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Original Article

Spatial Distribution of Pediatric Solid Tumors in Khuzestan Province, Iran: Environmental Insights from Geographic Information System (GIS)

Arash Alghasi[1], Roya Salehi Kahyesh[1*], Hamideh Habibi Fathabadi[1], Yaser Tahmasabi Birgani[2], Adele Khazami[3], Marzieh Abbasi Nesab[1], Aida Mofakher[3]

[1] *Thalassemia and Hemoglobinopathy Research Center, Health Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran*

[2] *Environmental Technologies Research Center (ETRC), Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran*

[3] *Clinical Research Development Center, Baghaei 2 Hospital, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran*

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[*] **Corresponding Author:**

Roya Salehi Kahyesh;
Thalassemia and Hemoglobinopathy Research Center, Health Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
Tel.: +98 9166016039
Email: alehikahish-r@ajums.ac.ir

ABSTRACT

Background: Environmental factors are increasingly linked to pediatric malignancies. This study aimed to evaluate the spatial distribution of pediatric solid tumors in Khuzestan Province, Iran, using Geographic Information System (GIS) and to explore potential spatial associations with environmental dust and wind patterns.

Methods: This hospital-based retrospective cross-sectional study analyzed data from 481 pediatric patients (aged <18 years) diagnosed with solid tumors at Baghaei 2 Hospital, Ahvaz, between 2019 and 2024. Medical records were reviewed to extract demographic data and geographic origins. Regional cumulative incidence was calculated using census data. Wind velocity and dust exposure maps were generated using GIS interpolation. Spatial correlations were assessed using Spearman's rank correlation.

Results: The cohort consisted of 275 boys (57.2%) and 206 girls (42.8%), with a mean age of 5.93±4.12.years. Central nervous system (CNS) tumors were the most prevalent diagnostic category (31%), followed by neuroblastoma (14%) and Wilms tumor (14%). The overall cumulative incidence of pediatric solid tumors in Khuzestan Province was estimated at 30.75 per 100,000 children. Spatial analysis revealed higher incidence rates in areas characterized by high dust exposure and reduced wind velocity; however, this environmental correlation did not reach statistical significance (P=0.07).

Conclusion: While this study highlights geographic variations in pediatric solid tumor incidence across Khuzestan, the correlation with dust and wind patterns remains statistically non-significant. Given the single-center nature of the study, findings should be interpreted with caution. Multi-center registries and prospective environmental modeling are required to clarify these potential environmental risk factors.

Keywords: Child; Solid Tumor; Spatial Distribution; Environmental Exposure; Geographic Information System

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Introduction

Pediatric cancers represent a significant global health concern and remain one of the leading causes of diseaserelated mortality among children worldwide. Although they are relatively rare compared with adult malignancies, their longterm health and socioeconomic impacts are considerable. Pediatric cancers differ biologically from adult cancers and are more often associated with developmental processes, genetic susceptibility, and environmental exposures rather than lifestylerelated risk factors [1, 2].

Solid tumors account for a substantial proportion of childhood malignancies and include a heterogeneous group of neoplasms such as central nervous system (CNS) tumors, neuroblastoma, Wilms tumor, bone sarcomas, and soft tissue sarcomas. Among these, CNS tumors are reported as the most common solid malignancies in children, followed by neuroblastoma and nephroblastoma (Wilms tumor) in many populations [3,4]. The incidence and distribution of pediatric cancers vary across geographic regions, suggesting that environmental and ecological factors may contribute to disease patterns [5].

Environmental exposures have been increasingly investigated as potential contributors to childhood cancer risk. Factors such as air pollution, industrial emissions, agricultural chemicals, and exposure to heavy metals have been suggested as possible environmental determinants [6 ,7]. Regions experiencing high levels of environmental pollution or specific climatic conditions may therefore demonstrate different spatial patterns of pediatric malignancies. Identifying geographic clusters and environmental correlates may help generate hypotheses regarding potential etiologic factors and guide targeted public health interventions.

