ORIGINAL ARTICLE

Parameters Affecting Length of Stay Among Neurosurgical Patients in an Intensive Care Unit

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ABSTRAK

Tujuan: *untuk menentukan faktor-faktor prediktif penentu lama rawat inap pasien bedah saraf di ICU.* ***Metode:*** *semua pasien yang masuk ICU bedah saraf RS Saraf Prasat, Bangkok, antara 1 Februari dan 31 Juli 2011 ikut serta dalam penelitian. Data demografi dan data klinis pasien untuk setiap variabel dikumpulkan dalam waktu 30 menit sejak masuk rumah sakit. Lama rawat inap di ICU dicatat dan dianalisis menggunakan model regresi linear dengan batas kemaknaan statistik p<0,05.* ***Hasil:*** *sebanyak 276 pasien masuk rumah sakit dan 89,1% di antaranya merupakan kasus elektif. Nilai rata-rata (IK 95%) dan median (minimum–maksimum) dari lama rawat inap di ICU adalah 2,36 (2,09-2,63) dan 2 (1-25) hari. Variabel yang berkaitan dengan lama rawat inap di ICU dan persentase perubahannya (IK 95%) meliputi Glasgow Coma Scale motor subscore (GCSm), 6,72% (-11,20 hingga -2,01) lebih rendah untuk setiap perubahan 1 skor poin; pH darah, 1,16% (0,11 hingga 2,21) lebih tinggi untuk setiap perubahan 0,01 satuan; dan jenis kegawatdaruratan saat masuk rawat, 58,30% (29,16 hingga 94,0) lebih tinggi bila dibandingkan dengan masuk rawat karena alasan elektif.* ***Kesimpulan:*** *GCSm, pH dan kegawatdaruratan saat masuk rawat ternyata merupakan variabel prediktif utama untuk lama rawat pasien bedah saraf yang dirawat di ICU. Meskipun demikian, model ini perlu diteliti lebih lanjut pada ukuran sampel yang lebih besar dan menggunakan analisis subkelompok.*

Kata kunci: *Glasgow coma scale score, pH, kegawatdaruratan saat masuk rawat, kinerja, prediksi.*

ABSTRACT

Aim: *to determine the predictive factors on the length of stay of neurosurgical patients in the ICU setting.* ***Methods:*** *all patients admitted to the neurosurgical ICU between February 1 and July 31, 2011 were recruited. Patient demographics and clinical data for each variable were collected within 30 minutes of admission. The ICU length of stay was recorded and analyzed by linear regression model with statistical significance at p-value <0.05.* ***Results:*** *there were 276 patients admitted, of whom 89.1% were elective cases. The mean (95% CI) and median (min-max) of ICU length of stay were 2.36 (2.09-2.63) and 2 (1-25) days. The variables associated with ICU length of stay and their percent change (95% CI) were the Glasgow Coma Scale motor subscore (GCSm), 6.72% (-11.20 to -2.01) lower for every 1 point score change; blood pH, 1.16% (0.11 to 2.21) higher for every 0.01 unit change; and emergency admission type, 58.30% (29.16 to 94.0) higher as compared to elective admission.* ***Conclusion:*** *the GCSm, pH and emergency admission were found to be the main predictive variables* *of neurosurgical patient length of stay in the intensive care unit, however, the model should be further explored in a larger sample size and using subgroup analysis.*

Keywords: *Glasgow coma scale score, pH, emergency admission, performance, prediction.*

INTRODUCTION

In assessing the performances of intensive care units (ICUs), three main considerations are relevant: effectiveness as measured by patient outcome[1]; efficiency of resource utilization as measured by the length of patient stay[2]; and qualitative factors such as complication rate, morbidity and the rate of infection.[3] The ICU length of stay is highly important to hospital providers, administrators, relatives and patients themselves for several reasons.[4-5] The significant implications for economic costs, patient outcomes and hospital management have been previously articulated.[6-8]

