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Subjectivity Of Estimating Blood Loss Among Health Care Providers In The Operating Room

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This is to certify that the thesis prepared by Hugh Andrew Siegel entitled **Subjectivity of Estimating Blood Loss Among Health Care Providers in the Operating Room** has been approved by his committee as satisfactory completion of the thesis requirement for the degree of Master of Science in Nurse Anesthesia.

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Abstract

SUBJECTIVITY OF ESTIMATING BLOOD LOSS AMONG HEALTH CARE PROVIDERS IN THE OPERATING ROOM

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This research utilized a descriptive study to establish a relationship between educational background and accuracy of estimating blood loss. The null hypothesis, that the educational background of health care providers in the operating room has no effect on the accuracy of estimating blood loss , was tested. Ten nurse anesthesia students, 8 certified registered nurse anesthetists, 16 operating room registered nurses, 12 anesthesiologists, and 9 surgeons were included in the sample population. A number of different protocols were utilized to assess the relative accuracy of blood volumes estimates. The study was separated into four stations. Station 1 consisted of three tables, each with different sizes and types of sponges with varying amounts of blood placed on them. Four estimates were required at each table, for a total of 12 estimates. Stations 2-3-4 contained different aggregates of blood-soaked materials, requiring a single estimate at each station. Repeated measures analysis of varience (ANOVA) revealed that the means across all groups in Station 1 reached statistical significance beyond $p = .05$ ($< .001$), and the hypothesis is

rejected for equal group means. However, the results for Stations 2-3-4 for equal group means did not reach statistical significance ($p = .136$), therefore, do not reject the null hypothesis of equal group means.

Chapter One

Introduction

During the course of a surgical intervention involving the active loss of whole blood from the patient, estimation of operative blood loss is a vital assessment made by all members of the health care team. The accurate evaluation of blood loss is a guide both to the treatment and to the identification of causes of excessive blood loss (Duthie et al.,1990). Numerous studies comparing estimations of blood loss to clinically measured techniques reveal statistically significant differences between the two groups. It has been pointed out that the higher the measured blood loss, the greater the difference between measured and estimated blood loss (Duthie et al., 1990). An average of 40 % error in estimating blood loss emphasizes the necessity for closely assessing the clinical response of the patient during an operation, to include measurement of vital signs and hemoglobin/hematocrit (H/H) values (Cullen, 1961). Estimations of blood loss from the operative field remains the standard measuring guideline, along with the laboratory measured H/H , for the replacement of fluid deficits that arise during a surgical procedure. The deficit is usually replaced with crystalloid and/or colloid solutions, or with various types of blood products, depending on the necessity of the replacement fluid.

In recent years, increasing attention has focused on the cost and risks of replacing blood loss with blood or blood products (Hahn, 1989). The primary concern of health care providers is the risk of transmitting disease (HIV, Hepatitis) through the transfusion of these products. Blood products that generally are not considered risk free include whole blood, packed cells, plasma, platelets, and cryoprecipitate (Cone, Day, Johnson, Murray, & Nelson, 1990). Transfusion of blood products has been a routine practice with little perceived risk, but now has become a routine practice with considerable risk to the patient (Spence, 1991). Therefore, accurate assessment of blood loss is essential for the surgical course of treatment for the patient.

Currently the literature lacks data relating to the subjectivity of estimating blood loss in the operating room among the various care givers in this setting. The purpose of this study is to determine if there is, in fact, a significant margin of error in estimating blood loss when compared to measured values, and to determine whether the educational background of the health care provider in the operating room is a contributing factor to accurately estimating this loss.

Statement of Purpose

The purpose of this study is to determine whether the educational background of health care providers in the operating room is a contributing factor in accurately estimating blood loss via visualization in a controlled setting.

Statement of the Problem

Is there a significant difference among the various caregivers in the operating room in accurately estimating blood loss during a surgical procedure?

Hypothesis

Educational background of health care providers in the operating room has no effect on the accuracy of estimating blood loss.

Variables

Independent. The independent variable is the educational background of the participant.

Dependent. The dependent variable is the precision and accuracy of subjectively estimating blood loss via visualization.

Definition of Terms

The operational definitions for the purpose of this study are listed below:

Educational background. Educational background is the level of education attained by the participant , to include: registered nurse, anesthesiologist, certified registered nurse anesthetist, and physician (surgeon).

Accuracy. Accuracy is the percent difference between the actual amount of blood and the amount that was estimated by the participant.

<u>Estimation</u>. Estimation is defined as the participants approximation of the volume of blood on the materials presented in the study. It was performed without the aid of measuring devices.

<u>Blood Loss</u>. Blood loss is the volume of blood that was measured and placed on sponges, towels, gowns, and drapes that are commonly used in the operating room.

Assumptions

The following assumptions are acknowledged by this investigator:

1. Subjects in this study verify level of education upon participating in the research study.

2. All stations utilized in the research process are unchanged from subject to subject.

Limitations

The limitations created by the methodology of the study include:

1. The participants subjectivity in making estimates at the various areas in the study.

2. The participants previous experience with the subject matter being investigated.

Delimitations

The delimitations imposed by the investigator include:

1. The sample is one of convenience: a non-probability sample of surgeons (attendings, residents), operating room nurses, certified registered nurse anesthetists, nurse anesthesia residents, and anesthesiologists at a single 1,052 bed mid-Atlantic, university teaching hospital.

Conceptual Framework

Before analyzing the subjectivity of estimating blood loss in the operating room by the various health care providers, it is necessary to understand the normal physiology of blood and blood products, and how it relates to hemodynamic stability during an operative procedure. The focus of this section is to present the concepts of blood physiology so that literature relating to estimations of blood loss, and blood and fluid replacement during an operation can be understood.

Blood Components

Blood is a suspension of various types of cells in a complex aqueous medium called plasma. Blood makes up approximately 6% of total body weight, and is essential for metabolism and the defense of the body. The normal adult has an average total volume of about 3L of plasma. Various constituents can be found in the plasma including proteins, lipids, electrolytes, amino acids, vitamins, carbohydrates, carbon dioxide, and gaseous oxygen which is dissolved in the plasma.

A closer look at the constituents in plasma shows how they work in unison to maintain a homeostatic environment for the cells they surround. The electrolytes in plasma maintain the optimal pH within physiological limits.

