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Neutrosophic Evaluation of Ethical Factors in Remote Medical Care

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Abstract

In the context of telemedicine and remote medical care, the evaluation of ethical factors plays a crucial role in ensuring the quality and safety of healthcare. This study employed neutrosophic logic and the Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) method within a bipolar neutrosophic environment to assess relevant ethical factors. Within the scope of this research, an evaluation and selection process was undertaken for ethical factors influencing remote medical care through telemedicine. The results revealed that "Patient Autonomy in Remote Decision-Making" was the most influential factor. Neutrosophic logic and the TOPSIS method in a bipolar neutrosophic environment provided a robust and equitable tool for addressing the complexity of medical ethics in the era of telemedicine. This approach may contribute to the enhancement of the quality and safety of remote medical care.

Keywords: Neutrosophic Evaluation, Bipolar Numbers, TOPSIS, Telemedicine, Ethics.

1 | Introduction

Telemedicine and remote medical care have experienced substantial growth in recent decades, further propelled by the COVID-19 pandemic. These healthcare modalities have provided effective solutions to enhance access to health services, enabling the remote delivery of medical care through information and communication technologies. However, as these practices become more commonplace, a series of crucial ethical considerations emerge that must be appropriately addressed.

The physician-patient relationship, historically established as the epicenter of healthcare, faces significant challenges in the context of telemedicine. The interpersonal aspect and trust characterizing this relationship must be maintained despite the physical distance between the physician and the patient. Physician-patient relationship, privacy of medical data, patient autonomy, and equity in access to care are fundamental ethical factors requiring careful attention in the context of telemedicine. In this framework, the identification and assessment of ethical factors influencing the quality of services provided become crucial.

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The selection and weighting of these ethical factors acquire significant importance due to the complexity of medical and ethical situations that can arise in telemedicine. The quality of healthcare services depends not only on clinical aspects but also on ethical considerations that may vary in importance depending on the context and individual circumstances of patients. Therefore, it is imperative to establish a systematic approach to identify and prioritize these ethical factors in clinical decision-making. In this perspective, the application of multicriteria selection methods emerges as a highly beneficial tool.

Medical ethics, at its core, confronts complex and ethically ambiguous situations requiring informed and ethical decision-making to provide the best possible care to patients. However, it is important to recognize that, in this context, clinical decisions cannot always be addressed definitively or deterministically due to the presence of indeterminacies and inherent uncertainties in clinical situations [1].

Indeterminacies may arise from a lack of complete information [2], uncertain diagnoses, or variability in patient responses to treatments [3]. On the other hand, inaccuracies can manifest themselves in the subjective evaluation of risks and benefits, as well as in the interpretation of patient values and preferences [4]. This uncertainty can make ethical decision-making challenging and sometimes subjective.

In this context, neutrosophic logic emerges as a valuable and promising approach to assist decision-makers in the field of medical ethics. Neutrosophic logic, developed by mathematician and philosopher Florentin Smarandache, focuses on managing situations where truth, falsehood, and indeterminacy can coexist in the same context [5]. This logic allows ambiguity and inaccuracies in decisions to be expressed formally and provides a framework that can help healthcare professionals consider and manage uncertainty in ethical decision-making [6].

In scientific literature, various multicriteria decision-making methods that consider uncertainty and imprecision in linguistic information have been proposed [7], [8]. One of the most widely used methods is the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), developed by Hwang and Yoon [9]. In the evolution of neutrosophy, bipolar neutrosophic numbers have been developed, representing an extension of neutrosophic numbers that take into account the polarity of linguistic information [10]. Bipolar neutrosophic numbers are employed in multiple decision-making to depict uncertainty and imprecision in linguistic information and have been applied in diverse areas, such as the assessment of teaching quality and provider selection [11].

In this context, this study aims to apply the TOPSIS method to address and analyze ethical factors in telemedicine within a bipolar neutrosophic environment. The selection of a Multiple Decision-Making Criteria (MDMC) approach like TOPSIS is justified due to its ability to handle situations where multiple conflicting criteria must be considered [12]–[14]. This aligns with the complexity of ethical dilemmas in telemedicine.

