Original Article

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A Comparison of the Cost and Consumption of Sevoflurane and Litholyme at Total Gas Flow Rates of 1 and 2 Liters Per Minute: A Randomized Controlled Trial

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Abstract:

Objective: This study aimed to compare the cost-effectiveness of low-flow (1 liter per minute (LPM)) and medium-flow (2 LPM) anesthesia.

Material and Methods: Seventy patients aged 18–60 years who were undergoing elective surgery under general anesthesia were randomly allocated to receive a total gas flow rate of 1 LPM (group 1) and 2 LPM (group 2) during the maintenance of anesthesia. The primary outcome was to compare the cost and consumption of sevoflurane and litholyme. The secondary outcomes were hemodynamic stability and time to extubation.

Results: The cost and consumption of sevoflurane in group 1 (197.3 Thai Bahts (THB)/hour (hr) and 9.6 milliliter (ml)/hr) were significantly less than those in group 2 (303.2 THB/hr and 14.8 ml/hr; p-value<0.001). Although there was no difference in the cost and consumption of litholyme between the two groups, the summary cost of sevoflurane and litholyme in group 1 (237.7 THB/hr) was significantly less than that in group 2 (339.6 THB/hr; p-value<0.001). The mean arterial pressure, heart rate, and time to extubation were not significantly different in both groups.

Conclusion: Patients undergoing elective surgery under general anesthesia with a total flow of 1 LPM can save on the cost of sevoflurane and litholyme, which is equivalent to 101.9 THB/hr.

Keywords: cost, litholyme, low-flow anesthesia, sevoflurane

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Introduction

Most reports in the literature have shown advantages of using the low-flow anesthesia technique, including reduced consumption of volatile anesthetic, reduced cost, increased airway humidity, and temperature preservation of the respiratory system, while preventing air pollution and being more eco-friendly.[1–3] However, possible disadvantages resulting from the inappropriate use of low-flow anesthesia may be hypoxemia, excessive or insufficient concentrations of the volatile agent, and hypercapnia. Furthermore, it increases the carbon dioxide (CO_2) absorbent consumption. The control of anesthetic concentration may slow down and lead to awareness or delayed awakening.

The low-flow technique minimizes the consumption of volatile anesthetics by reducing the fresh gas flow (FGF) usage. However, it increases the utilization of CO_2 absorbent and may not provide an economic advantage. This study aimed to compare the cost-effectiveness of low-flow (1 liter per minute (LPM)) and medium-flow (2 LPM) anesthesia.

