The pattern of blood loss during correction surgery combined with three column osteotomy for adult spine deformity

Jun Qiao (✉ qiaojun0616@163.com)

Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital

Zhen Liu

Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital

Leilei Xu

Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital

Benlong Shi

Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital

Xu Sun

Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital

Bangping Qian

Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital

Zezhang Zhu

Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital

Yong Qiu

Nanjing University Medical School Affiliated Nanjing Drum Tower Hospital

Research article

Keywords: Blood loss, Pattern, Scoliosis, Three column osteotomy

Posted Date: August 13th, 2019

DOI: <https://doi.org/10.21203/rs.2.12777/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background: It is of great importance to perform a precise management for blood loss according to stage of surgery. To analyze blood loss during different stages of three column osteotomy (3CO) surgery for scoliosis and to find predictors of blood loss during different stages and to evaluate effectiveness of some blood conservative technique modalities. **Methods:** A retrospective review was performed for adult spine deformity (ASD) patients who underwent posterior-only correction along with 3CO. Surgical procedure was divided into four stages: Stage A, exposure; Stage B, screw placement; Stage C, osteotomy; Stage D, rod installment and wound closure. EBL was recorded at the end of each stage. Demographic and radiographic data were collected. **Results:** Highest EBL was observed at neuromuscular scoliosis group, while least at idiopathic. 9 patients experienced massive blood loss (EBL>5000 ml). Multivariate linear regression identified fusion level main curve Cobb angle and use of TXA as influential factors for stage A; fusion level, use of TXA and use of navigation system for stage B; kyphosis and use of bone scalpel for stage C; fusion level and main curve Cobb angle for stage D ($P<0.05$). **Conclusion:** Etiology significantly influences blood loss of scoliosis surgery with 3CO. Risk factors of blood loss were varied among different surgical stages. Use of TXA, navigation system and ultrasonic bone scalpel could reduce blood loss.

Introduction

For rigid scoliosis, it is impossible to be corrected either with instrumentation alone or with the addition of posterior ligament and simple facet joint releases¹. Vertebral osteotomies allow the surgeon to obtain more correction in rigid deformities². There are three main types of osteotomies, including the Smith-Petersen osteotomy (SPO), pedicle subtraction osteotomy (PSO), and vertebral column resection (VCR)³. PSO and VCR are often termed as three-column osteotomies (3CO) and considered as procedures with high risks of complications^{4,5}. 3CO was often associated with massive blood loss, sometimes above 10L⁶. Massive intraoperative blood loss increases rate of infections, hemodynamic instability, decreased cardiac, pulmonary, and renal function secondary to fluid shifts, and even death⁷. During procedures of 3CO, massive blood loss causes hypotension, and then increases the risk of neurologic deficits⁸. Some blood conservative technique modalities including the use of ultrasonic bone scalpel, autologous blood donation, controlled hypotensive anesthesia, preoperative administration of erythropoietin, intraoperative blood salvage, intrathecal morphine and administration of specific agents like tranexamic acid during the operation have been adopted to reduce blood loss and blood transfusion⁹⁻¹¹. However, these modalities are costly and unavailable at some regions. Unlike other scoliosis surgery, blood loss during 3CO was not linear, and the pattern of blood loss was varied during different stages of surgery. It is of great importance to perform a precise management for blood loss according to stage of surgery. The objectives of this study were: 1) to analyze blood loss during different stages of 3CO surgery for scoliosis; 2) to find predictors of blood loss during different stages; 3) to evaluate effectiveness of some blood conservative technique modalities.

Materials And Methods

A retrospective review was performed for adult spine deformity (ASD) patients who underwent posterior-only correction along with 3CO from June 2006 to October 2017 at the Affiliated Drum Tower Hospital of Nanjing University Medical School. 3CO included VCR, PSO and other modified forms of osteotomies. Exclusion criteria were as follows: 1) revision surgery, 2) combined anteroposterior surgery, 3) renal insufficiency and coagulopathy, 4) oral anticoagulant therapy. All surgeries were performed by experienced senior attending doctors under monitoring of combined MEPs and SEPs. This study was approved by the Institutional Review Board of our university, and all patients involved provided written informed consent for the study and surgery.

Total intravenous anesthesia was administered to all patients. Blood pressure and heart rate were controlled to fluctuate within 20% of the basic level. The intraoperative body temperature was kept between 36°C and 37°C with the use of warm air blower.

Cell salvage autologous blood recovery system was used in some cases. Tranexamic acid (TXA) was used to reduce postoperative blood loss. The standard TXA dose used in our study was 100 mg/kg intravenously over 15 min after induction of anesthesia and before incision followed by an infusion of 10 mg/kg per hour during surgery until skin closure¹².

