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Efficacy of a problem, intervention, control, and outcomes (PICO)-based perioperative blood management plan developed for patients undergoing long-segment lumbar spine posterior surgery

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Abstract

Background This study aimed to develop and evaluate the effectiveness of a perioperative blood management plan based on the problem, intervention, control, and outcomes (PICO) model for long-segment lumbar spine posterior surgery.

Methods In this retrospective study, 51 patients who needed long-segment posterior lumbar spine surgery at the Second Affiliated Hospital of Nantong University Department of Spinal Surgery from July 2020 to June 2022 were included in the control group, while 51 patients who needed long-segment posterior lumbar spine surgery from July 2021 to June 2022 were selected as the observation group. Patients in the control group received conventional blood management, while those in the observation group were additionally administered an evidence-based perioperative blood management plan. We compared the intervention outcomes in both the groups.

Results Patients in the observation group demonstrated significantly higher postoperative hemoglobin levels and hematocrit at various time points compared to those in the control group ($P < 0.05$). Intraoperative blood loss, postoperative drainage volume, and average volume of allogeneic blood transfused per recipient, as well as the number and frequency of allogeneic blood transfusions, were significantly lower in the observation group ($P < 0.05$). The duration of surgical drain placement and postoperative hospital stay were notably shorter in the observation group ($P < 0.05$). The two groups did not differ significantly in the incidence of postoperative venous thromboembolism (VTE) ($P > 0.05$).

Conclusion The implementation of a perioperative blood management plan was effective in reducing the total blood loss and transfusion volume in the perioperative period, improving hemoglobin and hematocrit levels, facilitating earlier removal of surgical drains, and accelerating patient discharge.

Keywords Blood management, Evidence-based, Lumbar spine, Long-segment surgery, Perioperative

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Background

Long-segment lumbar spine posterior surgery is a common surgical approach for treating multi-segment degenerative diseases of the lumbar spine [1]. This procedure involves extensive dissection of paravertebral muscles, intervertebral bone bleeding, and bleeding from the spinal venous plexus, which can lead to substantial blood loss [2], often ranging from 1000 to 2000 mL [3]. International studies estimate the incidence of preoperative anemia in patients undergoing spinal surgery to be around 24%, with preoperative anemia and intraoperative and postoperative blood loss contributing to a substantial rate of postoperative acute anemia of up to 51%. Postoperative hemoglobin levels can decrease by 30 to 46 g/L, increasing the risk of postoperative infections and other complications [4, 5]. While allogeneic blood transfusion remains a strategy for correcting anemia, it carries inherent risks of virus transmission and infection [6].

Perioperative blood management involves several techniques employed at various stages of the surgical period to maintain blood quality and quantity. It aims to address preoperative and postoperative anemia, reduce intraoperative blood loss, and consequently minimize transfusions and complications, thereby enhancing patient safety [7]. Current domestic and international approaches to blood management focus primarily on optimizing surgical techniques, intraoperative use of tranexamic acid, and postoperative iron supplementation. However, the use of a comprehensive blood management plan throughout the entire process is still not very prevalent.

PICO (patient/problem, intervention, comparison, and outcomes) is a problem development tool commonly used in clinical research and nursing practice. Its core elements are population (P), intervention (I), control group or another comparable intervention (C) and outcome/observation effect index (C). The PICO model is a model of evidence-based medicine to construct clinical problems [8], which is widely used in clinical, nursing, occupational diseases, and other medical fields [9], and it is also the core problem of obtaining scientific core evidence [10–12].

In this study, we developed and validated a perioperative blood management plan for patients undergoing long-segment lumbar spine posterior surgery based on the problem, intervention, control, and outcomes (PICO) model, and the findings are reported in the following sections.

Materials and methods

General information

Based on a two-sample mean comparison, we calculated the required sample size N using the formula $N=2^{*}[(\mu_\alpha+\mu_\beta)\sigma/\delta]^2$. Here, N represents the sample size needed for each group, typically equal in number. Setting α at 0.05 and β at 0.10, values for $\mu_\alpha=1.645$ and $\mu_\beta=1.282$ were obtained from standard tables. The literature review and calculations indicated that $N=48$. Considering a 5% non-response rate, a minimum of 51 cases in each group was required, thus resulting in at least 102 cases. Based on these calculations, we used convenience sampling to select the definite diagnosis of lumbar disc herniation, lumbar spinal stenosis, lumbar spondylolisthesis, and lumbar degenerative scoliosis from July 2020 to June 2022 in the Department of Spinal Surgery of the Second Affiliated Hospital of Nantong University. This retrospective study included 102 patients who needed long-segment posterior lumbar surgery as the research object. All patients have symptoms of low back and leg pain, but after 6–12 weeks of regular conservative treatment, the pain is serious, affecting work and life, or nerve damage of lower limbs, or symptoms of cauda equina compression.

