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# Comparison of the Error Rates of an Anesthesiologist and Surgeon in Estimating Perioperative Blood Loss in Major Orthopedic Surgeries: Clinical Observational Study

# *Major Ortopedik Cerrahilerde Anesteziyolog ve Cerrahın Kan Kaybı Tahminlerindeki Hata Paylarının Karşılaştırılması: Klinik Gözlemsel Çalışma*

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**ABSTRACT**

***Objective:*** *Since the anesthesiologist and surgeon have different observation angles in the intraoperative period, their predictions based on clinical observation vary greatly. Whether these predictions accurately reflect actual blood loss is still a matter of debate. The aim of this study was to compare the clinical observations of anesthesiologists and surgeons on perioperative blood loss and transfusion requirements with laboratory results.*
***Methods:*** *Sixty patients who were scheduled for major orthopedic surgery were included in the study. Same anesthesiologist and the same surgeon were asked to estimate the amount of blood loss , and whether blood transfusion was needed during the perioperative period. The amount of blood loss was calculated synchronously using the perioperative hemoglobin value and the total blood volume. The blood loss estimates of the anesthesiologist and the surgeon were compared, with blood loss calculated in the laboratory.*
***Results:*** *The anesthesiologist's and the surgeon's estimates of perioperative mean blood loss volume were found to be lower than the blood volume calculated in the laboratory (p=0.01). When the estimated blood loss was less than 600 mL, it was considered as overestimation, and when it was more than 600 mL then it was interpreted as 20% underestimation (p=0.01). According to our findings, the rate of error in the perioperative blood loss estimates was 28.72%. When the blood loss was more than 1000 mL, the error rate of predictions was 34.03%; when it was less than 1000 mL, the error rate of predictions was 25.18%.*
***Conclusion:*** *We believe that when blood loss is more than 1000 mL in major orthopedic surgeries, the error in the estimation is increased, the amount of blood loss is difficult to predict, and the anesthesiologist makes a better prediction than the surgeon.*

***Keywords:*** *Blood loss, clinical observation, error rate, laboratory results, orthopedic surgeries*

**ÖZ**

***Amaç:*** *Anesteziyolog ve cerrah intraoperatif dönemde farklı gözlem açılarına sahip olduğundan, klinik gözleme dayalı tahminleri büyük değişkenlikler içermektedir. Bu tahminlerin gerçek kan kaybını ne kadar doğru yansıtabildiği halen tartışılan bir konudur. Bu çalışmada, anesteziyolog ve cerrahın, perioperatif kan kaybı ve transfüzyon gerekliliği hakkındaki klinik gözlemlerinin, laboratuvar sonuçları ile karşılaştırılması amaçlandı.*
***Yöntem:*** *Major ortopedik cerrahi planlanan, 60 olgu çalışmaya dahil edildi. Aynı anestezi uzmanından ve aynı cerrahtan kan kaybı miktarını ve kan transfüzyonuna gerek duyulup duyulmadığını perioperatif dönemde tahmin etmeleri istendi. Perioperatif hemoglobin değerleri ve total kan hacmi kullanılarak kan kaybı eşzamanlı hesaplandı. Anesteziyolog ve cerrahın tahminleri ile laboratuvara göre hesaplanan kan kaybı istatistiksel olarak karşılaştırıldı.*
***Bulgular:*** *Anesteziyolog ve cerrahın perioperatif ortalama kan kaybı volümü tahminleri, laboratuvar sonuçlarına göre hesaplanan kan kaybı volümünden daha düşük bulundu (p=0.01). Hesaplanan kan kaybı 600 mL'den az olduğunda tahminlerin daha yüksek, 600 mL'den yüksek olduğunda ise tahminlerin %20 daha düşük olduğu saptandı (p=0.01). Bulgularımıza göre, perioperatif kan kaybı tahmininde yanılma oranı %28.72 olarak saptandı. Kan kaybı 1000 mL'den fazla olduğunda tahminde yanılma oranı %34.03; 1000 mL'den az olduğunda yanılma oranı %25.18 olarak bulundu.*
***Sonuç:*** *Major ortopedik cerrahilerde kan kaybı 1000 ml'den fazla olduğunda tahminde yanılma oranının arttığı, kan kaybını tahmin etmenin güçleştiği ve anesteziyoloğun cerrahtan daha iyi tahminde bulunduğu düşüncesindeyiz.*

***Anahtar kelimeler:*** *Kan kaybı, klinik gözlem, hata oranı, laboratuvar sonuçları, ortopedik cerrahi*

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## INTRODUCTION

One of the most important tasks of anesthesiologists and surgeons is accurately monitoring and estimating perioperative blood loss (BL) [1]. Although some monitoring methods are currently used in the follow-up of perioperative BL, estimations based on clinical observations of anesthesiologists and surgeons are in the forefront [2]. However, these predictions, with different perspectives, are not standardized, and this issue still remains as a problem that needs to be addressed.

