SPINE

Blood management strategies in posterior corrective surgery for idiopathic scoliosis

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Abstract

Background

Corrective surgery for adolescent idiopathic scoliosis (AIS) is associated with large volumes of blood loss and a need for blood transfusion. Our study aim was to measure blood loss and blood products used intraoperatively in corrective surgery, and to identify modifiable factors that may influence blood loss.

Methods

The study was a retrospective review of patients who underwent posterior corrective surgery for AIS between 2015 and 2020 at a single centre. A total of 43 patients were identified, of which 36 met the inclusion criteria. Sociodemographic data, intraoperative blood loss parameters, transfusion requirements, and use of tranexamic acid (TXA), intraoperative cell salvage (ICS) and ultrasonic bone scalpel (UBS) were documented. Data were analysed to identify factors affecting intraoperative blood loss and blood transfusion.

Results

The 36 patients (30 female, 6 male) had a median age of 16 (interquartile range: 13–17) years. The mean duration of surgery was 355 (± 75.4) minutes, and the average number of segments fused was 10.3 (± 1.9). The mean estimated blood loss (EBL) was 722.2 (± 328.3) ml, with the mean percentage blood loss being 23 (± 11.6)%. A total of 11 patients (31%) received a blood transfusion; in these patients every 139.6 ml of blood lost resulted in one unit of blood being transfused ($p = 0.005$). Statistically significant differences in mean EBL were found with the use of TXA ($p = 0.018$) and UBS ($p = 0.01$). Use of ICS did not result in statistically significant differences in mean EBL. A direct correlation was also found with EBL and the duration of surgery ($p = 0.025$), and the number of segments fused ($p = 0.005$).

Conclusion

Multifactorial blood management strategies should be implemented to decrease blood loss and reduce the need for blood transfusion in corrective scoliosis surgery. These include the use of TXA, UBS and ICS. Additionally, attempts should be made to decrease the duration of surgery.

Level of evidence: 3

Keywords: adolescent idiopathic scoliosis, deformity spine surgery, blood transfusion, tranexamic acid

Introduction

Corrective procedures for adolescent idiopathic scoliosis (AIS) are frequently associated with large volumes of intraoperative blood loss, with reported losses up to approximately 4.5 litres.[1-3] This blood loss subsequently leads to an elevated incidence of blood transfusion, with transfusion rates being as high as 59% in children undergoing scoliosis surgery.[1,4]

Blood transfusions are unfortunately not without considerable risk and cost; consequently, it is reserved for clinically significant blood loss.[5] This necessitates that the managing surgeon have additional measures available to decrease intraoperative blood loss and the need for a transfusion.[6] Identification of modifiable factors influencing blood loss continues to remain the priority concern of recent research.[7] Multiple interventions are often instituted simultaneously to decrease blood loss and reduce the need for allogeneic blood transfusion, using a multidisciplinary blood management protocol. These interventions are separated into those for the preoperative and intraoperative periods.[1]

Dick et al., in a large retrospective cohort review, analysing 1 039 scoliosis correction procedures for children, reported a significant (approximately 70%) decline in allogeneic blood transfusions with the institution of multiple blood-saving interventions.[1] Similarly, Hassan et al.[2] reported that the institution of a blood management protocol resulted in low transfusion rates. Each study used different approaches to manage blood loss. It is, however, important to note that a multimodal approach to saving blood seems far more efficacious than the application of an isolated intervention.

While various blood loss prevention and management strategies are frequently used, the focus of many recent studies has been the use of antifibrinolytics and intraoperative cell salvage (ICS). Mikhail et al.[6] described antifibrinolytics as 'one of the greatest advancements' in reducing blood loss in spine surgery. The use of these agents has been shown to decrease transfusion requirements by up to approximately 50% in those undergoing major surgery.[8] A meta-analysis by Shrestha et al. found that the average blood loss for patients receiving antifibrinolytics was 525.2 ml lower ($p < 0.001$), and decreased the units of red blood cells (RBCs) transfused.[9]

ICS is another modality used for minimising the effect of blood loss. In it, blood from the operative field is drained and filtered to form an RBC concentrate that may be transfused back into the patient.[6] Its use has also been demonstrated to decrease the need for allogeneic blood transfusion.[1,2,6,10] In a retrospective case-control study by Bowen et al.,[11] it was established that allogeneic blood transfusion rates were lower in the ICS group. Unfortunately, there remains a limitation that a minimum volume of blood loss is required to produce a unit for transfusion.[6]

Use of the ultrasonic bone scalpel (UBS) has become increasingly popular.[7,12] It can efficiently cut bone while sparing and preventing damage to soft tissues. This is achieved by high-speed oscillation of the blade where the elastic nature of soft tissue absorbs the force of the UBS, minimising blood loss.[7,12,13] While no level 1 evidence currently exists to validate beneficial effects in AIS, the available literature is promising regarding its usage.

