

PHARMACOLOGICAL AND NON-PHARMACOLOGICAL TECHNIQUES TO REDUCE PERIOPERATIVE BLOODLOSS IN SPINE DEFORMITY SURGERY: FINDINGS OF A NARRATIVE REVIEW¹Waleed Mohammad Awwad, ²Khalid Murrad, ^{3*}Rohail Mumtaz and ⁴Sultan Ayoub Meo¹MD, FRCSC, Associate Professor, ²MBBS, Resident, ³MBBS, MCPS (Surg), FCPS (Orth), Associate Consultant, ⁴MBBS, MSc, FRCS., Professor
^{1,2,3}Orthopedic Surgery Department, King Saud University, Riyadh, Saudi Arabia.
⁴King Saud University, Riyadh, Saudi Arabia.***Corresponding Author: Rohail Mumtaz**

MBBS, MCPS (Surg), FCPS (Orth), Associate Consultant, Orthopedic Surgery Department, King Saud University, Riyadh, Saudi Arabia.

Article Received on 26/04/2021

Article Revised on 16/05/2021

Article Accepted on 06/06/2021

ABSTRACT

Introduction: Due to the increased complexity of spinal procedures performed to correct the deformities, there is a likelihood of more blood loss with most spinal procedures, which leads surgeons to devise some strategies to reduce the blood loss. The evidence from various studies reveals that different pharmacological and non-pharmacological strategies could be used to reduce blood loss among these adolescent patients. We aimed to review and synthesize the available literature on various techniques to reduce blood loss among such patients. **Methods:** We carried out an electronic search in Google Scholar and PubMed. We considered a study eligible if it was an original research study, published in English from 2010 to 2020, and had provided information on the various techniques and strategies to reduce blood loss during and after spinal surgery. **Results:** This review provided novel insights into the efficacy and safety of various pharmacological and non-pharmacological techniques in reducing blood loss perioperatively. We found pharmacological methods such as PEAK Plasmablate, use of tranexamic acid regardless of its dosage and modes of administration, blood transfusion, and non-pharmacological techniques such as preservation of spinous process, having two surgeons performing the surgery instead of one, screening of anemia before surgery, and a technique known as minimally invasive scoliosis surgery can reduce the perioperative complications, mainly blood loss, among patients indicating posterior spinal fusion surgery due to idiopathic scoliosis among adolescents. **Conclusion:** The findings of the review reveal that there is the benefit of using both non-pharmacological and pharmacological techniques to reduce blood loss. A comprehensive strategy with an interdisciplinary and multi-pronged approach is required to reduce blood loss during and after the spinal surgeries performed for deformities among adolescents.

KEYWORDS: Spinal surgery, deformity, strategies to reduce blood loss, Narrative review.**INTRODUCTION**

The frequency of spinal surgeries is on the rise for the past few years mostly in the developed countries such as the United States.^[1] Due to the increased complexity of procedures, there is a likelihood of more blood loss with most of the spinal procedures, which leads surgeons to devise some strategies to reduce the blood loss.^[2, 3] In addition, there are numerous disadvantages of blood loss during surgery such as inadequate visibility of the operation field, lengthier surgical time, prolonged hospital stays, and these, in turn, may affect the quality of life of patients.^[4, 5] These reasons for perioperative blood loss during deformity surgeries prepare surgeons to make necessary arrangements before surgery. Therefore, surgeons may need to ensure arranging blood transfusion in spinal surgeries to treat deformities such as idiopathic scoliosis.^[6] This is because the amount of

blood loss could be a lot depending upon the type of deformity. For instance, surgical procedures for idiopathic scoliosis (posterior spinal instrumentation and fusion surgery) may result in loss of blood as minimum as 800 ml and maximum as 1514 ml.^[7, 8] This loss might reach the limit of 4500ml in intricate pediatric spine surgery.^[9]

