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Evaluation of Multiple Factors in Pediatricians' Antibiotic Selection

Çocuk Hekimlerinin Antibiyotik Seçiminde Çoklu Faktörlerin Değerlendirilmesi

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Abstract

Objective: The pediatrics department frequently uses antibiotics. Understanding factors influencing antibiotic prescribing can enhance treatment success. This study aimed to explore these factors, highlighting their role in antibiotic selection and overall treatment effectiveness.

Material and Methods: Primary data was used in the study. The scope of the research consisted of pediatricians working in Konya province and its districts. The sample size of the research was calculated according to the snowball sampling method. The sample size started by selecting a pediatrician who met the research criteria, and other pediatricians were reached with the help of the selected pediatrician. The pediatrician was told to recommend someone or people with the same characteristics. Thus, 50 pediatricians were reached in the study by using the sampling method in question. In this study, the opinions of experts working in public institutions and organizations were taken to determine the multiple factors in pediatric physicians' choice of antibiotics. The data obtained by the researchers by conducting a face-to-face survey of pediatricians on a voluntary basis was analyzed using the Entropy and TOPSIS method.

Results: The first antibiotic agent preferred by the physicians was amoxicillin and clavulanic acid. While azithromycin was in the second place, clarithromycin was in the third place, the last two places were shared by cefdinir and cefixime. In the study, it was observed that the results obtained in terms of factors related to the physician and the parent were

Öz

Giriş: Pediyatri bölümü sıklıkla antibiyotik kullanmaktadır. Antibiyotik reçetelemeyi etkileyen faktörlerin anlaşılması tedavi başarısını artırabilir. Bu çalışma, antibiyotik seçimi ve genel tedavi etkinliğindeki rollerini vurgulayarak bu faktörleri araştırmayı amaçlamıştır.

Gereç ve Yöntemler: Çalışmada birincil veriler kullanılmıştır. Araştırmanın kapsamını Konya ili ve ilçelerinde görev yapan çocuk hekimleri oluşturmaktadır. Araştırmanın örneklem büyüklüğü kartopu örnekleme yöntemine göre hesaplanmıştır. Örneklem büyüklüğü, araştırma kriterlerine uyan bir çocuk doktorunun seçilmesi ile başlar ve seçilen çocuk doktorunun yardımı ile diğer çocuk doktorlarına ulaşılır. Çocuk doktoruna aynı özelliklere sahip kişi veya kişileri tavsiye etmesi söylenir. Böylece söz konusu örnekleme yöntemi kullanılarak çalışmada 50 çocuk hekimine ulaşılmıştır. Bu çalışmada çocuk hekimlerinin antibiyotik seçimindeki çoklu faktörlerin belirlenmesi amacıyla kamu kurum ve kuruluşlarında çalışan uzmanların görüşleri alınmıştır. Araştırmacılar tarafından gönüllülük esasına dayalı olarak çocuk hekimlerine yüz yüze anket uygulanarak elde edilen veriler Entropi ve TOPSIS yöntemi kullanılarak analiz edilmiştir.

Bulgular: Hekimler tarafından tercih edilen ilk antibiyotik ajan amoksisilin ve klavulanik asit oldu. İkinci sırada azitromisin, üçüncü sırada klaritromisin yer alırken, son iki sırayı sefdinir ve sefiksim paylaştı. Çalışmada hekim ve ebeveynle ilgili faktörler açısından elde edilen sonuçların genel sonuçlarla aynı olduğu gözlendi. İlaçla ilgili faktörler, maliyet ve geri ödeme koşulları sonuçları aynı olurken, Azitromisin bu sonuçlarda

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the same as the general results. While the results of drug-related factors, cost and reimbursement conditions were the same, azithromycin took the first place in these results. In all sub-solutions, the second-place option and the last two orders were the same. According to the sex of the physicians, the order of preferences of five male pediatric physicians was amoxicillin clavulanic acid > azithromycin > clarithromycin > cefdinir > cefixime, while 15 female physicians' preferences were determined to be azithromycin > amoxicillin clavulanic acid > clarithromycin > cefdinir > cefixime. Azithromycin was preferred first.

Conclusion: Multiple factors influence both diagnosis and treatment, affecting antibiotic selection and improving treatment success.

Keywords: Antibiotics, pediatricians, multiple factors, Entropy, TOPSIS

ilk sırada yer aldı. Tüm alt çözümlerde ikinci sıradaki seçenek ve son iki sıra aynıdır. Hekimlerin cinsiyetine göre beş erkek pediyatri hekiminin tercih sıralaması amoksisilin klavulanik asit > azitromisin > klaritromisin > sefdinir > sefiksim şeklindeyken, 15 kadın hekimin tercihleri azitromisin > amoksisilin klavulanik asit > klaritromisin > sefdinir > sefiksim şeklinde belirlenmiştir. Azitromisin ilk sırada tercih edilmiştir.

Sonuç: Çoklu faktörler hem tanı hem de tedaviyi etkileyerek antibiyotik seçimini etkiler ve tedavi başarısını artırır.

Anahtar Kelimeler: Antibiyotik, pediyatrist, çoklu faktörler, Entropi, TOPSIS

Introduction

Antibiotics are one of the most important therapeutic inventions in the history of medicine. The discovery of antibiotics more than 70 years ago ushered in an era of drug innovation and application in human and animal health and agriculture (1). However, over the years, its use in every field has brought along question marks. Antibiotic resistance has also occurred in some cases depending on treatment. In fact, the rise in antibiotic resistance is increasingly occupying the world medical public as a health problem and a global threat (2,3). Some authors even interpret this resistance as a shadow cast on the antibiotic age (4).