These ions also maintain the osmolarity of the plasma, typically around 280-300 milliosmoles/kg (Stoelting, 1991). Inspired oxygen diffuses from the pulmonary alveoli into the circulating plasma via the pulmonary capillaries and then to the red blood cells, where it combines with hemoglobin. Carbon dioxide also diffuses from the peripheral capillaries and is carried by the plasma to the lung where it can be excreted. The plasma normally contains about 7g of protein/deciliter (dl). The protein can be divided into two groups, the albumin and the immunoglobulins. Albumin maintains the colloid osmotic pressure that regulates the passage of water and diffusible solutes through the capillaries. When albumin is in a decreased concentration, fluid accumulation, or edema, can be expected. The other groups of proteins, the immunoglobulins, or antibodies arise upon stimulation of lymphocytes in response to their exposure to antigens. The immunoglobulins also consititute the majority of gamma globulin in plasma. Other plasma proteins include fibrinogen (needed in the clotting process), enzyme inhibitors, many enzymes and their precursors, proteins that mediate the biological effects of immune reaction (complement), and specific proteins that act as carriers for other blood constituents such as vitamins, iron, and hormones.

The blood also contains various cells, each with its own purpose to maintain homeostasis within the body. These cells include the erythrocytes, or red blood cells. The percentage of blood made up by the red blood cells is termed the hematocrit. Hemoglobin is a protein synthesized in the marrow by the precursors of the red blood cell. White blood cells, also called leukocytes, can be divided into five classes: neutrophils, basophils, monocytes, eosinphils, and lymphocytes. Leukocytes are the body's protection mechanism. The other cell found in blood are the platelets. They play an important role in the control of bleeding and in the formation of clots within blood vessels (Berne & Levy, 1988).

Oxygen content of blood

Blood loss during an operative procedure needs to be judiciously assessed throughout the course of the surgery. Replacement of the loss needs to be considered when a hypothetical point is reached. The primary reason for replacing blood loss with blood is to maintain the oxygen carrying capacity of the blood. This oxygen content is defined as the number of cc of oxygen contained in 100 ml of blood:

$$CaO2=Hb \times 1.34 \times SaO2 + 0.003 \times PaO2$$

where:

Hb = gm of hemoglobin/dl

1.34 = the number of cc of oxygen bound to 1 gm of saturated hemoglobin.

SaO2 = % oxyhemoglobin to total hemoglobin, fractional saturation.

0.003 = the oxygen solubility in plasma

PaO2 = the arterial oxygen tension, mmHg

If the hemoglobin is 100% saturated, the oxygen content of blood with 15 gm/dl of hemoglobin is 20ml/dl. For oxygen to be used in the tissue, it must be circulated, via the cardiac output, which averages 5 liters/min for an average adult at rest. Therefore, oxygen delivery is the product of cardiac output and oxygen content, or approximately 1,000ml/ minute (Miller, 1990). The tissues on an average extract 5 ml of oxygen from every 100 ml of blood flow. As the hematocrit decreases, the tissues may either extract more oxygen, if blood flow remains constant, increase blood flow if the volume of oxygen extracted is to remain constant, or to decrease oxygen consumption. Because cardiac tissue extracts at twice the rate of other tissues and because the normal compensation for anemia involves increased cardiac work, the heart has been considered the organ that determines the limit at which anemia is tolerated (Tremper, 1992).

Hemodynamic Preservation and Blood Loss

During the course of a surgical procedure, a large volume of blood can be lost in a short period of time. If not corrected, a situation similar to hemorrhaging occurs, in which the filling pressure of the vascular system is reduced (Yang & Puri, 1986). The consequence is diminished venous return and stroke volume. The mean arterial blood pressure hardly changes with blood loss of up to 15ml/kg body weight for the average adult, but falls considerably if more blood is lost. The body compensates for the changes in venous return and stroke volume by a series of mechanisms that Berne and Levy describe as negative feedback mechanisms. They are termed "negative" because the secondary change in pressure is opposite to the initiating change (Berne & Levy, 1988). Stimulation to the baroreceptors located in the intrathoracic vessels, including the aortic arch and carotid sinuses, is diminished during acute blood loss due to the reduction in mean arterial pressure and in pulse pressure. Because their activity is decreased they exert a smaller inhibitory influence on the vasomotor and cardioinhibitory centers, so that reflex vasoconstriction and increased heart rate are produced. Vasoconstriction occurs primarily in the resistance vessels of the viscera, skeletal muscle, skin, and kidneys. The coronary and cerebral vessels are excluded. Capacitance vessels in skin and viscera are also vasoconstricted, reducing the capacity of these regions and thus improves the filling pressure of the vascular system. The increased sympathetic discharge produced also attributes to venoconstriction. This sympathetic activation constricts certain blood reservoirs, that provide an autotransfusion of blood into the circulating bloodstream (Berne & Levy, 1988). In addition to the increased catecholamine release observed, vasopressin, a potent vasoconstrictor, is actively secreted by the posterior pituitary gland in response to increased blood loss. Removal of about 20% of the blood volume increases the vasopressin secretion to about 40 times the normal rate. Independent of the reactions of the baroreceptors, the capacity of the vascular system is also reduced by the "reverse stress relaxation" of the vessels, and thus is additionally adjusted to the reduced blood volume. Because of the constriction of the resistance vessels and decrease in venous pressure, the capillary pressure falls, so that more fluid moves from the interstitial space into the capillary bed. In this way the intravascular volume is expanded while the interstitial and intracellular volumes decrease. When a human has lost 500 ml of blood, only 15-30 minutes later 80-100% of the lost plasma has been replaced by interstitial fluid. After greater loss of blood, the plasma volume is returned to normal in 12-72 hours, during which time the protein losses not covered by the initial influx of albumin from extracellular regions are compensated by accelerated synthesis (Schmidt, 1980).

The kidneys play an important role during the acute stages of blood loss by their ability to conserve water. Because perfusion of the kidneys is restricted, urine production declines, and more sodium and nitrogen containing metabolites are retained in the blood. The concurrent activation of the renin-angiotensin-aldosterone mechanism has the end result of sodium and water reabsorption by the renal tubules with a rapid restoration of volume equilibrium.

If blood loss is severe, and the mean arterial pressure falls below 40 mm Hg, inadequate cerebral blood flow activates the sympathoadrenal system. The sympathetic nervous discharge is several times greater than the maximum that occurs when the baroreceptors cease to be stimulated, resulting in more pronounced vasoconstriction and myocardial contractility. Bradycardia and hypotension may occur during severe degrees of cerebral ischemia due to the vagal centers becoming activated (Berne & Levy, 1988).

