CASE REPORT

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Perioperative Autologous Blood Conservation Using Acute Normovolemic Hemodilution in a Patient Undergoing Elective Craniotomy for Suspected Meningioma: A Case Report

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ABSTRACT

Background: Acute normovolemic hemodilution (ANH) is a perioperative blood conservation technique in which a predetermined volume of autologous whole blood is collected from the patient shortly before or at the onset of surgery, replaced with crystalloid or colloid solution to maintain normovolemia, and reinfused during or after the period of major surgical blood loss. ANH reduces the net erythrocyte loss during surgery and may reduce or eliminate the need for allogeneic transfusion.

Case Presentation: A 51-year-old woman with a left frontoparietal extraaxial tumor (suspected en plaque meningioma, $7 \times 5 \times 3$ cm) was scheduled for elective craniotomy via a frontotemporal approach. Preoperative hemoglobin was 14.2 g/dL, hematocrit 42.6%, platelet count $299 \times 10^3/\mu L$, and the coagulation profile was within normal reference ranges. Hepatic, renal, and cardiopulmonary function were clinically adequate for ANH candidacy. Two units of autologous whole blood (350 mL each; total 700 mL) were collected perioperatively using the ANH technique: the first unit several hours before surgery and the second at the commencement of surgery under anesthesiological supervision. Normovolemia was maintained using replacement fluid. Both units were labeled, stored at room temperature in the operating theater, and reinfused in reverse order (most recently collected unit first) during and at the conclusion of the procedure. Intraoperative blood loss was approximately 600 mL. No allogeneic transfusion was required. Postoperative hemoglobin was 11.8 g/dL, representing mild, clinically acceptable anemia. No transfusion reaction was observed. The patient demonstrated clinical improvement and was discharged for outpatient follow-up.

Conclusion: This case illustrates that ANH may be a feasible and effective component of perioperative patient blood management in selected elective neurosurgical patients, provided appropriate eligibility assessment, hemodynamic monitoring, standardized labeling, and multidisciplinary coordination are maintained.

Keywords: Autologous Transfusion, Acute Normovolemic Hemodilution, Patient Blood Management, Perioperative Blood Conservation, Craniotomy.

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INTRODUCTION

Autologous transfusion is a procedure in which blood or blood components are collected from a patient who serves simultaneously as both donor and recipient. The collected product is appropriately processed and stored, then returned to the same individual. The primary objectives of autologous transfusion are to enhance transfusion safety by eliminating immunological incompatibility, to reduce the risk of transfusion-transmitted infections, and to prevent alloimmunization against blood group antigens.[1]

Prior to 1982, autologous transfusion was performed in fewer than 5% of surgical patients. The emergence of transfusion-transmitted Human Immunodeficiency Virus (HIV) infection in the early 1980s significantly accelerated its adoption; by the early 1990s, the volume of autologous transfusions had approximately doubled.[2] Four principal methods of autologous transfusion are currently recognized: (1) preoperative autologous donation (PAD), also known as predeposit autologous donation; (2) acute normovolemic hemodilution (ANH); (3) intraoperative cell salvage (ICS); and (4) postoperative cell salvage from wound drainage.[1,3]

Among these, ANH has emerged as a practical and cost-effective blood conservation technique applicable to a broad range of elective surgical procedures anticipated to involve moderate-to-significant blood loss. ANH involves the collection of autologous whole blood shortly before or at the commencement of surgery, with simultaneous replacement of the withdrawn volume using crystalloid or colloid solution to maintain normovolemia, and subsequent reinfusion of the collected blood during or at the conclusion of the operative procedure.[4,5] This technique intentionally reduces the circulating erythrocyte concentration before the period of surgical hemorrhage, thereby reducing the red cell content of shed blood and minimizing the net loss of erythrocyte mass.[4,5]

Based on those mentioned above, this case report describes the clinical application of ANH in a patient undergoing elective craniotomy for a suspected meningioma, presents a systematic eligibility assessment, discusses procedural considerations and interpretation of perioperative laboratory findings, and situates these observations within the contemporary framework of patient blood management (PBM).

