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Could High-Density Lipoprotein (HDL) Alone be a Predictive Biomarker for Patients with Erectile Dysfunction?

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ABSTRACT

This study aimed to assess High-Density Lipoprotein (HDL) levels as a predictor of ED in 105 men aged 20-60, to determine whether HDL levels alone could indicate Erectile Dysfunction (ED) risk independently of other factors. Despite the numerous cardiovascular risk factors associated with ED, this study uniquely focused on the predictive value of HDL levels, aiming to highlight its standalone significance in ED risk assessment. The study analyzed the interaction of HDL levels with variables such as BMI and smoking status to improve understanding of lipid profiles in assessing and managing ED Logistic regression was conducted to assess the link between low HDL levels (<40 mg/dL) and ED, while adjusting for confounding factors like age, BMI, smoking, and hypertension. The ROC curve analysis determined the optimal cutoff point for predicting ED using HDL levels. Patients with ED had significantly lower mean high-density lipoprotein (HDL) levels at 32.0 ± 10.9 mg/dL compared to the normal population's 48.3 ± 12.1 mg/dL ($p = 0.043$). In the ED group, 66.67% of patients had HDL levels below 40 mg/dL, which was higher than the 41.39% observed in the normal population ($p = 0.023$). Additionally, the ED population had a higher mean BMI of 27.4 ± 4.6 kg/m² compared to 24.0 ± 5.2 kg/m² in the normal population ($p = 0.011$). Smoking was also more prevalent among ED patients, with 53.33% being current smokers compared to 35.23% in the normal population ($p = 0.037$). Subgroup analyses revealed an interaction between low HDL and smoking ($B = 0.45$, $\beta = 0.30$, $p = 0.001$), as well as between low HDL and BMI ($B = 0.50$, $\beta = 0.35$, $p = 0.001$), indicating that these combinations exacerbated ED risk more than any individual factor. Our research suggests that HDL could function as a useful predictive biomarker for ED. Clinicians should consider evaluating the HDL levels of patients with ED and potentially managing low HDL levels to alleviate ED symptoms.

Keywords: Erectile dysfunction, high-density lipoprotein, HDL, biomarker, cardiovascular risk factors, dyslipidaemia.

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Yüksek Yoğunluklu Lipoprotein (HDL) Tek Başına Ereksiyon Bozukluğu Olan Hastalar İçin Bir Öngörücü Belirteç Olabilir mi?

ÖZ

Bu çalışma, 20-60 yaş arası 105 erkekte erektil disfonksiyonun (ED) bir öngörücüsü olarak High-Density Lipoprotein (HDL) düzeylerini değerlendirmeyi ve HDL düzeylerinin tek başına diğer faktörlerden bağımsız olarak ED riskini gösterebileceğini belirlemeyi amaçlamıştır. ED ile ilişkili birçok kardiyovasküler risk faktörüne rağmen, bu çalışma özellikle HDL seviyelerinin öngörü değerine odaklanmakta ve ED risk değerlendirmesindeki bağımsız önemini vurgulamayı amaçlamaktadır. Çalışma, lipid profillerinin ED değerlendirilmesi ve yönetimindeki anlayışı geliştirmek için HDL düzeylerinin BMI ve sigara içme durumu gibi değişkenlerle etkileşimini analiz etmiştir. ED ile düşük HDL düzeyleri (<40 mg/dL) arasındaki bağlantıyı değerlendirmek için yaş, BMI, sigara içme ve hipertansiyon gibi karıştırıcı faktörler dikkate alınarak lojistik regresyon yapılmıştır. ROC eğrisi analizi, HDL düzeylerini kullanarak ED'yi öngörmek için optimal kesme noktasını belirlemiştir. ED'li hastaların ortalama yüksek yoğunluklu lipoprotein (HDL) düzeyleri, normal popülasyonun 48.3 ± 12.1 mg/dL'ye kıyasla 32.0 ± 10.9 mg/dL olarak belirgin şekilde daha düşük bulunmuştur (p = 0.043). ED grubunda, hastaların %66.67'sinin HDL düzeyleri 40 mg/dL'nin altında olup bu oran, normal popülasyonda gözlemlenen %41.39'dan daha yüksekti (p = 0.023). Ayrıca, ED popülasyonunun ortalama BMI değeri normal popülasyonun 24.0 ± 5.2 kg/m²'sine kıyasla 27.4 ± 4.6 kg/m² olarak daha yüksekti (p = 0.011). Sigara içme de ED hastaları arasında daha yaygın olup, %53.33'ü şu an sigara içen kişiler iken normal popülasyonda bu oran %35.23 idi (p = 0.037). Alt grup analizleri, düşük HDL ile sigara içme (B = 0.45, β = 0.30, p = 0.001) ve düşük HDL ile BMI (B = 0.50, β = 0.35, p = 0.001) arasında bir etkileşim olduğunu ortaya koymuş ve bu kombinasyonların herhangi bir bireysel faktörden daha fazla ED riskini artırdığını göstermiştir. Araştırmamız, HDL'nin ED için yararlı bir öngörücü biyomarkır olarak işlev görebileceğini önermektedir. Klinisyenler, ED'li hastaların HDL düzeylerini değerlendirmeyi ve potansiyel olarak düşük HDL düzeylerini yöneterek ED semptomlarını hafifletmeyi hedeflemelidirler.

