Ulus Travma Acil Cerrahi Derg 2010;16 (2):149-154

Intensive care cost and survival analyses of traumatic brain injury

Travmatik beyin hasarının yoğun bakım maliyeti ve sağkalım analizleri

Necdet SÜT, Dilek MEMİŞ

BACKGROUND

Intensive care of Traumatic Brain Injury (TBI) is associated with substantial morbidity, mortality and cost; however, there is very little published work on this topic. The purpose of this study was to examine direct costs and survival outcomes of patients with TBI admitted to an intensive care unit (ICU).

METHODS

A retrospective review of the records of Trakya University Hospital's ICU from 2002-2006 was undertaken. Patients with TBI were determined and assessed regarding costs and survival.

RESULTS

The study group consisted of 126 patients, and 27.8% of them had been operated. Male gender (80.2%) was dominant, mean length of stay was 9.8±8.7 days, and motor vehicle injury (59.5%) was the major reason for ICU admission. Mortality rate was 50% and the Glasgow Coma Score (GCS) of the patients was 6.1±1.9. The average cost per ICU stay was US$ 4846±5084. Cost per life saved and per life-year saved were US$ 9533 and US$ 313.60, respectively. Survival rates were significantly different among injury types (p=0.010). GCS appeared to be a prognostic parameter in patient survival (Hazard Ratio: 0.643; 95%CI: 0.529-0.781; p<0.001).

CONCLUSION

Intensive care of TBI cases is characterized by high mortality and high cost.

Key Words: Cost analysis; intensive care; survival; trauma; traumatic brain injury.

AMAÇ

Travmatik beyin hasarının (TBH) yoğun bakımı, yüksek maliyet, mortalite ve morbiditeye dayalıdır, ancak bu konuda yayınlanmış çalışma sayısı oldukça azdır. Bu çalışmanın amacı, yoğun bakım ünitesine (YBÜ) kabul edilen TBH'li hastaların maliyetlerini ve sağkalım sonuçlarını incelemektir.

GEREÇ VE YÖNTEM

2002-2006 yılları arasında Trakya Üniversitesi Hastanesi YBÜ kayıtları geriye dönük olarak incelendi. TBH'li hastalar saptanarak yoğun bakım maliyetleri ve sağkalım sonuçları değerlendirildi.

BULGULAR

Çalışma grubu 126 hastadan oluşmaktadır ve bu hastaların %27,8'ine cerrahi girişim uygulanmıştır. Erkek cinsiyet (%80,2) daha sıktır, YBÜ'de kalış süresi ortalama 9,8±8,7 gündür ve motorlu taşıt yaralanmaları (%59,5) YBÜ'ye kabuldeki en önemli nedendir. Mortalite oranı %50 ve Glaskow Koma Skoru (GKS) ortalaması 6,1±1,9 olarak bulunmuştur. Ortalama yoğun bakım kalış maliyeti 4846±5084 $'dır. Kurtarılan her bir yaşam maliyeti ve kazanılan her bir yaşam yılı maliyeti sırasıyla 9533 $ ve 313,6 $ olarak hesaplandı. Yaralanma tipleri arasında sağkalım oranları istatistiksel anlamlı farklı bulundu (p=0,010). GKS'nin olguların sağkalım sonuçlarını kestirmede prognostik bir faktör olduğu saptandı (Hazard Oranı: 0,643; %95 GA: 0,529-0.781; p<0,001).

SONUÇ

TBH'nin yoğun bakım maliyetleri oldukça yüksek bulunmuştur, ayrıca yüksek düzeyde mortalite oranına da sahiptir.

Anahtar Sözcükler: Maliyet analizi; yoğun bakım; sağkalım; travma; travmatik beyin hasarı.

Department of Biostatistics, Trakya University Faculty of Medicine, Edirne, Turkey.

Trakya Üniversitesi Tıp Fakültesi Biyoistatistik Anabilim Dalı, Edirne.

