Applied Mathematics and Computational Intelligence
Volume 15, No. 4, 2026 [10-23]

Ranking the Hormone Therapy Medicines for Breast Cancer Using the Fuzzy AHP

Saeed Barzegari[1], Seyed Alireza Hasani[2], Reza Barzegari[3], Ibrahim Arpaci[4,5]*

[1]Department of Paramedicine, Amol Faculty of Paramedical Sciences, Mazandaran University of Medical Sciences, Sari, Iran
[2]Department of Nursing, Amol Faculty of Nursing and Midwifery, Mazandaran University of Medical Sciences, Sari, Iran
[3]Department of Management, Ahar Branch, Islamic Azad University, Ahar, Iran
[4]Department of Computer Engineering, Faculty of Engineering, Bursa Uludag University, 16285, Bursa, Türkiye
[5]Department of Computer Science and Engineering, College of Informatics, Korea University, Seoul 02841, Republic of Korea

*Corresponding author: ibrahimarpaci@uludag.edu.tr

Received: 14 August 2025
Revised: 6 February 2026
Accepted: 3 March 2026

ABSTRACT

This study aimed to use Chang's Fuzzy Analytic Hierarchy Process (FAHP) to rank hormone therapy drugs for post-menopausal women with breast cancer. The study involved presenting hierarchical charts to a panel of experts, which included three oncologists who have more than ten years of experience in hormone therapy for breast cancer. The experts were given a pairwise comparison matrix to assess the relative importance of each criterion and to express their responses as fuzzy numbers. The consistency ratio (CR) for all pairwise comparison matrices was confirmed to be less than 0.1, ensuring acceptable consistency in expert judgments. The expert panel used this approach to determine the extent of the criteria and sub-criteria. The results indicated that Anastrozole was the most preferred drug for hormone therapy in breast cancer patients who are post-menopausal, with a total score of 47.2, compared to Letrozole (35.7) and Exemestane (17.1). Anastrozole was 1.3 and 2.8 times more preferred than Letrozole and Exemestane. The study showed that Anastrozole was the most preferred drug due to its low cost, high survival rate, and effectiveness, and, most importantly, its sub-criteria, including OS, ORR, TTP, TTF, and DFS.

Keywords: Anastrozole, Breast Cancer, Exemestane, FAHP, Hormone Therapy, Letrozole.

1 INTRODUCTION

Breast cancer (BC) is one of the most prevalent cancers in the world, accounting for about one-third of all cancers that affect women [1]. According to WHO predictions, the incidence of breast cancer increases by 1.8 to 2 percent each year, particularly in developing countries and among older women. By 2050, the incidence of breast cancer is expected to rise to 3.2 million cases [2]. Studies have shown that approximately 77% of cases are diagnosed among post-menopausal women [3], and over 70%

of patients are Progesterone-Receptor positive (PR+) and Estrogen-Receptor positive (ER+) [4]. Hormone receptor status is critical in cancer invasion and progression [5]. Therefore, hormone therapy is essential for first-line treatment of patients with BC, as it improves survival and quality of life [6,7]. Currently, the first-choice hormone therapy drugs for post-menopausal patients with hormone-positive status are third-generation Aromatase inhibitors, including Anastrozole, Exemestane, and Letrozole [8]. These inhibitors can suppress hormone production by more than 95% and be effective in post-menopausal patients and those without ovarian function [9].

However, previous studies comparing these inhibitors have not consistently favored one drug over others, as they were limited to a single criterion or a few criteria [10,11]. Most prior studies did not investigate the roles of survival rate, efficiency, recurrence, side effects, or cost when comparing drugs, and, more importantly, they did not conduct a comprehensive comparison across all relevant criteria [10,11,12,13,14]. Therefore, determining the most appropriate hormone therapy drug for the treatment of breast cancer is not easy. For example, Letrozole has a higher clinical benefit and overall survival than other drugs, according to prior studies [13,15,14].

There are no significant differences in efficacy or safety between Letrozole and Anastrozole, or between Anastrozole and Exemestane [16,15,14]. Furthermore, the disease-free survival rates of Anastrozole (90%), Letrozole (89%), and Exemestane (88%) were higher than those of the other two [10]. In other studies, the survival rate [17], efficacy, and time to progression (TTP) of Anastrozole were reported to be greater than those of Exemestane [18]. However, the side effects of Anastrozole were greater than those of Exemestane, and the clinical benefits of Exemestane were greater than those of Anastrozole [17].

According to previous studies, there are several qualitative and quantitative criteria with varying values for comparing and selecting hormone therapy drugs for breast cancer. Determining the best drug for therapy is a complex process that can lead to confusion in decision-making [19]. “Multiple Criteria Decision-Making” (MCDM) methods can help professionals select and rank alternatives or choices in situations with numerous qualitative and quantitative criteria. The “Analytic Hierarchy Process” (AHP) is one of the most used MCDM methods. AHP, with its hierarchical structure, can determine the relative impact of different criteria on the ranking of alternatives. AHP assists professionals in making comprehensive, individual, and group decisions by providing an integrated structure of criteria, options, and sub-criteria. In this method, the weight or rank of each criterion is determined by pairwise comparisons among criteria, options, and sub-criteria, and by converting experts' experience and knowledge into numerical values [20].