A number of factors were found to be associated with length of stay in the ICU. Using a risk scoring algorithm, a set of variables that were predictive of length of stay in the ICU were identified and validated to understand their causative relationship.[9-10] However, the use of these factors in a predictive capacity in the subset of neurosurgical patients is less clear and often culminates in the ineffective allocation of resources. It has been suggested that this phenomenon may be attributed to variations in methodology[11-13], diversity of study populations[9,14], differing methods of outcome assessment[10,15], inadequate power of risk-scoring algorithms16 or outdated research.[11]

This study was conducted in a large, single, tertiary neurosurgical ICU to assess the predictive abilities of the factors associated with hospital mortality, in order to estimate the period of ICU care required by neurosurgical patients.

METHODS

This observational study was registered to the Thai Clinical Trials Registry with the identification number of TCTR 20151015002. Approval for the study (No. 10/2555) was received from the Prasat Neurological Institute Ethics Committee (Chairman: Suchat Hanchaiphiboolkul) on Feb 8, 2012. All new patients admitted into the neurosurgical ICU at Prasat Neurological Institute, Bangkok, during February 1–July 31, 2011, were recruited for the study. Written informed consent was obtained from all patients or from legal relatives in the case of unconsciousness. Patient clinical data and personal information were assessed and collected within 30 minutes of admission by 2 certified neurosurgical registrar nurses. Patient data for the following variables were collected: body temperature, mean arterial pressure, heart rate, respiratory rate, arterial oxygen tension (PaO_2), arterial carbon dioxide tension ($PaCO_2$), arterial pH, serum sodium, serum potassium, BUN, creatinine, hematocrit, white blood cell count, Glasgow Coma Scale (GCS) score (scored for verbal subscale as 1 in the case of intubated patients), urine output per day, blood glucose, albumin, bilirubin and the length of hospital stay prior to ICU admission. The length of ICU stay was defined as the number of calendar days between ICU admission date and ICU discharge date.

Descriptive statistics were used for demographic data and were reported as mean, standard deviation (SD), median, minimum-maximum, 95% confidence interval (95% CI), number and percentage. A logistic regression model was conducted using Stata Software Version 13.1 (Texas, USA, 2013) to determine the association of those variables and the mortality rate. The values were displayed in a Kaplan-Meier curve, showing the length of ICU length of stay and associated mortality rate (Figure 1). Patients who died before ICU discharge were censored. Multivariable and univariate analysis of these variables on the length of ICU stay was conducted using linear regression (**Table 1; Table 2; and Table 3**). The multivariable linear regression model used the $p<0.05$ for significance. Goodness of fit and likelihood ratio tests were also conducted to control for potential confounding of results and to demonstrate the performance of each predictive variable on the ICU length of stay. The effect of each factor was displayed in mean difference or percent difference between groups of predictors using a 95% confidence interval (95% CI).

RESULTS

A total of 276 patients were admitted to the neurosurgical ICU and were involved in this study. The mean of age (SD) were 47.84 (15.36) years with no comorbidity indicated chronic health problems, i.e., AIDS, hepatic failure, lymphoma, metastasis cancer, leukemia, immune-compromised, and cirrhosis. The demographics and patient characteristics are shown in **Table 1**. The overall hospital mortality was of 9 (3.26%) however there were no deaths during ICU stay. The mean (SD) and median (minimum-maximum) duration of patient stay in ICU was 2.55 (2.51) days and 2 (1-25) days. The corresponding duration of ICU stay for survivors was 2.45 (2.10) days and 2 (1-18) and 4.83 (6.74) days and 2 (1-25) days for non-survivors (**Table 1**). The median and (minimum-maximum) length of hospital stay prior to ICU admission was 3 (0-97) days for the study cohort; 3 (0-74) days for survivors; and 15.5 (0-97) days for non-survivors.