Inclusion criteria were: (1) patients undergoing their first surgery of ≥ 3 fused segments, including decompression, internal fixation, and fusion, with or without spinal deformity; (2) patients with a preoperative hemoglobin (Hb) ≥ 90 g/L, normal coagulation function, and platelet count; (3) patients with no history of preoperative blood transfusion.

Exclusion criteria were: (1) patients with coexisting chronic hemorrhagic or hematologic diseases; (2) patients with concurrent chronic renal failure or cirrhosis; (3) patients on antiplatelet therapy that could not be suspended; (4) patients with thrombotic diseases, such as cerebral infarction or atrial fibrillation.

The study was approved by the Ethics Committee of the First People's Hospital of Nantong (Approval No. 2020KT078). We obtained informed consent from all patients and their families. A comparison of general information between the two groups showed no significant statistical difference ($P>0.05$). Details are shown in Table 1.

Intervention methods

The same team of physicians performed the surgery for both the groups of patients. During the procedure, patients were positioned prone and underwent endotracheal intubation under general anesthesia. The surgical approach involved posterior decompression, bone graft fusion, and internal fixation surgery of the lumbar spine. Notably, autologous iliac bone grafting was not performed in either group. A flowchart showing the clinical workflow for both the observation and control groups is shown in Fig. 1. The differential interventions received by the two groups are displayed in Supplementary Table S1.

Table 1 Comparison of general data between the two group

Group	Cases	Gender (male/female)	Age (years, $\pm\bar{x}s$)	BMI (kg/m^2, $\pm\bar{x}s$)	Duration of surgery (min, $\bar{x}\pm s$)	Number of fused segments ($\bar{x}\pm s$)	Smoking (yes/no)	Alcohol use (yes/no)	Preoperative use of anticoagulants (yes/no)	Comorbid diseases (yes/no)
Observation group	51	30/21	57.29 ± 12.33	23.25 ± 3.60	245.59 ± 59.39	3.33 ± 0.62	16/35	21/30	1/50	22/29
Control group	51	27/24	58.88 ± 11.95	23.23 ± 3.68	255.88 ± 57.39	3.45 ± 0.70	14/37	17/34	1/50	23/28
t/χ2 value	_	0.36	−0.66	0.02	−0.89	−0.90	0.19	0.67	0.00	0.04
P value	_	0.55	0.51	0.98	0.38	0.37	0.66	0.41	1.00	0.84