The most important parameter of clinical observation is visual assessment. In many studies, it has been shown that the accuracy of visual assessment varies significantly and can only reflect 30%-50% of actual BL [3]. BL estimation can be misleading even in major surgeries, where invasive monitoring is performed [1]. Studies show that as the rate of BL increases, it becomes more difficult to make a correct prediction. When BL is greater than 1.000 mL, estimation becomes more challenging, with the probability of accurate prediction decreasing significantly when BL reaches 2.000 mL [2,4].

Estimation of blood loss is based on visual assessment of the surgical area, total amount of blood lost, the presence of microvascular bleeding, the amount of blood in the surgical sponge, the size of the clot, and the volume of blood in the aspirator [5,6]. While anesthesiologists follow all these factors, surgeons can only follow the bleeding in the surgical field. For the decision of correct amount of transfusion, estimated BL should be compared with laboratory results. The literature contains studies on the accurate calculation of perioperative BL. However, few studies have compared perioperative BL predictions of the anesthesiologist and the surgeon and the need for transfusion based on laboratory results.

In this study, we aimed to compare the clinical observations of anesthesiologist and surgeon on perioperative BL and requirement of transfusion with laboratory results.

## MATERIAL and METHODS

Before the study, ethics committee approval was obtained in accordance with the declaration of Helsinki (Ethics Committee IRB approval date: June 26, 2017; decision number: 07). The patients were selected from people who were admitted to the anesthesia clinic for surgery to be performed under general anesthesia. Patients were informed about the study and provided written informed consent.

The study included 60 ASA I-III patients with major lower extremity bone fractures, aged 18-80 years, who did not accept regional anesthesia. Patients who had chronic renal failure, acute coronary syndrome, thromboembolic event, infection, preoperative anemia (hemoglobin (Hb) <10 mg $dL^{-1}$), suspected allergy to any of the drugs used during anesthesia or suspected malignant hyperthermia were excluded from the study.

The anesthesiologist (age 40) and the surgeon (age 37), had 8 and 7 years of professional experience, respectively.

*Anesthesia technique.* A patient-heating blanket was laid on the operating table, and blood heaters were prepared in the operating room. The patients were monitored with electrocardiography (ECG), and measurements of heart rate (HR), blood pressure (BP), and peripheral oxygen saturation ($SpO_2$). Anesthesia was induced with 2 mg $kg^{-1}$ propofol, 2 µg $kg^{-1}$ fentanyl, and 0.6 mg $kg^{-1}$ rocuronium. Anesthesia was maintained with %1 sevoflurane, and 40% oxygen and 60% medical air during the operation. When needed, intravenous maintenance doses of fentanyl (0.5 µg $kg^{-1}$) and rocuronium (0.2 mg $kg^{-1}$) were administered. The maintenance fluid requirement for the patients was met with 0.9% NaCl. Hemodynamic parameters were recorded perioperatively at five-minute intervals.

The anesthesiologist and the surgeon were informed about the study in advance. A follow-up form was prepared for each patient at the beginning of the operation. This form contained separate columns for anesthesiologist and the surgeon. We asked the anesthesiologist and surgeon to estimate the amount of BL and transfusion based on their clinical observations at hourly intervals. The anesthesiologist and surgeon calculated the amount of blood in the perioperative period, weighing sponge, pad, compress and blood volume in the aspirator. Blood was sent to the laboratory for CBC control, and actual BL was calculated by CBC monitoring at hourly intervals. The responses of the anesthesiologist and surgeon, and CBC results were recorded. The critical limit for the requirement for transfusion was defined as the decrease in Hb value below 8 mg $dL^{-1}$ and BL exceeding 20% of the total blood volume or over 1.000 mL. The volume of BL allowed was calculated using total blood volume (TBV) and preoperative hematocrit (Hct) value. When the BL volume reached the allowed level, it was sent to the laboratory for control complete blood count (CBC) and transfusion was initiated. During transfusion, half of the BL was met by erythrocyte suspension and the other half by three volumes of crystalloid fluid.