The bipolar neutrosophic environment is introduced as an innovative theoretical framework that allows for a more flexible approach to ethical issues, recognizing the inherent ambiguity in many of these dilemmas [15]. This perspective, considering the existence of an intermediate degree of truth in the assessment of ethical factors, is particularly relevant for addressing the complexity and subjectivity of these matters in the field of telemedicine.

The application of the TOPSIS method in this context involves the identification of specific ethical criteria, their weighting, the evaluation of available alternatives, and the determination of the ideal solution. This approach will enable healthcare professionals, policymakers, and researchers to identify and prioritize the most relevant ethical factors in telemedicine and remote medical care, considering the peculiarities of the bipolar neutrosophic environment.

Ultimately, this study aims to contribute to the development of a robust ethical framework for telemedicine and remote care while demonstrating the utility and applicability of multicriteria decision-making methods, particularly the TOPSIS method, in ethical decision-making within an ever-evolving healthcare environment. The incorporation of the bipolar neutrosophic perspective in this context promotes a deeper and more nuanced reflection on ethical factors, allowing for the addressing of inherent ambiguities in these dilemmas and fostering informed and equitable ethical decision-making in telemedicine.

2 | Bipolar Neutrosophic TOPSIS Method

Definition 1. According to [4], suppose that C is a non-empty set, then a bipolar neutrosophic set (BNS) $\tilde{B}$ is defined in C: $\tilde{B} = \{c, \langle T_{\tilde{B}}^{+}(c), I_{\tilde{B}}^{+}(c), F_{\tilde{B}}^{+}(c), T_{\tilde{B}}^{-}(c), I_{\tilde{B}}^{-}(c), F_{\tilde{B}}^{-}(c)\rangle | c \in C\}$,where $T_{\tilde{B}}^{+}(c), I_{\tilde{B}}^{+}(c), F_{\tilde{B}}^{+}(c): C \to [0,1]$ and $T_{\tilde{B}}^{-}(c), I_{\tilde{B}}^{-}(c), F_{\tilde{B}}^{-}(c): C \to [-1,0]$. The TOPSIS method consists of the following: Let us consider a set $S = \{S_1, S_2, \cdots, S_m\}$ of m favorable alternatives and a set $T = \{T_1, T_2, \cdots, T_n\}$ of n attributes. Let $W = \left[w_{1w_2} \cdots w_n\right]^T$ be a vector of weights, where $0 \le wj \le 1$ and $\sum j = 1nwj = 1$. Suppose the rating value of each alternative Si, (i=1,2,⋯,m) with respect to attributes Tj, (j=1,2,⋯,n) is provided by the decision-maker in the form of bipolar neutrosophic sets (BNSs). The steps of the bipolar neutrosophic TOPSIS method are described as follows:

1. Each alternative's value is estimated concerning n criteria. The value of each alternative under each criterion is provided in the form of bipolar neutrosophic sets (BNSs) and can be expressed in a decision matrix. Each entry $k\_ij =< T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+}, T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-} >$ is characterized by $T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+}$, representing the degree of positive truth membership, indeterminacy, and falsity, respectively. Similarly, $T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-}$ reflect the degree of negative truth membership, indeterminacy, and falsity, respectively. These values adhere to the constraints $T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+} \in [0,1]$, $T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-} \in [-1,0]$, and $0 \le T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+}, T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-} \le 6$, where i=1,2,3,…,m and j=1,2,3,…,n.