Considering these factors, the objectives of our study were to review intraoperative blood loss and blood products used in posterior corrective surgery, and to identify modifiable factors that may influence blood loss in patients. The goal was to establish recommendations for reducing and predicting intraoperative blood loss and allogeneic blood transfusion.

Materials and methods

A retrospective record review was conducted on patients who underwent posterior corrective surgery for the treatment of AIS. Institutional review board approval for the study was obtained. Initially, patients admitted at our institution who underwent posterior corrective surgery during a six-year period (1 January 2015 to 31 December 2020) were identified using the theatre register. This identified a total of 49 patients who had undergone corrective scoliosis surgery. From these, six patients were excluded as they received corrective surgery for secondary scoliosis (i.e. congenital, neuromuscular and syndromic) or revision surgery. Retrieval of records of the remaining 43 patients was attempted, resulting in a further seven patients being excluded (three patients lacked adequate hospital records while the records of four had been lost).

A review of the files was undertaken on the remaining 36 patients. Basic demographic data were collected. Furthermore, weight, preoperative Hb, AIS Lenke type, and magnitude of the main curve (expressed as the Cobb angle) were documented. Each patient had osteotomies at certain levels depending on the severity of the deformity. These included facetectomies (inferior facet) with laminotomy and Ponte osteotomies. No vertebral column resection was done in this cohort. Details regarding the surgery were also noted including estimated blood loss (EBL); duration of the surgery; number of segments fused; and use of tranexamic acid (TXA), ICS and UBS. If transfusion was needed, the number of units transfused was included. EBL was approximated by the anaesthetic team based on the number of swabs used intraoperatively, and the blood volume collected via suction or ICS. Additionally, the estimated blood volume (EBV) of each individual patient was determined using the formula: body weight (kg) × 70 ml = EBV (in ml). This was used to further quantify EBL as a percentage of EBV to better account for blood loss based on patient weight.

Descriptive statistics were used to analyse the sociodemographic profile of the participants, blood loss and blood transfusion parameters. Inferential statistics were used to further delineate the relationship between these variables. For this, linear regression analysis was used to assess the relationship between EBL, EBL as a percentage of EBV, and the volume of blood transfused. Additionally, the independent t-test was used to determine if there was a difference in the mean EBL in patients who received TXA versus patients who did not. Similarly, this was applied to intraoperative use of ICS and UBS. The dependent t-test was also used to compare the patients' pre- and postoperative Hb levels. Linear regression was used to establish the relationship between EBL and duration of surgery, number of segments fused, Lenke type and Cobb angle. Values of $p < 0.05$ were considered statistically significant.

Results

A total of 36 patients were reviewed in our study. This included 30 females (83%) and six males (17%). Furthermore, patients had ages ranging from 11–30 years old. The median age of the patients was 16 (IQR: 13–17) years with 33 (92%) being younger than 20 years while only three (8%) being 20 years of age or older. The mean weight of patients was 46.3 (± 3.5) kg, ranging from a minimum of 34 kg to a maximum of 60 kg (*Table I*).

The average duration of each surgery was approximately 355 (± 75.4) minutes. Univariate linear regression showed an association between EBL and the duration of surgery, as every minute spent in theatre during surgery resulted in 1.6 ml of blood loss ($p = 0.025$).

The average number of segments fused was 10.3 (± 1.9) per surgery. Fifteen (42%) patients received fusion of between 10 and 11 segments. It was determined that the number of segments fused also influenced the EBL, as every segment fused during surgery resulted in 80.2 ml of blood loss ($p = 0.005$). Other parameters were tested for significance but did not show any statistically significant correlation with blood loss. These included the scoliosis Lenke type and the Cobb angle.

The mean EBL was 722.2 (± 328.3) ml (range 300–1 600), while the average EBV was calculated to be 3 241.6 ml. When assessing the blood loss as a percentage of EBV, it was determined that the mean blood loss was 23% (± 12) (range 7–51). During surgery, a total of 11 (31%) patients received a blood transfusion whereas the remaining 25 (69%) patients did not. Univariate linear regression showed a statistically significant association between EBL and the volume of blood transfused ($p = 0.005$), i.e. for every 139.6 ml of blood lost, one unit of blood was transfused (*Table II*). Similarly, it was found that a blood loss of 6% correlated with a transfusion of one unit of blood ($p = 0.001$).