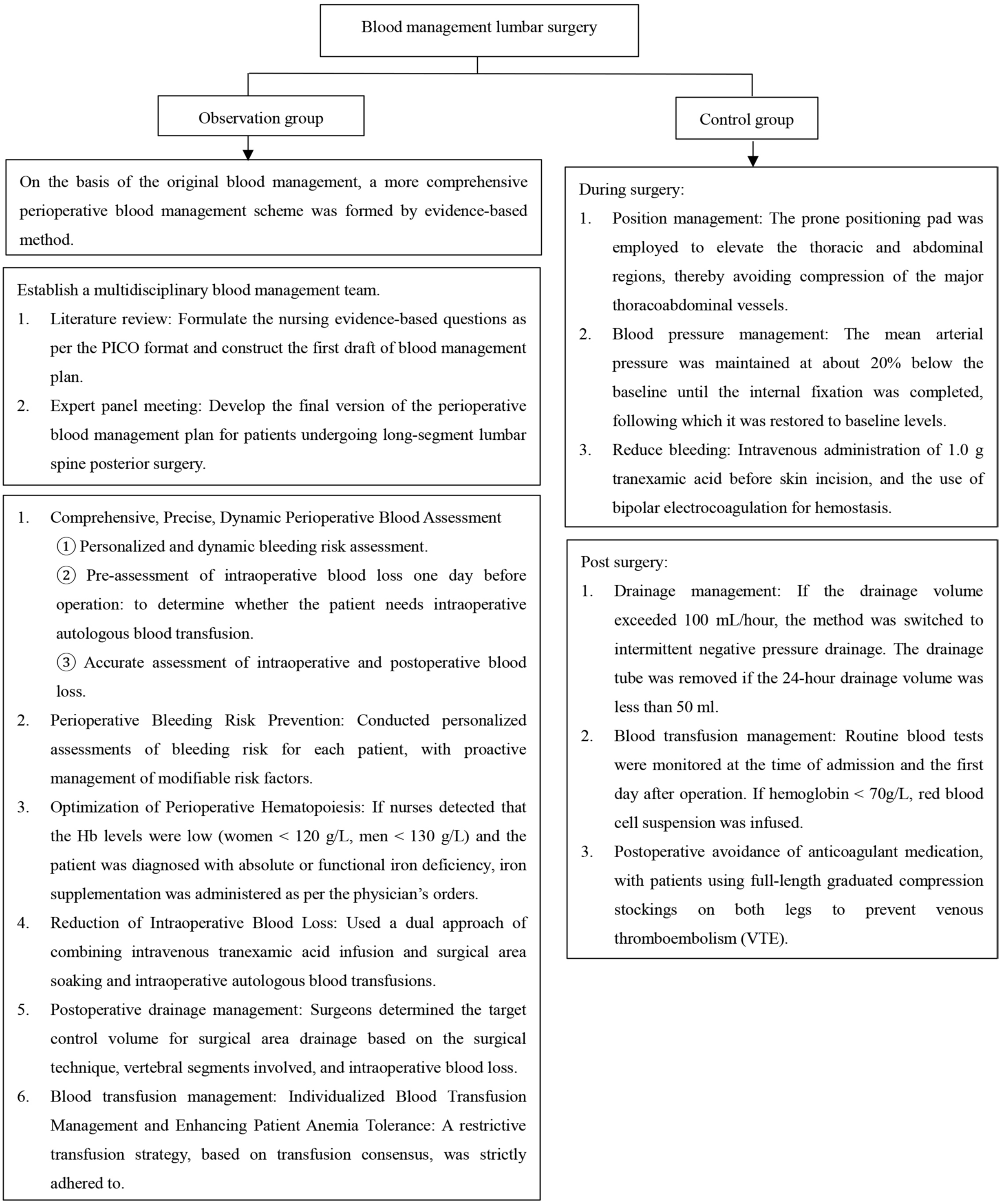

Fig. 1 Clinical workflow for both the observation and control groups

In the control group, we used a conventional perioperative blood management plan. During surgery, the prone positioning pad was employed to elevate the thoracic and abdominal regions, thereby avoiding compression of the major thoracoabdominal vessels. This approach decreased the pressure in the spinal venous plexus, consequently reducing bleeding. The mean arterial pressure was maintained at about 20% below the baseline until the internal fixation was completed, following which it was restored to baseline levels.

The following procedures were implemented additionally: (1) intravenous administration of 1.0 g tranexamic acid before skin incision, and the use of bipolar electrocoagulation for hemostasis. (2) Postoperative implementation of continuous negative pressure drainage in the surgical area: if the drainage volume exceeded 100 mL/h, the method was switched to intermittent negative pressure drainage. The drainage tube was removed if the 24-h drainage volume was less than 50 mL. (3) Regular monitoring of the complete blood count at the time of admission and the first day after operation, with the transfusion of red blood cell suspension if hemoglobin levels fell below 70 g/L. (4) Postoperative avoidance of anticoagulant medication, with patients using full-length graduated compression stockings on both legs to prevent venous thromboembolism (VTE).

In contrast, for patients in the observation group, we adopted a perioperative blood management plan based on the PICO framework, detailed as follows:

Establishment of a perioperative blood management team

We set up a specialized blood management team consisting of nine members. The department head and head nurse served as the team leaders, responsible for guiding the implementation, review, and quality control of the blood management plan. A physician and a provincial-level orthopedic specialist nurse were tasked with developing and implementing the blood management plan, as well as training, assessing, and communicating with team members. A doctorate physician and a graduate nurse were responsible for the evidence-based formulation of the blood management plan. One researcher each from the hematology, transfusion medicine, and pharmacy departments was involved in the review and clinical guidance of the management plan.

