ORIGINAL ARTICLE

Cost-Effectiveness of Early Goal-Directed Therapy Using the FloTrac/EV1000 Platform in Patients Undergoing Coronary Artery Bypass Graft with Cardiopulmonary Bypass: A Retrospective Analysis

Sanpicha Sornpirom, BN[1], Sirirat Tribuddharat, MD, PhD[2], Thepakorn Sathitkarnmanee, MD[2]

[1] CVT ICU, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand; [2] Department of Anesthesiology, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

Background: Coronary artery bypass graft (CABG) with cardiopulmonary bypass (CPB) is a high-risk surgery with significant morbidity resulting in a prolonged stay in the intensive care unit (ICU) at an increased cost. Early goal-directed therapy (EGDT) using the FloTrac/EV1000 platform improved outcomes in these patients with shorter ICU stay but with extra cost for a FloTrac transducer.

Objective: To assess the cost-effectiveness of implementing the FloTrac/EV1000 in these patients.

Materials and Methods: The present study was a retrospective study. Sixty adult patients who underwent CABG with CPB were included and divided into two groups: the EV1000 and the Control group. The EV1000 group was managed with EGDT protocol using FloTrac/EV1000 platform. The Control group was managed using a standard protocol. The ICU and hospital stay of both groups were compared. Then, the authors assessed the daily ICU cost by including another 62 patients admitted to the cardiovascular and thoracic (CVT) ICU. Finally, the extra cost of a FloTrac transducer was compared with the saved CVT ICU cost.

Results: The EV1000 group had a shorter CVT ICU stay, with mean difference of –23.7 h (95% CI –34.5 to –12.9, $p<0.001$). The EV1000 group had a shorter ventilator time, as well as a shorter hospital stay. The average daily CVT ICU cost was 10,020.05 Baht. The extra cost of a FloTrac sensor was 5,000 Baht. The saved cost of CVT ICU exceeds the cost of a FloTrac by 5,020.05 Baht.

Conclusion: The implementation of EGDT using the FloTrac/EV1000 platform in patients undergoing CABG with CPB improved patients' outcomes resulting in less CVT ICU cost and better resource management of CVT ICU beds. The extra cost of the FloTrac sensor was offset by the larger amount of CVT ICU cost that was saved.

Keywords: Cost-effectiveness; Early goal-directed therapy; FloTrac; Intensive care unit; ICU stay

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Coronary artery bypass graft (CABG) with cardiopulmonary bypass (CPB) is a high-risk surgery that results in high morbidity and mortality. Recently, perioperative mortality decreased due to improved patient care, but morbidity remains considerable[1]. Approximately 10% of the patients undergoing CABG with CPB required extended postoperative care due to hemodynamic instability, organ dysfunction, or multiorgan failure, resulting in increased cost in intensive care and hospital care[2].

Goal-directed therapy (GDT) refers to a medical approach that focuses on achieving specific targets or goals in the treatment of a particular condition. It is commonly used in critical care medicine, particularly in the management of critically ill patients.

Early goal-directed therapy (EGDT) is the principle of hemodynamic optimization by setting hemodynamic parameters as goals for the administration of fluids and inotropic or vasoactive drugs. EGDT has been shown to improve postoperative outcomes such as decrease in morbidity, mortality, as well as intensive care unit (ICU) and hospital stay, in patients undergoing major non-cardiac and cardiac surgery[2,3]. There are many methods to identify goals

Correspondence to:

Tribuddharat S.

Department of Anesthesiology, Faculty of Medicine, Khon Kaen University, 123 Mittraphap Road, Muang, Khon Kaen 40002, Thailand.

Phone: +66-81-6205920

Email: sirirat.tribuddharat@gmail.com

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of management such as central venous pressure (CVP) for preload and cardiac output via a Swan-Ganz catheter for cardiac contractility. However, these methods are static and do not show a correlation with preload, and do not improve clinical outcomes[4]. Arterial pressure-based cardiac output (APCO) is a minimally invasive monitoring system that measures cardiac output from arterial waveform. There are many platforms for APCO including FloTrac/EV1000, LiDCO, and PiCCO plus. These devices have gained popularity in recent years and have been validated, both intraoperatively and postoperatively, in various major non-cardiac and cardiac surgery, including Thai patients[4-12]. Studies revealed that the FloTrac/EV1000 platform improved outcomes in patients undergoing CABG with CPB, resulting in a reduction in cardiovascular and thoracic (CVT) ICU and hospital stay[10,11]. However, the use of the FloTrac sensor has an extra cost that impedes its implementation.