According to a perfect agreement of the assessors (Intraclass correlation coefficient: ICC 0.97, 95% CI 0.95-0.99), the results of the univariate linear regression model of the factors affecting ICU length of stay are shown in **Table 2**. In comparing the elective and emergency admission subgroups, patients with emergency admissions resulted in 81.08%, 95% CI (49.54 to 119.26); p-value <0.001 longer ICU length

Table 1. Patient characteristics and admission data

Variables	n (%)
Age (years), mean (SD)	47.84 (5.36)
Sex (male)	120 (43.5)
Type of admission	
- Elective	246 (89.1)
- Emergency	30 (10.9)
Diagnosis	
- Cerebral tumor	207 (75.0)
- Cerebral vascular lesion	28 (10.1)
- Spinal tumor	4 (1.5)
- Spinal spondylosis	11 (4.0)
- Other	26 (9.4)
Admission criteria	
- Impaired level of consciousness	39 (9.4)
- Impaired ability of airway protection	24 (5.8)
- Progressive respiratory impairment or required mechanical ventilation	37 (8.9)
- Seizures	15 (3.6)
- Clinical or evidence of raised intracerebral pressure	51 (12.3)
- Threatening medical complications	20 (4.8)
- Monitoring purpose	228 (55.1)

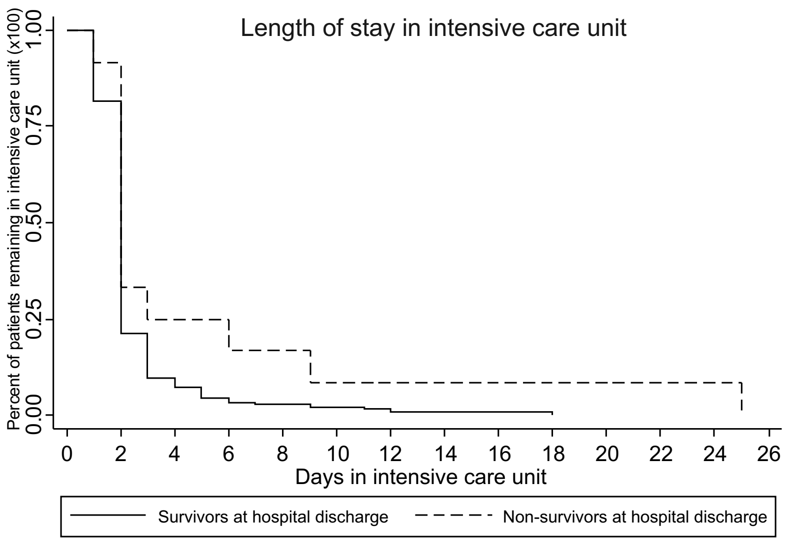

Figure 1. Kaplan Meier estimation for ICU length of stay as demonstrated by mortality rate at discharge