Anahtar kelimeler: Erektil disfonksiyon, yüksek yoğunluklu lipoprotein, HDL, biyobelirteç, kardiyovasküler risk faktörleri, dislipidemi

1 Introduction

Erectile dysfunction (ED) is characterized by a persistent difficulty in obtaining or maintaining adequate erection for satisfactory sexual activity. Globally, it is a prevalent condition that affected approximately 150 million men in 1995 and is projected to increase to 322 million by 2025. The causes of ED are diverse, and include vascular, neurogenic, hormonal, psychogenic, iatrogenic, and anatomical factors. It is classified into psychological, organic, or mixed types, with the organic form being the most common, accounting for more than half of the cases. Vascular factors are particularly important in organic ED, with arteriogenic ED being the most common and critical subtype.

Pathologies that affect the vascular system, such as atherosclerosis, endothelial dysfunction, and inflammation, contribute to arteriogenic ED by compromising the blood flow to the penile corpora cavernosa. For instance, penile atherosclerosis can cause structural changes that reduce blood flow to the penile corpora cavernosa, thereby hindering the increased blood volume required for erection. Endothelial dysfunction, a hallmark of atherosclerosis, is essential for arterial ED development.

The causes of ED can vary, and include vascular, neurogenic, hormonal, psychogenic, iatrogenic, and anatomical factors. The condition is classified into three types: psychological, organic, or mixed, with the organic form being the most prevalent, accounting for more than half of the cases. Among the

organic types, vascular factors play a significant role in ED, with arteriogenic ED being the most frequent and severe subtype.

Pathologies that affect the vascular system, such as atherosclerosis, endothelial dysfunction, and inflammation, contribute to arteriogenic ED by restricting blood flow to the penile corpus cavernosa. For instance, penile atherosclerosis can cause structural changes that reduce the blood flow to the penile corpora cavernosa, which is essential for erection. Endothelial dysfunction, a hallmark of atherosclerosis, is a critical factor in arterial ED development.

2 Material and Methods

2.1 Study Design and Participants

In this retrospective analysis, we assessed HDL levels in male patients who presented with symptoms of erectile dysfunction. Initially, 150 patients will be evaluated between 2021 and 2022. Following our strict inclusion and exclusion criteria, 105 of these patients, aged 18–60 years, were eligible for the study. Patients with a history of diabetes mellitus, hypoandrogenemia, prostate surgery, or coronary heart disease were excluded to minimise the impact of potential confounding factors. The study design was authorised by the institutional review board, and informed consent was obtained from all the patients.

2.2 Data Collection

Patient demographic and clinical information, including age, body mass index (BMI), smoking status, and comorbidities, were gathered from their medical records. Laboratory data, such as lipid profiles (total cholesterol, LDL, HDL, and triglycerides), were obtained from blood samples collected during the initial evaluation. The International Index of Erectile Function (IIEF) questionnaire was used to assess erectile dysfunction, with a score of 25 or lower considered indicative of ED.

This study was approved by the Ethics Institution of the Gazi Yaşargil Training and Research Hospital **(dated 30.09.2022 and numbered 190).**

2.3 Statistical Analysis

Descriptive statistics were utilized to summarize patients' demographic, clinical, and laboratory characteristics, including assessing the normality of data distribution using the Kolmogorov-Smirnov test. The independent samples t-test or Mann-Whitney U test was used for continuous variables, while the chi-squared test or Fisher's exact test was used for categorical variables. The presence of ED was analyzed in relation to HDL levels using logistic regression models adjusted for potential confounders. All statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, N.Y., USA). Receiver operating characteristic (ROC) curve analysis was conducted to evaluate the diagnostic performance of HDL level in predicting erectile dysfunction. The area under the ROC curve (AUC) was calculated to determine the accuracy of the test. All tests were two-tailed, and a p-value of less than 0.05 was considered statistically significant.

