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Original Article

Direct Cost of Anesthesia in Traumatic Patients with Massive Bleeding: a Prospective Cost Analysis Study

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ABSTRACT

Objective: This study aimed to quantify the direct cost as well as cost-to-charge ratio of anesthetic care in traumatic patients with intraoperative massive bleeding.

Material and Methods: This study was a prospective observational cost analysis study, conducted in Songklanagarind Hospital, Thailand. Traumatic patients from any mechanisms were recruited. Massive bleeding was defined as estimated blood loss of at least one blood volume in 24 hours or a half of blood volume in 3 hours. The cost components were valued by the bottom-up approach. The direct cost was divided into 4 categories; the labor cost, the capital cost, the material cost and the cost of drugs.

Results: From September 2017 to August 2018; 10 eligible patients were included. Seven patients had motorcycle accidents, two patients fell from height and another one was in a minibus accident. Two patients died on the operating table, and another two died within 48 hours. The median direct cost per case was 9,321 Baht (264 United States Dollars), and the cost-to-charge ratio was 0.62. The median Sequential Organ Failure Assessment Score was 8. The median intraoperative blood loss was 3,500 millimeters.

Conclusion: Our study provided information on the direct costs of anesthesia in traumatic patients with massive bleeding. The direct cost was 62.0% of the hospital charge. However, this study did not analyze the indirect cost.

Keywords: anesthesia; cost; cost-to-charge ratio; massive bleeding; trauma

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INTRODUCTION

Hemorrhagic shock appears to be the second leading cause of death in trauma patients, especially for thoracic, abdominal and pelvic injuries. Massive hemorrhage can occur as a result of high velocity falls of over six meters, or intense firearm and blast injuries. As a result, primary treatment usually involves surgeries to control bleeding.[1]

Anesthetic management in trauma patients with severe bleeding requires intensive care. As such, anesthetic treatment carries many costs. Some of which include, but are not limited to, specialized personnel, special instruments; such as a rapid transfusion system, blood products and disposable materials used during the operation. Informed decisions concerning anesthesia care require knowing the costs of that care and identifying the factors contributes.[2]

In Songklanagarind Hospital, the hospital charges of anesthetic care are influenced by four factors: the hourly rates, the charge of equipment, materials and drugs used during care. In Thailand, simple or complicated anesthesia determines the hourly rates, which are regulated by the Comptroller General's Department. The charge of anesthesia in a complicated case is 2,400 Baht for the first hour and 1,800 Baht for each subsequent hour. This covers the cost of labor and standard monitoring equipment, along with any indirect costs of the operating room. While hospitals are aware of the exact charges to a patient's hospital bill, this can rarely reflect the true cost of providing care.[3] This study aimed to report the direct cost and cost-to-charge ratio of anesthetic care in traumatic patients with intraoperative massive bleeding, which have never been quantified.

MATERIAL AND METHODS

This study was designed as a prospective observational costing study to be conducted in the operating theatre of Songklanagarind Hospital, a teaching hospital and trauma center in Southern Thailand. This study covered the course of one year, from September of 2017 to August of 2018, and had been approved by the Office of Human Research Ethics Committee, Faculty of Medicine, Prince of Songkla University.

Patient selection

The subjects included trauma patients, who had undergone surgery with intraoperative massive bleeding. This was defined as: an estimated loss of blood of at least one blood volume (65 milliliter per kilogram of body weight) in 24 hours or a half of blood volume in 3 hours.[4] Eligible patients were selected from the ages of 15 years and older, who were suffering from any type of injury and were operated on under general anesthesia. Patients were excluded if cost data was incomplete.

Data collection

Methodology followed a step-by-step guideline for disease-specific costing studies in low- and middle-income countries, a mixed methodology.[5] Definition of the study perspective set from that of the health care provider. Setting of the unit under observation was the department of anesthesiology at Songklanagarind Hospital. The direct costs composed of four main components: the labor costs, capital costs, material costs, and cost of drugs.[5] Indirect expenses, such as building and overhead costs were not included. Valuation of cost items through the use of a bottom-up approach, wherein patient utilization data was multiplied by unit prices, leading to cost estimates for individual patients.[5] Cost items were valued in Thai Baht.

