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Acute Normovolemic Haemodilution In Patients Undergoing Lumbosacral Spine Surgeries

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ABSTRACT

Introduction: Extensive surgical procedures, like lumbosacral spine surgeries, involve significant blood loss, and increasing reliance on homologous blood transfusion, which carries risks such as infections, immunosuppression, and transfusion reactions. Acute Normovolemic Haemodilution (ANH), a blood conservation strategy, offers a safer and cost-effective alternative by withdrawing the patient's blood preoperatively, maintaining normovolemia with crystalloids or colloids, and reinfusing fresh blood intraoperatively.

Methodology: This randomized control study included 60 patients undergoing elective lumbosacral spine surgeries, divided equally into Group HBT (Homologous Blood Transfusion) and Group ANH (Acute Normovolemic Haemodilution). Hemodynamic parameters (heart rate, blood pressure, MAP), haematological indices (haemoglobin, haematocrit), coagulation profiles (platelet count, aPTT, INR), electrolyte levels, and blood loss were monitored pre-, intra-, and post-operatively. Statistical analysis was performed using SPSS v20.0, and a p-value of <0.05 was considered significant.

Results: Hemodynamic parameters: At the end of ANH, Group ANH showed a significant decrease in systolic (8%) and diastolic blood pressure (7%) compared to Group HBT ($p<0.05$), with MAP also falling significantly ($p<0.05$) but clinically manageable.

Haematological changes: Haemoglobin decreased by 1.1 g/dL in Group ANH versus 0.8 g/dL in Group HBT ($p<0.05$), while haematocrit fell 2.9% versus 1.9%, respectively.

Blood loss and EABL: Group ANH had a significantly higher Estimated Allowable Blood Loss (701.8 ± 151 ml) compared to Group HBT (487.1 ± 126 ml) ($p<0.001$), though actual blood loss was similar ($p>0.05$).

Coagulation and electrolytes: No significant differences were observed in coagulation profiles (aPTT, INR) or electrolyte levels ($p>0.05$).
Conclusion: ANH is a safe, feasible, and effective technique for reducing homologous transfusion requirements in spine surgeries. It ensures hemodynamic stability, increases allowable blood loss, and has minimal impact on coagulation and electrolyte balance.

Keywords: Acute Normovolemic Haemodilution, Homologous Transfusion, Blood conservation, Hemodynamic changes, Lumbosacral Spine surgery, Coagulation Profile.

INTRODUCTION

The rising need for extensive surgical procedures, often associated with significant blood loss, has increased the demand for intra-operative and post-operative blood replacement. Despite advances in blood safety, allogenic blood transfusion carries risks such as the transmission of infections, hemolytic reactions, immunosuppression, and severe allergic responses. To address these concerns, strategies like autologous transfusion, including pre-operative autologous blood donation (PABD), intra-operative blood salvage, and acute normovolemic haemodilution (ANH), have been introduced[1].ANH involves withdrawing whole blood from the patient before surgery, maintaining normovolemia by replacing the blood with crystalloids or colloids and re-infusing it post-surgery. This technique is cost-effective, simple, and eliminates the need for filtering, washing, or storage. It provides fresh blood with preserved platelet function, avoiding storage-related complications, hypothermia, and clerical errors leading to transfusion incompatibility. However, its adoption remains limited due to concerns about prolonged operative time and the need for additional monitoring.In India, Lumbosacral spine surgeries are common, and these surgeries require high blood transfusion requirements due to significant blood loss[2]. ANH offers a safe, economical alternative to homologous transfusion in these cases[3]. This study evaluates ANH's safety and hemodynamic effects compared to conventional transfusion in patients undergoing lumbosacral spine surgeries at Karpaga Vinayaga Institute of Medical Sciences & Research Centre, highlighting its potential benefits.

OBJECTIVES

Primary Objective:

- To evaluate the safety and efficacy of acute normovolemic haemodilution (ANH) as a blood conservation strategy in patients undergoing lumbosacral spine surgeries.