Although AHP uses rigid numerical scales in pairwise comparisons, it may not accurately reflect human judgment [21]. Due to the fuzzy nature of pairwise comparisons, decision-makers may not express their opinions in rigid numerical terms. Ambiguity and fuzziness are prominent features of decision-making [22], and decision-makers tend to prefer ranges over fixed numbers in their judgments [23]. To address such shortcomings, the fuzzy theory was integrated with AHP [21, 24]. Consequently, the “Fuzzy Analytic Hierarchy Process” (FAHP) method became the most widely used Fuzzy Multiple Criteria Decision-Making (FMCDM) method [25]. Given the numerous advantages and disadvantages of Anastrozole, Letrozole, and Exemestane, aggregating experts’ opinions to select and rank these drugs for hormone therapy in postmenopausal women with breast cancer is challenging. Thus, the study aimed to rank these drugs based on experts’ opinions using the FAHP method.

2 MATERIAL AND METHODS

Breast cancer (BC) is one of the most prevalent cancers in the world, accounting for about one-third of all cancers that affect women [1]. According to WHO predictions, the incidence of breast cancer increases by 1.8 to 2 percent each year, particularly in developing countries and among older women. By 2050, the incidence of breast cancer is expected to rise to 3.2 million cases [2]. Studies have shown that approximately 77% of cases are diagnosed among post-menopausal women [3], and over 70% of patients are Progesterone-Receptor positive (PR+) and Estrogen-Receptor positive (ER+) [4]. Hormone receptor status is critical in cancer invasion and progression [5]. Therefore, hormone therapy is essential for first-line treatment of patients with BC, as it improves survival and quality of life [6,7]. Currently, the first-choice hormone therapy drugs for post-menopausal patients with hormone-positive status are third-generation Aromatase inhibitors, including Anastrozole, Exemestane, and Letrozole [8]. These inhibitors can suppress hormone production by more than 95% and be effective in post-menopausal patients and those without ovarian function [9].

However, previous studies comparing these inhibitors have not consistently favored one drug over others, as they were limited to a single criterion or a few criteria [10,11]. Most prior studies did not investigate the roles of survival rate, efficiency, recurrence, side effects, or cost when comparing drugs, and, more importantly, they did not conduct a comprehensive comparison across all relevant criteria [10,11,12,13,14]. Therefore, determining the most appropriate hormone therapy drug for the treatment of breast cancer is not easy. For example, Letrozole has a higher clinical benefit and overall survival than other drugs, according to prior studies [13,15,14].

There are no significant differences in efficacy or safety between Letrozole and Anastrozole, or between Anastrozole and Exemestane [16,15,14]. Furthermore, the disease-free survival rates of Anastrozole (90%), Letrozole (89%), and Exemestane (88%) were higher than those of the other two [10]. In other studies, the survival rate [17], efficacy, and time to progression (TTP) of Anastrozole were reported to be greater than those of Exemestane [18]. However, the side effects of Anastrozole were greater than those of Exemestane, and the clinical benefits of Exemestane were greater than those of Anastrozole [17].

According to previous studies, there are several qualitative and quantitative criteria with varying values for comparing and selecting hormone therapy drugs for breast cancer. Determining the best drug for therapy is a complex process that can lead to confusion in decision-making [19]. “Multiple Criteria Decision-Making” (MCDM) methods can help professionals select and rank alternatives or choices in situations with numerous qualitative and quantitative criteria. The “Analytic Hierarchy Process” (AHP) is one of the most used MCDM methods. AHP, with its hierarchical structure, can determine the relative impact of different criteria on the ranking of alternatives. AHP assists professionals in making comprehensive, individual, and group decisions by providing an integrated structure of criteria, options, and sub-criteria. In this method, the weight or rank of each criterion is determined by pairwise comparisons among criteria, options, and sub-criteria, and by converting experts' experience and knowledge into numerical values [20].

Although AHP uses rigid numerical scales in pairwise comparisons, it may not accurately reflect human judgment [21]. Due to the fuzzy nature of pairwise comparisons, decision-makers may not express their opinions in rigid numerical terms. Ambiguity and fuzziness are prominent features of decision-making [22], and decision-makers tend to prefer ranges over fixed numbers in their judgments [23]. To address such shortcomings, the fuzzy theory was integrated with AHP [21,24].