Twenty-one (58%) patients received a preoperative bolus of TXA while 15 (42%) patients did not. It is important to highlight that all the patients operated on from 2017 onwards received TXA, which

Table I: Sociodemographic information

Demographics	
Age (years) < 20 > 20	Frequency (%) 33 (92) 3 (8)
Sex Female Male	Frequency (%) 30 (83) 6 (17)
Weight	Mean (SD) 46.3 (± 6.7) kg

Table II: Correlation between blood loss parameters and blood transfused

	Coefficient	95% Confidence interval	p-value
EBL	139.6	45.1–234.1	0.005
EBL as a percentage of EBV	5.8	2.7–9.0	0.001

EBL: estimated blood loss; EBV: estimated blood volume

constituted 19 (53%) patients, whereas before this period, only two (6%) patients received TXA. An analysis comparing patients who received and did not receive TXA demonstrated that patients who received TXA had a lower mean EBL of 602.4 (± 219.9) ml compared to patients who did not receive TXA, with a mean EBL of 890 (± 385.5) ml. The mean difference of 287.6 ml was statistically significant (p = 0.018). During the duration of the study, only three (8%) patients received the use of ICS whereas 33 (92%) patients did not. Use of ICS was not found to be statistically significant (p = 0.194). Eighteen (50%) patients had intraoperative use of UBS while the remaining 18 patients did not. Similar to TXA, the data indicated that patients who received UBS had a lower mean blood loss, i.e. 558.3 (± 199.5) ml when UBS was utilised versus 886.1 (± 353.9) ml. The mean difference of 327.8 ml was statistically significant (p = 0.01).

Discussion

AIS has frequently been associated with and known to have a preponderance for the female sex.[14,15] Similarly, patients in our study were primarily female, constituting 30 (83%) patients in the study cohort. Correspondingly, retrospective record reviews also demonstrated a female predominance ranging from 67.9% found by Dick et al.[1] to 84.3% shown by Ohrt-Nissen et al.[16] Patients with AIS undergoing posterior correction are at an increased risk of experiencing substantial blood loss.[17] This is related to the large incision, extensive soft tissue dissection and prolonged operative times[1,2,6,17] The mean EBL of patients in our study was 722.2 (± 328.3) ml while the mean blood loss as a percentage of EBV was 23 (± 12)%. In a systematic review by Shapiro and Sethna, the authors appraised multiple studies regarding AIS.[18] They determined the mean EBL of patients undergoing posterior correction ranged from 600–1 000 ml in the reviewed literature, which was consistent with the findings reported in our study. Additionally, it was noticed that different authors favoured differing methods of comparing data regarding blood loss, making comparisons difficult.

Patients with AIS undergoing corrective surgery remain a group at high risk of receiving an RBC transfusion due to the frequently large volumes of blood lost during the procedure.[1-3,16] In our study, 11 (31%) patients received a blood transfusion. This finding concurred with those reported in literature. Ohrt-Nissen et al.[16] reported a transfusion rate of 30.5%, while Dick et al.[1] reported a transfusion rate of 24.4%. The lowest rate was noted by Hassan et al.[2] who found a transfusion rate of 14.2%.

Use of antifibrinolytics, specifically TXA, in posterior corrective surgery for AIS, has recently gained added popularity as more literature continues to demonstrate its efficacy.[19] Our study compared EBL among patients who received TXA and patients who did not. It was found that patients who received TXA had 287.7 ml (p = 0.018) lower blood loss. Randomised control trials conducted by Sethna et al.[20], Lykissas et al.[21], and Goobie et al.[22] similarly demonstrated a reduced blood loss with the administration TXA (*Table III*). Interestingly, all patients undergoing corrective surgery from 2017 received TXA. This was related to a shift in unit policy secondary to literature supporting its use in limiting blood loss.

ICS is frequently employed when a large volume of blood loss is anticipated. Likewise, the adequate use of ICS is dependent on this blood loss to be able to produce a transfusable unit of RBC. While our study had too few patients to establish a statistically significant relationship, available literature demonstrates its efficacy. Bowen et al.[11] validated that not only did ICS usage decrease allogeneic blood transfusion rates (6% versus 55%, p < 0.05), but also that mean allogeneic transfusion volumes were lower (0.4 ml/kg versus 9.1 ml/kg, p < 0.05).