The evidence suggests an appreciable percentage of need for blood transfusion after deformity surgeries ranging between 8 to 30%.^[10, 11] Aside from the type of surgery, surgical technique, time of surgery, and stage of surgery, certain demographic characteristics such as age, gender, and extent of surgical complications also determine the blood loss, thereby increase the need for blood transfusion and other modalities for the fast recovery of the patients.^[8] Although blood transfusion and other

pharmacologic and nonpharmacologic blood-saving modalities have been used to decrease blood loss, there are complications associated with all procedures.^[12-14] For instance, blood transfusion can lead to some complications such as transfusion-related reactions, propensity to acquire transfusion-related infections, and immunosuppression.^[12, 13] Such consequences will increase the stay of patients in the hospital, which in turn will increase the cost for the patients.^[15,16] Given this, it is the responsibility of the surgeons to make necessary arrangements prior to surgery and during the surgery that could help reduce the loss of blood during and after the procedure. Although several techniques have been proposed in individual studies that may help to lessen the perioperative loss of blood while performing spinal surgery, the findings of those studies are not reviewed and synthesized. Therefore, we aimed to undertake a narrative review of the studies that have assessed the suitable pre and intraoperative techniques to reduce the loss of blood while performing spine surgery.

MATERIALS AND METHODS

Various databases including PubMed, Science Direct, and Google Scholar were searched. For this narrative review, comprehensive searches such as controlled vocabulary and text-word searches were conducted by the authors in various databases mentioned above. The research studies that were published to assess the efficacy and safety of various pharmacological and non-pharmacological techniques to reduce blood loss while performing deformity surgeries were included. Besides, we restricted our inclusion criteria to publishing year from 2010 to 2020 and all those articles that were published in English language and assessed the efficacy in human studies across the world. Only primary and original full-text articles were examined that were relevant to the objective of interest. All research studies in different databases were searched by applying specific keywords in the search engine. For example, such searching words or sentences included 'How to lessen the loss of blood during spinal surgery', 'methods to decrease blood loss while performing deformity surgeries,' 'blood loss and deformity surgery', 'efficacy and safety of various techniques to reduce the blood loss' and "how to avoid loss of blood in deformity surgery". Search in the mentioned electronic databases was followed up using a specific technique known as snowball sampling that included searching of references in a backward and forward way to identify the articles that fulfilled the eligibility criteria. Further, the references of the eligible article were also examined to not miss any pertinent articles that met the objective of the review. After searching for different databases and following the above criteria, 9 studies having full-text articles were reviewed and included in this review.

Findings of the narrative review

A study was conducted by Piazzolla *et al.* where they evaluated the efficacy of PEAK Plasmablade and contrasted the same with bipolar sealer and basic

electrocautery during the spinal procedure performed for idiopathic scoliosis among adolescents in a randomized controlled trial.^[17] Authors found a substantial decrease in the total period for surgery (p-value: 0.0087), a substantial reduction in the blood loss during surgery (p-value: 0.001), which in turn resulted in higher levels of hemoglobin (p:0.01) after the surgery. The authors concluded that PEAK Plasmablade is successful in lessening the blood loss while performing the surgery for idiopathic scoliosis when compared to the other standard methods.^[17]

Likewise, Nissen *et al.* aimed to assess the benefit of transfusing blood and the efficacy of standard perioperative patient blood management program including tranexamic acid prophylaxis, and restrictive fluid therapy such as restriction of artificial colloids among patients managed with posterior instrumented fusion.^[18] According to the researchers, patients who received blood transfusion had reduced levels of hemoglobin (Hb).^[18] Further, they found that determinants of blood transfusion included an amount of estimated loss of blood, hemoglobin levels prior to surgery, and year of surgery (18). Authors found this perioperative blood management program effective in reducing the necessity of red blood transfusion and it was found that proper screening of patients for anemia before the surgery is critical in reducing the need of blood transfusion perioperatively.^[18]

Similarly, a recently conducted a randomized controlled trial (RCT) assessed the efficiency of tranexamic acid (multiple doses) in decreasing the loss of blood after scoliosis surgery among adolescents.^[19] The authors found a substantial decrease in the mean loss of blood after surgery among patients who were given tranexamic acid regardless of its dose.^[19] They also found a substantial reduction in the total loss of blood and improvement in Hb levels among patients who received tranexamic acid. Overall, the authors found that tranexamic acid with multiple doses is safe and effective in managing post-operative blood loss regardless of route of administration.^[19]

