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Comprehensive Evaluation of Esophageal Cancer Surgical Treatment Quality in Tertiary Hospitals of a Prefecture-level City Using the TOPSIS Method

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Abstract: This study employed the TOPSIS method to conduct a comprehensive evaluation of the esophageal cancer surgical treatment quality in tertiary hospitals of a prefecture-level city in China from January to September 2023. The analysis aims to provide data support for health administrative departments and hospitals, guiding the optimization of future treatment strategies. The results reveal that among the participating hospitals, Hospital 8 had the highest treatment quality, while Hospital 2 had the lowest. Based on these findings, we recommend accelerating the development and accreditation of relevant disciplines in underperforming hospitals to promote the standardization and regulation of esophageal cancer diagnostics and treatment, thereby improving overall treatment outcomes.

Keywords: TOPSIS method; Comprehensive Evaluation; Esophageal Cancer.

1. Research Background

Esophageal cancer is one of the more prevalent malignancies globally. According to the World Health Organization, it accounts for approximately 570,000 new cases annually, making it the sixth leading cause of cancer-related deaths. The incidence rates of esophageal cancer are particularly high in Asia, Eastern Europe, and Southern Africa. In China, due to dietary habits and genetic factors, the incidence of esophageal cancer remains high globally. This high incidence rate necessitates deeper insights into the prevention, diagnosis, and treatment of esophageal cancer.

Esophageal cancer is primarily categorized into two histological types: squamous cell carcinoma and adenocarcinoma. Squamous cell carcinoma is commonly associated with smoking, alcohol consumption, and the intake of hot foods, whereas adenocarcinoma is more often linked to gastroesophageal reflux disease and obesity. These types differ in their biological behavior, treatment approaches, and prognosis, making a detailed understanding of their diagnostic, pathological mechanisms, and treatment strategies crucial for improving treatment outcomes.

In recent years, there have been significant advances in the treatment of esophageal cancer. Surgery remains the most effective method for local control of the disease, while adjunctive therapies such as radiotherapy and chemotherapy can improve survival rates post-surgery. Additionally, the use of targeted therapies and immunotherapies has provided new hope for patients with advanced esophageal cancer. For example, drugs targeting the epidermal growth factor receptor (EGFR) and immune checkpoint inhibitors have shown promising results in some patients.

2. Data Sources and Methods

(1) Data Sources

The data used in this study were sourced from the Health Insurance Bureau of a city in China, ensuring authenticity and reliability. Through literature review, we selected 11 key indicators to build a comprehensive evaluation system for the quality of esophageal cancer treatment. These indicators, widely considered important for assessing medical quality, cover four dimensions: treatment efficiency, cost-effectiveness, safety, and clinical outcomes. The aim is to comprehensively evaluate the quality of esophageal cancer treatment across hospitals.

(2) Indicator Definition and Selection Rationale

Discharges: The number of esophageal cancer patients who completed treatment and were discharged during the evaluation period. A higher number of discharges generally correlates with larger hospital size and clinical experience, serving as an essential indicator of a hospital's capacity to manage complex cases.

Length of Stay: Reflects the average number of days patients stayed in the hospital from admission to discharge. A shorter length of stay may indicate a more efficient treatment process and management system.

Average Cost per Stay: The average cost incurred per patient admission, highlighting the economic burden of treatment. This metric helps assess the cost efficiency of hospitals.

Average Medication Costs: The average expenditure on medications during a patient’s hospital stay, measuring the economic burden of drug treatment.

Average Material Costs: The average cost of medical materials used during a patient’s stay, reflecting the hospital's efficiency in using medical resources.

31-Day Readmission Rate: The proportion of patients readmitted for the same reason within 31 days after discharge, an important indicator of the durability of the hospital's treatment effects and patient satisfaction.

Antibiotic Usage Days: Represents the average number of days antibiotics were used by patients during their stay, with fewer days suggesting effective infection control and rational antibiotic management.

Cost of Antibiotics: The average cost of antibiotics used during a patient's hospital stay, combined with the number of antibiotic usage days, reflects the hospital's performance in infection control and drug management.