Secondary Objectives:

- Includes comparing hemodynamic changes, cost-effectiveness, and feasibility of ANH versus homologous blood transfusion while highlighting its advantages, such as reduced transfusion-related risks and preserved blood quality.
- Additionally, the study addresses the lack of data on ANH use in spine surgery patients in India.

MATERIALS & METHODS

Study Details

This study was conducted in the Department of Anaesthesiology operating theatre with patients undergoing lumbosacral spine surgeries from the Department of Orthopaedics, Karpaga Vinayaga Institute of Medical Sciences & Research Centre, Chengalpattu District. The study was carried out over one year, data collection involving 60 patients undergoing elective lumbosacral spine surgery were randomly divided into two groups:
Group HBT (Control Group): 30 patients received homologous blood transfusion.
Group ABT (Haemodilution Group): 30 patients underwent acute normovolemic haemodilution (ANH).

Inclusion and Exclusion Criteria

Inclusion: Patients aged above 18 to 60 years, pre-operative haemoglobin >10 g/dL, and haematocrit >30%.
Exclusion: Patients with cardiac, pulmonary, renal, or liver disease, uncontrolled hypertension, coagulation disorders, infections, hypoalbuminemia, or unwillingness to consent.
Pre-operative Preparation & Conduct of General Anaesthesia

Patients underwent routine PAC with screening investigations (e.g., haemoglobin, PCV, coagulation profile, ECG, chest X-ray) and were pre-medicated with Alprazolam and Ranitidine. Baseline parameters like pulse rate, blood pressure, oxygen saturation, and urine output were recorded.
All patients received General Anaesthesia with controlled ventilation. Patients were premedicated intravenously with Inj. Glycopyrrolate 0.01mg/kg and Inj. Ondansetron 0.1mg/kg, for analgesia Inj. Fentanyl 2µg/kg was given. Induction and paralysis were done using Inj. Propofol 2mg/kg, Inj. Vecuronium 0.1mg/kg loading dose followed by one-fourth of loading dose for maintenance, and sevoflurane at 1 MAC. At the end of the procedure, reversal was done with Inj. Glycopyrrolate 0.01mg/kg and Inj. Neostigmine 0.05mg/kg.

ANH Procedure
Two IV cannulas were inserted: one for crystalloid or colloid infusion and another for blood withdrawal. Blood was withdrawn from the antecubital vein based on the Gross Formula until the haematocrit reached 30%, with simultaneous volume replacement (3 mL crystalloid or 1 mL colloid per mL of blood withdrawn). Blood bags were labeled and stored near the patient for re-infusion. Vital signs were continuously monitored during withdrawal.

Post-operative Care
Patients were monitored in the ICU for 24 hours and followed up until discharge. Post-operative blood was reinfused after achieving haemostasis or if haemoglobin dropped below 8 g/dL. Haemoglobin, PCV, and RBC counts were frequently measured.

Ethical Considerations
The study received Institutional Ethics Committee approval. Strict confidentiality and anonymity were maintained, with all collected data used solely for research and discarded post-thesis publication. Ethical principles were adhered to throughout the study.

STATISTICAL ANALYSIS
Data were entered into Microsoft Excel 2010, and statistical analysis was performed using SPSS version 20.0. Descriptive statistics, including frequency, percentage, mean, standard deviation, median, and interquartile range, were presented using tables, graphs, and diagrams. For inferential statistics, parametric tests such as the Student's t-test were used to compare means of continuous variables after confirming normality using the Kolmogorov-Smirnov test ($p = 0.789$). Chi-square tests were applied for categorical variables, with Yates's correction for continuity to reduce approximation errors. Factorial repeated measures ANOVA was employed to analyze changes in continuous variables (e.g., hemodynamic parameters, coagulation profiles) between the haemodilution and control groups (between-subject factors). A p-value of <0.05 was considered statistically significant for all tests.

RESULTS
This study evaluated the safety of acute normovolemic haemodilution (ANH) and compared its hemodynamic effects with conventional homologous blood transfusion in patients undergoing elective lumbosacral spine surgeries. The findings provide insight into hemodynamic stability, haematological changes, and blood loss outcomes between the two groups.

