesia clinical information system which improved the reporting accuracy of quality control data. The database was maintained by specialized quality control group at our department to ensure accurate and detailed medical records. We retrospectively reviewed the clinical data of patients diagnosed with central placenta previa who underwent cesarean section at the Union Hospital, Tongji Medical College, Huazhong University of Science and Technology from May 2016 to December 2018. Inclusion criteria were: (1) diagnosis of central placenta previa by pre-operative ultrasound or magnetic resonance imaging examinations; (2) American Society of Anesthesiologists (ASA) physical status I to III; and (3) singleton pregnancy. Exclusion criteria were: (1) pregnancies complicated with severe cardiac, hepatic, or renal dysfunction; (2) acute or chronic infection; or (3) incomplete medical record. The acquisition and collection of data were completed by Wu X and Li CY. Analysis and interpretation of the data were independently performed by Wu J and Xia LM.

A total of 361 patients were finally included in this study and the principal exposure was IOCS *vs.* ABT [Supplementary Figure S1, http://links.lww.com/CM9/A162]. In this study, 196 patients received autologous transfusion using IOCS (IOCS group) and 165 patients accepted ABT (ABT group). The primary outcome was postoperative hospital stay. Secondary outcomes were post-operative hemoglobin level, amounts of heterologous blood transfusion, adverse events, and neonatal outcomes.

Demographics including age, height, weight, and ASA physical status were recorded. Hemoglobin level, hematocrit (HCT), white blood cell count, platelet (PLT), fibrinogen (FIB), activated partial thromboplastin time (APTT), prothrombin time (PT), plasma D-dimer (DD), C-reactive protein before surgery and at the third day after operation were documented. Duration of surgery, anesthesia technique, intra-operative blood loss, urine output, fluid infusion (crystalloid or colloid fluid), neonatal Apgar (Activity, Pulse, Grimace, Appearance, and Respiration) score and amount of blood transfusion (autologous or allogeneic) were also collected. Non-invasive blood pressure, heart rate, and oxygen saturation were recorded immediately before and after blood transfusion. Length of hospital stay, admissions to intensive care unit (ICU), and post-operative complications were examined.

Anesthesia methods

Upon arrival at the operating room, intravenous access and standard monitoring including electrocardiography, non-invasive blood pressure, and pulse oximetry were established. Anesthesia techniques used in this study were general anesthesia and epidural anesthesia. General anesthesia was induced with intravenous propofol (2.0–2.5 mg/kg) and rocuronium (0.5–1.0 mg/kg). Endotracheal intubation was performed and fentanyl (200 μg) was injected after delivery of the fetus. The maintenance of anesthesia was provided with sevoflurane and remifentanil and the anesthetic depth was real-time assessed by the Narcotrend monitoring system (version 4.0; Monitor Technik, Bad Bramstedt, Germany). Continuous epidural anesthesia was performed using midline approach and loss-of-resistance technique. The epidural catheter was secured 4 to 5 cm beyond the needle tip and local anesthetics were administered through the catheter to achieve adequate sensory dermatome blockade.

IOCS

The Cell Saver BW-8200B autologous blood recovery system (WanDong Health Sources Corporation, Beijing, China) was used for IOCS in the IOCS group. A separate sucker was established to waste amniotic fluid before the delivery of placenta. The blood from the surgical field was suctioned by another sucker into a sterile reservoir through a heparinized double-lumen tube and filter. The suction pressure was set at 150 mmHg and limited to 200 mmHg in cases of heavy bleeding. The filtered collection was processed by the Cell Saver system in a centrifuge to pack red blood cells and then washed with saline solution to remove plasma, PLTs, activated clotting factors, extracellular potassium, free hemoglobin, anti-coagulant, and cellular debris. The washed blood was pumped to the re-infusion bag with standard labels. The processed autologous blood was filtered with a leukocyte depletion filter to remove amniotic fluid contamination including fetal squamous cells, lamellar bodies, and phospholipids and significantly reduce bacterial contamination and then re-infused to the patient. For the ABT group, allogeneic blood was transfused depending on the maternal hemoglobin concentration, blood loss, and vital signs.