2. In case the criteria weights are not equally assigned and are completely unknown to the decision-maker, it is employed the deviation maximization method to determine the unknown criteria weights. Therefore, the weight of the attribute Tj and its normalized weight is established according to Eqs. (1) and (2):

$$w_j = \frac{\sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}|}{\sqrt{\sum_{j=1}^{n} \left(\sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}|\right)^2}}, \tag{1}$$

$$w_j^* = \frac{\sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}|}{\sum_{j=1}^{n} \left(\sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}|\right)}. \tag{2}$$

3. The weighted neutrosophic bipolar cumulative decision matrix is calculated by multiplying the attribute weights by the aggregate decision matrix as follows:

$$K * W = [k_{ij}^{w_j}]_{m\times n} = \begin{bmatrix} k_{11}^{w_1} & k_{12}^{w_2} & \cdots & k_{1n}^{w_n} \\ k_{21}^{w_1} & k_{22}^{w_2} & \cdots & k_{2n}^{w_n} \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ k_{m1}^{w_1} & k_{m2}^{w_2} & \cdots & k_{mn}^{w_n} \end{bmatrix} \quad (3)$$

$$k_{ij}^{w_j} =< T_{ij}^{w_j+}, I_{ij}^{w_j+}, F_{ij}^{w_j+}, T_{ij}^{w_j-}, I_{ij}^{w_j-}, F_{ij}^{w_j-} >$$
$$=< 1-(1-T_{ij}^{+})^{w_j}, (I_{ij}^{+})^{w_j}, (F_{ij}^{+})^{w_j}, -(-T_{ij}^{-})^{w_j}, -(-I_{ij}^{-})^{w_j}, -(1-(1-(-F_{ij}^{-}))^{w_j}) >,$$

4. In real-life decision-making, two types of attributes are generally applied: benefit-type attributes and cost-type attributes. The bipolar neutrosophic positive relative ideal solutions (BNRPIS) and the bipolar neutrosophic negative relative ideal solutions (BNRNIS) for both types of attributes are defined in Eqs. (5) and (6):

$$BNRPIS = (\langle {}^{+}T_1^{w_1+}, {}^{+}I_1^{w_1+}, {}^{+}F_1^{w_1+}, {}^{+}T_1^{w_1-}, {}^{+}I_1^{w_1-}, {}^{+}F_1^{w_1-}\rangle, \langle {}^{+}T_2^{w_2+}, {}^{+}I_2^{w_2+}, {}^{+}F_2^{w_2+}, {}^{+}T_2^{w_2-}, {}^{+}I_2^{w_2-}, {}^{+}F_2^{w_2-}\rangle, \dots, \langle {}^{+}T_n^{w_n+}, {}^{+}I_n^{w_n+}, {}^{+}F_n^{w_n+}, {}^{+}T_n^{w_n-}, {}^{+}I_n^{w_n-}, {}^{+}F_n^{w_n-}\rangle), \quad (5)$$

$$BNRNIS = (\langle {}^{-}T_1^{w_1+}, {}^{-}I_1^{w_1+}, {}^{-}F_1^{w_1+}, {}^{-}T_1^{w_1-}, {}^{-}I_1^{w_1-}, {}^{-}F_1^{w_1-}\rangle, \langle {}^{-}T_2^{w_2+}, {}^{-}I_2^{w_2+}, {}^{-}F_2^{w_2+}, {}^{-}T_2^{w_2-}, {}^{-}I_2^{w_2-}, {}^{-}F_2^{w_2-}\rangle, \dots, \langle {}^{-}T_n^{w_n+}, {}^{-}I_n^{w_n+}, {}^{-}F_n^{w_n+}, {}^{-}T_n^{w_n-}, {}^{-}I_n^{w_n-}, {}^{-}F_n^{w_n-}\rangle), \quad (6)$$

So that, for the benefit type criteria, j=1, 2, …, n

$$\langle {}^{+}T_j^{w_j+}, {}^{+}I_j^{w_j+}, {}^{+}F_j^{w_j+}, {}^{+}T_j^{w_j-}, {}^{+}I_j^{w_j-}, {}^{+}F_j^{w_j-}\rangle = \langle max(T_{ij}^{w_j+}), min(I_{ij}^{w_j+}), min(F_{ij}^{w_j+}), min(T_{ij}^{w_j-}), max(I_{ij}^{w_j-}), max(F_{ij}^{w_j-})\rangle,$$
$$\langle {}^{-}T_j^{w_j+}, {}^{-}I_j^{w_j+}, {}^{-}F_j^{w_j+}, {}^{-}T_j^{w_j-}, {}^{-}I_j^{w_j-}, {}^{-}F_j^{w_j-}\rangle = \langle min(T_{ij}^{w_j+}), max(I_{ij}^{w_j+}), max(F_{ij}^{w_j+}), max(T_{ij}^{w_j-}), min(I_{ij}^{w_j-}), min(F_{ij}^{w_j-})\rangle.$$