Demographic Parameters
The demographic characteristics, including age, weight, and ASA grade distribution, were comparable between the control and haemodilution groups ($p>0.05$). The mean age (48.53 ± 8.8 vs. 44.6 ± 5.23 years) and mean weight (58.6 ± 3.4 vs. 56.03 ± 6.57 kg) showed no statistically significant differences, ensuring homogeneity between the groups. These results align with a previous study by Chen et al[2]., where similar age and weight distributions were reported in lumbosacral spine surgeries which ensures homogeneity and reduces confounding factors.

Hemodynamic Parameters
Heart Rate (HR): In our study, there was no statistically significant difference in mean heart rates between the two groups, though both groups showed variations over time. This transient change in heart rate is a known thing in ANH which is due to fluid shifts. Li Q et al[3]., observed similar findings where HR showed time-

dependent variations but no intergroup differences, indicating that ANH does not impose significant cardiac stress.

Blood Pressure (SBP, DBP, and MAP): A statistically significant fall in systolic and diastolic blood pressures was observed at the end of haemodilution in the ANH group ($p<0.05$) in our study. Similarly, mean arterial pressure (MAP) declined significantly in the haemodilution group compared to the control group. These findings align with the study done by Mohammadi et al[4]., where mild hypotension was reported during the haemodilution phase of ANH. However, it was clinically manageable and did not lead to any adverse outcomes.

Haematological Parameters

Haemoglobin and Haematocrit: The ANH group experienced a greater decline in haemoglobin (1.1 g/dL vs. 0.8 g/dL) and haematocrit (2.9% vs. 1.9%) levels compared to the control group, with statistical significance ($p<0.05$). This reduction is expected due to the dilutional effect of ANH. However, the levels remained within clinically acceptable limits, supporting the safety of the procedure. These findings contrast with Do et al[1]., who observed no significant changes in haemoglobin levels between ANH and control groups.Coagulation Parameters: Platelet count, bleeding time, clotting time, aPTT, and INR did not show significant differences between the groups, either at baseline or during the perioperative period. This aligns with Liu X et al[5]., who reported no significant impact on coagulation profiles with ANH. The stability of coagulation parameters ensures that ANH does not increase the risk of bleeding.

Electrolyte Levels

Sodium and potassium levels showed no significant intergroup differences, except for a mild and transient fall in sodium levels (T1 and T2), which recovered to baseline. This indicates that ANH has minimal impact on electrolyte balance, consistent with findings in a study done by Midorikawa Y et al[6].,

Blood Loss and EABL

The estimated allowable blood loss (EABL) was significantly higher in the haemodilution group (701.8 ± 151 ml) compared to the control group (487.1 ± 126 ml, $p<0.001$). However, actual blood loss did not differ significantly between the groups, despite a higher observed value in the haemodilution group. These results suggest that ANH increases the capacity to tolerate blood loss without necessitating transfusion, supporting its role in blood conservation strategies with a similarity being observed by a study done by Shander et al[7].,

Clinical Significance and Safety

The overall findings demonstrate that ANH is a safe and effective technique for reducing homologous blood transfusion requirements. Hemodynamic changes, including mild hypotension, are transient and clinically manageable. ANH does not compromise coagulation parameters or electrolyte balance, further establishing its safety profile. These findings are in line with studies by Rehm et al[8]., and Santoso et al[9]., which highlight the effectiveness and safety of ANH in surgical settings during radical hysterectomy.

DISCUSSION

Acute Normovolemic Hemodilution (ANH) is a blood conservation technique used to minimize allogenic transfusion during surgeries with anticipated blood loss. In lumbosacral spinal surgeries, ANH helps maintain normovolemia while reducing red cell loss. This discussion with various studies explores its efficacy, safety, and role in optimizing outcomes in spine surgery patients.