Statistical analysis

Statistical analysis was performed using SPSS 22.0 (IBM Corp., New York, USA). All line graphics were made with GraphPad Prism version 6.01 for Windows (Graph Pad Software, San Diego, CA, USA). Continuous data are expressed as the mean ± standard deviation or median (range). Categorical data are reported as the number (percentage). The independent sample *t* test was used for between-group comparisons of normally distributed data.

The non-normally distributed continuous data were compared using the Mann-Whitney *U* test. A two-sided paired *t* test was performed to examine differences at individual time points within each group. Categorical data were compared using Chi-square test or Fisher's exact test, where appropriate. A *P* value of <0.05 was considered statistically significant. To correct for selection bias, propensity score matched analysis was performed to balance differences in the baseline variables between the IOCS group and ABT group. Multivariate logistic regression model was constructed according to pre-operatively known covariates including age, height, weight, ASA class, anesthesia technique, and duration of surgery. The propensity score was calculated via logistic regression analysis and the nearest-neighbor algorithm was used with a caliper of 0.01. Patients in the IOCS group were matched 1:1 to patients in the ABT group. After propensity score matching, the standardized differences between groups were calculated to ensure balances in baseline characteristics. The matched cohort was used to validate the relationship between treatment factors and the outcome. Kaplan-Meier curves and the log-rank test were used for comparing the percentage of patients discharged from hospital over time.

Results

This study consisted of 361 patients, 196 (54.3%) of whom accepted autologous transfusion using IOCS with the remaining 165 (45.7%) receiving ABT. As shown in Table 1, there were statistically significant differences in age ($P = 0.018$) and weight ($P = 0.040$) between the IOCS group and ABT group before propensity score matching. To eliminate baseline differences, propensity score matching was performed and 137 pairs of cases between the two groups were successfully matched. After propensity score matching, no significant differences in baseline characteristics were found between the IOCS group and ABT group. The proportion of patients receiving general anesthesia between the ABT group and the IOCS group was not significantly different (35.0% *vs.* 43.8%, $P = 0.138$).

Within the matched cohort, the median volume of autologous blood re-infusion was 300 mL (range: 100–1800 mL) in the IOCS group and 37 cases (27.0%) in the IOCS group also received ABT. Compared with the ABT group, the amounts of transfused allogeneic red blood cell and fresh frozen plasma were significantly lower in the IOCS group [Table 2]. Allogeneic red blood cell transfusion was lower at 0 unit (range: 0–11.5 units) in the IOCS group when compared with 2 units (range: 1–20 units) in the ABT group ($P < 0.001$). There were no significant differences in intra-operative blood loss, crystalloid fluid infusion, colloid fluid infusion, urine output, and neonatal Apgar score between the IOCS group and ABT group (all $P > 0.05$).

Table 3 showed that post-operative hemoglobin level and HCT values in the IOCS group were significantly higher than those in the ABT group. The post-operative hemoglobin level in the IOCS group and ABT group was 101.3 ± 15.4 and 96.3 ± 16.6 g/L, respectively, which were significantly different ($t = 2.615$, $P = 0.009$). Compared with the ABT group, the postoperative C-reactive protein was significantly lower in the IOCS group ($t = -2.084$, $P = 0.038$). Furthermore, patients in the IOCS group were associated with significantly shorter length of hospital stay, compared with ABT group (8.9 ± 4.1 days *vs.* 10.3 ± 5.2 days, $t = -2.506$, $P = 0.013$). The post-operative length of hospital stay was 5.3 ± 1.4 days for patients in the IOCS group and 6.6 ± 3.6 days for those in the ABT group ($t = -4.056$, $P < 0.001$). As shown in Figure 1, the log-rank test demonstrated that there was significant difference in post-operative length of hospital stay between the two groups ($P < 0.001$). Pre-operative hemoglobin, HCT, C-reactive protein, and ICU admission were similar

Table 1: Baseline characteristic data of patients before and after propensity score matching.