Blood Substitutes

During the past century, there has been an enormous amount of research into the development of a red blood cell substitute that may be utilized during resusitative efforts. The most important functions of a red cell substitute would be the ability to transport oxygen and carbon dioxide effectively and to support circulatory functions. A viable red blood cell substitute would have to be temperature stable, readily available, and universally compatible. It should also have a satisfactory intravascular persistence, and a long shelf life. In regards to safety, this product should be free of any undesirable side effects that might produce organ dysfunction, and should not pose a risk of transmitting transfusion-related infectious hazards such as hepatitis and acquired immuno-deficiency syndrome (Gould, Lakshman, Sehgal, & Moss, 1992).

Blood substitutes useful during an operative procedure can be classified into two broad categories: 1) those that increase the delivery of oxygen indirectly by volume expansion; and: 2) those that have the capability of directly increasing oxygen content. Category 1 includes crystalloids and colloids, and Category 2 includes two classes of blood substitutes that have been developed in the past few decades. These are the perflurocarbons and stroma-free hemoglobin (SFH) (Spence,1991). Both have potential clinical applications but neither have developed to the point of wide-spread clinical acceptance

(Tremper,1992). Only one perflurocarbon product has had significant clinical testing, that being Fluosol DA-20%. Reports cite favorable results in increasing delivery of oxygen to anemic patients, yet concerns about adverse reactions, complement activation from components of the solution, and efficacy of the product soon followed. Stroma-free hemoglobin products have been in development for years. However, concerns in regards to renal toxcity and excessive oxygen affinity have limited their breakthrough into the market (Spence, 1991).

Replacement fluids for intraoperative blood loss

Intravascular volume replacement must be undertaken during an operative procedure to counteract preoperative dehydration, insensible intraoperative losses, sequestration of fluid around the site of surgery, and intraoperative loss of body fluids including blood (Ramsay, 1991). Crystalloid and colloid solutions are the fluids most often infused during surgery to combat these losses. Crystalloid solutions with the osmolality of plasma, such as Ringer's lactate or normal saline, are distributed only to the extracellular water. When infused rapidly, equilibration between the vascular and interstitial compartments takes less than 1 hour. Due to the similarities in osmolality, these solutions should be used for large-volume replacement during hypovolemia. Colloids are defined as solutions containing large molecules that can not pass from the vascular compartment to the interstitial space. They exert an oncotic pressure that holds on to a volume of water and electrolytes. Administration of colloids results in the absorption of interstitial fluid into the vascular space. For this reason, patients with severe hypovolemia, which could result from increased intraoperative blood loss, should be treated with a colloid solution along with infusion of crystalloid solutions to counteract the loss (Ramsay, 1991).

Estimation of allowable blood loss

Several formulas have been derived for estimating allowable pre-transfusion blood loss. The formula most often utilized is the following:

$$ABL = EBV \times Ho - Hf/Ho$$

where ABL is the allowable blood loss; EBV is the patient's estimated blood volume; Ho is the patient's initial hematocrit for hemoglobin concentration; and Hf is the patient's minimum allowable hematocrit. In 1983, Dr. J. Gross described the formula as linear, writing that it implies the fractional decrease in hemoglobin or hematocrit is equal to the fraction of the total blood volume lost. He further details the fact that intravascular volume usually is maintained prior to blood transfusion by administration of crystalloids; hematocrit therefore should decrease gradually. He states that each milliliter of blood contains progressively less hemoglobin, therefore the above formula overestimates the hemoglobin loss. Gross introduces a different formula which would correct for the dilution that results during an operative procedure. His equation:

$$ABL = EBV \times (Ho - Hf/ Hav)$$

where Hav is the average of the initial and minimum allowable hemoglobin concentrations or hematocrits. Verbally, this formula states that the allowable blood loss is equal to the estimated blood volume multiplied by a fraction whose numerator is the difference between the initial and minimum allowable hemoglobin concentration (or hematocrit) and whose denominator is the average of the initial and minimum allowable hemoglobin (or hematocrit) concentration. Gross utilized this formula during several studies and the corrected equation provided a closer approximation to the allowable blood loss for a given target hematocrit than did the earlier equation. The point is made that to insure an adequate hematocrit for oxygen transport while minimizing unnecessary blood transfusions, a scheme for deciding when erythrocytes should be transfused is desired. Gross writes that the old formula may underestimate the blood loss by up to 500 ml in a patient with an initial hematocrit of 45%, and because of the accuracy and ease of use, the new formula should be considered for calculation of allowable pre-transfusion blood loss during surgical procedures when intravascular volume is maintained (Gross, 1983). Albert, Gravel, Turmel and Albert ,in 1965, however, write that blood volume measurements are " meaningless " and that the results often do not correlate with the clinical picture.

Estimation and education

Estimation of operative blood loss is a subjective measurement that is performed by various members of the health care team during a surgical procedure. The members of the team are from different educational backgrounds, so the question presented is whether this difference in educational fields of practice would have a statistically significant bearing of the results of estimating operative blood loss. Cavonius believes that differences in estimation performance are based on persisting individual differences, and that these differences are the result of the way in which an individual's nervous system processes sensory stimulation, rather than a result of response bias. It is also stated that individual differences do not reflect any persisting attribute of the subject's sensory or judgmental processes, and that individual deviations from the group means are random. Presenting results of various experiments testing individual estimation behavior, Cavonius found that subjects tend to use similar scales for different sense modalities, which was interpreted as a manifestation of response bias. Also reported was the fact that individuals differed in their discrimination of sensory input because of a factor, such as motivation, that is unrelated to sensitivity. Whatever the cause, one might predict that poor discriminators would produce a relatively low grade when making estimates, since they would tend to perceive all stimuli as similar (Cavonius, Hilz, & Chapman, 1974).

Cahan and Cohen address the issue of schooling and intelligence in their 1989 report. They note that unlike most other age-related factors, schooling is not inherent to chronological age. An analytical distinction between schooling and other factors that may affect intelligence development is desirable on theoretical grounds: school is explicitly aimed at the development of intellectual abilities. The learning processes involved in many school activities are thought to affect the formation of the cognitive strategies needed for successful performance on general ability tests (Cahan, & Cohen, 1989). Therefore, differences in estimation behavior and educational background can be considered when analyzing the subjectivity of estimating blood loss during an operative procedure.

Summary

Estimation of blood loss during an operative procedure is made by various members of the health care team. An accurate estimation is of major clinical importance to sufficiently replace the deficit of the patient, be it with blood or non-blood substitutes. Estimating blood loss is a subjective behavior, with various components that need to be considered. Educational background differs with each member of the health care team and may be a variable accounting for the highly subjective nature of estimating blood loss. The conceptual framework proposes the normal physiology of blood and blood products, to include replacement criteria, and also addresses the issue of education and estimation behavior. The purpose of the study is to determine if there is a statistically significant difference in estimating operative blood loss among the health care providers in the operating room, all who come to practice with various educational backgrounds.

