

## Comparison of visually estimated blood loss with direct hemoglobin measurement in multilevel spine surgery

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**BACKGROUND:** Estimates of blood loss in the operating room are typically performed as a visual assessment by providers, despite multiple studies showing this to be inaccurate. Use of a less subjective measurement of blood loss such as direct measurement of the hemoglobin (Hb) mass lost from the surgical field may better quantify surgical bleeding. The objective of this investigation was to compare anesthesiologist estimates of intraoperative blood loss with measured Hb loss.

**STUDY DESIGN AND METHODS:** Sixty patients undergoing posterior spine surgery were enrolled in a prospective, randomized trial comparing intraoperative blood loss using unipolar cautery alone or with use of a bipolar tissue sealant device. Hb concentration and fluid volume were measured from all surgical sponges, suction canisters, and the cell salvage device. Using the volume and concentration of Hb from each solution allowed calculation of Hb mass, which was converted into volume of blood lost and compared with estimates of blood loss documented by the anesthesia team. A single-sample t test of no difference was used to compare estimated with measured blood loss.

**RESULTS:** Mean estimated blood loss exceeded measured blood loss by 246 mL (860 mL vs. 614 mL,  $p < 0.0001$ ).

**CONCLUSION:** Estimated blood loss exceeded measured blood loss by 40% on average. The likely etiology of this discrepancy relates to the inability to visually determine Hb concentration of sanguineous solutions in suction canisters and surgical sponges. Ramifications of excessive bleeding estimates include unnecessary transfusion and overadministration of intravenous fluids, both of which may have deleterious effects.

Accurate estimation of blood loss in the perioperative period is a necessary tool for physicians to recognize significant hemorrhage and guide appropriate transfusion decisions. The majority of literature relating to accuracy of estimated blood loss comes from either simulations or studies involving childbirth. Although these studies have demonstrated that visual estimates of blood loss by providers are inaccurate,<sup>1-5</sup> there is little in the literature evaluating estimates of blood loss by providers for elective, intraoperative cases. Literature that is available suggests that blood loss estimates are volume dependent, with providers tending to underestimate at higher volumes,<sup>5-7</sup> which may lead to unrecognized hypovolemia. Alternatively, overestimates of blood loss could potentially result in unnecessary blood transfusion.

Although anemia itself is a clinical predictor of adverse outcome and increased mortality,<sup>8,9</sup> multiple studies across diverse patient populations demonstrate that red blood cell (RBC) transfusion is associated with a range of deleterious sequelae including pulmonary edema, renal failure, multiorgan failure, myocardial infarction, infection, increased hospital stay, and death.<sup>10-13</sup> The Cochrane systematic review of multiple randomized trials found that liberal blood transfusion versus a more restrictive strategy is associated with a 20% increase in mortality and 56% increase in ischemic events.<sup>14</sup> With the increased risks associated with both anemia and RBC transfusion, the decision whether or not to transfuse

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should ideally be guided by an accurate estimate of intraoperative blood loss alongside clinical and laboratory evaluation.

There is not currently a gold standard for measurement of intraoperative blood loss. For measurement of blood loss in childbirth, however, photometric methods have been shown to be the most accurate of the commonly used methods, although the time and cost required make it impractical for routine clinical use.<sup>4</sup> The Hemocue 201+ (Hemocue and Dronfield, Derbyshire, UK) is a portable point-of-care device that uses the azide-methemoglobin reaction and photometry absorbance and is reported to have precise measurement of hemoglobin (Hb) within 1.5% when compared to international reference method.<sup>15</sup> Direct measurement of Hb mass lost from the surgical field with this device may more accurately quantify surgical blood loss. Our study aims to compare anesthesiologist estimates of intraoperative blood loss with measured Hb loss using the Hemocue 201+ to determine the accuracy of intraoperative blood loss estimation.