	Before PSM			After PSM		
Characteristics	**IOCS (*n* = 196)**	**ABT (*n* = 165)**	***P***	**IOCS (*n* = 137)**	**ABT (*n* = 137)**	***P***
Age (years)	33.3 ± 4.6	32.4 ± 4.9	0.018	33.0 ± 4.6	32.9 ± 5.1	0.804
Height (cm)	157.6 ± 7.1	158.2 ± 8.5	0.505	157.9 ± 6.5	157.9 ± 9.0	0.975
Weight (kg)	66.8 ± 8.6	65.5 ± 7.0	0.040	65.3 ± 7.6	65.5 ± 6.2	0.862
ASA class, *n* (%)			0.819			0.917
I	7 (3.6)	4 (2.4)		5 (3.6)	4 (2.9)	
II	134 (68.4)	114 (69.1)		98 (71.5)	97 (70.8)	
III	55 (28.1)	47 (28.5)		34 (24.8)	36 (26.3)	
Anesthesia technique, *n* (%)			0.241			0.138
GA	88 (44.9)	64 (38.8)		60 (43.8)	48 (35.0)	
CEA	108 (55.1)	101 (61.2)		77 (56.2)	89 (65.0)	
Duration of surgery (min)	86.6 ± 38.6	86.5 ± 42.0	0.986	87.6 ± 41.7	84.7 ± 41.4	0.562
Cardiovascular disease, *n* (%)	39 (19.9)	28 (17.0)	0.476	26 (15.8)	24 (14.5)	0.754
Diabetes, *n* (%)	22 (11.2)	20 (12.1)	0.791	15 (10.9)	14 (10.2)	0.844
Anemia, *n* (%)	112 (57.1)	84 (50.9)	0.236	91 (66.4)	79 (57.7)	0.135
Hepatic insufficiency, *n* (%)	9 (4.6)	5 (3.0)	0.444	4 (2.9)	3 (2.2)	0.701
Renal disease, *n* (%)	11 (5.6)	8 (4.8)	0.772	5 (3.6)	4 (2.9)	0.734

Data are presented as the mean ± standard deviation or *n* (%). PSM: Propensity score matching; IOCS: Intra-operative cell salvage; ABT: Allogeneic blood transfusion; ASA: American Society of Anesthesiologists; GA: General anesthesia; CEA: Continuous epidural anesthesia.

Table 2: Intra-operative variables in the matched cohort.

Variables	IOCS ($n=137$)	ABT ($n=137$)	Statistics	P
Intra-operative blood loss (mL)	750 (200–5000)	800 (200–4400)	−1.074*	0.283
Crystalloid fluid infusion (mL)	1000 (500–6000)	1500 (200–4850)	−1.391*	0.164
Colloid fluid infusion (mL)	0 (0–2000)	375 (0–2500)	−1.423*	0.155
Cell salvaged blood re-infusion (mL)	300 (100–1800)	0	−15.320*	<0.001
Allogeneic blood transfusion, *n* (%)	37 (27)	137 (100)	157.471†	<0.001
Total RBC units transfused (Unit)	0 (0–11.5)	2 (1–20.0)	−10.658*	<0.001
Fresh frozen plasma (mL)	0 (0–1550)	0 (0–1650)	−3.429*	0.001
Urine output (mL)	200 (100–1000)	250 (100–1500)	−1.940*	0.052
Apgar score at 1 min	9.2 ± 0.6	9.1 ± 0.6	1.509‡	0.132

* *Z* value. † χ^2 test. ‡ *t* value. Data are presented as the mean ± standard deviation, median (range) or *n* (%). IOCS: Intra-operative cell salvage; ABT: Allogeneic blood transfusion; RBC: Red blood cell.

Table 3: Peri-operative outcome data in the matched cohort.