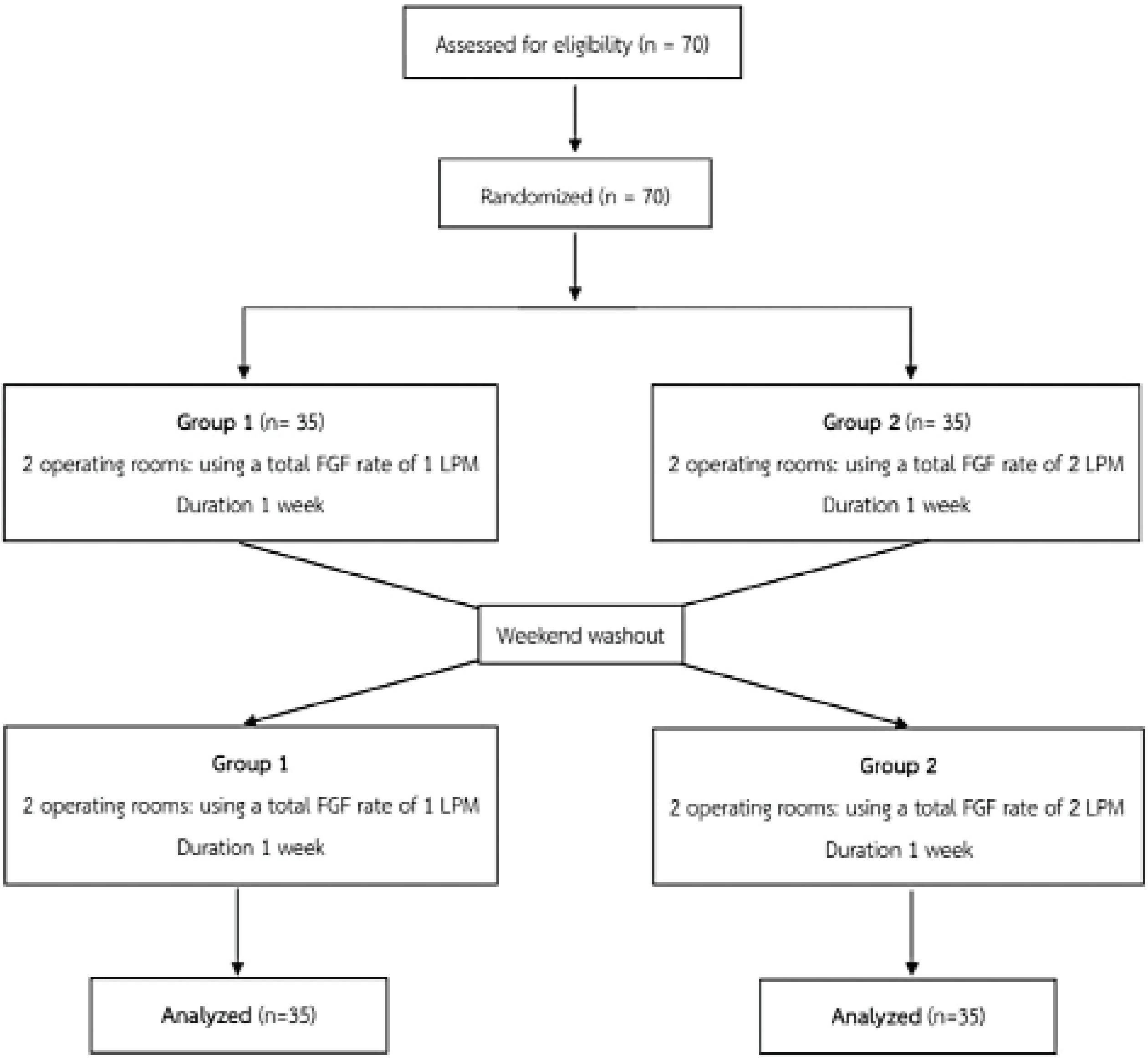
Material and Methods

Study design and participants

This study was a randomized controlled trial conducted on 70 patients, aged 18–60 years old, with an American Society of Anesthesiologists (ASA) classification of I–III, who were undergoing elective surgery; under general anesthesia, utilizing the Flow-i anesthesia machine (Maquet, Solna, Sweden) with a manual gas control mode, in 4 operating rooms at Songklanagarind Hospital (Thailand), from December 2019 to February 2020. The exclusion criteria were ASA class IV or V, bronchoscopic or thoracic surgery, a history of alcohol or drug abuse, or contraindication for using volatile anesthetic agents. The study protocol was approved by the institutional ethics committee of the Faculty of Medicine, Prince of Songkla University (REC. 61-079-8-4) and registered in the Thai Clinical Trial Register (TCTR 20190805002).

Study protocol

Informed consent was obtained from all participants. To reduce the selection bias, 4 operating rooms were randomized with cross-over allocation into two groups that used a total FGF rate of either 1 LPM or 2 LPM. This FGF rate was fixed and used for 1 week before being switched to another FGF rate in the following week. The anesthetic machines were routinely checked before the commencement of the schedule, and it was ensured that the anesthetic circuit leakage was less than 150 ml/min. Litholyme was changed every Monday morning, and when the inspiratory CO_2 reached 5 mmHg. Upon arriving at the operating theatre, ASA standard monitoring was adopted. After intubation, a wash-in period in group 1 used a total FGF rate of 2 LPM to maintain 1 minimal alveolar concentration (MAC) of sevoflurane; the total FGF was then decreased to 1 LPM. In group 2, an FGF rate of 2 LPM was used during the maintenance of anesthesia with 1 MAC of sevoflurane. All patients received mechanical ventilation with a tidal volume of 6-8 ml/kg based on the ideal body weight and a frequency of 12-16 breaths/min. Tidal volume and ventilation rate were modified to maintain the end-tidal CO_2 levels at 30-40 mmHg. Similarly, sevoflurane concentration was adjusted to maintain the mean arterial pressure (MAP) and heart rate (HR) within 20% of the baseline values. At the last stitch of the skin suture, sevoflurane was turned off and the oxygen flow was increased to 6 LPM. Patients were extubated after the extubation criteria were met. We collected information such as demographic data (age, sex, height, weight, body mass index, ASA classification, department), the cost and consumption of sevoflurane and litholyme, intraoperative hemodynamic status (MAP and HR),



