Methods of Blood Loss Quantification in Major Abdominal Surgery: A Narrative Review

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ABSTRACT

Blood loss in major abdominal surgery is an essential parameter in the evaluation of strategies aimed at reducing perioperative bleeding. It is also an important parameter of quality of the surgical procedure, along with postoperative morbidity and mortality, radicality of the surgical resection, etc. However, blood loss quantification remains unreliable and inaccurate.

The methods used to measure blood loss can be categorized as visual estimation, gravimetric method, direct measurement, spectrophotometry, calculation methods, colorimetric analysis, and miscellaneous. The aim of this work is to review up-to-date knowledge about the various methods of blood loss quantification and then to introduce study, which should compare more methods of blood loss quantification in a real surgical setting.

KEYWORDS

blood loss quantification; abdominal surgery

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INTRODUCTION

Blood loss during major abdominal surgery is an essential parameter in the evaluation of strategies aimed at reducing perioperative bleeding such as pharmacological interventions, anaesthetic management, and surgical techniques. Blood loss estimate is an important parameter of quality of the surgical procedure, along with postoperative morbidity and mortality, radicality of the surgical resection, number of retrieved lymph nodes, duration of the surgical procedure, or some other parameters (e.g. postoperative pancreatic fistula in case of pancreatic resections, biliary leak in case of liver resection, or anastomotic leak in case of biliary reconstruction) (1–4).

Quantified blood loss plays a key role in blood transfusion decisions, along with other information such as haemoglobin values and individual transfusion triggers. Negative impact of intraoperative blood loss on outcomes has been well characterized in many studies. Inappropriate transfusion of blood products is associated with risks and influences patient's outcome (5). Lower blood loss contributes to better perioperative outcomes (6).

It is important and very well-known fact that perioperative transfusions affect long-term outcome in patients undergoing liver resection for primary liver tumours, metastatic colorectal cancer and also in patients undergoing pancreatic resection (7, 8). Blood transfusion produces host immunosuppression and has been postulated to result in adverse outcome for patients undergoing surgical resection of malignancies. Blood transfusion is associated with adverse outcome and this effect is dose-related. Even patients receiving only one or two units have a more adverse outcome. Blood conservation methods should be used to avoid transfusion, especially in patents currently requiring limited amounts of transfused blood products (7, 8).

However, blood loss quantification remains unreliable and inaccurate (9–13). It is noteworthy that loss of lower blood volumes is estimated more correctly than loss of higher blood volumes. However, large blood loss is life-threatening and therefore more relevant in transfusion decisions. The methods used to measure blood loss can be categorized as visual estimation, gravimetric method, direct measurement, spectrophotometry, calculation methods, colorimetric analysis, and miscellaneous (5, 14). The aim of this work is to review up-to-date knowledge about the various methods of blood loss quantification and then to introduce study, which should compare more methods of blood loss quantification in a real surgical setting.

VARIOUS METHODS OF BLOOD LOSS EVALUATION

There are several methods of blood loss evaluation in surgical procedures. They range from simple visual estimate, through more precise methods, e.g. gravimetric method, direct measurement method, calculation method to spectrophotometric method, which is considered as the most precise one.

Visual estimation of blood loss is still the standard method of choice in many cases. It is the simplest method, on the other hand, it is also the most inaccurate (15). Apart from measuring the volume of the suctioned blood in the suction canisters, a visual estimate of blood shed on the floor, spread in the surgeons' gowns and gloves and hidden in drapes and sponges must be done. A broad deviation of the visual estimates and little coincidence with the actual values has been found (15). Over- and underestimations by 2 or even 3-fold are rather common; underestimations are more frequent. A significant trend to overestimate diluted blood was found. Even though these certain sites were known to exhibit diluted blood, e.g. suction canisters. On the other hand, laparotomy pads and sponges fully saturated with blood are grossly underestimated. Age, gender and length professional experience of the physicians does not influence the magnitude of estimation errors. Only the professional groups' estimates differ: anaesthetists tend to overestimate, on the other hand orthopaedic or general surgeons tend to underestimate the blood loss. Irrigation fluids, lymph, bile, serum, ascites, urine, and other fluids often combine with lost blood, but do not alter its appearance to an extent that is typically appreciable visually, which can affect estimated blood loss (16). Visual estimation of operative blood loss is unreliable and inaccurate. No provider specialty, level of experience, or self-assessment of ability is associated with improved estimation (17). Very often, visual estimate of blood loss relies on a discussion between a surgeon and an anaesthesiologist until a consensus is reached (18).