Labor cost

Labor costs were determined to be variable costs; thus attending time of the staff was recorded. The staff consisted of the anesthesiologist, the resident, the nurse anesthetist, the nurse anesthetist student and the nursing assistant. The attending time was classified into on-duty

shifts which ranged from 8:30 ante meridiem to 4:30 post meridiem, and overtime shifts which were calculated separately.

The total labor cost was calculated from the following equation.[6]

Total labor cost = Σ(Person-hours category x wage)

Person-hours category was defined as the summation of the total attending time of each personnel category. The on-duty and overtime hourly wages were also calculated separately for each personnel. On-duty wage was the mean annual salary divided over 1,768 hours, which was the product of 8 working hours per day, and 221 working days per year. Overtime wage was set at the mean wage per hour.

Capital cost

Equipment available in all operating rooms were determined to be a fixed cost, and were accounted for regardless if they were used for the patient. Only shared equipment were variable costs; therefore, the nurse anesthesiologist made a record of them if they were either in use, or on standby. The equipment used in anesthetic practice included anesthetic machines, patient monitoring systems, anesthetic gas analyzers, defibrillators, rapid infusers, infusion pumps, syringe pumps, intravenous fluid line warmers, patient warmers, ultrasound machines and arterial blood gas analyzers.

The capital cost was calculated from the following equation.[5]

Cost per case = ((Purchasing price/life year) + maintenance cost)/total case in 1 year

The purchasing price was defined as the total of all equipment purchased. According to the criteria from the Comptroller General's Department, the lifetime of medical equipment was 12 years. In 2017, the total cases were reported to be 17,326. This figure was used for the equipment available in all operation rooms. Combined use of the ultrasound machines and rapid infusers consisted of actual data, while estimations of defibrillator use were provided by the number of American Society of Anesthesiologists physical status IV and V patients. Overall use of shared equipment, for example circulating warm-water blankets and syringe pumps, were also estimated to be approximately 5.0% of total cases.

Material cost

These were also determined to be a variable cost. The precise number of materials used was acquired after the surgery by counting the leftover materials in the anesthetic cart. In the case of an emergent situation, if the cart was not used, plastic bags would be collected and counted upon completion of the operation.

A list of materials used during anesthetic practice included; endotracheal tubes, suction catheters, bacterial filters, syringes, needles, IV catheters, IV infusion set, blood transfusion set, central venous catheter set, extension tubes, three-way stopcocks, electrocardiogram electrodes, pressure transducers, pressure monitoring tubes, gauze pads, medical gloves, EDTA tubes, transparent film dressings and Bispectral index sensors.

Materials not available in the cart, such as a central venous catheter set, were recorded by the nurse anesthetist. Any blood contaminated materials were not specifically recorded and were estimated to be 10 pieces of cotton balls, 10 pieces of gauze pads and one box of medical gloves per operation. The material cost is the amount of material used multiplied by the cost per piece.

Cost of drugs

The cost of drugs was established as a variable cost. The cost of intravenous drugs and fluids were obtained from the pharmaceutical division, and were recorded in units of ampoule and bottle, respectively. Volatile anesthetic agents were recorded by the percent of concentration

and flow, and were valued per millimeter. The volume of volatile anesthetic agents was calculated from the following formula.[6]

Volume of volatile anesthetic agent = QtMP/22.4ρ

In the above formula, Q is the flow rate of air and oxygen mixed (liter/minute), t is the time (minute), M is the molecular weight (gram/mol), P is the percent by gaseous volume of the agent, and ρ is the density of the agent (gram/millimeter) set at 20 degree Celsius. Molecular weight of desflurane and sevoflurane are 168 and 200.1 g/mol. Density of desflurane and sevoflurane are 1.45 and 1.50 g/mL, respectively.[7]

Oxygen consumption was calculated from oxygen flow rate (liter/minute) multiplied by time (minute). Costs of oxygen consumption were calculated at 6.35 Baht per cubic meter or 0.00635 per Liter. The unit cost of medical air was not included in the calculation.

Study procedure

Selected patients underwent anesthesia managed by the in-charge anesthesiologist. The in-charge nurse anesthetist was assigned to record the on-duty time of anesthetic personnel, and the type of equipment used in the study record form. All staffs would be recorded for whether they were present for the entire duration of the operation. Start and end times were documented if staffs were only present for some part of the operation.