Consequently, the “Fuzzy Analytic Hierarchy Process” (FAHP) method became the most widely used Fuzzy Multiple Criteria Decision-Making (FMCDM) method [25]. Given the numerous advantages and disadvantages of Anastrozole, Letrozole, and Exemestane, aggregating experts’ opinions to select and rank these drugs for hormone therapy in postmenopausal women with breast cancer is challenging. Thus, the study aimed to rank these drugs based on experts’ opinions using the FAHP method.

2.1 Participants

Since the AHP is not a statistical method, there is no need to prove the statistical hypothesis or test the statistical significance. For this reason, a large sample size is not required. Moreover, there is no standardized method for determining sample size in these studies; sample size depends on the study's purpose and the availability of samples [23]. Therefore, a panel of experts, including three oncologists who had at least ten years of experience in hormone therapy for breast cancer, was recruited. The study's objectives and process were explained in detail to the experts, and their questions and ambiguities were resolved. All experts who participated in the study provided informed consent, and they were informed that their personal information would be kept confidential.

2.2 Step 1: Determine sub-criteria and criteria

The sub-criteria and criteria were determined using a semi-structured interview with experts and a systematic review of papers indexed in ScienceDirect, PubMed, Scopus, and Google Scholar. Determined criteria affecting the selection of hormone therapy drugs included survival rate, efficiency, recurrence, side effects, and cost. The survival rate is divided into two sub-criteria involving “Disease-Free Survival” (DFS) and “Overall Survival” (OS). The efficiency criterion is divided into three sub-criteria, including “Time to Treatment Failure” (TTF), “Time to Progression” (TTP), and “Objective Response Rate” (ORR). The side effects criterion encompasses sub-criteria for severe, moderate, and mild side effects. To classify side effects as severe, moderate, or mild, we first identified the side effects for each alternative. Then we had experts categorize each side effect into an appropriate class. The panel of experts confirmed the sub-criteria and criteria defined in the first stage. Accordingly, the study's hierarchical structure is presented in Figure 1, which includes the purpose, criteria, alternatives, and sub-criteria.

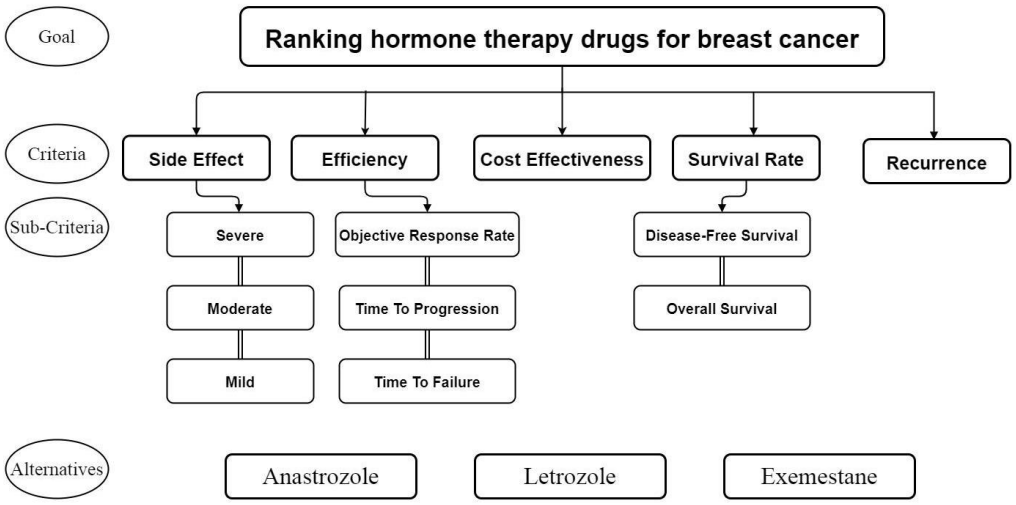


Figure 1: Hierarchical structure of the study

2.3 Step 2: Pairwise comparison matrices

First, pairwise comparison matrices constructed from a hierarchical structure were trained using data from oncologists. For pairwise comparisons of the criteria, a 4 × 4 matrix was constructed. In contrast, for the pairwise comparison of the survival rate sub-criteria, efficacy sub-criteria, and side-effect sub-criteria, a 2*2, 3*3, and 3*3 matrix was designed. 13 pairwise comparison matrices (1*3 dimension) have been created to compare alternatives according to each criterion and sub-criterion. In the next step, participants completed matrices using the language variables presented in Table 1. Finally, these variables were converted to corresponding triangular fuzzy numbers [26].