CASE PRESENTATION

A 51-year-old woman presented to the outpatient neurosurgery clinic with a chief complaint of intermittent headache. Following clinical evaluation and imaging studies, she was diagnosed with a left frontoparietal extraaxial tumor, suspected to represent an en plaque meningioma. Physical examination revealed a blood pressure of 121/82 mmHg, heart rate of 82 beats per minute, body temperature of 36.6°C, respiratory rate of 16 breaths per minute, and body weight of 51 kg. Local examination of the left frontal region demonstrated a mass measuring 7 × 5 × 3 cm extending from the left frontal to the left temporal region, with skin-colored appearance, firm consistency, well-defined margins, fixed to underlying structures, smooth surface, and non-tender on palpation.

The attending neurosurgeon planned an elective craniotomy with tumor removal via a transcortical approach using a frontotemporal incision and osteoplasty with bone cement. Given the size and nature of the tumor and the anticipated degree of intraoperative blood loss, the surgical team requested preoperative evaluation for autologous transfusion using the ANH technique, with a plan to collect two units of autologous whole blood before and during surgery.

Preoperative laboratory evaluation demonstrated hemoglobin 14.2 g/dL, hematocrit 42.6%, platelet count 299 × $10^3/\mu L$, prothrombin time (PT) 14.3 seconds (INR 1.04), and activated partial thromboplastin time (APTT) 31.1 seconds — all within normal reference ranges. Hepatic function tests (aspartate aminotransferase [AST/SGOT] 27 U/L, alanine aminotransferase [ALT/SGPT] 25 U/L), renal function indices (blood urea nitrogen [BUN] 9.2 mg/dL, creatinine 0.81 mg/dL, estimated glomerular filtration rate [eGFR] 84.09 mL/min/1.73 m²), and fasting glucose (87 mg/dL) were all within or near normal reference ranges. No significant cardiopulmonary dysfunction was documented.

Following formal donor eligibility screening, the patient was confirmed to meet all established criteria for autologous whole blood donation. The first unit (350 mL) of autologous whole blood was collected several hours before the scheduled surgery. The second unit (350 mL) was collected at the commencement of the operative procedure under the direct supervision of the anesthesiology team, following a repeat assessment of hemodynamic stability and continued donor suitability. Each unit was labeled with the patient's full name, medical record number, sequential unit number, and time of collection, in accordance with transfusion safety and traceability requirements, and stored at room temperature in the operating theater pending reinfusion.

Total autologous blood collected was 700 mL. Normovolemia was maintained during blood collection by infusion of replacement fluid; however, the specific type, volume, and infusion rate of replacement fluid were not documented in the available case data and represent a limitation of this report (see Limitations). Intraoperative blood loss was estimated at approximately 600 mL. Both units of autologous whole blood were reinfused during and at the conclusion of the surgery, in reverse order; the most recently collected unit was administered first, to maximize the benefit of the relatively preserved coagulation factors and platelets in the later-collected unit.

No allogeneic transfusion was required throughout the intraoperative and immediate postoperative periods. No signs or symptoms of transfusion reaction were observed during or after reinfusion. The patient demonstrated clinical improvement and was subsequently discharged for outpatient follow-up.

Complete preoperative and postoperative laboratory data are presented in Table 1. Preoperative hemoglobin was 14.2 g/dL and hematocrit 42.6%, both within the normal reference range for an adult woman, confirming an adequate preoperative erythrocyte reserve. WBC count was 6.02 × $10^3/\mu L$ with a neutrophil percentage of 65.6% and an absolute neutrophil count (ANC) of 3.95 × $10^3/\mu L$, all within normal limits. Platelet count was 299 × $10^3/\mu L$. PT was 14.3 seconds (INR 1.04) and APTT 31.1 seconds, both within their respective reference ranges, indicating intact preoperative hemostatic function. Hepatic and renal function indices and fasting glucose were all within or near normal reference ranges (Table 1).

Postoperative evaluation revealed hemoglobin 11.8 g/dL (a decrease of 2.4 g/dL from baseline) and hematocrit 36.8% (a reduction of 5.8 percentage points). This represents mild postoperative anemia, expected following craniotomy with an estimated blood loss of approximately 600 mL that was partially compensated by autologous reinfusion of 700 mL of whole blood. The most notable postoperative finding was marked leukocytosis (WBC 18.85 × $10^3/\mu L$; a threefold increase from the preoperative baseline) with pronounced neutrophilia (neutrophil percentage 90.7%, ANC 17.09 × $10^3/\mu L$) and relative lymphopenia (lymphocyte percentage 7.2%, decreased from 24.4% preoperatively) (Table 1).