Analogously, for cost type criteria, j=1, 2, …, n

$$\langle {}^{+}T_j^{w_j+}, {}^{+}I_j^{w_j+}, {}^{+}F_j^{w_j+}, {}^{+}T_j^{w_j-}, {}^{+}I_j^{w_j-}, {}^{+}F_j^{w_j-}\rangle = \langle min(T_{ij}^{w_j+}), max(I_{ij}^{w_j+}), max(F_{ij}^{w_j+}), max(T_{ij}^{w_j-}), min(I_{ij}^{w_j-}), min(F_{ij}^{w_j-})\rangle,$$
$$\langle {}^{-}T_j^{w_j+}, {}^{-}I_j^{w_j+}, {}^{-}F_j^{w_j+}, {}^{-}T_j^{w_j-}, {}^{-}I_j^{w_j-}, {}^{-}F_j^{w_j-}\rangle = \langle max(T_{ij}^{w_j+}), min(I_{ij}^{w_j+}), min(F_{ij}^{w_j+}), min(T_{ij}^{w_j-}), max(I_{ij}^{w_j-}), max(F_{ij}^{w_j-})\rangle.$$

5. The normalized Euclidean distance of each alternative $\langle T_{ij}^{w_j+}, I_{ij}^{w_j+}, F_{ij}^{w_j+}, T_{ij}^{w_j-}, I_{ij}^{w_j-}, F_{ij}^{w_j-}\rangle$ with respect to the BNRPIS $\langle {}^{+}T_j^{w_j+}, {}^{+}I_j^{w_j+}, {}^{+}F_j^{w_j+}, {}^{+}T_j^{w_j-}, {}^{+}I_j^{w_j-}, {}^{+}F_j^{w_j-}\rangle$ can be calculated using (7) and the normalized Euclidean distance of each alternative $\langle T_{ij}^{w_j+}, I_{ij}^{w_j+}, F_{ij}^{w_j+}, T_{ij}^{w_j-}, I_{ij}^{w_j-}, F_{ij}^{w_j-}\rangle$ with respect to the BNRNIS $\langle {}^{-}T_j^{w_j+}, {}^{-}I_j^{w_j+}, {}^{-}F_j^{w_j+}, {}^{-}T_j^{w_j-}, {}^{-}I_j^{w_j-}, {}^{-}F_j^{w_j-}\rangle$ can be calculated utilizing (8):

$$d_N(S_i, BNRPIS) = \sqrt{\frac{1}{6n}\sum_{j=1}^{n}\left\{\begin{array}{c}(T_{ij}^{w_j+} - {}^{+}T_j^{w_j+})^2 + (I_{ij}^{w_j+} - {}^{+}I_j^{w_j+})^2 + (F_{ij}^{w_j+} - {}^{+}F_j^{w_j+})^2 + \\ (T_{ij}^{w_j-} - {}^{+}T_j^{w_j-})^2 + (I_{ij}^{w_j-} - {}^{+}I_j^{w_j-})^2 + (F_{ij}^{w_j-} - {}^{+}F_j^{w_j-})^2\end{array}\right\}} \quad (7)$$

$$d_N(S_i, BNRNIS) = \sqrt{\frac{1}{6n}\sum_{j=1}^{n}\left\{\begin{array}{c}(T_{ij}^{w_j+} - {}^{-}T_j^{w_j+})^2 + (I_{ij}^{w_j+} - {}^{-}I_j^{w_j+})^2 + (F_{ij}^{w_j+} - {}^{-}F_j^{w_j+})^2 + \\ (T_{ij}^{w_j-} - {}^{-}T_j^{w_j-})^2 + (I_{ij}^{w_j-} - {}^{-}I_j^{w_j-})^2 + (F_{ij}^{w_j-} - {}^{-}F_j^{w_j-})^2\end{array}\right\}} \quad (8)$$