Geographic Information System (GIS) technology has emerged as a powerful tool in spatial epidemiology for mapping disease distribution and analyzing spatial relationships between health outcomes and environmental factors. GISbased approaches allow researchers to visualize geographic patterns, detect spatial clustering, and explore potential environmental determinants of disease occurrence [8, 9]. Such analyses have been increasingly applied in cancer epidemiology to identify highrisk areas and to support environmental health investigations. Khuzestan Province, located in southwestern Iran, is characterized by unique environmental conditions, including extensive industrial activities, petrochemical complexes, oil production facilities, and frequent dust storms. These environmental characteristics may potentially influence population health, including the risk of malignancies. However, limited studies have investigated the spatial distribution of pediatric solid tumors in this region. Therefore, the present study aimed to analyze the spatial distribution of pediatric solid tumors in Khuzestan Province using Geographic Information System (GIS) techniques and to explore potential associations with environmental and climatic factors. Understanding the spatial patterns of pediatric malignancies may contribute to identifying highrisk areas and provide insights for future environmental and epidemiological research.

Materials and methods

Study Design and Setting

This retrospective cross-sectional study was conducted to investigate the spatial distribution of pediatric solid tumors in Khuzestan Province, located in southwestern Iran. Khuzestan is one of the largest and most industrialized provinces of the country and is characterized by extensive oil, petrochemical, and agricultural activities, as well as frequent dust storms and specific climatic conditions.

Study Population

The study population consisted of children and adolescents under 18 years of age who were diagnosed with solid malignant tumors and were admitted to Baqaei 2 Hospital in Ahvaz, a major referral center for pediatric oncology in Khuzestan Province. Patients diagnosed during the study period were included in the analysis.

Inclusion and Exclusion Criteria

Inclusion criteria were: (1) age less than 18 years at the time of diagnosis, (2) confirmed diagnosis of a malignant solid tumor based on histopathological evaluation, and (3) documented residence in Khuzestan Province at the time of diagnosis.

Exclusion criteria included incomplete medical or geographic information, patients residing outside the province, and cases with hematologic malignancies such as leukemia or lymphoma.

Data Collection

Demographic and clinical information, including age, sex, type of tumor, and place of residence, was extracted from hospital medical records. Tumor types were classified according to standard pediatric oncology diagnostic categories. Population data for each county were obtained from official census sources to estimate incidence rates. Environmental and climatic data, including rainfall levels, wind patterns, and indicators of dust storms, were obtained from regional meteorological and environmental monitoring agencies.

Spatial Analysis

Geographic coordinates of patients' places of residence were identified based on county-level

administrative boundaries. Spatial mapping and visualization of tumor distribution were performed using ArcGIS software version 10.3 (ESRI, Redlands, CA, USA). Incidence rates of pediatric solid tumors were calculated for each county and expressed per 100,000 population. Geographic distribution maps were generated to identify spatial patterns and potential clustering of cases.

Ethical Considerations

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Patient confidentiality was maintained throughout the study, and all data were analyzed anonymously. Ethical approval for the study was obtained from the Ahvaz Jundishapur University of Medical Sciences ethics committee with ethical code: IR.AJUMS.REC.1398.557.

Results

Patient Characteristics

A total of 481 pediatric patients with solid tumors were included in the study. All patients were younger than 18 years at diagnosis and were residents of Khuzestan Province. The mean age at diagnosis was 5.93 ± 4.12 years. Of the patients, 206 (42.8%) were female, and 275 (57.2%) were male.

Distribution of Tumor Types

Among the identified cases, central nervous system (CNS) tumors were the most common malignancies, accounting for approximately 31% of all cases. Neuroblastoma and Wilms tumor were the next most frequent tumors, each representing about 14% of the total cases. Other malignancies included rhabdomyosarcoma, osteosarcoma, Ewing sarcoma, retinoblastoma, germ cell tumors, and liver tumors (Figure 1).

Incidence Rate

The cumulative incidence of pediatric solid tumors in Khuzestan Province during the study period was estimated at 30.75 cases per 100,000 population. The incidence rates varied across different counties of the province, indicating a heterogeneous spatial distribution.

Geographic Distribution

Spatial analysis revealed noticeable geographic variation in tumor incidence across Khuzestan Province. Shadegan County had the highest cumulative incidence rate of pediatric solid tumors (96.63 per 100,000 population), whereas Gotvand County had the lowest (6.55 per 100,000 population). Several counties, including Ahvaz, Mahshahr, and Abadan, also showed relatively elevated incidence rates compared with other regions (Table 1), illustrating clustering of cases in the southern and southwestern regions of the province.