Table 1. The Equivalent triangular fuzzy numbers for linguistic pairwise comparisons

Linguistic Variables (Importance)	Triangular Fuzzy Numbers (Reciprocals)	Triangular Fuzzy Numbers
Extreme	(1/9, 1/9, 1/9)	(9, 9, 9)
Very strong	(1/8, 1/7, 1/6)	(6, 7, 8)
Strong	(1/6, 1/5, 1/4)	(4, 5, 6)
Moderate	(1/4, 1/3, 1/2)	(2, 3, 4)
Equal	(1, 1, 1)	(1, 1, 1)
Intermediate values	(1/3, 1/2, 1), (1/5, 1/4, 1/3), (1/7, 1/6, 1/5), and (1/9, 1/8, 1/7)	(1, 2, 3), (3, 4, 5), (5, 6, 7), and (7, 8, 9)

2.4 Step 3: Use the FAHP to prioritize alternatives, criteria, and sub-criteria

The FAHP pairwise comparison matrix is as follows: each element is a fuzzy triangular number, with the first component representing the lowest value (a12) and the second representing the average (b12). The third component represents the highest value (c12).

$$\begin{bmatrix} (1,1,1) & (a_{12},b_{12},c_{12}) & \cdots & (a_{1n},b_{1n},c_{1n}) \\ (a_{21},b_{21},c_{21}) & (1,1,1) & \cdots & \vdots \\ \vdots & \vdots & \cdots & \vdots \\ (a_{n1},b_{n1},c_{n1}) & (a_{n2},b_{n2},c_{n2}) & \ldots & (1,1,1) \end{bmatrix} \quad (1)$$

First, the pairwise comparison matrix's Si value is determined for each row using the formula below:

$$\tilde{S}_i = \sum_{j=1}^{m} \tilde{M}_{g_i}^{j} \otimes \left(\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{M}_{g_i}^{j} \right)^{-1} \quad (2)$$

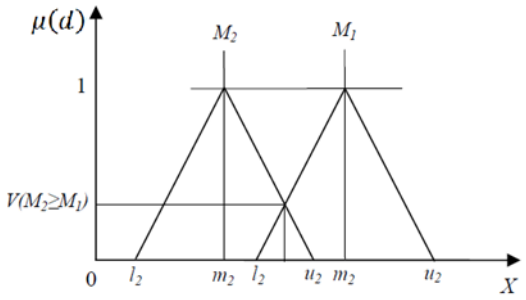
In this formula, i and j denote the number of rows and columns, respectively [27]. The subsets of this formula can be calculated using the following formulas: li, mi, and ui, which are the first, second, and third components of fuzzy numbers.

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g^i}^{i} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \quad (3)$$

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} m_{g^i}^{j} \right]^{-1} \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \quad (4)$$

Next, assuming that M1 = (l1, m1, u1) and M2 = (l2, m2, u2) are two triangular fuzzy numbers, we calculated the magnitude of triangular fuzzy numbers using the following formula:

$$\mu(d) = \begin{cases} 1 & m_2 \geq m_1 \\ \dfrac{u_1 - l_2}{(u_1 - l_1) - (m_2 - l_2)} & otherwise \\ 0 & l_1 \geq u_2 \end{cases} \quad (5)$$



(6)

Finally, the following formula was used to calculate the weight of criteria, sub-criteria, and alternatives:

$$W = \left(d\left(A_1\right), d\left(A_2\right), \cdots, d\left(A_n\right)\right)^{\tau} \quad (7)$$

$$W' = \left(d'\left(A_1\right), d'\left(A_2\right), \cdots, d'\left(A_n\right)\right)^{\tau} \quad (8)$$

$$d'(A_i) = MinV\left(S_i \geq S_k\right) \quad (9)$$

2.5 Step 4: Assessing the consistency

The "Consistency Ratio" (CR) of each pairwise comparison matrix and our findings was calculated. If it exceeded 0.1, the comparisons were deemed irrational, and the matrices were returned to the experts for correction. The CR is the ratio of the "Consistency Index" (CI) to the "Random Consistency Index" (RI).

$$CR = CI / RI \quad (10)$$

The value of RI is obtained using Table 2, and the following formula was used to calculate CI:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (11)$$

Table 2. Random consistency index values for pairwise comparison matrices of different sizes

N	2	3	4	5	6	7	8	9	10
RI	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.51

N: The number of items in the comparison matrix

By averaging the matrix's eigenvectors, it is possible to determine max, the matrix's principal eigenvalue. The matrix eigenvector was computed as a weighted sum of the vector elements, with weights determined by their associated priority values [28].

3 RESULTS

Three oncologists with an average of 18 years of experience in breast cancer care completed the pairwise comparison matrices. The weights of each criterion and sub-criterion were calculated using Chang's triangular FAHP (See Table 3). The highest normalized weight was associated with the survival rate (42.9%). Therefore, the most essential criterion for physicians in choosing hormone therapy was the patient's survival rate, followed by recurrence (22.1%), efficiency (20.2%), side effects (10.3%), and cost (4.5%). The weight of each criterion's sub-criteria was also calculated, and the most crucial sub-criteria for survival and recurrence were ORR (52) and OS (86), respectively. Furthermore, the highest weight for sub-criteria related to side effects was severe (62.5%), followed

by moderate (28.5%) and mild (9.5%). Since the CR values for all matrices were less than 0.1, comparisons were performed without issue, and the results are valid.

