

Research article

Fluid Balance Calculation Tool for Predicting Postoperative Hematocrit and Intraoperative Blood Loss during Cardiac Surgery

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Abstract

Background and Purpose: Fluid balance management is important in cardiac surgery. During cardiac surgery, patients receive fluid from the anesthesiologist, perfusionist, and surgical field. Greater fluid intake can be obtained from within the surgical field by pumping back through the heart-lung machine. Therefore, it is difficult to calculate the actual fluid balance, which is necessary to predict postoperative hematocrit. Inaccurate calculation of fluid balance can increase the risk of postoperative complications. This study was performed to develop a tool that can calculate the body fluid intake and output of patients undergoing open-heart surgery. The results of the tool can be used to predict postoperative hematocrit and intraoperative blood loss.

Methods: Information technology experts constructed an intake/output chart application, which was used to collect cardiac surgery data at Chulabhorn Hospital during the period from November 2020 to January 2021.

Results: This study included 20 patients (10 men and 10 women; mean age, 68 years). The surgeries consisted of coronary artery bypass graft (CABG) (12 cases, 60%), valve surgery (seven cases, 35%), and combined CABG and valve surgery (one case, 5%). The mean predicted postoperative hematocrit (according to the application) was 33.9%, while the mean actual postoperative hematocrit was 34.06%; these values did not significantly differ ($p = 0.064$). The mean estimated blood loss during cardiac surgery was 488.40 mL.

Conclusions: Our intake/output chart application can correctly predict postoperative hematocrit and intraoperative blood loss in patients undergoing cardiac surgery.

Keywords: Fluid Balance, Predicted Hematocrit, Cardiac Surgery, Cardiopulmonary Bypass

Introduction

Cardiac surgeries are complex and involve many factors, including surgical techniques, various types of equipment and devices, and the combined efforts of professionals from diverse fields (e.g., anesthesiologists, nurse anesthetists, surgeons, operating room nurses, and cardiovascular perfusionists). There are multiple types of simple and complex cardiac surgeries, most of which require many hours, large volumes of blood, and extensive fluid intake through blood vessels. Intraoperative blood loss is generally substantial and difficult to measure; patients receive treatment as necessary by anesthesiologists and perfusionists while they are within the surgical field. Therefore, it is difficult to calculate the actual fluid balance, which is necessary to predict postoperative hematocrit. However, the estimation of fluid balance is an important task during cardiac surgeries. Inaccurate calculation of fluid balance can increase the risk of postoperative complications.¹⁻³

In this context, intraoperative blood conservation is essential and can be achieved through techniques such as intraoperative cell salvage or acute normovolemic hemodilution,⁴ which reduce the risk of postoperative complications. Other techniques for intraoperative blood conservation (e.g., techniques used for pediatric cardiac patients) have been explored; they include reduced cardiopulmonary bypass (CPB) circuit volume, retrograde arterial prime and venous antegrade prime, and modified ultrafiltration. These techniques are used to remove the fluid overload and can also enhance the speed of postoperative recovery.⁵⁻⁸

Hematocrit is a measure of the ratio of the volume occupied by red blood cells to the volume of whole blood (intravascular fluid); this ratio can be used to calculate intraoperative blood loss.⁹ When patients lose blood, they are administered crystalloid solutions (e.g., 0.9% sodium chloride [saline]), colloid solutions, or blood and blood components.^{10,11} The volume of intraoperative blood loss can be estimated from the number of gauze used for absorbing blood in the operative field, or by weighing gauze with blood to calculate blood loss.¹² If postoperative

hematocrit values could be predicted with a degree of similarity to actual hematocrit values, this would allow the determination of actual intraoperative blood loss. The actual fluid intake for a patient could then be calculated, along with the volume of excess fluid that must be removed. Prior to operations, a hematocrit test will be carried out. The fluid flow in the patient's body must be estimated and used as the starting value to calculate the red blood cell mass before the operation. The patient will be experiencing blood loss for the entire operation period, therefore the perfusionist and anesthesiologist must input red blood cells to the patient's body to maintain the hematocrit level. The red blood cell mass before and after the operation should be about the same level. These calculations would provide useful information for patients with symptoms of heart attack and fluid retention before cardiac surgery.^{13,14}

This study was performed to construct a standardized and efficient intake/output (I/O) chart application that could predict postoperative hematocrit and intraoperative blood loss in patients undergoing cardiac surgery.