Chapter Two

Review of Literature

It has been shown that there is a statistically significant difference when estimations of operative blood loss have been compared to actual measured values. In 1961, Stuart Cullen, M. D., editor of *Anesthesiology*, described the discrepancy found when estimations are compared to measurements. He detailed a study in which 53 patients scheduled for "major surgery" had their blood volume measured by using the radioactive iodinated serum albumin dilution technique 24 hours prior to surgery. The blood volume was again measured by this technique 2 hours after surgery in the recovery room. The average blood loss measured equalled 734 ml. The average discrepancy between estimates and the measured blood loss was 299 ml. (standard deviation +/- 239). Cullen pointed out that when the estimated loss was greater than measured, the average discrepancy was 224 ml. (31 cases). When it was lower than measured, the average difference was 400 ml (22 cases). Cullen wrote that the results obtained did not confirm that clinical estimation of blood loss gave a close approximation to the actual loss. He concluded by stating that an average of 40 % error emphasizes the necessity for closely assessing the clinical response of the patient during the operation in deciding how much blood should be replaced. He wrote the estimated loss should guide, but not necessarily determine, the amount of replacement (Cullen, 1961). An extensive literature search for this study demonstrates the discrepancy found between estimated values of blood loss and actual measured values.

Measuring operative blood loss

Blood loss during an operative procedure is usually estimated by the health care providers throughout the course of the surgery. This is an in-exact science which usually leads to many different values. Several methods of measuring blood loss have been described in the literature. In the 1940's, the concentration of blood in irrigating fluids was calculated through color comparisons with tubes containing known concentrations of hemoglobin (deCampos, deCampos, Cordeiro, Borrelli, & deGoes, 1986). In the latter part of the 1950's, this technique was modified for the analysis of nonhemolytic solutions. During this period, a blood loss monitoring device was introduced by Leveen and Rubricius, that actually measured changes in conductivity associated with different concentrations of blood and electrolytes. Chemical reactions used later to calculate the amount of hemoglobin in irrigating solutions were based on the transformation of hemoglobin to cyanmethemoglobin and were measured photometrically (deCampos, 1986). This technique, described in 1969 by Bond was named the Haemoglobin-Extraction-Dilution technique. The error in determinations of hemoglobin with this system varies with the laboratory and the frequency of calibration; it may be as low as less than 0.5% (Bond, 1969). Bond described several sources of error with this technique. He classified the error as error due to dilution of the known volume of water by the volume; error due to inadequate mixing or non-uniformity of the hemoglobin solution; error associated with the inaccurate measurement of large volumes of water; errors associated with the determination of hemoglobin of blood and of the aqueous solution of hemoglobin; and errors associated with variability of the hemoglobin shed due to surgery (Bond, 1969). He later wrote this method had an irreducible level of error due to inaccuracy in making the basic measurement, and stated that the value is between 0.69% to 1.11%. It was also pointed out that this method becomes somewhat useless when blood loss exceeds 500 to 600ml, due to the fact that volumes of water in amounts greater than 50 liters would have to be utilized during the measurements.

Other methods of measuring blood loss during a surgical procedure include actually weighing soiled materials from the operative field to determine the loss. Visual estimation of blood loss, however, remains the standard for guidance in the event of replacement therapy.

Laboratory determination versus estimation of operative blood loss

According to findings of Duthie and associates (1991), there is a great discrepancy between the values of visually estimated blood loss when compared to laboratory determined values. Blood loss during normal delivery was measured in a total of 62 patients, all who had no obstetric or medical complications and who underwent normal delivery. Blood loss was estimated visually by the chief attendant and recorded in the patient's record. Blood loss was also measured in the laboratory using the alkaline-haematin method. The findings of the study exhibited that the measured blood loss was significantly higher ($p < .05$) than the estimated blood loss. The group of patients were subdivided into primiparas (37) and multiparas (25). In primigravidas, the mean (+ or- standard error of the mean) estimated blood loss was 260 +/- 12 cc and the mean measured blood loss was 401 +/- 29 cc. In multiparas the mean estimated blood loss was 220 +/- 10 cc, and the mean measured blood loss was 319 +/- 41 cc. The mean estimated blood loss was significantly lower ($p < .05$) than the mean measured blood loss in both groups. Of considerable clinical significance, the study illustrated the point that the higher the measured blood loss, the greater the difference between the measured and estimated blood loss. In the event of underestimating blood loss, the inevitable result would be that a proportion of patients would not receive the attention and treatment necessary following excessive blood loss. The study also identified that the tendency to overestimate blood loss could be equally dangerous. The authors suggested that if blood loss is to be assessed realistically, an educated guess must be combined with measurement of the patient's vital signs and the hematocrit. The identification of a major discrepancy between measured and estimated blood loss underlines the need for continued vigilance.

Intraoperative methods of reducing blood loss

The choice of anesthesia and operative technique can influence the amount of blood lost during surgery. Yoshikawa, Sano, and Kanri wrote, for example, that care should be taken as to blood loss during an oral and maxillofacial surgery as the operative field involves the vascular system (Yoshikawa, Sano, & Kanri, 1989). A number of operative approaches have been modified from existing techniques or newly developed to minimize blood loss in both vascular and orthopedic surgery. For example, an end-to-side portocaval shunt over a splenorenal shunt is prefered by vascular surgeons because there is much less blood loss with this approach. New advances in the field of grafts, such as the woven Dacron graft essentially eliminate blood loss from extravasation during aortic bypass and replacement due to the minimum porosity of the material. Different approaches to surgical procedures have also been associated with a decrease in blood loss. For example, a modified approach to aortic aneurysm surgery by a Dr. Leather in which the standard transperitoneal approach is switched to a retroperitoneal approach demonstrated a decrease in estimated blood loss from 1,700 cc to 600 cc. Spence noted that the sine qua non of bloodless surgery is careful, skillful operative technique. He wrote that dissection along anatomic planes is essential and requires a thorough knowledge of anatomy. Rip and tear surgical techniques only lead to avulsion of vessels and increased bleeding (Spence, 1991).

A great majority of the literature reviewed studied the effect of hypotensive anesthesia on blood loss. Sollevi, in his 1988 paper, noted that the clinical introduction of controlled (deliberate or induced) hypotension, i.e., an intentional reduction of systemic blood pressure below the level normally occurring during surgical anesthesia, is generally attributed to Gardner (1948) who described the use of arteriotomy as a method of inducing hypotension intraoperatively. In the early 1950s, the use of short-acting ganglion-blocking agents, made a more predictive reduction in blood pressure possible, further enhanced the use of perioperative hypotension. More recently, however, many pharmacological agents have been used for inducing controlled hypotension. Such agents include various intravenous vasodilators acting via different pharmacological principles, and inhalation anesthetics (Sollevi, 1988).