Spatial Patterns and Environmental Factors

GIS-based mapping suggested that areas with higher tumor incidence geographically overlapped with regions characterized by higher dust exposure and reduced wind circulation. However, this association did not reach statistical significance (P = 0.07) (Table 2).

Geographic Distribution

Marked geographic heterogeneity was observed across the province. Shadegan County had the highest cumulative incidence rate (96.63 per 100,000 population), whereas Gotvand County had the lowest rate (6.55 per 100,000 population). Elevated incidence rates were also observed in Ahvaz, Mahshahr, and Abadan. The spatial distribution map generated using GIS is presented in Figure 2.

Spatial overlay analysis suggested that areas with higher tumor incidence corresponded geographically with regions experiencing higher dust exposure and reduced wind circulation. However, this association did not reach statistical significance (P = 0.07). (See Figure 2).

Spatial analysis of the topographic wind map of Khuzestan Province showed that the northern, northeastern, and eastern regions had the greatest proportion of days characterized by strong winds. (See Figure 3).

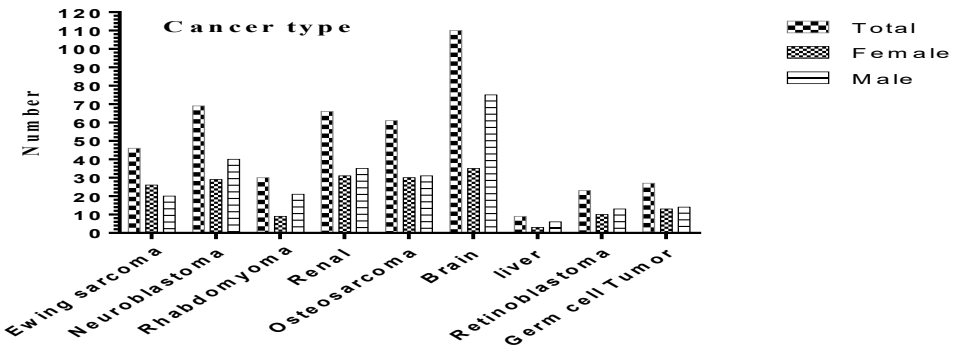

Figure 1: Distribution of pediatric solid tumor types among study participants in Khuzestan Province.

Table 1: Geographic distribution of pediatric solid tumors by county in Khuzestan Province (Incidence rates per 100,000 population)

County	Total Incidence	Nephroblastoma	Neuroblastoma	Hepatoblastoma	Germ Cell Tumor	Soft Tissue Sarcoma
Shadegan	18.5	4.2	6.5	1.5	2.0	4.3
Gotvand	2.1	0.5	0.8	0.2	0.3	0.3
Ahvaz	15.2	3.1	4.9	1.2	1.8	4.2
Khorramshahr	8.7	1.5	2.8	0.6	1.0	2.8
Abadan	9.5	1.8	3.0	0.7	1.2	2.8
Hoveyzeh	4.3	0.8	1.3	0.3	0.5	1.4
Masjed Soleyman	3.1	0.6	1.0	0.2	0.4	0.9
Izeh	5.9	1.1	1.9	0.4	0.7	1.8
Andimeshk	7.2	1.4	2.3	0.5	0.9	2.1
Dezful	8.1	1.6	2.6	0.6	1.1	2.2
Shush	6.5	1.3	2.1	0.4	0.8	1.9
Bagh-e Malek	3.8	0.7	1.2	0.3	0.5	1.1
Omidiyeh	5.2	1.0	1.7	0.3	0.7	1.5
Behbehan	6.8	1.3	2.2	0.5	0.9	2.0
Ramhormoz	4.9	0.9	1.6	0.3	0.6	1.5
Hendijan	2.9	0.5	0.9	0.2	0.4	0.9
Dasht-e Azadegan	4.1	0.8	1.3	0.3	0.5	1.2
Haftkel	1.9	0.4	0.6	0.1	0.3	0.5
Aghajari	2.5	0.5	0.8	0.2	0.4	0.6
Mahshahr	7.5	1.5	2.4	0.6	1.0	2.0
Bandar-e Imam	6.2	1.2	2.0	0.4	0.8	1.8

Note: Data are presented as incidence rates per 100,000 population. "—" indicates no reported cases.