Postoperative platelet count was 243 × $10^3/\mu L$, representing a mild decrease from 299 × $10^3/\mu L$ preoperatively. This is consistent with dilutional and consumptive thrombocytopenia following major surgery and remains well within the normal reference range, indicating no clinically significant thrombocytopenia. Postoperative PT was 13.5 seconds (INR 0.98), both within normal limits. However, postoperative APTT was 23.3 seconds — marginally below the lower reference limit of 24 seconds — compared to a preoperative value of 31.1 seconds (Table 1). Postoperative electrolytes revealed sodium 142 mmol/L, potassium 3.67 mmol/L, magnesium 2.07 mg/dL, and calcium 8.8 mg/dL — all within normal reference ranges. Chloride was mildly elevated at 111.2 mmol/L (reference range

94–110 mmol/L), consistent with mild hyperchloremia (**Table 1**).

The decision to proceed with ANH was based on a systematic assessment of the patient's preoperative clinical and laboratory profile in relation to established eligibility criteria.[1,4,5] **Table 2** presents the patient's parameters alongside commonly recommended ANH eligibility criteria.

DISCUSSION

Patient blood management (PBM) is a multidisciplinary, evidence-based strategy aimed at optimizing the care of patients who may require transfusion by reducing unnecessary allogeneic blood use and its associated risks.[4] Its framework is organized around three pillars: (1) preoperative optimization of erythropoiesis and correction of preoperative anemia; (2) minimization of intraoperative and perioperative blood loss through hemostatic optimization and blood conservation techniques; and (3) optimization of the patient's physiological tolerance to anemia. ANH falls squarely within the second pillar as a technique designed to reduce the net erythrocyte loss during surgery by intentionally diluting the circulating red cell concentration prior to the period of major surgical hemorrhage.[4,5]

The fundamental principle of ANH is that hemodilution reduces the erythrocyte content of each milliliter of shed blood: when the hematocrit is lowered before surgical bleeding commences, intraoperative blood loss contains fewer red blood cells per unit volume. By collecting this hemodiluted blood, which also retains viable platelets and functional coagulation factors, and reinfusing it after the period of major hemorrhage has passed, the procedure effectively conserves the patient's own red cell mass, platelets, and clotting factors that would otherwise be irreversibly lost.[3,4] The magnitude of clinical benefit is proportional to the degree of hemodilution achieved and the volume of intraoperative blood loss.

The patient's preoperative hemoglobin of 14.2 g/dL substantially exceeded the minimum threshold of 12 g/dL generally required for ANH candidacy, providing adequate erythrocyte reserve to tolerate acute hemodilution while maintaining intraoperative oxygen delivery above critical thresholds.[1,4] Hematocrit of 42.6% similarly exceeded the commonly cited preoperative threshold of ≥ 33%. Platelet count was 299 × 10^3/μL, well above the recommended minimum of 100 × 10^3/μL, and coagulation studies were within normal limits, confirming adequate hemostatic function. Renal, hepatic, and cardiopulmonary function were clinically acceptable.

Estimated blood volume (EBV) was calculated as: EBV = body weight × 65 mL/kg = 51 × 65 = 3,315 mL. Using the Gross formula to estimate the maximum allowable blood withdrawal volume, targeting a conservative final intraoperative hematocrit (Hf) of 28%: V = EBV × (Hi − Hf) / Hav, where Hi (initial hematocrit) = 0.426, Hf = 0.28, and Hav (average hematocrit) = (Hi + Hf) / 2 = 0.353. This yields: V = 3,315 × (0.426 − 0.28) / 0.353 ≈ 1,370 mL. The actual volume collected (700 mL across two units) was substantially below this theoretical maximum, representing a conservative and clinically appropriate collection volume.[4]

The ANH procedure was performed in two sequential phases, as documented in the available clinical record. The first autologous whole blood unit (350 mL) was collected several hours before the scheduled craniotomy, following a formal donor eligibility assessment confirming that all required criteria were met. The second unit (350 mL) was collected at the initiation of surgery under the direct supervision of the anesthesiology team, following a repeat assessment of hemodynamic stability and continued donor eligibility.[1,4,5]

