The estimated cost of surgically managed isolated traumatic head injury secondary to road traffic accidents

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OBJECTIVE Traumatic brain injury due to road traffic accidents occurs mainly in the younger age group in which injury-related disability leads to long-term impact on employment and economic and social consequences across the lifespan. This study was designed to assign a monetary cost (in Malaysian ringgits [RM]) to the treatment of patients with surgically treated isolated traumatic head injury as determined up to 1 year after injury.

METHODS Relevant resource items used were identified and valued using the direct measurement of costs method, cost accounting methods, standard unit costs method, fees, charges and/or market prices method. These values were then tabulated to generate the total costs for each patient, via a combination of macro-costing and micro-costing methods. Malaysian currency values were converted to US dollars according to the average conversion rate for the period from January to May 2016: RM1 = US\$0.2452.

RESULTS This costing study analyzed data from 49 patients. The estimated cost for the 1st year of care for all patients was RM1,471,919.80 (US\$360,914.735), with a mean ($\pm$ SD) cost per case of RM30,039.18 $\pm$ 22,986.25 or \$7365.61 $\pm$ \$5636.23. The mean cost of care per case was RM11,041.35 $\pm$ 10,936.88 or \$2707.34 $\pm$ \$2681.72 for mild head injury, RM32,550.00 $\pm$ 20,998.76 or \$7981.26 $\pm$ \$5148.90 for moderate head injury, and RM36,917.86 $\pm$ 23,697.34 or \$9052.26 $\pm$ \$5810.59 for severe head injury. Severe head injury ($p = 0.001$), sustaining 2 or more intracranial pathologies ($p = 0.01$), having a poor Glasgow Outcome Scale (GOS) score (GOS score 1–3) ($p = 0.02$), requiring a tracheostomy ($p < 0.001$), and contracting pneumonia ($p < 0.001$) were significantly associated with higher cost. Logistic regression analysis revealed that cost of care increased by RM591.60 or \$145.06 per year increment of age ($\beta = \text{RM}591.60$, $p = 0.05$).

CONCLUSIONS The mean cost of treatment for traumatic head injury is high compared to the per capita income of RM37,900 in 2016. The cost values generated in this study provide baseline cost estimates that the authors hope will be used as a guide to determine where adequate funding should be allocated to provide timely and appropriate delivery of care.

<https://thejns.org/doi/abs/10.3171/2018.1.FOCUS17796>

KEYWORDS cost of care; Malaysia; head injury; road traffic accidents

HHEAD injury is defined as blunt and/or penetrating injury to the head and/or brain due to an external force with temporary or permanent impairments to the brain function which may or may not result in underlying structural changes in the brain.^{3,9}

Economic and health consequences of traumatic brain injury (TBI) secondary to road traffic accidents are known to be substantial. According to the Global Status Report on Road Safety 2015 published by the World Health Organization (WHO), which included data from Malaysia and

ABBREVIATIONS DC = direct costs; GCS = Glasgow Coma Scale; GDP = gross domestic product; GOS = Glasgow Outcome Scale; HSB = Hospital Sungai Buloh; ICU = intensive care unit; MoH = Ministry of Health; RM = Malaysian ringgit; TBI = traumatic brain injury; WHO = World Health Organization.

ACCOMPANYING EDITORIAL DOI: 10.3171/2018.2.FOCUS1888.

SUBMITTED December 30, 2017. **ACCEPTED** January 31, 2018.

INCLUDE WHEN CITING DOI: 10.3171/2018.1.FOCUS17796.

TABLE 1. Summary of study characteristics

Characteristic	Description
Study population	Neurosurgical patients operated on in HSB btwn April 1, 2015, and April 1, 2017
Data collected	Demographic characteristics, type of MVA, types of injury sustained, & surgeries done; costs incurred for surgery, hospitalization, medications, & examinations; clinic follow-up data obtained up to 1 yr after admission
Inclusion criteria	Age 16–60 yrs, ICD-10 code S06* “intracranial injury,” clear history of an MVA, injuries requiring neurosurgical intervention, absence of other system involvement from current MVA, treatment records available in HSB HIS
Data analysis	Macrocosting & microcosting calculation, data crunch & analysis w/ SPSS software, results

HIS = health information system; HSB = Hospital Sungai Buloh; MVA = motor vehicle accident.