Butler *et al.* conducted an observational study to assess the effectiveness of tranexamic acid in decreasing the loss of blood, the proportion of the total volume of the loss of blood, and the requirement for transfusing the blood to adolescents who underwent idiopathic scoliosis surgery.^[20] The authors found that the proportion of blood loss was substantially reduced among cases (adolescent patients who received tranexamic acid) (p-value: <0.05) as opposed to the control group. Authors overall found that tranexamic acid is useful in lessening the proportion of total of loss blood by 30% among cases than controls.^[20] In addition, El-Sharkawi conducted a prospective randomized controlled trial to assess the influence of topical against parenteral tranexamic acid on the loss of blood loss while performing a spinal deformity surgical procedure.^[21] The author did not find

any substantial differences in the loss of blood while performing the surgery among those who received topical tranexamic acid as opposed to those who received intravenous tranexamic acid; however, intraoperative blood loss was substantially reduced among patients either receiving parenteral or topical tranexamic acid as opposed to those who received no tranexamic acid.^[21] The study revealed that tranexamic acid can be effective in reducing blood loss regardless of its mode of administration and topical tranexamic acid is as efficacious as intravenous tranexamic acid.^[21]

Arun-Kumar et al undertook an RCT to assess the effectiveness of tranexamic acid in decreasing the loss of blood via various modes of administration (intravenous (IV), local infiltration, and topical) in spinal surgeries for deformities on 104 patients(22). The authors found that all of the modes were effective in decreasing blood loss. More specifically, the reduction of blood loss was 67% in the topical group, 33% in local, 55.5% in the IV group.^[22] Po-Liang Lai et al. undertook a research to compare the rate of fusion, duration of surgery, volume of loss of blood among harvesting versus conserving the spinous process among adolescents undergoing a surgical procedure for idiopathic scoliosis.^[23] Authors found no statistically significant difference among the randomized arms, except the loss of blood that was higher in the arm of harvesting than the group of preserving (p:0.048) and also the reduced pain in the back in the latter than former (p:0.03). The authors concluded that resection of the spinous process as bone graft might not be required while performing the surgical procedure (posterior fusion) of idiopathic scoliosis among adolescents.^[23]

Apart from pharmacological approaches, researchers have also assessed the impact of one versus two surgeons in reducing blood loss after surgery. For example, a study by Kwan et al. compared the loss of blood during surgery at various phases of surgery and compared the one versus two surgeons.^[24] The authors demonstrated that among patients that underwent surgical procedure for adolescent idiopathic scoliosis (posterior fusion of spine), there was less volume of blood loss, lower risk of transfusing blood, and reduced time of surgery among those where two surgeons performed the surgery as opposed to one.^[24] One study also assessed the role of a special technique known as minimally invasive scoliosis surgery on perioperative outcomes such as hospital stay and blood loss. The authors analyzed the data of around 84 patients that were collected prospectively either with minimally invasive scoliosis surgery technique or muscle splitting approach.^[25] Authors found a reduction in an estimated loss of blood and hospital stay with proper technique as opposed to the latter and recommended to use minimally invasive scoliosis surgery technique to reduce the complications such as blood loss.^[25]

Other considerations to reduce perioperative blood loss in spine deformity surgery

Mean arterial blood pressure

There is always discussion about mean arterial blood pressure between the person who performs the surgery and the one who gives anesthesia. There should be a balance between demands of the vital organs for blood and a request of surgeon to keep the mean arterial blood pressure (MAP) lower as high MAP can lead to increased higher intra-operative blood loss. The existing evidence suggests that keeping MAP to 65mm Hg or less can lead to reduction in the blood loss by 33%.^[26] However, such lower MAP might increase the probability of poor perfusion to spinal cord particularly when there is previous injury of spinal cord.^[27] To avoid this, it is imperative to carry out intra-operative neuromonitoring to detect the hypoperfusion of spinal cord, thereby permanent neurological deficits.^[28] Although MAP of less than or equal to 70mmHg could be considered as appropriate, it is recommended to maintain MAP above 80mmHg during the manipulation of neural elements to reduce the probability of ischemia mainly for patients with vascular diseases or other comorbid such as stroke, chronic renal failure, and Diabetes.^[28]