Variables	IOCS ($n=137$)	ABT ($n=137$)	Statistics	P
Pre-operative hemoglobin (g/L)	107.1 ± 13.6	110.0 ± 11.8	−1.908*	0.057
Pre-operative hematocrit (%)	32.2 ± 4.7	33.1 ± 3.3	−1.872*	0.062
Pre-operative CRP (mg/L)	5.42 ± 9.0	5.39 ± 7.05	0.018*	0.986
Post-operative hemoglobin (g/L)	101.3 ± 15.4	96.3 ± 16.6	2.615*	0.009
Post-operative hematocrit (%)	30.7 ± 4.3	28.8 ± 4.4	3.489*	0.001
Post-operative CRP (mg/L)	49.9 ± 36.9	59.2 ± 37.1	−2.084*	0.038
Length of stay (day)	8.9 ± 4.1	10.3 ± 5.2	−2.506*	0.013
Post-operative length of stay (day)	5.3 ± 1.4	6.6 ± 3.6	−4.056*	<0.001
ICU admission, *n* (%)	8 (5.8)	14 (10.2)	1.779†	0.182

* *t* value. † χ^2 test. Data are presented as the mean ± standard deviation or *n* (%). IOCS: Intra-operative cell salvage; ABT: Allogeneic blood transfusion; CRP: C-reactive protein; ICU: Intensive care unit.

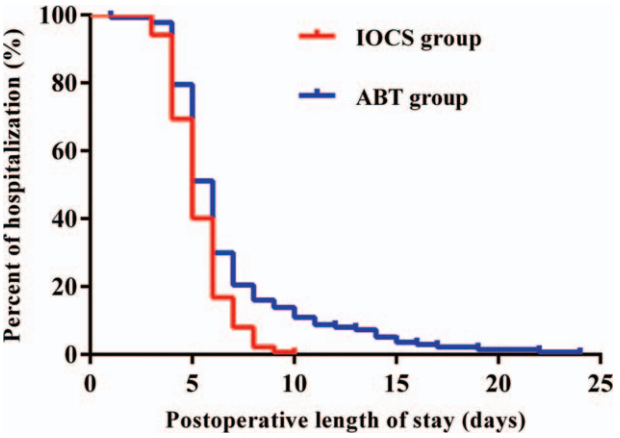

Figure 1: Post-operative length of hospital stay, demonstrating that patients in the IOCS group were associated with a shorter length of post-operative stay ($P < 0.001$). IOCS: Intra-operative cell salvage.

between the two groups (all $P > 0.05$). Adverse events including amniotic fluid embolism, disseminated intravascular coagulation, and respiratory distress syndrome were not found in all parturient women.

For patients in the IOCS group, mean arterial pressure and heart rate were not significantly increased after autologous blood re-infusion compared to the baseline values before infusion (all $P > 0.05$) [Table 4]. The APTT, PT, and plasma DD were slightly higher at the third day after operation, when compared with pre-operative values in the IOCS group. However, these differences were not statistically significant (all $P > 0.05$). The post-operative FIB showed a less significant decrease in the IOCS group ($P = 0.211$). For patients in the ABT group, there were no significant differences in mean arterial pressure and heart rate after ABT, compared with the baseline values before transfusion (all $P > 0.05$). No significant differences were observed between pre-operative and post-operative values of coagulation function in the ABT group (all $P > 0.05$) [Table 4].

Discussion

This study demonstrated that autologous blood re-infusion using IOCS was associated with shorter length of post-operative hospital stay in cesarean section for women with central placenta previa, compared to ABT. The results also showed that patients in the IOCS group had a significantly higher level of postoperative hemoglobin and HCT than those in the ABT group. Furthermore, IOCS greatly reduced the requirements of allogeneic red blood cell transfusion and fresh frozen plasma infusion during obstetric surgery. Meanwhile, no significant changes were found in hemodynamic data during autologous blood re-infusion.