Since cost-effectiveness is a measure used to evaluate the efficiency of a particular intervention, policy, or investment in terms of the costs incurred compared to the outcomes achieved, it is noteworthy that a study evaluating the cost-effectiveness of implementing FloTrac in cardiac surgery is currently lacking. Therefore, the objective of the present study was to fill this gap by assessing the cost-effectiveness of applying EGDT using the FloTrac/EV1000 platform in patients undergoing CABG with CPB.

The primary objective of the present study was to compare the additional cost associated with the FloTrac sensor to the cost savings in the CVT ICU. The present study analysis aimed to determine if the potential benefits and cost savings achieved in the ICU outweigh the expenses incurred by implementing the FloTrac sensor.

The secondary objective of the present study was to compare the occurrence of postoperative complications between the two groups. This aspect was important to evaluate the impact of the FloTrac/EV1000 platform on patient outcomes and assessed its potential role in reducing complications following cardiac surgery.

Materials and Methods

The present study was a retrospective, comparative study approved by the Institutional Review Board (HE631648) and registered at ClinicalTrials.gov (NCT05826795). The study was carried out according to the Declaration of Helsinki and the ICH GCP, and the requirement for informed consent was waived. There were two steps in the present study:

1. Assessing the efficacy of the FloTrac/EV1000 platform.
2. Assessing the daily CVT ICU cost.

Assessing the efficacy of the FloTrac/EV1000 platform

The inclusion criteria were adult patients who underwent elective CABG with CPB at a tertiary university hospital in Thailand between July 2018 and June 2020. The exclusion criteria were patients that required an intra-aortic balloon pump or extracorporeal membrane oxygenator, as well as medical records with incomplete data.

The patients were divided into two groups: the EV1000 and Control. The intraoperative hemodynamic optimization in the EV1000 was managed using EGDT via the FloTrac/EV1000 platform and the Control was managed using standard protocol as described in the study of Tribuddharat et al.[11]. The extracted data for comparison were demographic and clinical data, CVT ICU stay, ventilator time in CVT ICU, postoperative complications, and hospital stay.

Assessing the daily CVT ICU cost

The authors also evaluated the cost of the CVT ICU by including the admitted patients in October 2021 to identify the average daily cost. The cost of a FloTrac sensor and the ICU cost saved was compared.

Statistical analysis

The sample size of 30 patients per group was calculated based on data from a previous study[11], an α value of 0.05, a β value of 0.2, and a 30% decrease in ICU stay. Continuous data were tested for normal distribution and presented as mean ± standard deviation (SD) or median (interquartile range) and compared using the unpaired t-test or the Mann-Whitney U test. The categorical data were presented as number (%) and compared using chi-square or Fisher exact test. The p-value less than 0.05 was considered statistically significant. Statistical analysis was performed using SPSS Statistics for Windows, version 16.0 (SPSS Inc., Chicago, IL, USA).

Results

Assessing the efficacy of the FloTrac/EV1000 platform

Thirty patients for each group were included. The demographic and clinical data of patients in both

Table 1. Patients' characteristics and clinical data

Variable	EV1000 (n=30)	Control (n=30)	p-value
Age (y)	64.5±8.1	65.3±7.5	0.681
Sex: male	17 (56.7)	23 (76.7)	0.100
Height (cm)	159.7±5.0	160.2±6.4	0.703
Weight (kg)	61.1±12.0	64.5±12.0	0.266
Number of vessel anastomosis			0.451
1	1 (3.3)	0 (0.0)	
2	15 (50.0)	19 (63.3)	
3	13 (43.3)	11 (36.7)	
4	1 (3.3)	0 (0.0)	
Functional class			0.128
2	8 (40.0)	14 (70.0)	
3	11 (55.0)	6 (30.0)	
4	1 (5.0)	0 (0.0)	
ASA classification			0.159
2	3 (10.0)	7 (23.3)	
3	25 (83.3)	23 (76.7)	
4	2 (6.7)	0 (0.0)	
Ejection fraction (%)	56.5±10.9	58.2±12.7	0.585
Anesthesia time (min)	405.7±103.1	442.8±88.5	0.139
Crystalloid intake (mL·h^{-1})	312.3±112.2	251.3±93.6	0.026
Blood loss (mL)	910.0±200.6	973.3±328.5	0.372
Urine output (mL·h^{-1})	230.1±136.0	144.0±67.5	0.003