Controlled Hypotension

This implies to reduce the systolic blood pressure to 80 to 90mmHg, decreased MAP to 50-65 mmHg or 30% reduction in the baseline MAP. This is done to reduce the blood loss while performing the surgery. The existing evidence suggests applying controlled hypotension with a MAP of 60 to 65mmHg to mitigate the blood loss.^[29] This is usually done as a part of intra-operative procedure to restrict allogenic requirements of transfusion.^[30]

Pre-operative hemoglobin

Since there is always a probability that patient might lose a reasonable amount of blood during surgery, it is crucial to correct the anemia prior to surgery to avoid complications. Generally, patients should be advised to get their hemoglobin checked three to four weeks before the surgery and anemic patients with a hemoglobin (Hb) of less than 11gm/dl should be optimized using appropriate therapies such as iron supplementation or blood transfusion if necessary(6). This is because hemoglobin concentration is an important factor that helps surgeons to decide when and to what extent the blood transfusion should be done. Furthermore, levels of pre-operative hemoglobin guide for post or intra-operative blood transfusion if required. For instance, patients with a Hb of less than 11 gm/dl are about 50-fold higher risk of transfusion than the ones with Hb of > 14gm/dl.^[6]

Curve Magnitude

The curve is described as the Cobb angle of the main curve and is usually measured pre-operatively and as several time points after the surgery. In addition to the

other factors such as surgical expertise, pre-op Hb, time of surgery, curve magnitude also predicts the risk of blood transfusion.^[18] The magnitude of curve (measured by Cobb) also predicts for the blood transfusion and the studies reveal that the likelihood of transfusion increases by three times with a Cobb angle of 70° to 80°.^[6] Moreover, patients with a Cobb angle of more than 80 degree at a 5-fold increased risk of transfusion. This informs surgeons to perform surgery as soon as curve's angle become 50 degree instead of waiting for further progression of curve.^[6]

Technique for facetectomy and decortication

Facetectomy is a surgical technique to release the pressure on the roots of the spinal nerve near to the facet joint when pharmacological treatment does not help to control pain. While performing facetectomy, one of the expert surgeons makes small incision to uncover the spine. During that time, it might be required to perform laminotomy to remove the lamina partially in order to reach the facet joint. After reaching to the facet joint, the smallest amount of either one or both joints is removed to release the pressure on the roots of pinched spinal nerves. After nerve roots are relaxed, the procedure is completed by closing the incision. The facetectomies may be performed at all levels to improve the flexibility and to assist in the spinal fusion.

DISCUSSION

Loss of blood while performing surgical procedures (posterior spinal fusion) for idiopathic scoliosis among adolescents can be substantial. The management of perioperative blood loss has become a crucial area of interest for surgeons dealing with spinal surgeries. Several techniques including pharmacological and non-pharmacological have been reported that evaluate the effectiveness and safety of such techniques to reduce complications mainly blood loss in a cost-effective way.^[28] It seems that both pharmacological and non-pharmacological techniques are required to overcome the issues of perioperative complications that could be possible due to the intricate nature of surgery for deformities of the spine. For example, this review provided novel insights into the efficacy and safety of various pharmacological and non-pharmacological techniques in reducing blood loss perioperatively.

Pharmacological techniques such as PEAK Plasmablate, use of tranexamic acid regardless of its dosage and modes of administration, red blood cells transfusion, and non-pharmacological techniques such as preservation of spinous process, having two surgeons performing the surgery instead of one, screening of anemia before surgery, and a technique known as minimally invasive scoliosis surgery can reduce the perioperative complications, mainly loss of blood among patients undergoing a surgical procedure for adolescent idiopathic scoliosis. The findings regarding no difference in various modes of administration for tranexamic acid are supported by similar evidence in the literature, which

was further endorsed by the findings of the current review.^[31] This narrative review provided a pathway about how to approach a patient with idiopathic scoliosis and what safety measures need to be undertaken to lessen the loss of blood in spinal surgery.