Correspondence *(İletişim):* Necdet Süt, M.D. Trakya Üniversitesi Tıp Fakültesi Biyoistatistik Anabilim Dalı, 22030 Edirne, Türkiye.
Tel: +90 - 284 - 235 76 41 Fax *(Faks)*: +90 - 284 - 235 76 52 e-mail *(e-posta):* necdetsut@yahoo.com

Traumatic Brain Injury (TBI) is caused by a blow or a jolt to the head or a penetrating head injury that disrupts the normal function of the brain,[1] and it is a leading cause of death and disability.[2] TBI affects about 0.7-0.8 million persons of a total 67.8 million[3] persons in Turkey and requires hospitalization in an estimated 250,000 patients[4] each year. However, in the United States (US), TBI affects 1.5 to 2.0 million persons each year.[5,6] Almost a quarter of these patients require hospitalization, and about 52,000 of these events result in death;[2,6,7] the prevalence rate for TBI is approximately 0.2%. In addition to mortality and disability, the economic consequences of TBI are also substantial. In the US in 1985, lifetime medical care costs of TBI were estimated to total $4.5 billion, including $3.5 billion in hospital costs alone.[6,8] The annual economic burden of TBI to society was estimated to be approximately $37.8 billion.[8] In 2000, direct medical costs and indirect costs, such as lost productivity, of TBI totaled an estimated US $60 billion in the US.[9]

Even though the economic burden of TBI to society is high, there have been few studies to estimate the intensive care unit (ICU) cost[10] and overall cost[6,8,11-14] of TBI. In Turkey, the economic consequences and survival outcomes of TBI have not been examined to date. Cost analyses and modelling studies can help to develop a strategy in order to evaluate practice guidelines and care maps in ICUs.[15]

In this study, we aimed to examine intensive care costs and survival outcomes in patients with TBI.

MATERIALS AND METHODS

Patients with TBI treated at Trakya University Hospital from 2002 to 2006 were reviewed retrospectively from the ICU records. One hundred and twenty-six patients with TBI admitted to the ICU were included in the study. According to the primary admission problems, the patients were divided into: (i) motor vehicle crash (59.5%); (ii) fall injury (30.2%); or (iii) miscellaneous (gunshot injury=4.8%, blow to head injury=4.0%, crashing injury=1.5%).

The study protocol was approved by the local ethics committee.

Cost Assessment

Direct medical ICU costs of TBI (such as medication, laboratory tests and diagnostic imaging, etc.) were calculated. The total direct medical cost per patient for each resource item was calculated according to the following formula:

Total direct cost = $\sum$ unit cost x resource use.[16]

They were assessed retrospectively by evaluating hospital records for the previous years. These data included the costs of: a) medications, b) diagnostic tests (such as biochemical and radiological tests), c) equipment, and d) intensive care stay. The total dose for the medications was assessed according to the dose prescribed in the patient charts. The unit cost per medication was based on the pharmacy market prices set by the Ministry of Health of Turkey for those years. The costs of diagnostic tests and hospitalization (including bed, medication, consultation, etc.) were calculated according to the standard unit price list, provided by the accounts department of the Trakya University Medical Faculty Hospital.

All costs were expressed as US dollars using the mean annual purchasing power parity values of Turkey from 2002 to 2006 (1 US$= 1.51, 1.50, 1.43, 1.35 and 1.56 TL, respectively).[17]

Costs per life saved and per life-year saved were calculated. In order to calculate per life-year saved, life expectancy at birth in Turkey was obtained from the World Health Report 2005,[18] and was 68 years for males and 73 years for females. Calculation of per life-year saved for overall TBI is shown in the appendix; calculations by operation status of TBI were done in the same manner.

Statistical Analysis

The numeric results were expressed as min-max (mean±sd) median, and categorical results were expressed as a number (percentage). Normality distribution of the variables was tested using one sample Kolmogorov-Smirnov test. Differences between groups were assessed using the Mann-Whitney U test due to the non-normal distribution. The chi-square test was used to compare the differences of categorical variables among the groups. The Kruskal-Wallis test was used to compare differences among groups due to non-normal distribution and then the Bonferroni post-hoc test was used when a significant difference was found. The survival time was determined using the Kaplan-Meier survival analysis. Prognostic effects of the variables were examined using Cox proportional hazards model. A p-value <0.05 was considered as statistically significant. Statistica 7.0 (StatSoft Inc. Tulsa, OK, USA) statistical software was used for statistical analyses.

Survival Analysis

Survival analysis is a collection of statistical procedures for data analysis for which the outcome variable of interest is time until an event occurs.[19] The event can be death, disease presence, relapse from remission, or rejection of transplantation.