The beginning of the modern antibiotic age is generally associated with the names Paul Ehrlich and Alexander Fleming. The basic idea of these researchers was based on the observation that aniline and other synthetic dyes, which were first introduced at that time, stained certain microbes but not others (4,5). Antibiotics are very effective bioactive substances obtained biologically or synthetically that stop or kill the growth of microorganisms (6). The antibiotic category includes many different classes of drugs that differ in their spectrum of action, side effect profiles, pharmacokinetics and pharmacodynamics, and clinical use (7).

When used wisely, antibiotics play a vital role in preventing bacterial resistance, providing healthcare at the highest quality and reducing healthcare costs (8). However, this antibiotic administration should be applied at the right time, at affordable cost, for the right duration, with the right drug and at the right dose (2). Since in many studies, antibiotics are recommended by pharmacists or friends as well as the patient's physician, the above criteria may not be met (2,9,10).

Many factors come into play when doctors prescribe antibiotics. One of these is the fear of the side effects of antibiotics. Some studies have found that physicians sometimes experience fear about prescribing the correct antibiotics (2,11). It is evaluated that the fear of doctors when prescribing antibiotics can be prevented by delaying prescribing, doctor education and clinical decision support systems (11).

Another issue that affects antibiotic prescribing behavior is patient expectations. Studies have shown that patients exaggerate their illnesses when requesting antibiotics. It is thought that this situation can be resolved by managing patient expectations and informing patients about the use of antibiotics (12,13). One of the factors affecting physicians' choice of antibiotics is their level of knowledge about antibiotics. Studies have shown that as physicians' knowledge levels increase, factors such as age, height, weight, and use of antibiotics in the last week, which affect antibiotic prescribing, are taken into more consideration when prescribing antibiotics (14). In addition to the factors listed above, factors affecting antibiotic prescribing include the severity and duration of infections, uncertainty about diagnosis, potential patient loss, and the influence of pharmaceutical companies (15).

There are not sufficient studies in the literature to determine the factors affecting physicians' attitudes and behaviors in prescribing antibiotics. There are few studies on this subject in Türkiye. The aim of this study was to evaluate multiple factors affecting pediatricians' antibiotic preferences. The study is important in terms of revealing the factors affecting antibiotic choice and filling the gap in the literature. Multi-criteria decision making (MCDM) methods can be used for this.

MCDM is an approach that brings together different disciplines such as economics, informatics, psychology, mathematics and social sciences, allowing decision makers to evaluate multidimensional decision problems and make decisions. MCDM problems can also be defined as problems in which more than one criterion is optimized, and the most appropriate alternative is selected from possible solution sets. This method helps decision makers make more solid and informed decisions by providing an objective and structured approach in complex decision processes (16,17).

Decision-making processes such as antibiotic selection often rely on subjective judgments and subjectivity. This poses significant risks in making the right treatment choice and can have direct impacts on treatment effectiveness and patient health. Therefore, approaches based on objective data and clinical guidelines should be adopted to ensure the accuracy of such decisions. In solving such problems, using MCDM methods can enable us to reach correct results by providing an objective and structured approach in the decision-making process.

Materials and Methods

Primary data was used in the study. The scope of the research consisted of pediatricians working in Konya province and its districts. The sample size of the research was calculated according to the snowball sampling method. The sample size started by selecting a Pediatrician who met the research criteria, and other Pediatricians were reached with the help of the selected Pediatrician. The pediatrician was told to recommend someone or people with the same characteristics. Thus, 50 pediatricians were reached in the study by using the sampling method in question.

In this study, the opinions of experts working in public institutions and organizations were taken to determine the multiple factors in pediatric physicians' choice of antibiotics. The data obtained by the researchers by conducting a face-to-face survey of pediatricians on a voluntary basis was analyzed using the Entropy and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method.

Methods

Data Set Used in the Study

Fifty pediatricians working in Konya were selected for the study. According to the aspects of the physicians, the following 21 criteria were determined. These criteria were used to choose antibiotics named azithromycin, clarithromycin, amoxicillin clavulanic acid, cefdinir and cefixime. Pediatricians evaluated five different antibiotics out of seven points according to the criteria given below. The study aimed to determine the antibiotic usage preferences of pediatric patients. Entropy and TOPSIS methods were used for this study.

Main criterion 1. Regarding drug: CC1: Posology (Taken once, twice, three times a day), CC2: Implementation of drug (oral, intravenous, intramuscular), CC3: Taste of drug, CC4: Clinical effectiveness of the drug, CC5: Suitability of the drug for the patient, CC6: Originality of the drug, CC7: Whether the drug has an equivalent in suitable indication, CC8: Does not interact with other drugs, CC9: Safety of drug-side effect profile (allergies, constipation, diarrhea, abdominal pain, headache, etc.), CC10: Possibility of creating tolerance, CC11: Pharmaceutical form of the drug (tablet, syrup, etc.).

Main criterion 2. Regarding physician: CC12: Fundamental training received in specialization, CC13: Personal experience regarding drugs, CC14: Duration of use for treatment, CC15: Need to monitor the patient during treatment.

Main criterion 3. Regarding cost and reimbursement conditions of the drug: CC16: Whether it is within the coverage of reimbursement or not, CC17: Box price of the drug, CC18: Cost during treatment,

Main criterion 4. Regarding to parent: CC19: Education level, CC20: Income level, CC21: Family's level of awareness.

In the literature, various studies address different applications of MCDM methods in the field of medicine. These studies emphasize the importance and impact of using MCDM methods in decision-making processes in the field of medicine.

In RSIA Tiara, it has been determined that some patients do not want to take prescriptions written by physicians. Patients' reluctance to use prescriptions is due to price, variety, quality, taste and uncomfortable usage of the drugs. A decision support system has been proposed to overcome this problem (18).

Albahri et al. have developed a new decision-making framework by grouping coronavirus disease-2019 patients (19). The weights of the laboratory criteria were analyzed using the Entropy method, and the treatment method to be applied to the patients was analyzed using the TOPSIS method. The results showed that patients were classified according to their health status and asymptomatic carriers were also taken into account.