The study by Li Y et al[10]., concludes that combining acute normovolemic hemodilution with tranexamic acid effectively reduces blood loss and transfusion requirements in lumbar spinal fusion surgery. Tranexamic acid reduces bleeding but doesn't eliminate transmission need, combined measures may help, but larger studies needed for confirmation hence in our study we didn’t combine Tranexamic acid

Our study demonstrated the safety and effectiveness of employing ANH for lumbosacral spine surgeries similar to the study done by Liu T et al[11]., which concluded that acute normovolemic hemodilution maintains anesthetic efficacy stabilizes plasma drug concentrations and promotes faster post-operative recovery in elderly patients undergoing spinal surgery demonstrating its safety and effectiveness.

The need for the selection of ANH for our study to employ in spine surgery was its safety, and effectiveness was like the survey done by Dai J et al[12]., In our research moderate – ANH was employed, and it reduced RBC

transfusion, bleeding and showed better outcomes with similarity observed by the study done by Abbasi T et al[13].,

CONCLUSION

ANH is a safe and feasible alternative to conventional homologous blood transfusion in patients undergoing elective hysterectomy. It effectively increases allowable blood loss while maintaining hemodynamic stability, with minimal impact on coagulation and electrolyte parameters. This study supports the adoption of ANH as part of blood conservation strategies in surgical practice.

Table 1: Demographic Parameters

Parameter	Control Group (n=30)	Haemodilution Group (n=30)	*p*-value
Age (years, Mean ± SD)	48.53 ± 8.8	44.6 ± 5.23	>0.05
Weight (kg, Mean ± SD)	58.6 ± 3.4	56.03 ± 6.57	>0.05
ASA Grade 1 (%)	70% (21/30)	73.3% (22/30)	>0.05
ASA Grade 2 (%)	30% (9/30)	26.7% (8/30)	>0.05

Table 2: Hemodynamic Parameters

Parameter	Control Group (Mean ± SD)	Haemodilution Group (Mean ± SD)	*p*-value
Heart Rate (bpm)	85.2 ± 7.5	86.4 ± 8.3	>0.05
Systolic BP (mmHg, T3)	127.5 ± 8.6	120.4 ± 7.8	<0.05
Diastolic BP (mmHg, T3)	80.6 ± 5.4	75.2 ± 6.1	<0.05
Mean Arterial Pressure (T3)	96.2 ± 4.7	91.8 ± 5.3	<0.05

Table 3: Hematological Parameters

Parameter	Control Group (Mean ± SD)	Haemodilution Group (Mean ± SD)	*p*-value
Hemoglobin Fall (g/dL, T2)	0.8 ± 0.2	1.1 ± 0.3	<0.05
Hematocrit Fall (%)	1.9 ± 0.5	2.9 ± 0.6	<0.05
Platelet Count (x10⁹/L)	210 ± 30	205 ± 28	>0.05
Bleeding Time (min)	2.1 ± 0.3	2.2 ± 0.4	>0.05
Clotting Time (min)	5.5 ± 0.6	5.6 ± 0.5	>0.05
aPTT (seconds)	30.2 ± 2.4	30.6 ± 2.3	>0.05
INR	1.01 ± 0.1	1.02 ± 0.1	>0.05

Table 4: Electrolyte Levels

Parameter	Control Group (Mean ± SD)	Haemodilution Group (Mean ± SD)	*p*-value
Sodium Levels (mEq/L, T1)	137.5 ± 2.4	136.8 ± 2.3	>0.05
Sodium Levels (mEq/L, T2)	136.2 ± 2.2	135.5 ± 2.5	>0.05
Potassium Levels (mEq/L)	4.2 ± 0.3	4.1 ± 0.4	>0.05

Table 5: Blood Loss and EABL

Parameter	Control Group (Mean ± SD)	Haemodilution Group (Mean ± SD)	*p*-value
Estimated Allowable Blood Loss (ml)	487.1 ± 126	701.8 ± 151	<0.001
Actual Blood Loss (ml)	350.2 ± 90.5	375.4 ± 95.2	>0.05

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