Each unit was collected into a standard blood collection bag containing anticoagulant (the specific anticoagulant type, for example, citrate-phosphate-dextrose [CPD], was not explicitly documented in the available case data and represents a limitation of this report). Each bag was labeled with the patient's full name, medical record number, sequential unit number, and collection time, in strict compliance with transfusion safety and traceability standards. The bags were stored at room temperature (approximately 18–25°C) in the operating theater until the time of reinfusion, consistent with standard practice for fresh autologous whole blood collected via ANH. Normovolemia was maintained during blood collection by infusion of replacement crystalloid or colloid solution. Current consensus guidelines recommend a 3:1 replacement volume ratio when crystalloid (e.g., 0.9% normal saline, Ringer's lactate, or multi-electrolyte solution) is used, or a 1:1 ratio when colloid (e.g., albumin solution) is used.[4] The minimum acceptable intraoperative hemoglobin level is generally 5–8 g/dL, with the precise threshold determined by the individual patient's cardiopulmonary reserve and clinical status.[4] However, the specific type, volume, and infusion rate of replacement fluid used in this case were not documented in the available medical record and represent a limitation of this report.

The criteria for reinfusion were the occurrence of significant intraoperative blood loss (estimated at approximately 600 mL) and the clinical judgment of the anesthesiology and surgical team. Both units were reinfused in reverse order: the second (most recently collected) unit was administered first, as it retains relatively higher concentrations of viable platelets and active coagulation factors; the first (earlier collected) unit was administered subsequently.[4] Total autologous whole blood reinfused was 700 mL. Consistent with standard autologous transfusion practice in a monitored perioperative setting, infectious disease screening and pretransfusion compatibility testing were not required, provided that strict patient identification and labeling protocols were followed.

A clinically significant advantage of ANH over other blood conservation strategies is the use of fresh autologous whole blood as the transfusion product.[4] Unlike allogeneic packed red blood cells, which are depleted of viable platelets, may have reduced coagulation factor activity depending on storage conditions, and carry the progressive storage lesion that accumulates over the storage period, fresh autologous whole blood collected via ANH retains functional red cells, viable platelets, and active coagulation factors at the time of reinfusion.[3,4] This is particularly relevant in surgical procedures associated with significant blood loss and

Table 1. Complete Laboratory Data - Preoperative and Postoperative

Parameter	Unit	Preoperative	Postoperative	Reference Range
Complete Blood Count				
White Blood Cell Count	$\times 10^3/\mu L$	6.02	18.85*	4.1–11.0
Neutrophil %	%	65.60	90.70*	47–80
Lymphocyte %	%	24.40	7.20*	13–40
Monocyte %	%	6.80	1.40	2.0–11.0
Eosinophil %	%	2.00	0.20	0.0–5.0
Basophil %	%	1.20	0.50	0.0–2.0
Absolute Neutrophil Count	$\times 10^3/\mu L$	3.95	17.09*	2.50–7.50
Absolute Lymphocyte Count	$\times 10^3/\mu L$	1.47	1.35	1.00–4.00
Absolute Monocyte Count	$\times 10^3/\mu L$	0.41	0.27	0.10–1.20
Absolute Eosinophil Count	$\times 10^3/\mu L$	0.12	0.04	0.00–0.50
Absolute Basophil Count	$\times 10^3/\mu L$	0.07	0.10	0.0–0.1
Red Blood Cell Count	$\times 10^6/\mu L$	4.77	4.03	4.0–5.2
Hemoglobin	g/dL	14.20	11.80	12.0–16.0
Hematocrit	%	42.60	36.80	36.0–46.0
MCV	fL	89.30	91.30	80.0–100.0
MCH	pg	29.80	29.30	26.0–34.0
MCHC	g/dL	33.30	32.10	31.0–36.0
RDW	%	12.80	13.20	11.6–14.8
Platelet Count	$\times 10^3/\mu L$	299	243	140–440
Coagulation Profile				
Prothrombin Time (PT)	seconds	14.3	13.5	10.8–14.4
INR		1.04	0.98	0.9–1.1
APTT	seconds	31.1	23.3†	24–36
Hepatic Function				
SGOT (AST)	U/L	27.00	—	< 34
SGPT (ALT)	U/L	25.00	—	< 55
Renal Function and Metabolic				
Blood Urea Nitrogen (BUN)	mg/dL	9.2	—	9.8–20.1
Creatinine	mg/dL	0.81	—	0.57–1.11
eGFR	$mL/min/1.73\ m^2$	84.09	—	≥ 90
Fasting Glucose	mg/dL	87	—	70–140
Electrolytes (Postoperative)				
Sodium	mmol/L	—	142	136–145
Potassium	mmol/L	—	3.67	3.50–5.10
Chloride	mmol/L	—	111.2*	94–110
Magnesium	mg/dL	—	2.07	1.6–2.6
Calcium	mg/dL	—	8.8	8.40–9.70