İzgüden et al. have determined the ranking of OECD countries according to the criteria determined in terms of health equipment and health indicators (20). In the research, the Entropy method was used to calculate the criterion weights, and the ARAS and SAW methods were used to rank the countries. Regarding health equipment, criteria such as mammography, computer tomograpghy scanner, radiotherapy, magnetic resonance imaging device and number of hospital beds were included in the evaluation. The criteria for health indicators include life expectancy at birth, infant mortality rate and under-five mortality rate.

When the studies in the literature were examined, it was observed that, to the best of the authors' knowledge, Entropy and TOPSIS methods were not used together in antibiotic selection.

Entropy Method

Entropy method provides an objective approach to calculate the criteria weights in MCDM problems. This method makes calculations based on the data in the decision matrix and does not require subjective evaluation. Due to this feature, it is a frequently preferred method in the literature. Entropy method has an application process consisting of four stages. This process supports the decision-making process by providing a fair and measurable method to decision makers and is used in solving complex multi-criteria problems (21).

Information Entropy theory was first explained in the work done by Shannon. According to information Entropy theory, the quality or quantity of information possessed in the decision-making process is the determinant of the correct and reliable solution in solving the problem. For this reason, the Entropy method is used to measure the amount of useful information provided in the realization of different evaluations in the decision-making process (22). Entropy is an objective weighting method. It does not consider the judgments of decision makers. This method usually consists of five stages.

Stage 1. If you have *n* pieces as selection criteria and *m* pieces as alternatives to create the decision matrix, this matrix is usually arranged as follows:

$$A_{ij} = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{pmatrix}$$

Stage 2. Decision matrix normalization:

$$r_{ij} = \frac{x_{ij}}{\sum x_{ij}} \quad [1]$$

$i =$ Alternative value, $j =$ Criterion value, $r_{ij} =$ Normalized value.

After the indexes are standardized $R = (r_{ij})_{mxn}$ shows in the normalized index matrix.

Stage 3. Determining the Entropy value for each criterion: In this formula; k, $k = 1/\ln(m)$ is calculated fixed value.

$$e_j = -k \sum r_{ij}.\ln\left(r_{ij}\right)\left(i = 1,\dots,m; j = 1,\dots,n\right) \quad [2]$$

Stage 4. Determining the degree of d_j differentiation of information provided by any attribute *J*: d_j value represents intensity of contrast of X_j. d_j value shows the significance of X_j the criterion by revealing its objective weight. The higher value of the d_j is, the more important X_j criterion is for the problem.

$$d_j = 1 - e_j,\ \left(i = 1,\dots,m; J = 1 = 1,\dots,n\right) \quad [3]$$

Stage 5. Determining the Entropy weight of criteria: The determined weights are used to explain how significant the criteria are. The size of the Entropy weight of the criteria shows how significant that criterion is in the decision-making process. Determining the Entropy weight of the criteria is calculated as shown in equation (4).

$$w_j = \frac{1 - e_j}{\sum\left(1 - e_j\right)},\ \sum w_j = 1\left(j = 1,\dots,n\right) \quad [4]$$

$w_j =$ Weight value, $e_j =$ Entropy value.

As can be seen, the Entropy method is an easy-to-use objective evaluation method that does not require subjective judgments.

TOPSIS Method

The TOPSIS method was developed by Chen and Hwang with the help of Hwang and Yoon. TOPSIS is a MCDM technique that can be applied directly to data without the need for qualitative translation. This method can be effectively applied to a decision problem consisting of *n* pieces alternatives and *m* pieces criteria (23). In the TOPSIS method, understandable results are obtained with a small number of input parameters. In this method, the selected alternative is aimed to be as close to the ideal solution as possible, while the alternatives that are not the ideal solution are aimed to be as far as possible. In this way, a decision-making criterion is provided to determine the most suitable alternative (23). The steps of the TOPSIS method are as follows.

Stage 1. The objectives and evaluation criteria of the problem are determined.

Stage 2. Creating a decision matrix. n pieces alternative $\left(a_1, a_2, \dots, a_n\right)$ is listed one under the other and criteria and features of the alternatives $\left(y_{1m}, y_{2m}, \dots, y_{nm}\right)$ is listed against them.

$$D = \begin{pmatrix} y_{11} & \dots & y_{1m} \\ \vdots & \vdots & \vdots \\ y_{n1} & \dots & y_{nm} \end{pmatrix} \quad [5]$$

Stage 3. Standardization of the decision matrix (Normalization): The normalization process is performed by calculating the sum of the squares of the criterion values in a decision matrix and taking the square root of this sum. Thus, the value of each criterion has equal weight in the normalized form of the matrix.

$$r_{ij} = \frac{y_{ij}}{\sqrt{\sum y_{ij}^2}}, \left(i = 1,\dots,n; j = 1,\dots,m\right) \quad [6]$$

$$R = \begin{pmatrix} r_{11} & \dots & r_{1m} \\ \vdots & \vdots & \vdots \\ r_{n1} & \dots & r_{nm} \end{pmatrix} \quad [7]$$

Stage 4. Creating the weight decision matrix: The normal matrix is weighted and normalized to determine the weight values of the criteria. This normalized matrix is then multiplied by the criterion weights to form the *V* matrix for the purpose. This process ensures that the criteria are weighted according to their importance, so the *V* matrix helps make the right decisions to meet the objectives.

$$V = \begin{pmatrix} v_{11} & \dots & v_{1m} \\ \vdots & \vdots & \vdots \\ v_{n1} & \dots & v_{nm} \end{pmatrix} \quad [8]$$

Stage 5. Determination of positive ideal values $\left(A^+\right)$ and negative ideal values $\left(A^-\right)$: As a result of the operations performed on the weighted normalized matrix, the values representing the best performance are determined as the positive ideal solution, while the values representing the worst performance are defined as the negative ideal solution. These ideal solutions help determine directions and goals in the decision-making process.