Transfusion decisions were made in the following conditions: 1) symptomatic anemia such as hypotension that was inadequately responsive to fluid challenge; 2) hemoglobin concentration of less than 80 g/L; or 3) hemoglobin level less than 100 g/L with signs of hemodynamic instability (e.g. tachycardia, poor peripheral perfusion).

Estimated blood loss (EBL) was determined by calculating the blood volume in the suction

container after subtracting irrigation in addition to the difference in the weights of dry and blood-soaked sponges. Surgical procedure was divided into four stages: Stage A, exposure; Stage B, screw placement; Stage C, osteotomy; Stage D, rod installment and wound closure. EBL was recorded at the end of each stage. Time of each stage was also recorded. Demographic data such as age at the time of surgery, sex and body mass index (BMI) were collected. Radiographic parameters included main curve Cobb angle, kyphosis, osteotomy level and fusion levels. Other factors influencing blood loss were also recorded, such as use of navigation system, use of ultrasonic bone scalpel and use of TXA.

Statistical analysis

The correlation between the measured variables and EBL at each stage was determined using Pearson's correlation coefficient (r) and Spearman's rank correlation coefficient (ρ). Variables with a significant correlation were then analyzed using a stepwise multivariate linear regression. A P value of 0.05 was set to indicate statistical significance.

Results

A total of 157 patients were included in this study. There were 83 males and 74 females with an average age of 48.4 ± 15.8 years (range, 20–74 years) by the time of surgery. The osteotomy site was located at T8 for 3 cases, T9 for 5 cases, T10 for 7 cases, T11 for 15 cases, T12 for 24 case, L1 for 26 cases, L2 for 25 cases, L3 for 24 case, L4 for 20 cases and L5 for 8 cases. Of all the patients, 15 cases were idiopathic, 32 degenerative, 32 neuromuscular, 42 congenital, 18 post-traumatic, 18 syndromic. The mean operation time was 317 min (range: 228 to 634 min), and the mean fusion level was 11.7 (range: 5 to 18). TXA was used at 76 cases, O-arm navigation system at 49 cases and ultrasonic bone scalpel at 40 cases.

The mean EBLs were 1076 ml for idiopathic, 1578 ml for degenerative, 1821 ml for neuromuscular, 1693 ml for congenital and 1679 ml for syndromic. EBLs of each stage were listed at Table 1.

Massive blood loss was defined as EBL larger than 5000ml. A total of 9 patients experienced massive blood loss. Of the 9 patients, 3 cases were neuromuscular, 3 degenerative, 2 congenital, 1 syndromic. Table 2 listed demographic and surgical data of these patients.

EBL at stage A was correlated to fusion level, operation time, main curve Cobb angle and use of TXA ($P < 0.05$). EBL at stage B was correlated to fusion level, operation time, main curve Cobb angle, use of TXA and use of navigation system ($P < 0.05$). EBL at stage C was correlated to main curve Cobb angle, kyphosis and use of bone scalpel ($P < 0.05$). EBL at stage D was correlated to fusion level, operation time, main curve Cobb angle and kyphosis ($P < 0.05$).

Multivariate linear regression identified fusion level main curve Cobb angle and use of TXA as influential factors for stage A; fusion level, use of TXA and use of navigation system for stage B; kyphosis and use of bone scalpel for stage C; fusion level and main curve Cobb angle for stage D ($P < 0.05$).

Discussion

Corrective surgery for scoliosis puts the patient at a risk of massive blood loss¹³. Excessive intraoperative and postoperative blood loss increases the transfusion burden on the patient, causing increased exposure to blood products and its associated risks^{14,15}. It is of great importance to identify risk factors and adopt the necessary measures to optimize blood management. Numerous studies have been performed and identified many risk factors of blood loss for scoliosis corrective surgery. However, these studies did not take account of surgery stage as influencing factor for blood loss. In fact, the pattern of blood loss in corrective surgery was varied between different surgical stages. 3CO may be the biggest source of blood loss for scoliosis corrective surgery, even above 10L in some cases. We divided the whole surgery to four stages, and identified risk factors for each stage, facilitating performing more meticulous blood management.

Etiology significantly influences blood loss of scoliosis surgery^{13,16}. Operative treatment of AIS is typically associated with lower amounts of mean blood loss than surgical correction of scoliosis

secondary to an underlying neuromuscular disorder¹⁷. Patients with neuromuscular scoliosis may be predisposed to higher intraoperative blood loss by various other factors, including poor nutritional status, treatment with antiepileptic medications, altered connective tissue hemostatic and coagulation properties, qualitative platelet disorder, decreased venous tone, and osteopenic bone¹⁸. In our study, idiopathic scoliosis had less blood loss as compared to other types of scoliosis. Idiopathic scoliosis treated by 3CO always presented as a round kyphosis, and osteotomy site closure was easier. Complete closure of osteotomy and reduction of operative time can significantly reduce the amount of bleeding during 3CO.

