Evaluation of intensive care performance in hospitals

Hastanelerde yoğun bakım servislerinin performanslarının değerlendirilmesi

Intensive care performance

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Öz

Amaç: Bu çalışmanın amacı, Kocaeli ili merkez ve ilçelerinde yer alan kamu hastanelerinin yoğun bakım servislerinin performansları açısından değerlendirilmesi ve karşılaştırılmasıdır. Gereç ve Yöntem: Bu amacı gerçekleştirmek için toplam 9 hastanenin 2016 yılına ait yoğun bakım verileri gri ilişkisel analiz yöntemiyle değerlendirilmiştir. Bulgular: Yapılan analiz sonucunda; yoğun bakım mortalite oranının en düşük olduğu; ventilatör başına bağlı kalan hasta sayısının, ventilatör başına bağlı kalınan gün sayısının, yoğun bakım yatağı başına yatılan gün sayısının, yoğun bakım yatağı başına taburcu edilen hasta sayısının, hemşire başına yoğun bakımdan taburcu edilen hasta sayısının ve yatak doluluk oranının en yüksek olduğu birinci sıradaki hastane 0,77 gri ilişkisel derece ile A Hastanesi olmuştur. Tartışma: Bu araştırmada kullanılan gri analiz yönteminin farklı hastanelerin yoğun bakım ünitelerinin performanslarını karşılaştırmak için kullanılabileceği gösterilmiştir.

Anahtar Kelimeler

Yoğun Bakım; Performans; Gri İlişkisel Analiz; Hastane

Abstract

Aim: The purpose of this study is to evaluate and compare the performances of intensive care units in public hospitals located in Kocaeli province (its central district and other districts). Material and Method: To this end, the intensive care data of nine hospitals from the year 2016 were evaluated through grey relational analysis method. Results: At end of the analysis, Hospital A was found to have the intensive care with the highest grey relational degree (0.77): the lowest intensive care mortality rate, the biggest number of; patient dependent on each ventilator, days with a patient dependent on each ventilator, days with a patient hospitalized per intensive care bed, patients discharged per intensive care bed, patients discharged from intensive care per nurse, and the highest occupancy rate. Discussion: It was revealed that grey analysis method applied in the present study can be used for comparing the intensive care units of different hospitals as well.

Keywords

Intensive Care; Performance; Grey Relational Analysis; Hospital

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Introduction

An intensive care unit (ICU) is a department of a hospital that uses the most advanced technology for critical patients and high-risk patients and provides aggressive treatments by use of invasive and noninvasive interventions [1]. Recently, a fast, considerable increase has taken place in the number of intensive care beds in Turkey. According to the most recent statistics published by the Ministry of Health, total number of intensive care beds which was 20,977 in 2011 (The Ministry of Health + university + private hospitals) rose to 31,525 in 2015 [2]. Given the current increase and costs, efficient and effective service offered in intensive care units has become a priority issue for health managers, especially in the context of use of resources. Also, performance measurement and financial incentives are highly interrelated in the field of health care services [3-4].

Performance measurement is an instrument used for monitoring and controlling organizational activities for establishments and units to accomplish the predetermined objectives [5]. Performance is measured by evaluating the effectiveness and efficiency of the activities conducted [6]. The present study specifically focuses on performance measurement in intensive care units. The literature review shows that the performance of intensive care units are measured through diagnostic scoring systems such as "Acute Physiology and Chronic Health Evaluation (APACHE)" [7-8]; "Simplified Acute Physiology Score (SAPS)" [9-10-11], or "Mortality Prediction Model (MPM)" [12-13] as well as "Analytical Hierarchy Process (AHP)" [14] and "Data Envelopment Analysis (DEA)" [15-16]. Diagnostic scoring systems involve logistic regression equations that make mortality estimates for case mixes in specific intensive care units. In these studies, the ratio of estimated mortality to observed mortality (standardized mortality ratio - SMR) was used for comparing the performances of different intensive care units [32]. AHP employs a multidimensional quantitative performance measurement model [14]. Apart from these methods, data envelopment analysis, TOPSIS, and grey relational analysis are among the multi-criteria decision-making methods that can be used.