Positive ideal solution,

$$A^{+}=\{(\max v_{(ij)} \mid j \in J), (\min v_{ij} \mid j \in J), \quad [9]$$

Negative ideal solution,

$$A^{-}=\{(\min v_{ij} \mid j \in J), (\max v_{ij} \mid j \in J), \quad [10]$$

Calculated sets,

$$A^{+}=\left\{v_1^{+}, v_2^{+}, \ldots, v_m^{+}\right\} \text{ ve } A^{-}=\left\{v_1^{-}, v_2^{-}, \ldots, v_m^{-}\right\}$$

Expressed as above (24).

Stage 6. Finding distance (discrimination) measurements: The deviations of the alternatives from the ideal solutions are obtained by the Euclidean distance. The distance to the positive value is called the positive ideal separation, the distance to the negative value is called the negative ideal separation and is calculated as follows:

$$S_i^{+}=\sqrt{\sum\left(v_{ij}-v_j^{+}\right)^2} \quad [11]$$

$$S_i^{-}=\sqrt{\sum\left(v_{ij}-v_j^{-}\right)^2} \quad [12]$$

Stage 7. Calculating relative closeness and determining rankings: It is determined using positive ideal and negative ideal distance measures, with the help of calculating the relative closeness C_i^{+} of the alternatives to the ideal solution.

$$C_i^{+}=\frac{S_i^{-}}{S_i^{+}+S_i^{-}} \quad [13]$$

It is calculated as above. C_i^{+} value is measured between $[0.1]$ and as closeness to 1 shows that it gets closer to the positive ideal solution, as closeness to 0 shows that it gets closer to the negative ideal solution.

Results

At this stage of the study, antibiotic types were evaluated and ranked using Entropy and TOPSIS methods according to the determined criteria. Physicians' evaluations were considered in the study. First, the initial decision matrix was created by taking the arithmetic average of the scores given for each criterion for antibiotics. In the next step, the importance coefficients of the criteria were calculated using the Entropy method and the antibiotics were ranked using the TOPSIS method. Calculations were made using Microsoft Excel.

Obtaining Criterion Weights with Entropy

Step 1. Creating the decision matrix

The first step of the Entropy method is to create the decision matrix. The decision matrix shown in Table 1 was obtained by taking the arithmetic average of the pediatricians' opinions.

Table 1. Decision matrix for antibiotics

	Antibiotics				
Criteria	**Azithromycin**	**Clarithromycin**	**Amoxicillin clavulanic acid**	**Cefdinir**	**Cefixime**
CC1	6.66	4.74	5.92	3.28	3.54
CC2	6.30	4.7	5.88	3.74	3.06
CC3	5.72	5.18	5.96	3.7	3.84
CC4	5.68	4.9	6.44	3.78	3.52
CC5	6.34	4.94	6.18	3.64	3.12
CC6	5.92	5.16	5.98	3.72	3.32
CC7	6.04	5.04	6.14	3.86	3.34
CC8	5.56	5.16	6.24	4.36	3.12
CC9	6.3	4.86	5.96	3.84	3.32
CC10	5.56	5.12	5.9	3.96	3.38
CC11	5.82	5.32	5.66	3.86	3.26
CC12	5.2	5.22	6.7	3.34	3.3
CC13	6.14	4.7	6.14	3.78	3.96
CC14	6.5	4.52	5.3	4.24	3.9
CC15	6.26	4.56	5.74	3.74	3.52
CC16	6.14	5.06	6.14	3.7	3.38
CC17	6.30	5.24	5.72	3.74	3.22
CC18	6.34	5.32	5.82	3.3	2.86
CC19	5.82	5.34	5.92	3.52	3.02

Table 1. Decision matrix for antibiotics (continue)

	Antibiotics				
Criteria	**Azithromycin**	**Clarithromycin**	**Amoxicillin clavulanic acid**	**Cefdinir**	**Cefixime**
CC20	5.9	5.20	5.98	3.64	3.22
CC21	5.76	5.42	6.16	3.58	3.1

CC1: Posology (Taken once, twice, three times a day), CC2: Implementation of drug (oral, intravenous, intramuscular), CC3: Taste of drug, CC4: Clinical effectiveness of the drug, CC5: Suitability of the drug for the patient, CC6: Originality of the drug, CC7: Whether the drug has an equivalent in suitable indication, CC8: Does not interact with other drugs, CC9: Safety of drug-side effect profile (allergies, constipation, diarrhea, abdominal pain, headache, etc.), CC10: Possibility of creating tolerance, CC11: Pharmaceutical form of the drug (tablet, syrup, etc.), CC12: Fundamental training received in specialization, CC13: Personal experience regarding drugs, CC14: Duration of use for treatment, CC15: Need to monitor the patient during treatment, CC16: Whether it is within the coverage of reimbursement or not, CC17: Box price of the drug, CC18: Cost during treatment, CC19: Education level, CC20: Income level, CC21: Family's level of awareness.

The rows of the decision matrix contain evaluation criteria, and the columns contain decision alternatives. Five decision alternatives and 21 evaluation criteria were used in the study.

Step 2. Obtaining the normalized decision matrix

In this step, the decision matrix is normalized with the help of equation [1]. In other words, the row value for each criterion is normalized by dividing by the row totals. The decision matrix obtained after the normalization process is seen in Table 2.