179 other countries reflecting 6.97 billion people or 97% of the world’s population, up to 50 million people incur non-fatal injuries, while a staggering 1.25 million deaths occur as a result of road traffic accidents globally each year.¹² In 2012, road traffic accidents were the leading cause of death among people aged 15–29 years, the ninth leading cause of death across all age groups globally, and are predicted to become the seventh leading cause of death by 2030.¹² In 2015, the global rate of road traffic deaths was at 17.4 per 100,000 population, while the reported estimate rate was 24 per 100,000 population for Malaysia.¹² *Health Facts 2016*, published by the Planning Division of Health Informatics Centre of Ministry of Health (MoH) Malaysia, reported that in 2015, ICD-10: S00-T98, injury and other consequences of external causes, was the fourth (7.54%) most common cause of hospitalization in MoH hospitals and private hospitals in Malaysia.¹⁰ It was the third most common reason for emergency department visits at MoH hospitals, contributing to 11.65% of the total of attendances.¹¹ Meanwhile, ICD-10-CM: V00-Y99, external causes of morbidity, was the fifth most frequent cause of death in the MoH hospitals.¹⁰ In the United States, the estimated burden of TBI on the national economy in 2010 was approximately \$76.5 billion, outweighing costs for acute care and rehabilitation.¹² Reports also indicate that in low- and middle-income countries, road traffic deaths and injuries were estimated to cause economic losses of up to 5% of their respective gross domestic product (GDP) compared to the estimated 3% of GDP lost to road traffic deaths and injuries globally.¹²

The high incidence of TBI in the young age group translates into long-term disability. This has an adverse impact upon employment and economic and social consequences across the lifespan of the affected individuals.² The loss of life, the potential for lifelong morbidity among survivors, and the social and financial implications for their family members make this a pressing public health and medical problem. Emphasis on the primary, secondary, and tertiary prevention of traumatic head injuries, especially injuries sustained in road traffic accidents, is still far from satisfactory, whereas treatment in our government hospitals is heavily subsidized, obscuring the actual cost of treatment, especially when compared to the costs of treatment in the private medical setting.

The systematic review by Lu et al. published in the *Journal of Neurotrauma* in 2013 revealed that a total of 28 studies worldwide were published regarding the economic impact of traumatic head injury since 2000 to August

2012.⁶ Twenty-five percent of the articles focused on diagnostic strategies, 22% on injury-prevention efforts, and 11% on the cost-effectiveness of surgical treatment, while the rest looked into health care costs and effectiveness of rehabilitation and other treatment strategies.⁶

Until now, there has been no similar research regarding the cost of treatment for surgically managed isolated traumatic head injury in Malaysia. This lack of information regarding the cost of treatment for traumatic head injury limits our understanding of its impact on our health care system and society in general.

The objectives of the study were to determine the estimated cost of treatment for surgically managed isolated TBI secondary to road traffic accidents in a publicly funded health care system in Malaysia and its related factors among patients with surgically managed isolated TBI due to road traffic accidents.

Methods

This study was an analysis of data from cases involving patients who were operated in a publicly funded hospital—Hospital Sungai Buloh (HSB), Selangor, Malaysia—between April 1, 2015, and April 1, 2016, and was approved by the Malaysian Medical Research Ethics Committee. The inclusion criteria are shown in Table 1 along with a summary of other study characteristics. A total of 1409 patients were identified but only 49 patients who fulfilled the criteria were selected for data analysis. These patients were followed up until 1 year after admission and were stratified according to the severity of head injury and diagnosis of brain injury according to the ICD-10 codes (Table 2).