Grey relational analysis technique was deemed suitable for the present study because the number of the variables used was small, and evaluation criteria were based on maximum or minimum rather than input and output approach. Also, grey relational analysis technique is frequently adopted when the sample is small, and there is not enough information about the sample. With the use of this method, the study aimed to evaluate and compare the performances of intensive care units of nine public hospitals providing service in Kocaeli province.

Grey Relational Analysis

Grey relational analysis (GRA) is a relatively new analysis method that was developed by Professor Deng Julong Huazhong in the People's Republic of China based on the grey system theory. The main point of GRA is to find a grey relational order that can be used for defining the relationships between the relevant factors depending on data series. When sample size is not large enough, GRA can be used instead of linear relationship and typical distribution [17].

Systems with imperfect information are defined as grey systems. The application purpose of the grey system is to lay a bridge between social sciences and natural sciences. Thus, it is possible to say that it is a point of intersection for different disciplines. The grey system theory is applied in a variety of fields such as agriculture, ecology, economy, management, history, geography, and law [18]. The number of studies employing grey analysis in the field of heath care services is rapidly increasing as well [17-19-20-21-22].

The grey system theory focuses on problems that have a small sample and involve insufficient information. According to Professor Julong Deng, its founder, the system has six basic principles: information differences, non-uniqueness, minimal information, recognition base, new information priority, and absolute greyness [23]. GRA, which is part of the grey system theory, is a multi-criteria decision-making technique that allows measuring the relationship and ordering depending on the degree of similarity or difference of the trends between the components [24]. The steps to be followed for ordering the alternatives through GRA are presented below [25].

Step 1. Creating the reference series

$$x_0 = \left(x_0(1),\ x_0(2),\ x_0(3) \dots, x_0(j) \dots, x_0(n)\right)$$

j referring to units and x_i referring to comparison series

$$\left(x_i(1),\ x_i(2) \dots, x_i(j) \dots, x_i(n)\right), \text{i= 1,2,3…m}$$

x_i comparison series can be expressed by use of matrix form as follows;

$$X_i = \begin{bmatrix} x_1(1) & \dots & x_1(n) \\ \vdots & \dots & \vdots \\ x_n(1) & \dots & x_m(n) \end{bmatrix}$$

Step 2. Normalizing the dataset

A dataset can be evaluated in three different ways: 1) the approach in which the maximum score is better; 2) the approach in which the minimum score is better; and 3) the approach in which the ideal value is better. There are different formulations of normalization for each type.

max χ_i (j): The maximum value in the unit subject to ordering
max $\chi_i^{(j)}$ (j):: The minimum value in the unit subject to ordering
x 0b (j): The ideal value to be determined for the unit subject to ordering

The conversion formula in which higher scores are accepted better

$$x_i'(j) = \frac{x_i\ \ (j) - \min x_i^{(j)}(j)}{\max x_i^{(j)}(j) - \min x_i^{(j)}(j)} \qquad (1)$$

The conversion formula in which lower scores are accepted better

$$x_i'(j) = \frac{max\ x_i^{(0)}(j) - x_i^{(\ \ )}(j)}{\max x_i{}^j(j) - \min x_i^{(j)}(j)} \qquad (2)$$

The conversion formula in which the ideal score is accepted better

$$x_i'(j) = \frac{x_i^{(0)}(j) - x\,0b \quad (j)}{\max x_i{}^j(j) - \mathrm{x}\,0b \quad (j)} \qquad (3)$$

Also, the reference series values are normalized through the formula mentioned above. Following the normalization process, the data matrix turns out to be as follows:

$$X'_i = \begin{bmatrix} x'_1(1) & \dots & x'_1(n) \\ \vdots & \dots & \vdots \\ x'_n(1) & \dots & x_{,m}(n) \end{bmatrix}$$

