Review

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Estimating surgical blood loss: A review of current strategies in various clinical settings

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Abstract

The estimation of surgical blood loss is routinely performed during and after surgical procedures and has morbidity and mortality implications related to the risk of under- and over-resuscitation. The strategies for estimating surgical blood loss include visual estimation, the gravimetric method, the colorimetric method, formula-based methods, and other techniques (e.g., cell salvage). Currently, visual estimation continues to be the most widely used technique. In addition, unique considerations exist when these techniques are applied to various clinical settings such as massive transfusion, cardiac surgery, and obstetrics. Ultimately, when using estimated surgical blood loss to guide perioperative fluid management and transfusion thresholds, it is also important to mitigate the risks associated with resuscitation by targeting a goal-directed fluid therapy approach by utilizing markers of fluid-responsiveness to optimize stroke volume (cardiac output) and delivery of oxygen.

Keywords

Estimated blood loss, surgical blood loss, methods of blood loss estimation, resuscitation, goal-directed fluid therapy

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Background

Surgical blood loss or intraoperative blood loss are commonly used terms to describe the loss of blood during a surgical procedure. This volume of blood loss is typically estimated and is termed estimated blood loss (EBL).[1] EBL is a standard component of the medical record that impacts clinical decision-making and serves as an important metric in surgical outcomes research.[1]

Increased EBL as well as intraoperative blood transfusions are associated with postoperative morbidity and mortality.[2–5] Despite the known challenges related to accuracy, EBL is routinely documented by both the surgical and anesthesiology teams. Perioperative morbidity and mortality may be influenced by both under- and over-estimation of EBL, where the unrecognized loss of substantial blood volume may lead to reduced delivery of oxygen and end-organ dysfunction, and the overestimation of blood loss may lead to unnecessary blood product transfusions.[4] Complications of transfusions include hemolytic reactions, allergic reactions, circulatory overload, transfusion-related acute lung injury, transmission of infection, and immune sensitization.[6] The current strategies to determine EBL and their application in various clinical settings will be reviewed here.

Methods of literature search

We identified studies through updated searches with CENTRAL and MEDLINE, to September 2024. Additionally, we used reference lists of other published reviews and relevant manuscripts to identify other studies.

Current strategies to estimate surgical blood loss

Visual estimation. The conventional method for measuring EBL is visual estimation, which includes all of the following: degree of saturation of surgical gauze (e.g., laparotomy sponges) and surgical drapes, blood present on other surfaces including the floor or sides of an operating room table, and the use of suction canisters (see Figures 1–3).

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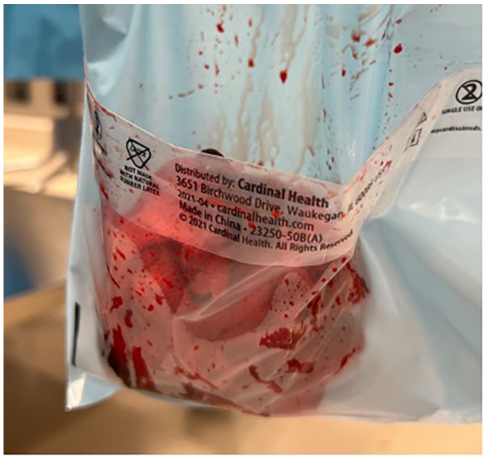

Figure 1. Image of saturated surgical sponge.
Source: Photographed by Alexander Stoker in 2023.

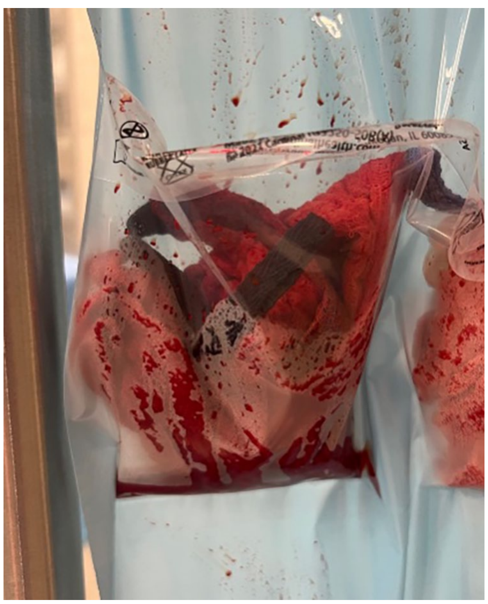

Figure 2. Image of supersaturated surgical sponge.
Source: Photographed by Alexander Stoker in 2023.