Table 3: Normalized weight of each criterion and sub-criterion

Criteria and Sub-Criteria	Normalized Weights	Dimensions	RI	Λ	CI	CR
Cost	4.5					
Survival	42.9					
Efficiency	20.2	5	1.12	5.44	0.109	0.096
Side-effect	10.3					
recurrence	22.1					
Mild complication	9					
Moderate complication	28.5	3	0.58	3.08	0.043	0.074
Severe complication	62.5					
TTF (Time-to-Treatment Failure)	33.2	3	0.58	3.11	0.054	0.094
TTP (Time to Progression)	14.8					
ORR (Objective Response Rate)	52					
OS (overall survival)	86					
DFS (disease-free survival)	14	2	0	0	0	0

Table 4: The weights of the criteria and sub-criteria for three aromatase inhibitors

	Anastrozole	Letrazole	Exomestane	Dimensions	RI	Λ	CI	CR
Cost	49.3	34.1	16.1	3	.58	3.07	.033	.057
Survival	51.9	33.1	15	3	.58	3.06	.03	.031
Efficiency	50.8	33.1	16.1	3	.58	3.08	.04	.031
Side-effects	37	38.3	24.7	3	.58	3.05	.023	.034
Recurrence	39.6	42.5	17.9	3	.58	3.1	.051	.089
DFS	51.5	33.1	15.4	3	.58	3.1	.05	.086
OS	53.3	32.6	14.1	3	.58	3.04	.02	.036
TTP	50.4	34.4	15.2	3	.58	3.06	.031	.053
TTF	50.7	34.4	16.9	3	.58	3.08	.041	.071
OR	52.5	32.4	12.7	3	.58	3.06	.031	.053
Mild side effects	37.7	40.2	22.1	3	.58	3.04	.021	.036
Moderate side-effects	36.1	37.7	26.2	3	.58	3.04	.02	.035
Severe side-effects	36.6	33.5	29.9	3	.58	3.05	.02	.039

Sub-criterion weights and criteria for each drug were then calculated. According to the results presented in Table 4, Anastrozole had the highest survival rate (1.6 and 3.2 times greater than Letrozole and Exemestane), as well as the highest efficiency (1.5 and 3.2 times greater than Letrozole and Exemestane), and the lowest cost (1.4 and 3 times lower than Letrozole and Exemestane). However, according to experts, Letrozole had the fewest side effects and recurrences, with a slight difference compared with Anastrozole. The CR values for all matrices were below 0.1, indicating acceptable validity.

Combining the weights from Tables 3 and 4 yielded the normalized weight and rank for each drug. According to the results, Anastrozole (47.2) has the highest weight and ranking, followed by Letrozole (35.7) and Exemestane (17.1). As a result, Anastrozole is 1.3 and 2.8 times more preferred than Letrozole and Exemestane for hormone therapy for breast cancer in menopausal women.

4 CONCLUSION

Selecting the most effective drug to treat severe diseases is a substantial challenge for clinicians who must evaluate various aspects and characteristics of different options to choose the most appropriate drug. In this study, hormone therapy medicines for postmenopausal patients with breast cancer were ranked based on experts' knowledge and experiences using the FAHP method, one of the most common methods for decision-making based on expert knowledge and experiences.

Survival rate is one of the most critical factors in drug selection, with a weight of 42.9% in the present study. Recurrence, side effects, and cost also play significant roles. Anastrozole had the highest weight based on the survival rate among the three aromatase inhibitors. However, compared to the other two drugs (Letrozole and Exemestane), they had a higher cost in terms of weight. A previous study showed that postmenopausal women who took tamoxifen for two years as adjunctive therapy were less likely to experience a recurrence of breast cancer, and administering Anastrozole significantly improved overall survival [29].

In another study, patients with advanced breast cancer receiving two aromatase inhibitors, Anastrozole and Letrozole, were investigated, with Letrozole having a higher ORR than Anastrozole (19.1% vs. 12.3%). However, there was no difference in the TTP of the drugs, so it was recommended that Letrozole be used as a second-line treatment for postmenopausal women with advanced breast cancer. Another study revealed that Letrozole had a higher DFS than tamoxifen [30]. Furthermore, Anastrozole prevented disease recurrence more efficiently [31].

Regarding efficacy, Letrozole has a higher ORR than Anastrozole (19.1% vs. 12.3%). However, TTP, which indicates the time from diagnosis or treatment to deterioration or metastasis, did not differ between the two drugs [15]. In the present study, Anastrozole showed better efficacy than the other two aromatase inhibitors. However, a clinical trial indicated that none of the three aromatase inhibitors was superior in efficacy [10]. Such differences might be due to the differences in the methodologies used in the studies.

In a study by Nabholtz et al. [32] that used survival analysis, the results showed that Anastrozole had a higher TTP than tamoxifen, consistent with our findings [32]. Furthermore, a clinical investigation of Anastrozole and Letrozole revealed that both drugs were clinically useful, with median durations

of response and clinical benefit. There was also no statistically significant difference in overall survival, and both drugs were well tolerated [15].