The findings of the review are consistent with the literature, which favors for an integrated and multi-pronged approach such as a team of surgeons and other health care professional is required to address the issue of blood loss and to provide a high quality of care.^[32] In addition to the above-mentioned techniques, the literature also focuses on the pattern of blood loss that needs to be evaluated by surgeons at various stages of surgery. Such evaluation may help surgeons to devise a strategy to manage the perioperative complications as evidenced in the literature.^[33] For example, the literature not only highlights the importance of pharmacological and non-pharmacological techniques but there is evidence that periapical surgeons that perform osteotomies increased the chances of blood loss without any improvement.^[34] This in turn increased the unnecessary need for a transfusion, which suggests that factors other than patient-related demographic or clinical characteristics should also be kept in mind while performing the spinal surgeries.^[34]

There is one more ambiguity among surgeons to use or not use the wound drains after surgery as they may reduce some complications. Although the surgeons in their practice have a tendency to use such drains, there is no research based evidence that could support the use of such drains to improve the outcomes after surgery.^[35, 36] Besides, there are no standard guidelines to use wound drains and there is wide discrepancy and controversy about the usage of drains practically.^[37] However, this is an area of interest that need to be explored in the future.

Apart from these considerations, preservation of spinous process has also been evaluated to assess the effect on blood loss. It appears that existing literature suggests preserving the spinous process in order to prevent the blood loss during surgery. Although other surgical outcomes between harvesting and preserving the spinous process seem to be comparable, there is significant lower blood loss and a lower degree of pain when spinous process is preserved. Therefore, harvesting the spinous process and use the same as local bone graft might not be required in posterior fusion for adolescents' patients with idiopathic scoliosis.

CONCLUSION

The findings of the review reveal that there is benefit of using both non-pharmacological and pharmacological techniques to reduce the blood loss. A comprehensive strategy with interdisciplinary and multipronged approach is required to reduce the blood loss during and after the spinal surgeries performed for deformities among adolescents. Surgeons need to evaluate the patients for anemia and other patient related factors that

might influence the perioperative complications after performing the spinal surgery. There is no one magic solution that can work for all patients to reduce the blood loss because of independent nature of patients, their age, co-morbid. However, this review has provided a pathway to surgeons about various pharmacological and non-pharmacological strategies that should be kept in mind to aim for decreasing the loss of blood in spinal surgical procedure.

ACKNOWLEDGMENT

The authors are thankful to the Deanship of Scientific Research, King Saud University, Riyadh, Saudi Arabia, for supporting the work through a research group project (RGP-VPP 181).