TABLE 2. ICD-10 codes for diagnosis of head injury

S06 Intracranial injury
S06.0 Concussion
S06.2 Traumatic cerebral edema
S06.3 Focal brain injury
S06.4 Extradural hemorrhage
S06.5 Traumatic subdural hemorrhage
S06.6 Traumatic subarachnoid hemorrhage
S06.7 Intracranial injury with prolonged coma
S06.8 Other intracranial injuries
S06.9 Intracranial injury, unspecified

TABLE 3. Formulas for case cost calculation

Formula	Explanation
$ETC = DC + IDC$	The estimated total cost of treatment (ETC) was computed from both direct costs (DC) & indirect costs (IDC) incurred during admission & up to 1 yr after admission.
$DC = PC + IC + HC$	Direct costs were calculated via the micro-costing method, which is the total cost for cost of procedure(s) (PC), cost of investigations (IC), & costs of hospitalization (HC).
$PC = orc + opc$	PC included total operating room costs (orc) & individual operative costs (opc).
$IC = labc + radc$	IC included all the laboratory (labc) & radiological costs (radc).
$HC = icuc + wadc + clinc + rxc$	HC was a total of costs incurred during ICU stay (icuc), ward stay (wadc), clinic follow-ups (clinc), & medication costs (rx).
$IDC = (\text{maintenance funding per year} \times \% \text{ of area involved}) / (\text{total patient load per year})$	

Data Collection

Demographic data, patients' premorbid status, nature of road traffic accident, type of intracranial injury, treatment and surgical details, and discharge status up to 1 year after admission were collected from the HSB hospital information system and intraoperative logs. Identification of the resources used to deliver the services during admission and follow-up visits were noted. Measurement of resource utilization and calculation of the costs it incurred were performed. Surface area data were obtained from the HSB Department of Engineering; financial data were obtained from the HSB Revenue Department, HSB Finance Department, and HSB financial reports (Laporan Peruntukan dan Perbelanjaan Mengurus dan Pembangunan, JPKA Bil 3/2015, Bil 3/2016).

Cost of Treatment Calculation

The focus of this study was to generate the cost of treatment in a publicly funded health care system. The estimated total cost of treatment for each patient included in the study was calculated and reported (see Table 3). The estimated cost was generated using a combined approach of both micro-costing methods and macro-costing methods as reported by Fishman et al.⁴ Micro-costing methods were used for calculation of direct costs of surgical procedures, cost of investigations, and cost of hospitalization. Calculation of each surgical procedure included the cost of usage of the operating room, which was assigned an hourly weight representing the intensity of utilization to cost and, individual operative costs, which were generated via cost of item utilization. A similar method was used for calculation of the cost of investigations, which included all the laboratory and radiological costs. The cost of hospitalization was the total of costs incurred during ICU stay, ward stay, and clinic follow-up as well as medication costs. All the identified relevant resource items utilized were valued using the direct measurement of costs method, cost accounting methods, standard unit costs method, fees, charges, and/or market prices method.

A top-down costing approach or macro-costing methods were used for calculation of indirect costs. Indirect costs included all the predictor variables of overhead costs associated with building maintenance, labor charges, gas, water and electricity, fuel and transportation maintenance, etc., which were not identified in the direct costs. The indi-

rect cost per case is modeled as a function to the predictor variables as stated above. This sets the stage for efficient derivation of cost-per-case estimates where the indirect unit cost was generated via the funding available for HSB maintenance, divided according to surface area involved by said activity and by the total of units of activity (patients load). Here, cost calculation excluded costs incurred by patients and family such as loss of income or out-of-pocket expenses or home care expenses.

The calculation of individual costs for each patient was performed with Microsoft Excel for Mac (version 15.15 151008) according to the formulas shown in Table 3. These were then totaled for each patient with IBM SPSS Statistics (version 22, release 22.0.0.0, 64-bit version). The average per-patient cost was estimated as a mean value by dividing the total costs by the total number of patients. The average cost of treatment was generated for patients stratified according to sex, severity of head injury, and diagnosis.