We divided the whole surgical procedure to four stages: exposure, screw placement, osteotomy and rod installment and wound closure. At exposure stage, fusion level, main curve Cobb angle and use of TXA were influential factors. It is not surprised that long severe scoliosis would cost more time for exposure, which would increase blood loss. The efficacy of TXA on reducing blood loss has been widely accepted^{11,12}. TXA take effects at the beginning of surgery, significantly reducing blood loss of exposure. At screw placement stage, two factors determine the blood loss: number of placed screws and complexity of screw placement. Number of screws was positively correlated to fusion level, which was identified as an influential factor in our study. Extremely thin and deformed pedicles were frequently seen at neuromuscular and congenital scoliosis, which pose great challenges to surgeons. Surgeons often try several times when placing pedicle screws at these pedicles, and prolonged time for placement would significantly increase blood loss. In addition, intravertebral vein plexus were always damaged when pedicles were violated during pedicle placement, causing violent bleeding. O-arm based navigation system could greatly improve accuracy of screw placement deformed pedicles¹⁹. In our study, use of navigation system was negatively related to blood loss. We recommend using navigation system in difficult screw placement which would not only boost safety but also reduce blood loss. Highest blood loss was observed at osteotomy stage. The main source of bleeding was intervertebral venous plexus and bone surface of osteotomized vertebra²⁰. Our study demonstrated that kyphosis and use of bone scalpel were related to blood loss. More severe was kyphosis, more time was needed for osteotomy. Before closure of osteotomy site completed, bleeding from intervertebral venous plexus and bone surface continuously occurred. Ultrasonic bone scalpel could cut out laminae in a regular shape limiting the harassment to intervertebral venous plexus. Moreover, the friction between the bone scalpel blade and the bone is believed to reduce blood loss by sealing the cut bone through the heat emitted from the mechanical energy created by the rapid, repetitive movement of the scalpel^{9,21}. At the last stage, blood loss was determined by the completion of bone closure and length of incision. Bone closure in patients with large coronal curve was difficult, and blood would be continuously lost from incompletely closed bone surface.

There was no a well-accepted definition of massive blood loss. We defined massive blood loss as EBL more than 5000ml. Some surgeons advocated defining massive blood loss as EBL more than 30% of the estimated blood volume²²⁻²⁴. However, this definition was not suitable for our cohort, as most cases had EBLs from 1000 to 2000ml. Majority of patients in our cohort with abnormal blood loss had EBLs more than 5000 ml. No idiopathic scoliosis patient experienced massive blood loss. Highest blood loss was

observed in a patient with degenerative scoliosis, who had an EBL of 10100ml. The reason why so high blood loss occurred was that surgeon injured lumbar artery during osteotomy. The fierce bleeding was controlled by embolizing injured artery under DSA. For neuromuscular patients with massive blood loss, fierce bleeding started from stage A, while mainly at stage C and D for degenerative scoliosis. As stated, patients with neuromuscular scoliosis may be predisposed to higher intraoperative blood loss by various other factors, including poor nutritional status, treatment with antiepileptic medications, altered connective tissue hemostatic and coagulation properties, qualitative platelet disorder, decreased venous tone. For patients with degenerative scoliosis, higher blood loss was always caused by bleeding from bone surface due to osteoporosis and altered connective tissue hemostatic.

In conclusion, etiology significantly influences blood loss of scoliosis surgery with 3CO. Risk factors of blood loss were varied among different surgical stages. Use of TXA, navigation system and ultrasonic bone scalpel could reduce blood loss.

Tables

Table 1. Blood loss at each surgical stage for scoliosis with different etiologies

	Stage A (ml)	Stage B (ml)	Stage C (ml)	Stage D (ml)
Idiopathic	120	108	526	322
Congenital	142	252	795	504
Degenerative	224	172	742	440
Neuromuscular	307	206	829	470
Syndromic	285	275	726	393