Kaplan-Meier survival analysis

Kaplan-Meier (KM) survival analysis is a method that estimates survival rates, plots or hazard functions for time to event data. Time to event data might include, for instance, time to a report of symptomatic

Table 1. Sample characteristics of the patients

	Total (n=126)	Survivor (n=63)	Non-survivor (n=63)	p
Age, years	34.5±20.4	30.6±17.6	38.4±22.2	0.029
Sex, male	101 (80.2)	49 (77.8)	52 (82.5)	0.655
Operation status, yes	35 (27.8)	21 (33.3)	14 (22.2)	0.164
Length of stay, days	9.8±8.7	10.5±7.5	9.2±9.9	0.059
Mechanic ventilation, days	8.2±8.4	8.0±7.0	8.5±9.6	0.926
Glasgow Coma Score	6.1±1.9	6.9±1.9	5.3±1.7	<0.001
Cause of injury				
Motor vehicle crash	75 (59.5)	41 (65.1)	34 (54.0)	
Fall	38 (30.2)	13 (20.6)	25 (39.7)	0.041
Miscellaneous	13 (10.2)	9 (14.3)	4 (6.3)	

Mean±SD; n (%).

relief following a treatment or time to making a contribution following receipt of a fund-raising appeal.[20]

Survival rates over time might be estimated when patients drop out or are studied for different lengths of time. Estimated survival rates are computed using a product limit formula.[19]

Kaplan-Meier models survival based only on time dependence, without covariate effects, and it is assumed that event probabilities depend only on time. If covariates other than time are thought to be important in determining duration to outcome, KM results will be misleading. In this situation, Cox proportional hazards model, which incorporates covariates, should be preferred.[20]

Cox proportional hazards model

Cox proportional hazards model is a popular mathematical model used for analyzing survival data.[19] This model is designed for analysis of time until an event or time between events. One or more predictor variables, called covariates, are used to predict a status (event) variable. The classic univariate example is time from diagnosis with a terminal illness until the event of death. The central statistical output is the hazard ratio. Assumptions of Cox proportional hazards model are: True starting time, clearly defined events, absence of outliers, no small samples, proper model specification, independent observations, not applying single-event models to multiple-event data, exogenous covariates, factor invariance, baseline distribution of survival times, hazard rate linearity, log linearity, no high multicollinearity, random sampling, and no censoring patterns.[20]

RESULTS

We studied 126 consecutive patients (101 male/25 female) admitted to the ICU between January 2002 and December 2006. The characteristics of the patients who were admitted to the ICU due to TBI are shown in Table 1 at baseline and by survival status (survivor vs. non-survivor). The mean age was 34.5±20.4 years and male gender (80.2%) was significantly dominant. The Glasgow Coma Score (GCS) was 6.1±1.9 and length of stay was 9.8±8.7 days. Of the patients, 63 (50%) died in the ICU, and of the deaths, 17 (27%) occurred in the first 48 hours. In the non-survivors group, age was significantly higher (p=0.029) while GCS was significantly lower (p<0.001) than in the survivor group. The major reason for ICU admission was motor vehicle injury (59.5%), and mortality rate in the miscellaneous category was significantly lower than in the motor vehicle crash and fall injuries categories (p=0.041). Sex, operation status, length of stay, and mechanical ventilation days were not significantly different between survivors and non-survivors (p>0.05 for all comparisons).

Total costs and costs according to survival outcome are shown in Table 2. Mean stay and daily intensive care costs of TBI were US$ 4846±5084 and US$ 575±471, respectively. Costs per life saved and per life-year saved were calculated as US$ 9533 and US$ 313.60, respectively. Stay/daily costs were not significantly different between survivors and non-survivors (p>0.05 for all comparisons).

Costs, costs per life saved, and costs per life-year saved are shown in Table 3 by causes of injury. Daily

Table 2. Total costs and costs according to survival outcome

	Total (n=126)	Survivors (n=63)	Non-survivors (n=63)	p
Daily cost[a]	14-2890 (575±471) 459	17-2571 (538±422) 439	14-2990 (613±519) 494	0.620
Stay costs[a]	205-34305 (4846±5084) 3093	205-19181 (4986±4161) 4067	244-34305 (4701±5922) 2836	0.221

[a] US dollar; Min-Max (Mean±SD) Median.