One of the most recent advancements in pursuit of decreasing blood loss during corrective surgery for AIS is UBS.[7] In our study, it was found that patients who received UBS had a lower mean EBL of 327.78 ml (p = 0.01). Bartley et al. described that the use of UBS resulted in a lower EBL per level fused.[12] They reported the EBL per level fused to be 48 (± 30) ml in patients who received UBS versus 72 (± 28) ml in patients who did not.[12]

Corrective surgery for scoliosis is not only associated with large volumes of blood loss but also prolonged surgical procedures.[17] As the surgical field is exposed during this time, the risk of hypothermia and the sequelae of coagulopathy remain. As such, prolonged operative times are one of the major surgery-related factors postulated to increase EBL.[4,6,17] However, steps can be taken to optimise surgical time and therefore blood loss. These include meticulous haemostasis during the procedure, the surgical team being familiar with each step of the surgery, and lastly the skill of the surgeon with pedicle screw insertion.[12] It was established in our study that every minute spent in theatre resulted in 1.63 ml of blood loss (p = 0.025). Alamanda et al.[23] correspondingly reported that every 10 minutes in surgery increased blood loss by 6.7% of the total blood volume. Hence, increased surgical time was found to be an independent predictor of blood loss.[23]

Dick et al.[1] reported the use of a 'multidisciplinary blood conservation integrated care pathway program' which integrated blood-saving strategies including: the use of TXA, ICS, restrictive transfusion triggers and preoperative Hb optimisation.[1] They

Table III: Comparison of EBL in recipients of TXA versus non-recipients

Study	TXA administered		No TXA		p-value
	Number of patients	Blood loss (ml)	Number of patients	Blood loss (ml)	
Present study	21	602.4 (± 219.9)	15	890 (± 385.5)	0.018
Sethna et al.[20]	23	1 230 (± 535)	21	2 085 (± 1 188)	< 0.01
Lykissas et al.[21]	25	537 (± 320)	24	1 245 (± 896)	0.027
Goobie et al.[22]	56	836 (± 373)	55	1 031 (± 484)	0.02

TXA: tranexamic acid

reported a dramatic decline in the rate of transfusion, starting from 89.2% (before any measures were introduced) to 20.1% following the institution of the integrated care pathway.[1] Similarly, Fletcher et al.[24] established best practice guidelines for reducing blood loss in patients receiving posterior instrumentation for AIS. In their study, 21 spine deformity surgeons reached a unanimous consensus regarding routine administration of TXA, intraoperative use of UBS and restrictive Hb transfusion triggers (i.e. Hb < 7 g/dL).

Taking our findings and the results of reviewed literature into consideration, the following recommendations are made regarding strategies to decrease blood loss and risk of allogeneic blood transfusion during posterior corrective surgery for AIS:

- Effective preoperative planning – considering the number of segments to be fused
- Surgical time efficiency – ensuring meticulous intraoperative haemostasis and surgical team being familiar with the surgery
- Routine administration of prophylactic TXA
- Standard use of intraoperative UBS
- Intraoperative use of ICS – especially when a large EBL is anticipated
- Restrictive Hb transfusion triggers (Hb < 7 g/dL) – to decrease unwarranted transfusions

As this was a retrospective study, it exhibited the limitations associated with this type of study, i.e. difficulty with the retrieval of patient information and patient records. Another limitation was that the study was conducted at a single centre and had a relatively small sample size for a meaningful multivariate analysis to be done. It is recommended that a follow-up study with a prospective design and a larger study sample be conducted in future. Postoperative blood loss and transfusion requirements should also be investigated. Additionally, topical compared to intravenous TXA should be investigated.

Conclusion

Modifiable factors found to affect intraoperative blood loss in our study included the use of TXA, and intraoperative deployment of UBS. Additional factors found to contribute to blood loss included the duration of surgery and the number of segments fused. Overall, we recommend the routine institution of this multifactorial blood management strategy, with the anticipation being that intraoperative blood loss and the need for allogeneic blood transfusion should decrease.

Ethics statement

The author/s declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

Prior to the commencement of the study ethical approval was obtained from the following ethical review board: Human Research Ethics Committee (HREC) of the University of the Witwatersrand, clearance certificate no. M210325.

Permission to conduct the study was also obtained from the departmental head of departments (HODs) and chief executive officer (CEO) of the hospital.

All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed written consent was not obtained from patients as this was a retrospective study.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

MHSA: study conceptualisation, study design, data capture, data analysis, manuscript preparation, manuscript revision
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