Sollevis' research concentrated on the concepts and controversy of hypotensive anesthesia and blood loss. He wrote the idea behind hypotensive anesthesia is to reduce surgical blood loss thereby either diminishing the need for blood transfusion or improving the surgical field. He also discussed the controversy regarding the value of controlled hypotension for blood loss reduction. He noted that controlled studies verifying beneficial effects of hypotension were essentially lacking in the early literature (more than 20 years ago). Further, the induction of hypotension may increase the risk of tissue damage due to hypoperfusion. Complication and contraindications are also discussed by Sollevi. There is a potential risk of cardiovascular complications affecting different vital organs when systemic blood pressure is reduced. Mortality was reported as early as 1961 with this technique, but the incidence is extremely low. Severe complications are often associated with mismanagement of the hypotensive agent used. Sollevi pointed out that during the last 10-25 years, anesthetic techniques and perioperative monitoring have improved, and that the knowledge of the respiratory and hemodynamic physiology during anesthesia and of the pharmacological action of the hypotensive agents was also greatly enhanced. In order to minimize the risk of various cardiovascular complications, it is generally considered unwise to induce controlled hypotension for blood loss reduction in patients with ischemic heart disease (heart failure), cerebrovascular disorders, severe pulmonary, renal, and hepatic disorders, uncontrolled hypertension, hypotension, severe anemia. Also addressed was the fact that there are several contraindications that have to be taken into account that are related to the various specific hypotensive agents (Sollevi, 1988).

Another issue addressed in Sollevis' report is the relationship between the degree of reduced systemic blood pressure and the influence on perioperative blood loss. It has been assumed that the more the blood pressure is reduced, the more effective is the prevention of bleeding. His findings indicate it is possible that a mean arterial pressure below 60 mmHg lacks any additional effect in reducing blood loss, while it produced a risk of inadequate organ perfusion. He concluded it is evident that the relationship between the degree of blood pressure reduction and blood loss still remains to be elucidated (Sollevi, 1988).

In 1987, Lennon et al., described the effects of intraoperative blood salvage and induced hypotension on transfusion requirements during spinal surgical procedures. Blood loss that occurs during surgical correction of scoliosis usually necessitates the transfusion of blood products perioperatively. Preoperative phlebotomy, intraoperative hemodilution, induced hypotension, and intraoperative autologous transfusion are techniques used to decrease the need for perioperative transfusions (Bovill & Norris, 1989). In their report, they reported the efficacy of induced hypotension and intraoperative autologous transfusion in decreasing homologous transfusion requirements during surgical procedures for the correction of scoliosis (Lennon et al., 1987).

Deliberate hypotension was induced in 81 of 142 patients who did not receive intraoperative autologous transfusion. They found that the use of induced hypotension was not associated with a decrease in blood transfusion requirements in comparison with the requirements for those in whom hypotension was not induced. The paper did, however, describe reports of beneficial effects of intraoperative hypotension during surgical procedures for the correction of scoliosis. Malcolm-Smith and McMaster reported a 70% reduction in blood loss in 44 patients in whom hypotension was induced (systolic blood pressures of 60 to 70 mmHg) during surgical correction of scoliosis. They are quick to note that the use of deliberate hypotension poses theoretical concerns. For example, neurologic damage caused by hypotension-induced ischemia may occur. They wrote, however, that current physiological research demonstrates that autoregulation of spinal cord blood flow occurs between mean pressures of 50 and 150 mHg, and cerebral blood flow remains normal at a mean pressure of 50 mmHg in healthy men (Lennon et al., 1987).

The Lennon and associates report detail three major methods of autologous transfusion which may be used during spinal surgical procedures. First, the patient may preoperatively donate blood that is stored as liquid or frozen units in the blood bank until the time of operation. The success of this technique, however, may be limited by the shelf life of stored blood and by the occasional need for multiple donations.

Another method described is that of intraoperative hemodilution. Blood is withdrawn at the onset of the surgical procedure and is replaced with crystalloid solution. The blood is then returned to the patient during or at the end of the operation. In a study reviewed, only 9 of 27 patients required homologous blood during their hospital stay (Lennon et al., 1987).

The third type of autologous transfusion described is that of shed blood that is salvaged intraoperatively. With use of this technique, blood is aspirated from the surgical field, centrifuged, washed, and returned to the patient. The report describes a 50 % decrease in homologous blood requirements in a total of 99 procedures, most involving spinal operations with the use of this technique. In the study, a mean of 2.3 units of blood (range, 1-7 units) was salvaged intraoperatively. Patients who received autologous transfusions were given a mean of 2.0 units of homologous blood intraoperatively in comparison with 5.1 units in the group who did not undergo blood salvage. Patients who were given autologous transfusions received 43 % less homologous blood for the entire hospital stay than those who were not (6.0 versus 3.4 units). Lennon and associates concluded that because all the patients were well matched demographically and all procedures were performed by the same surgeon, the reduction in homologous blood transfused was probably attributable to the usc of autologous transfusion and not to differences in surgical technique or patient selection (Lennon et al, 1987).

Estimation of blood loss by anesthetists

In 1985, Gordon Kempe, CRNA , demonstrated that there was a lack of correlation between experience and accuracy in estimating blood loss following his study which he titled Estimation of Blood Loss by Anesthetists. Kempes' study consisted of 36 anesthetists representing all the different positions of anesthesia providers in a mid-Atlantic teaching institution. They were asked to estimate the amount of blood on various materials that are usually found in an operating room setting. These materials included dry sponges, wet sponges (moistened with saline), sheets, gowns, and drapes. They were also asked to include the years of experience in their chosen field. The results of Kempes' study supported the literature demonstrating that blood loss estimation by visual assessment is an inaccurate method with average error approaching 50%. No difference in accuracy among the various groups existed by position in the anesthesia department. Among all the groups, an estimation error of 0.5 was consistent with reports in the literature.

Summary

The review of the literature demonstrates the judicious need for closely monitoring the patient during the course of a surgical procedure that involves the active loss of blood. A typical underestimation of blood loss is usually seen when comparing measures of estimated versus those of laboratory determination.

No studies have been found in the literature that compare the estimating abilities of the health care providers in the operating room that make these essential measurements;.although, Kempes' study (1985) did examine one of these professions. This study sought to compare the subjective nature of estimating blood loss by the various caregivers, and evaluate if the level of education was a contributing factor in making a more accurate measurement.