CONSORT=consolidated standards of reporting trials, FGF=fresh gas flow, LPM=liters per minute

Figure 1 CONSORT flow diagram

and time to extubation. The consumption of sevoflurane was checked by the volatile anesthetics usage mode in the anesthesia machine; the cost of sevoflurane in our hospital, at the time of the study, was 5,652 THB per 250 ml bottle (22.61 THB/ml). The consumption of litholyme was evaluated via canister per working hour, calculated from the amount of canisters usage in total anesthetic time. The cost of litholyme was 414 THB per 1.18 kg bag, which can be used for 2 canisters (207 THB/canister).

Outcomes

The primary outcome was to compare the cost and consumption of sevoflurane and litholyme at FGF rates of 1 and 2 LPM. The secondary outcome was to compare the differences in hemodynamic stability (intraoperative MAP and HR) and time to extubation between these two techniques.

Sample size calculation and statistical analysis

The sample size per group was 32, which was calculated using two independent means formulas: the two-tailed significance of 0.01 and the power of 0.9 based on previous data.[4] Because a drop-out rate of 10% was expected, the desired sample size was 35 subjects per group. The sample size required for this study was 70 patients.

Data were analyzed by using the R program, version 2.13.0. a chi-square test, and Fisher's exact test were used to compare categorical variables and a t-test was used to compare continuous variables between the two groups. Changes in MAP and HR were compared using the linear mixed model. A p-value less than 0.05 was considered to be statistically significant.

Results

Seventy patients were enrolled in this study (Figure 1). Each group included 35 patients, the data of whom were used to analyze the cost and consumption of sevoflurane. Twenty-one canisters of litholyme were assigned to group 1 and 15 canisters to group 2 for the analysis of the cost and consumption of litholyme. All the intraoperative courses of the patients were uneventful. There was no significant difference in the demographic and intraoperative data between the groups (Table 1). The cost and the consumption of sevoflurane in group 1 (197.3 THB/hr and 9.6 ml/hr) were significantly less than that in group 2 (303.2 THB/hr and 14.8 ml/hr) (p-value<0.001). Even though there was no difference in the cost and consumption of litholyme between the groups, the summarized costs of sevoflurane and litholyme in group 1 (237.7 THB/hr) were also significantly less than that in group 2 (339.6 THB/hr) (p-value < 0.001) (Table 2). The mean litholyme canister life was 5.8 and 5.7 hr in groups 1 and 2, respectively (p-value=0.927). Furthermore, there were no significant differences in MAP, HR, or in regards to the time to extubation between the groups (p-value=0.484, 0.343, and 0.325 respectively) as shown in Figure 2, Figure 3 and Table 1.

Discussion

Recently, the Thai public health system has increased its focus on cost reduction. Anesthesiologists, like other specialists, have to reduce the excessive costs accumulated by using too many anesthesia options, including the duration of anesthesia, oxygen (O_2) and air consumption, utilization of volatile anesthetics, and CO_2 absorbent. FGF is one important factor that influences the consumption of volatile anesthetics. Therefore, the use of low-flow methods minimizes the volatile anesthetics usage and results in lower costs.