Table 2: Environmental Factors and Pediatric Solid Tumor Incidence by County

County	Total Tumor Incidence (per 100,000)	Dust Exposure Level	Wind Circulation Level
Shadegan	18.5	High	Low
Ahvaz	15.2	High	Low
Abadan	9.5	Moderate	Moderate
Khorramshahr	8.7	Moderate	Low
Dezful	8.1	Low	High
Mahshahr	7.5	High	Low
Andimeshk	7.2	Low	High
Behbehan	6.8	Moderate	Moderate
Shush	6.5	Moderate	Moderate
Bandar-e Imam	6.2	High	Low
Izeh	5.9	Low	Moderate
Omidiyeh	5.2	High	Low
Ramhormoz	4.9	Moderate	Moderate
Hoveyzeh	4.3	High	Low
Dasht-e Azadegan	4.1	Moderate	Moderate
Bagh-e Malek	3.8	Low	High
Masjed Soleyman	3.1	Low	High
Hendijan	2.9	Moderate	High
Aghajari	2.5	Moderate	High
Gotvand	2.1	Low	High
Haftkel	1.9	Low	High

Note: Environmental data are general estimates; levels are shown as High, Moderate, or Low based on available geographic and environmental patterns. Statistical association between tumor incidence and environmental factors did not reach conventional significance ($P = 0.07$).

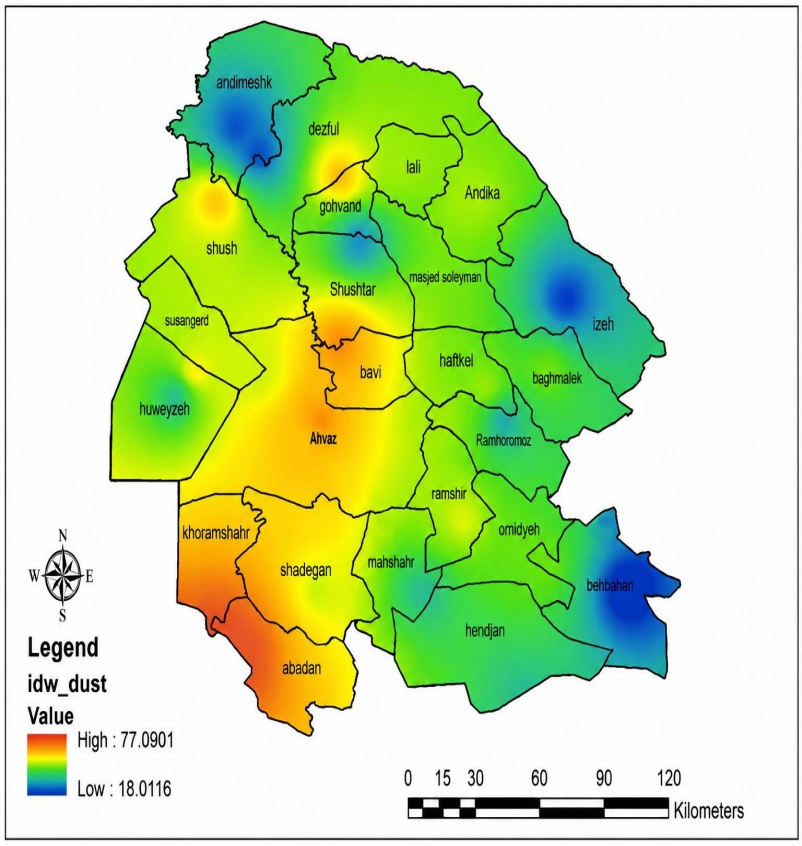

Figure 2: Spatial distribution of dust exposure levels across Khuzestan Province.