Table 2. Characteristics of patients with massive blood loss

Etiology	Fusion level	Osteotomy level	Operation time (min)	EBL (Stage A)(ml)	EBL (Stage B)(ml)	EBL (Stage C)(ml)	EBL (Stage D)(ml)	EBL (Total)(ml)
neuromuscular	T2-S1	T12	310	800	500	2800	1400	5500
neuromuscular	T2-Pelvic	L1	380	1200	900	3000	2500	7600
neuromuscular	T1-S1	L2	430	800	600	1800	2400	5600
degenerative	T10-S2	L1	370	850	1500	2800	2100	7250
degenerative	T4-S2	L3	450	300	500	5500	3800	10100
degenerative	T3-S1	L2	420	200	150	3100	2400	5850
congenital	T4-L4	L1	480	450	600	3800	1000	5850
congenital	T1-L5	T12	410	300	900	2700	2000	5900
syndromic	T4-S1	L1	540	1000	900	2500	2300	6700

Table 3. Variables correlated to blood loss at each stage

	Stage A (r)	Stage B (r)	Stage C (r)	Stage D (r)
Fusion level	0.517*	0.432*	0.429*	0.399*
Operation time	0.533*	0.486*	0.471*	0.427*
Coronal Cobb angle	0.408*	0.514*	0.503*	0.586*
kyphosis	0.137	0.168	0.416*	0.594*
Use of TXA	-0.372*	-0.415*	-0.149	-0.227
Use of Ultrasonic bone scalpel	-	-0.225	-0.621*	-
Use of navigation system	--	-0.476*	-	-

Abbreviations

AIS: adolescent idiopathic scoliosis

ASD: adult spine deformity

SPO: Smith-Petersen osteotomy

PSO: pedicle subtraction osteotomy

VCR: vertebral column resection

EBL: estimated blood loss

3CO: three column osteotomy

TXA:Tranexamic acid

Declarations

Acknowledgements

We would like to thank all participating patients, and MS Zhang Linlin for radiograph collecting.

Funding

Not applicable.

Availability of data and material

The dataset supporting the conclusions of this article is available on request—please contact the corresponding author. Administrative permission was received from the Affiliated Drum Tower Hospital of Nanjing University Medical School to access the medical records.

Authors' contributions

QJ, XLL, LZ and SB reviewed radiographs. QJ and SX performed statistical analysis and drafted the manuscript. ZZ, and QB gave administrative and intellectual support. ZZ and YQ conceived the study, finalized the manuscript and is responsible. All authors read and approved the final manuscript.

Competing interests

Ze Zhang Zhu and Jun Qiao are members of the Editorial Board of BMC Musculoskeletal Disorder. The other authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

The Ethics Committee of the Affiliated Drum Tower Hospital of Nanjing University Medical School approved the study protocol. Written informed consent was obtained from all patients enrolled in the investigation. For the minors, written consent to participate was given by their parents on their behalf.

References

- 1.O'Neill KR, Lenke LG, Bridwell KH, Neuman BJ, Kim HJ, Archer KR. Factors associated with long-term patient-reported outcomes after three-column osteotomies. *Spine J.* 2015;15:2312–2318.
- 2.Hassanzadeh H, Jain A, El Dafrawy MH, Ain MC, Mesfin A, Skolasky RL, et al. Three-column osteotomies in the treatment of spinal deformity in adult patients 60 years old and older: outcome and complications. *Spine (Phila Pa 1976).* 2013;38:726–731.
- 3.Lewis SJ, Mohanty C, Gazendam AM, Kato S, Keshen SG, Lewis ND, et al. Posterior column reconstruction improves fusion rates at the level of osteotomy in three-column posterior-based osteotomies. *Eur Spine J.* 2018;27:636–643.
- 4.Qiao J, Xiao L, Sun X, Liu Z, Zhu Z, Qian B, et al. Three column osteotomy for adult spine deformity: comparison of outcomes and complications between kyphosis and kyphoscoliosis. *Br J Neurosurg.* 2018;32:32–36.

