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Intra-Operative Hemorrhage: A Review of Literature

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Abstract

Despite the tremendous innovation in field of medical science and technology; intraoperative hemorrhage remains one of the major surgical complications encountered in day-to-day surgical practice. The morbidity and mortality associated with surgical hemorrhage are considerable and it remains a restraining factor for advanced surgical procedures. Intra operative hemorrhage may sometime cause significant complications and may even lead to alarming events.

Clinical Significance: Clinicians should know the amount of blood loss during the surgical procedures to detect and treat any aberrant changes immediately. There are very few published reports on different techniques to measure intra-operative hemorrhage. However, there are on reports, which compile all the different techniques, which could be used for measuring intra-operative bleeding. This review compiles various ways to measure intra-operative blood loss to update and alert clinicians about its consequences.

Keywords: Hemorrhage; Intra-operative bleeding

Introduction

Of the many battles the surgeon encounters during years in practice, none is more demoralizing or critical than uncontrolled hemorrhage. Rapid, deliberate action is necessary to gain control of unanticipated surgical bleeding. It is a medical emergency, frequently encountered by physicians and dentists during surgical procedures. Significant loss of intra-vascular volume may lead sequentially to hemodynamic instability, decreased tissue perfusion, cellular hypoxia, and organ damage and may even cause death [1,2].

In dentistry most hemorrhagic events occur during extractions or periodontal and Implant surgeries [3,4]. Generally, these are self-limiting. Most events occur due to perforation of the lingual cortex, during implant procedures; commonly during mandibular anterior implants [5-7]. Other causes of life threatening events were reported during surgeries when subjects suffered from congenital or acquired bleeding disorders (Table 1) [8-10]. Also, in case of intra oral hemangiomas, even relatively minor invasive procedures may precipitate prolonged uncontrollable bleeding which may be troublesome [11].

An adult human has 4-7 liters of blood in his/her circulation; thus, the loss of 350-500 ml of blood might be negligible which occurs even in the case of blood donation. However, when loosing 30% (or more) of the blood volume, symptoms of hypo-volemic shock might develop. In 1953, De Wardener et al. said that if oligaemia is not corrected in such patients they are liable to sudden post-operative hypotension [12]. Stanton and Lyon stressed the importance of adequate replacement of whole blood during and after surgical operations [13]. They have demonstrated that, although there is a compensatory increase in plasma volume following uncompensated blood loss, there is no increase in the number of red cells. Without blood transfusion the red cell volume does not return to normal for several weeks. This uncompensated red cell loss leads to reduction in the oxygen carrying power of the blood. This may result in varying degrees of hypoxia, which tend to prolong post-operative recovery in periodontal healing tissues or elsewhere in the body. In addition, in patients already possessing a diseased myocardium, it may lead to cardiac and circulatory disturbances and possibly cardiac failure. Coller et al. in 1944 and in 1946 suggested that it is most propitious for the patient when the blood lost during the surgery is redeemed during the procedure itself [14,15]. They also believed that even minimal blood loss retards convalescence, and that all the blood lost, in even poor risk patients, must be replaced with equal quantities of whole blood. The urgency for replacement is dependent on many factors. These include amount of blood loss, duration of surgery and the response of the patient to the operative procedures. It is therefore appropriate to emphasize that accurate replacement of blood loss during operative surgery depends on the accurate measurement of blood loss as it occurs. For measuring the amount of blood lost, the surgeon and the anesthetist (if any) are in a strong position to influence the cardio-vascular homeostasis of their patient. They must

	Factor affected	Bleeding severity & factor
Haemophilia A [1]	Factor VIII levels Decreased	Severe: < 1 IU/dL Moderate: 1- 5 IU/dL Mild : >5 - < 40 IU/dL
Haemophilia B [1]	Factor IX levels decreased	Severe: < 1 IU/dL Moderate: 1- 5 IU/dL Mild : >5 - < 40 IU/dL
Von Willebr and Disease [2]		
Type 1	VWF: Ag levels decreased	Variable, usually mild-to moderate
Type 2	Dysfunctional VWF	Variable, usually moderate
Type 3	VWF absent	Severe (VWF: Ag undetectable, factor VIII < 10 IU/dL)

VWF- Ag: Von Willebrand Factor Antigen

Table 1: Common inherited bleeding disorders [8-10].

