New Techniques

The blood loss analyzer—
A new way to estimate blood loss

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In this article, the author addresses the problem of accurately estimating blood loss during surgery. He reviews methods by which blood loss has been traditionally calculated, and describes a newly developed computerized device that enables the anesthetist to compute blood loss and assess replacement needs with greater accuracy.

The principal difficulty in determining blood loss is clearly expressed by the teachings of J. L. Rubricius (contained in U.S. Patent 2,899,636 on August 6, 1957). Rubricius describes that during surgery, the major portion of blood lost from patients is absorbed by sponges and gauze used in the critical areas of the surgery; when these are removed, a considerable amount of blood collected therein becomes coagulated, making a volumetric determination of the blood loss difficult.

In a typical operating room situation, these sponges are placed on a plastic sheet for observation and the volume of blood is estimated by the operating room personnel, primarily by the anesthesia personnel. Such a procedure allows considerable margin for error. Only a few operating room personnel can, with any accuracy at all, visualize a sponge and calculate the amount of blood contained in it to within 5 cc. “Eyeballing” can miss up to as much as 5-10 cc of blood per sponge. This may not appear to be a critical difference in an adult, but in an infant, this loss may represent a significant percentage of blood volume. A truly accurate estimate requires a more scientific method.

Background

Blood loss in adults is divided into four categories, primarily based upon the clinical symptoms that are exhibited by patients who have suffered such blood losses. An estimated blood loss of 500-700 cc is considered minor, representing approximately 10-15% of an adult’s total blood volume. Patients with minor blood loss may experience a rare vasovagal syncope. A moderate loss is one of 750-1500 cc, approximately 20-30% of the total blood volume. A patient in this category with a loss of less than 1000 cc may experience a decrease in pulse pressure and a slight tachycardia, tachypnea and postural hypotension.

A major loss of anything above 1200-1500 cc in adults may constitute a hemorrhagic shock. These patients not only experience shock with a drop in systolic pressure and cold clammy skin, there is also a decrease of urine output to less than 30 cc per hour. At this point, a drop of 50% below normal systolic pressure occurs in these patients. A loss of greater than 45% may be irreversible, and a patient at that time becomes hypoxic and totally unresponsive.

In infants, the volume loss of approximately 90-120 cc represents 30-40% of total volume. The infant enters a state of listlessness and becomes hypothermic. In children under four years of age, the systolic pressure will be less than 65 mmHg. If these losses are directly related to a surgical procedure, then steps must be immediately taken to correct this situation in the form of replacement therapy. The smaller the patient, the more diffi-
culty may be experienced in measuring blood loss accurately.

Newborns tolerate considerable variations in blood loss. This can be demonstrated by the substantial amount of blood that may be infused from the placenta at birth. A newborn can safely be given 10-20 ml/kg of fluid in the first hour during surgery, plus replacement of blood loss. The newborn initially compensates well for hypovolemia by movement of the fluid from the large extracellular, extracellular fluid compartment.\(^5\)

**Estimating blood loss**

Estimated blood loss (EBL) based solely on the hematocrit may be inaccurate and is not a reliable reflection of true blood loss. An increase in hematocrit normally indicates dehydration. The type of dehydration most likely to produce shock is the hypotonic type in which there is a depletion of both water and electrolytes, with electrolyte loss predominating. This results in a diminished extracellular fluid space and a lowered concentration of electrolytes in the remaining fluid.\(^6\) This condition is primarily seen in acute blood loss.

With sodium depletion and a decrease in plasma volume, each increase of 3% in the hematocrit indicates a decrease of 150 mEq of sodium. Thus, treatment is necessary to replace sodium. A decrease in the hematocrit, reflecting a reduced number of red cells, does not always reflect blood loss; it may reflect overhydration. In acute losses, the hematocrit may not change significantly for several hours because of the time it takes for the body fluids to flood the cells.\(^7\)

As fluid is lost from the body, the blood volume can usually fall to about 75-80% of normal before there are significant changes in blood pressure, pulse and central venous pressure. Further decreases in blood volume can result in shock. As a corollary, if the patient in shock is given just enough fluid and/or blood to get him out of shock, he remains hypovolemic with a blood volume that is probably about 20-25% lower than normal. Thus, additional fluid or blood should be given before reducing intake to maintenance levels. If interstitial fluid has also been lost because the hypovolemia or shock was present for more than an hour or two, this must also be replaced.