Step 3. Creating the absolute value table

In this step, the absolute value Δ_{0i} (j) of the difference between x'_0 and x'_i is calculated.

$$\Delta_{0i}(j) = |x'_0(j) - x'_i(j)|$$

$$= \begin{bmatrix} \Delta_{01}(1) & \dots & \Delta_{01}(n) \\ \vdots & \dots & \vdots \\ \Delta_{0m}(1) & \dots & \Delta_{0m}(n) \end{bmatrix}$$

Step 4. Calculating the grey relational coefficient

The following formula is applied for calculating the grey relational analysis coefficient:

$$\gamma 0i(j) = \frac{\Delta_{min} + \delta\Delta_{max}}{\Delta_{0i}(j) + \delta\Delta_{max\wedge}}$$

Δ max= $\max_i \max_j \Delta_{0i}(j)$, Δ min= $\min_i \min_j \Delta_{0i}(j)$ and $\delta \in [0,1]$

Step 5. Calculating the grey relational degree

$$r(0i) = \frac{1}{n}\sum_{j=1}^{n} \gamma\left(x_0(j), x_i(j)\right)$$

$r(x_0, x_i)$ indicates the grey relational degree between and . The alternative having the highest grey relational degree with the reference series will be the series having the most similarity to the reference series, and so it will be the best option.

If weight is to be applied to evaluation criteria, the formula will be as follows:

$$r(0i) = \sum_{j=1}^{n} [Wi(j) * r0i(j)]$$

Material and Method

The population of the study consists of 11 public hospitals affiliated to Kocaeli Union of Public Hospitals. However, as two of them did not have data about intensive care use, the data of nine hospitals were included in the evaluation. The data of the study cover the period from January 2016 to December 2016. The performance criteria used in the study are as follows:

- the number of patients dependent on each ventilator,
- the number of days with a patient dependent on each ventilator,
- the number of days with a patient hospitalized per intensive care bed,
- the number of patients discharged per intensive care bed,
- the number of patients discharged from intensive care per nurse,
- total number of patients who died in intensive care unit
- intensive care occupancy rate,
- intensive care mortality rate.

Among these criteria, intensive care mortality rate was wished to be low, whereas others were wished to be high or big. The data of the study were analyzed via MS. Office Excel.

Results

Table 1 presents the hospitals whose intensive care units were put in order of performance regarding the criteria determined through the grey system approach and the reference values.

Normalization was made to prevent vast differences between the scores of the hospitals evaluated concerning the comparison criteria. While intensive care mortality rate was normalized through the second formula in Table 2, other criteria were normalized by the first formula.

Table 3 presents the values obtained through calculation of the absolute differences between the normalized reference series value and the normalized alternative values. The formula in the third step was used in calculations.

The values in Table 4 were obtained through the formula in the fourth step.

Δ max = 1 and Δ min = 0

γ coefficient was taken as 0.5 in accordance with the literature.

Table 5 presents the grey relational degree scores obtained through grey relational coefficients and ordering (from large to small) based on these scores. According to the ordering obtained, Hospital A was found to have the intensive care with the highest grey relational degree (0.77): the lowest intensive care mortality rate, the biggest number of; patients dependent on each ventilator, days with a patient dependent on each ventilator, days with a patient hospitalized per intensive care bed,