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relate this operative blood loss to the pre-operative status and condition of the patient, to the anticipated need of blood replacement and the response of the particular individual to hemorrhage and his reaction to the surgical procedure. Thus, the aim of this review is to make the practitioners aware of different methods of estimating intraoperative hemorrhage thereby addressing the need for immediate replacement of lost blood, especially in medically compromised patients.

Blood Loss & Dental Surgery

Excessive bleeding is distressing for both patients and clinicians, and can delay completion of the procedure. It compromises wound healing and predispose it to infection. The bleeding risk of a dental procedure varies with how easy it is to access the site and apply local haemostatic measures. For a simple procedure, local haemostatic measures, such as pressure or topical agents, can usually be applied to the potential site(s) of hemorrhage. In contrast, there may be little or no access to bleeding sites following deep surgery and some flap surgeries [11].

Another complication that may crop up during surgery is in case the patient has known history of coagulation or bleeding anomaly. These abnormalities are among the major problems encountered in the surgical or critically ill patient. Although most of these patients have no intrinsic abnormalities of homeostasis, either their underlying disease or the therapy of the disease may produce clinically significant bleeding problems. The surgeon must be able to recognize these abnormalities quickly and address them before clinically significant problems arise. Failure to do so may result in a significant increase in morbidity and mortality in the acutely ill patient or any surgical patient. Table 1 embodies various bleeding disorders, coagulation factor related and bleeding severity that follows the disorders [8-10].

McIvor and Wengraf reported that, the maximal volume of blood loss during periodontal surgery was 62 ml, while minimal was 0.5 ml [10]. Also, Torres-Lagares et al. in 2010 studied effectiveness of intra-alveolar application of chlorhexidine gel in reducing incidence of alveolar osteitis and bleeding complications in oral surgery (patients with bleeding disorders). They concluded that, application of chlorhexidine reduced the incidence of alveolar osteitis and episodes of bleeding complications [16]. Barganza et al. reported that the intra operative bleeding ranged from 17.80 ± 9.57 ml to 31.93 ± 15.72 ml depending on NSAIDs intake pre-operatively, whereas Moore et al. [17,18] described that intra operative hemorrhage ranged from 54.9 ± 36.0 to 70.2 ± 53.0 ml depending on epinephrine concentration in the local anesthetic agent. Buckley et al. studied blood loss in periodontal flap surgery using lidocaine 2% with either 1: 50,000 or 1: 100,000 epinephrine. Blood loss was determined by the cyanmethemoglobin comparison technique. The study proved that procedures using lidocaine 2% with 1: 100,000 epinephrine generally had more than twice as much blood loss as those using lidocaine 2% with 1: 50,000 epinephrine.

There have been many assessments made for blood loss during surgery. Gatch and Little in 1924 were the first to report the measurement of blood loss during some of the more common operations in general surgery. They employed the acid hematin method that involves washing all the sponges, linen and instruments free of blood and then adding hydrochloric acid to make the washing a 0.1 N solution. This solution was calorimetrically compared with a sample of acid hematin solution prepared from the blood of the patients taken before operation [19].

In medical literature, there have been very few papers published dealing with blood loss. Various methods have been tried; most popular have been the gravimetric, volumetric, colorimetric methods and measuring the difference between pre- and post-operative plasma volumes. In this paper, we have attempted is to list down all the methods available for estimation of blood loss during surgery and discuss their pros and cons.

Methods

Most surgeons make some estimation of blood loss from the appearance of the operative field and the number of swabs used. This method is easiest and widely practiced. However, there is a wide discrepancy between the type and site of the surgery and size of the swab used. Thornton has stated that it is difficult for most observers to distinguish between a blood loss of 500 ml. and one of 1500 ml. Bonica and Lyter, in summarizing the work of 17 other investigators concluded that the surgeon's estimate is always less than the actual loss [20,21].

Following are the various methods used for measurements of Intra-Operative blood loss:

Visual estimation: Visual estimation is the most frequently practiced method of determining blood loss during many surgical procedures most reports are during childbirth. This method is used despite repeated studies showing its inaccuracy. There were 23 publications reviewed that evaluated the accuracy of visual estimation of blood loss. Some found underestimation was common, others overestimation, and still others found inconsistencies but without any particular pattern. Prasertcharoensuk et al. compared visual estimation with direct measurement of blood loss during vaginal births. The incidence of hemorrhage was underestimated in the visual estimation by 89% [22].