Table 3. Costs according to causes of traumatic brain injury

	Motor Vehicle Crash (n=75)	Fall (n=38)	Miscellaneous (n=13)	p
Daily cost[a]	14-2890 (582±473) 471	51-2571 (561±545) 418	286-1003 (576±193) 596	0.220
Stay costs[a]	244-22300 (4646±4872) 3018*	205-13572 (3791±3013) 2947*	858-34305 (8791±8355) 7428	0.021
Cost per life saved[a]	8578	10207	12698	–
Cost per life-year saved[a]	272.5	312.9	667.5	–

[a] US dollar; Min-Max (Mean±SD) Median; * p<0.05 compared with miscellaneous.

costs were similar among causes of injury; however, cost per ICU stay was higher among those in the miscellaneous group (US$ 8791±8355) compared with those in motor vehicle crash (US$ 4646±4872) and fall (US$ 3791±3013) groups (p=0.021).

Median overall survival of patients with TBI was 14 days (Std. Error=2.2; Fig. 1), and survival rate was 88.0% at 48 hours. Fig. 2 shows the Kaplan-Meier survival curves of patients with TBI by causes of injury. The median survival times for fall, motor vehicle and miscellaneous injuries were 10 (Std.Error=2.3), 15 (Std.Error=3.6) and 59 (Std.Error=0) days, respectively. Survival rates were significantly different among injury types (p=0.010). There was a statistically significant difference between fall and miscellaneous injuries (p=0.004); however, there were no statistically significant differences between motor vehicle crash and fall injuries (p=0.064), or between motor vehicle crash and miscellaneous injuries (p=0.079). Survival rates for motor vehicle, fall and miscellaneous injuries were 85.1%, 92.1% and 92.3%, respectively, at 48 hours, whilst they were 69.2%, 52.4% and 92.3%, respectively, at the seventh day.

As shown in Table 4, among the different variables (age, sex, operation status, injury type and GCS) entered in the multivariate Cox proportional hazard models, only GCS appeared to be a prognostic parameter in patient survival (hazard ratio [HR]: 0.643; 95% confidence interval [CI]: 0.529-0.781; p<0.001).

DISCUSSION

The main findings of this study are: (i) the average intensive care cost of TBI per day and per stay in the ICU of a university hospital in Turkey were estimated as US$ 575 and US$ 4846, respectively; (ii) Average costs per ICU stay for survivor and non-survivor cases were estimated as US$ 4986 and US$ 4701, respectively; (iii) of the patients, 50.0% died in the ICU and fall injury had the highest mortality; (iv) motor vehicle injury (59.5%) was the major reason for ICU admission; and (v) costs per life saved and per life-year saved were calculated as US$ 9533 and US$ 313.60, respectively.

There are several limitations to this study. Data were obtained retrospectively and from a single ICU. Therefore, it may not be representative of all TBI patients, and the inclusion of additional data might change the results. Furthermore, our sample size was relatively small. Results of the present study might be representative of intensive care costs of TBI patients in Turkey, but one needs to be careful in interpreting the estimated costs, due to the fact that the study was conducted in the ICU of a university hospital.

Brain injury is the largest single cause of death in the acute phases of care of trauma patients.[2] Although the economic burden of TBI to society is substantial,

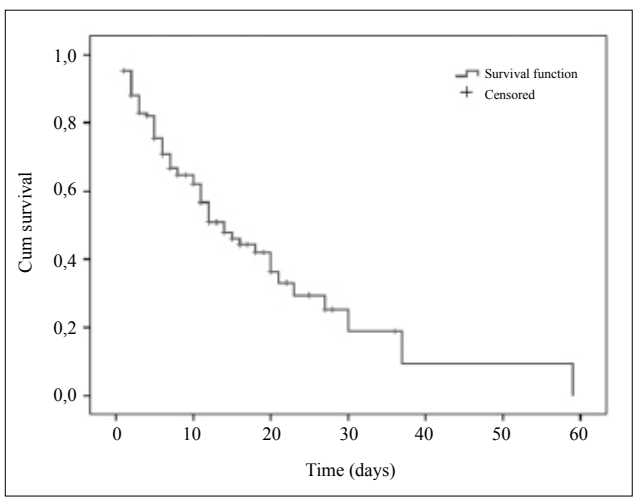

Fig. 1. Overall survival functions of patients with traumatic brain injury.