In obstetric practice, one concern for widespread use of IOCS was the theoretical risk of amniotic fluid embolism.[15] It was demonstrated that cell salvage in conjunction with a leukocyte depletion filter significantly reduced

Table 4: Peri-operative data of coagulation function and vital signs in the matched cohort.

Variables	IOCS ($n = 137$)		ABT ($n = 137$)	
	Value	*P*	Value	*P*
MAP (mmHg)		0.244		0.249
Pre-infusion	79.5 ± 13.9		81.3 ± 14.3	
Post-infusion	80.3 ± 13.8		82.3 ± 14.0	
HR (beats/min)		0.184		0.106
Pre-infusion	83.7 ± 16.0		88.0 ± 16.2	
Post-infusion	85.0 ± 15.8		89.0 ± 16.6	
APTT (s)		0.194		0.082
Pre-operative	31.6 ± 2.6		31.7 ± 2.7	
Post-operative	32.1 ± 2.7		33.8 ± 3.8	
PT (s)		0.126		0.114
Pre-operative	12.4 ± 0.6		12.4 ± 0.8	
Post-operative	13.2 ± 1.4		13.4 ± 1.8	
FIB (g/L)		0.211		0.295
Pre-operative	3.9 ± 0.6		3.7 ± 0.7	
Post-operative	3.0 ± 0.9		3.1 ± 1.2	
Plasma D-dimer (mg/L FEU)		0.136		0.443
Pre-operative	2.0 ± 1.3		2.8 ± 3.4	
Post-operative	2.2 ± 1.9		3.2 ± 5.7	

Data are presented as the mean ± standard deviation. IOCS: Intra-operative cell salvage; ABT: Allogeneic blood transfusion; MAP: Mean arterial pressure; HR: Heart rate; APTT: Activated partial thromboplastin time; PT: Prothrombin time; FIB: Fibrinogen; FEU: Fibrinogen equivalent unit.

the alpha-fetoprotein and fetal squamous cell contaminants.[16] To date, there have been no reported cases of amniotic fluid embolism in cell salvage for cesarean delivery, which makes this risk entirely theoretical.[17] Historically, another concern for IOCS usage was fetal red cell contamination and maternal-fetal alloimmunization.[18] However, it was reported that the incidence of fetal red cell contamination was very low and no adverse clinical signs were observed during the autologous blood re-infusions using IOCS.[19] The use of cell salvage is recommended and concerns over amniotic fluid embolism and fetal red cell contamination should not be barriers to adoption of IOCS in cesarean section.[17] There were only a few case reports describing acute hypotension associated with a leukocyte depletion filter during re-infusion of IOCS blood, which was limited evidence.[20,21] The use of leukocyte depletion filters was advocated during re-infusion with IOCS in obstetrics.[13,20] In the current study, a double suction technique in combination with leukocyte depletion filter was used and no case of amniotic fluid embolism or severe hypotension was identified in the IOCS group.

In previous studies, IOCS with leukocyte depletion filter utilization was associated with shorter average hospital stay and a lower likelihood of allogenic blood transfusion in metastatic spine tumor surgery.[22] Autologous blood transfusion was also reported to decrease the length of stay in hospital and allogeneic transfusion-related complications in open-heart surgery.[23] Our results revealed that IOCS reduced the need for allogeneic red blood cell and fresh frozen plasma, with 73% of the patients avoiding ABT in the IOCS group. A previous retrospective cohort study showed that intra-operative salvaged erythrocytes could have decreased exposure to allogeneic red blood cell in 55.6% patients during cesarean delivery.[24] IOCS is a simple and effective blood conservation technique, which differentiates it from allogeneic transfusion associated with limited availability and multiple side effects.[25] ABT was reported to have increased risk of postoperative infections, compared to autologous re-infusion.[26] For pregnant Jehovah's Witnesses patients who refused ABT, IOCS was investigated as an important alternative therapy to improve obstetric outcomes.[27] It was demonstrated that salvaged blood had very high rate of erythrocyte viability, which made re-infused autologous blood valuable in blood management.[28] In our study, maternal coagulation function was normal after autologous blood re-infusion and the fresh frozen plasma requirements were decreased in the IOCS group, suggesting that autologous blood was more physiological compared with allogeneic blood. The lower rate of allogenic blood transfusion, higher postoperative hemoglobin levels, high erythrocyte viability, and physiological traits might suggest the reasons for shorter length of hospital stay in patients receiving autologous blood re-infusion using IOCS.