6. The revised proximity degree of each alternative to the BNRPIS, represented as ρi, is calculated using the following formula:

$$\rho(S_i) = \frac{d_N(S_i, BNRNIS)}{max\{d_N(S_i, BNRNIS)\}} - \frac{d_N(S_i, BNRPIS)}{min\{d_N(S_i, BNRPIS)\}}, i = 1,2, \dots, m. \quad (9)$$

7. Using the revised proximity degrees, the lower ratio is determined for each alternative as set out in (10), where each value of $IR(i)$ is in the closed unit interval [0,1]:

$$IR(i) = \frac{\rho(S_i)}{\underset{1 \le i \le m}{min}(\rho(S_i))} \quad (10)$$

8. The alternatives are ranked based on the ascending order of the lower ratio values, and the best alternative with the minimum choice value is chosen.

3 | Identification of Ethical Factors

The initial phase of this research focused on identifying and formulating a list of critically relevant ethical factors influencing remote medical care through telemedicine. The formulation of this list was conducted through a rigorous process, including a comprehensive review of existing literature on medical ethics and telemedicine, as well as consultation with highly qualified experts in these fields. The identified ethical factors are considered foundational for understanding and addressing the inherent ethical challenges in providing remote medical services. The identified factors include:

1. Patient Data Confidentiality: The confidentiality of patient medical information is a fundamental pillar in remote medical care. Ensuring the protection of health data and patient privacy is essential for building trust in telemedical services.
2. Informed Consent in the Digital Environment: Informed consent plays a crucial role in telemedicine. Patients must be fully informed and provide voluntary consent before participating in remote medical consultations or treatments.
3. Remote Physician-Patient Relationship: The quality of the relationship between the physician and the patient should not diminish in the telemedicine environment. Maintaining effective and empathetic communication is essential for providing ethical and satisfactory medical care.
4. Equitable Access to Medical Care: Telemedicine should ensure equitable access to medical care, regardless of the patient's geographic location or socioeconomic status. Equity is a fundamental ethical principle.
5. Patient Autonomy in Remote Decision-Making: Patients should be able to actively participate in decision-making about their medical care, even remotely. Their autonomy and preferences should be respected.

6. Ethics in Remote Treatment Prescriptions: The prescription of remote treatments must adhere to the same ethical standards as in face-to-face consultations, ensuring the provision of the most suitable treatment for the patient.
7. Privacy and Security of Medical Information: Protecting patient medical information is essential to ensure privacy and security. Telemedicine should employ effective measures to prevent unauthorized access.
8. Ethics in Communication and Teleconsultation: Ethical communication is crucial in telemedicine. Empathy, clarity, and the quality of communication are critical aspects of remote medical care.
9. Medical and Legal Responsibility in Telemedicine: Health professionals practicing telemedicine must assume the same medical and legal responsibility as in traditional settings. Ethics and legality are fundamental in this mode of care.

The development of this list of ethical factors was based on a comprehensive approach that considers the diversity of ethical and legal challenges faced by telemedicine. These factors are not only relevant for ethical decision-making but also provide a solid foundation for policy design and clinical practice in this constantly evolving field. The selection of these criteria is a crucial step and was carried out in consultation with experts in medical ethics and telemedicine. The chosen evaluation criteria were grounded in the relevance and practical importance of the identified ethical factors, designed to capture the fundamental aspects impacting the quality and ethics of remote medical care. The four defined evaluation criteria are explained in detail below:

1. Impact on Healthcare Quality (IHQ): This criterion focuses on evaluating how each ethical factor influences the overall quality of remote medical care. Healthcare quality is a fundamental element in medical practice, and telemedicine is no exception. The aim is to determine whether an ethical factor contributes to improving the quality of care, maintaining or even surpassing the standards of in-person care, or if it could lead to a deterioration in healthcare quality.
2. Ethics and Legality (EL): Ethics and legality are essential pillars in remote medical practice. This criterion analyzes the extent to which an ethical factor complies with the ethical and legal principles governing telemedicine. Ethical factors must align with current ethical and legal regulations to ensure ethical and legal medical care.
3. Equity and Accessibility (EA): Equity in access to medical care is a fundamental principle. This criterion evaluates whether an ethical factor contributes to the promotion of equity, especially for marginalized populations or those with difficulties accessing medical care. Telemedicine should be inclusive and accessible to all, and this criterion seeks to ensure that.
4. Patient Decision-Making (PDM): Active patient participation in decision-making is a crucial aspect of ethical medical care. This criterion assesses the extent to which an ethical factor allows and promotes informed decision-making by the patient in the context of telemedicine. Patient autonomy and their ability to participate in decisions related to their care are fundamental.

These criteria were carefully selected to capture the essential aspects of ethics in remote medical care. By considering the impact on healthcare quality, ethics and legality, equity and accessibility, and patient decision-making, a comprehensive evaluation is achieved, allowing for the identification of the most influential and relevant ethical factors in this constantly evolving context.

4 | Calculation of the Priority Order Vector According to the Neutrosophic Method

The evaluation of alternatives through the previously established criteria is a fundamental step in selecting the most influential ethical factors in remote medical care through telemedicine. This process involves assigning values to each ethical factor based on its performance in each of the defined evaluation criteria. To carry out this assessment, a decision matrix of bipolar numbers was used.

The "decision matrix" is a tool that allows for the comparison and rating of alternatives based on the evaluation criteria. In this context, the alternatives represent different ethical factors being evaluated, and the evaluation criteria are the parameters through which these factors are judged. See Table 1.

Table 1. Bipolar number decision matrix.

	IHQ(w=0.26)	EL(w= 0.28)	EA(w= 0.22)	PDM(w= 0.24)
A1	(0.9, 0.5, 0.7, -0.6, -0.4, -0.4)	(0.9, 0.5, 0.7, -0.7, -0.2, -0.4)	(0.2, 0.7, 0.5, -0.4, -0.4, -0.3)	(0.4, 0.6, 0.5, -0.3, -0.7, -0.4)
A2	(0.3, 0.6, 0.1, -0.5, -0.7, -0.5)	(0.2, 0.6, 0.1, -0.5, -0.3, -0.7)	(0.4, 0.2, 0.5, -0.6, -0.3, -0.1)	(0.2, 0.7, 0.5, -0.5, -0.3, -0.2)
A3	(0.3, 0.5, 0.2, -0.4, -0.3, -0.7)	(0.4, 0.5, 0.2, -0.3, -0.8, -0.5)	(0.9, 0.5, 0.7, -0.3, -0.4, -0.3)	(0.3, 0.7, 0.6, -0.5, -0.5, -0.4)
A4	(0.6, 0.7, 0.5, -0.2, -0.1, -0.3)	(0.8, 0.4, 0.6, -0.1, -0.3, -0.4)	(0.6, 0.3, 0.6, -0.1, -0.4, -0.2)	(0.8, 0.3, 0.2, -0.1, -0.3, -0.1)
A5	(0.4, 0.5, 0.2, -0.3, -0.8, -0.5)	(0.9, 0.5, 0.7, -0.3, -0.4, -0.3)	(0.3, 0.7, 0.6, -0.5, -0.5, -0.4)	(0.8, 0.4, 0.6, -0.1, -0.3, -0.4)
A6	(0.5, 0.3, 0.3, -0.7, -0.2, -0.4)	(0.8, 0.4, 0.6, -0.1, -0.3, -0.4)	(0.6, 0.3, 0.6, -0.1, -0.4, -0.2)	(0.4, 0.2, 0.5, -0.6, -0.4, -0.4)
A7	(0.2, 0.6, 0.1, -0.5, -0.3, -0.7)	(0.4, 0.2, 0.5, -0.6, -0.4, -0.4)	(0.2, 0.6, 0.1, -0.5, -0.3, -0.7)	(0.2, 0.6, 0.1, -0.5, -0.3, -0.7)
A8	(0.4, 0.6, 0.5, -0.3, -0.7, -0.4)	(0.2, 0.6, 0.1, -0.5, -0.3, -0.7)	(0.4, 0.7, 0.5, -0.2, -0.1, -0.3)	(0.8, 0.4, 0.6, -0.1, -0.3, -0.4)
A9	(0.9, 0.5, 0.7, -0.3, -0.4, -0.3)	(0.3, 0.7, 0.6, -0.5, -0.5, -0.4)	(0.2, 0.6, 0.1, -0.5, -0.3, -0.7)	(0.2, 0.6, 0.1, -0.5, -0.3, -0.7)