Number of Surgeries per Admission: The number of surgeries a patient undergoes during a single hospital stay, with more surgeries potentially reflecting the management of more complex cases.

Complication Rate: The rate at which patients experience complications during treatment, a critical indicator of hospital safety in treatment.

Mortality Rate: The proportion of patients who die during their hospital stay, directly reflecting the safety and effectiveness of the hospital's treatment. A lower mortality rate typically indicates high-quality medical services and effective disease management.

(3) Research Methodology

This study employs the TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution), a decision-making approach that is popular for its simplicity and effectiveness in various fields. This method involves creating a decision matrix where each row represents an evaluation subject and each column represents an indicator. All indicators are first normalized to eliminate the influence of different scales and units. After normalization, the Euclidean distance of each option from the ideal best (the best values of all indicators) and the ideal worst (the worst values of all indicators) solutions is calculated. The options are then assessed by comparing these distances to determine the relative performance, selecting the option with the closest proximity to the ideal solution as the best choice.

The TOPSIS method, known for its simplicity and efficiency, has been applied across various fields. For instance, in supply chain management, TOPSIS is used to evaluate and select suppliers by considering multiple criteria such as cost, quality, and delivery time to determine the best supplier. In environmental management, the method is employed to assess different pollution control technologies, choosing the most suitable technology based on factors like economic cost, emission reduction efficiency, and implementation difficulty. Additionally, in human resources management, TOPSIS is utilized to evaluate and select employees, making decisions on promotions or rewards based on a comprehensive consideration of performance, skills, and experience.

This method effectively synthesizes an evaluation outcome from multiple indicators, which is particularly important for managing medical quality assessments that involve multiple standards. By applying this approach to the evaluation of esophageal cancer treatment quality, we can not only systematically analyze the overall performance of each hospital but also provide health administrative departments with a scientific tool for decision-making support. This assists them in making more informed choices regarding resource allocation and policy formulation.

TOPSIS Method Steps:

1.Normalization: Convert all indicators to a dimensionless form to ensure comparability between different metrics. During the comprehensive evaluation, it is essential that all indicators trend in the same direction. Low-performing indicators are converted to high-performing indicators using methods such as inversion or the difference method. The normalized data matrix is denoted by XX.

2. Construction of the Decision Matrix: Based on the normalized data, construct a decision matrix that includes all evaluation subjects and indicators.

$$Z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \qquad Z = \begin{bmatrix} Z_{11} & Z_{12} & \cdots & Z_{1m} \\ Z_{21} & Z_{22} & \cdots & Z_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ Z_{n1} & Z_{n2} & \cdots & Z_{nm} \end{bmatrix} \tag{1}$$

3.Calculation of Ideal Best and Worst Solutions: Identify the best and worst values for each indicator from the decision matrix Z, which forms the basis for determining distances.

Best Solution:

$$Z^+ = (Z_{i1\,max}, Z_{i2\,max}, \dots, Z_{im\,max}) \tag{2}$$

Worst Solution:

$$Z^+ = (Z_{i1\,min}, Z_{i2\,min}, \dots, Z_{im\,min}) \tag{3}$$

4.Calculation of Distances: For each hospital, compute the Euclidean distance to both the ideal best and worst solutions to assess its relative performance.

Distance to the Best Solution:

$$D_i^+ = \sqrt{\sum_{j=1}^{m} (Z_{ijmax} - Z_{ij})^2} \tag{4}$$

Distance to the Worst Solution:

$$D_i^- = \sqrt{\sum_{j=1}^{m} (Z_{ijmin} - Z_{ij})^2} \tag{5}$$

5.Determination of Relative Closeness: By comparing the distances to the best and worst solutions, rank all hospitals. The hospitals are sorted by the closeness coefficient CiCi, where a larger CiCi value indicates a better overall performance.