Hb-Hct values in all patients were measured within six hours preoperatively and were measured again within two hours postoperatively. The amount of blood transfused to the patient was calculated as units.

The reference value for total blood volume was 75 mL $kg^{-1}$ for men and 65 mL $kg^{-1}$ for women. TBV was obtained by multiplying patient weight with reference values [8,9]. Using each patient's preoperative Hb, Hb loss was converted to volume of BL in milliliters with the following formula: (volume of BL=measured Hb loss in g × (100 mL $dL^{-1}$)/(preoperative Hb in g $dL^{-1}$).

The number of red blood cell (RBC) units transfused were recorded [7,8]. Then, anesthesiologist's and surgeon's estimates of BL and requirement for transfusion were compared with BL calculated according to the laboratory. For statistical analysis, the data collected within the first 120 minutes were evaluated.

### Statistical Analysis

Descriptive statistics for the continuous variables were expressed as mean, standard deviation, minimum and maximum values, and categorical variables were expressed as numbers and percentages. In terms of continuous variables, independent t-test was used to compare groups. In addition, intraclass correlation coefficient (ICC) was calculated to determine agreement of the clinical observations of anesthesiologist and surgeon with laboratory results. A p-value of < 0.05 was considered statistically significant. Statistical Package for the Social Sciences (SPSS) v. 23.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data.

For the number of differences between estimates of anesthesiologist and surgeon, previous studies have established a standard deviation (σ) of 3. Effect size (d) was assumed to be 0.8, and a Z value of 1.96 was used for the 0.05 type I error rate. The sample size was found to be 54 using the equation for sample size calculation (n=Z2.σ2/d2), and 60 patients were included in the study.

## RESULTS

All patients who underwent surgery for major bone fractures of lower-extremities were operated under general anesthesia. Demographic data of the cases are shown in Table I.

The perioperative mean BL volume predictions of the anesthesiologist and the surgeon were found to be

**Table I. Descriptive statistics and comparison results**

| | Mean±Std. Dev | Min-Max | p value |
|---|---|---|---|
| Age (years) | 59.43±13.51 | 28-80 | |
| Male (n: 38) | 62.39±12.57 | 32-80 | 0.611 |
| Female (n:22) | 57.27±14.02 | 28-75 | |
| Weight (kg) | 82.82±8.39 | 65-120 | |
| Male (n: 38) | 81.05±9.23 | 65-100 | 0.032 |
| Female (n:22) | 87.50±13.43 | 70-120 | |
| Duration of surgery (min) | 107.83±21.18 | 70-170 | |
| Male (n: 38) | 106.71±19.77 | 85-160 | 0.594 |
| Female (n:22) | 109.77±23.78 | 70-170 | |
| Duration of anesthesia (min) | 120.13±24.97 | 85-188 | |
| Male (n: 38) | 121.45±20.38 | 100-180 | 0.596 |
| Female (n:22) | 117.86±31.79 | 85-188 | |
| ASA | | | |
| I / II / III (n) | 6/39/15 | | 0.150 |

*ASA: American society of anesthesiologists*

**Table II. Comparison of estimated and calculated perioperative blood loss volumes (mL)**

| | Volume of blood loss | | |
|---|---|---|---|
| | Less than 600 mL (n:20) | More than 600 mL (n:40) | Mean |
| Estimation of anesthesiologist (mL) | 561±129.12[a] | 874±330.81[b] | 784.83±337.20[b] |
| Estimation of surgeon (mL) | 455±127.63[ab] | 758±313.55[c] | 659.16±304.55[c] |
| Measured blood loss (mL) | 447±108.49[b] | 1121±370.14[a] | 897.11±443.74[a] |
| p value | 0.01 | 0.01 | 0.01 |

*Values are given as mean ± std. dev. Superscript letters in the same column indicate significant differences between the groups (p<0.05). [a]: comparing to estimation of anesthesiologist (p<0.001). [b]: comparing to estimation of surgeon (p<0.001) [c]: comparing to measured blood loss. Analysis done by unpaired student 't' test.*