Obtaining the normalized matrix from the decision matrix is a critical step in the process of selecting the most influential ethical factors in remote medical care. The normalized matrix is calculated by multiplying the values in the decision matrix by the weights assigned to each evaluation criterion. This normalization is essential to ensure that the ethical factors are evaluated in a weighted manner according to the importance of each criterion. See Table 2.

Table 2. Normalized decision matrix.

	IHQ	HE	EA	PDM
A1	(0.45, 0.835, 0.911, -0.876, -0.788, -0.124)	(0.475, 0.824, 0.905, -0.905, -0.637, -0.133)	(0.048, 0.925, 0.859, -0.817, -0.817, -0.075)	(0.115, 0.885, 0.847, -0.749, -0.918, -0.115)
A2	(0.089, 0.876, 0.55, -0.835, -0.911, -0.165)	(0.061, 0.867, 0.525, -0.824, -0.714, -0.286)	(0.106, 0.702, 0.859, -0.894, -0.767, -0.023)	(0.052, 0.918, 0.847, -0.847, -0.749, -0.052)
A3	(0.089, 0.835, 0.658, -0.788, -0.731, -0.269)	(0.133, 0.824, 0.637, -0.714, -0.939, -0.176)	(0.397, 0.859, 0.925, -0.767, -0.817, -0.075)	(0.082, 0.918, 0.885, -0.847, -0.847, -0.115)
A4	(0.212, 0.911, 0.835, -0.658, -0.55, -0.089)	(0.363, 0.774, 0.867, -0.525, -0.714, -0.133)	(0.183, 0.767, 0.894, -0.603, -0.817, -0.048)	(0.32, 0.749, 0.68, -0.575, -0.749, -0.025)
A5	(0.124, 0.835, 0.658, -0.731, -0.944, -0.165)	(0.475, 0.824, 0.905, -0.714, -0.774, -0.095)	(0.075, 0.925, 0.894, -0.859, -0.859, -0.106)	(0.32, 0.803, 0.885, -0.575, -0.749, -0.115)
A6	(0.165, 0.731, 0.731, -0.911, -0.658, -0.124)	(0.363, 0.774, 0.867, -0.525, -0.714, -0.133)	(0.183, 0.767, 0.894, -0.603, -0.817, -0.048)	(0.115, 0.68, 0.847, -0.885, -0.803, -0.115)
A7	(0.056, 0.876, 0.55, -0.835, -0.731, -0.269)	(0.133, 0.637, 0.824, -0.867, -0.774, -0.133)	(0.048, 0.894, 0.603, -0.859, -0.767, -0.233)	(0.052, 0.885, 0.575, -0.847, -0.749, -0.251)
A8	(0.124, 0.876, 0.835, -0.731, -0.911, -0.124)	(0.061, 0.867, 0.525, -0.824, -0.714, -0.286)	(0.106, 0.925, 0.859, -0.702, -0.603, -0.075)	(0.32, 0.803, 0.885, -0.575, -0.749, -0.115)
A9	(0.45, 0.835, 0.911, -0.731, -0.788, -0.089)	(0.095, 0.905, 0.867, -0.824, -0.824, -0.133)	(0.048, 0.894, 0.603, -0.859, -0.767, -0.233)	(0.052, 0.885, 0.575, -0.847, -0.749, -0.251)

From the information gathered in the normalized matrix, the calculation of the Bipolar Neutrosophic Positive Relative Ideal Solution (BNRPIS) and the Bipolar Neutrosophic Negative Relative Ideal Solution (BNRNIS) for each evaluation criterion was carried out. These ideal solutions are crucial for the process of selecting and ranking ethical factors in remote medical care.