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{6}$$

3. Results

This study evaluated the performance of tertiary hospitals in a prefecture-level city in esophageal cancer treatment from January to September 2023. The analysis, as shown in Table 1, assessed 11 indicators. The number of discharges was considered a positive indicator (higher is better), whereas the length of stay, average cost per stay, average medication costs, average material costs, 31-day readmission rate, days of antibiotic use, cost of antibiotics, number of surgeries per admission, complication rate, and mortality rate were considered negative indicators (lower is better).

In this study, for indicators like the length of stay, average cost per stay, average medication costs, average material costs, days of antibiotic use, cost of antibiotics, and number of surgeries per admission, which are absolute non-zero values, the inverse method was used to convert them to high-performing indicators. For the 31-day readmission rate, complication rate, and mortality rate, some data points were zero and relative values; the difference method was used for conversion, and appropriate positive integers were multiplied to scale the transformed values between 0 and 100.

Table 1. Quality Indicators for Esophageal Cancer Treatment in Tertiary Hospitals of a City, January to September 2023.

Hospital	Discharges	Length of Stay	Average Cost per Stay	Average Medication Costs	Average Material Costs	31-Day Readmission Rate	Antibiotic Usage Days	Cost of Antibiotics	Number of Surgeries per Admission	Complication Rate	Mortality Rate
Hospital 1	61	19.02	106,498	25,248	41,625	4.92%	13.57	3,425	1.26	0	0
Hospital 2	15	28.73	113,495	21,460	38,314	0	18.27	3,146	1	6.67%	0
Hospital 3	6	21.5	62,007	10,679	17,786	0	12.83	1,291	1	0	0
Hospital 4	5	25	83,927	15,521	32,007	0	13.4	1,776	1.4	0	0
Hospital 5	106	22.35	97,888	13,552	32,253	2.83%	11.03	1,672	1.77	2.83%	0
Hospital 6	106	21.12	78,216	8,409	35,640	0.94%	12.09	1,633	1	14.15%	0.94%
Hospital 7	50	17.64	85,908	19,121	36,233	2.00%	9.36	3,192	1.04	10.00%	0
Hospital 8	5	14.4	81,901	11,051	64,454	0	4.6	778	1	0	0
Hospital 9	120	18.65	95,549	15,569	48,471	2.50%	8.89	1,868	1.08	11.67%	0

$$X = \begin{pmatrix} 61 & 5.26 & 9.39 & 3.96 & 2.4 & 0 & 7.37 & 2.92 & 7.92 & 14.15 & 0.94 \\ 15 & 3.48 & 8.81 & 4.66 & 2.61 & 4.92 & 5.47 & 3.18 & 10 & 7.48 & 0.94 \\ 6 & 4.65 & 16.13 & 9.36 & 5.62 & 4.92 & 7.79 & 7.75 & 10 & 14.15 & 0.94 \\ 5 & 4 & 11.92 & 6.44 & 3.12 & 4.92 & 7.46 & 5.63 & 7.14 & 14.15 & 0.94 \\ 106 & 4.47 & 10.22 & 7.38 & 3.1 & 2.09 & 9.07 & 5.98 & 5.64 & 11.32 & 0.94 \\ 106 & 4.73 & 12.79 & 11.89 & 2.81 & 3.97 & 8.27 & 6.12 & 10 & 0 & 0 \\ 50 & 5.67 & 11.64 & 5.23 & 2.76 & 2.92 & 10.68 & 3.13 & 9.62 & 4.15 & 0.94 \\ 5 & 6.94 & 12.21 & 9.05 & 1.55 & 4.92 & 21.74 & 12.85 & 10 & 14.15 & 0.94 \\ 120 & 5.36 & 10.47 & 6.42 & 2.06 & 2.42 & 11.25 & 5.35 & 9.23 & 2.48 & 0.94 \end{pmatrix}$$

