Intraoperative Blood and Coagulation Factor Replacement During Neurosurgery

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KEYWORDS

• Blood components • Blood replacement • Blood transfusion • Coagulation
• Intraoperative procedures

KEY POINTS

- The decision to transfuse during a neurosurgical procedure should be based on multiple data points, including vital signs, laboratory studies, and observations of the surgical field.
- Up-to-date knowledge on available blood products, components, and factors is critical when deciding when and how to replete a neurosurgery patient intraoperatively.
- The type of neurosurgical procedure, underlying pathologic condition, and surgical technique all influence the probability of requiring an intraoperative transfusion.

INTRODUCTION

In the late nineteenth century, the field of neurosurgery struggled with perioperative mortality rates of 30% to 50%. Of the many drivers of perioperative mortality, one of the most significant was large-volume intraoperative blood loss. Any significant blood loss during surgery presented a major challenge because of a lack of understanding regarding blood types and compatibility, an inability to store blood for extended periods of time, and a paucity of available donors intraoperatively.[1]

The safe transfusion of blood products to counteract intraoperative bleeding became possible in the twentieth century after several advances. In 1901, Karl Landsteiner published his seminal work on the 4 primary blood groups, but his findings were not widely adopted until the 1920s. ABO terminology was not accepted until the 1937 Congress of the International Society of Blood Transfusion. In 1943, based on the work of Richard Lewinsohn, Peyton Rous, and J. R. Turner, the use of citrate-phosphate-dextrose solution was adopted, allowing for the anticoagulation and storage of blood for up to 28 days before transfusion—a development that led to blood banks. Finally, 2 landmark contributions by Edwin Cohn (the fractionation of plasma proteins with ethyl alcohol in 1946 and the first cell separator developed in 1951) paved the way for modern-day blood component therapy.[2]

In this article, the authors review the use of intraoperative blood and coagulation factor replacement as it pertains to modern neurosurgical practice. Various methods of assessing hemodynamic and coagulation status intraoperatively are discussed, as are blood components and coagulation factors available for transfusion. Updated

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information is provided on current strategies for intraoperative transfusion in cranial and spinal surgery and on the management of patients whose personal beliefs preclude transfusion.

INTRAOPERATIVE ASSESSMENT OF HEMODYNAMIC AND COAGULATION STATUS

Many of the same techniques used during the preoperative workup can also be used to evaluate hemodynamic and coagulation status during neurosurgery. Because many patients begin surgery with both intravenous and arterial access, it is not difficult to repeat any routine hematologic laboratory studies, platelet function assays, or even thromboelastography several times during a procedure.

Determining when it is appropriate to reassess hemodynamic and coagulation status intraoperatively begins with clinical observations, including the degree of blood loss from the surgical field and the presence or absence of normal clot formation with routine hemostatic maneuvers (eg, electrocautery, topical hemostatic agents). The patient's vital signs should also be observed closely. Physiologic indicators of blood loss (eg, reduced urine output, tachycardia, narrowed pulse pressure, hypotension, hypoxemia) may signal the need for earlier laboratory evaluation. Intraoperative assessments (eg, complete blood count, prothrombin time [PT], international normalized ratio [INR], activated partial thromboplastin time [aPTT]) can be compared with the patient's preoperative baseline when considering transfusion.

Other common laboratory studies not routinely conducted preoperatively may provide valuable insight on a patient's coagulation state during surgery. Fibrinogen, fibrin degradation product, and D-dimer levels provide useful information about ongoing processes related to coagulation. Fibrinogen is the terminal target of the coagulation cascade and is continuously consumed during surgery as fibrin clots form. A fibrinogen level of greater than 100 to 200 mg/dL is typically sufficient to provide normal clotting function; however, lower levels may prompt repletion with cryoprecipitate or a different fibrinogen-containing transfusate.[3] Furthermore, serial measurements of plasma fibrinogen may help detect consumptive coagulopathy, such as disseminated intravascular coagulation (DIC). Fibrin degradation product and D-dimer levels from fibrinolysis may also indicate ongoing DIC if abnormally elevated.

Thromboelastography is increasingly popular for monitoring coagulation status intraoperatively. Thromboelastography-guided transfusion algorithms have been shown to reduce perioperative fresh frozen plasma (FFP) transfusion requirements in multiple surgical specialties (eg, hepatic surgery, cardiac surgery, neurosurgery).[4–6] Intraoperative thromboelastography can also be used to identify patients at high risk for excessive bleeding, and in some cases, thromboelastography has proved superior to more conventional measures such as platelet count.[7,8] Furthermore, neurosurgical reports indicate that hypocoagulability measured on perioperative thromboelastography may predict increased risk of postoperative hematoma in pediatric patients undergoing craniotomy for primary brain tumors.[9]

Other novel modalities for monitoring hematologic and coagulation parameters have also been explored. For example, pulse CO-oximetry has been demonstrated to provide a noninvasive, relatively accurate estimate of hemoglobin concentration using a fingertip sensor. Continuous, noninvasive hemoglobin monitoring also reduces the need for intraoperative blood transfusions during elective orthopedic surgery.[10] A recent systematic review demonstrated good overall correlation between mean CO-oximetry measurements and traditional laboratory measurements, but noted a wide range of agreement ($\pm$2.2–3.0 perioperatively), which may limit the utility of CO-oximetry for guiding clinical decision making.[11] Point-of-care hemoglobinometers have also been demonstrated to correlate closely with traditional laboratory hematology analyzers intraoperatively and may provide another rapid, nominally invasive means of hemoglobin monitoring.[12]

The importance of monitoring hematologic and coagulation status intraoperatively is best illustrated by DIC, which is a potentially catastrophic hematologic complication of surgery, particularly cranial neurosurgery. DIC is a consumptive coagulopathy characterized by widespread, systemic activation of primary and secondary coagulation. This activation can cause extensive thrombus formation in the microvasculature of multiple organ systems, resulting in dysfunction. During surgery, ongoing activation of the coagulation cascade consumes plasma anticoagulants such as antithrombin III, protein C, and tissue factor (TF) inhibitor, thus predisposing patients to overactivation of the coagulation cascade. The systemic release of TF during cranial neurosurgery because of manipulation of brain tissue may further contribute to hyperactivation of the TF pathway of secondary hemostasis.

The clinical phenotype of DIC during surgery varies, depending on the balance between plasma thrombin and plasmin levels, and it may range from extensive thrombosis to abnormal, persistent bleeding from the surgical field. No single