Regarding safety concerns in the use of low flow sevoflurane, clinicians should adjust inspired concentration and fresh gas flow rate in order to minimize exposure to Compound A that sevoflurane exposure should not exceed 2 MAC·hours at flow rates of 1 to less than 2 LPM. Fresh

Table 1 Characteristics and operative data of the study patients

Parameters	Group 1 (n=35)	Group 2 (n=35)	p-value
Age (years), mean (S.D.)	53.0 (44.0, 55.5)	49.0 (40.0, 56.0)	0.332
Sex, n (%)			1
Male	8.0 (22.9)	8.0 (22.9)	
Female	27.0 (77.1)	27.0 (77.1)	
Weight (kg), mean (S.D.)	59.1 (53.2, 65.4)	57.0 (52.5, 66.0)	0.828
Height (cm), mean (S.D.)	159.2 (8.4)	159.4 (7.8)	0.935
BMI (kg/m^2)	23.7 (20.9, 25.7)	22.7 (21.1, 25.6)	0.677
ASA classification, n (%)			0.077
I	2.0 (5.7)	7.0 (20.0)	
II	31.0 (88.6)	23.0 (65.7)	
III	2.0 (5.7)	5.0 (14.3)	
Department, n (%)			1
General surgery	33.0 (94.3)	34.0 (97.1)	
Obstetrics & Gynecology	2.0 (5.7)	1.0 (2.9)	
Intraoperative Fentanyl consumption (mcg)	150.0 (100.0, 200.0)	150.0 (112.5, 150.0)	0.546
Total operative time (hr)	1.5 (1.2, 3.1)	1.3 (1.1, 1.8)	0.086
Total anesthetic time (hr)	2.2 (1.5, 3.8)	2.0 (1.4, 2.3)	0.106
Time to extubation (min)	13.7 (12.2, 15.4)	13.1 (11.3, 15.0)	0.325

Data are presented as median (inter-quartile range) unless otherwise indicated

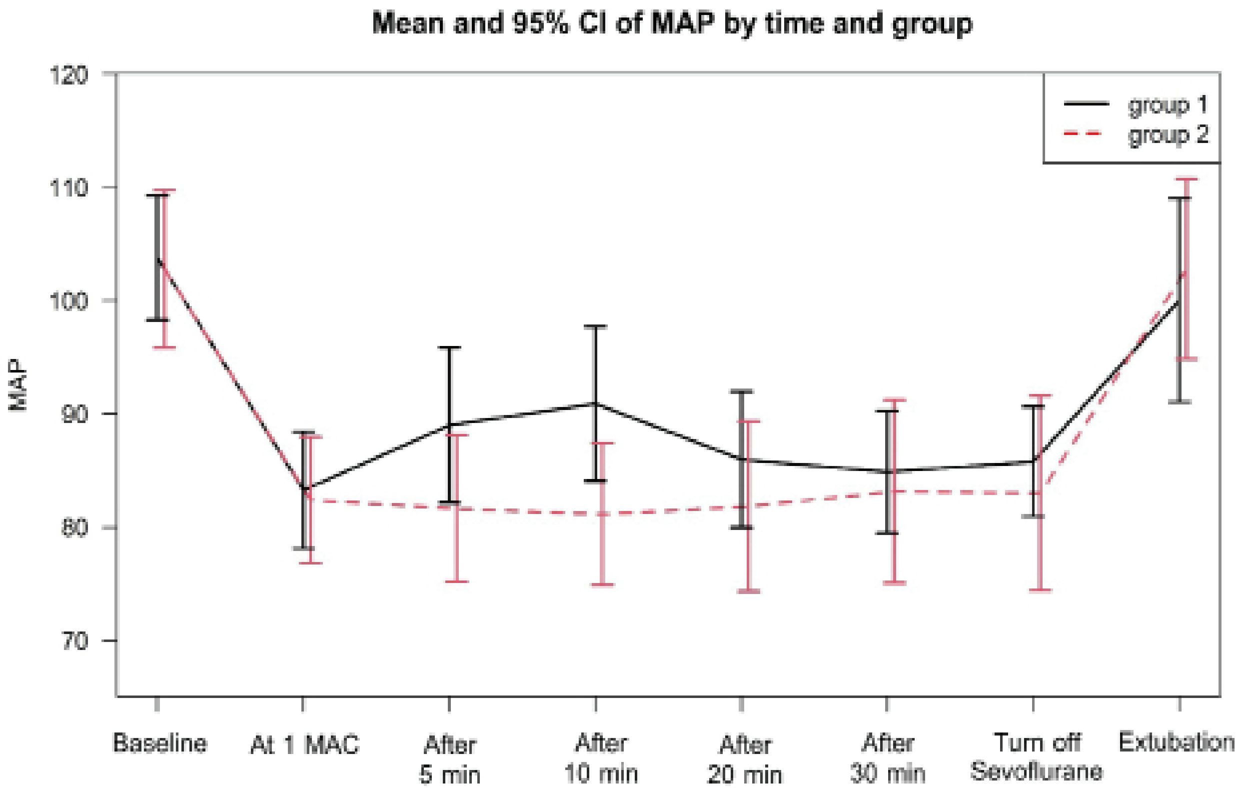
BMI=body mass index, ASA=American Society of Anesthesiologists, S.D.=standard deviation, kg/m^2=kilogram per square meter, mcg=microgram, hr=hour, min=minute