Allogeneic blood is increasingly expensive and the financial benefits of salvaged blood using IOCS have been considered. It was found that IOCS technique was cost-saving in cases with high risk of hemorrhage but not cost-saving during routine cesarean deliveries.[29] Cell salvage was the cost-saving blood conservation strategy by reducing usage of allogeneic blood and decreasing blood processed costs.[30] In a healthcare system perspective, an economic analysis of 2328 patients suggested that allogeneic blood was significantly expensive than cell salvage, with an average cost up to $200 of an allogeneic blood unit and $89.46 of an equivalent cell salvage unit.[31] From the societal perspective, cell salvage was cost-effective for cases at high risk for obstetric hemorrhage

with an incremental cost-effectiveness ratio up to $34881 per quality-adjusted life-year gained.[14] In our study, significantly shorter length of postoperative hospital stay and higher post-operative hemoglobin levels in the IOCS group could also help decrease the medical and care costs.

The manpower planning and training are barriers to implementing IOCS in some medical institutions. The comprehensive competency training program has been introduced to overcome concerns relating to training.[19] In clinical practice, cell salvage equipment is easy to set up in several minutes with friendly user interface and control panel. Compared with the allogeneic red blood cell transfusion, the advantages of IOCS are especially outstanding in emergencies once the predictable or unexpected hemorrhage is identified and the cell salvage could be rapidly set up without delay. In our hospital, cell salvage machines are classified as anesthetic equipment and the overall system is managed by the department of anesthesiology. The cell salvage machine was operated by anesthetic nurses under the supervision by the anesthesiologists. The standard operating procedure for cell salvage has been established in our hospital and all personnel involved in cell salvage have been trained and skilled in the management and facilitation of cell salvage and autologous blood re-infusion system. The simple structure, easy-to-understand interface, and fully automated process for cell salvage machine make operation efficient. The cell salvage device is a powerful blood conservation technique and has been widely applied in many medical fields including orthopedics, pediatrics, neurosurgery, cardiac surgery, and malignancy.[13] It was recommended that cell salvage should be universally available for immediate use at any time in medical institutions, especially in cases at high risk of hemorrhage.[5]

This study has several limitations. First, this was a retrospective observational study. Therefore, propensity score matching analysis was performed to reduce confounding bias and balance differences of baseline data between the two groups in our study. Large randomized controlled trials are still needed to determine the efficacy of IOCS technique in obstetrics. Second, we did not collect maternal blood sample from the salvaged blood bag to detect fetal red cell contamination and any positive antibodies. It would be better to establish a central electronic database containing this information to authoritatively assess the safety of the IOCS technique. Third, our study was a single-center research with unknown generalizability in other institutions and long-term follow-up was not completed. Multi-center clinical trials are required in future work to provide strong evidence for the application of IOCS during cesarean delivery.

In conclusion, this retrospective observational study using propensity score matched analysis suggested that IOCS was associated with shorter length of postoperative hospital stay and higher post-operative hemoglobin levels during cesarean delivery. Furthermore, autologous blood re-infusion using IOCS reduced the need for allogeneic red blood cell and fresh frozen plasma in obstetrics.

Acknowledgements

The authors would like to acknowledge the nurse anesthetists at Union Hospital in Wuhan, China for their assistance with this work.

Funding

This research was supported by the grants from the National Natural Science Foundation of China (No. 81772131 to JW), and the B. Braun Anesthesia Scientific Research Foundation (No. BBDF-2018-005 to XW).

Conflicts of interest

None.