Methods

Population and sample size

This retrospective clinical study included 20 patients who underwent cardiac surgery at Chulabhorn Hospital. The sample size was calculated based on the non-inferiority or superiority test formula for continuous data.^{15,16}

Methodology

This study (EC CRI 116/2564) has been approved by the Human Research Ethics Committee, Chulabhorn Research Institute.

The following data concerning intraoperative fluid intake were collected: data from anesthesiologists, comprising the volume and types of crystalloid solutions, colloid solutions, and blood components administered during surgeries; data from perfusionists, comprising crystalloid solutions, colloid solutions, and blood components used for the CPB circuit; and data from scrub nurses, comprising the 0.9% normal saline solution used in the surgical field.

I/O Record Chart of Cardiovascular Surgery (CVT)

Name: _____	Date: 01/08/2022	Surgeon: _____
Age: _____	Dr: _____	Anesthetist: _____
YN: _____	Operation: _____	Perfusionist: _____
AN: _____		

Intake			
section	Fluid	Vol(ml)	Total(ml)
Anesthesia	Crystalloid	_____	_____
	colloid	_____	
	PRC	_____	
	FFP	_____	
	LPFC	_____	
	Other	_____	
Perfusionist	Crystalloid	_____	_____
	colloid	_____	
	PRC	_____	
	Other	_____	
Scrub Nurse	NSS	_____	_____
	Sterile Water	_____	
	Other	_____	



Output			
section	Fluid	Vol(ml)	Total(ml)
Anesthesia	Urine	_____	_____
	Other	_____	
	Other	_____	
Perfusionist	Urine in CPB	_____	_____
	CUF	_____	
	MUF	_____	
	Remain in Circuit	_____	
	Other	_____	
Scrub Nurse	Gauze and Swab	_____	_____
	Wall suction	_____	
	Other	_____	
	Other	_____	

	Anesthesia	Perfusionist	Scrub Nurse	Summary
Total Intake(ml)	_____	_____	_____	_____
Total Output(ml)	_____	_____	_____	_____
I/O ☐ Neg ☐ Pos				

<https://argupi-h007.web.app/>

Figure 1. Intake/output record chart and link used to record data and calculate the volume of blood loss during surgery.

The following data concerning intraoperative fluid output were collected: data from anesthesiologists, including the volumes of urine measured before and after CPB; data from perfusionists, including the volumes of urine measured during the operation as well as the volumes of conventional ultrafiltration fluid, modified ultrafiltration fluid, and solutions and blood remaining in the heart and lung machine; and data from scrub nurses, including the blood volume calculated by counting the gauze and surgical swabs, as well as the volumes of blood aspirated into all suction containers.

All of the above data were recorded in the Intake/Output Record Chart Application designed by the research team to calculate fluid intake and output for determination of fluid balance in each patient.

Data collection forms

The following forms were used: Cardio-Pulmonary Bypass Record Form; Anesthetic Record

Form; Surgical Swab Counting and Record Board; and Intake/Output Record Chart.

Data analysis

Age, sex, and surgical methods were analyzed. Fluid intake and output were used to calculate hematocrit based on the following formula:

$$C_1 V_1 = C_2 V_2$$

Where C_1 is hematocrit before CPB (percent), C_2 is predicted postoperative hematocrit (percent), V_1 is estimated blood volume (mL) + Intake volume (mL), and V_2 is estimated blood volume + Output fluid volume (mL).^{17,18}

The actual hematocrit was measured from each patient's postoperative blood sample, using hematocrit centrifuge in the laboratory. Then, actual hematocrit values were compared with predicted hematocrit values using paired Student's t-tests.

Results

The analysis included 10 men (50%) and 10 women (50%); the mean age was 68.05 years (standard deviation, 8.19 years). The surgeries consisted of coronary artery bypass graft (CABG) (12 cases, 60%), valve surgery (seven cases, 35%), and combined CABG and valve surgery (one case, 5%).

The mean predicted postoperative hematocrit (according to the application) was 33.9%, while the mean actual postoperative hematocrit was 34.06%; these values did not significantly differ ($p = 0.064$). The P value was set less than 0.05.

Additionally, the mean estimated intraoperative blood loss was 488.40 mL (standard deviation, 130.48 mL).

Table 1. Demographic data of 20 patients.