Chapter Three

Methodology

The literature review produced evidence there is a statistical difference when comparing estimations of operative blood loss to those of actual measurements. The purpose of this study was to determine if there was a statistically significant difference among the various members of the health care team who are involved in making these estimations, and to compare the groups for accuracy of estimation.

Research Design

The research utilized a descriptive study to establish a relationship between educational background and accuracy of estimating blood loss. Information was also collected to determine if possible differences occur in relationship to years of experience in a particular field of practice. The study also sought to determine if estimating differences exist due to placing blood on various types of sponges, drapes and towels or by collecting the sponges differently.

Population

The subjects participating in the study were from several departments of a large 1,052 bed mid-Atlantic teaching hospital, which included the departments of anesthesia, nurse anesthesia, nursing, and surgery. The participants were categorized in their appropriate group, with the different levels of practice differentiated on the study form.

Sample and Setting

A non-probability based sample of convenience consisted of the various health care providers. The level of education was determined at the time of the study and documented. It was limited to those volunteers who were able to participate in the study at the time of the research.

The study was conducted during the early afternoon of a routine workday. Time and place for the study was determined by convenience to both the participants and the researcher. All conflicts in scheduling was considered and resolved at the time of the study.

Data Collection Procedure

The volunteers were requested to participate in the study by a general public announcement. Data forms were distributed at the time of the research, and participants were requested to answer all questions concisely.

The research design is that presented by Kempe in 1985. There were 15 estimations of blood volume to be measured by the participants of the study. The location of each estimation was called a station. Blood was placed into a basin via use of a syringe. The blood used for the study was donated by the blood bank of the institution, for it had expired and was expendable. The materials were then placed into the basin and absorbed the blood. The absorbant materials used for the experiment consisted of 4 inch by 4 inch sponges and 18 inch by 18 inch sponges for Stations 1, 2, and 3. Station 4 used other materials as described below:

Station 1 consisted of 12 sponges arranged into three groups. Group A used 4 dry 4 inch by 4 inch sponges. Group B used 4 dry 18 inch by 18 inch sponges. Group C used 4 wet 18 inch by 18 inch sponges. These were moistened by adding normal saline to the sponges and squeezing the excess saline out by hand. This last group of sponges were termed "wet laps".

Station 2 consisted of a clear plastic bag in which five sponges, premoistened with blood product were placed; the bag was sealed closed. Station 3 consisted of a 20 gallon bucket on the floor in which five 18 inch by 18 inch sponges were placed in view by draping the sponges over the bucket's edge.

Station 4 consisted of a table with sheets, towels, drapes and two soiled surgeon gowns. The blood was distributed on the gowns and the drapes and placed on the center of the table in full view of the participants; this was to simulate an operating room setting. The participants were asked not to disturb the materials on the table.

The participants were told that they might manipulate any of the objects in Stations 1-3, yet were to leave the bag in Station 2 sealed. The participants were asked to make their observations concerning Station 4 without touching the area, as if it were a sterile field. A form was provided for the participant, and they were asked to record all estimations. The sheet also inquired information as to years of experience in their field of practice (see Appendix A).

Upon completing the study, the participants were given a list with the correct amount of blood for each estimation. The maximum amount of blood that each sponge could absorb was also pointed out to each participant.

Data Analysis

The data were analyzed by measures of analysis of variance (ANOVA) used to test the significance of differences between means (Polit, & Hungler, 1991). A pre-determined p level of $< .05$ was considered significant to test the hypothesis. The data was reviewed to determine whether different levels of educational background produced a statistically significant estimation of blood loss.

Chapter Four

Results

This study used a number of different protocols to assess the relative accuracy of blood volume estimates by nurse anesthesia students, certified registered nurse anesthetists, operating room nurses, anesthesiologists, and surgeons. Ten nurse anesthesia students, eight certified registered nurse anesthetists, sixteen operating room nurses, twelve anesthesiologists, and nine surgeons were included in the sample population. The purpose of the study was to determine if the different levels of educational background was a contributing factor in estimating blood loss. A significance of $p = .05$ was used for data analysis.

For the purpose of statistical clarity, the subject groups were numbered as follows:

Group 1: nurse anesthesia students (10)

Group 2: certified registered nurse anesthetists (8)

Group 3: operating room nurses (16)

Group 4: anesthesiologists (12)

Group 5: surgeons (9)

The statistical analysis was divided into Stations. The first analysis is of Station 1 (see Table 1) which consisted of three tables, each with different sizes and types of sponges with varying amounts of blood. Four estimates were required at each table, for a total of 12 estimates. All data are in terms of deviations from true volumes in cc (see Appendix B).

Table 1

Descriptive statistics for Station 1

Group	Statistic	Table 1	Table 2	Table 3	All Tables
	N=	40	40	40	120
1	Mean =	5.525	0.875	3.438	3.279
	S. Dev. =	9.334	28.317	25.316	22.473
	N=	32	32	32	96
2	Mean =	0.609	-4.563	3.656	-0.099
	S. Dev. =	6.566	18.694	17.368	15.431
	N=	64	64	64	192
3	Mean =	8.656	16.750	22.266	15.891
	S. Dev. =	13.180	31.358	34.709	28.468
	N=	48	48	48	144
4	Mean =	7.042	9.167	9.167	8.458
	S. Dev. =	13.035	20.736	22.096	18.938
	N=	36	36	36	108
5	Mean =	7.472	-2.306	6.222	3.796
	S. Dev. =	15.300	18.133	17.278	17.344
All	N=	220	220	220	660
Groups	Mean =	6.370	5.991	10.652	7.671
	S. Dev. =	12.339	26.237	26.752	22.840

Analyzing on the basis of level of education, the best estimates were obtained by the certified registered nurse anesthetists (CRNA's). They also had the smallest standard deviation (were more consistent). The poorest estimators were the operating room nurses. They also had the largest standard deviation. The nurse anesthetist students and the surgeons had about the same mean error, although the surgeons had less spread to their estimates. Table 3 produced larger mean estimating errors than did Tables 1 and 2.

To assess the significance of these differences, the following ANOVA table is instructive:

Table 2

ANOVA summary for Station 1

Source	Sum Sqs	df	Mean Sq	F - ratio	*p*
Group	22792.974	4	5678.243	11.808	< 0.001
Table	2608.251	2	1304.126	2.702	0.068
Group*Table	6771.305	8	846.413	1.754	0.083
Error	311262.41	.. 645	482.577		

The group effect tests the hypothesis that all groups are statistically equal. It reaches statistical significance well beyond $p = .05$, therefore, the null hypothesis of equal group means is rejected.

To learn more about the group effect, a post-hoc Tukey HSD test was performed (Table 3).