Once blood volume falls 15-25% or more, the transfer of fluid from the interstitial space to the plasma volume is very rapid and may exceed 500 ml/hr for the first few hours. This swift transfer of fluid from the interstitial space into the intracellular fluid compartment may continue until the interstitial fluid volume falls to about 50% of normal. If further fluid is lost, the blood volume will then fall rapidly. If the fluid loss is relatively slow, however, fluid can be shifted from the intracellular space to the interstitial space and then to the vascular space to help compensate for the deficit.

It usually takes 6-48 hours after an acute hemorrhage for the blood volume to be restored to normal by interstitial fluid transfer. Thus, the hemoglobin and hematocrit may remain relatively normal for several hours after severe hemorrhage; it may then continue to fall in spite of no further blood loss for 24-48 hours as further dilution of the remaining red cells continues.

The fall in hematocrit after the hemodilution is complete will generally give some idea as to how much blood was lost. Thus, if the hematocrit fell from 50% to 40% 48 hours after an acute hemorrhage (that is, a 20% drop in hematocrit), one can assume that about 20% of the blood volume has been lost.\(^8\) Replacement therapy is determined by the anesthetist and surgeon in charge of the procedure.

Blood loss within a surgical procedure can be from several different sources: (1) it can be from the sponges themselves as they are removed from the operating cavity; (2) it can be calculated as suction loss, whereby the blood is actually evacuated from the cavity by suction apparatus; and (3) it can be from what is classified as incidental loss, which is the blood that is accumulated on the surgeon’s glove, on the drapes around the incision and from pure evaporation. The total loss is usually estimated to be 25% more than that which can be measured, thus taking into account the incidental blood loss.\(^4\)

The loss of blood by suction could be readily estimated with accuracy. Once removed from the operating cavity, the blood lost on sponges could be calculated with a great deal of tedious work using gram dietary scales. Incidental blood loss was not easily calculated due to the fact that evaporation plays a significant role in this loss. Now, however, with the advent of a computerized scale, the first two methods, blood loss from sponges and suctioning can be calculated very accurately and quickly.

**Blood volume determination**

In order to calculate blood loss with accuracy, the blood volume must be determined. It can be computed in several different ways, some of which are more accurate than others. The first is based on average blood volume which ranges from 6-8%
of total body weight; calculations based on this
average yield just that—an average. Another
method uses an average number of milliliters of
blood per kilogram of body weight. However, the
third and most accurate method for estimating
total blood volume for pediatric patients and
adults is by square meter body surface area.5

Estimating blood volume from surface area
derives its accuracy from considering both the
weight and the height of a patient, giving a square
meter surface area. Estimates from surface area are
about 2600-2800 ml/M² in adults and children.
This has been verified in the laboratory by the use
of radioisotopes. Values obtained by radiiodinated
serum albumin (RISA) are often higher than those
obtained with radioactive chromium (⁶¹Cr) tagged
red cells.2 With these detectable nontoxic materi-
als, the blood volume can be determined up to 10
times daily because the total quantity of radiation
in 20 measurements does not exceed the dose de-
ivered in taking an x-ray chest film.

An example of a semiautomatic instrument
for blood volume estimation is the Volemetron™
computer analyzer. It yields a whole blood volume
or plasma volume, depending on the specimen.6
Measurements of body surface area have shown
that blood volume can be calculated by a formula
that is based on weight and height of the subject
as follows:7

\[
\text{Body surface area} = \text{weight}^{0.425} \times \text{height}^{0.725} \times 0.007184.
\]

This formula is computed into the analyzer
for each patient to ensure an exact measurement.
Then, with square meters of body surface area
determined, the blood loss can be calculated. Body
surface area is expressed in square meters, weight
in kilograms, and height in centimeters. The an-
alyzer computes height and weight using the metric
scale, even when inches and pounds are entered
into the system.