Step 3. Calculation of Entropy values for criteria

In this step, the Entropy value (e_j) of each criterion was calculated using the normalized decision matrix seen in Table 2. In calculating the Entropy values, first the normalized values in

Table 2. Normalized decision matrix according to the Entropy method information differentiation and weight values of the criteria

	Antibiotics							
Criteria	**Azithromycin**	**Clarithromycin**	**Amoxicillin clavulanic acid**	**Cefdinir**	**Cefixime**	**ej**	**dj**	**wj**
CC1	0.277	0.196	0.245	0.135	0.146	0.976	0.023	0.0593
CC2	0.261	0.194	0.243	0.154	0.126	0.971	0.028	0.0728
CC3	0.237	0.214	0.246	0.153	0.159	0.992	0.007	0.0203
CC4	0.235	0.202	0.266	0.156	0.145	0.986	0.013	0.0347
CC5	0.262	0.204	0.256	0.150	0.129	0.978	0.022	0.0561
CC6	0.245	0.213	0.247	0.154	0.137	0.982	0.017	0.0451
CC7	0.251	0.208	0.254	0.159	0.138	0.987	0.013	0.0331
CC8	0.23	0.213	0.258	0.181	0.129	0.988	0.011	0.0291
CC9	0.261	0.201	0.246	0.159	0.137	0.984	0.016	0.0408
CC10	0.231	0.212	0.244	0.164	0.141	0.983	0.016	0.0419
CC11	0.242	0.22	0.234	0.159	0.135	0.981	0.018	0.0473
CC12	0.215	0.216	0.277	0.138	0.136	0.971	0.028	0.0738
CC13	0.254	0.194	0.254	0.156	0.164	0.995	0.004	0.0120
CC14	0.269	0.187	0.219	0.175	0.161	0.994	0.005	0.0153
CC15	0.259	0.188	0.237	0.155	0.145	0.979	0.021	0.0534
CC16	0.254	0.209	0.254	0.153	0.140	0.985	0.014	0.0364
CC17	0.26	0.217	0.236	0.154	0.133	0.982	0.017	0.0455
CC18	0.262	0.221	0.241	0.136	0.118	0.964	0.035	0.0916
CC19	0.241	0.222	0.245	0.145	0.125	0.970	0.029	0.0756
CC20	0.244	0.215	0.247	0.150	0.133	0.978	0.021	0.0555
CC21	0.238	0.224	0.255	0.148	0.12	0.977	0.022	0.0592

ej: Entropy value, dj: the degree of divergence (or differentiation) of the values for criterion, wj: Weight value.
CC1: Posology (Taken once, twice, three times a day), CC2: Implementation of drug (oral, intravenous, intramuscular), CC3: Taste of drug, CC4: Clinical effectiveness of the drug, CC5: Suitability of the drug for the patient, CC6: Originality of the drug, CC7: Whether the drug has an equivalent in suitable indication, CC8: Does not interact with other drugs, CC9: Safety of drug-side effect profile (allergies, constipation, diarrhea, abdominal pain, headache, etc.), CC10: Possibility of creating tolerance, CC11: Pharmaceutical form of the drug (tablet, syrup, etc.), CC12: Fundamental training received in specialization, CC13: Personal experience regarding drugs, CC14: Duration of use for treatment, CC15: Need to monitor the patient during treatment, CC16: Whether it is within the coverage of reimbursement or not, CC17: Box price of the drug, CC18: Cost during treatment, CC19: Education level, CC20: Income level, CC21: Family's level of awareness.

Table 2 were multiplied by the logarithm values of these values. Then, the Entropy values obtained as a result of this process were calculated by taking the sum of the values and using equation [2]. The *k* value in equation [2] is the Entropy coefficient and is the logarithmic version of the number of alternatives in the decision matrix. For example, since there were 5 decision alternatives in this study, the value of *m* was accepted as 5 and based on the formula, k = 1/ln(5) = 0.621. The Entropy values obtained with the help of equation [2] are given in Table 2.

Step 4. Calculating the degree of differentiation of information

Each (e_j) value found in this step was subtracted from the number 1 and (d_j) values were calculated with the help of equation [3]. For example, the CC1 value in Table 2 was subtracted from the number 1 (1-0.977) with the help of equation [3] and the result was found to be 0.023 as seen in Table 2.

Step 5. Calculating criterion weights

The last step of the Entropy method is to obtain the criterion weights. In this step, the Entropy weights of the criteria were obtained with the help of equation [4]. For example, the criterion weight for CC1 was obtained by dividing the value of 0.023 by the sum of the d_j column. The relevant results are given in Table 2.

The sum of the weight values of the 21 criteria seen above is equal to 1. The values obtained in this step will be used as criterion weights in the next step, the TOPSIS method application.

Antibiotic Sorting by TOPSIS Method

Step 1. Creating the decision matrix

In the first step of the TOPSIS method, the decision matrix is created. This step is the same as the first step of the Entropy method. Table 1 will also be used in the TOPSIS method.

Step 2. Creating the normalized decision matrix (R)

Equation [6] was used for the normalization process to convert the criterion values of the alternatives into constant units. The normalized decision matrix is seen in Table 3.

Table 3. Normalized decision matrix according to the TOPSIS method

	Azithromycin	Clarithromycin	Amoxicillin clavulanic acid	Cefdinir	Cefixime
CC1	0.595	0.423	0.529	0.293	0.316
CC2	0.563	0.420	0.525	0.334	0.273
CC3	0.511	0.463	0.532	0.330	0.343
CC4	0.507	0.437	0.575	0.337	0.314
CC5	0.566	0.441	0.552	0.325	0.278
CC6	0.529	0.461	0.534	0.332	0.296
CC7	0.539	0.451	0.548	0.345	0.298
CC8	0.496	0.461	0.557	0.389	0.278
CC9	0.563	0.434	0.532	0.343	0.296
CC10	0.496	0.457	0.527	0.353	0.302
CC11	0.520	0.475	0.505	0.345	0.291
CC12	0.464	0.466	0.598	0.298	0.294
CC13	0.548	0.420	0.548	0.337	0.353
CC14	0.581	0.404	0.473	0.378	0.348
CC15	0.559	0.407	0.513	0.334	0.314
CC16	0.548	0.452	0.548	0.331	0.302
CC17	0.563	0.468	0.512	0.334	0.287
CC18	0.566	0.475	0.521	0.295	0.255
CC19	0.521	0.477	0.529	0.314	0.269
CC20	0.527	0.465	0.534	0.325	0.287
CC21	0.514	0.484	0.551	0.321	0.277