Development of an evidence-based perioperative blood management plan

(1) Literature review: We retrieved publications from international and Chinese literature and analyzed these using the Question Development Tool of the Johns Hopkins Nursing Evidence-Based Practice Model. We formulated the nursing evidence-based questions as per the PICO format. The identified Problem (P) was the significant intraoperative and postoperative blood loss and the high incidence of postoperative anemia in patients undergoing long-segment lumbar spine posterior surgery. The Intervention (I) involved measures of blood management implemented by the multidisciplinary medical and nursing staff. The Control (C) was not applicable in this study. The Outcomes (O) aimed at dynamically and accurately assessing the patient's risk of bleeding, blood loss, hemoglobin (Hb), hematocrit (HCT), and thrombotic risk throughout the treatment process. The goal was to optimize hematopoiesis, reduce blood loss, provide rational transfusions, and improve anemia tolerance, ultimately reducing patient blood loss and transfusion volume, improving postoperative Hb and Hct, and promoting faster patient recovery.
(2) Expert panel meeting: We identified 10 medical and nursing experts from Jiangsu Province with high professional proficiency and clinical experience in the field [average age (42.3 ± 3.28) years, average experience (19.32 ± 4.62) years, all holding mid-level or higher professional designations, with an expert authority coefficient of 0.88]. They discussed, refined, and finalized the content of the draft through collaborative deliberations in group sessions to develop the final version of the perioperative blood management plan for patients undergoing long-segment lumbar spine posterior surgery.

Comprehensive, precise, dynamic perioperative blood assessment

(1) Personalized and dynamic bleeding risk assessment: Bleeding risk was evaluated through collecting a detailed medical history, physical examination, and coagulation function tests [13], including hypertension, abnormal liver function, abnormal renal function, stroke, bleeding, unstable INR value, old age > 65 years old, drugs, drinking, and score 1 point for each risk factor. A bleeding risk score of ≥ 3 points indicated a "high risk," necessitating periodic re-evaluation. Nurses used the Caprini score chart to assess the risk of VTE at the time of admission, post-surgery, and when there were any changes in the patient's condition. On the fifth postoperative day, an ultrasound examination of the major vessels of the lower limb was conducted to check for any occurrence of deep vein thrombosis (DVT). Relevant blood indicators were continuously monitored to evaluate for anemia to facilitate analyzing its causes and implementing appropriate intervention measures.
(2) Preoperative estimation of intraoperative blood loss: on the day before surgery, the operating surgeon estimated the likely intraoperative blood loss

based on the surgical method and the number of spinal segments involved. This estimation, combined with the patient's Hb and hematocrit (Hct) levels, guided decisions regarding the need for an intraoperative autologous blood transfusion.

(3) Accurate assessment of intraoperative and postoperative blood loss: this included both intraoperative blood loss and postoperative drainage volume. Intraoperative blood loss was calculated as the volume of fluid suctioned by the suction device minus the total volume of saline solution used for irrigation plus the net increase in weight of the gauzes used during surgery. This task was managed by a designated circulating nurse in the operating room who was trained by the blood management team to ensure data accuracy. Postoperative drainage volume: this volume was accurately measured and recorded by nurses who extracted the drainage using syringes. It was ensured that all patients had a stable effective circulating blood volume postoperatively, with total fluid replacement controlled within 2000 mL in the first 24 h post-surgery to enable accurate estimation of total blood loss.

Perioperative bleeding risk prevention We conducted personalized assessments of bleeding risk for each patient, with proactive management of modifiable risk factors. These measures included controlling systolic blood pressure to less than 160 mmHg, avoiding the concurrent use of medications such as antiplatelet drugs and nonsteroidal anti-inflammatory drugs (NSAIDs), and prohibiting alcohol consumption.

For patients previously on warfarin for conditions such as atrial fibrillation or cardiovascular surgery, the anticoagulant was discontinued 5 days prior to surgery. Starting on the day following discontinuation, low molecular weight heparin (LMWH) was administered as bridging therapy. The last dose of LMWH was given within 24 h prior to the surgery. Postoperatively, LMWH treatment was resumed 24 h after the procedure.

Warfarin or similar anticoagulants were reinstated following the removal of the surgical drainage tube.

Optimization of perioperative hematopoiesis If nurses detected that the Hb levels were low (women < 120 g/L, men < 130 g/L) and the patient was diagnosed with absolute or functional iron deficiency, iron supplementation was administered as per the physician's orders. The required iron dose (mg) = patient weight (kg) × (target Hb value—actual Hb value) (g/L) × 0.24 + iron storage (mg) [14]. Intravenous administration of 200 mg/day of iron sucrose was carried out three times a week until the iron deficiency was fully rectified.

Reduction of intraoperative blood loss

(1) We used a dual approach of combining intravenous tranexamic acid infusion and surgical area soaking. Prior to making the skin incision, 1.0 g of tranexamic acid was administered intravenously, and before closing the incision at the end of the surgery, the surgical area was soaked for 5 min with a solution containing 1.0 g of tranexamic acid [15].
(2) We used intraoperative autologous blood transfusions. Physicians conducted a preoperative assessment of patients, considering criteria such as Hb levels greater than 110 g/L and Hct higher than 33%. If intraoperative blood loss exceeded 500 ml, the anesthesiologist was notified to ensure readiness for preoperative autologous blood donation.