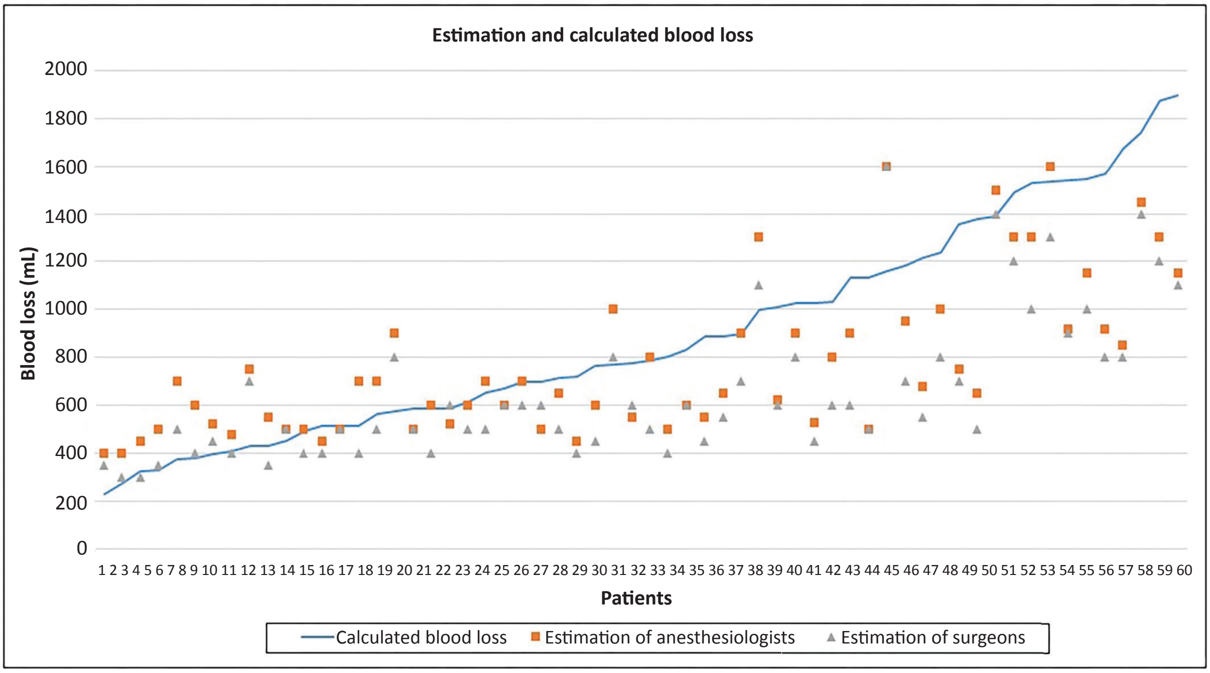


**Figure 1. Comparison of measured and estimating blood loss in all patients.**

underestimated compared with blood volume calculated according to laboratory results ($p<0.05$). The values were overestimated when predicted BL was less than 600 mL and underestimated when predicted BL was higher than 600 mL ($p<0.05$, Table II).

According to our findings, the mean error rate was found to be 28.72% in the perioperative BL estimates. When BL was more than 1.000 mL, the predictive error rate was high (34.03%); when it was less than 1.000 mL, the error rate was lower (25.18%, $p<0.05$, Table III). Estimated and calculated volumes of blood lost in patients are shown in Figure 1.

When BL was less than 1.000 mL, the error rates of the anesthesiologist and surgeon were similar ($p=0.07$); when BL was more than 1.000 mL, the error rate of the anesthesiologist was lower than that of the surgeon ($p=0.023$, Table III). Based on laboratory results, error rate was determined based on calculated BL. The difference between the estimated and calculated values was determined by taking the percentage of this number. Intraclass correlation coefficients for the agreement are shown in Table IV.