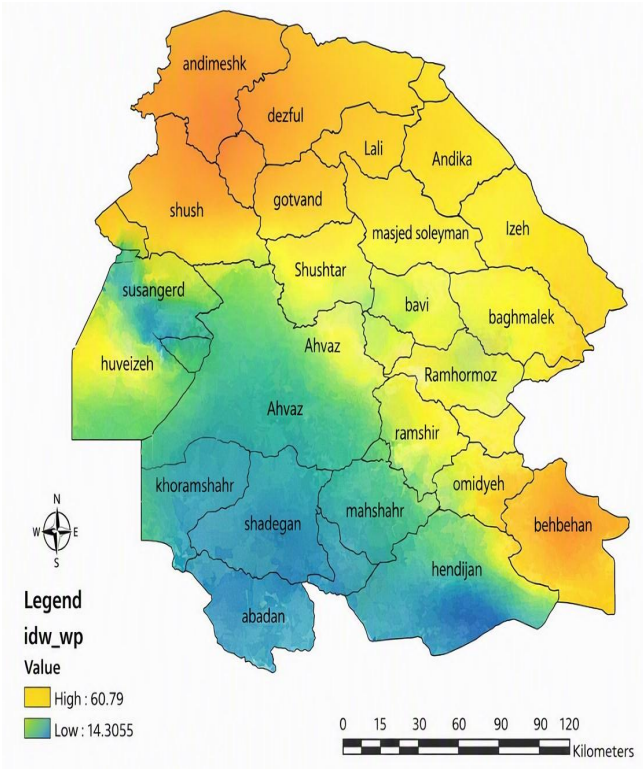

Figure 3: Spatial distribution of the percentage of days characterized by strong winds in Khuzestan Province.

Discussion

The present study provides an overview of the spatial distribution of pediatric solid tumors in Khuzestan Province and highlights possible environmental patterns that may be relevant to their occurrence. In this study, the male-to-female ratio was 1.32, indicating a higher frequency of solid tumors among boys than girls. This finding is consistent with previous reports from Fars, Yazd, Sari, and India, which also reported male predominance in childhood malignancies [8, 11]. Previous evidence has suggested that male sex may be positively associated with several childhood cancers [12]. Sex-related differences in childhood cancer occurrence may be influenced by perinatal factors, immune system differences, hormonal factors, and variation in susceptibility to environmental exposures [12, 14].

Khuzestan Province, located in southwestern Iran, is characterized by extensive oil and petrochemical industries, agricultural activities, population mobility, and recurrent dust events. Studies conducted in southwestern Iran have documented substantial particulate matter exposure and important health consequences associated with air pollution and dust storms, particularly in Ahvaz and Dezful [15, 16]. In addition, remote-sensing and machine-learning studies have identified areas along the Iran–Iraq border, including parts of Khuzestan, as susceptible to dust generation. Nevertheless, these studies have not directly evaluated the spatial distribution of pediatric solid tumors [17]. Therefore, the present study was designed to describe the geographic distribution of pediatric solid tumors and to explore their potential spatial overlap with dust exposure and wind patterns.

In the present study, central nervous system tumors were the most common group of pediatric solid tumors. This finding is consistent with previous reports identifying CNS tumors as one of the leading solid malignancies in children [1, 2, 13]. The predominance of CNS tumors may reflect both the underlying disease burden and improved diagnostic access in referral centers.

One of the main findings of this study was the unequal geographic distribution of pediatric solid tumors across different counties of Khuzestan Province. Higher incidence rates were observed in some southern and southwestern counties, particularly Shadegan, whereas lower rates were observed in other areas of the province. This heterogeneous pattern suggests that the burden of pediatric solid tumors may not be uniformly distributed across the province.

GIS-based mapping showed spatial overlap between areas with higher tumor incidence and regions characterized by greater dust exposure and reduced wind circulation [18]. GIS has been increasingly used in public health surveillance and cancer epidemiology to identify spatial patterns, generate etiologic hypotheses, and support environmental health investigations [7, 19]. However, the observed spatial association in the present study did not reach statistical significance. Therefore, these findings should be interpreted cautiously and considered hypothesis-generating rather than confirmatory. These considerations are particularly relevant to pediatric cancers because of their relatively low incidence and the potential instability of county-level estimates.