Table 2. Univariate analysis of the predictors of ICU length of stay

Variables	Mean (SD)	Median (min-max)	Percentage difference (95% CI)	p
Age (per annum increase)	47.84 (15.39)	47 (9-87)	0.39 (-0.02 to 0.80)	0.06
Heart rate (per 1 beat/min increase)	82.21 (16.66)	80 (50-144)	0.21 (-0.17 to 0.59)	0.28
MAP (per 1 mmHg increase)	108.72 (22.43)	104 (58-166)	0.27 (-0.03 to 0.57)	0.08
Temperature (per 0.1ºC increase)	36.47 (0.77)	36.5 (34-39)	0.58 (-0.24 to 1.41)	0.16
RR (per 1 breath/min increase)	18.22 (3.88)	18 (10-28)	-2.32 (-3.89 to 0.74)	0.004
Hematocrit (per 1 % increase)	34.90 (4.70)	35.1 (22-49)	-0.40 (-1.73 to 0.96)	0.56
WBC count (per 103/µL increase)	14.10 (5.65)	13.50 (4.4-38.4)	1.48 (0.36 to 2.61)	0.01
Urine output/day (per 1 ml increase)	2646.0 (1072.0)	2450 (175-8350)	0 (0 to 0)	0.29
Blood glucose (per 1 mg/dl increase)	163.79 (49.95)	153.5 (87-442)	-0.07 (-0.20 to 0.05)	0.26
BUN (per 1 mg/dl increase)	10.86 (7.27)	9.5 (3-96)	1.06 (0.18 to 1.93)	0.02
Creatinine (per 1 mg/dl increase)	0.81 (0.33)	0.7 (0.4-3.2)	15.86 (-4.48 to 40.52)	0.13
Sodium (per 1 mEq/l increase)	137.98 (3.83)	138.2 (124.6-155.7)	-1.10 (-2.72 to 0.55)	0.19
Albumin (per 1 g/dl increase)	3.06 (0.53)	3.1 (1.4-5.4)	-18.10 (-27.27 to -7.77)	0.001
Bilirubin (per 1 mg/dl increase)	0.81 (0.40)	0.8 (0.1-3.4)	17.40 (0.06 to 37.74)	0.05
PaO2 (per 1 mmHg increase)	200.74 (86.63)	199 (58-416)	-0.08 (-0.15 to -0.04)	0.03
PaCO2 (per 1 mmHg increase)	37.69 (6.99)	38 (17-59)	-1.44 (-2.32 to -0.56)	0.002
pH (per 0.01 unit increase)	7.39 (0.07)	7.38 (7.11-7.60)	2.17 (1.26 to 3.09)	<0.001
GCS (per 1 score increase)	10.33 (3.63)	12 (3-15)	-4.52 (-6.10 to -2.93)	<0.001
GCSe (per 1 score increase)	2.66 (0.96)	3 (1-4)	-13.92 (-19.23 to -8.25)	<0.001
GCSv (per 1 score increase)	2.69 (1.38)	3 (1-5)	-8.68 (-12.67 to -4.51)	<0.001
GCSm (per 1 score increase)	4.99 (1.77)	6 (1-6)	-9.12 (-12.16 to -5.96)	<0.001
Potassium (per 1 mEq/l increase)	3.78 (0.43)	3.78 (2.15-5.55)	-12.35 (-24.25 to 1.42)	0.08
Length of stay prior to ICU admission (per 1 day increase)	5.82 (9.31)	3 (0-97)	0.41 (-0.27 to 1.10)	0.24

MAP: mean arterial pressure, RR: respiratory rate, GCS: Glasgow coma scale score, GCSe: Eye subscale in Glasgow coma scale score, GCSv: Verbal subscale in Glasgow coma scale score, GCSm: Motor subscale in Glasgow coma scale score, ICU: Intensive care unit. * Statistical significance at p-value <0.05.

Table 3. Multivariable analysis of the predictors of ICU length of stay

Variables	n (%)	Mean (SD)	Percentage difference (95% CI)	p-value
GCSm (in 1 point score increments)		4.99 (1.77)	-6.72 (-11.20 to -2.01)	0.006*
pH (in 0.01 unit increase)		7.39 (0.07)	1.16 (0.11 to 2.21)	0.03*
Type of admission:				
- Elective	246 (89.1)		58.30 (29.16 to 94.0)	<0.001*
- Emergency	30 (10.9)			

GCSm: Glasgow Coma Scale motor subscale score. * Statistical significance at p-value <0.05.

of stay than patients with elective admissions. Female patients had 8.3%, 95% CI (-19.29 to 4.19); p-value 0.18, shorter ICU stays compared with male patients. Patients admitted without cerebral tumors had 1.56%, 95% CI (-6.7 to 3.72; p-value 0.56 shorter stays than those patients with cerebral tumors. Multivariable analysis of the predictors of the ICU length of stay is demonstrated in **Table 3**.

DISCUSSION

The relationship between prolonged ICU stay and the rising cost of medical treatment has been previously documented.[17-19] This study shows the predictive capacity of neurosurgical patients' clinical variables on the length of stay in the ICU. It is crucial to identify and understand these variables in order to develop strategies to manage ICU costs as well as patient outcomes. The need for extended ICU stays is often required, as shown in this study, and must be anticipated by both patients and relatives.