Values are presented as mean±SD or numbers (%).

ASA=American Society of Anesthesiologists

groups were similar. The EV1000 group received more crystalloid intake and had more urine output compared to the other group (Table 1).

The EV1000 group had a shorter CVT ICU stay, with mean difference of –23.7 h (95% CI –34.5 to –12.9, p<0.001). In addition, the EV1000 group had significantly shorter ventilator time and overall hospital stay (Table 2).

The EV1000 group had significantly lower atrial fibrillation (AF) with rapid ventricular response. Although not statistically significant, the EV1000 group also had lower rates of acute respiratory distress syndrome (ARDS), adrenal insufficiency, and postoperative nausea or vomiting (PONV) (Table 3).

Table 3. Postoperative complications

	EV1000 (n=30)	Control (n=30)	p-value
Pleural effusion	3 (10.0)	4 (13.3)	1.000
AF with Rapid ventricular response	1 (3.3)	8 (26.7)	0.011
Lung congestion	0 (0.0)	1 (3.3)	1.000
ARDS	0 (0.0)	3 (10.0)	0.237
Adrenal insufficiency	0 (0.0)	4 (13.3)	0.112
PONV	0 (0.0)	4 (13.3)	0.112

Values are presented as numbers (%).

AF=atrial fibrillation; ARDS=acute respiratory distress syndrome; PONV=postoperative nausea and/or vomiting

Table 4. ICU expenditure

Variable	Value
Number of patients	62
Total nights (d)	215
Average nights per patient (d)	3.47±1.68
Average daily cost (Baht)	10,020.05±1,316.38

Values are presented as mean±SD

Assessing the daily CVT ICU cost

Regarding the daily CVT ICU cost analysis, the authors included the other 62 patients with 215 nights of CVT ICU stay. The average daily CVT ICU cost was 10,020.05±1,316.38 Baht (Table 4).

With the extra cost of a FloTrac transducer in Thailand of 5,000 Baht, the EGDT using FloTrac/EV1000 platform could save the cost for one night of a CVT ICU admission, which could be interpreted as saving cost of 5,020.05 Baht.

Discussion

The current study demonstrated that the implementation of EGDT using the FloTrac/EV1000 platform in patients undergoing CABG with CPB improved postoperative outcomes, resulting in shorter stays in the CVT ICU and hospital, as well as shorter ventilator times.

Patients with ischemic heart disease may develop intraoperative hypotension (IOH), which

Table 2. Postoperative outcomes

	EV1000 (n=30)	Control (n=30)	Mean difference	95% CI	p-value
ICU stay (h)	47.4±8.5	71.1±27.9	–23.7	–34.5 to –12.9	<0.001
Ventilator time (h)	14.9±6.2	31.2±15.3	–16.3	–22.5 to –10.2	<0.001
Hospital stay (d)	9.3±1.7	10.6±2.8	–1.3	–2.4 to –0.1	0.036

Values are presented as mean±SD.

ICU=intensive care unit

further decreases blood flow to the heart and vital organs, leading to an increase in postoperative morbidity and mortality. Early identification and management of IOH results in better outcomes[10]. The standard protocol set the mean arterial pressure (MAP) at between 90 and 105 mmHg as the goal of management. However, MAP does not always represent cardiac output. There are three factors that determine MAP: preload, cardiac contractility, and afterload. The FloTrac/EV1000 platform provides data on these three factors—stroke volume variation (SVV), stroke volume, and systemic vascular resistance—as goals for EGDT to administer fluid, inotropic and vasoactive intermittent drug titration for hemodynamic optimization.