3 Results

A total of 105 patients aged 20–60 years who presented to the ED between 2021 and 2022 were included in this study. The mean age of the patients was 51.2 ± 11.3 years, and the mean BMI was 27.4 ± 4.6 kg/m². Of these patients, 56 (53.3%) were current smokers, and 19 (18.1%) had a history of

hypertension. The mean HDL cholesterol levels were substantially lower in the ED group than in the normal population, with values of 32 ± 10.9 mg/dL versus 48.3 ± 12.2 mg/dL, respectively (p = 0.043). A greater proportion of the ED population had HDL cholesterol levels < 40 mg/dL (66.67 %), in contrast to 41.39% in the normal population (p = 0.023). The average age in the ED group was significantly younger at 51.2 ± 11.3 years compared to 58 ± 9.8 years in the normal cohort (p = 0.049). Body Mass Index (BMI) was notably higher in the ED population, averaging 27.4 ± 4.6 kg/m², while the normal population averaged 24 ± 5.2 kg/m² (p = 0.011). Current smoking status was significantly more prevalent in the ED group, with 53.33% smokers than in the normal population (35.23 %; p = 0.037). The incidence of hypertension was slightly higher in the ED population (18.10 %) than that in the normal population (16.59 %); however, this difference was not statistically significant (p = 0.052).

The demographic and clinical characteristics of the patients and their comparisons are summarised in Table 1.

Table 1: *Analysis of Demographic, Clinical, and Laboratory Characteristics of the Study Populations*

Variable	Normal Population (N = 4,250)	ED Population (N = 105)	P-value
Mean HDL (mg/dL)	48.3 ± 12.1	32.0 ± 10.9	0.043*
Individuals with HDL <40 mg/dL	1,759 (41.39%)	70 (66.67%)	0.023**
Mean Age (years)	58.0 ± 9.8	51.2 ± 11.3	0.049*
Mean BMI (kg/m²)	24.0 ± 5.2	27.4 ± 4.6	0.011*
Current Smokers (%)	1,497 (35.23%)	56 (53.33%)	0.037**
Hypertension (%)	705 (16.59%)	19 (18.10%)	0.052**

SD: Standard Deviation; HDL: High-Density Lipoprotein; BMI: Body Mass Index; ED: Erectile Dysfunction
* independent samples t-test, ** chi-square (χ^2) test

Subgroup analyses were performed to evaluate the associations between age, body mass index (BMI), smoking status, and the prevalence of erectile dysfunction (ED). The mean high-density lipoprotein (HDL) levels differed significantly across age groups, with the lowest levels observed in the 40-49 age bracket (31.5 ± 10.5 mg/dL, p = 0.026). The proportion of individuals with HDL levels below 40 mg/dL was highest among the 25-29.9 kg/m² BMI subgroup (75.00%, p = 0.019), suggesting a strong link between moderate overweight status and lipid abnormalities in ED patients.

In terms of age distribution, younger ED patients (20-39 years) presented with a mean HDL level of 35.0 ± 11.0 mg/dL, while those in the 50-60 years range exhibited a mean HDL of 30.0 ± 10.8 mg/dL.

The differences in mean HDL levels between these age groups were statistically significant ($p = 0.035$ and $p = 0.042$, respectively), indicating age-related variations in lipid profiles among patients with ED.

Analysis of the impact of BMI showed that patients with a BMI of less than 25 kg/m² showed significantly higher mean HDL levels (33.0 ± 11.1 mg/dL, $p = 0.033$) compared to those with a BMI of 25-29.9 kg/m² or higher. This trend highlights the impact of body weight on lipid metabolism in the ED.

Smoking status also demonstrated a significant relationship with ED; smokers had a mean HDL level of 30.4 ± 10.6 mg/dL and constituted 100% of the smoking subgroup within the ED population, affirming the detrimental effects of smoking on cardiovascular and sexual health ($p = 0.015$). Non-smokers, on the other hand, had a higher mean HDL level of 33.5 ± 11.2 mg/dL, although this was still associated with ED ($p = 0.048$). Table 2 provides detailed subgroup analyses.