Surgical Gauze (e.g., laparotomy sponges). Surgical gauze of various sizes is used during surgical procedures and can be used to estimate EBL. The amount of blood contained within a surgical sponge varies significantly based on the degree of saturation and whether the sponge used was dry at the time of application. Visual estimation of blood loss using laparotomy sponges also varies with actual color of the sponge. In a study by Piekarski et al.,[7] involving 53 anesthesia providers estimating a known volume of expired donated blood in surgical sponges, the median visual EBL was significantly higher in white sponges compared to green sponges (250 ml in white sponges and 150 ml in green sponges compared to an actual median volume of 103 ml).[7]

Algadiem et al.[8] showed that a 30 cm by 30 cm sized gauze contains 100 ml of blood when saturated and created a visual analog showing various sizes of surgical gauze, the degree of saturation and corresponding volume of blood contained for each visual reference.[8] They also describe an additional 30% capacity (130 ml) of this sponge when supersaturated and a 30% decrease in absorptive capacity when the gauze was wet with saline, highlighting the importance of knowing whether sponges are dry prior to use.[8]

Suction canisters. In addition, the visual estimation of EBL also includes the use of suction canisters.

These canisters are graduated and collect blood and other fluids (e.g., bodily fluids and irrigation or diluting solutions). When the volume of these other fluids are known, it is then possible to determine the volume of blood contained within the canister. However, precise measurements are frequently difficult as there may be irrigation or diluting solution that is lost or not collected by the suction canister. In a prospective randomized trial by Guinn et al.[9] involving 60 patients undergoing multilevel spinal surgery, the mean EBL as documented by the anesthesiology team exceeded the measured blood loss by 246 ml.[9] In a simulation study involving 53 anesthesia providers and a known volume of expired donated whole blood diluted into suction canisters filled with electrolyte solution, Gerdessen et al.[10] found the median EBL by participants to be 500 ml, while the actual median blood volume was 281.5 ml, highlighting the tendency to overestimate blood volume diluted into another liquid solution.[10] Interestingly, a recent prospective observational cohort study evaluating EBL estimation in major abdominal surgery found that both surgeons and anesthesiologists overestimated EBL when using the visual estimation method as compared to spectrophotometric measurement.[11]

Gravimetric method. The gravimetric method of estimating EBL involves weighing an absorptive substance such as a surgical sponge before and after use to determine the amount of blood contained within that substance with the assumption that every additional gram represents 1 ml of blood.[12] Inaccurate estimation of EBL with the gravimetric method may be caused by surgical sponges containing fluids other than blood, such as irrigation solution, amniotic fluid, bile, intestinal contents, pus, or other fluids. Interestingly, the gravimetric method may neither be precise nor accurate. A comparison of blood loss determined by the gravimetric method in surgical sponges from general gynecologic surgeries to the hemoglobin level determined by spectrophotometer analysis (photometric method) found no correlation between methods.[13]

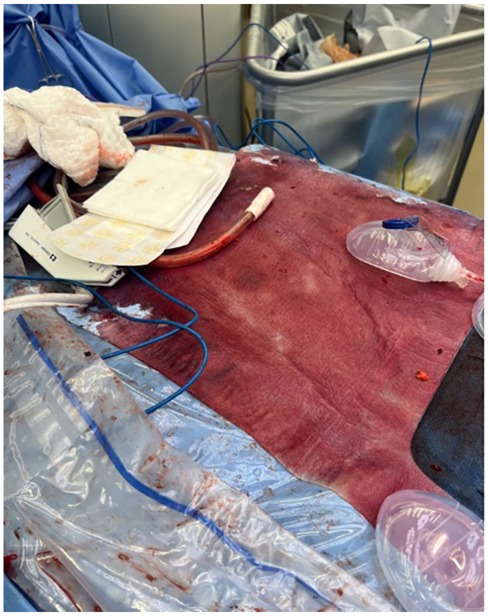

Figure 3. Image of saturated surgical drapes at the conclusion of an orthotopic liver transplant.
Source: Photographed by Alexander Stoker in 2023.