References

1. Allahdin S, Voigt S, Htwe TT. Management of placenta praevia and accreta. J Obstet Gynaecol 2011;31:1–6. doi: 10.3109/01443615.2010.532248.
2. Lal AK, Hibbard JU. Placenta previa: an outcome-based cohort study in a contemporary obstetric population. Arch Gynecol Obstet 2015;292:299–305. doi: 10.1007/s00404-015-3628-y.
3. Kollmann M, Gaulhofer J, Lang U, Klaritsch P. Placenta praevia: incidence, risk factors and outcome. J Matern Fetal Neonatal Med 2016;29:1395–1398. doi: 10.3109/14767058.2015.1049152.
4. Baumfeld Y, Herskovitz R, Niv ZB, Mastrolia SA, Weintraub AY. Placenta associated pregnancy complications in pregnancies complicated with placenta previa. Taiwan J Obstet Gynecol 2017;56:331–335. doi: 10.1016/j.tjog.2017.04.012.
5. Klein AA, Bailey CR, Charlton AJ, Evans E, Guckian-Fisher M, McCrossan R, *et al*. Association of anaesthetists guidelines: cell salvage for peri-operative blood conservation 2018. Anaesthesia 2018;73:1141–1150. doi: 10.1111/anae.14331.
6. Bolton-Maggs PHB. Serious hazards of transfusion - conference report: celebration of 20 years of UK haemovigilance. Transfus Med 2017;27:393–400. doi: 10.1111/tme.12502.
7. Hendrickson JE, Hillyer CD. Noninfectious serious hazards of transfusion. Anesth Analg 2009;108:759–769. doi: 10.1213/ane.0b013e3181930a6e.
8. Catling S. Blood conservation techniques in obstetrics: a UK perspective. Int J Obstet Anesth 2007;16:241–249. doi: 10.1016/j.ijoa.2007.01.014.
9. Jakovina Blazekovic S, Bicanic G, Hrabac P, Tripkovic B, Delimar D. Pre-operative autologous blood donation versus no blood donation in total knee arthroplasty: a prospective randomised trial. Int Orthop 2014;38:341–346. doi: 10.1007/s00264-013-2185-x.
10. Catic D, Milojkovic A, Steblovnik L. Preoperative autologous blood donation in placenta previa patients. Transfus Apher Sci 2018;57:793–796. doi: 10.1016/j.transci.2018.11.003.
11. Joubert KE. Acute normovolaemic haemodilution–is it a solution to reduce perioperative blood transfusions? J S Afr Vet Assoc 2007;78:188–194. doi: 10.4102/jsava.v78i4.321.
12. Goucher H, Wong CA, Patel SK, Toledo P. Cell salvage in obstetrics. Anesth Analg 2015;121:465–468. doi: 10.1213/ANE.0000000000000786.
13. Ashworth A, Klein AA. Cell salvage as part of a blood conservation strategy in anaesthesia. Br J Anaesth 2010;105:401–416. doi: 10.1093/bja/aeq244.
14. Lim G, Melnyk V, Facco FL, Waters JH, Smith KJ. Cost-effectiveness analysis of intraoperative cell salvage for obstetric hemorrhage. Anesthesiology 2018;128:328–337. doi: 10.1097/ALN.0000000000001981.
15. Waters JH, Biscotti C, Potter PS, Phillipson E. Amniotic fluid removal during cell salvage in the cesarean section patient. Anesthesiology 2000;92:1531–1536. doi: 10.1097/00000542-200006000-00008.
16. Sullivan I, Faulds J, Ralph C. Contamination of salvaged maternal blood by amniotic fluid and fetal red cells during elective Caesarean section. Br J Anaesth 2008;101:225–229. doi: 10.1093/bja/aen135.