**Table III. Average error rate in total blood loss estimation (%)**

| | Blood loss of less than 1000 mL (%) | Blood loss of more than 1000 mL (%) | p value |
|---|---|---|---|
| Anesthesiologist's error rate | $^{\#}$26.28±22.93$^{a}$ | 30.63±14.83$^{c}$ | 0.01$^{\#}$ |
| Surgeon's error rate | $^{\#}$24.09±16.30$^{a}$ | 37.42±15.96$^{a}$ | 0.01$^{\#}$ |
| Average error rate | $^{\#}$25.18±16.47$^{b}$ | 34.03±14.51$^{b}$ | 0.01$^{\#}$ |
| p value | 0.07 | 0.023 | |

*Values are given as mean ± std. dev. $^{\#}$: difference from other group (more than 1000) is statistically significant. $^{a,b,c}$: different lower cases in the same column represent statistically significant differences between the groups. The calculation of the error rate was based on the calculated blood loss. Estimated values were calculated by percentage of difference from calculated value.*

Perioperatively, transfusions were administered to 17 patients based on laboratory results (28.3%). The mean Hb, and Htc values measured postoperatively was significantly lower than the preoperative values respectively (1.9 g $dL^{-1}$, 4.68% and $p=0.043$, $p=0.035$). Although statistically significant, BL was within the clinically normal limits (Table V).

**Table IV. Intraclass correlation coefficients for the agreement**

| | | Anesthesiologist | Surgeon | Lab test |
|---|---|---|---|---|
| Blood loss of less than 1000 mL (%) | Anesthesiologist | 1 | | |
| | Surgeon | 0.729** | 1 | |
| | Lab test | 0.816** | 0.755** | 1 |
| Blood loss of more than 1000 mL (%) | Anesthesiologist | 1 | 0.747** | |
| | Surgeon | 0.596** | 1 | |
| | Lab test | 0.658** | 0.693** | 1 |

***: p<0.01*

**Table V. Analysis of hemodynamic data**

| | Mean±Std. Dev | Min-Max | p value |
|---|---|---|---|
| Heart rate (pulse/min) | 74.42±11.49 | 54-142 | |
| Mean blood pressure (mmHg) | 109.68±14.96 | 63-159 | |
| Hemoglobin (g/dL) | | | |
| Preoperative (n:60) | 11.97±1.78 | 10.0-17.9 | 0.043* |
| Postoperative (n:60) | 10.07±1.55 | 8.5-15.8 | |
| Hematocrit (%) | | | |
| Preoperative (n:60) | 35.39±5.33 | 28.5-52.3 | 0.035* |
| Postoperative (n:60) | 30.71±4.56 | 25.4-46.9 | |

**: Statistical significance between the groups (p<0.05)*

## DISCUSSION

In the current study, the clinical estimations of anesthesiologist and surgeon regarding perioperative blood loss (BL) were found to be lower when compared with the laboratory values. The estimated average error rate was found to be 28.72%. In cases in which BL was greater than 1.000 mL, the error rate was higher and it was more difficult to estimate the BL. In our hospital, perioperative blood transfusion was used in 28.3% of the patients who underwent surgery due to major bone fractures of the lower extremities.

The most important limitation of this study was that it was based on the evaluation of only one anesthesiologist and surgeon. However, this issue may be the subject of other studies.

During surgery, BL should be monitored continuously to maintain homeostasis and to provide adequate oxygen transport to the tissues [1]. Accurate estimation of perioperative BL is important to identify patients requiring blood transfusion [9]. Overestimation of BL may lead to unnecessary transfusions and intravenous fluid overdose, and underestimation may lead to delayed perioperative hemorrhage, diagnosis, and treatment. All of these conditions have harmful effects [10-12]. Although BL is usually measured via visual assessment, different methods can be used to measure perioperative BL in the operating room. In fact, despite the fact that many studies show the inaccuracy of visual estimates, these estimates are used in practice [12].

Visual evaluation is carried out by measuring the blood in the aspirator; the amount of blood in the surgical compress, pad, and gauze; the size of the clot; and the observation and measurement of microvascular bleeding [12]. Accurate calculation of BL is important in major surgeries such as performed for large bone fractures, radical prostatectomy, nephrectomy, hysterectomy, and intracranial hemorrhage. In these types of major surgeries, narrowing of the surgical area, and distribution of blood into different locations make it difficult to correctly calculate BL.