	Patients (n=20)
Age (years)	68.05 ± 8.19
Sex	
Male	10 (50)
Female	10 (50)
Surgery	
CABG	12 (60)
Valve	7 (35)
Combined CABG and valve	1 (5)

CABG = coronary artery bypass graft

Data are shown as mean ± standard deviation or No (%).

Table 2. Intraoperative fluid intake and output data collected in this study

	Intake	Output
Anesthesiologist	Crystalloid solution Colloid solution Blood components	Urine
Perfusionist	Crystalloid solution Colloid solution Blood components	Urine output during CPB Conventional ultrafiltration fluid Modified ultrafiltration fluid Residual volume in CPB circuit Perioperative cell salvage volume
Scrub nurse (intraoperative field)	Normal saline solution use during surgery Sterile water use during surgery	Estimated blood volume from gauze and swab counts Volume in wall suction reservoirs

CPB = cardiopulmonary bypass

Items	IN	Out	
Gauze 4x4	10+10+10+10+10+10		Suare = 6 red blood cells = 8
Roll swab	5+5+5+5+5+5		Antico = 8 Effect = 2
Abd. Swab			Antico = 4 Vessel count = 2
Peanut		3000-3000-3000 -100 = 2000	Wile testing
Cottonoid	NS 500 + 1000	800-1100 -800 = 300	Sium = 10
Irrigate	+6000+1000+1000		

a.

Priming and Other Fluid			
Intake→Crystalloid	4100 ml	Colloid	250 ml
		Heparin	mg
20/25% Albumin	700 ml	Manitol	200 ml
FFP	457 ml	CPG	4200 ml
Other		Total	6129 ml
Output→Urine	363 ml	CUF	3150 ml
		MUF	1500 ml
		Total	6013 ml
Dif. I/O fluid			916 ml

b.

Figure 2. Conventional record forms (a, b)

Discussion

Cardiac surgeries are complex and involve substantial blood loss; they require large volumes of blood. The transfusion of large amounts of blood can lead to postoperative complications and poor surgical outcomes.^{19,20} During cardiac surgery, a heart-lung machine is used; the machine's circuit carries blood combined with a crystalloid solution (i.e., priming solution). Crystalloid or colloid solutions are used more in adult cardiac surgeries than in pediatric cardiac surgeries. During each surgery, some of these solutions diffuse out of blood vessels and into body tissues. Therefore, blood or solutions must be occasionally added into the circuit to maintain the fluid volume in the heart-lung machine and ensure that the machine functions optimally. These fluids may enter various tissues, including pulmonary tissues, where they can cause impaired gas exchange.^{21,22}

During cardiac surgery, red blood cells and crystalloid or colloid solutions are added into the cardiopulmonary circuit; this maintains the appropriate hematocrit level because a large amount of blood is needed while the heart-lung

machine is in use.^{23,24} Additionally, red blood cells and solutions are administered by anesthetists during the surgery; 0.9% normal saline solution is also used in the surgical field, or blood is aspirated and injected into the cardiopulmonary circuit or removed via wall suction reservoirs. All of these processes hinder the estimation of intraoperative blood loss, resulting in excessive use of red blood cells. Low hematocrit could result from the dilution of intravascular hematocrit by crystalloid or colloid solutions. Moreover, intraoperative blood loss is difficult to estimate because fluid in the wall suction reservoirs is blood combined with cleaning solutions used during the surgery. Therefore, the actual volumes of intraoperative fluid intake and output cannot be measured.

In the present study, the predicted hematocrit level (according to the application) was similar to the actual hematocrit level measured in each patient immediately after surgery. This finding suggests that the predicted hematocrit calculation can be applied to guide the use of red blood cells after open-heart surgery.

This study has some limitations because patients in the population treated with cardiac surgery have different health conditions. Those treated with medicines that have an effect on blood hardening, e.g., anticoagulants or antiplatelets or diuretics, could also result in errors of pre- and post-operative blood volumes.

Conclusions

Our application successfully predicted hematocrit values, which indicated that the fluid intake and output volumes could be calculated at levels similar to actual volumes; thus, intraoperative blood loss could be accurately estimated. This approach will help to reduce the amount of blood provided to patients after open-heart surgery, thereby mitigating the risk of complications related to blood transfusion.

This issue has to be further studied as the number of patients in this study is quite low, while the patients have been treated with diverse approaches of surgery. There were also several uncontrollable factors during the preoperative, intraoperative, and postoperative periods.

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