Table 2: *Characteristics of Erectile Dysfunction Patients by Age, Body Mass Index, and Smoking Status*

ED Subgroup	Number (n)	Mean HDL (mg/dL)	HDL <40 mg/dL (%)	Mean Age (years)	Mean BMI (kg/m²)	Smokers (%)	P-value
20-39 years	25	35.0 ± 11.0	16 (64.00%)	29.5 ± 5.5	28.0 ± 4.8	12 (48.00%)	0.035*#
40-49 years	30	31.5 ± 10.5	22 (73.33%)	44.8 ± 2.9	27.0 ± 4.5	20 (66.67%)	0.026*#
50-60 years	50	30.0 ± 10.8	32 (64.00%)	55.2 ± 3.0	28.5 ± 4.7	24 (48.00%)	0.042*#
BMI <25 kg/m²	35	33.0 ± 11.1	20 (57.14%)	52.0 ± 11.0	23.5 ± 1.5	14 (40.00%)	0.033*#
BMI 25-29.9 kg/m²	40	31.0 ± 10.7	30 (75.00%)	50.5 ± 10.5	27.2 ± 1.4	25 (62.50%)	0.019**#
BMI ≥30 kg/m²	30	30.5 ± 10.9	20 (66.67%)	49.8 ± 11.5	31.0 ± 3.5	17 (56.67%)	0.021**#
Non-smokers	49	33.5 ± 11.2	29 (59.18%)	52.7 ± 10.8	27.3 ± 4.9	-	0.048*
Smokers	56	30.4 ± 10.6	41 (73.21%)	49.6 ± 11.9	27.5 ± 4.3	56 (100.00%)	0.015**

HDL: High-Density Lipoprotein; BMI: Body Mass Index; ED: Erectile Dysfunction; n: Sample Size; mg/dL: Milligrams per Deciliter; kg/m²: Kilograms per Square Meter; %: Percentage; P-value: Probability Value

*Independent samples t-test, **Chi-square test, # ANOVA (Analysis of Variance) analysis

3.1 Interaction Effects of Low HDL and Smoking on the Risk of Erectile Dysfunction

Multiple regression analysis was conducted to examine the relationship between low high-density lipoprotein (HDL) levels and smoking status on the risk of erectile dysfunction (ED), a multiple regression analysis was conducted. The model included individual predictors of low HDL levels, defined as HDL less than 40 mg/dL, smoking status, and an interaction term between these two variables.

The results indicated that both low HDL levels and smoking status were significant predictors of ED risk on their own. Low HDL levels were associated with increased risk of ED ($B = 0.35$, $\beta = 0.25$, $p = 0.01$) and smoking ($B = 0.30$, $\beta = 0.20$, $p = 0.02$). However, the interaction term between low HDL and smoking was particularly noteworthy as it revealed a significant interaction effect ($B = 0.45$, $\beta = 0.30$, $p = 0.001$), suggesting that the combined presence of these two risk factors leads to a greater probability of ED than that predicted by either factor alone (Table 3).

Table 3: *Regression Analysis of Low HDL and Smoking Interaction on ED Risk*

Predictor	B Coefficient	Standard Error	Beta (β)	p-value	95% CI
Constant	0.20	0.05	-	-	(0.10, 0.30)
Low HDL (<40 mg/dL)	0.35	0.08	0.25	0.01*	(0.19, 0.51)
Smoking Status	0.30	0.09	0.20	0.02*	(0.12, 0.48)
Low HDL * Smoking	0.45	0.10	0.30	0.001**	(0.25, 0.65)

B (Unstandardised Coefficient): reflects the change in the dependent variable for each unit change in the independent variable.
β (Standardised Coefficient): This shows the number of standard deviations the dependent variable will change as a result of a one standard deviation change in the independent variable.
CI: Confidence Interval; HDL: High-Density Lipoprotein; ED: Erectile Dysfunction
*p < 0.05, **p < 0.01

3.2 Interaction Effects of Low HDL and BMI on the Risk of Erectile Dysfunction

Regression analysis was conducted to investigate the interaction effects of low high-density lipoprotein (HDL) level and body mass index (BMI) on the risk of erectile dysfunction (ED). The model included low HDL levels, defined as less than 40 mg/dL, BMI as a continuous variable, and the product of low HDL and BMI to assess the interaction effect.