Statistical Analysis

Inferential statistical analysis was performed with the use of commercially available software IBM SPSS Statistics (version 22, release 22.0.0.0, 64-bit version). A p value < 0.05 was considered significant. Descriptive statistics were calculated, and univariate analysis and logistic regressions were performed to identify factors for high costs.

Results

Demographic Data of the Study

Data from 49 cases were analyzed for patient demographic characteristics, comorbidities, nature of road traffic accident, type of intracranial injury, treatment details, and discharge status 1 year after admission.

The patient group included 45 men and 4 women with a mean age of 29.96 years (range 18–54 years). Forty-three patients (87.8%) had no significant comorbidities; 2 patients had hypertension, 2 had congenital heart disease, 1 had diabetes mellitus, and 1 had a history of ischemic heart disease. A total of 38 patients were motorcyclists (77.6%), 7 were car passengers or drivers (14.3%), 3 were pedestrians (6.1%), and 1 was a cyclist (2%). The severity of head injury was graded according to the Glasgow Coma

Scale (GCS) on presentation. GCS scores of 3–8 were considered to indicate severe head injury, while scores of 9–12 and 13–15 were considered to indicate moderate and mild head injury, respectively. Twenty-six patients (53.1%) had severe head injury, 12 (24.5%) had moderate head injury, and the remaining 11 (22.4%) had mild head injury. Seventeen participants had anisocoria on presentation (34.7%). Forty participants sustained 2 or more intracranial pathologies (81.6%) while 8 participants had isolated extradural hematoma (16.3%) and one had isolated subdural hematoma (2%).

The mean ($\pm$ SD) hospital stay was 20.14 ± 19.36 days and the mean intensive care unit (ICU) stay was 7.73 ± 5.97 . A total of 43 patients (87.8%) required ICU admission; 22 (51.2%) of these patients stayed in the ICU up to 7 days and another 12 (27.9%) stayed up to 14 days in the ICU. Twenty-seven patients contracted pneumonia (55.1%) and 5 had decubitus ulcers (10.2%) during their stay. Twenty-six patients (53.1%) required tracheostomies while 9 participants underwent cranioplasty within a year (18.4%).

The primary outcome was measured using the Glasgow Outcome Scale (GOS) at 1 year duration. GOS scores of 1, 2, and 3 (signifying death, vegetative state, and severe disability, respectively) were considered to represent poor outcomes while GOS scores of 4 and 5 (signifying moderate disability and good recovery, respectively) were considered to represent good outcomes. Thirty-three participants achieved good GOS outcomes (67.3%), while the remaining 16 participants (32.7%) had poor GOS outcomes. A summary of patient demographic and clinical characteristics is presented in Table 4.

Twenty-six patients sustained severe head injury. In this group, 21 (80.8%) were riding a motorcycle at the time of the accident, 24 (92.3%) sustained 2 or more intracranial pathologies, 18 (69.2%) required tracheostomies, and 15 (57.5%) recovered with good GOS outcomes. The mean time to surgery for the 26 patients in the severe head injury subgroup was 607.54 ± 249.11 minutes. Their mean duration of hospital stay for this subgroup was 23.96 ± 22.50 days and their mean length of ICU stay was 9.58 ± 5.65 days.

Estimated Cost of Treatment

The estimated annual cost for all patients was RM1,471,919.80 (in Malaysian ringgits [MR]) or \$360,914.73, with the mean ($\pm$ SD) cost per case of RM30,039.18 $\pm$ 22,986.25 (95% CI RM23,436.76–36,641.60) or \$7365.61 $\pm$ \$5636.23 (95% CI \$5746.69–\$8984.52). Female patients had a mean cost of care of RM40,035.07 $\pm$ 29,172.68 (95% CI –RM6385 to 86,455.31) or \$9816.60 $\pm$ \$7153.14 (95% CI –\$1565.60 to \$21,198.84), whereas male patients had a mean cost of care of RM29,150.66 $\pm$ 22,549.60 (95% CI RM22,376.01–35,925.31) or \$7147.74 $\pm$ \$5529.16 (95% CI \$5486.60–\$8808.89). The total cost of care for the patient who was injured while riding a bicycle was RM69,167.03 or \$16,959.76. The mean cost of care for patients who were injured as pedestrians was RM54,167.19 $\pm$ RM41,404.36 (95% CI RM48,686.93–157,021.31) or \$13,281.80 $\pm$ \$10,152.35 (95% CI \$11,938.34–\$38,501.63). The mean