Table 3

Post-hoc Tukey HSD test for Station 1

Matrix of Paired Mean Difference

	1	2	3	4	5
1	-				
2	-3.378	-			
3	12.611	15.990	-		
4	5.179	8.557	-7.432		
5	0.517	3.895	-12.094	-4.662	-

Matrix of Pairwise Probabilities

	1	2	3	4	5
1	-				
2	0.794	-			
3	< 0.001	- 0.001	-		
4	0.313	0.026	0.018		
5	> 0.999	0.713	< 0.001	0.454	-

Five of the ten contrasts reach significance at $p = .05$. Four involve the operating room nurses, the other involves the anesthesiologists and CRNA interaction.

The second analysis is of Stations 2-3-4, which had different aggregates of blood-soaked materials, requiring a single estimate at each station. Descriptive statistics are included in Table 4.

Table 4

Descriptive statistics for Stations 2-3-4

Group	Statistic	Station 2	Station 3	Station 4	All Stations
	N =	10	10	10	30
1	Mean =	-21.700	-33.500	-58.000	-37.7339
	S. Dev. =	36.9234	38.948	28.402	37.158
	N =	8	8	8	24
2	Mean =	-19.250	-45.750	-62.750	-42.583
	S. Dev. =	39.860	43.381	57.718	49.036
	N =	16	16	16	48
3	Mean =	-10.000	-13.125	-42.500	-21.875
	S. Dev. =	47.645	62.009	53.944	55.703
	N =	12	12	12	36
4	Mean =	8.333	-12.333	-35.417	-13.139
	S. Dev. =	89.654	66.[illegible]06	58.544	72.809
	N =	9	9	9	27
5	Mean =	-17.222	-42.222	-55.000	-38.148
	S. Dev. =	42.947	41.466	38.079	42.407
	N =	55	55	55	165
All	Mean =	-10.655	-26.164	-48.764	-28.527
Groups	S. Dev. =	55.635	53.971	48.888	54.878

Several points are worth noting. First, the absolute errors are larger than at Station 1. Secondly, although at Station 1 the errors were generally in the direction of over-estimation, at Stations 2-3-4 the errors were in the direction of under-estimation. Thirdly, Station 4 produced greater mean estimation errors than did Stations 2 and 3. At Stations 2-3-4, the operating room nurses and the anesthesiologists produced the best estimates. Further analysis by ANOVA yields the following inferential evidence (Table 5):

Table 5

ANOVA summary for Stations 2-3-4

Source	Sum Sqs	df	Mean Sq	F- ratio	p
Group	20,432.464	4	5,108.116	1.780	0.136
Station	39,110.153	2	19,555.077	6.814	0.001
Group*Statn	2,577.215	8	322.152	0.112	0.999
Error	43,0494.21	150	2,869.961		

The group effect does not reach statistical significance at $p = .05$, therefore we do not reject the hypothesis of equal group means. The interaction effect does not reach statistical significance, either; however, the Station effect does reach statistical significance and we reject the hypothesis of equal means. The post-hoc Tukey HSD test further explores this significance (see Table 6).

Table 6

Post-hoc Tukey HSD test for Stations 2-3-4

Matrix of Paired Mean Differences

	2	3	4
2	-		
3	-17.418	-	
4	-38.766	-21.347	-

Matrix of Pairwise Probabilities

	2	3	4
2	-		
3	0.222	-	
4	0.001	0.105	-

The contrast between the mean estimation errors of Stations 2 and 4 reaches statistical significance. It appears from analyzing the data that it is tougher to estimate blood volume on drapes, sheets, and surgical gowns than it is to estimate on sponges. The results of the interaction between Station 2 and Station 4 reaches statistical significance beyond a $p < .05$.

Chapter Five

Discussion

The purpose of this study was to determine whether the educational background of health care providers in the operating room is a contributing factor in accurately estimating blood loss via visualization in a controlled setting. The hypothesis stated that educational background of the health care providers in the operating room has no effect on the accuracy of estimating blood loss via visualization. Based on the statistical tests utilized in this study, there was a lack of descriptive significance between increased accuracy in estimating blood loss and educational background. By study design, where all data was in terms of deviations from true volumes, Station 1 produced a group effect of statistical significance well beyond pre-established level of significance ($p < .001$). Stations 2, 3, and 4 produced a group effect which does not reach statistical significance at $p = .05$ ($p = 0.136$).

Macro analysis of the means across all measurements between all groups in Station 1 rejects the null hypothesis of equal group means. The ANOVA revealed that the group effect reached statistical significance at $p < .001$. The other two effects for Station 1 do not reach statistical significance at $p = .05$. In other words, do not reject the hypothesis of equal means for the three tables of Station 1. Macro analysis of the means across all measurements between groups in Stations 2,3,and 4 does not reach statistical significance at $p = .05$.

Therefore, do not reject the hypothesis of equal group means for Stations 2,3,and 4. The interaction effect for these stations does not reach statistical significance, however, the station effect does reach statistical significance and we reject the hypothesis of equal means.

Further micro analysis of the paired mean differences were performed by use of a post-hoc Tukey HSD test on the group effect for Station 1. Five of the 10 contrasts reached significance at $p = .05$. Four of these contrasts involved the OR nurses who proved to be the poorest estimators for Station 1; they also had the largest standard deviation for this station. Micro analysis of Stations 2,3,and 4 was similarly performed by the Tukey HSD test, and demonstrated the contrast between the mean estimation errors of Stations 2 and 4 reached statistical significance.

Comparison of Results to Previous Studies

An extensive literature review revealed one study with which this study could be compared, that being the Kempe study of estimating behaviors among anesthesia providers in the operating room. Both studies support the findings that blood loss estimation by visual assessment is an inaccurate method. A finding that differed between the two studies was the fact that the participants in the Kempe study found it more difficult to estimate blood loss on the sponges, while the participants in this study found it more difficult (greater deviation from the actual amount) to estimate blood loss on the drapes, gowns, and sheets. Overall, there was no difference in accuracy among the various groups in both studies.

<u>Limitation with the study</u>

The time to perform the study was limited (4 hours) due to the tendency of the blood products to dry on the materials presented for estimation. A limited amount of blood was received for the study which made the project a one day event.

<u>Recommendations for further study</u>

The recommendations for future study are:

1. Replicate the study with a greater number of corresponding subjects. Encourage all members of the health care team to participate in the study, and possibly award the subjects for their participation.

2. Replicate the study on several different occasions; possibly at different parts of the work day to generate a greater number of participants.

3. Repeat the study with a greater volume of blood products to expand the number of estimations made by the participants.