## MATERIALS AND METHODS

The investigational protocol was approved by the Duke University Investigational Review Board (Durham, NC) and registered with ClinicalTrials.gov (NCT01300559). After informed consent was obtained, 60 adult patients (age  $\geq 18$  years) undergoing elective, multilevel, posterior lumbar decompression and fusion by a single orthopedic surgeon were enrolled in a prospective, randomized trial comparing intraoperative blood loss using unipolar cautery alone or unipolar cautery plus use of the bipolar tissue sealant device. All patients suffered from degenerative conditions of the spine including spinal stenosis, spondylolisthesis, and/or degenerative scoliosis. Exclusion criteria consisted of existing spinal cord injury with neurologic deficit or previously diagnosed coagulopathy, preoperative Hb level of less than 11 g/dL, prothrombin time/international normalized ratio of greater than 1.3, partial thromboplastin time of greater than 40, and platelet count of less than  $100 \times 10^3$ . Patients were also excluded if taking nonaspirin medications producing a bleeding diathesis undetectable by screening labs such as clopidogrel or ticlopidine within 7 days of surgery or valproic acid (associated with thrombocytopenia). All patients received general endotracheal anesthesia with surgery performed in the prone position. Hypotensive anesthesia was not used in this predominantly elderly population of patients.

Hb concentrations were measured with a hematology analyzer (Hemocue 201+, Hemocue and Dronfield). Intraoperatively, shed blood was preferentially aspirated from the surgical field into a cell salvage device (COBE Laboratories, Aurora, CO) containing citrate as anticoagulant.

The cell salvage device canister was filled with 200 mL of citrate solution before the start of surgery, and one drop per second of the solution flowed into the canister throughout the surgery. Every 100 mL of the citrate solution contained 0.73 g of citric acid (anhydrous), USP; 2.20 g of sodium citrate (dehydrate), USP; and 2.45 g of dextrose (monohydrate), USP. Heparinized saline solution (5000 units of heparin to 1 L of normal saline) was added to wall suction containers, 325 mL into each 3-L suction canister (Medi-Vac Guardian suction canister, Cardinal Health, Dublin, OH), to prevent clotting of any blood aspirated into wall suction. Blood removed from the field in surgical sponges was recovered by immediately soaking the sponges in a container holding 750 mL of the citrated solution. Before the salvaged blood from the cell saver device was processed, collected blood was mixed by agitation of the collection container and Hb concentration (g/dL) was measured from an aliquot of the salvaged blood via a sampling port inserted at the base of the collection chamber using sterile technique. Volume (dL) of the salvaged blood was measured by use of the gradations on the side of the collection chamber. Volume and concentration allowed calculation of Hb mass in the shed blood (volume in dL  $\times$  Hb concentration in g/dL = Hb mass in g). All cell saver-salvaged blood was processed and the RBCs in saline were returned to the patient. Upon completion of surgery all surgical sponges soaked in citrated saline were wrung into the soak container. The soak solution was then added to the sanguineous solution in the wall suction containers. After mixing, Hb concentration was measured and total volume of fluid in the wall suction container was recorded from the gradations on the side of the canister (Medi-Vac Guardian 3-L suction canister, Cardinal Health) before discard. Hb loss in surgical sponges and wall suction was then calculated as above. Preoperatively, patient Hb was measured. Using each individual patient's preoperative Hb, Hb lost was converted to volume of blood loss with the formula Volume in mL = measured Hb loss in g  $\times$  (100 mL/dL)/(Preoperative Hb in g/dL). The number of RBC units transfused were recorded. Adverse events were monitored and defined as any undesirable clinical occurrence in any enrolled study patient during study participation.

This study was performed as a side study of a prospective, randomized trial comparing intraoperative blood loss using unipolar cautery alone or unipolar cautery plus use of the bipolar tissue sealant device (Aquamantys, Medtronic Advanced Energy, LLC, Portsmouth, NH).<sup>16</sup>

## Statistical analysis

A single-sample t test of no difference was used to compare estimated with measured blood loss. A linear regression model tested whether the difference was asso-