CC1: Posology (Taken once, twice, three times a day), CC2: Implementation of drug (oral, intravenous, intramuscular), CC3: Taste of drug, CC4: Clinical effectiveness of the drug, CC5: Suitability of the drug for the patient, CC6: Originality of the drug, CC7: Whether the drug has an equivalent in suitable indication, CC8: Does not interact with other drugs, CC9: Safety of drug-side effect profile (allergies, constipation, diarrhea, abdominal pain, headache, etc.), CC10: Possibility of creating tolerance, CC11: Pharmaceutical form of the drug (tablet, syrup, etc.), CC12: Fundamental training received in specialization, CC13: Personal experience regarding drugs, CC14: Duration of use for treatment, CC15: Need to monitor the patient during treatment, CC16: Whether it is within the coverage of reimbursement or not, CC17: Box price of the drug, CC18: Cost during treatment, CC19: Education level, CC20: Income level, CC21: Family's level of awareness.

Table 4. Discrimination criteria for antibiotics, weighted normalized decision matrix, positive and negative ideal solution values, closeness values to the ideal solution and ranking

	Azithromycin	Clarithromycin	Amoxicillin clavulanic acid	Cefdinir	Cefixime	A^+	A^-
CC1	0.035	0.024	0.032	0.017	0.018	0.035	0.017
CC2	0.033	0.025	0.031	0.019	0.016	0.033	0.016
CC3	0.031	0.027	0.032	0.019	0.021	0.031	0.019
CC4	0.029	0.026	0.033	0.019	0.018	0.033	0.018
CC5	0.034	0.026	0.032	0.019	0.016	0.033	0.016
CC6	0.032	0.027	0.031	0.019	0.017	0.031	0.017
CC7	0.031	0.026	0.032	0.021	0.017	0.032	0.017
CC8	0.029	0.02	0.032	0.022	0.016	0.032	0.016
CC9	0.033	0.025	0.031	0.021	0.017	0.033	0.017
CC10	0.029	0.027	0.031	0.021	0.017	0.031	0.017
CC11	0.031	0.028	0.029	0.021	0.017	0.031	0.017
CC12	0.027	0.027	0.035	0.017	0.017	0.035	0.017
CC13	0.032	0.025	0.032	0.019	0.021	0.032	0.019
CC14	0.034	0.023	0.027	0.022	0.021	0.034	0.021
CC15	0.033	0.024	0.031	0.019	0.018	0.033	0.018
CC16	0.033	0.026	0.032	0.019	0.017	0.032	0.017
CC17	0.033	0.027	0.031	0.019	0.016	0.03	0.016
CC18	0.033	0.028	0.031	0.017	0.015	0.033	0.015
CC19	0.030	0.028	0.032	0.018	0.015	0.031	0.015
CC20	0.031	0.027	0.031	0.019	0.016	0.031	0.016
CC21	0.030	0.028	0.032	0.018	0.016	0.032	0.016
$S_{(i)}^{(-)}$	0.065	0.042	0.065	0.011	0.001		
$S_{(i)}^{(+)}$	0.010	0.030	0.009	0.060	0.069		
$C_{(i)}^{(+)}$	0.867	0.585	0.873	0.164	0.025		
Ranking	**2**	**3**	**1**	**4**	**5**		

A^+: Positive ideal solution, A^-: Negative ideal solution, $S_{(i)}^{(-)}$: Negative ideal separation, $S_{(i)}^{(+)}$: Positive ideal separation, $C_{(i)}^{(+)}$: Relative proximity.
CC1: Posology (Taken once, twice, three times a day), CC2: Implementation of drug (oral, intravenous, intramuscular), CC3: Taste of drug, CC4: Clinical effectiveness of the drug, CC5: Suitability of the drug for the patient, CC6: Originality of the drug, CC7: Whether the drug has an equivalent in suitable indication, CC8: Does not interact with other drugs, CC9: Safety of drug-side effect profile (allergies, constipation, diarrhea, abdominal pain, headache, etc.), CC10: Possibility of creating tolerance, CC11: Pharmaceutical form of the drug (tablet, syrup, etc.), CC12: Fundamental training received in specialization, CC13: Personal experience regarding drugs, CC14: Duration of use for treatment, CC15: Need to monitor the patient during treatment, CC16: Whether it is within the coverage of reimbursement or not, CC17: Box price of the drug, CC18: Cost during treatment, CC19: Education level, CC20: Income level, CC21: Family's level of awareness.

Step 3. Creating the weighted normalized decision matrix (*V*)

The weighting process is carried out by multiplying the values in Table 3 with the criterion weights given in Table 2, which are found by the Entropy method. The weighted normalized decision matrix is given in Table 4.

Step 4. Obtaining positive ideal and negative ideal solution values

In this step, the distances of the decision alternatives to the positive ideal and negative ideal decision point are calculated with the help of equation [9] and equation [10]. Since all the evaluation criteria in the study have utility functions, the positive ideal solution value in the formula was chosen from the largest row value in Table 4, and the negative ideal solution value was chosen from the smallest row value in Table 4. For example, since the largest number in the CC1 row in Table 4 is 0.003, this number was determined as the positive ideal solution value. On the other hand, since the smallest value in the same row was 0.002, this number was determined as the negative ideal solution value and the same process was repeated for all criteria. The resulting solution sets are given in Table 4.

Step 5. Calculation of discrimination measurements

In this step, the distances of the alternatives to the positive and negative ideal solution are calculated by using the positive ideal and negative ideal solution values of the criteria. In this process, which is based on the weighted normalized matrix, A^+ and A^- values are subtracted from the weighted values and their squares are taken. Then, $S_{(i)}^{(+)}$ and $S_{(i)}^{(-)}$ values are obtained respectively by taking the square root of the sum of the row values. The discrimination measures calculated with the help of equation [11] and equation [12] are given in Table 4.