Direct measurement

Direct measurement is one of the oldest methods of accurately determining blood loss. Different reports enumerated used different tools to collect blood for direct measurement, in an attempt to quantify normal blood loss. Several researchers used various drapes with built-in pouches to assist with direct collection [23-25].

Gravimetric:

A) Patient weighing: In this method a special accurate weighing table is used to amount the pre- and post-operative weight of the patient. From the patient's loss of weight (1 gram is almost equal to 1 ml of blood), blood loss is assayed. However, it is difficult to measure small losses accurately with this technique. The method is elementary, inexpensive, and hardly requires any time or technology. Intra-operative discrepancies like drinking glucose (in case of giddiness), or urination have to be acknowledged.

Johar and Smith in 1993 assessed the accuracy of gravimetric estimation of intraoperative blood loss using the calorimetric method. Using the patient's preoperative hemoglobin measurement, the amount of blood present in the sponges was determined [26]. The gravimetric and colorimetric measurements were statistically examined and the authors found that there was hardly any cogent statistical correlation between the amount of blood loss estimated by the gravimetric method and the actual blood loss as measured by the colorimetric method (P=0.074). From the study, the conclusion that was drawn was that the gravimetric method of assessing intraoperative blood loss is neither precise nor accurate [9,27].

B) Swab weighing: This method embodies weighing of unused swabs before surgery, which are re-weighed immediately after surgery before discarding them from the operative field. From their variance in weight between the two, blood loss is calculated. This method is also facile, quick, does not require any elaborative technique and is inexpensive. However, sources of miscue includes other fluids assimilated in the swab, e.g. saliva, pus, inflammatory exudates etc. Also, blood aspirated by suction, blood swallowed by the patient and blood lost on instruments, gloves, drapes, scrubs, and by evaporation are other causes that may account for errors in calculation [11,14,20].

Volumetric: In volumetric method the content of any fluid to be introduced into the operative field is accounted pre-operatively and any surfeit fluid present in the aspirator jar after the surgery is surmised to be blood. Again even this method joins the league of easy, inexpensive and technique free methods, as described above. In this case, sources of error are fluids other than blood and any bulk of material, which includes cotton pellet, tooth substance, cement, amalgam or even dressing materials, if any are aspirated [11,14,20].

Colorimetric: This approach of calculating blood loss was first described by Pilcher and Scheard. This one bears washing of blood-stained swabs, instruments, drapes, scrubs, gloves etc., two or three times and then collecting the fluid left after the washing along with the contents present in the aspirator jar. This fluid is amassed in a container holding an agent, which alters hemoglobin to a more permanent pigment such as methemoglobin or cyanomethemaglobin. In cases where an immediate result is not required, the items and instruments may be soaked for 24 hours as a substitute to washing. By computing the hemoglobin concentration of the fluid in the container on a colorimeter, and its total volume, its hemoglobin content is calculated. If the patient's pre-operative hemoglobin is already listed, the amount of patient's blood in the container can be measured. This whole process can also be automated to give consecutive readings of blood that has been lost during the surgery. Devices that can perform this procedure are now available commercially (Photo Colorimeter[1], Digital photoelectric colorimeter,[2],[3],[4] SMART3[5]). It is a certain method, which gives accurate reading. However, few sources of error includes variations in the patient's hemoglobin during operation, failure to collect all blood lost from the operative field and instability of hemoglobin that undergoes quick degradation, thus resulting an under estimation of the blood lost. In contrast to the previous methods, this method is expensive, time consuming, technique sensitive and requires trained personnel to carry through the whole procedure accurately [11,18,27,28].

Labelled red cells: In this method, a sample of patient's blood is incubated with Cr 51, after which the red cells are washed, measured for gamma radiation on a scintillation counter, and are returned to the cardiovascular system. Pre-operatively the amount of Cr 51 present in the peripheral blood is tallied; and at the end of the operation all blood-stained swabs, instruments, drapes, scrubs, gloves etc., are measured for gamma radiation and the volume of the blood lost is taken into account. It is a reliable and accurate method. However, it is very expensive, time consuming, technique sensitive and needs trained personnel, and requires bulky instruments. In addition, radiation hazards that the handling personnel comes across during the procedure restrains the usage of this method to research [17].

Blood volume measurement: This is a methodology, which follows the principle of measuring the difference between pre- and post-operative blood volumes, which may further inform the amount of surgical hemorrhage. In this, a known quantity of dye or radioactive tracer is injected into a vein. After a delay of a few minutes, which permits the dye to be evenly distributed throughout the cardiovascular compartment, a sample of blood is withdrawn. From the dilution of the injected substance in the blood sample, post surgery, the blood volume is calculated.