Postoperative blood loss reduction Surgeons determined the target control volume for surgical area drainage based on the surgical technique, vertebral segments involved, and intraoperative blood loss. During the drainage process, nurses adjusted the drainage method based on the actual drainage volume and target control volume. This included total negative pressure, partial negative pressure, zero negative pressure, and intermittent negative pressure drainage methods. The drain was removed when postoperative drainage volume was < 50 mL/24 h followed by localized pressure dressing.

Individualized blood transfusion management and enhancing patient anemia tolerance A restrictive transfusion strategy, based on transfusion consensus, was strictly adhered to. Patients were carefully monitored for indications for transfusion. If Hb fell to < 70 g/L, two units of red blood cell suspension were transfused. For patients with Hb levels between 70 and 90 g/L, if symptoms like an increase in heart rate of over 30% above the baseline, hypotension, or fatigue were present, one unit of red blood cell suspension was administered. Because of the large amount of bleeding after surgery, in order to find the continuous decline of Hb caused by postoperative bleeding in time, take timely treatment measures and evaluate the therapeutic effect of blood transfusion in time. Hematology reassessment was done the next day, and if Hb remained within the aforementioned range and other sources of bleeding were ruled out, another transfusion was performed.

Implementation of the plan

(1) Rigorous selection of implementers: nurses involved in the study were required to hold a nurse practitioner or higher qualification and to be recognized as city-level, provincial-level, or national-level orthopedic specialist nurses. Physicians needed to possess a master's degree or higher and hold a designation of attending Physician or higher. All professionals were required to have a minimum of 3 years of specialized experience and demonstrate excellent communication and execution skills. Personnel who implemented the plan underwent comprehensive training through online and offline multimedia inputs and scenario simulations. The content of the training included information about long-segment lumbar spine posterior surgery, the impact of blood loss on patient recovery, and specific strategies for blood management. Eligibility to participate in the study mandated passing an assessment conducted by the team leader, which included both theoretical and clinical practice evaluations.
(2) Precision management throughout the process: precision management principles were employed to enhance the accuracy of perioperative assessments and data calculations. This approach ensured the accuracy and reliability of the research results.
(3) Patient engagement and team analysis: the team interviewed patients throughout the study to maintain continuous engagement. Team meetings were convened weekly to analyze and discuss issues encountered in the implementation of the blood management plan. This collaborative process aimed to optimize and standardize the implementation of the long-segment lumbar spine posterior surgery blood management plan.

Evaluation indices

Hb and Hct

Hb and Hct levels were measured at admission, immediately post-surgery, on the first and third day post-surgery, and at discharge.

Intraoperative blood loss and postoperative drainage volume

Data were collected from surgical and nursing records.

Number of allogeneic blood transfusion recipients and average volume of allogeneic blood transfused per recipient

Since the patients in our cohort did not receive preoperative transfusions, the number of allogeneic blood transfusion recipients referred to the count of patients who underwent allogeneic blood transfusions intraoperatively and/or postoperatively. A patient receiving transfusions both during and after surgery was counted as one incidence. The average volume of allogeneic blood transfused per recipient was calculated as the mean transfusion volume among those who received transfusions.

Postoperative incidence of VTE

A routine ultrasound examination of the major vessels of the lower limb was performed for all patients on the fifth postoperative day. The number of cases of postoperative VTE was compiled from the hospital information system.

Duration of surgical area drain placement and postoperative hospital stay length

The duration of surgical area drain placement was calculated as the time in hours from drain placement to removal, with removal criteria being a postoperative drainage volume of less than 50 mL/day. The length of the postoperative hospital stay was computed from data in the hospital information system.

Method of data collection

Before the commencement of the study, we prepared and provided the team with unified guidelines on terminology and data collection methods. Two nursing graduate students who were not involved in the implementation of the intervention were specifically assigned to collect patients' basic information and data related to each evaluation index. All the data were collected and handed over on the same day.