The **gravimetric method** was first described by Wangensteen (19). It is based on weighing surgical sponges before and after surgical use. Estimated blood loss is determined by assessing the weight difference before and after use, with every gram of weight equivocal to 1 mL of blood loss (18). For minor procedures in which major blood loss is not expected, accurate measurement is trivial. For procedures in which major blood loss is expected, such as during orthopaedic surgery, allogeneic blood transfusion is often the mainstay for intraoperative and postoperative hemodynamic management, making accurate determination of blood loss a necessity. The gravimetric method is easy but neither precise nor accurate (20), especially with increased dilution by rinsing fluid (21, 22).

Direct measurement of blood loss is also a simple and long-established method that is mainly used in the field of obstetrics (5). A calibrated collection bag with a scale is designed especially for vaginal deliveries. Current blood loss can be immediately read from the scale (23, 24). Blood loss measurement in vaginal deliveries is especially important because studies of maternal deaths show that most deaths due to postpartum haemorrhage involve delayed and substandard care in the diagnosis and management of blood loss (23).

Delay in the diagnosis and treatment of postpartum haemorrhage may result from an underestimation of blood loss at delivery. Assessment of postpartum blood loss, particularly after vaginal birth, is recognised as difficult. Many studies found that visual estimates of peripartum blood loss are often inaccurate, showing an overestimation of blood loss at low volumes and an underestimation at larger volumes, the magnitude of underestimation typically increasing with the volume of haemorrhage (25).

When bleeding is excessive but before haemorrhage has become catastrophic, appropriate management will take place without delay, so reducing the incidence of severe postpartum haemorrhage. Study results show significant deviations from real blood loss (23). Lack of identification of women with excessive postpartum bleeding is a problem, potentially leading to higher levels of medical intervention if the bleeding progresses to severe haemorrhage.

Calculation Method: Various mathematical approaches can be used to calculate blood loss in current clinical practice. There are several mathematical formulas and they have been modified over time: Nadler, Liu, Mercuriali, Bourke, Ward, Gross, Lisander, Meunier, Camarasa, Lopez-Picado. All calculation formulas require an estimation of the total blood volume of the patient. The formulas take into account height, weight, body surface area and gender of the patient (26, 27). Perioperative red blood cell loss (RBCL) is calculated by adding the difference in circulating red blood cells from before to after surgery (28–31). The formulas take into consideration volume of blood transfusion, they differentiate between autologous and homologous blood. All blood loss estimation formulas showed a significant tendency to overestimate blood loss (5, 9, 32).

Spectrophotometry is the most precise, but also the most expensive and complex to use. It is considered to be a benchmark for measurement of the blood loss (18). Haemoglobin mass loss is assessed in the lost blood using the spectrophotometric method.

With this method, intraoperative samples extracted from surgical sponges and suction canisters are measured postoperatively with absorption spectrometry, enabling direct haemoglobin (Hgb) measurement within the samples. Spectrophotometric measuring of haemoglobincyanide is the reference method for haemoglobinometry in human blood recommended by the International Council for Standardization in Haematology since 1967 (ICSH) (33). However, the main drawback of this method is a lack of practical and accurate real-time intraoperative EBL assessment. The blood los sis actually calculated after the end of the surgical procedure (18).