Colorimetric method. Colorimetric method uses monitoring platforms, which combine mobile imaging with computer vision and machine learning algorithms to measure hemoglobin mass. One computer-based program, the Triton System with Feature Extraction Technology (Gauss Surgical Inc., Los Altos, CA, USA), allows one to take photographs of items such as surgical sponges to determine contained hemoglobin mass. In a prospective multicenter study including 46 patients undergoing procedures with significant expected blood loss, Holmes et al.[14] showed the Triton System to provide an accurate measurement of hemoglobin mass on surgical sponges as compared to manual rinsing measurements.[14]

Formula-based calculations

Several formulas have been used to estimate EBL. These are based on the principal of assuming a euvolemic state in the pre- and postoperative periods and measuring the change in hemoglobin (or hematocrit) value during the procedure while correcting for the hemodilution effect. Some of these formulas include Ward's formula, Bourke's formula, Gross' formula, Lopez–Picado's formula, the Hemoglobin Balance formula, and the Orthopedic Surgery Transfusion Hemoglobin European Overview formula. For example, Gross' formula is

$$\text{Estimated blood loss} = \text{EBV} \times \left[\left(\text{Hct}_0 - \text{Hct}_f \right) / \text{Hct}_{AV} \right]$$

where EBV is estimated blood volume (and is calculated using Moore's Formula), Hct_0 is the initial hematocrit before surgery, Hct_f is final hematocrit, and Hct_{AV} is the average of the initial and minimum hematocrit.

These formulas differ in their correction for blood hemodilution and estimation of patient blood volume.[15] In a prospective observational study by Jaramillo et al.,[15] six formulas were evaluated in eighty patients undergoing urologic laparoscopic surgery to assess for agreement with directly measured blood and found that the formulas correlated poorly with direct measurement of blood loss with the majority of studied formulas overestimating blood loss.

In a prospective randomized control trial involving 157 volunteers who donated 500 ml of blood and were randomized to receive either no intravenous (IV) fluid or 2 L of IV crystalloid fluid, Ross et al.[16] created a formula to predict hemoglobin levels from an EBL and volume replacement.[16] The authors describe both the effect of hemodilution due to crystalloid infusion as well the equilibration process of mobilizing interstitial fluid to maintain intravascular volume in the control group who did not receive IV fluid.[16] While this study involved hemoglobin measurements only in the first 30 min after blood donation, it emphasizes the importance of considering the hemodilution effect from both intravenously administered fluid as well as mobilization of interstitial fluid when attempting to calculate blood loss based on pre- and postprocedure hemoglobin values.[16]

Cell salvage

Using cell salvage to collect blood lost in the surgical field and readminister to patients is another opportunity to estimate EBL. The yield of red blood cells returned to a patient after processing a collected sample (i.e., efficiency) is dependent on several factors including the degree of negative pressure used to collect blood from the surgical field, suction tip size, anticoagulant used to prevent clot formation in the collection reservoir, and quality of red blood cell wash during processing. It is possible to calculate blood loss during a surgical procedure by knowing the average hematocrit of washed salvaged red blood cell, the average patient hematocrit during salvage, the volume of processing bowl, number of bowls processed, and estimating salvage efficiency as described by Waters.[17] Using proper techniques to optimize salvage efficacy, 60% of lost red blood cells can be recovered.[17]

Considerations in various clinical settings

Massive transfusions. In situations of massive blood loss, an accurate quantification of EBL may be even more challenging as blood may spill onto the floor and as a result the suction canisters may not contain all of the blood loss (Figure 4). In a study of the visual estimation of EBL, medically untrained bystanders tended to underestimate large volumes of blood loss, whereas when overestimation occurred it was only small volumes.[18] Underscoring the difficulty in massive transfusion scenarios, this tendency to underestimate large volumes of blood loss was also demonstrated with physicians and Emergency Medical Technicians.[19–21]