Other measuring techniques, though accurate
and reliable, require the use of radioactive mate-
rials bound either to proteins or red blood cells.
It is the ratio between the amount of tracer admin-
istered and the concentration in the vascular com-
partment that is proportional to the volume of the
diluent (the blood volume).8

It might be noted that the average healthy
person has about 70 ml/kg of blood. For the obese
patient this figure is much lower, in the range of
50-60 ml/kg due to excessive amounts of adipose
tissue which is relatively avascular. The range for
lean, athletic individuals is higher, usually 75-85
ml/kg. The average for a newborn is around 80-90
ml/kg, due to the large percentage of vessels to
perfuse. Infants have approximately 75 ml/kg.
Children contain about 70 ml/kg, the same as
adults; the volume in infants begins reaching adult
levels at about three months of age.9

By knowing the estimated blood volume, the
anesthetist will be able to make an accurate judg-
ment of the patient’s loss of blood and plan replace-
ment therapy accordingly. Blood loss should be
calculated from the beginning of the surgical pro-
cedure in the following cases:

1. All pediatric patients.
2. All geriatric or severely debilitated patients.
3. Any time a cavity is opened (thoracic, ab-
dominal).
4. Any time a 250 cc or greater loss of blood
is anticipated.
5. Any time the anesthetist in charge requests
that it be monitored by the circulating nurse.9
6. Any patient in ASA category 3, 4, or 5.

New technique
A new, safe and accurate scale to measure and
record blood loss (developed by the author) is the
Comeau Blood Loss Analyzer® (CBLA) scale. It is
a precision computerized scale system (Figure 1).
The patient’s height and weight are entered into
the computer; the scale automatically computes
the square meter body surface area, multiplies that
by 2700 cc (which equals the patient’s total blood
volume) and displays 10% of that total. That
figure is used to notify the circulating nurse when
10% blood volume is lost.

The device works by weighing the sponges as

![Figure 1](image-url)

The CBLA® scale and suction units.
they are placed in a container upon the scale. The machine also keeps track of the number of sponges that have been placed in the container and weighs the suction, so that there is an ongoing total of blood loss measured in cubic centimeters. When the total estimated blood loss reaches the 10% figure, a warning message is flashed on the display screen and an audible alarm is activated. If the estimated total blood volume is beyond the capacity of the computerized scale, the operator is prompted to manually enter the alarm setting. As soon as the alarm setting value has been confirmed, the scale is automatically ready to weigh sponges. There is no flow sheet needed for keeping track of total blood loss.

The display of this machine is permanently illuminated so that it is easily recognizable from any vantage point in the room. At any point during the process, the circulating nurse or anesthetist can either add to or subtract from the estimated blood loss, such as in the case when an irrigation solution is used in combination with the sponges. This machine is versatile in that it not only accounts for large amounts of blood in adults but, it can also calculate very small amounts in premature infants.

This machine enables the operator to have an ongoing total of sponges (minus the dry weight of the sponges) plus a second-by-second tally of blood lost by way of suction. The analyzer has the capability of monitoring two separate suction canisters simultaneously. The weighing of the sponges and the monitoring of blood loss due to suction is continuously updated and reflected on a readout for the anesthetist's constant evaluation. The entire mechanism has been continuously tested and has been found to be within ±2 grams of error.

The blood loss estimating function is accomplished by weighing the fluid containing sponges from the patient and the contents of the suction apparatus, deducting the weight of the sponges and containers and displaying the net result to the scale operator. These values should be less than 2% of the full scale outputs of the transducers.

Summary

Regardless of the means used to estimate blood loss, clinical observation of the patient with frequent assessment of cardiovascular status is the basis of total management. It is very important that EBL be reported with some accuracy using a device that has the ability to weigh blood loss. Why? The overall mortality rate from blood transfusion has been reported to be as high as one death per 5000 units given.10 This is a highly subjective number. There are undoubtedly cases in which death has resulted from the administration of one unit of blood. However, the most common pattern would be one in which a patient received many units of blood and still died as a result of his primary disease.10

Until recently, blood loss determination was merely a function of estimation or clinical observation due to the previously mentioned drawbacks of manual scale systems. With new advances in computers, the ease at which blood soaked sponges can now be weighed and calculated can be as simple as a touch of a button.

REFERENCES


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Perry J. Comeau, CRNA, BS, is a graduate of Fort Hays State University in Hays, Kansas, where he received his degree in nursing in 1967. Prior to becoming a nurse anesthetist, he served three years in the U.S. Army in recovery room and cardiovascular intensive care. Mr. Comeau received his anesthesia education at St. Francis School of Anesthesia at Wichita, Kansas, and graduated in 1970.

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