Table 2 Cost and consumption of sevoflurane and litholyme

Parameters	Group 1 (n=35)	Group 2 (n=35)	p-value
Cost of sevoflurane (THB/hr)	197.3 (172.8, 223.7)	303.2 (261.6, 324.6)	<0.001
Sevoflurane consumption (ml/hr)	9.6 (8.4, 10.9)	14.8 (12.8, 15.8)	<0.001
Cost of litholyme (THB/hr)	46.0 (32.5, 64.4)	38.8 (23.3, 68.4)	0.262
Litholyme consumption (canister/working hr)	0.2 (0.1, 0.2)	0.2 (0.1, 0.3)	0.619
Summary cost of sevoflurane and litholyme (THB/hr)	237.7 (220.3,293.2)	339.6 (289, 451.8)	<0.001

Data are presented as median (inter-quartile range) unless otherwise indicated.

THB/hr=Thai Baht per hour, ml/hr=milliliters per hour

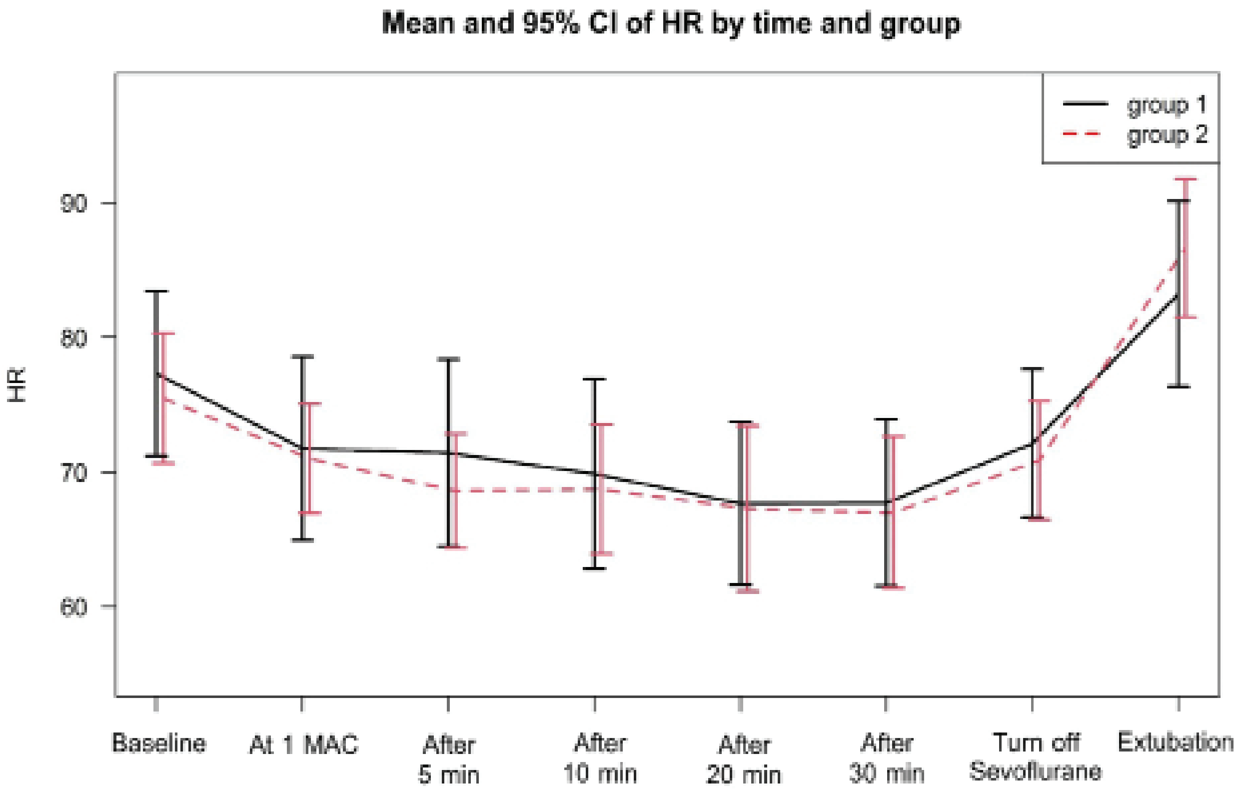


MAP=mean arterial pressure, MAC=minimal alveolar concentration

Figure 2 Variation in intraoperative mean arterial pressure

gas flow rates less than 1 LPM are not recommended.[5] However, a new generation of CO_2 absorbent, litholyme, produce neither Compound A nor carbon monoxide.[6] Therefore, the FGF rate at 1 LPM was used in regards to over 80% of patients undergoing general anesthesia in our institute.

This study found that the cost and consumption of sevoflurane in group 1 were significantly less than that in group 2. Our result was similar to previous studies[4,7,8] that reported that sevoflurane expenditure and cost-effectiveness were significantly reduced in low-flow anesthesia patients. On the other hand, when the lower FGF was used, more exhaled CO_2 passed through the CO_2 absorbent, resulting in an increased consumption of CO_2 absorbent. Nevertheless, we found that the cost and consumption of litholyme between both groups were not significantly different. The summary cost of sevoflurane and litholyme was significantly less in the low-flow group. Correspondingly, Atchison, et al.[7] and Feldman, et al.[9] concluded that the cost of absorbents increase slower than the rate that the cost of volatile anesthetics decrease, so the total costs are still minimized.



HR=heart rate, MAC=minimal alveolar concentration

Figure 3 Variation in intraoperative heart rate