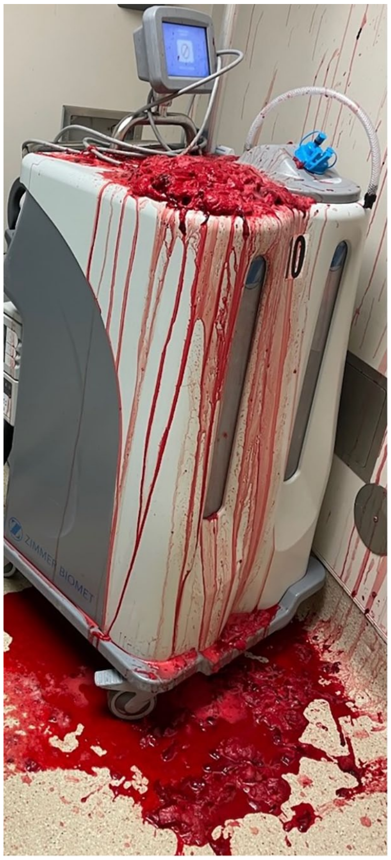

Figure 4. Image of large volume suction canister used in a massive transfusion scenario which malfunctioned due to accumulation of coagulated blood and resulted in blood spilling on the exterior portion of device and the floor.
Source: Photographed by Megan Fah in 2023.

In situations of large volume resuscitation such as trauma cases, major vascular cases, liver transplantation, or maternal hemorrhage, it may be reasonable to estimate the EBL based on the amount of blood products required to achieve a euvolemic state. When using rapid transfusion systems such as the Belmont®, it is possible to measure the total volume transfused through the rapid infuser and may be useful in determining an estimated EBL.

It is also important to recognize that during orthotopic solid organ transplantation, there is blood volume within the explanted organ that is lost and directly affects the circulating blood volume in the recipient. Further, there is potential blood loss associated with performing a blood flush of a newly implanted organ. There may be other specific surgical procedures such as removal of a large tumor in which a substantial volume of blood is lost when the tumor is excised.

Cardiac surgery. Challenges inherent to estimating EBL in cardiac surgery include the effect of hemodilution from crystalloid priming of the cardiopulmonary bypass circuit, hemodilution from cardioplegic solution use, and hemolysis.

Strategies to minimize the effect of hemodilution and decrease the need for transfusion associated with cardiopulmonary bypass include the use of retrograde or antegrade autologous priming, hemoconcentration by using ultrafiltration, and using a lower volume cardioplegia solution. The use of acute normovolemic hemodilution or cell scavenging may preserve total red blood cell mass however may contribute to the challenge of accurately estimating EBL.

In a study involving 54 patients undergoing cardiac surgery requiring cardiopulmonary bypass and measuring blood volume, plasma volume and red blood cell volume using a dilution tracer method, Nelson et al.[22] found that decreases in hematocrit observed were due to red blood cell losses and not due to hemodilution with an average red blood cell loss of 38% and an average plasma volume decrease of 8%.[22]

Obstetrics. Estimating blood loss during labor and delivery presents several unique challenges including quantifying blood mixed with amniotic fluid, urine or meconium, differentiating fluid collected before and after delivery of the placenta, and collection of blood in nonsurgical drapes such as bedsheets or in disposable under-pads. The America College of Obstetricians and Gynecologists committee opinion for quantitative blood loss in obstetric hemorrhage published in 2019 has tips for quantification of blood loss during both vaginal as well as cesarian birth and emphasizes that quantitative methods are more accurate than visual estimation.[23]

In a prospective study of 109 women in labor or undergoing Cesarian section comparing EBL using the gravimetric or visual method, Dutton et al.[24] found that gravimetric method yielded a higher EBL than with visual methods in instrumental deliveries and Cesarian sections.[24] These authors also found that EBL was underestimated in 75% of women and that in cases of increased blood loss, there was a larger discrepancy between the two methods.[24]

It is also important to recognize the development of postpartum hemorrhage, as delayed diagnosis and treatment is associated with significant morbidity and mortality.[25] In addition to accurate estimation of EBL, recognition of risk factors for postpartum hemorrhage, which include uterine atony, lacerations or uterine rupture, retained placenta, clotting factor deficiency, electrolyte derangement, and advanced maternal age, may help in preparation for prompt recognition and treatment of significant blood loss.[26,27]