Previous studies have shown multiple independent predictors of higher ICU length of stay in various settings. In the case of traumatic brain injury, the severity grading, mass lesion on admission head computed tomography, and delirium symptoms were found to be highly predictive of the length of ICU stay.[20-21] Additionally, the Boston Acute Stroke Imaging Scale has been shown to be highly predictive of in-hospital mortality, as having the occurrence of complications, length of stay and hospitalization cost of acute ischemic stroke patients.[22]

Although the pre-admission assessment of neurological deterioration, as evaluated by the GCS, was determined as a good predictor of higher ICU length of stay, the GCSm subscale has been shown to be a superior predictive tool.[23] Its simplicity to administer and high predictability of mortality in both neurological and neurosurgical patients make it superior to the GCS.[24] Moreover, Acker et al. has shown that the GCSm alone does not differ in identifying children with serious traumatic brain injury from the GCS. Eliminating the eye and verbal components of GCS does not adversely affect the accuracy of this predictive tool.[25]

Our data analysis demonstrated that the Glasgow Coma Scale score was also a strong indicator for ICU length of stay. Multiple linear regression analysis conducted separately from the motor subscale showed the percent difference of -2.95%, 95% CI (-4.55 to -1.24); p= 0.001 per 1 point score increase. The percent difference for the emergency admission subset was 54.70%, 95% CI (26.43 to 89.67); p-value <0.001, while the percent difference for pH was 1.11%, 95% CI (0.06 to 2.16); p= 0.04 per 0.01 unit increase. To account for the issue of multicollinearity, the adjusted r2 from multivariable analysis was taken into account. The test showed higher adjusted r2 (0.23) for the group of variables containing GCSm score, while the GCS composed was 0.22. Therefore, the GCSm was selected as an acceptable predictor of the length of ICU stay for neurosurgical patients.

Biochemical variables, especially pH balance, affect ICU length of stay because of its potential impairment of cerebral blood flow and cerebrovascular vascular reactivity. This is likely due to pH being the dominant blood flow regulator under normal physiological brain conditions.[26-28] These surrogated events may lead to ultimate clinical outcome as well as the ICU length of stay. The multivariable analysis conducted in this study showed that the pH balance is predictive of higher duration of ICU admission. Surprisingly, previous studies have shown inconclusive evidence of this relationship.[29-32] Further study should be conducted to confirm a causal effect.

For obvious reasons, many neurosurgical patients present to the ICU unexpectedly because of a rapid deterioration of their condition. The review of a powerful predictor among emergency hospital admission type affected ICU length of stay has been previously established.[33-34] Scenario simulation practice, development of standard treatment protocols together with a qualified neurocritical care service team have been suggested to improve quality of care and shorten the duration of ICU stay.[29,35]

In this study of neurosurgical ICU admissions, there were no patients with emergency admissions for continuous monitoring or after performing complex neurosurgery. The majority of patients were admitted for clinically increased intracranial pressure or impending brain damage, which may clarify the longer ICU stay phenomenon.

From previous studies, the intraoperative variables identified as affecting the length of ICU stay, such as perioperative transfusion, perioperative complications, and location of brain lesions, were considered to be independent.[21,36-38] One limitation of this study is that analysis of the post-operative group alone was not completed and may have been relevant. In future studies, further patient sub-group analysis of intraoperative factors such as blood transfusion, location of lesions in the brain and complications during the operation should be included. Additionally, most of the study cohort was diagnosed with cerebral tumors or cerebral vascular lesions. There was only a small subset of spinal pathology patients and none with traumatic brain injuries. Therefore, the patient diagnosis upon ICU admission is relevant before generalizing these results to other circumstances and further subgroup analysis is needed in future research.

CONCLUSION

The length of stay for neurosurgical patients in the ICU differed from 1-25 days. The Glasgow Coma Scale score motor subscale (GCSm), pH, and the type of hospital admission (emergency/ elective) were shown to be predictors of the duration of stay in the ICU. In the future, the validity of this model should be further explored in a multicenter study with a larger and more varied cohort of patients as well as in smaller subgroups of patients.