REFERENCES

- Rajae SS, Bae HW, Kanim LE, Delamarter RB. Spinal fusion in the United States: analysis of trends from 1998 to 2008. *Spine*, 2012; 37(1): 67-76.
- Bible JE, Mirza M, Knaub MA. Blood-loss Management in Spine Surgery. *The Journal of the American Academy of Orthopaedic Surgeons*, 2018; 26(2): 35-44.
- Pauyo T, Verma N, Marwan Y, Aoude A, Khashan M, Weber MH. Canadian Consensus for the Prevention of Blood Loss in Spine Surgery. *Spine*, 2017; 42(1): E50-e5.
- Meert KL, Kannan S, Mooney JF. Predictors of red cell transfusion in children and adolescents undergoing spinal fusion surgery. *Spine*, 2002; 27(19): 2137-42.
- Kwan MK, Chiu CK, Chan CY. Single vs two attending senior surgeons: assessment of intraoperative blood loss at different surgical stages of posterior spinal fusion surgery in Lenke 1 and 2 adolescent idiopathic scoliosis. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 2017; 26(1): 155-61.
- Soliman HAG, Beausejour M, Joncas J, Roy-Beaudry M, Barchi S, Mac-Thiong JM, et al. Predicting lowest hemoglobin level and risk of blood transfusion in spinal fusion surgery for adolescent idiopathic scoliosis. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 2019; 28(6): 1342-8.
- Szpalski M, Gunzburg R, Sztern B. An overview of blood-sparing techniques used in spine surgery during the perioperative period. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 2004; 13 Suppl 1(Suppl 1): S18-27.
- Hu SS. Blood loss in adult spinal surgery. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 2004; 13 Suppl 1(Suppl 1): S3-5.
- Shapiro F, Sethna N. Blood loss in pediatric spine surgery. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 2004; 13 Suppl 1(Suppl 1): S6-17.
- Basques BA, Anandasivam NS, Webb ML, Samuel AM, Lukasiewicz AM, Bohl DD, et al. Risk Factors for Blood Transfusion With Primary Posterior Lumbar Fusion. *Spine*, 2015; 40(22): 1792-7.
- Butler JS, Burke JP, Dolan RT, Fitzpatrick P, O'Byrne JM, McCormack D, et al. Risk analysis of blood transfusion requirements in emergency and elective spinal surgery. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 2011; 20(5): 753-8.
- Janssen SJ, Braun Y, Wood KB, Cha TD, Schwab JH. Allogeneic blood transfusions and postoperative infections after lumbar spine surgery. *The spine journal : official journal of the North American Spine Society*, 2015; 15(5): 901-9.
- Schwarzkopf R, Chung C, Park JJ, Walsh M, Spivak JM, Steiger D. Effects of perioperative blood product use on surgical site infection following thoracic and lumbar spinal surgery. *Spine*, 2010; 35(3): 340-6.
- Cheriyian J, Cheriyian T, Dua A, Goldstein JA, Errico TJ, Kumar V. Efficacy of intraoperative cell salvage in spine surgery: a meta-analysis. *Journal of neurosurgery Spine*, 2020: 1-9.
- Blanchette CM, Wang PF, Joshi AV, Asmussen M, Saunders W, Kruse P. Cost and utilization of blood transfusion associated with spinal surgeries in the United States. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 2007; 16(3): 353-63.
- Purvis TE, Goodwin CR, De la Garza-Ramos R, Ahmed AK, Lafage V, Neuman BJ, et al. Effect of liberal blood transfusion on clinical outcomes and cost in spine surgery patients. *The spine journal : official journal of the North American Spine Society*, 2017; 17(9): 1255-63.
- Piazzolla A, Bizzoca D, Solarino G, Parato C, Moretti B. Plasma Technology Reduces Blood Loss in Adolescent Idiopathic Scoliosis Surgery: A Prospective Randomized Clinical Trial. *Global spine journal*, 2020: 2192568220928344.
- Ohrh-Nissen S, Bukhari N, Dragsted C, Gehrchen M, Johansson PI, Dirks J, et al. Blood transfusion in the surgical treatment of adolescent idiopathic scoliosis-a single-center experience of patient blood management in 210 cases. *Transfusion*, 2017; 57(7): 1808-17.
- Zhang Z, Wang LN, Yang X, Liu LM, Xiu P, Zhou