This study sought to show statistical significance in estimating blood loss when compared to measured values, and to determine whether the educational background of the health care providers in the operating room is a contributing factor to estimating this loss. The hypothesis stated that educational background would have no effect on the accuracy of estimation blood loss via visualization. Results indicated that the estimating errors were generally in the direction of *over*-estimation for Station 1 and that the group effect reached statistical significance beyond a <u>p</u> value of .05, therefore,we reject the hypothesis of equal group means. Stations 2, 3, and 4 produced results in the direction of *under*-estimation, and that the group effect did not reach statistical significance; therefore we do not reject the hypothesis of equal group means.

In conclusion, based on the results from the statistical analysis, estimation of operative blood loss by health care providers in the operating room remains an inexact science and, further necessitates the need to judiciously assess the patient for detrimental effects that might occur during periods of excessive bleeding.

References

References

Albert, S., Gravel, Y., Turmel, Y., & Albert, C. (1965). Pitfalls in blood volume measurement. Anesthesia & Analgesia, 44, 804-814.

Berne, R. M., & Levy, M. N. (Eds.). (1988). Physiology. (2nd ed.). St. Louis: Mosby.

Bond. A. G. (1969). Determination of operative blood loss. Anesthesia, 24, 219-229.

Bovill, D. F., & Norris, T. R. (1989). The efficacy of intraoperative autologous transfusion in major shoulder surgery. Clinical Orthopaedics, 240, 137-140.

Cahan, S., & Cohen, N. (1989). Age versus schooling effects on intelligence development. Child Development, 60, 1239-1249.

Cavonius, C. R., Hilz, R. & Chapman, R. M. (1974) A possible basis for individual differences in magnitude estimation behavior. British Journal of Psychology, 65, 85-91.

Cone, J., Day, L. J., Johnson, G. K., Murray, D. G., & Nelson, C. L. (1990). Blood products: optimal use, conservation, and safety. Instructional Course Lectures, 39, 431-434.

Cullen, S. C. (1961). Estimation of blood loss in the operating room. Anesthesiology, 22, 318-319.

de Campos Freire, G., de Campos Pachelli, L., Cordeiro, P., Borrelli, M., & de Goes, G. M. (1986). Blood loss during and following transurethral resection. The Prostate, 8, 87-92.

Duthie, S. J., Ven, D., Yung, G. L., Guang, D. Z., Chan, S. Y., & Ma, H. K. (1991). Discrepancy between laboratory determination and visual estimation of blood loss during normal delivery. European Journal of Obstetrics, Gynecology, and Reproductive Biology, 38, 119-124.

Gould, S. A., Lakshman, R. S,. Sehgal, H. L., & Moss, G. S. (1992). Artificial Blood: Current Status of Hemoglobin Solutions. Critical Care Clinics, 8, 293-309.

Gross, J. B. (1983). Estimating Allowable Blood Loss: Corrected for Dilution. Anesthesiology, 58, 277-279.

Hahn, R. G. (1989). Estimating allowable blood loss with correction for variations in blood volume. Acta Anaesthesiology Scandinavia, 33, 508-512.

Kempe, Gordon. (1985). " Estimation of Blood Loss by Anesthetists". Medical College of Virginia, Virginia Commonwealth University. Thesis.

Lennon, R. L., Hosking, M. P., Gray, J. R., Klassan, R. A., Popovsky, M. A., & Warner, M. A. (1987). The effects of intraoperative blood salvage and induced hypotension on transfusion requirements during spinal surgical procedures. Mayo Clinic Proceedings, 62, 1090-1094.

Miller, R. D. (Ed.). (1990). Anesthesia. (3rd ed.). New York: Churchill Livingstone.

Polit, D. F., & Hungler, B. P. (Eds.). (1991). Nursing Research-Principles and Methods. Philadelphia: J. B. Lippincott.

Ramsey, J. G. (1991). Methods of reducing blood loss and non-blood substitutes. Canadian Journal of Anaesthesia, 38, 595-599.

Schmidt, E. (Ed.). (1980). Human Physiology. Berlin: Springer.

Spence, R. K. (1991). The status of bloodless surgery. Transfusion Medicine Reviews, 5, 274-286.22.

Sollevi, A. (1988). Hypotensive anesthesia and blood loss. ACTA Anaesthesia Scandinavia Supplement, 89, 39-43.

Stoelting, R. K. (Ed.).(1991). Pharmacology and Physiology in Anesthetic Practice. (2nd. ed.). Philadelphia: J. B. Lippincott.

Tremper, K. K. (1992). Techniques and solutions to avoid homologous blood transfusion. ASA Annual Refresher Course Lectures, 136, 1-7.

Yang, S. C., & Puri V. K. (1986). Role of preoperative hemodynamic monitoring in intraoperative fluid management. The American Surgeon, 52, 536-540.

Yoshikawa, T., Sano, K., & Kanri, T. (1989). Clinical assessment of anesthesia and estimated blood loss during maxillary sinus surgery. Anesthesia Progress, 36, 242-243.

Appendix A

Appendix A

Dear Health Care Provider:

A study is being conducted to determine the blood loss estimating skills of the health care providers at this institution. Your voluntary participation in this study is greatly appreciated. The data collected includes brief facts about your occupation; names are not requested and anonymity will be maintained.

Please complete the following information and place your estimation of the amounts of blood in the spaces provided.

General Information

Age:_____. Profession:____________________. (Please be specific)
Number of Years Practicing:_______ Circle one: Male Female

Station 1: Please write your estimation of the amount of blood on each sponge.

Table 1 (dry 4X4)	Table 2 (dry laps)	Table 3 (wet laps with NS)
1.____cc.	5.____cc.	9.____cc.
2.____cc.	6.____cc.	10.____cc.
3.____cc.	7.____cc.	11.____cc.
4.____cc.	8.____cc.	12.____cc.

Station 2: Please write your estimation of the total amount of blood contained on the 5 sponges in the clear plastic bag. Please do not open the bag. ______cc.

Station 3: Please write your estimation of the total amount of blood on the 5 sponges in the bucket. __________cc.

Station 4: Please write your estimation of the amount of blood contained on the operating room table drapes and gowns. Please do not handle the objects. _______cc.

Appendix B

Appendix B

Control Volumes of Blood Products

Station 1

1. 10 cc	2. 15.cc	3. 8 cc	4. 12 cc
5. 30 cc	6. 15 cc	7. 40 cc	8. 38 cc
9. 10 cc	10. 25 cc	11. 35 cc	12. 20 cc

Station 2

90 cc

Station 3

125 cc

Station 4

125 cc

Vita

[redacted]