An anesthetic cart was prepared, containing a precise amount of disposable materials. The leftover materials, following the operation, were counted. In the event the cart remained unused, the nursing assistant collected plastic bags from materials to be counted afterwards.

Data for anesthetic drugs, intravenous fluids, fresh gas flow rate, oxygen concentration and percent of volatile anesthetic agents were documented in the anesthetic record. During the operation, the nurse anesthetist routinely charged the patients. Following the operation, the charge data of each patient was retrieved from the hospital database. Informed consents were obtained within 72 hours following the surgery, but were waived if the patients died in the operating room, or within the 72-hour period.

RESULTS

Characteristics of the patients

During the period from September 2017 and August 2018, 16 eligible patients were included. However, six of those were excluded from the study; due to incomplete data, so only 10 patients were enrolled (Table 1). Of the ten, seven patients (70.0%) had motorcycle accidents, two patients (20.0%) fell from extreme heights and one (10.0%) was due to a minibus accident. Main injuries included abdominal in 5 patients (50.0%), thoracic in 2 patients (20.0%), pelvic fracture in 2 patients (20.0%) and head trauma in one (10.0%). The median Sequential Organ Failure Assessment (SOFA) Score was 8. The estimated intraoperative blood loss varied from 1,800 to 15,000 ml. The median intraoperative blood loss was 3,500 ml. Two patients (20.0%) died on the operating table and two (20.0%) died within 48 hours. Informed consents were received from the remaining six patients (60.0%), whom survived until hospital discharge.

Direct costs

On duty and overtime wages are shown in Table 2. The costliest unit per time was the anesthesiologist, and was a category that received extra payment for every 30 minutes of overtime. Hourly wages for anesthesiologists on duty averaged 534.46 Baht, along with an hourly base wage of 49.22 Baht for overtime, and 400 Baht for each consecutive half-hour of overtime.

The ratios of total attending times compared to operating times are shown in Figure 1. The total attending times of nurse anesthetists and residents were 2.23 and 1.70 times of the operating hours respectively. The anesthesiologists assumed responsibility for many operating

rooms simultaneously, while management of anesthesia during the maintenance periods were assumed by residents. This resulted in a total attending time of 0.52 compared to the operating times.

Costs and charges of each piece of equipment per case are displayed in Table 3. Due to the limitations of users in one year, the Level 1® H-1200 and Belmont® rapid infuser costed 23,056 and 158,333 Baht per case respectively. The Level 1® H-1200 was only used by two patients in this study.

Direct costs of anesthesia ranged from 6,198 to 32,376 Baht. The median direct cost was 9,321 Baht. Meanwhile, the proportions of the direct costs are displayed in Figure 2. Capital expenses were the main contributor, accounting for 50.5% of total costs, and labor costs coming in second at 24.2%.

Table 1 Descriptive patient data

Characteristics	Number (%)
Age (years)	45 (23-55)
Gender: male	8 (80.0%)
American Society of Anesthesiologists Physical Status Classification	
2	1 (10.0%)
3	2 (20.0%)
4	5 (50.0%)
5	2 (20.0%)
Mechanism of injury	
Motorcycle accident	7 (70.0%)
Fall from height	2 (20.0%)
Minibus accident	1 (10.0%)
Number of organ injuries	4 (3-5)
Main organ injury	
Abdomen	5 (50.0%)
Thorax	2 (20.0%)
Pelvic bone	2 (20.0%)
Brain	1 (10.0%)
Sequential Organ Failure Assessment Score	8 (5-10)
Estimated blood loss (mL)	3,500 (2,250-4,500)
Operative outcome	
Death on the operating table	2 (20.0%)
Death within 48 hours	2 (20.0%)
Survive until hospital discharge	6 (60.0%)

Data was presents as number (%) or median (interquatile range, mL=millimeters

Charge and cost-to-charge ratio

The main contributors of total anesthesia charges were hourly wages and equipment, at 44.1% and 33.2%, respectively; which can be seen in Figure 3. This cost to charge ratio ranged from 0.37 to 1.59, with a median ratio of 0.62. However, there were 2 out of 10 patients who used the Level 1® rapid infuser, resulting in a cost-to-charge ratio of over 1.0.

When comparing the mean costs and charges in Figure 4, materials resulted in the greatest loss among direct costs, which was 819 Baht per case or 54.5%. Losses of 565 Baht per case, or 8.6% were also observed in capital costs. However, revenues of 91.9% profit were generated from the drugs being used. Hourly charges to the labor costs were not compared, due to the inclusion of labor costs along with the indirect costs.