The analysis revealed that low HDL levels (B = 0.30, β = 0.22, p = 0.03) and low BMI (B = 0.20, β = 0.18, p = 0.04) were significant predictors of increased ED risk. More importantly, the interaction term between low HDL level and BMI was a significant predictor of ED risk (B = 0.50, β = 0.35, p = 0.001). This indicates that the combination of low HDL levels and high BMI has a compounding effect on the likelihood of ED beyond the impact of each individual factor (Table 4).

Table 4: *Regression Analysis of Low HDL and BMI Interaction on ED Risk*

Predictor	B Coefficient	Standard Error	Beta (β)	p-value	95% CI
Constant	0.25	0.07	-	-	(0.11, 0.39)
Low HDL (<40 mg/dL)	0.30	0.10	0.22	0.03*	(0.10, 0.50)
BMI (Continuous)	0.20	0.05	0.18	0.04*	(0.10, 0.30)
Low HDL * BMI	0.50	0.12	0.35	0.001**	(0.26, 0.74)

B Coefficient: Unstandardized regression coefficient; Beta (β): Standardized regression coefficient; CI: Confidence Interval; HDL: High-Density Lipoprotein; BMI: Body Mass ındex; ED: Erectile Dysfunction
*p < 0.05, **p < 0.01

4 Discussion

This study was designed to elucidate the relationship between high-density lipoprotein (HDL) levels and erectile dysfunction (ED), while considering additional factors such as age, BMI, smoking status, and hypertension. The findings revealed that men with ED had significantly lower mean HDL levels than the normal population, which aligns with previous research suggesting that low HDL cholesterol

is a marker of endothelial dysfunction and atherosclerosis, which are closely linked to the pathogenesis of ED.

Our findings are consistent with those reported by Eaton et al. (2007), who found a significant association between low HDL levels and ED in a retrospective study of 988 men [1]. Similarly, Li et al. (2020) reported that low HDL levels were significantly correlated with arteriogenic ED [2], whereas Culha et al. (2020) [3] demonstrated a significant correlation between atherogenic indices including HDL and ED. Liao et al. (2021) found an association between low HDL levels and ED in their study, highlighting the potential value of HDL as a predictive biomarker [4].

The data from this study reinforce the hypothesis that low HDL cholesterol level, BMI, and smoking status are significant predictors of ED. These findings highlight the importance of a multifactorial approach to the evaluation and treatment of ED, emphasising the need for screening and management of lipid disorders and lifestyle modifications as part of the ED management protocols.

Furthermore, our subgroup analysis revealed that individuals with a BMI between 25-29.9 kg/m² had the highest proportion of low HDL levels (<40 mg/dL), suggesting that even a moderate overweight status can significantly affect lipid abnormalities associated with ED. This finding is supported by the work of Ermiş et al. [5] and Li et al. [2], who identified dyslipidaemia as a risk factor for ED and highlighted the importance of managing the lipid levels in these patients.

The younger ED cohort (20-39 years) demonstrated relatively higher HDL levels, suggesting that factors other than age may contribute to ED development in this subgroup. This may align with the observations of Liao et al. [4] that haematological parameters, including lipid profiles, can vary with age and influence erectile function differently.

In assessing the impact of BMI on HDL levels, patients with a BMI of less than 25 kg/m² showed significantly higher HDL levels. This relationship underscores the findings of Sambel et al. [6], in which a higher BMI was correlated with worse lipid profiles, and consequently, an increased risk of ED. Our data suggest that even within the non-obese range, variances in BMI can have clinically relevant effects on lipid metabolism in the context of ED.

This study also confirmed the detrimental impact of smoking on HDL levels, with smokers in the ED population presenting lower mean HDL levels. This finding complements the evidence presented by Kovac et al. [7] that smoking is a modifiable risk factor that negatively affects both vascular and sexual health, reiterating the need for smoking cessation interventions as a part of ED management. Our findings advocate for a multifaceted approach to the management of ED, considering not only traditional cardiovascular risk factors, but also the integration of lifestyle modifications addressing weight management and smoking cessation to ameliorate the lipid profile and potentially reduce the incidence of ED.

In this comprehensive analysis, we sought to understand the intricate dynamics of low high-density lipoprotein (HDL) levels, smoking status, body mass index (BMI), and their collective impact on the risk of erectile dysfunction (ED). By leveraging regression modelling, our study sheds light on the independent and interactive effects of these variables on ED, revealing compelling evidence that the interplay between lipid profiles, lifestyle factors, and body composition significantly contributes to ED risk.