A) Radioactive iodine (I): The first method is this includes intra venous injection of human albumin labeled with I^{131} or I^{132} which gets distributed throughout the cardiovascular system within 15 minutes. After this time has elapsed, a sample of venous blood is withdrawn and the plasma volume is calculated. The blood volume is measured from the hematocrit reading of a sample of venous blood post surgery. The difference between the two reveals the volume of intra-operative hemorrhage. I^{131} has a shorter half-life than I^{132} and that is the reason why it is more suitable to estimate repeated blood volume in a spur of time, but the problem lies in the utilization of expensive procedures and apparatus [18].

An instrument with a built-in computer called Volumetron is now available. This device enables simple and quick measurement of blood volumes using I^{131} labeled albumin. After a few minutes of insertion of the appropriate blood samples, the values are. Sources of errors in this case are the different hematocrit readings obtained on samples of blood drawn from different parts of the cardiovascular system, and leakage of albumin from the cardiovascular fluid compartment [29-31].

B) Radio-active chromium: Second in line is this method in which a sample of patient's blood is labeled with Cr^{51}, as described above, and flowed back to the cardiovascular system. After a few minutes, a sample of venous blood is withdrawn and the patient's total red cell volume is calculated pre and post surgically, from the hematocrit reading. This method is précised for measuring blood volume loss, but again it is elaborative and requires expensive equipment [28,30,31].

C) Radioactive phosphorus: Labeling of red cells with P32 as previously described for Cr^{51}. They are then measured for beta radiation and are injected into the cardiovascular system. Blood volume is calculated from red cell volume. Owing to the short biological half-life of P^{32}, repeated estimations of blood volume are possible without having to increase the dose of P^{32}. As a technique for measuring operative blood loss, the advantages and disadvantages are the same as described for Cr^{51} [30,32].

Photometry: Photometers are used to measure the intensity of the light produced by an unknown source in terms of a standard source. The general technique is to locate the two sources so that they give the same illumination to two adjacent surfaces. The photometer was invented by Charles Wheatstone (1802-1875). It originally had a glass bead stuck to the piece of putty in the upper right-hand corner. When the ivory handle on the crank was turned, the internal and external gearing made the bead travel in the rosette-pattern shown on the left, with each of the lights leaving a trail behind due to the persistence of vision. Many modifications have been made to it and Jansen H in 1978 introduced the photometric method to measure free Hb in the haemolysed irrigant fluid. The research using this method has been limited because it has to use some sophisticated apparatus such as portable photometer for hemoglobin detection, HemoCue photometer. The test is simple to perform and gives highly reliable results within a few minutes [33-35].

Electrolytic conductivity: Leveen and Rubricus in 1958 introduced an automatic blood loss meter, which worked on electrolyte conductivity. It was based on the fact, that the specific conductivity of blood depends upon the electrolyte concentration, and has a constant value. The

[1]Photo Calorimeter- Labtronics, Panchkula, Haryana, India
[2]Digital colorimeter- Topac, Cohasset, MA, USA
[3]Digital colorimeter- Systonic, Panchakula, Haryana, India
[4]Digital colorimeter- Industrial Equipm, ents & Controls Pty Ltd, Austraila
[5]SMART3- LaMotte, Chestertown, Maryland, USA

mechanism consisted of a water-filled tub, containing an agitator, which extracts the electrolytes from the blood sponges and clothes. A suction pump transfers blood from the operating table directly into the tub. A conductivity bridge measures changes in conductants. Automatic temperature compensation is accompanied by the introduction of a thermistor into one arm of the conductivity bridge. A servomechanism continuously brings the bridge into null balance, in order to have a direct reading instrument. This method has the advantage of giving reading but disadvantage is that it is dependent on the constancy of the electrolyte content of the blood during the period of estimation [36].

Urine strip method: A urine test strip is a basic diagnostic instrument used to determine pathological changes in the urine in standard urinalysis. In 2007, Ungjaroenwathana et al. used this method to estimate total blood in irrigating fluid in patients with transurethral resection of prostate surgery. Blood was collected prior to the operation, immediately post-operation and 24-hour post-operation. Total Hb and number of red blood cells (RBCs) were measured. Volume of irrigating fluid used during the surgery was recorded. The treated irrigating fluid was diluted into various concentrations and filled in the plate and tested by the urine strip. Blood loss was calculated by two methods, spectrophotography and urine strip method. The results showed that urine strip method for blood loss detection is a reliable and accurate though the technique is not best for detection but is practical and useful in immediate post-operative evaluation of blood loss [34].