Table 1. Dataset and reference values of hospitals performance criteria

	Maks	Maks	Maks	Maks	Maks	Maks	Maks	Min
	The number of patients dependent on each ventilator	The number of days with a patient dependent on each ventilator	The number of days with a patient hospitalized per intensive care bed	The number of patients discharged per intensive care bed	The number of patients discharged from intensive care per nurse	Total number of patients who died in intensive care unit	Intensive care occupancy rate	Intensive care mortality rate
Reference	68.28	260.82	371.12	60.67	53.85	595.00	101.68	0.08
Hospital A	68.28	225.12	371.12	49.05	39.79	595.00	101.68	0.24
Hospital B	36.55	245.65	339.12	45.12	26.23	255.00	92.91	0.23
Hospital C	22.18	233.27	331.84	36.42	27.68	128.00	90.92	0.20
Hospital D	24.77	107.85	321.29	45.71	32.00	230.00	88.02	0.38
Hospital E	62.18	260.82	313.37	60.67	37.23	216.00	85.85	0.16
Hospital F	3.00	24.00	74.83	9.33	11.20	7.00	20.50	0.12
Hospital G	0.67	2.33	151.50	23.25	18.60	12.00	41.51	0.12
Hospital H	39.21	38.02	264.42	55.23	53.85	459.00	72.44	0.08

Table 2. Normalized values

	The number of patients dependent on each ventilator	The number of days with a patient dependent on each ventilator	The number of days with a patient hospitalized per intensive care bed	The number of patients discharged per intensive care bed	The number of patients discharged from intensive care per nurse	Total number of patients who died in intensive care unit	Intensive care occupancy rate	Intensive care mortality rate
Reference	1	1	1	1	1	1	1	1
Hospital A	1.00	0.86	1.00	0.77	0.67	1.00	0.00	1.00
Hospital B	0.53	0.94	0.89	0.70	0.35	0.42	0.11	0.53
Hospital C	0.32	0.89	0.87	0.53	0.39	0.21	0.13	0.32
Hospital D	0.36	0.41	0.83	0.71	0.49	0.38	0.17	0.36
Hospital E	0.91	1.00	0.81	1.00	0.61	0.36	0.19	0.91
Hospital F	0.03	0.08	0.00	0.00	0.00	0.00	1.00	0.03
Hospital G	0.00	0.00	0.26	0.27	0.17	0.01	0.74	0.00
Hospital H	0.57	0.14	0.64	0.89	1.00	0.77	0.36	0.57

Table 3. Absolute value table

	The number of patients dependent on each ventilator	The number of days with a patient dependent on each ventilator	The number of days with a patient hospitalized per intensive care bed	The number of patients discharged per intensive care bed	The number of patients discharged from intensive care per nurse	Total number of patients who died in intensive care unit	Intensive care occupancy rate	Intensive care mortality rate
Hospital A	0.00	0.14	0.00	0.23	0.33	0.00	1.00	0.00
Hospital B	0.47	0.06	0.11	0.30	0.65	0.58	0.89	0.47
Hospital C	0.68	0.11	0.13	0.47	0.61	0.79	0.87	0.68
Hospital D	0.64	0.59	0.17	0.29	0.51	0.62	0.83	0.64
Hospital E	0.09	0.00	0.19	0.00	0.39	0.64	0.81	0.09
Hospital F	0.97	0.92	1.00	1.00	1.00	1.00	0.00	0.97
Hospital G	1.00	1.00	0.74	0.73	0.83	0.99	0.26	1.00
Hospital H	0.43	0.86	0.36	0.11	0.00	0.23	0.64	0.43

Table 4. Gray relational data table (criteria equal weighted)

	The number of patients dependent on each ventilator	The number of days with a patient dependent on each ventilator	The number of days with a patient hospitalized per intensive care bed	The number of patients discharged per intensive care bed	The number of patients discharged from intensive care per nurse	Total number of patients who died in intensive care unit	Intensive care occupancy rate	Intensive care mortality rate	The number of patients dependent on each ventilator
Hospital A	1.00	0.78	1.00	0.69	0.60	1.00	0.33	1.00	0.77
Hospital B	0.52	0.89	0.82	0.62	0.44	0.46	0.36	0.52	0.59
Hospital C	0.42	0.82	0.79	0.51	0,45	0.39	0.37	0.42	0.54
Hospital D	0.44	0.46	0.75	0.63	0.49	0.45	0.38	0.44	0.51
Hospital E	0.85	1.00	0.72	1.00	0.56	0.44	0.38	0.85	0.71
Hospital F	0.34	0.35	0.33	0.33	0.33	0.33	1.00	0.34	0.43
Hospital G	0.33	0.33	0.40	0.41	0.38	0.34	0.66	0.33	0.41
Hospital H	0.54	0.37	0.58	0.83	1.00	0.68	0.44	0.54	0.63