After analyzing costs, Anastrozole was the least expensive of the three aromatase inhibitors. Rocchi et al. [35] reported that Anastrozole was more cost-effective than tamoxifen. Similarly, Lux et al. [36] found that Anastrozole was superior to tamoxifen in terms of efficacy, safety, and cost in the adjuvant therapy of hormone receptor-positive postmenopausal patients. Mansel et al. [37] also supported these findings.

In terms of side effects, Letrozole had fewer side effects than the other two aromatase inhibitors. Anastrozole was also found to have fewer side effects than tamoxifen [33]. Bell et al. [34] reported that joint pain, fatigue, joint and muscle stiffness, and myalgia were the most common side effects of aromatase inhibitors, which sometimes led to the discontinuation of treatment by patients.

Another important criterion in drug selection is the likelihood of disease recurrence. The present study showed that Letrozole had a lower disease recurrence rate than the other two aromatase inhibitors. On the other hand, Exemestane was associated with more side effects and a higher recurrence rate. A study by the Group [30] comparing Tamoxifen and Letrozole in postmenopausal women, with a sample size of 8010, demonstrated that patients taking Letrozole experienced fewer relapses than those taking Tamoxifen. Furthermore, Letrozole was found to be safer than Tamoxifen.

5 CONCLUSION

In this study, we used the process of fuzzy hierarchical analysis based on expert panel evaluations to rank hormone therapy drugs in postmenopausal patients with a history of receiving tamoxifen. Our findings demonstrated that Anastrozole was the most preferred drug. This study highlights the potential use of FAHP in facilitating decision-making about drug selection for the treatment of women with breast cancer. Considering various factors, such as costs, benefits, and risks, enables us to make informed decisions and provide the most appropriate treatment for patients. Therefore, FAHP can offer the best choice to treat breast cancer patients by providing explicit information and helping healthcare professionals make informed decisions.

Several limitations of the study should be acknowledged. Firstly, the study relied on expert panel evaluations, which may be subject to bias or individual opinions. Secondly, using a fuzzy analytic hierarchy process may have limitations, such as potential inconsistency in the criteria assigned by experts. Finally, the study did not consider individual patient characteristics or preferences, which may impact treatment decisions. Despite these limitations, the present study provides valuable insights into the decision-making process surrounding hormone therapy drug selection in breast cancer treatment.

ACKNOWLEDGEMENT

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Ethics approval

number: IR.MAZUMS..REC.1397.1200. Informed consent was obtained from all participants involved in the study.

REFERENCES

[1] R. L. Siegel, K. D. Miller, A. G. Sauer, S. A. Fedewa, L. F. Butterly, J. C. Anderson, and A. Jemal, "Colorectal cancer statistics, 2020," *CA: A Cancer J. Clinicians*, vol. 70, no. 3, pp. 145–164, 2020, doi: 10.3322/caac.21601.

[2] Z. Tao, A. Shi, C. Lu, T. Song, Z. Zhang, and J. Zhao, "Breast cancer: epidemiology and etiology," *Cell Biochem. Biophys*., vol. 72, no. 2, pp. 333–338, 2015, doi: 10.1007/s12013-014-0459-6.

[3] S. Alizadeh, K. Moshfeghi, M. Kalantari, and K. Ebrahimi, "Lymph-node involvement and tumor markers in patients with breast cancer," *J. Arak Univ. Med. Sci*., vol. 12, no. 4, pp. 44–50, 2010.

[4] S. J. Aurit, S. S. Devesa, A. S. Soliman, and C. Schairer, "Inflammatory and other breast cancer incidence rate trends by estrogen receptor status in the Surveillance, Epidemiology, and End Results database (2001–2015)," *Breast Cancer Res. Treat*., vol. 175, no. 3, pp. 755–764, 2019, doi: 10.1007/s10549-019-05193-0.

[5] F. Homaei-Shandiz, H. Saeidi-Saedi, and N. Sharifi, "Correlation of estrogen and progesterone receptors with menopausal status in breast cancer patients referred to Omid and Ghaem hospitals," *J. Birjand Univ. Med. Sci*., vol. 16, no. 2, pp. 42–48, 2009.

[6] J. Ferlay et al., "Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012," *Int. J. Cancer*, vol. 136, no. 5, pp. E359–E386, 2015, doi: 10.1002/ijc.29210.

[7] I. Migliaccio, L., Malorni, C., D. Hart, C., Guarducci, and A. Di Leo, "Endocrine therapy considerations in postmenopausal patients with hormone receptor positive, human epidermal growth factor receptor type 2 negative advanced breast cancers," *BMC Med*., vol. 13, no. 1, pp. 1–6, 2015, doi: 10.1186/s12916-015-0280-0.