REFERENCES

1. Barie PS, Ho VP. The value of critical care. Surg Clin North Am. 2012;92(6):1445-1462. process. Crit Care Nurs Q. 2014;37(1):93-102.
2. Burns GB, Hogue V. WellStar Paulding Hospital intensive care unit case study: achieving a research-based, patient-centered design using a collaborative
3. Wetzel RC, Sachedeva R, Rice TB. Are all ICUs the same? Paediatr Anaesth. 2011;21(7):787-93.
4. Mejaddam AY, Elmer J, Sideris AC, et al. Prolonged emergency department length of stay is not associated with worse outcomes in traumatic brain injury. J Emerg Med. 2013;45(3):384-91.
5. Witcher R, Stoerger L, Dzierba AL, et al. Effect of early mobilization on sedation practices in the neurosciences intensive care unit: a preimplementation and postimplementation evaluation. J Crit Care. 2015;30(2):344-7.
6. Semei-Spencer TT, Kinthala S, Fakoory M, et al. Outcomes and Health-related Quality of Life following Intensive Care Unit Stay in Barbados. West Indian Med J. 2014;63(5):447-53.
7. Reponen E, Korja M, Niemi T, et al. Preoperative identification of neurosurgery patients with a high risk of in-hospital complications: a prospective cohort of 418 consecutive elective craniotomy patients. J Neurosurg. 2015;123(3):594-604.
8. Thompson G, O'Horo JC, Pickering BW, et al. Impact of the electronic medical record on mortality, length of stay, and cost in the Hospital and ICU: A systematic review and metaanalysis. Crit Care Med. 2015;43(6):1276-82.
9. Vasilevskis EE, Kuzniewicz MW, Cason BA, et al. Mortality probability model III and simplified acute physiology score II: assessing their value in predicting length of stay and comparison to APACHE IV. Chest. 2009;136(1):89-101.
10. Zimmerman JE, Kramer AA, McNair DS, et al. Acute physiology and chronic health evaluation (APACHE) IV: hospital mortality assessment for today's critically ill patients. Crit Care Med. 2006;34(5):1297-310.
11. Moran JL, Bristow P, Solomon PJ, et al. Mortality and length-of-stay outcomes, 1993-2003, in the binational Australian and New Zealand intensive care adult patient database. Crit Care Med. 2008;36(1):46-61.
12. Nathanson BH, Higgins TL, Teres D, et al. A revised method to assess intensive care unit clinical performance and resource utilization. Crit Care Med. 2007;35(8):1853-62.
13. Al Tehewy M, El Houssinie M, El Ezz NA, et al. Developing severity adjusted quality measures for intensive care units. Int J Health Care Qual Assur. 2010;23(3):277-86.
14. Niskanen M, Reinikainen M, Pettila V. Case-mix-adjusted length of stay and mortality in 23 Finnish ICUs. Intensive Care Med. 2009;35(6):1060-7.
15. Zimmerman JE, Kramer AA. Outcome prediction in critical care: the Acute Physiology and Chronic Health Evaluation models. Curr Opin Crit Care. 2008;14(5):491-7.
16. Verburg IW, de Keizer NF, de Jonge E, et al. Comparison of regression methods for modeling intensive care length of stay. PLoS One. 2014;9(10):e109684.
17. Curtis K, Lam M, Mitchell R, et al. Acute costs and predictors of higher treatment costs of trauma in New South Wales, Australia. Injury. 2014;45(1):279-84.
18. Yuan Q, Liu H, Wu X, et al. Characteristics of acute treatment costs of traumatic brain injury in Eastern China--a multi-centre prospective observational study. Injury. 2012;43(12):2094-9.
19. Chan CL, Ting HW, Huang HT. The incidence, hospital expenditure, and, 30 day and 1 year mortality rates of spontaneous intracerebral hemorrhage in Taiwan. J Clin Neurosci. 2014;21(1):91-4.
20. Lazaridis C, Yang M, DeSantis SM, et al. Predictors of intensive care unit length of stay and intracranial pressure in severe traumatic brain injury. J Crit Care. 2015;30(6):1258-62.
21. Naidech AM, Beaumont JL, Rosenberg NF, et al. Intracerebral hemorrhage and delirium symptoms. Length of stay, function, and quality of life in a 114-patient cohort. Am J Respir Crit Care Med. 2013;188(11):1331-7.