DISCUSSION

The direct cost and cost-to-charge ratio of traumatic patients with massive intraoperative bleeding were the main analysis of this study. Anesthetic management often required a higher number of personnel, special equipment, for example, rapid infusers, and a large amount of disposable materials. During the one year of research, 10 eligible patients were selected and data was collected from these.

It was reported by Macario that, with the exclusion of physician costs, at least half of all costs in the operating

Table 2 Mean in time and overtime wage

	Number	Mean annual salary (Baht/year)	Mean on duty wage (Baht/hour)	Mean overtime wage (Baht/hour)
Anesthesiologist	22	944,927	534.46	49.22 (baseline)+400 Baht/30 minutes
Resident	31	292,966	165.70	84.38
Nurse anesthetist	75	389,087	220.07	124.48
Nurse anesthetist student	8	Included in nurse anesthetist data		62.50
Nursing assistant	44	61,164	34.60	69.06

Table 3 Calculated equipment cost per case and charge

Equipment	Number	Total purchasing price (Baht)	Maintenance cost per year (Baht)	Use/year	Calculated cost per case (Baht)	Charge (Baht)
Anesthetic machine	30	51,318,000	1,098,886	17,326	310	–
Monitoring system	32	33,475,000	581,305	17,326	195	–
Arterial line	–	–	–	–	–	240
CVP	–	–	–	–	–	240
Gas analyzer	19	3,800,000	1,114	17,326	18	–
Inhalation agent	–	–	–	–	–	360
$EtCO_2$	–	–	–	–	–	240
Defibrillator	8	3,745,000	19,400	499[a]	664	480
Rapid infuser						
Level 1® H–1200	1	830,000	–	3	23,056	7,900
Belmont®	1	1,900,000	–	1	158,333	32,637
Infusion pump	21	1,837,500	–	17,326	9	75
Syringe pump	7	348,285	103,252	–	–	–
Intravenous fluid line	23	989,000	19,800	17,326	6	75
warmer						
Patient warmer						
3M™ Bair hugger™	4	2,297,171	96,035	17,326	17	240
Circulating warm water pad	4	2,400,000	12,500	866[b]	245	750
Ultrasound	5	13,500,000	–	1,901	592	1,200
Arterial blood gas analyzer[c]	–	–	–	–	240	815

a=Estimated from number of ASA classification IV and V patients
b=Estimated to be 5.0% of total case
c=The arterial blood gas analyzer belonged to the service agency. The cost of solution per one sample was 240 Baht
CVP=central venous pressure, $EtCO_2$=end tidal carbon dioxide