**TABLE 1. Demographics of study population and characteristics of surgery performed**

Characteristic	Mean	±SD	Range
Age (years)	62.2	±10.6	40-86
Height (inches)	66.3	±4.1	60-77
Weight (lbs)	183.6	±36.3	115-254
Body mass index	29.3	±4.7	19.7-39.5
Surgery time (min)	212.4	±42.4	93-294
Number screws used	6.3	±1.2	4-10
Total number of spinal levels	2.4	±0.8	2-5
Length of stay (days)	4.5	±1.9	1-14
Preoperative Hb (g/dL)	13.8	±1.5	11.1-17.1

Characteristic	Frequency	Percent
Sex		
Female	41	68.33
Male	19	31.67
Race		
African American	11	18.33
Native American	1	1.67
Caucasian	48	80
Type of surgery		
Primary	32	53.33
Revision	28	46.67
Transfusion		
None	28	46.67
Yes: no RBCs	3	5
Yes: including RBCs	29	48.33

ciated with the amount of measured blood loss. The non-linearity of fit was tested with a quadratic term. The association of estimated and measured blood loss with number of blood products received was tested with Pearson correlation tests and linear regression.

## RESULTS

A total of 60 adult patients were included in this study. The characteristics of the study population are listed in Table 1. Mean estimated blood loss by anesthesia providers exceeded measured blood loss by  $246 \pm 271$  mL (mean  $\pm$  SD;  $860 \pm 452$  mL vs.  $614 \pm 311$  mL,  $p < 0.0001$ ) or 40% (Table 2). The 95% confidence limits of the mean difference were 176 to 316 mL. Estimated blood loss was nearly always greater than measured blood loss, regardless of the total blood loss volume (Fig. 1). The size of the difference was estimated to increase 17.9 mL per 100-mL increase in amount of measured blood loss, although this association did not reach significance ( $p = 0.1170$ ). There was significant association between number of RBC units given and both estimated blood loss ( $R = 0.26793$ ,  $p = 0.0385$ ) and measured blood loss ( $R = 0.46216$ ,  $p = 0.0002$ ).

## DISCUSSION

The majority of literature on the inaccuracy of visual estimates of providers for blood loss comes from either simulations of blood loss or from estimates during childbirth.

This is one of few studies examining provider estimates of blood loss in the operating room for elective, potential high-blood-loss surgery. Previous studies have suggested that providers typically overestimate blood loss at small volumes, and underestimate at large volumes, with this effect increasing as the actual blood loss increases.<sup>3,6,7,17</sup> Despite the relatively large volumes of blood loss in our study, providers consistently overestimated blood loss when compared to measured blood loss, with the size difference between estimated and measured blood loss tending to increase as measured blood loss increased. This overestimation of blood loss could lead to unnecessary transfusion and overadministration of intravenous (IV) fluids, either of which could cause deleterious effects.

There are multiple reasons why providers may overestimate blood loss. Since anesthesiologists have historically been told that they underestimate blood loss at large volumes, it is possible that they may try to “correct” this by increasing reported blood loss from what they initially estimate. Also, solution in suction canisters contains more than just blood: pleural fluid, urine, irrigation fluid, and other fluids are frequently mixed in, and it is impossible for the provider to quantify the correct amount of Hb in the solution by appearance only. This applies to surgical sponges as well. Saturated large surgical sponges contain approximately 100 mL of fluid,<sup>6</sup> but it is difficult to determine both the degree of saturation and the Hb content of the fluid by visual estimate alone.