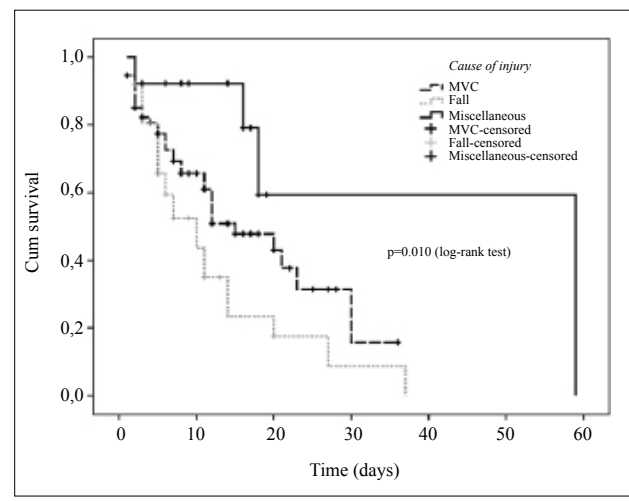

Fig. 2. Survival functions of patients with traumatic brain injury by causes of injury.

Table 4. Cox regression model according to entered variables in patients with traumatic brain injury

	p	Hazard Ratio	95% Confidence Interval
Age	0.187	1.008	0.996-1.021
Sex	0.090	1.820	0.910-3.637
Operation status	0.277	1.444	0.745-2.797
Injury type			
Fall	0.327	1.835	0.545-6.171
Miscellaneous	0.064	3.162	0.933-10.716
GCS	**<0.001**	0.643	0.529-0.781

Reference categories are: motor vehicle crash for injury type, operated for operation status, female for sex.
GCS: Glasgow Coma Score.

there have been only a few studies[2,6,10,21] conducted to estimate the costs of TBI (in the US, Australia and New Zealand). TBI requires hospitalization in an estimated half million persons[22] each year (incidence rate 0.2%), and hospitalization costs were estimated as approximately $3.5 billion in 1985 in the US.[8] In Turkey, TBI has a higher incidence (0.36%) and requires hospitalization in an estimated quarter million persons[4] annually, but to date, its economic consequences have not been examined. Therefore, in the present study, we sought to ascertain ICU costs and survival outcomes of patients with TBI.

Consistent with prior researches,[2,5,6,8,11,22-25] male gender (80.2%) was dominant and motor vehicle crashes (59.5%) were the most common mechanisms of TBI.

Intensive care costs were not significantly different between operated and non-operated groups. On the basis of our results regarding intensive care cost per life saved and per life-year saved, intensive care of TBI seems feasible.

When we compared the intensive care cost of TBI with other countries, some differences were shown. In the present study, mean intensive care cost was calculated as US$ 4846; however, it was calculated as US$ 10725 (A$ 14150; 1 US$= A$ 1.3194) in New Zealand.[10] In the US,[2] the hospital cost of TBI, which included ICU costs, was calculated as US$ 28428. These differences probably arise from the ICU facilities of these hospitals, or patient characteristics, or the lower purchasing power and health expenditures in Turkey.

In conclusion, in the present study, the mean ICU cost (US$ 4846) of TBI seems to be low; however, the economic effects of TBI for patients and health care payers seem substantial, due to the fact that gross national income per capita based on purchasing power of parity for the year 2007 is US$ 8020.[26]