Statistical analysis

Two personnel independently entered the data. We used SPSS software version 26.0 for the analysis. Quantitative data were expressed as the mean and standard deviation. For data conforming to a normal distribution, comparisons between groups were made using the independent sample t-test, while comparisons of postoperative Hb and Hct values at different time points between the two groups were conducted using repeated measures analysis of variance. Categorical data were analyzed using the Chi-square test. A P value of < 0.05 was considered statistically significant. To address potential confounding factors, multivariate regression analysis was performed. For continuous outcome variables such as hemoglobin (Hb), hematocrit (Hct), blood loss, and length of stay, multiple linear regression models were used to estimate the effect of the intervention while adjusting for baseline characteristics including age, sex, BMI, smoking status, alcohol

Table 2 Comparison of perioperative Hb values at different time points between the two groups

Group	Cases	Admission ($\bar{x}\pm s$)	Immediate post-op ($\bar{x}\pm s$)	Day 1 post-op ($\bar{x}\pm s$)	Day 3 post-op ($\bar{x}\pm s$)	Discharge day ($\bar{x}\pm s$)
Observation group	51	141.35 ± 14.01	127.06 ± 9.93	120.35 ± 10.19	117.37 ± 9.48	135.06 ± 9.99
Control group	51	141.37 ± 10.68	115.20 ± 11.82	104.96 ± 10.78	101.78 ± 11.42	117.71 ± 9.22
$F_{interaction}$ value	–	48.512				
$P_{interaction}$ value	–	< 0.001				
F_{group} value	–	37.16				
P_{group} value	–	< 0.001				
F_{time} value	–	322.42				
P_{time} value	–	< 0.001				

Table 3 Comparison of perioperative Hct values at different time points between the two groups

Group	Cases	Admission ($\bar{x}\pm s$)	Immediate post-op ($\bar{x}\pm s$)	Day 1 post-op ($\bar{x}\pm s$)	Day 3 post-op ($\bar{x}\pm s$)	Discharge day ($\bar{x}\pm s$)
Observation group	51	42.19 ± 3.90	37.96 ± 2.93	36.23 ± 2.77	35.49 ± 2.62	39.93 ± 2.41
Control group	51	42.72 ± 3.17	35.11 ± 3.63	32.03 ± 3.27	30.93 ± 3.54	36.07 ± 2.86
$F_{interaction}$ value	–	22.83				
$P_{interaction}$ value	–	< 0.001				
F_{group} value	–	29.38				
P_{group} value	–	< 0.001				
F_{time} value	–	239.86				
P_{time} value	–	< 0.001				

use, number of fused segments, comorbidities, and preoperative anticoagulant use.

Results

Comparison of general data between the two groups

There were no significant statistical differences between the two groups in age, gender, body mass index (BMI), smoking status, alcohol use, duration of the surgery, number of fused segments, comorbid diseases, or preoperative use of anticoagulants ($P > 0.05$). Details are given in Table 1.

Comparison of perioperative Hb and Hct values at different time points between the two groups

There was no significant difference in Hb and Hct values at admission between the patients in the two groups ($P > 0.05$). However, patients in the observation group had significantly higher Hb and Hct values immediately after the surgery, on the first and third day post-surgery, and on the day of discharge compared to those in the control group ($P < 0.05$). Details are given in Tables 2 and 3.

Comparison of intraoperative and postoperative blood loss between the two groups

Patients in the observation group had significantly lower intraoperative blood loss and postoperative drainage volume when compared to those in the control group ($P < 0.05$). Details are given in Table 4.

Table 4 Comparison of intraoperative blood loss and postoperative drainage volume between the two groups

Group	Cases	Intraoperative blood loss ($\bar{x}\pm s$)	Postoperative drainage volume ($\bar{x}\pm s$)
Observation group	51	264.71 ± 86.77	186.27 ± 56.64
Control group	51	362.75 ± 137.06	243.14 ± 75.51
t value	–	−4.32	−4.30
P value	–	< 0.001	< 0.001

Comparison of allogeneic blood transfusions between the two groups

The number of allogeneic blood transfusion recipients was significantly lower in the observation group as compared to the control group ($P < 0.05$). Details are given in Table 5.

Comparison of the duration of postoperative drain placement and the duration of postoperative hospital stay between the two groups

The duration of postoperative drain placement and the length of postoperative hospital stay were significantly

Table 5 Comparison of the number of recipients of allogeneic blood transfusion between the two groups

Group	Cases	Allogeneic blood transfusion (yes/no)
Observation group	51	2/49
Control group	51	18/33
$\chi2$ value	–	15.92
P value	–	< 0.001

Table 7 Comparison of the incidence of postoperative VTE between the two groups

Group	VTE incidence (yes/no)
Observation group	2/49
Control group	3/48
$\chi2$ value	0.21
P value	0.65

lower for patients in the control group when compared to those in the observation group ($P<0.05$). Details are given in Table 6.

Comparison of the incidence of postoperative VTE between the two groups

There was no significant difference in the incidence of postoperative VTE between the two groups ($P>0.05$). Details are given in Table 7.