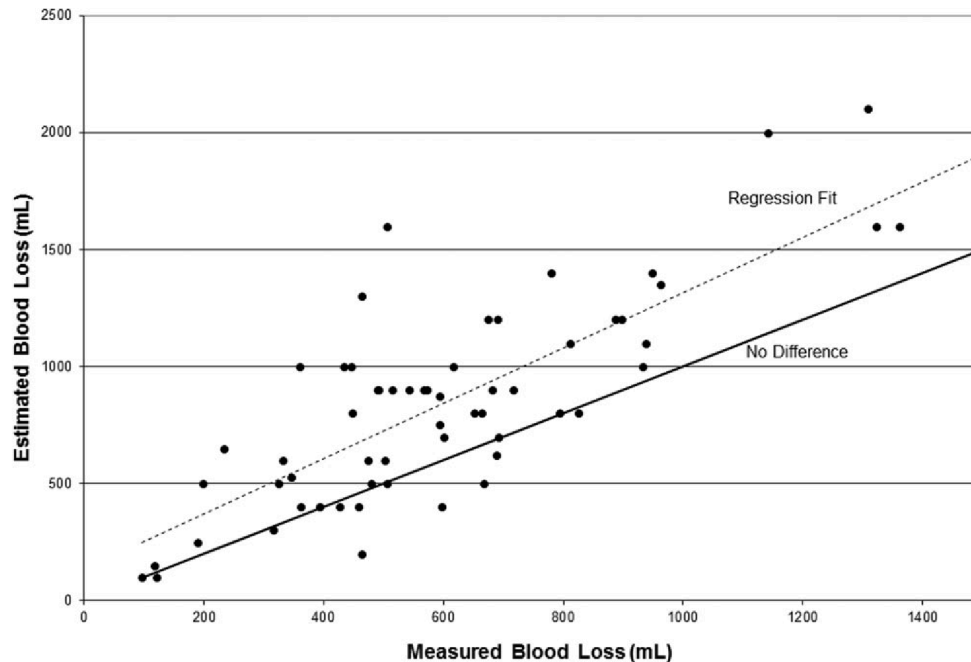
Transfusion of RBC units correlated with both estimated blood loss and measured blood loss. Providers were blind to the measured blood loss, so transfusion decisions were made based on estimates of blood loss, intraoperative Hb measurements, and clinical evaluation. It is impossible to know if providers would have made different transfusion decisions if the measured blood loss data had been available to them intraoperatively.

The primary limitation of this trial is related to small sample size. Although only one type of surgery performed by one individual surgeon was included, this may be a strength for this trial by providing consistent surgical technique. Another limitation is the accuracy of the volume and of the Hb concentration measured. The Hemocue 201+ (Hemocue and Dronfield) is reported by Hemocue to be accurate within 1.5% when compared to the international reference method and was chosen as the most accurate device available for the range of Hb values anticipated, but there may have been some error at low Hb concentrations. Volume of solution was determined by the gradations on 3-L suction canisters, which may also have introduced error. Furthermore, while every attempt was made to measure all blood lost during the surgical procedure, blood soaking into the drapes was not measured. Even though this variable could impact results, the surgeon made a conscious effort to recover all blood from the field. We also did not control for level of experience of

**TABLE 2. Comparison of Hb loss and measured blood loss with estimated blood loss**

Measurement	Mean	( $\pm$ SD)	Range	Lower 95% CL for mean	Upper 95% CL for mean
Hb loss (g)	84.3	41.5	14.4-197.3	73.6	95
Measured blood loss (mL)	613.8	310.5	96.6-1617.2	533.6	694
Estimated blood loss (mL)	859.5	100-2100	742.7	976.3	

CL = confidence limit.

**Fig. 1. Comparison of estimated and measured blood loss in mL for all study patients.**

the anesthesia providers recording the estimated blood loss; however, several studies have suggested that level of experience does not correlate with accuracy of estimated blood loss.<sup>1,6</sup>

This study offers further evidence of the inaccuracy of visual estimates of blood loss by providers in the operating room. Whether providers overestimate or underestimate blood loss, this subjective and inaccurate estimate provides a poor guide for transfusion and may cause providers to administer inappropriate amounts of IV fluid or blood products. As technology improves, use of continuous Hb assessment and bedside Hb concentration devices may help to improve blood loss estimates and guide appropriate transfusion strategies.

In conclusion, our study confirmed the inaccuracy of visually estimated blood loss by providers in the operating room. We found that even at relatively high blood loss volumes, providers overestimated blood loss on average by 40% compared to measured blood loss. Until a more accurate bedside tool is able to assist in determining accurate blood loss, we must rely on a combination of clinical assessments and laboratory tests to help guide the need for appropriate fluid resuscitation and RBC transfusion.

#### CONFLICT OF INTEREST

The authors have no financial relationship with the study sponsor, other than the research grant for this project.

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