Colorimetric blood loss estimation – a smartphone application (Triton™) developed by Gauss Surgical Inc. is able to calculate blood loss by taking photographs of used surgical gauze and canisters. The colorimetric technique analyses photographic and geometric information from relevant areas, with the aim of automatically filtering out the effects of non-blood components mixed in each sponge and canister and calculating the Hb mass present in the gauze or canister from the image. By entering the preoperative Hb-level, the blood loss can then be calculated (5). This method has been found to be accurate across many sponge types and lighting conditions (22) as well as to be an accurate determinant of blood loss assessment in adult patients (21). High degrees of correlation with the reference blood volumes were found in several studies, however only with limited number of patients (21, 22, 34–37). Large studies with more patients are needed to confirm these results.

DISCUSSION

Even though, there are many methods of blood loss quantification or estimation, no study yet compared more methods to assess the deviations from the spectrophotometry as the most accurate method.

We decided to conduct a clinical trial in order to compare several methods of blood loss quantification or estimation in real surgical settings. The primary aim of the trial is to compare several methods of blood loss quantification, e.g. visual estimation by a surgeon (sEBL) and an anaesthesiologist (aEBL), gravimetric method (vGBL), calculation method (vCBL), and spectrophotometry in real surgical settings. We hypothesized that visual estimation, gravimetric measurement, and calculation method will significantly differ from measured haemoglobin loss by spectrophotometry.

All adult patients who are scheduled for elective liver or pancreas surgery in our department are assessed as participants of the trial. Signed informed consent must be provided. Operating surgeon must have experience with at least 200 cases. Patients with coagulation disorder or unable or unwilling to participate are excluded.

Patients are assessed for eligibility in the study, and their anthropometric data (height, weight) and clinically relevant data is recorded prior to the surgery. Venous blood samples for blood count (including haematocrit and haemoglobin concentrations) are drawn before incision, at one hour after closure, and at 24 and48 hours after surgery. All samples are analysed at the central laboratory using an automated haematology analyser XN-10 (Sysmex, Kobe, Japan).

The suction canister is heparinized before surgery (10,000 IU of heparin in 100 ml saline solution) to prevent clotting. The total volume contained in the canister is measured after the end of the surgical procedure by a system capable of determining differences up to ±10 mL and weighted by a Kern, PCB 6000-0 with an accuracy of ±1 g (Balingen, Germany). The sample from the canister is analysed for haemoglobin concentrations by spectroscopy using the XN-10 (Sysmex, Kobe, Japan), and cell count in "body fluid" mode, which is more sensitive to lower cell counts in fluids.

The volume of irrigation fluids used during surgical procedure is carefully recorded as well as infusions, injections and transfusion volume. If necessary, vasoactive agents are titrated to obtain a mean blood pressure of >65 mmHg during procedure. All laparotomy pads are weighted and counted before and after surgery. At the end of the operation, an estimated blood loss is obtained from the anaesthesiologist and surgeon. Postoperative complications are graded based on severity according to the Clavien-Dindo definition (38).

The primary outcome of the trail is to compare several methods of blood loss quantification (visual estimation by surgeon and anaesthesiologist, gravimetric method, calculation method, and spectrophotometry) in real surgical settings.

The anaesthesiologist and surgeon's estimate of blood loss is based on a visual assessment of blood loss in the suction canister and surgical pads after subtracting the volume of added fluids, which both know.

The suction canister and surgical pads are weighed before and after the surgical procedure. Estimated blood loss is determined by assessing the weight difference after subtracting weight of added fluids. Every gram of weight difference equivocal to 1 mL of blood loss.