Table 5. Sort of hospitals by gray relational Degree

	Grey relational degree	Sorting
Hospital A	0.77	1
Hospital B	0.59	4
Hospital C	0.54	5
Hospital D	0.51	6
Hospital E	0.71	2
Hospital F	0.43	7
Hospital G	0.41	8
Hospital H	0.63	3

patients discharged per intensive care bed, patients discharged from intensive care per nurse, and the highest occupancy rate. The hospital with the lowest grey relational degree (0.41) was found to be Hospital G. No weighting was done as equal importance was attached to all the performance criteria during ordering.

Discussion

In health care services, effectiveness is the measure of to what extent patients' needs are met, while efficiency is the measure of how economically the resources of an establishment are used for ensuring a particular level of patient satisfaction; that is, efficiency is about the use of resources and costs, whereas effectiveness is about reaching the best clinical results in the units where patients are served. Measures of effectiveness and efficiency are two important parts of performance evaluation. In the present study, the performances of the intensive care units of hospitals providing service in Kocaeli province were evaluated and compared regarding clinical results and use of resources.

Duration of hospitalization in a hospital or intensive care is a suitable measure of use of resources, which is commonly employed [26-27-28-29-30]. Examining mortality rates and durations of staying in intensive care together brings synergy to the evaluation of the effectiveness of intensive care units. Mortality rates may stand as an indicator of clinical performance, and a patient's duration of staying in intensive care may be an indicator of use of resources. When they are evaluated together, the efficiency of a unit may be showed [30]. In the present study, in addition to the measures of duration of staying in intensive care as to the use of resources (the number of days with a patient hospitalized per intensive care bed, the number of patients discharged per intensive care bed, intensive care occupancy rate), the use of ventilator in intensive care (the number of patients dependent on each ventilator) and the number of nurses (the number of patients discharged from intensive care per nurse) were included in evaluation. Moreover, as a negative value, mortality rates were examined for each intensive care unit. The data from the last one-year period were analyzed for each intensive care unit.

According to the results obtained from the analyses, when the performances of the intensive care units were ordered in terms of the criteria determined, Hospital A was seen to rank first with the biggest number of; patients dependent on each ventilator, days with a patient dependent on each ventilator, days with a patient hospitalized per intensive care bed, patients discharged per intensive care bed, patients discharged from intensive care

per nurse, the highest occupancy rate, and the lowest mortality rate (grey relational degree: 0.77).

As the results of the present study allow the comparison of the performances of intensive care units of health establishments, they will be guiding for future efforts for improvement and development. Furthermore, these kinds of studies provide information to establishments providing health care services and their managers so that they can check and monitor the performances of intensive care units. As grey analysis was adopted for data evaluation in the present study, the case mix of the patients admitted to intensive care and the differences in institutional factors were not taken into consideration, and no risk adjustments were made for them. We recommend making these kinds of risk adjustments for mortality rates that are to be used for evaluating intensive care performance in future research.

The main purpose of performance measurement system is to ensure continuous improvement and enhance organizational performance. Choosing appropriate factors (sub-factors and factors under them), using a suitable quantitative measurement framework, and employing clear methodological steps for practices are critically important to achieve success in this regard. It was revealed that grey analysis method applied in the present study can be used for comparing the intensive care units of different hospitals as well.

The results of this study have limitations on generalization to all intensive care units. The sample of the study consists of intensive care units in public hospitals and Kocaeli province. And also, the research only covers one year period. Future studies with larger samples and wider time periods are expected to produce more effective results.

Compliance with Ethical Standards

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

Ethical Approval

Not required for this study. However written permission was received from Kocaeli Union of Public Hospitals before the investigation.

Competing interests

The authors declare that they have no competing interests.

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