$$Z = \begin{pmatrix} 0.29 & 0.35 & 0.27 & 0.17 & 0.26 & 0 & 0.23 & 0.15 & 0.29 & 0.45 & 0.35 \\ 0.07 & 0.23 & 0.25 & 0.21 & 0.28 & 0.43 & 0.17 & 0.16 & 0.37 & 0.24 & 0.35 \\ 0.03 & 0.31 & 0.46 & 0.41 & 0.61 & 0.43 & 0.24 & 0.39 & 0.37 & 0.45 & 0.35 \\ 0.02 & 0.26 & 0.34 & 0.28 & 0.34 & 0.43 & 0.23 & 0.29 & 0.27 & 0.45 & 0.35 \\ 0.51 & 0.30 & 0.29 & 0.33 & 0.33 & 0.18 & 0.28 & 0.30 & 0.21 & 0.36 & 0.35 \\ 0.51 & 0.31 & 0.36 & 0.53 & 0.30 & 0.35 & 0.25 & 0.31 & 0.37 & 0 & 0 \\ 0.24 & 0.37 & 0.33 & 0.23 & 0.30 & 0.25 & 0.33 & 0.16 & 0.36 & 0.13 & 0.35 \\ 0.02 & 0.46 & 0.35 & 0.40 & 0.17 & 0.43 & 0.67 & 0.65 & 0.37 & 0.45 & 0.35 \\ 0.58 & 0.35 & 0.30 & 0.28 & 0.22 & 0.21 & 0.34 & 0.27 & 0.34 & 0.08 & 0.35 \end{pmatrix}$$

Based on matrix ZZ, the ideal best and worst value vectors are obtained as follows:

$$Z^{+} = (0.58，0.46，0.46，0.53，0.61，0.43，0.67，0.65，0.37，0.45，0.35)$$

$$Z^{-} = (0.02，0.23，0.25，0.17，0.17，0.00，0.17，0.15，0.21，0.00，0.00)$$

Calculate the Euclidean distances D_i^+ and D_i^-, as well as the relative closeness C_i of each evaluation subject to the ideal solution. The subjects are then ranked according to the size of C_i, where a larger C_i value indicates closer proximity to the optimal level, as shown in Table 2.

Table 2. Relative Closeness to Optimal Values and Ranking of Esophageal Cancer Treatment Indicators in Tertiary Hospitals of a City

Hospital	D_i^-	D_i^+	C_i	Ranking
Hospital 1	0.65	1.01	0.39	8
Hospital 2	0.64	1.04	0.38	9
Hospital 3	0.95	0.76	0.55	2
Hospital 4	0.76	0.91	0.46	6
Hospital 5	0.78	0.74	0.52	3
Hospital 6	0.76	0.86	0.47	5
Hospital 7	0.59	0.90	0.40	7
Hospital 8	1.07	0.73	0.60	1
Hospital 9	0.76	0.82	0.48	4

(1) Ranking Results:

Hospital 8 exhibited the best overall performance in the comprehensive evaluation. This hospital excelled in nearly all key indicators, particularly in length of stay, antibiotic use, and complication rate, demonstrating outstanding treatment outcomes and patient management. Conversely, Hospital 2 displayed the poorest overall performance, especially in antibiotic use and average cost per stay, suggesting potential areas for improvement in patient care and clinical treatment.

(2) Analysis of Key Indicators:

Discharges: Hospitals 5 and 6 performed excellently, each with 106 discharges, indicating high capacity and patient throughput. Hospitals 4 and 8 had fewer discharges, with only 5, which might reflect a smaller size or a focus on more specialized treatments. The low discharge numbers in some hospitals may represent a lack of representativeness in the data analysis.

Length of Stay: Hospital 8 had the shortest average stay, at 14.4 days, indicating efficient treatment and management processes. Hospital 2 had the longest average stay, at 28.73 days, suggesting that its treatment processes might be complex or its management efficiency needs improvement.

Average Cost per Stay: Hospital 2 had the highest average cost per stay at 113,495 yuan, possibly due to the use of more expensive treatment methods or technologies. Hospital 3 had the lowest average cost, at 62,007 yuan, suggesting better cost control or possibly less severe patient conditions.

Complication Rate: Hospital 8 had a complication rate of

0%, indicating exceptional medical quality and patient safety management. Hospital 6 had the highest complication rate, at 14.15%, which may indicate a need for further optimization in clinical operations and post-treatment management.