In the current study, although the average error rate was 25.18% when intraoperative BL was less than 1.000 mL, the average error rate increased to 34.03% when BL was more than 1.000 mL. The estimations of the anesthesiologist were closer to the calculated BL and therefore more accurate than the estimations of the surgeon. The anesthesiologist had the opportunity to better observe the surgical field, to measure the amount of accumulated blood in the aspirator and sponge, and to follow the hemodynamic changes. In this respect, the situation was easier for the anesthesiologists than for the surgeons. Although the surgeon can observe the surgical area, he or she may not be able to monitor BL while focusing on performing the surgical procedure. This fact is also consistent with the surgeons' lower estimates of BL.

Similar to our study, McCullough et al. [13] reported that the actual BL calculated was significantly different from the BL estimates of both anesthesiologists and surgeons. The anesthesiologists' average estimate of BL of 457 mL was less than that of the surgeons' (494 mL). The average error rates were calculated as 25.5% and 27.5% for the anesthesiologists and the surgeons, respectively. The estimates of the anesthesiologists and the surgeons were similar. This may be due to the similar levels of experience of the individuals making the estimations. Chang et al. [14] suggested that assessing the patient's body mass index (BMI) during radical prostatectomy could help predict BL. In their study, 716.9 mL of BL was estimated as 387.3 mL, with an error rate of above 50%. In Chang et al.'s study [14], the high error rate might have been due to the use of BMI. In our study, the anesthesiologist estimated true blood loss of 897 mL as 784.83 mL with a volumetric difference of 113 mL, and the surgeon estimated BL as 659.16 mL with a volumetric difference of 237 mL. In our study, although high error rates were observed, postoperative mean Hb-Hct values reached normal limits with transfusions. This result shows that the decisions for transfusion were clinically justified.

Brecher et al. [15] estimated that actual perioperative BL was 2.1 times the perioperative BL estimated by anesthesiologists. The results of our study are considered to be consistent with the majority of the other studies in the literature.

These error rates, which have a significant effect on the estimation of BL, can be related to the amount of bleeding and the surface where the blood is dispersed. It has been reported in the literature that an increase in BL and the distribution of blood over a large surface area increases the error rate in predictions of BL [16].

Previous studies have shown that BL estimation errors increase with visual assessment. Interestingly, Guinn et al. [12] reported that BL was consistently overestimated. They said that as BL increased, the rate of error in estimations of BL increased. Previous studies have suggested that providers typically overestimate small volumes of BL and underestimate its large volumes, and error rates increase as the actual volume of BL increases [3,17-19].

In the current study, when the BL calculated by laboratory testing was less than 600 mL, we observed that the BL was overestimated by clinicians, and when the BL calculated by laboratory testing was more than 600 mL, it was underestimated by clinicians. In contrast, Razvi et al. [20] stated that when the calculated BL was less than 150 mL, it was overestimated, and when the calculated BL was more than 300 mL, it was underestimated.

When the causes of BL estimation errors are examined, the difficulty in calculating the blood in the aspirator and surgical sponge is seen as a significant misleading factor [21]. The fluid deposited in the aspirator may contain liquids other than pure blood. Depending on the location and type of surgery, irrigation fluid, pleural fluid, intra-abdominal fluid, urine, and other fluids are frequently mixed in the aspirator. In this case, it is not possible to accurately estimate the amount of Hb in the blood and liquid content in the aspirator by visual evaluation alone. This issue is also present when estimating the amount of blood immersed in the surgical pad, sponge, and compresses [10]. It is difficult to visually estimate both the saturation level and the Hb content of the liquid. Apart from these, the location and shape of the surgical field and the observer's level of experience can be counted among the factors affecting accuracy of estimation and error rates [5,17,22,23].

For the surgical team to manage the patient's clinical condition with respect to bleeding and decrease in Hb levels, a precise and timely measurement of Hb may have a significant effect on reducing morbidity. In recent years, noninvasive Hb-monitoring devices are new technology in pulse oximeter systems, which show Hb levels continuously. These devices represent the most advanced diagnostic technology for improving the health of patients under anesthesia. According to a meta-analysis, noninvasive hemoglobin measurement has acceptable accuracy in comparison with the standard invasive method [24]. With increasing use of these devices in the follow-up of perioperative blood, loss satisfactory results can be achieved.

In conclusion, we found that in major orthopedic surgeries, when the BL was more than 1.000 mL, the margins of error of the anesthesiologist and the surgeon estimations of BL increased. In addition, BL is difficult to predict, and anesthesiologist appear to predict it more accurately than the surgeon. We believe that more comprehensive studies are needed on this issue.

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