22. Zhao Y, Zhao M, Li X, et al. The predictive value of the Boston Acute Stroke Imaging Scale (BASIS) in acute ischemic stroke patients among Chinese population. PLoS One. 2014;9(12):e113967.
23. Majidi S, Siddiq F, Qureshi AI. Prehospital neurologic deterioration is independent predictor of outcome in traumatic brain injury: analysis from National Trauma Data Bank. Am J Emerg Med. 2013;31(8):1215-9.
24. Ting H-W, Chen M-S, Hsieh Y-C, et al. Good mortality prediction by Glasgow Coma scale for neurosurgical patients. J Chin Med Assoc. 2010;73(3):139-43.
25. Acker SN, Ross JT, Partrick DA, et al. Glasgow motor scale alone is equivalent to Glasgow Coma scale at identifying children at risk for serious traumatic brain injury. J Trauma Acute Care Surg. 2014;77(2):304-9.
26. ter Laan M, van Dijk JM, Elting JW, et al. Sympathetic regulation of cerebral blood flow in humans: a review. Br J Anaesth. 2013;111(3):361-7.
27. Jaeger M, Lang EW. Cerebrovascular pressure reactivity and cerebral oxygen regulation after severe head injury. Neurocrit Care. 2013;19(1):69-73.
28. Kollmar R, Georgiadis D, Schwab S. Alpha-stat versus pH-stat guided ventilation in patients with large ischemic stroke treated by hypothermia. Neurocrit Care. 2009;10(2):173-80.
29. Kesinger MR, Nagy LR, Sequeira DJ, et al. A standardized trauma care protocol decreased in-hospital mortality of patients with severe traumatic brain injury at a teaching hospital in a middle-income country. Injury. 2014;45(9):1350-4.
30. Wang CH, Huang CH, Chang WT, et al. Association between early arterial blood gas tensions and neurological outcome in adult patients following in-hospital cardiac arrest. Resuscitation. 2015;89:1-7.
31. Bazzazi A, Hasanloei MA, Mahoori A, et al. Correlation between arterial blood gas analysis and outcome in patients with severe head trauma. Ulus Travma Acil Cerrahi Derg. 2014;20(4):236-40.
32. Solaiman O, Singh JM. Hypocapnia in aneurysmal subarachnoid hemorrhage: incidence and association with poor clinical outcomes. J Neurosurg Anesthesiol. 2013;25(3):254-61.
33. Kim SM, Hwang SW, Oh EH, et al. Determinants of the length of stay in stroke patients. Osong Public health Res Perspect. 2013;4(6):329-41.
34. Witiw CD, Ibrahim GM, Fallah A, et al. Early predictors of prolonged stay in a critical care unit following aneurysmal subarachnoid hemorrhage. Neurocrit Care. 2013;18(3):291-7.
35. Burns JD, Green DM, Lau H, et al. The effect of a neurocritical care service without a dedicated neuro-ICU on quality of care in intracerebral hemorrhage. Neurocrit Care. 2013;18(3):305-12.
36. Seicean A, Alan N, Seicean S, et al. Surgeon specialty and outcomes after elective spine surgery. Spine (Phila Pa 1976). 2014;39(19):1605-13.
37. Boling CC, Karnezis TT, Baker AB, et al. Multi-institutional study of risk factors for perioperative morbidity following transnasal endoscopic pituitary adenoma surgery. Int Forum Allergy Rhinol. 2016;6(1):106-7.
38. Mekitarian Filho E, Brunow de Carvalho W, Cavalheiro S, et al. Perioperative factors associated with prolonged intensive care unit and hospital length of stay after pediatric neurosurgery. Pediatr Neurosurg. 2011;47(6):423-9.