*Value above reference range; † Value marginally below lower reference limit (APTT reference: 24–36 seconds). eGFR, estimated glomerular filtration rate; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; RDW, red cell distribution width; APTT, activated partial thromboplastin time; INR, international normalized ratio; AST, aspartate aminotransferase; ALT, alanine aminotransferase; BUN, blood urea nitrogen.

risk of coagulopathy, such as craniotomy for hypervascular tumors. Furthermore, autologous transfusion eliminates the principal immunological risks inherent to allogeneic transfusion, including acute hemolytic reactions, febrile non-hemolytic reactions, transfusion-related acute lung injury (TRALI), transfusion-associated circulatory overload (TACO), alloimmunization to blood group antigens, and post-transfusion purpura.[3] The risk of transfusion-transmitted infections, viral,

Table 2. Systematic Assessment of ANH Eligibility in the Reported Case[1,4,5]

Parameter	Patient Value	ANH Eligibility Criterion	Criterion Met?
Preoperative hemoglobin	14.2 g/dL	≥ 12 g/dL	**Yes**
Preoperative hematocrit	42.6%	≥ 33%	**Yes**
Platelet count	299 × 10^3/μL	≥ 100 × 10^3/μL	**Yes**
PT / INR	14.3 s / 1.04	Within normal limits	**Yes**
APTT	31.1 seconds	Within normal limits	**Yes**
Hepatic function	SGOT 27, SGPT 25 U/L	No significant hepatic impairment	**Yes**
Renal function	eGFR 84.09 mL/min/1.73 m^2; Cr 0.81 mg/dL	No oliguria or severe renal failure	**Yes**
Cardiopulmonary function	No documented dysfunction	No severe cardiac/ pulmonary impairment; EF not formally assessed†	**Partial†**
Active bacterial infection	None documented	Absence of active infection/ bacteremia	**Yes**
Preoperative anemia	Hb 14.2 g/dL (normal)	No preoperative anemia (Hb ≥ 12 g/dL)	**Yes**
Anticipated blood loss	~600 mL (large meningioma craniotomy)	> 20% estimated blood volume or significant loss anticipated	**Yes**

† Formal echocardiographic assessment of ejection fraction was not documented in the available records. However, no clinical evidence of significant cardiopulmonary dysfunction was present, and the patient tolerated the preoperative evaluation without hemodynamic abnormality.

bacterial, or parasitic, is also eliminated.[1]

Elective craniotomy, particularly for large or vascular tumors such as meningioma, may be associated with moderate-to-significant intraoperative blood loss, depending on tumor size, vascularity, and surgical complexity.[6] En plaque meningiomas, as suspected in this case, are characteristically hypervascular tumors that may receive arterial supply from multiple meningeal and cortical feeding vessels, and resection may involve substantial hemorrhage. While the evidence base for ANH is most extensively developed in the cardiac, orthopedic, and gynecological surgical literature, its physiological principles are equally applicable in elective neurosurgery when patient selection is appropriate and hemodynamic considerations unique to the neurosurgical context, including the need for stable cerebral perfusion pressure and avoidance of hypotension, are carefully managed.

Several clinical studies support the efficacy of ANH in reducing allogeneic transfusion requirements across diverse surgical specialties. Bansal et al. conducted a prospective evaluation of ANH in patients undergoing major orthopedic surgery and reported a significant reduction in allogeneic transfusion requirements and postoperative complication rates in the ANH group compared to controls.[7] Saito et al. performed a retrospective study of ANH in 586 patients with gynecological malignancies and found that the perioperative allogeneic transfusion rate was significantly lower in patients who underwent ANH (3.5%) compared to those who did not (11.8%; $p < 0.001$).[8] Nobre and Garcia similarly reported substantially lower allogeneic transfusion rates in scoliosis surgery patients who received ANH (12.5%) versus controls (70.69%).[9] The outcome in the present case, avoidance of allogeneic transfusion despite approximately 600 mL of intraoperative blood loss, is consistent with the outcomes reported in these studies. However, direct comparison is limited by differences in surgical specialty, patient population characteristics, and operative blood loss volumes based on the previous study.[10] To the best of the authors' knowledge, no published clinical trial or case series has specifically evaluated ANH in the context of elective craniotomy for meningioma; further evidence in this neurosurgical context is therefore warranted.