cost for patients who were injured as car passengers or drivers was RM27,597.57 $\pm$ 18,197.21 (95% CI RM10,797.96–44,427.18) or \$6766.92 $\pm$ \$4461.96 (95% CI \$2647.66–\$10,893.55) and that for motorcyclists was RM27,554.43 $\pm$ 21,048.44 (95% CI RM20,635.97–34,472.88) or \$6756.35 $\pm$ \$5161.08 (95% CI \$5059.94–\$8452.75).

The mean cost of care for per case of mild head injury was RM11,041.35 $\pm$ 10,936.88 (95% CI RM3693.86–18,388.85) or \$2707.34 $\pm$ \$2681.72 (95% CI \$905.73–\$4508.95), moderate head injury was RM32,550.00 $\pm$ 20,998.76 (95% CI RM19,208.07–45,892.02) or \$7981.26 $\pm$ \$5148.90 (95% CI \$4709.82–\$11,252.72) and severe head injury was RM36,917.86 $\pm$ 23,697.34 (95% CI RM27,346.30–46,489.42) or \$9052.26 $\pm$ \$5810.59 (95% CI \$6705.31–\$11,399.21). Patients who sustained a single pathology spent on average RM12,601 $\pm$ 10,999.76 (95% CI RM4145.83–21,056.16) or \$3089.77 $\pm$ \$2697.14 (95% CI \$1016.56–\$5162.97) compared to those with 2 or more pathologies at RM33,962.77 $\pm$ 23,227.47 (95% CI RM25,534.27–41,391.28) or \$8327.67 $\pm$ \$5695.38 (95% CI \$6261.00–\$10,149.14). A detailed breakdown for the average cost per patient according to their characteristics is reported in Table 5.

For numerical predictors, logistic regression was utilized (Table 6). It was noted that for age, cost of care increases by RM591 (\$144.91) per year increment of age (β = RM591.60; 95% CI RM0.31–1182.96; p = 0.05). There was also a significant increase in cost of care with ICU admission, where cost is increased by RM2645.42 (\$648.66) per day of ICU stay (β = RM2645.42; 95% CI RM1798.80–3492.05; p < 0.001). However, duration of total hospital stay and duration of surgery failed to demonstrate a significant contribution to cost of care (p > 0.05).

Univariate analysis of variance demonstrated that the treatment for severe head injury was significantly more expensive than treatment for mild head injury (β = RM25,876.61; 95% CI RM10,747.74–41,005.27; p = 0.001). This was also true for participants sustaining more than 1 pathology (β = RM21,361.78; 95% CI RM5300.85–37,422.70; p < 0.05) and for participants who had a poor GOS outcome (β = RM15,948.71; 95% CI RM2503.80–29,393.62; p < 0.05). Conversely, it was demonstrated that patients who did not have a tracheostomy (β = –RM30,375.69; 95% CI –RM40,350.34 to –20401.03; p < 0.001) or did not contract pneumonia (β = –RM31,100.42; 95% CI –40,942.28 to –21,258.55; p < 0.001) had a significantly lower cost of care. This is as illustrated in Table 7.