The environmental characteristics of Khuzestan Province may provide a plausible context for the observed spatial heterogeneity. Recurrent dust storms, industrial emissions, agricultural activities, petrochemical pollution, and localized environmental contamination are among the environmental concerns in this region. Previous studies have suggested that environmental exposures, including air pollution and other ecological risk factors, may contribute to childhood cancer risk [4, 5, 20]. In addition, climate-related environmental changes may influence childhood cancer risks, access to care, and outcomes [6]. Environmental exposures have increasingly been investigated as potential contributors to childhood cancer risk. Recent evidence has focused on ambient air pollution, particulate matter, industrial emissions, pesticides, heavy metals, radon, and other environmental contaminants. A recent scoping review of studies published during the last decade identified air pollution as the most frequently investigated environmental factor in relation to childhood cancer, with positive associations reported for several childhood malignancies, including leukemia, Wilms tumor, and other rare tumors [20-22]. However, the available evidence remains heterogeneous, and differences in exposure assessment, cancer classification, study design, and potential confounding factors limit causal interpretation.

Shadegan, which showed the highest incidence in our analysis, is located in the southwestern part of the province and is environmentally distinct because of its proximity to wetland ecosystems, agricultural zones, and industrially affected areas. Environmental degradation in this region, including water contamination, petrochemical pollution, agricultural runoff, and oil-related pollution, has been reported previously. Although the present study was not designed to directly measure individual exposure to these hazards, such contextual factors may help explain the observed spatial pattern and support the need for more detailed environmental studies in this area. Our findings are broadly consistent with previous Iranian studies suggesting that environmental and geographic factors may contribute to variation in cancer incidence. Rostami et al. investigated the incidence of gastric cancer in Khuzestan Province using GIS and reported a relationship between geographic factors and cancer distribution [19]. Similarly, Mosavi-

Jarrahi et al. used GIS-based methods to examine clustering of childhood cancer in Tehran and suggested that environmental pollution and population density may contribute to the asymmetric distribution of childhood cancers [3]. Another national study also reported geographic variation in childhood cancer occurrence in Iran [20].

Several mechanisms may underlie geographic variation in pediatric cancers. These include differences in prenatal and early-life environmental exposures, genetic susceptibility, residential proximity to pollution sources, agricultural pesticide exposure, and variation in access to diagnostic and referral services. International evidence also indicates substantial variation in childhood cancer incidence across regions, supporting the importance of geographic and environmental investigations [18, 23].

Regarding specific tumor types, environmental factors may be relevant to the occurrence of certain pediatric solid tumors. Kamihara et al. emphasized global variation in neuroblastoma incidence and highlighted the importance of population-based cancer registries, particularly in low- and middle-income countries [23]. In addition, environmental and genetic factors have both been discussed in relation to sarcoma etiology [24, 30]. Although these findings do not establish a direct causal relationship, they support further investigation of environmental and climatic factors in relation to pediatric solid tumors.

The ecological nature of the environmental assessment is an important limitation. Dust exposure and wind circulation were classified at the county level. They were not based on individual residential histories, personal monitoring, satellite-derived exposure estimates, or time-varying particulate matter measurements. Consequently, ecological fallacy and exposure misclassification cannot be excluded. In addition, because the study was conducted at a referral hospital, the geographic distribution of cases may reflect differences in referral pathways, healthcare access, population density, diagnostic availability, and migration patterns. The calculated incidence estimates should therefore be interpreted as preliminary area-level estimates rather than definitive population-based incidence rates.

Conclusion

This study provides preliminary data on the geographic distribution of pediatric solid tumors in Khuzestan Province and utilizes GIS as a descriptive tool to identify potential areas of interest. While a spatial overlap was observed between high-incidence areas and regions with specific environmental conditions—namely, dust exposure and reduced wind circulation—this association did not reach statistical significance. Consequently, these findings remain hypothesis-generating. A complex interplay of environmental, socioeconomic, and referral-related factors may influence the observed spatial heterogeneity. Given the limitations of a hospital-based retrospective design and the use of qualitative environmental estimates, these results cannot establish a causal link. Future population-based studies, incorporating individualized environmental exposure assessments and comprehensive registry data, are essential to elucidate the etiology of pediatric solid tumors in this region and to inform public health strategies.

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Conflict of Interest

The authors declare that they have no conflicts of interest to disclose.

Authors' Contributions

All authors contributed equally to the conception, design, and preparation of the manuscript. All authors have read and approved the final version of the manuscript.

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Ethical Considerations

Ethical approval for the study was obtained from the Ahvaz Jundishapur University of Medical Sciences ethics committee with ethical code: IR.AJUMS.REC.1398.557.

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