Step 6. Calculating closeness to ideal solution

In the last step of the TOPSIS method, the closeness of the alternatives to the ideal solution is calculated. This process is obtained by dividing the negative ideal solution values by itself and the sum of the positive ideal solutions and is shown with the help of equation [13]. The C_i^+ values obtained as a result of the application are given in Table 4.

Finally, the values of antibiotics are listed from largest to smallest and the selection or ranking of pediatricians is obtained. The results are seen in Table 4.

Discussion

The study conducted by Gonzalez-Gonzalez et al. to evaluate the attitudes and behaviors of physicians in the quality of antibiotic prescription was conducted on 2100 physicians between 2008 and 2010 (11). In the study, it was determined that the main attitude of physicians regarding the quality of the prescription was fear, and this situation led physicians to tend to prescribe broad-spectrum antibiotics. The second factor, which is less common than fear, in prescribing antibiotics is the physician's indifference towards the patient.

Rezal et al. conducted a literature study on physicians' knowledge, perception and behavior in prescribing antibiotics (15). When 14 articles written between 1990 and 2014 were analyzed in the study, it was found out that physicians still have insufficient knowledge and misconceptions about prescribing antibiotics. Furthermore, in the same study, it was stated that antibiotics were prescribed even though it was known that they had limited effect in some cases. As a result of the study, the factors affecting antibiotic prescribing were stated as the severity and duration of infections, uncertainty about diagnosis, potential patient loss and the influence of pharmaceutical companies.

Lum et al., on the factors affecting antibiotic prescription and decision-making in primary health care, conducted a study with 23 general practitioners using a mixed method, including semi-structured interviews and a discrete choice experiment called discrete choice experiment (DCE) (13). Three main themes emerged in this study including the difficulties in prescribing, delayed antibiotic prescriptions and patient expectations. According to the DCE, duration of symptoms and patient expectations had the greatest impact on antibiotic prescribing. Taken together, these results suggest that the key challenges to prudent antibiotic prescribing are as follows: 1. Patient expectations, a significant surmountable barrier, 2. Medical colleagues' prescribing practices, cultural background, and professional etiquette, 3. Uncertainty of diagnosis and patients' expectations for antibiotics. As a result of the same study, it was clear that these difficulties created pressure on general practitioners to write prescriptions.

In a study titled "Antibiotic Preferences of Family Physicians in Various Indications in Kayseri" conducted by, as a result of a survey conducted on 162 family physicians, 96% of the physicians who attended the scientific meeting on antibiotic use in the last three years and 89.1% of the physicians who did not attend the scientific meeting stated that they chose broad-spectrum antibiotics as the first choice in bacterial-induced acute tonsillopharyngitis in children (9). As a result of the study, it was observed that family physicians preferred broad-spectrum antibiotics instead of narrow-spectrum antibiotics as the first choice when looking at antibiotic preferences in pediatric and adult patients for infectious diseases that are common in primary care. Most physicians reported that they chose amoxicillin or narrow-spectrum penicillins as the first choice in bacterial acute tonsillopharyngitis in children.

A workshop was held by the American Thoracic Society on the use of antibiotics in intensive care units (2). The Centers for Disease Control and Prevention, the American Association of Critical Care Nurses, the American College of Chest Physicians and the Society of Critical Care Medicine also participated in the creation of the workshop report. The study stated that one of the problems in intensive care units was due to the lack of correct antibiotic management. There were no precautions against overuse of antibiotics. The study stated that the reason for excessive use of antibiotics was the fear of missing the causative pathogen rather than lack of knowledge, and it was recommended that general practitioners attend continuing medical training on antibiotic management in intensive care.

A study was conducted by Yiğit and Karagöl to evaluate parental attitudes and knowledge regarding rational antibiotic use (8). As a result of the survey conducted on 545 samples, it was revealed that as the knowledge level of parents increased, their attitudes towards rational antibiotic use increased. Besides, in the study, it was observed that mothers' knowledge and attitude scores regarding rational antibiotic use were higher than fathers'. A significant relationship was observed between education level and rational antibiotic use, and it was observed that as the education level increased, knowledge about antibiotic use also increased. In the study, the relationship between age and knowledge and attitudes about rational antibiotic use was also analyzed, and it was observed that the level of knowledge did not increase with age, but the attitude scores decreased.

In the survey study conducted by Budak on the evaluation of dentists' knowledge and attitudes in prescribing antibiotics, 400 physicians were included (14). According to the study results, approximately half of the dentists examined less than three children daily, while approximately half examined more than five children daily. Most physicians (72.75%) made decisions based on symptoms when prescribing antibiotics. When determining antibiotic dose in pediatric patients, 63.75% of the physicians adjusted it according to weight, while 88.75% asked whether they had used antibiotics in the last week when prescribing antibiotics. All physicians (99.25%) prescribed oral antibiotics. In the study, physicians' antibiotic knowledge level was found to be 11.63 out of 17 points. (This rate is 68.41 out of 100 points). The active ingredient of the antibiotic preferred by physicians was 26.75% amoxicillin, 72.5% amoxicillin clavulanic acid, 0.25% erythromycin, 0.25% azithromycin and 0.5% other. In the example, when asked about the antibiotic to be given in case of penicillin allergy, 45.75% of the physicians preferred azithromycin, 25.5% preferred erythromycin, 23.5% preferred cefazolin and 5.25% preferred tetracycline. In the study, the knowledge level of female pediatric dentists about prescribing antibiotics was found to be significantly higher than that of male dentists, and the knowledge level of dentists with 11 years or more of service was found to be significantly lower than that of dentists with 1-5 years of experience. In the study, the knowledge levels of physicians who examined more patients daily were significantly higher than those who examine fewer patients. In the study, the knowledge level of those who adjusted the antibiotic dosage according to weight was higher than those who adjusted the antibiotic dosage according to age and severity of the disease. The knowledge level of physicians who asked about antibiotic use in the last week was significantly higher than those who did not. The level of knowledge of those who explained antibiotic use and its consequences to their parents was significantly higher than those who diğd not. Finally, the knowledge level of those who knew the term antibiotic resistance was significantly higher than those who did not.