Discussion

This study explored the monetary costs of treating surgically managed isolated TBIs due to road traffic accidents within the treatment setting of a Malaysian public hospital, using a combination of micro-costing and macro-costing methods. In 2009, Fishman et al. reviewed and illustrated approaches for assigning costs to health services where they proposed that the focus should be both on the quantity of real resources consumed and the unit prices assigned to each utilized resource.⁴ They concluded that the direct estimation of costs is useful for empirical analyses, and the approaches include direct estimation of health

TABLE 4. Summary of demographic and clinical characteristics of 49 TBI patients

Characteristic	No. of Patients (%)
Age in yrs	
16–20	11 (22.4)
21–30	18 (36.7)
31–40	10 (20.4)
41–50	7 (14.3)
51–60	3 (6.1)
Sex	
Male	45 (91.8)
Female	4 (8.2)
Mode of transport	
Pedestrian	3 (6.1)
Bicycle	1 (2)
Motorcyclist	38 (77.6)
Car	7 (14.3)
GCS score	
3–8	26 (53.1)
9–12	12 (24.5)
13–15	11 (22.4)
Diagnosis	
Isolated extradural hematoma	8 (16.4)
Isolated subdural hematoma	1 (2)
>2 pathologies	40 (81.6)
ICU admission	
Yes	43 (87.8)
No	6 (12.2)
Duration of ICU stay	
<1 wk	22 (51.2)
2 wks	12 (27.9)
3 wk	8 (18.6)
4 wks	1 (2.3)
>1 mo	0 (0)
Surgery	
EVD only	13 (26.5)
Craniotomy, CE w/o EVD	8 (16.3)
Craniotomy, CE w/ EVD	2 (4.1)
Craniectomy, CE w/o EVD	11 (22.4)
Craniectomy, CE w/ EVD	15 (30.6)
2nd surgery required	
Yes	10 (20.4)
Craniectomy, CE w/o EVD	7 (14.3)
EVD insertion	2 (4.1)
VP shunt	1 (2)
No	39 (79.6)
Tracheostomy	
Yes	23 (46.9)
No	26 (53.1)
Cranioplasty	
Total no. of craniectomies	26
Underwent cranioplasty	9 (34.6)

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TABLE 4. Summary of demographic and clinical characteristics of 49 TBI patients

Characteristic	No. of Patients (%)
Pneumonia	
Yes	27 (55.1)
No	22 (44.9)
Decubitus ulcer	
Yes	5 (10.2)
No	44 (89.8)
Urinary tract infection	
Yes	4 (8.2)
No	45 (91.8)
Thrombophlebitis	
Yes	6 (12.2)
No	43 (87.8)
Deep vein thrombosis	
Yes	0
No	49 (100)
GOS score	
1 (dead)	10 (20.4)
2 (vegetative)	2 (4.1)
3 (severe disability)	4 (8.2)
4 (moderate disability)	9 (18.4)
5 (good recovery)	24 (49.0)

CE = clot evacuation; EVD = external ventricular drainage; VP = ventriculo-peritoneal.

care costs through micro-costing, “macro-costing” techniques, and “standardized resource use assignments” to determine unit cost on the basis of prior judgments about the relative usage of intended resources.⁴ Hence with this and the designed formulas, this study was able to generate the estimated mean cost of treatment per case for the 1st year after sustaining traumatic head injury.

The gross national income of Malaysia was recorded at RM1077.7 billion in 2016 and RM1125 billion in 2015 with a per capita income of RM37,900 in 2016 and RM36,300 in 2015.³ The median household income was RM5228 in 2016.^{7,10} In 2015, the total health expenditure was RM52.6 billion with RM27.1 billion or 51% of this total amount spent in the public sector.⁸ Household out-of-pocket health spending in 2015 was RM19.9 billion or 38% of the total expenditure on health care.⁸ Since 1997, the total expenditure on health care has increased from 2.94% of the Malaysian GDP to 4.55% in 2015, while the per capita spending on health care had increased from RM380 in 1997 to RM1687 in 2015.⁸ In 2016, the total MoH allocation was RM23,031,066,400 or 8.62% of the national budget for a total of 2,465,727 hospitals and 60,478 special medical institutions.¹⁰ A total of RM21,430,802,000 was allocated for the operating sector, and the rest for the development sector.¹⁰

Collectively, our findings illustrate the extreme monetary burden of surgical treatment of traumatic head injury.