[8] L. Gibson, D. Lawrence, C. Dawson, and J. Bliss, "Aromatase inhibitors for treatment of advanced breast cancer in postmenopausal women," *Cochrane Database Syst. Rev*., no. 4, 2009, doi: 10.1002/14651858.CD003370.pub3.

[9] R. G. Margolese et al., "Anastrozole versus tamoxifen in postmenopausal women with ductal carcinoma in situ undergoing lumpectomy plus radiotherapy (NSABP B-35): a randomised, double-blind, phase 3 clinical trial," *Lancet*, vol. 387, no. 10021, pp. 849–856, 2016, doi: 10.1016/S0140-6736(15)01168-X.

[10] S. De Placido et al., "Adjuvant anastrozole versus exemestane versus letrozole, upfront or after 2 years of tamoxifen, in endocrine-sensitive breast cancer (FATA-GIM3): a randomized, phase 3 trial," *Lancet Oncol*., vol. 19, no. 4, pp. 474–485, 2018, doi: 10.1016/S1470-2045(18)30116-5.

[11] J. Geisler, "What differences between the non-steroidal aromatase inhibitors anastrozole and

letrozole of clinical importance?" *Br. J. Cancer*, vol. 104, no. 7, pp. 1059–1066, 2011, doi: 10.1038/bjc.2011.58.

[12] T. He et al., "Comparative effectiveness of tamoxifen, toremifene, letrozole, anastrozole, and exemestane on lipid profiles in breast cancer patients: a network meta-analysis," *Medicine*, vol. 99, no. 2, 2020, doi: 10.1097/MD.0000000000018550.

[13] J. Karnon, "Cost-effectiveness of letrozole, anastrozole, and exemestane for early adjuvant breast cancer," *Expert Rev. Pharmacoecon. Outcomes Res*., vol. 7, no. 2, pp. 143–153, 2007, doi: 10.1586/14737167.7.2.143.

[14] I. Smith et al., "Comparative efficacy and safety of adjuvant letrozole versus anastrozole in postmenopausal patients with hormone receptor-positive, node-positive early breast cancer: final results of the randomized phase III Femara versus Anastrozole Clinical Evaluation (FACE) trial," *J. Clin. Oncol*., 2017, doi: 10.1200/jco.2016.69.2871.

[15] C. Rose et al., "An open randomised trial of second-line endocrine therapy in advanced breast cancer: comparison of the aromatase inhibitors letrozole and anastrozole," *Eur. J. Cancer*, vol. 39, no. 16, pp. 2318–2327, 2003, doi: 10.1016/S0959-8049(03)00630-0.

[16] H. Iwata et al., "A randomized, double-blind, controlled study of exemestane versus anastrozole for the first-line treatment of postmenopausal Japanese women with hormone-receptor-positive advanced breast cancer," *Breast Cancer Res. Treat*., vol. 139, no. 2, pp. 441–451, 2013, doi: 10.1007/s10549-013-2573-3.

[17] S. M. Campos, J. P. Guastalla, M. Subar, P. Abreu, E. P. Winer, and D. A. Cameron, "A comparative study of exemestane versus anastrozole in patients with postmenopausal breast cancer with visceral metastases," *Clin. Breast Cancer*, vol. 9, no. 1, pp. 39–44, 2009, doi: 10.3816/CBC.2009.n.007.

[18] A. Llombart-Cussac et al., "Exemestane versus anastrozole as front-line endocrine therapy in postmenopausal patients with hormone receptor-positive, advanced breast cancer: final results from the Spanish Breast Cancer Group 2001-03 phase 2 randomized trial," *Cancer*, vol. 118, no. 1, pp. 241–247, 2012, doi: 10.1002/cncr.26299.

[19] J. G. Dolan, "Shared decision-making: transferring research into practice: the Analytic Hierarchy Process (AHP)," *Patient Educ. Couns*., vol. 73, no. 3, pp. 418–425, 2008, doi: 10.1016/j.pec.2008.07.032.

[20] Y. Katsumura, H. Yasunaga, T. Imamura, K. Ohe, and H. Oyama, "Relationship between risk information on total colonoscopy and patient preferences for colorectal cancer screening options: analysis using the analytic hierarchy process," *BMC Health Serv. Res*., vol. 8, no. 1, pp. 1–8, 2008, doi: 10.1186/1472-6963-8-106.

[21] M. Shaverdi, M. R. Heshmati, and I. Ramezani, "Application of fuzzy AHP approach for financial performance evaluation of Iranian petrochemical sector," *Procedia Comput. Sci*., vol. 31, pp. 995–1004, 2014, doi: 10.1016/j.procs.2014.05.352.

[22] L. Abdullah and N. Zulkifli, "Integration of fuzzy AHP and interval type-2 fuzzy DEMATEL: an application to human resource management," *Expert Syst. Appl*., vol. 42, no. 9, pp. 4397–4409, 2015, doi: 10.1016/j.eswa.2015.01.021.