Various difficulties are encountered in the use of antibiotic prescriptions in the field of pediatrics by patients due to different reasons. To overcome this problem, the MCDM approach has been proposed. In this study, factors affecting drug use were determined as four main headings and twenty-one sub-criteria. Fifty pediatricians participated in this study and evaluated the active ingredients of five antibiotics according to 21 criteria. At the end of the study, as seen in Table 4, the first preferred antibiotic agent was amoxicillin clavulanic acid. While azithromycin was in the second place, clarithromycin was in the third place, the last two places were shared by cefdinir and cefiksime.

In order to analyze the results in more detail, the problem was solved separately according to four main factors and the results in Table 5 were obtained. When the results were examined, it was seen that the results obtained in terms of factors

Table 5. Ranking antibiotic preferences according to four main factors, physician sex and professional experience

	Methods				
Criteria	**Azithromycin**	**Clarithromycin**	**Amoxicillin clavulanic acid**	**Cefdinir**	**Cefixime**
1. Evaluation of antibiotics in terms of drug-related factors	0.969	0.562	0.941	0.196	0.035
Preference ranking	1	3	2	4	5
2. Evaluation of antibiotics in terms of physician-related factors	0.734	0.574	0.855	0.159	0.041
Preference ranking	2	3	1	4	5
3. Evaluation of antibiotics in terms of factors related to the cost and reimbursement conditions of the drug	1.000	0.692	0.883	0.098	0.000
Preference ranking	1	3	2	4	5
4. Evaluation of antibiotics in terms of parental factors (sociocultural level)	0.874	0.474	1.000	0.160	0.000
Preference ranking	2	3	1	4	5
Indicator of male physicians' preferences $C_{(i)}^{(+)}$	0.851	0.486	0.901	0.236	0.059
Preference ranking	2	3	1	4	5
Indicator of preferences of female physicians $C_{(i)}^{(+)}$	0.761	0.646	0.757	0.028	0.242
Preference ranking	1	3	2	4	5
Less than 13 years $C_{(i)}^{(+)}$	0.801	0.689	0.799	0.211	0.162
Preference ranking	1	3	2	4	5

Table 5. Ranking antibiotic preferences according to four main factors, physician sex and professional experience (continue)

	Methods				
Criteria	**Azithromycin**	**Clarithromycin**	**Amoxicillin clavulanic acid**	**Cefdinir**	**Cefixime**
Above 13 years $C_{(i)}^{(+)}$	0.882	0.498	0.806	0.166	0.137
Preference ranking	1	3	2	4	5

$C_{(i)}^{(+)}$: Relative proximity.

related to the physician and the parent were the same as the general results. While the results of drug-related factors, cost and reimbursement conditions were the same, azithromycin took the first place in these results. In all sub-solutions, the second-place option and the last two orders were the same.

While other studies in the literature have found that the knowledge level of female physicians is significantly higher than that of male physicians, in our study it was found that the selection of active ingredients differed according to sex (14). While the order of preferences of the 20 male pediatric physicians who participated in the survey was found to be amoxicillin clavulanic acid (0.901) > azithromycin (0.851) > clarithromycin (0.486) > cefdinir (0.224) > cefixime (0.059), the preference of thirty female physicians was determined to be azithromycin (0.801) > amoxicillin clavulanic acid (0.799) > clarithromycin (0.689) > cefdinir (0.211) > cefixime (0.162).

While in a study in the literature, the knowledge level of those with professional experience of 11 years or more was found to be significantly low, in our study, the experience was determined as less than and above 13 years, and the ranking of both results were similar (14). Azithromycin was preferred first (Table 5). Amoxicillin was chosen in the study conducted by according to the TOPSIS method in the study conducted by us, these two alternatives (azithromycin and amoxicillin clavulanic acid) were calculated to be the antibiotics closest to the ideal solution. After these, it was determined that clarithromycin was in the third place, and cefdinir and cefixime were in the last two places.

Conclusion

Various difficulties are encountered in the use of antibiotic prescriptions in the field of pediatrics by patients due to different reasons. To overcome this problem, the MCDM approach has been proposed.

The first preferred antibiotic agent was amoxicillin clavulanic acid. The results of drug-related factors, cost and reimbursement conditions were the same, and Azithromycin took the first place in these results. In all sub-solutions, the second-place option and the last two orders were the same.

While other studies in the literature found that the knowledge level of female physicians was significantly higher than that of male physicians, in our study it was found that the selection of active ingredients differed according to sex.

While in a study in the literature, the knowledge level of those with professional experience of 11 years or more was found to be significantly low, in our study, experience was determined as less than and above 13 years, and the ranking of both results was the same. Azithromycin was preferred first.

According to the TOPSIS method in the study conducted by us, these two alternatives (azithromycin and amoxicillin clavulanic acid) were calculated to be the antibiotics closest to the ideal solution. After these, it was determined that clarithromycin was in the third place, and cefdinir and cefixime were in the last two places.

Suggestions

It is observed that multiple factors determining the treatment as well as the diagnosis are effective in the selection of antibiotic therapy and increase the success achieved in the treatment. In this respect, it is recommended that physicians take these factors into consideration when choosing antibiotic therapy.

Ethics Committe Approval: This study was approved by T.C. KTO Karatay University Faculty of Medicine, Drug and Non-Medical Device Research Ethics Committee (Decision no: 2024/052, Date: 06.06.2024).

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