Comprehensive Analysis: Utilizing the TOPSIS method, the data were processed to score hospitals based on their performance across key indicators. Hospitals that excelled received high scores on most indicators, while those that performed poorly scored lower. This approach not only made the results clearer and more accurate but also highlighted the specific differences in esophageal cancer treatment quality among hospitals, emphasizing the significance of data analysis for practical decision-making.

The analysis revealed significant variations in performance across key indicators among different hospitals, likely related to factors such as hospital size, resources, expertise, and management efficiency. For instance, Hospitals 5 and 6 demonstrated exceptional capability in handling capacity, while Hospital 8 excelled in treatment efficiency and patient safety. Although Hospital 2 needs to improve in areas like complication rate and length of stay, it performed well in maintaining a low mortality rate. These findings can assist hospitals in identifying their strengths and weaknesses, enabling them to enhance their service quality and efficiency further.

4. Discussion:

The comprehensive evaluation of esophageal cancer treatment quality reveals that Hospitals 8, 3, and 5 achieved a Closeness Coefficient (Ci) value greater than 0.5, indicating superior performance compared to the other six hospitals, which all scored below 0.5. This demonstrates a significant variation in treatment quality among the nine tertiary hospitals in the city, suggesting an overall moderate level of healthcare delivery.

Moreover, our analysis underscores the importance of complication rates and readmission rates as critical indicators for assessing hospital treatment quality. High rates of complications and readmissions not only reflect the health status of patients post-treatment but may also indicate inadequacies in the hospitals' handling of complex cases. Hospital administrators should consider these metrics as a basis for improving clinical pathways and enhancing the quality of patient care.

The key to raising the level of treatment for esophageal cancer lies in effective organization and scientific management rather than solely relying on new drugs and technologies. Therefore, accelerating the development and certification of departments, promoting the standardization and regulation of esophageal cancer diagnostics and treatment, and improving the overall level of care are crucial. To achieve this goal, it is imperative for tertiary hospitals to enhance their organizational structures, refine regulations and procedures, improve diagnostic and treatment processes, strengthen interdisciplinary collaboration, and conduct relevant training and education.

Additionally, based on the current study's findings, health policy makers are advised to pay attention to the differences in quality among hospitals and to formulate targeted policies to reduce these disparities. For example, providing additional resources such as professional training and technological upgrades to underperforming hospitals could significantly enhance their treatment quality.

5. Future Research Directions

Methodological Improvements: Although the TOPSIS method has provided an effective tool for quantifying and comparing the quality of hospital treatment for esophageal cancer, it relies on accurate weight assignments, which have a decisive impact on the results. Typically, these weights are based on literature reviews and expert opinions. A limitation of our evaluation study is the lack of consideration for the weight of each indicator. By assigning different weights based on the management of esophageal cancer treatment quality, the evaluation results could become more targeted and easily adopted by hospital managers.

Additionally, the method assumes that all evaluation indicators are independent, overlooking possible interactions among them, which is particularly crucial in a medical environment where various aspects of treatment are interconnected. Another limitation of the TOPSIS method is that it only provides a relative ranking and cannot quantify the actual differences between hospitals.

Future research might explore more complex decision analysis methods, such as fuzzy TOPSIS or simulation-based approaches, which could better handle uncertainties in weight determination and dependencies among indicators. Also, designing more comprehensive studies for determining weights, such as using the Data Envelopment Analysis (DEA) approach to objectively assess each indicator's weight, might improve the accuracy and fairness of the evaluation results.

Technological and Therapeutic Innovations: With advances in medical technology, including machine learning and artificial intelligence, new technologies have begun to play a role in treatment strategies and patient management. Future research should consider how to integrate these technologies into the treatment and assessment of esophageal cancer, particularly in terms of personalized treatment and prognosis prediction.

Interdisciplinary and Multicenter Collaboration: The treatment of esophageal cancer is a complex process that involves experts from multiple disciplines. Future studies could benefit from establishing networks for interdisciplinary collaboration and conducting multicenter research to enhance the universality and applicability of the findings. Such cooperation would help integrate more data resources, improving the reliability and practicality of research.

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