- ZJ, et al. The effect of multiple-dose oral versus intravenous tranexamic acid in reducing postoperative blood loss and transfusion rate after adolescent scoliosis surgery: a randomized controlled trial. *The spine journal : official journal of the North American Spine Society*. 2021; 21(2): 312-20.
20. Butler E, Garber T, Ledonio C, Polly DW, Cohn C. Tranexamic Acid Administration in Adolescent Idiopathic Scoliosis Surgery Reduces% Total Blood Volume Loss. *Global spine journal*, 2016; 6(1_suppl): s-0036-1582779-s-0036-.
 21. El-Sharkawi M, Sayed S, Gad W, El-Meshtawy M. Effect of Topical versus Parental Tranexamic Acid on Blood Loss in Spinal Deformity Surgery. A Prospective Randomized Controlled Trial. *Global spine journal*, 2016; 6(1_suppl): s-0036-1582659-s-0036-.
 22. Arun-Kumar V, Naresh-Babu J. Is There a Role for Preoperative Local Infiltration of Tranexamic Acid in Elective Spine Surgery? A Prospective Randomized Controlled Trial Analyzing the Efficacy of Intravenous, Local Infiltration, and Topical Administration of Tranexamic Acid. *Global spine journal*, 2021; 11(1): 21-7.
 23. Lai P-L, Yeh Y-C, Niu C-C, Chen L-H, Chen W-J. Should the Spinous Process be Harvested as Bone Graft in Idiopathic Scoliosis Surgery? *Global spine journal*, 2016; 6(1_suppl): s-0036-1582681-s-0036-.
 24. Kwan MK, Chiu CK, Chan CYW. Single vs two attending senior surgeons: assessment of intraoperative blood loss at different surgical stages of posterior spinal fusion surgery in Lenke 1 and 2 adolescent idiopathic scoliosis. *European Spine Journal*, 2017; 26(1): 155-61.
 25. Yang JH, Chang D-G, Suh SW, Damani N, Lee H-N, Lim J, et al. Safety and effectiveness of minimally invasive scoliosis surgery for adolescent idiopathic scoliosis: a retrospective case series of 84 patients. *European Spine Journal*, 2019; 1-9.
 26. Verma K, Lonner B, Dean L, Vecchione D, Lafage V. Reduction of Mean Arterial Pressure at Incision Reduces Operative Blood Loss in Adolescent Idiopathic Scoliosis. *Spine deformity*, 2013; 1(2): 115-22.
 27. Kamel I, Zhao H, Koch SA, Brister N, Barnette RE. The Use of Somatosensory Evoked Potentials to Determine the Relationship Between Intraoperative Arterial Blood Pressure and Intraoperative Upper Extremity Position-Related Neurapraxia in the Prone Surrender Position During Spine Surgery: A Retrospective Analysis. *Anesthesia and analgesia*, 2016; 122(5): 1423-33.
 28. Mikhail C, Pennington Z, Arnold PM, Brodke DS, Chapman JR, Chutkan N, et al. Minimizing blood loss in spine surgery. *Global spine journal*, 2020; 10(1_suppl): 71S-83S.
 29. Bali Ç, Güler Üö. Evaluation Of The Effectiveness And Reliability of Low-Dose Tranexamic Acid Used In Adolescent Idiopathic Scoliosis Surgery, 2021.
 30. Martin DP, Samora WP, Beebe AC, Klamar J, Gill L, Bhalla T, et al. Analgesic effects of methadone and magnesium following posterior spinal fusion for idiopathic scoliosis in adolescents: a randomized controlled trial. *Journal of anesthesia*, 2018; 32(5): 702-8.
 31. Winter SF, Santaguada C, Wong J, Fehlings MG. Systemic and Topical Use of Tranexamic Acid in Spinal Surgery: A Systematic Review. *Global spine journal*, 2016; 6(3): 284-95.
 32. Borden TC, Bellaire LL, Fletcher ND. Improving perioperative care for adolescent idiopathic scoliosis patients: the impact of a multidisciplinary care approach. *Journal of multidisciplinary healthcare*, 2016; 9: 435-45.
 33. Chiu CK, Chan CYW, Aziz I, Hasan MS, Kwan MK. Assessment of intraoperative blood loss at different surgical stages during posterior spinal fusion surgery in the treatment of adolescent idiopathic scoliosis. *Spine*, 2016; 41(9): E566-E73.
 34. Koerner JD, Patel A, Zhao C, Schoenberg C, Mishra A, Vives MJ, et al. Blood loss during posterior spinal fusion for adolescent idiopathic scoliosis. *Spine*, 2014; 39(18): 1479-87.
 35. Ovadia D, Drexler M, Kramer M, Herman A, Lebel DE. Closed wound subfascial suction drainage in posterior fusion surgery for adolescent idiopathic scoliosis: a prospective randomized control study. *Spine*, 2019; 44(6): 377-83.
 36. Diab M, Smucny M, Dormans JP, Erickson MA, Ibrahim K, Lenke LG, et al. Use and outcomes of wound drain in spinal fusion for adolescent idiopathic scoliosis. *Spine*, 2012; 37(11): 966-73.
 37. Waly F, Alzahrani MM, Abduljabbar FH, Landry T, Ouellet J, Moran K, et al. The Outcome of Using Closed Suction Wound Drains in Patients Undergoing Lumbar Spine Surgery: A Systematic Review. *Global spine journal*. 2015; 5(6): 479-85.