Multivariate regression analyses

To further control for potential confounding variables, adjusted analyses were conducted. After adjusting for baseline factors including age, sex, BMI, comorbidities, and surgical characteristics, the intervention group remained significantly associated with better outcomes ($P<0.05$).

Discussion

Impact of the blood management plan on perioperative Hb and Hct levels

The blood management plan that we developed was effective in improving perioperative Hb and Hct levels in patients undergoing long-segment lumbar spine posterior surgery, consistent with the findings of Xi et al. [16] Such surgeries often involve significant trauma and bleeding. Many elderly patients who already have compromised hematopoietic function are in an anemic state preoperatively. The incidence of postoperative anemia can be as high as 80–90% [17], increasing perioperative mortality, infection rates, and the proportion of red blood cell transfusions [18].

Iron deficiency anemia is the most common cause of perioperative anemia in patients undergoing orthopedic surgeries. Implementing iron supplementation therapy early can rapidly restore Hb levels [19]. As compared to oral iron supplementation, intravenous iron sucrose enters the bone marrow more quickly to participate in red blood cell production and replenish ferritin, thereby increasing hemoglobin levels. In this study, we undertook precise assessments of iron deficiency and standardized intravenous treatment with iron sucrose, which, combined with bleeding risk prevention measures and strategies to reduce blood loss, effectively prevented rapid postoperative declines in Hb and Hct.

We also found that the most significant decrease in hemoglobin occurred immediately post-surgery in both groups, with the greatest reduction observed on the third postoperative day. The Hb and Hct levels at all postoperative time points were better in the observation group compared to the control group, with statistically significant differences ($P<0.05$). After adjusting for potential confounding variables using multivariate regression models, the PICO-based perioperative blood management plan remained independently associated with improved hemoglobin levels and reduced transfusion rates. These findings suggest that the observed benefits were not solely due to baseline differences, further strengthening the internal validity of the results.

Table 6 Comparison of the duration of postoperativedrain placement and the duration of postoperative hospital stay between the two groups

Group	Duration of postoperative drain placement ($\bar{x}\pm s$)	Duration of postoperative hospital stay ($\bar{x}\pm s$)
Observation group	44.51 ± 11.94	7.08 ± 1.29
Control group	69.39 ± 12.31	9.12 ± 1.71
t value	– 10.36	– 6.81
P value	< 0.001	< 0.001

Impact of the blood management plan on total surgical blood loss, number of allogeneic blood transfusion recipients, and average volume of allogeneic blood transfused per recipient

Our blood management plan effectively reduced the total blood loss, the number of allogeneic blood transfusion recipients, and the average volume of allogeneic blood transfused per recipient in patients who underwent long-segment lumbar spine posterior surgery. These findings align with those reported by Wei et al. [20] Long-segment lumbar spine posterior surgery often results in significant blood loss due to extensive surgical trauma, considerable bleeding from bone surfaces, and substantial postoperative drainage, leading to a high rate of transfusions. The focus of blood management is to reduce bleeding and limit transfusions, with the key focus being the reduction of bleeding risk and the amount of blood loss [21].

In this study, we introduced a bleeding risk score table to assess the risk of bleeding, pre-evaluated intraoperative blood loss, and enhanced the rate of intraoperative autologous blood transfusion. We also determined patients' Hb levels, monitored patients for symptoms of anemia, and tracked transfusion volume, aiding medical staff in accurately identifying patients with transfusion indications and reducing wastage of blood resources. We used re-transfused concentrated red blood cells, which have better viability and oxygen-carrying capacity compared to banked blood. This effectively improved patients' tolerance to postoperative anemia as well as reduced both the number of recipients of allogeneic blood transfusions and the average volume of allogeneic blood transfused per recipient. Based on intravenous infusion of tranexamic acid before skin incision in routine surgery, the combined application of soaking in the operation area before the end of the operation and the closure of the incision, two time nodes and two different medication routes effectively reduced the amount of bleeding during and after operation.

We also implemented postoperative dynamic adjustment of the drainage method based on target control volumes, which helped to prevent risks associated with excessive or insufficient drainage, such as excessive bleeding or spinal epidural hematoma compressing the spinal cord and nerves. In the observation group, 10 patients received intraoperative autologous blood transfusions, and two patients received 700 mL of allogeneic red blood cell suspension, averaging 350 mL per recipient. In the control group, 18 patients received a total of 9500 mL of allogeneic red blood cell suspension, with an average transfusion volume of 528 mL. The results showed that the postoperative hospitalization days in the observation group were shorter than those in the control group. Since there was no incision infection in the two groups after operation and there was no significant difference in the incidence of VTE between the two groups, the author thought that the postoperative hospitalization time was not affected by other complications, with statistically significant differences ($P < 0.05$).