TABLE 5. Summary of estimated costs of care for patients with surgically treated isolated TBI sustained in road traffic accidents

Variable	N	Total Cost of Care in RM*			
		Min	Max	Mean $\pm$ SD	95% CI
All patients	49	4089.97	81,077.04	30,039.18 $\pm$ 22,986.25	23,436.76–36,641.60
Sex					
Female	4	15,563.83	81,077.04	40,035.07 $\pm$ 29,172.68	–6385.18 to 86,455.31
Male	45	4089.97	79,069.71	29,150.66 $\pm$ 22,549.6	22,376.01–35,925.31
Mode of transportation					
Pedestrian	3	6489.24	81,077.04	54,167.19 $\pm$ 41,404.36	48,686.93–157,021.31
Cyclist	1	—	—	69,167.03	—
Motorcyclist	38	4089.97	79,069.71	27,554.43 $\pm$ 21,048.44	20,635.97–34,472.88
Car driver or passenger	7	6964.44	59,081.85	27,597.57 $\pm$ 18,197.21	10,767.96–44,427.18
GCS score category					
Severe	26	4457.49	81,077.04	36,917.86 $\pm$ 23,697.34	27,346.30–46,489.42
Moderate	12	10,253.93	69,167.03	32,550 $\pm$ 20,998.76	19,208.07–45,892.02
Mild	11	4089.97	33,816.72	11,041.35 $\pm$ 10,936.88	3693.86–18,388.85
Diagnosis					
2 or more pathologies	40	4457.49	81,077.04	33,962.77 $\pm$ 23,227.47	26,534.27–41,391.28
Single pathology	9	4089.97	33,816.72	12,601 $\pm$ 10,999.76	4145.83–21,056.16

* RM1 = US\$0.2452.

A total of RM1.5 million was spent for a small population of 49 patients in a single publicly funded hospital. The baseline cost of care for surgically treated cases of traumatic head injury was RM30,039.18 $\pm$ 22,986.25 for the 1st year after trauma. This number was significant when compared to the per capita income of RM37,900, and the per capita spending on health care of RM1687.

A distinguishing contrast was demonstrated with increasing severity of head injury. Mild head injury had a mean cost of RM11,041.35 $\pm$ 10,936.88 (\$2707.34 $\pm$ \$2681.72) compared to moderate head injury at RM32,550 $\pm$ 20,998.76 (\$7981.26 $\pm$ \$5148.90) and severe head injury at RM36,917.86 $\pm$ 23,697.34 (\$9052.26 $\pm$ \$5810.59). The increment of cost when comparing mild to severe head injury (RM25,876.51 or \$6590.12) was statistically significant. The same holds true for cases in which patients sustained more than 1 intracranial injury, for whom the cost of care increased by RM21,361.78 (\$5237.91), which was also a statistically significant difference.

This study also showed that with each day of ICU stay, the cost of care was significantly increased (by RM2645.42 [\$648.66] per day) ($p < 0.001$). There was also an increase with increasing age (by RM591.6 [\$144.91] per year of increasing age), although it narrowly missed statistical significance ($p = 0.050$). Also, patients who had a tracheostomy and had a significantly higher mean cost than those who did not have a tracheostomy (difference of RM30,375.69 [\$7448.12]) and patients who contracted pneumonia had a significantly higher mean cost than those who did not contract pneumonia (difference of RM31,100.42 [\$7625.82]). These points illustrate the importance of prevention efforts in terms of road safety modifications, increasing public awareness, and raising car safety profiles.

The limitation of this study is that we did not assess societal costs, out-of-pocket expenses, and loss of income by both the patient and care givers, and the cost incurred for postoperative rehabilitation and physiotherapy. The purpose of this paper was to illustrate the baseline cost of treatment needed in a publicly funded hospital from the health care provider's point of view. It serves to provide a minimum estimation for future funds allocation to publicly funded hospitals with neurosurgical services by policymakers and health care financiers.