Similar to the present study, Shelgaonkar, et al.[8] and Kepekçi, et al.[10] researched the safety of low flow anesthesia and found that a patient's hemodynamic stability was comparable when receiving both low and moderate flow anesthesia. Thus, the low flow technique can be used safely when careful monitoring is applied.

The speed of emergence while recovering from volatile anesthetics is directly related to alveolar ventilation and inversely related to blood gas solubility. Prolonged duration of anesthesia increases emergence time due to tissue uptake, depending on the concentration used and drug solubility.[11] Moreover, lower FGF has a long time constant that leads to slower emergence[2], which was similar to the results of Jeong, et al.[12] that showed that the emergence time in a group of 2 LPM was significantly longer than that in a group of 4 and 6 LPM. On the contrary, Shelgaonkar, et al.[8] mentioned that a low flow group had an earlier recovery phase. However, Kepekçi, et al.[9] reported that the recovery process between the moderate and low flow techniques was comparable, similar result as per our findings.

This study has some limitations. First, only 4 out of 33 operating rooms were assigned to collect data because these operating rooms only had elective surgery under general anesthesia on weekdays and had the same model of anesthetic machines, which could evaluate the usage of volatile anesthetics. Second, according to the research protocol, each operating room switched the total fresh gas flow every week. As a result, the litholyme canisters were changed every Monday morning even though they were not exhausted. Finally, the mean operative time did not exceed 1.5 hr. A prolonged operation time should be considered for future studies.

In conclusion, patients undergoing elective surgery under general anesthesia, with a total flow of 1 LPM utilize more litholyme, although the increase is no statistically significant, than those with a total flow of 2 LPM. However, this low-flow anesthesia technique consumes remarkably less sevoflurane; resulting to a cost-saving of 101.9 THB/hr.

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Conflict of interest

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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