Other Techniques:

A. Other techniques for assessing operative blood loss are dependent upon serum specific gravity [11]. However, this technique is not commonly used. Plasma volume may be measured by labeling albumin with dyes such as Vital Red or Evans Blue instead of radioactive Iodine, but these methods have little application to the measurement of operative blood loss. Red cells can be tagged with Fe^{55} or Fe^{59}, to measure blood volume, but their usage is restricted as they involve a relatively high dose of radiation (as said by Murray & Ports in 1960) [11]. Measuring the contents present in the suction bottle, can also be done for measuring intra operative hemorrhage (with adjustments made for the amount of saline irrigation used).

B. A procedure in 1997 was developed in which a mathematical model of blood loss for a surgical hospitalization based on mathematical principles for blood loss and hemodilution. The model was designed so that the calculation of blood loss would be based on easily measured factors such as the patient's blood volume, the number and type of red cell units transfused the initial hematocrit, the discharge hematocrit, the transfusion trigger, the volume of intraoperatively salvaged blood transfused, and the amount of hemodilution performed. In this study, the blood loss measured was compared with the intraoperative blood loss actually estimated by the anesthesiologist in 250 consecutive patients. The result showed that calculated blood loss was on average 2.1 times the intraoperative blood loss estimated by the anesthesiologist.

It was concluded that the use of such mathematical modeling to rapidly estimate a patient's blood loss has the potential to allow ready, objective comparisons between sites and even surgeons. It also allows for a more judicial and informed decision in the situation that any blood be available or the blood-conservation techniques that can be employed for a specific patient [37].

From the data penned down on the methods, it can be concluded

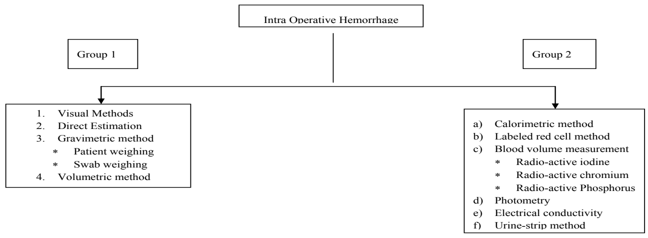

Figure 1: Flow chart.

that all these methods can be further branched as Group 1: methods that are easy to perform, not requiring any explicit apparatus, and are economical but may not be as reliable and accurate as the latter group. These include gravimetric & volumetric methods.

The second group, group 2: enlists methods, which are more accurate & reliable, but are time consuming, expensive, require specific apparatus and are technique sensitive. These methods also require trained personnel to execute the procedure. These are calorimetric, labeled red cell method, blood volume measurement (radioactive Iodine, Chromium and Phosphorus), photometry, electrical conductivity and finally urine strip method (Figure 1).

Amongst all the methods enlisted, volumetric and calorimetric methods can be considered better than the others can, as volumetric method is easy to perform, cost effective, does not require any technique and is more accurate than the other methods of the first group. Calorimetric method is also commendable. Though more expensive than volumetric method, it is more economical than the rest in the second group. It does not necessarily require a specific apparatus to proceed and gives a detailed account of the blood lost.

In the last few decades, a number of studies have been carried out to apprehend the best-suited method for estimating the blood loss during surgical procedures. We need more studies and researches to conclude this point.

Conclusion

There are number of studies addressing the causes for intraoperative bleeding and their management, however, there is scarcity of literature on methods determining the quantity of intra-operative blood loss. The intent of this article is mainly to make the practitioners aware of different methods of estimating intraoperative hemorrhage and thereby addressing the need for immediate replacement of lost blood, especially in medically compromised patients, with preexisting bleeding disorders. In addition, this review helps in determining the anticipated quantity of blood loss following specific surgical procedures, for accurate pre-operative preparations, to avoid any untoward consequences of excessive blood loss.

Various methods for estimation of intraoperative blood loss have been enumerated and explained. However, no method is considered the gold standard. Each method has its own advantages and disadvantages. Considering a specific method is dependent on operators' choice, feasibility and cost-benefit ratio. Based on the available research it is observed that there is insufficient literature to consider one specific method as ideal over the other. Hence, further studies and innovations in techniques for estimating blood loss are warranted.

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