Nevertheless, it important to note that complete cost of illness estimates have high value for public health decision makers. Ideally, the structure of analysis should incorporate estimating effects from the health care sector and the socioeconomic impact. Estimated health care costs must include the actual monetary cost of hospitalization in ICUs and general wards, the cost of surgery for each procedure, and the cost of medication and necessary investigations to arrive at the diagnosis or during the course of treatment or stay as described in detail above. Socioeconomic factors should also be taken into account. These factors should in-

TABLE 6. Association between cost and numerical predictors

Predictors	Costs in RM*		p Value
	Crude β	95% CI	
Age (per yr)	591.6	0.31–1182.96	0.050
Duration of surgery (per minute)	12.6	–55.8 to 81	0.710
Duration of ICU stay (per day)	2645.4	1798.80–3492.05	<0.001
Duration of total stay (per day)	252.5	–8.64 to 513.61	0.058

* RM1 = US\$0.2452.

TABLE 7. Association between cost of care and nominal predictors

Predictors	Costs in RM		p Value
	Crude β	95% CI	
Sex			
Female	10,884.41	-13,287.73 to 35,056.55	0.370
Male	—	—	—
Mode of transportation			
Pedestrian	26,569.62	-4026.91 to 57,166.15	0.087
Cyclist	41,568.46	-5830.47 to 88,969.40	0.084
Motorcyclist	-43.14	-18,279.88 to 18,193.60	0.990
Car passenger/driver	—	—	—
GCS score category			
Severe	25,876.51	10,747.74–41,005.27	0.001
Moderate	21,508.69	3951.19–39,066.19	0.017
Mild	—	—	—
Diagnosis			
2 or more pathologies	21,361.78	5300.85–37,422.70	0.010
Single pathology	—	—	—
GOS score			
1–3 (poor outcome)	15,948.71	2503.80–29,393.62	0.020
>3 (good outcome)	—	—	—
Tracheostomy			
No	-30,375.69	-40,350.34 to -20,401.03	<0.001
Yes	—	—	—
Pneumonia			
No	-31,100.42	-40942.28 to -21,258.55	<0.001
Yes	—	—	—

clude 1) individual impact (affordability of hospitalization bills, time lost due to illness, loss of income, and psychosocial impact) and the 2) societal impact (loss of productivity due to disability, impact on the patient's family and on society beyond).

The combination of health care costs and socioeconomic costs will generate the complete costs of illness. Such an accurate costing can contribute to the efficient allocation of resources within the health system and identify where cost reduction is feasible and justifiable. Conversely, misleading or absent cost data can lead to unfair comparisons and flawed policy choices.

Conclusions

Integrated knowledge of the epidemiology, economic consequences, and disease burden of TBI will help us identify the burden and magnitude of the problem. The estimated costs of treatment generated in this study provide preliminary baseline estimates that can help us to generate potential savings from interventions aimed at reducing the incidence of TBI or at improving areas needed for treatment of TBI.

Integrated knowledge of the epidemiology, economic consequences, and disease burden of traumatic brain injury will help us identify the burden and magnitude of the problem. The estimated costs of treatment generated in

this study provide preliminary baseline estimates that can help us to generate potential savings from interventions aimed at reducing the incidence of TBI or at improving accessibility to TBI treatment.

This information should allow us to prioritize intervention and allocation of funds—specifically for policymakers in terms of optimizing health care policy, planning for allocating scarce resources, and developing effective health care delivery and rehabilitation services.

Acknowledgments

This study was supported by Hospital Sungai Buloh Neurosurgery Department and Hospital Sungai Buloh Clinical Research Centre. We would like to thank the Director General of Health Malaysia for his permission to publish this article.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: all authors. Acquisition of data: You, Liew. Analysis and interpretation of data: You, Liew, Musa, Idris. Drafting the article: You, Liew, Rosman, Idris. Critically revising the article: You, Liew, Musa, Idris. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: You. Statistical analysis: You, Liew, Musa, Idris. Administrative/technical/material support: all authors. Study supervision: Liew, Rosman, Musa, Idris.

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