Discussion

The optimal technique for estimating EBL remains controversial. In a meta-analysis comparing perioperative EBL techniques by Gerdessen et al.,[28] the visual method had the lowest correlation with the corresponding reference method; however, the authors found there to be no gold-standard reference method and that the described validated method varied widely among studies included.[28] In a meta-analysis comparing EBL techniques in major noncardiac surgery involving 26 studies and 3297 patients, Tran et al.[1] found visual estimation techniques to be the most frequently studied.[1] These visual techniques generally resulted in lower EBL compared to formula-based estimation or other techniques; however, in pooled analyses the effect was not statistically significant, possibly due to sample size limitations.[1]

The accurate quantification of EBL is essential for appropriate resuscitative fluid management and transfusion therapy. In this regard, it is recommended to utilize a goal-directed approach by assessing fluid responsiveness, a physiologic state where additional IV fluid specifically increased stroke volume and the delivery of oxygen.[29–31] Fluid responsiveness can be assessed with an arterial line by utilizing pulse contour (waveform) analysis pulse pressure respiratory variation or other monitors (e.g., continuous arterial pressure-derived cardiac output monitors) and study has confirmed its efficacy.[32] However, other endpoints of resuscitation used to guide therapy include echocardiography data including stroke volume (cardiac output) calculations, left ventricular end-diastolic area, vena cava size and collapsibility, transmitral flow patterns, and assessment of diastolic function, in addition to blood pressure, systemic venous oxygen saturation, urine output, and metabolic trends suggestive of poor end-organ oxygen delivery (e.g., lactate).[31]

The threshold for transfusion continues to be a topic of debate and varies on the clinical scenario as well as patient-specific factors. Transfusion patterns have traditionally been separated into a restrictive transfusion threshold of 7–8 g/dL and liberal transfusion thresholds of 9–10 g/dL.[33] Recommendations from the 2023 Association for Advancement of Blood and Biotherapies international guidelines, which are based on 45 randomized controlled trials with over 20,000 participants, state that for hemodynamically stable hospitalized adult patients, a restrictive hemoglobin-based transfusion threshold should be used with a general threshold of 7 g/dL, a threshold of 7.5 g/dL for patients undergoing cardiac surgery, and 8 g/dL for patients with preexisting cardiovascular disease or undergoing orthopedic surgery.[33] Consistent with the authors statement that good practice should consider the overall clinical context when making transfusion decisions, the goal of transfusion should be to optimize oxygen-carrying capacity, cardiac output, and oxygen delivery while minimizing the risks of transfusion-related adverse events.

Limitations

This study has potential limitations. This is not a systematic review and a quantitative meta-analysis was not performed. Due to the nature of this narrative review, there is inherent possibility of unintentional selection and author bias. Additionally, there is significant variability in sample sizes of the studies included in this review, and there is potential for a study to be underpowered due to limited sample size.

Conclusion

Despite the known inaccuracies, the visual estimation technique continues to be the most widely used method for estimating EBL. Known challenges to accurately estimate EBL exist in various clinical settings and the optimal technique for estimating EBL depends on the clinical situation.

Author contributions

Alexander D Stoker: Manuscript conceptualization, analysis, writing, and editing. Will J Binder: Manuscript conceptualization, analysis, writing, and editing. Peter E Frasco: Manuscript conceptualization, analysis, writing, and editing. Steven T Morozowich: Manuscript conceptualization, analysis, writing, editing. Layne M Bettini: Manuscript analysis, editing. Andrew W Murray: Manuscript analysis, editing. Megan K Fah: Manuscript analysis, editing. Andrew W Gorlin: Manuscript conceptualization, analysis, editing.

Declaration of conflicting interests

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Ethics approval

Ethical approval was not sought for the present study because this study did not involve recruitment of any subjects, no patients were assigned to any therapies or interventions and no patients or personnel were exposed to any discernable risks given that this was a review article.

Informed consent

Informed consent was not sought for the present study because this study did not involve recruitment of any subjects, no patients were assigned to any therapies or interventions, and no patients or personnel were exposed to any discernable risks given that this was a review article.

Trial registration

Not applicable.

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