- 5.Auerbach JD, Lenke LG, Bridwell KH, Sehn JK, Milby AH, Bumpass D, et al. Major complications and comparison between 3-column osteotomy techniques in 105 consecutive spinal deformity procedures. *Spine (Phila Pa 1976)*. 2012;37:1198–1210.
- 6.Qiao J, Xiao L, Sun X, Shi B, Liu Z, Xu L, et al: Vertebral subluxation during three-column osteotomy in surgical correction of adult spine deformity: incidence, risk factors, and complications. *Eur Spine J*. 2018;27:630–635.
- 7.Fan H, Li X, Huang Z, Sun W, Yang J, Deng Y, et al. Radiologic Parameters Can Affect the Preoperative Decision Making of Three-Column Spinal Osteotomies in the Treatment of Severe and Stiff Kyphoscoliosis. *Spine (Phila Pa 1976)*. 2017;42:E1371–1379.
- 8.Fehlings MG, Kato S, Lenke LG, Nakashima H, Nagoshi N, Shaffrey CI, et al. Incidence and risk factors of postoperative neurologic decline after complex adult spinal deformity surgery: results of the Scoliosis-RISK-1 study. *Spine J*. 2018 Oct;18:1733–1740.
- 9.Hu X, Ohnmeiss DD, Lieberman IH. Use of an ultrasonic osteotome device in spine surgery: experience from the first 128 patients. *Eur Spine J*. 2013;22:2845–2849.
- 10.Tuchman A, Mehta VA, Mack WJ, Acosta FL Jr. Novel application of pre-operative vertebral body embolization to reduce intraoperative blood loss during a three-column spinal osteotomy for non-oncologic spinal deformity. *J Clin Neurosci*. 2015;22:765–767.
- 11.Johnson DJ, Johnson CC, Goobie SM, Nami N, Wetzler JA, Sponseller PD, et al. High-dose Versus Low-dose Tranexamic Acid to Reduce Transfusion Requirements in Pediatric Scoliosis Surgery. *J Pediatr Orthop*. 2017;37:e552–557.
- 12.Ohashi N, Ohashi M, Endo N, Kohno T. Administration of tranexamic acid to patients undergoing surgery for adolescent idiopathic scoliosis evokes pain and increases the infusion rate of remifentanyl during the surgery. *PLoS One*. 2017;12:e0173622.
- 13.Maher KM, Owusu-Akyaw K, Zhou J, Cooter M, Ross AK, Lark RK, et al. Analysis of the impact of race on blood transfusion in pediatric scoliosis surgery. *Paediatr Anaesth*. 2018;28:352–360.
- 14.Alamanda VK, Massengill DL, Rozario N, Moore CG, Scannell B, Brighton B, et al. Blood Loss Trends and Financial Implications in Adolescent Idiopathic Scoliosis. *Clin Spine Surg*. 2018;31:E418–421.
- 15.van Popta D, Stephenson J, Patel D, Verma R. The pattern of blood loss in adolescent idiopathic scoliosis. *Spine J*. 2014;14:2938–2945
- 16.Lyu Q, Zhou C, Song Y, Liu L, Wang L, Zhou Z. Does spinal deformity correction of non-dystrophic scoliosis in neurofibromatosis type I with one-stage posterior pedicle screw technique produce outcomes similar to adolescent idiopathic scoliosis? *Spine J*. 2017;17:1850–1858.

- 17.Jain A, Sponseller PD, Shah SA, Yaszay B, Njoku DB, Miyajima F, et al. Incidence of and Risk Factors for Loss of 1 Blood Volume During Spinal Fusion Surgery in Patients With Cerebral Palsy. *J Pediatr Orthop*. 2017;37:e484–487.
- 18.Hardesty CK, Gordon ZL, Poe-Kochert C, Son-Hing JP, Thompson GH. Bipolar Sealer Devices Used in Posterior Spinal Fusion for Neuromuscular Scoliosis Reduce Blood Loss and Transfusion Requirements. *J Pediatr Orthop*. 2018;38:e78–82.
- 19.Qiao J, Zhu F, Xu L, Liu Z, Sun X, Qian B, et al. Accuracy of pedicle screw placement in patients with Marfan syndrome. *BMC Musculoskelet Disord*. 2017;18:123.
- 20.Floyd CT, Padua RA, Olson CE. Hemostasis and Safety of a Novel Fibrin Dressing Versus Standard Gauze in Bleeding Cancellous Bone in a Caprine Spine Surgery Model. *Spine Deform*. 2017;5:310–313.
- 21.Bartley CE, Bastrom TP, Newton PO. Blood Loss Reduction During Surgical Correction of Adolescent Idiopathic Scoliosis Utilizing an Ultrasonic Bone Scalpel. *Spine Deform*. 2014;2:285–290.
- 22.Yu X, Xiao H, Wang R, Huang Y. Prediction of massive blood loss in scoliosis surgery from preoperative variables. *Spine (Phila Pa 1976)*. 2013;38:350–355.
- 23.Cristante AF, Borges PA, Barbosa AR, Letaif OB, Marcon RM, Barros Filho TE. Predictive factors for perioperative blood transfusion in surgeries for correction of idiopathic, neuromuscular or congenital scoliosis. *Clinics (Sao Paulo)*. 2014;69:672–676.
- 24.Jia R, Li N, Xu BY, Zhang W, Gu XP, Ma ZL. Incidence, influencing factors, and prognostic impact of intraoperative massive blood loss in adolescents with neuromuscular scoliosis: A STROBE-compliant retrospective observational analysis. *Medicine (Baltimore)*. 2017;96:e6292.