Impact of the blood management plan on the duration of surgical drain placement and the duration of postoperative hospital stay

The blood management plan that we developed was beneficial in reducing the duration of surgical drain placement and shortening the postoperative hospital stay for patients following long-segment lumbar spine posterior surgery. These findings are consistent with the research conducted by Huang et al. [22] A surgical drain placed for a prolonged period of time can result in increased pain, limited mobility, and a greater risk of infection. In this study, patients in the observation group had drainage controlled to a 24-h target volume, with real-time adjustments to the drainage method and timely removal of the drainage tube. This effectively reduced the duration of drain placement, revealing a statistically significant difference between the two groups ($P < 0.05$).

Long-segment lumbar spine posterior surgery, due to its extensive trauma and significant blood loss, typically results in prolonged postoperative hospital stays and recovery times. Low hemoglobin levels can impact muscle strength recovery and reduce rehabilitation capacity. By implementing a scientifically sound perioperative blood management plan, we found that postoperative hemoglobin levels were effectively improved, eliminating fatigue and weakness caused by anemia and promoting early ambulation and recovery. Our results indicated that the duration of postoperative hospital stay in the observation group was significantly shorter than that of the control group ($P < 0.05$).

Impact of the blood management plan on the incidence of postoperative VTE

The correlation between blood management and the incidence of VTE has been relatively underexplored in current research. Patients undergoing long-segment lumbar spine posterior surgery are at high risk for VTE due to substantial blood loss and postoperative anemia, which can delay mobilization and reduce physical activity, further elevating the risk of VTE.

In this study, concerns arose regarding whether the combined intravenous and local use of tranexamic acid in the observation group might increase the risk of VTE. However, research indicates that intravenous use of tranexamic acid reduces systemic absorption, and its local application has minimal impact on coagulation function, hence not increasing the risk of VTE [23].

No patient in any of the groups in this study experienced pulmonary embolism postoperatively. On the fifth postoperative day, ultrasound examination of major vessels of the lower limb revealed that there were three patients who developed intermuscular venous thrombosis in the control group, while there were two such cases in the observation group. There was no significant difference between the two groups in the incidence of postoperative VTE. This, consistent with the findings of Shi et al. [24], may be attributed to factors such as reduced blood loss, shorter postoperative bed rest, and the maintenance of the muscle "pump" action under the blood management plan.

One key limitation of this study lies in the control of intraoperative blood loss, particularly regarding surgical technique optimization.

Summary

In conclusion, this study implemented a perioperative blood management protocol based on PICO evidence-based principles for patients undergoing long-segment posterior lumbar spine surgery, leading to significant improvements in blood management throughout the surgical process. The protocol effectively reduced total perioperative blood loss, allogeneic transfusion rates, and the incidence of postoperative anemia. It also shortened the duration of postoperative drainage tube use and hospital stays, thereby accelerating postoperative recovery. These improvements not only facilitated early ambulation and lumbar function rehabilitation but also reduced hospitalization costs by lowering transfusion expenses and shortening recovery time. Long-term follow-up studies are needed to investigate whether patients who received perioperative blood management achieve better functional outcomes, as indicated by improved Oswestry Disability Index scores and overall quality of life. Overall, this PICO-based blood management strategy demonstrated both clinical and economic advantages, aligning well with the goals of enhanced recovery after surgery.

Abbreviations

PICO	Problem, intervention, control, outcomes
HB	Hemoglobin
HCT	Hematocrit
VTE	Venous thromboembolism

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40001-025-02656-7.

Supplementary materials 1.

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Author contributions

Conception and design of the research: Hong Gao and Hai-Yan Gu. Acquisition of data: Hong Gao, Ting-Ting Wang, and Qin Xuan. Analysis and interpretation of the data: Hong Gao, Ting-Ting Wang, and Guan-Hua Xu. Statistical analysis: Hong Gao and Qin Xuan. Obtaining financing: Hong Gao, Ting-Ting Wang, and Hai-Yan Gu. Writing of the manuscript: Hong Gao. Critical revision of the manuscript for intellectual content: Hong Gao, Ting-Ting Wang, and Guan-Hua Xu. All the authors read and approved the final draft.

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Availability of data and material

All data generated or analyzed during this study are included in this article. Further enquiries can be directed to the corresponding author.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. The study was approved by the Ethics Committee of the Nantong First People's Hospital (NO.2020KT078). Written informed consent was obtained from all the participants.

Consent to publication

Not applicable.

Competing interests

The authors declare no competing interests.

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