[23] K. Schmidt, I. Aumann, I. Hollander, K. Damm, and J.-M. G. von der Schulenburg, "Applying the Analytic Hierarchy Process in healthcare research: a systematic literature review and evaluation of reporting," *BMC Med. Inform. Decis. Mak*., vol. 15, no. 1, pp. 1–27, 2015, doi: 10.1186/s12911-015-0234-7.

[24] P. J. Van Laarhoven and W. Pedrycz, "A fuzzy extension of Saaty's priority theory," *Fuzzy Sets Syst*., vol. 11, no. 1-3, pp. 229–241, 1983, doi: 10.1016/S0165-0114(83)80082-7.

[25] A. Mardani, A. Jusoh, and E. K. Zavadskas, "Fuzzy multiple criteria decision-making techniques and applications: two decades review from 1994 to 2014," *Expert Syst. Appl*., vol. 42, no. 8, pp. 4126–4148, 2015, doi: 10.1016/j.eswa.2015.01.003.

[26] M. J. Liberatore and R. L. Nydick, "The analytic hierarchy process in medical and health care decision making: a literature review," *Eur. J. Oper. Res*., vol. 189, no. 1, pp. 194–207, 2008, doi: 10.1016/j.ejor.2007.05.001.

[27] S. Barzegari, H. Rostamian, E. Firoozi-Majd, and I. Arpaci, "Application of fuzzy AHP for medication decision making in iron-chelating medications for thalassemia," *Pharmacy*, vol. 13, no. 3, p. 86, 2025, doi: 10.3390/pharmacy13030086.

[28] C.-C. Sun, "A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods," *Expert Syst. Appl*., vol. 37, no. 12, pp. 7745–7754, 2010, doi: 10.1016/j.eswa.2010.04.066.

[29] M. Kaufmann et al., "Improved overall survival in postmenopausal women with early breast cancer after anastrozole initiated after treatment with tamoxifen compared with continued tamoxifen: the ARNO 95 study," *J. Clin. Oncol*., vol. 25, no. 19, pp. 2664–2670, 2007, doi: 10.1200/jco.2006.08.8054.

[30] BIG 1-98 Collaborative Group, "A comparison of letrozole and tamoxifen in postmenopausal women with early breast cancer," *N. Engl. J. Med*., vol. 353, no. 26, pp. 2747–2757, 2005, doi: 10.1056/NEJMoa052258.

[31] I. E. van Hellemond et al., "Efficacy of anastrozole after tamoxifen in early breast cancer patients with chemotherapy-induced ovarian function failure," *Int. J. Cancer*, vol. 145, no. 1, pp. 274–283, 2019, doi: 10.1002/ijc.32093.

[32] J. M. Nabholtz, J. Bonneterre, A. Buzdar, J. F. Robertson, and B. Thurlimann, "Anastrozole (Arimidex) versus tamoxifen as first-line therapy for advanced breast cancer in postmenopausal women: survival analysis and updated safety results," *Eur. J. Cancer*, vol. 39, no. 12, pp. 1684–1689, 2003, doi: 10.1016/s0959-8049(03)00326-5.

[33] ATAC Trialists' Group, "Comprehensive side-effect profile of anastrozole and tamoxifen as adjuvant treatment for early-stage breast cancer: long-term safety analysis of the ATAC trial,"

Lancet Oncol., vol. 7, no. 8, pp. 633–643, 2006, doi: 10.1016/S1470-2045(06)70767-7.

[34] S. Bell, B. McNeish, L. Dalton, and K. McLean, "Aromatase inhibitor use, side-effects and discontinuation rates in gynecologic oncology patients," *Gynecol. Oncol*., vol. 153, no. 3, p. e16, 2019, doi: 10.1016/j.ygyno.2019.03.142.

[35] A. Rocchi and S. Verma, "Anastrozole is cost-effective vs tamoxifen as initial adjuvant therapy in early breast cancer: Canadian perspectives on the ATAC completed-treatment analysis," *Support Care Cancer*, vol. 14, no. 9, pp. 917–927, 2006, doi: 10.1007/s00520-006-0035-8.

[36] M. P. Lux et al., "Cost-effectiveness analysis of anastrozole versus tamoxifen in adjuvant therapy for early-stage breast cancer: a health-economic analysis based on the 100-month analysis of the ATAC trial and the German health system," *Oncol. Res. Treat*., vol. 33, no. 4, pp. 155–166, 2010, doi: 10.1159/000286233.

[37] R. Mansel, G. Locker, L. Fallowfield, A. Benedict, and D. Jones, "Cost-effectiveness analysis of anastrozole vs tamoxifen in adjuvant therapy for early stage breast cancer in the United Kingdom: the 5-year completed treatment analysis of the ATAC trial," *Br. J. Cancer*, vol. 97, no. 2, p. 152, 2007, doi: 10.1038/sj.bjc.6603804