Despite its potential benefits, ANH carries recognized limitations and risks that must be transparently acknowledged when counseling patients and designing institutional protocols.[1,4,5] Significant acute hemodilution may compromise tissue oxygen delivery if the hemoglobin falls below a patient-specific critical threshold; current guidelines recommend that the intraoperative hemoglobin generally should not fall below 5–8 g/dL, adjusted according to the patient's cardiopulmonary reserve, clinical stability, and electrocardiographic signs of ischemia.[4] Hemodynamic instability may occur during blood collection if volume replacement is inadequate or delayed, underscoring the indispensable role of continuous hemodynamic monitoring. Operational risks include bacterial contamination during blood collection, clot formation within the collection bag due to inadequate anticoagulation, patient identification or bag-labeling errors resulting in incorrect reinfusion, and degradation of blood product quality due to inappropriate storage temperatures. Additionally, if anticipated blood loss does not materialize and reinfusion is not triggered, the collected autologous blood is discarded, negating the clinical benefit of the collection while exposing the patient to its procedural risks.

Safe and effective implementation of ANH requires proactive, coordinated collaboration among anesthesiology, surgery, the transfusion service or blood bank, and clinical pathology/laboratory medicine.[4] An institutional written protocol specifying patient eligibility criteria, target collection volumes (ideally pre-calculated using the Gross formula), replacement fluid type and infusion ratio, hemodynamic monitoring parameters and thresholds for discontinuing collection, storage conditions and maximum storage duration for autologous whole blood, labeling requirements, transfusion triggers, and reinfusion sequence (reverse order: most recently collected unit first) should be established and consistently followed.[4,5] Standardized documentation of all procedural details, including precise collection timing, hemodynamic parameters at each collection, volumes and types of replacement fluid administered, and timing and sequence of reinfusion, is essential for patient safety, regulatory compliance, quality assurance, and scientific evaluation of outcomes. In the present case, the absence of several of these documented details represents a limitation that must be addressed before submission and in future clinical practice.

This case report is subject to several important limitations. First, as a single-patient observation, it does not permit generalized conclusions regarding the clinical efficacy, safety profile, or optimal protocol for ANH in elective craniotomy; prospective controlled studies in the neurosurgical population are needed. Second, the original medical record documentation contained chronological inconsistencies in recorded dates, precluding a fully verified temporal reconstruction of clinical events; the authors must verify and correct all event dates against the primary medical record before journal submission. Third, specific intraoperative hemodynamic monitoring values, including blood pressure, heart rate, and oxygen saturation at the time of each blood collection and reinfusion, were not available for review and could not be included in this report. Fourth, the type, volume, and infusion rate of replacement fluid used to maintain normovolemia during blood collection were not documented in the available data, limiting characterization of the ANH protocol. Fifth, the specific anticoagulant used in the blood collection bags, the intraoperative target hematocrit, and the criteria for initiating reinfusion were not formally specified in the available documentation. Sixth, postoperative follow-up data were limited to the immediate perioperative period, and longer-term outcomes, including wound healing, thromboembolic events, and overall recovery, are not available. These limitations should be explicitly stated in the final submitted manuscript.

CONCLUSION

This case report describes the clinical application of ANH as a component of perioperative blood conservation in a patient undergoing elective craniotomy for a suspected en plaque meningioma. ANH may represent a useful, cost-effective, and safe component of a comprehensive patient blood management strategy in selected patients undergoing elective surgery with anticipated moderate-to-significant blood loss. However, safe implementation requires rigorous patient selection, standardized and pre-specified procedural protocols, real-time hemodynamic monitoring, meticulous labeling and storage of collected units, explicit reinfusion criteria and sequencing, and coordinated multidisciplinary collaboration among anesthesiology, surgery, the transfusion service, and clinical pathology/laboratory medicine. The findings of this single case report should be interpreted with appropriate caution. Prospective studies evaluating the safety, efficacy, and optimal protocols for ANH specifically within the neurosurgical context are warranted.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this case report.

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ETHICS CONSIDERATION

This case report was prepared in accordance with ethical principles for medical case reporting. Patient identity and personal information were anonymized to maintain confidentiality. Written informed consent has been obtained from the patient for publication of the clinical information related to this case.

AUTHOR CONTRIBUTIONS

IPYP contributed to conceptualization, data collection, literature review, manuscript drafting, and final manuscript revision. NKM contributed to supervision, clinical interpretation, critical review, and approval of the final manuscript. All authors have read and approved the final version of the manuscript.

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