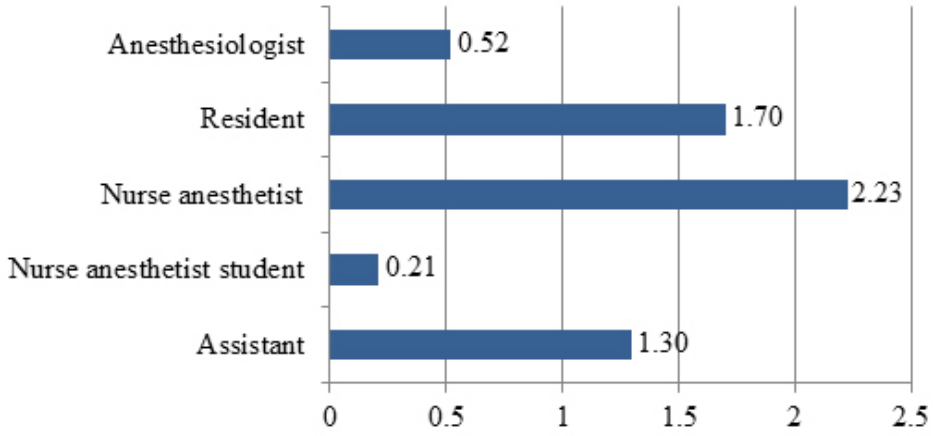

Figure 1 The ratios of total attending times compared to operating times

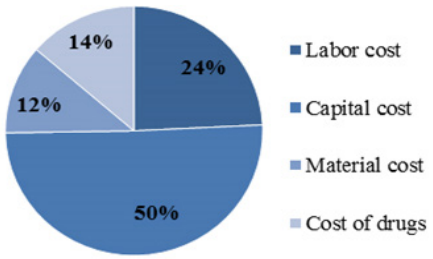

Figure 2 Proportions of the direct costs

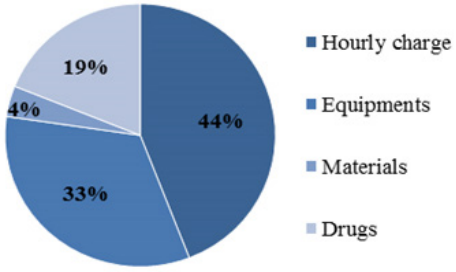

Figure 3 Proportions of the charges

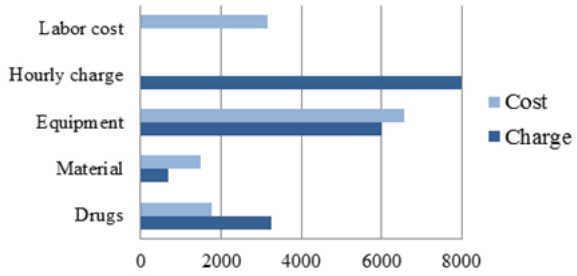

Figure 4 Comparison of the mean costs and the charges

room exist in the fixed overhead costs.[3] Although, the indirect costs were not analyzed in this study, it is estimated that the total costs would overcome the charges.

Capital costs resulted in being a large contributor to overall costs. With the high capitals deriving from the Level 1® H-1200 rapid infuser being used only 3 times in 2017, the cost per case was calculated to be 23,056 Baht. According to the Comptroller General's Department, the charge of the Level 1® H-1200 rapid infuser is 7,900 Baht; thus, the break-even point would be 9 users per year. In addition, the Belmont® rapid infuser was only purchased after the Level 1® H-1200, so the anesthesia personnel are less familiar with it. The charge of the Belmont® rapid infuser is 32,637 Baht, and the break-even point was calculated to be 5 cases per year, but it was only used once by a non-trauma patient in 2017. However, they are still necessary pieces of equipment, because Songklanagarind Hospital is the level-1 trauma center of southern Thiland.

The data from this study varies from that of Pier-thong, who reported on the cost analysis of anesthetic services at Police General Hospital, Thailand in 2013.[8] In this previous research, the labor cost was reported to be 64.0% of the total cost, but it was found to be 24.2% in this study. This data could be underestimated due to the calculations of labor costs, with the actual attending time

of personnel. In this study, the anesthesiologist assumed responsibility for many operating rooms, so actual attending times could not reach 100% of the operating times. Moreover, wages directly correlated with the duration of employment. It is estimated that 30.0% of anesthesiologists in the department have not reached an employment tenure of two years, therefore the mean wages tended to underestimate the labor costs.

Material cost was the greatest loss of direct costs, as most of the materials were not included in the charges. This resulted in a mean loss of 819 Baht per case. As an example: the charge of an arterial line insertion is 480 Baht per case, but the cost of all materials used was 684.7 Baht. This figure already excludes the Jelco® intravenous catheters which cost 19.26 Baht per piece.

There were several limitations to this study. The small sample size was a contributing factor, with 38.0% dropping out, due to missing cost data. Also, this study did not analyze any indirect costs associated with the operation, such as building and overhead costs. Therefore, similar research carried out at different places, and separate times may produce different results.

Secondly, the study only observed and took the perspective of the department of anesthesia. Therefore, costs of other resources within the operation room, such as blood component preparation and rational thrombo-elastography analysis were not included. This research also did not include costs associated with preoperative and postoperative care.

Finally, there were variations regarding the severity of injuries in patients as well as the types of surgeries used. SOFA Score ranged from 0 to 15 and estimated intraoperative blood loss ranged from 1,800 to 15,000 mL.

CONCLUSION

This research provides a comprehensive understanding towards the study of anesthesia costs during intensive treatments. Based on primary data collected over the duration of a year, the results suggest that there is a high cost in connection to anesthesia for trauma patients with severe bleeding: with the median costs being 9,321 Baht per patient. The median cost-to-charge ratio was 0.62.

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CONFLICT OF INTEREST

There are no potential conflicts of interest to declare.

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