For calculation method, López-Picado's formula (32) is used to estimate blood loss based on anthropometric and haematological parameters:

$$vCBL = \frac{[EBV \times (Hct_i - Hct_f) + transfused\ RBC\ volume]}{Hct_{mean}}$$

where Hct_i (initial haematocrit) is the patient's preoperative haematocrit, Hct_f (final haematocrit) is the patient's postoperative haematocrit. Postoperative time point of the final haematocrit is not specified in the original formula, therefore in accordance with another studies (1). Hct_f in this trail is determined 48 hours after surgery or when haematocrit reached the nadir level after operation. The transfused RBC volume is calculated as follows: 1 Unit packed homologous blood = 450 mL × haematocrit of the transfused blood; 1 Unit packed autologous blood = 450 mL × haematocrit in the pre-surgical anaesthesia consultation. Hct_{mean} is the mean haematocrit (between Hct_i and Hct_f). EBV is the estimated blood volume determined using the ICSH formula (27):

a) Female:
EBV (mL) = Plasma volume (mL) + red cell volume (mL) = [weight (kg)$^{0.425}$ × height (cm)$^{0.725}$] × 0.007184 × 2.217 + age (years) × 1.06
b) Male:
EBV (mL) = Plasma volume (mL) + red cell volume (mL) = [weight (kg)$^{0.425}$ × height (cm)$^{0.725}$] × 0.007184 × 3.064 – 825

For spectrophotometry as the most accurate method, haemoglobin mass loss for each case is calculated using the spectrophotometric measured haemoglobin concentration from the suction canister. This value is multiplied by the total volume of the suction canisters and the calculated fluid volume from surgical pads.

To obtain total lost haemoglobin mass loss:

hbMBL = *hemoglobin concentration from canister* × (*suction canister volume* + *fluid volume from surgical pads*)

where fluid volume from surgical pads is calculated as:

$$fluid\ volume\ from\ surgical\ pads = \frac{(suction\ canister\ volume) \times (weight\ difference\ of\ surgical\ pads\ before\ and\ after\ use)}{weight\ of\ suction\ canister\ volume}$$

where vMBL is measured blood loss in volume units (mL).

The blood loss is calculated using measured hemoglobin mass loss (hbMBL) and patient's average pre- and postoperative hemoglobin, the vMBL is obtained:

$$vMBL = \frac{hbMBL\ (measured\ hemoglobin\ mass\ loss\ in\ g)}{mean\ (pre\ and\ postoperative)\ hemoglobin\ (in\ g/dL)}$$

The sample size calculation is based on the data from a previous study (16). According to this study power calculations revealed that a sample size of 35 pairs would be needed to detect a 2-fold difference between two methods with 83 percent power to detect the mean difference of 100 mL between these two methods. With an expected dropout rate over 20%, we plan to enrol 45 patients into the study. Patients undergoing elective liver or pancreas surgery will be recruited to reach target sample size.

In conclusion, most surgical departments use the surgeon and anaesthesiologists' visual estimations to determine blood loss during surgery. Such an estimate is, however, often inaccurate. There is no gold standard for determining blood loss in the course of surgical procedures. Determining blood loss accurately in real conditions is a difficult task for many reasons: different suctioning techniques, different use of surgical drapes (soaking part of the drapes in saline before use), different habits of instrumented nurses in the management of flushing fluid, different degrees of admixture of lymphatic fluid, bile, and ascites in the suctioned fluid throughout the course of procedures.

In order to make the measurement of blood loss as accurate as possible, it is necessary to develop a measurement methodology in real conditions that considers the above-mentioned problems.

ABBREVIATIONS

aEBL	estimated blood loss by anesthesiologist in volume units (mL)
EBV	estimated blood volume
hbMBL	measured hemoglobin mass loss in mass units (g)
Hct_i	initial hematocrit, is the patient's preoperative hematocrit
Hct_f	final hematocrit
Hct_{mean}	mean hematocrit (between Hct_i and Hct_f)
RBC	red blood cell
sEBL	estimated blood loss by surgeon in volume units (mL)
vCBL	calculated blood loos in volume units (mL)
vGBL	gravimetric blood loss in volume units (mL)
vMBL	measured blood loss in volume units (mL)

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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