The EV1000 group received more crystalloid according to the SVV value and had more urine output, reflecting better tissue perfusion. Once all organs receive adequate blood supply, postoperative outcomes improve, leading to a decrease in postoperative complications, as well as length of stay in the ICU and hospital.

The reduction in CVT ICU stay in the present study is similar to other studies. Kapoor et al. applied EGDT using a FloTrac/Vigileo platform in CABG with CPB and revealed that EGDT reduced the stay in the CVT ICU by –2.30 d (95% CI –3.44 to –1.16, $p<0.001$)[10]. Tribuddharat et al. reported that EGDT using the FloTrac/EV1000 platform reduced the stay in the CVT ICU in CABG with CPB and off-pump CABG (OPCAB) by –29.5 h (95% CI –17.2 to –41.8, $p<0.001$) and –1.3 d (95% CI –1.8 to –0.8, $p<0.001$), respectively[11,12]. Kapoor et al. showed that EGDT using the FloTrac/EV1000 platform in patients undergoing OPCAB reduced the stay in the CVT ICU by –1.7 d (–1.9 to –1.4, $p<0.001$)[13]. The decrease in postoperative complications, although without statistical significance, in the EV1000 group was also similar to the previous studies[11,12]. This shows that implementation of EGDT using the FloTrac/EV1000 platform has benefits in patients undergoing CABG with CPB.

The average daily cost of ICU stay in the present study was 10,020.05±1,316.38 Baht (~US$ 300±39), which is much lower than other studies. Dasta et al. reported that the average daily ICU cost from 253 U.S. hospitals was US$ 2,193±2,956[14]. Lefrant et al. reported that the daily ICU cost among 21 ICUs in France was € 1,423±520[15].

The daily cost of the CVT ICU in the present study hospital is significantly lower compared to that in the U.S. and Europe. This is because the present study hospital operates as a government institution with a non-profit policy. Additionally, the cost of living in Thailand is considerably lower, contributing to the overall reduced expenses.

The present study revealed that the FloTrac/EV1000 platform could reduce the CVT ICU stay by 23.7 h, or approximately 1 d, thus the CVT ICU cost was saved by 10,020.05 Baht (~US$ 300). The average cost of a FloTrac sensor in Thailand is around 5,000 Baht (~US$ 150). Hence, the saved CVT ICU cost exceeds the cost of the FloTrac by 5,020.05 Baht. This cost-effectiveness can be greater in the U.S. and Europe where the daily costs of ICU are much higher. Besides the reduced CVT ICU cost, the shorter CVT ICU stay improves the resource management of CVT ICU beds, thus, more critically ill patients can be admitted for proper management.

Limitation

The present study has limitations. Since this was a retrospective study, there might be confounding factors that were not well balanced. The cost of the ICU was assessed from one tertiary care ICU. Additionally, the sample size for the present study was small, warranting the need for a multicenter study with a larger sample size to further validate the results and enhance statistical power.

Conclusion

The implementation of EGDT using FloTrac/EV1000 platform in patients undergoing CABG with CPB results in shorter CVT ICU and hospital stay. The extra cost of the FloTrac sensor was offset by the larger amount of CVT ICU cost that was saved. Furthermore, the shorter stay in the CVT ICU improves the resource management of the CVT ICU beds. The present study highlights the cost-effectiveness of using the FloTrac/EV1000 platform in improving patient outcomes and reducing healthcare costs for CABG patients.

What is already known on this topic?

CABG with CPB is a high-risk surgery with significant morbidity and prolonged stays in the ICU.

Early EGDT using the FloTrac/EV1000 platform has shown improvements in postoperative outcomes and reduced ICU and hospital stays in patients undergoing major noncardiac and cardiac surgeries.

What does this study add?

This study demonstrated that EGDT using the FloTrac/EV1000 platform resulted in shorter CVT

ICU stays, reduced ventilator time, and overall shorter hospital stays in patients undergoing CABG with CPB.

The cost savings from implementing the FloTrac/EV1000 platform exceeded the additional cost of the FloTrac sensor, indicating cost-effectiveness.

Availability of data

The data used to support the findings of the present study are available from the corresponding author upon request.

Conflicts of interest

The authors declare no conflict of interest.

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