REFERENCES

1. National Center for Injury Prevention and Control. Available from URL: http://www.cdc.gov/ncipc/tbi/#PDF [accessed 10 Jully 2008].
2. Fakhry SM, Trask AL, Waller MA, Watts DD; IRTC Neurotrauma Task Force. Management of brain-injured patients by an evidence-based medicine protocol improves outcomes and decreases hospital charges. J Trauma 2004;56:492-500.
3. Turkish Statistical Institute. Available from URL: http://www.tuik.gov.tr / PreIstatistikTablo.do?istab_id=192 [accessed 15 January 2008].
4. Saip S. Posttravmatik baş ağrıları. Available from URL: http://www.ctf.edu.tr/stek/pdfs/39/3907.pdf [accessed 19 January 2007].
5. Sosin DM, Sniezek JE, Thurman DJ. Incidence of mild and moderate brain injury in the United States, 1991. Brain Inj 1996;10:47-54.
6. McGarry LJ, Thompson D, Millham FH, Cowell L, Snyder PJ, Lenderking WR, et al. Outcomes and costs of acute treatment of traumatic brain injury. J Trauma 2002;53:1152-9.
7. Sosin DM, Sniezek JE, Waxweiler RJ. Trends in death associated with traumatic brain injury, 1979 through 1992. Success and failure. JAMA 1995;273:1778-80.
8. Max W, Mackenzie EJ, Rice DP. Head injuries: costs and consequences. J Head Trauma Rehabil 1991;6:76–91.
9. Finkelstein E, Corso P, Miller T. The Incidence and economic burden of injuries in the United States. New York (NY): Oxford University Press; 2006.
10. Havill JH, Sleigh JW, Kersel DA, Marsh NV. Profile and cost of head injury patients admitted to the Waikato Hospital Intensive Care Unit. N Z Med J 1998;111:161-3.
11. Kreutzer JS, Kolakowsky-Hayner SA, Ripley D, Cifu DX, Rosenthal M, Bushnik T, et al. Charges and lengths of stay for acute and inpatient rehabilitation treatment of traumatic brain injury 1990-1996. Brain Inj 2001;15:763-74.
12. Brooks CA, Lindstrom J, McCray J, Whiteneck G. Cost of medical care for a population-based sample of persons surviving traumatic brain injury. J Head Trauma Rehabil 1995;104:1-13.
13. Lehmkuhl LD, Hall KM, Mann N, Gordon WA. Factors that influence costs and length of stay of persons with traumatic brain injury in acute care and inpatient rehabilitation. J Head Trauma Rehabil 1993;8:88-100.
14. Sut N, Memis D. Intensive care costs of acute poisoning cases. Clin Toxicol (Phila) 2008;46:457-60.
15. Süt N, Türe M, Şenocak M. Sağlık alanında karar vermede döngüsel süreçlerin kullanımı: Bir markov model uygulaması. Trakya Üniversitesi Tıp Fakültesi Dergisi 2007;24:109-13.
16. Sut N, Seyahi E, Yurdakul S, Senocak M, Yazici H. A cost analysis of Behcet's syndrome in Turkey. Rheumatology (Oxford) 2007;46:678-82.
17. Central Bank of the Republic of Turkey Exchange Rates.

Available from URL: www.tcmb.gov.tr [accessed 15 February 2007].
18. The World Health Report 2005. Available from URL: http://www.who.int/whr/2005/annexes-en.pdf [accessed 25 January, 2007].
19. Kleinbaum DG. Survival analysis: A self-learning text. New York: Springer; 1995.
20. Survival Analysis. Available from URL: www2.chass.ncsu.edu/garson/pa765, [accessed 19 January 2008].
21. Bennett BR, Jacobs LM, Schwartz RJ. Incidence, costs, and DRG-based reimbursement for traumatic brain injured patients: a 3-year experience. J Trauma 1989;29:556-65.
22. Thurman D, Guerrero J. Trends in hospitalization associated with traumatic brain injury. JAMA 1999;282:954-7.
23. Masson F, Thicoipe M, Aye P, Mokni T, Senjean P, Schmitt V, et al. Epidemiology of severe brain injuries: a prospective population-based study. J Trauma 2001;51:481-9.
24. Centers for Disease Control and Prevention (CDC). Traumatic brain injury--Colorado, Missouri, Oklahoma, and Utah, 1990-1993. MMWR Morb Mortal Wkly Rep 1997;46:8-11.
25. High WM, Hall KM, Rosenthal M, Mann N, Zafonte R, Cifu DX, et al. Factors affecting hospital length of stay and charges following traumatic brain injury. J Head Trauma Rehabil 1996;11:85-96.
26. World Bank, World Development Indicators database –GNI per capita 2005 - Available from URL: http://siteresources.worldbank.org/DATASTATISTICS/Resources/GNIPC.pdf [accessed on 14 July 2008].