17. Sullivan IJ, Ralph CJ. Obstetric intra-operative cell salvage: a review of an established cell salvage service with 1170 re-infused cases. Anaesthesia 2019;74:976–983. doi: 10.1111/anae.14630.
18. Dhariwal SK, Khan KS, Allard S, Wilson M, Moore P, Group SS. Does current evidence support the use of intraoperative cell salvage in reducing the need for blood transfusion in caesarean section? Curr Opin Obstet Gynecol 2014;26:425–430. doi: 10.1097/GCO.0000000000000116.
19. Ralph CJ, Sullivan I, Faulds J. Intraoperative cell salvaged blood as part of a blood conservation strategy in Caesarean section: is fetal red cell contamination important? Br J Anaesth 2011;107:404–408. doi: 10.1093/bja/aer168.
20. Sreelakshmi TR, Eldridge J. Acute hypotension associated with leucocyte depletion filters during cell salvaged blood transfusion. Anaesthesia 2010;65:742–744. doi: 10.1111/j.1365-2044.2009.06190.x.
21. Kessack LK, Hawkins N. Severe hypotension related to cell salvaged blood transfusion in obstetrics. Anaesthesia 2010;65:745–748. doi: 10.1111/j.1365-2044.2010.06301.x.
22. Elmalky M, Yasin N, Rodrigues-Pinto R, Stephenson J, Carroll C, Smurthwaite G, *et al*. The safety, efficacy, and cost-effectiveness of intraoperative cell salvage in metastatic spine tumor surgery. Spine J 2017;17:977–982. doi: 10.1016/j.spinee.2017.03.004.
23. Oz BS, Arslan G, Kaya E, Gunay C, Cingoz F, Arslan M. Comparison of results of autologous versus homologous blood transfusion in open-heart surgery. Cardiovasc J Afr 2013;24:121–123. doi: 10.5830/CVJA-2013-020.
24. Fong J, Gurewitsch ED, Kang HJ, Kump L, Mack PF. An analysis of transfusion practice and the role of intraoperative red blood cell salvage during cesarean delivery. Anesth Analg 2007;104:666–672. doi: 10.1213/01.ane.0000253232.45403.e5.
25. Grainger H, Catling S. Intraoperative cell salvage in obstetrics. J Perioper Pract 2018;28:51–58. doi: 10.1177/1750458918755960.
26. Innerhofer P, Klingler A, Klimmer C, Fries D, Nussbaumer W. Risk for postoperative infection after transfusion of white blood cell-filtered allogeneic or autologous blood components in orthopedic patients undergoing primary arthroplasty. Transfusion 2005;45:103–110. doi: 10.1111/j.1537-2995.2005.04149.x.
27. Tanaka M, Matsuzaki S, Endo M, Kakigano A, Mimura K, Takiuchi T, *et al*. Obstetric outcomes and acceptance of alternative therapies to blood transfusion by Jehovah's witnesses in Japan: a single-center study. Int J Hematol 2018;108:432–437. doi: 10.1007/s12185-018-2490-7.
28. Colwell CW Jr, Beutler E, West C, Hardwick ME, Morris BA. Erythrocyte viability in blood salvaged during total joint arthroplasty with cement. J Bone Joint Surg Am 2002;84:23–25. doi: 10.2106/00004623-200201000-00004.
29. Albright CM, Rouse DJ, Werner EF. Cost savings of red cell salvage during cesarean delivery. Obstet Gynecol 2014;124:690–696. doi: 10.1097/AOG.0000000000000465.
30. Samnaliev M, Tran CM, Sloan SR, Gasior I, Lightdale JR, Brustowicz RM. Economic evaluation of cell salvage in pediatric surgery. Paediatr Anaesth 2013;23:1027–1034. doi: 10.1111/pan.12233.
31. Waters JR, Meier HH, Waters JH. An economic analysis of costs associated with development of a cell salvage program. Anesth Analg 2007;104:869–875. doi: 10.1213/01.ane.0000258039.79028.7c.

How to cite this article: Wu X, Yao SL, Wu J, Li CY, Xia LM. Intraoperative cell salvage for cesarean delivery: a retrospective study using propensity score matched analysis. Chin Med J 2020;133:183–189. doi: 10.1097/CM9.0000000000000620