Table 3. Positive and negative ideal solutions for criterion.

$BNRPIS$	$BNRNIS$
(0.45, 0.731, 0.55, -0.911, -0.55, -0.089)	(0.056, 0.911, 0.911, -0.658, -0.944, -0.269)
(0.731, 0.55, -0.911, -0.55, -0.089, 0.061)	(0.911, 0.911, -0.658, -0.944, -0.269, 0.475)
(0.55, -0.911, -0.55, -0.089, 0.061, 0.905)	(0.911, -0.658, -0.944, -0.269, 0.475, 0.637)
(-0.911, -0.55, -0.089, 0.061, 0.905, 0.905)	(-0.658, -0.944, -0.269, 0.475, 0.637, 0.525)

The calculation of the Euclidean distance between each ethical factor and the Ideal Solutions for each evaluation criterion was performed, allowing the derivation of values representing the proximity of each factor to the ideal solutions. The Euclidean distance is a metric used to measure the proximity or similarity between two points in a multidimensional space. In this context, the points represent the ethical factors and the ideal solutions in the space defined by the evaluation criteria. By calculating the Euclidean distance between each ethical factor and the ideal solutions, values are obtained indicating how close or far each factor is from being ideal in each criterion. From these data, the calculation of proximity degrees and the relationship index can be performed. The results are shown in Table 4.

Table 4. Ranking of the most influential ethical factors.

	ϱ(Si)	**IR(i)**
1. Confidentiality of patient data.	-0.513	0.9821
2. Informed consent in the digital environment.	-0.271	0.51961
3. Remote doctor-patient relationship.	-0.205	0.39228
4. Equitable access to health care.	-0.148	0.28306
5. Patient autonomy in remote decision-making.	-0.522	1
6. Ethics in prescribing remote treatments.	-0.088	0.16815
7. Privacy and security of medical information.	-0.215	0.41281
8. Ethics in communication and teleconsultation.	-0.506	0.96999
9. Medical and legal liability in telemedicine.	-0.037	0.07024

An IR value close to 1 indicates that an ethical factor is closer to the positive ideal solution, while a value close to 0 suggests that the factor is closer to the negative ideal solution. The results show that the ethical factor "Patient autonomy in remote decision making" obtained the highest IR value, reaching the maximum value of 1. This indicates that this ethical factor is significantly close to the positive ideal solution in all criteria of evaluation, which positions it as the most influential ethical factor in remote medical care. In contrast, the ethical factor "Ethics in prescribing remote treatments" obtained a lower IR value, suggesting that its ethical performance is less favorable in relation to the established criteria. The obtained priority order vector is [S9, S6, S4, S3, S7, S2, S8, S1, S5].

5 | Conclusions

This study demonstrated the utility of neutrosophic logic and the TOPSIS method in a bipolar neutrosophic environment for evaluating ethical factors in remote healthcare. The study was based on a review of existing scientific literature and consultation with experts in medical ethics and telemedicine. The evaluation of ethical factors was carried out through the application of the neutrosophic TOPSIS method, which allows for an equitable and objective assessment of factors in a bipolar neutrosophic environment. The results revealed that the ethical factor "Patient autonomy in remote decision-making" was the most influential in remote medical care, reaching the maximum value of the Classification Index (CI). This indicates that patient autonomy plays a crucial role in ethical decision-making in the context of telemedicine. The application of neutrosophic logic in ethical decision-making in medicine allowed decision-makers to recognize and address the inherent ambiguity in clinical situations. The results provide important guidance for healthcare professionals and policymakers seeking to improve quality and ethics.

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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