Our findings substantiate previous research showing that low HDL levels are a noteworthy predictor of ED, as demonstrated by a B coefficient of 0.35 ($p = 0.01$). This association is in accordance with the meta-analyses by Zhao et al. [8] and Guo et al. [9], who identified dyslipidaemia as a critical risk factor for ED. The low HDL levels observed in our ED cohort further reinforce the notion that lipid metabolism abnormalities can have profound effects on erectile function, potentially through mechanisms involving vascular health and endothelial function.

Smoking status also emerged as a significant predictor, with a B coefficient of 0.30 ($p = 0.02$), corroborating the systematic review by Gandaglia et al. [10], which underscores the detrimental effects of smoking on cardiovascular and sexual health. The interaction between low HDL levels and smoking status yielded a B coefficient of 0.45 ($p = 0.001$), underscoring a synergistic effect where the combination of these two risk factors amplifies the probability of ED more than either factor in isolation. This observation aligns with that of Li et al. (2020), who reported a significant influence of smoking on blood lipid parameters and arteriogenic ED.

The relationship between BMI and ED was further examined, revealing that both low HDL levels and high BMI were significant predictors of ED. The interaction between these factors was particularly pronounced ($B = 0.50$, $p = 0.001$), suggesting that the concurrence of dyslipidaemia and obesity may act in concert to increase ED risk. This interaction echoes the findings of Besiroglu et al. [11] and Culha et al. [3] who elucidated the compounded effects of metabolic syndrome components on ED.

Regression analysis underscores a vital clinical implication: management strategies for ED should not only focus on individual cardiovascular risk factors but also consider the exacerbating effects of their interactions. Specifically, the joint occurrence of smoking and low HDL levels or high BMI warrants aggressive lifestyle interventions and lipid management.

4.1 Limitations and Future Research

A potential limitation of this study is its retrospective design, which may have restricted our ability to infer causality. Prospective studies are warranted to confirm these findings and explore the mechanisms underlying the observed associations. Additionally, the exclusive focus on a male population between 20-60 years old and the exclusion of patients with certain comorbidities may limit the generalisability of the results. Future research could involve a broader participant base, including different age groups and individuals with varied health conditions, to enhance the applicability of these findings. Investigations into the potential biological mechanisms linking HDL levels with ED, particularly through longitudinal studies, could provide deeper insights into this association and aid in the development of targeted therapeutic interventions.

5 Conclusions

This study revealed that low high-density lipoprotein (HDL) levels, smoking status, and body mass index (BMI) play crucial roles in the development of erectile dysfunction (ED). The relationship between smoking and HDL levels suggests that lifestyle factors can worsen the risk of dyslipidemia. These findings are important for understanding the complex nature of ED and emphasize the need for comprehensive management strategies. Our findings suggest a need for public health strategies aimed at improving cardiovascular health through smoking cessation and weight management to mitigate the risk of ED. In conclusion, this study highlights the importance of managing cardiovascular health and addressing lifestyle factors such as smoking cessation and weight management to reduce the risk of ED.

6 Declarations

6.1 Study Limitations

Explain all possible limitation faced in the study which might significantly affect research outcome.

6.2 Acknowledgements

There is no person or institution contributing to this research other than the authors.

6.3 Funding source

Provide funding source, supporting grants with grant number. The name of funding agencies should be written in full. If there is no funding source, write “No financial support was received for this research.

6.4 Competing Interests

There is no conflict of interest in this study.

6.5 Authors’ Contributions

Abdullah AKKURT: Contributed to the article by developing ideas or hypotheses for the research and/or article; planning the materials and methods to achieve results; assuming responsibility for conducting experiments; organizing and reporting data; taking charge of explaining and presenting results; overseeing the literature review during the study; accountable for the creation of the entire manuscript or its main sections; and revising not only for spelling and grammar but also for intellectual content and other contributions.

Ercan KAZAN: Made contributions to the article, including the development of ideas or hypotheses; planning of materials and methods; overseeing experiments; data organization and reporting; result interpretation and presentation; literature review; and significant involvement in the manuscript's creation and revision, extending beyond mere editing for language to substantial intellectual contributions.

Cemal NAS: Contributed to the article by developing ideas or hypotheses for the research and/or article; planning the materials and methods to achieve results; assuming responsibility for conducting experiments; organizing and reporting data; taking charge of explaining and presenting results; overseeing the literature review during the study; accountable for the creation of the entire manuscript or its main sections; and revising not only for spelling and grammar but also for intellectual content and other contributions.

7 Human and Animal Related Study

If the work involves the use of human/animal subjects, each manuscript should contain the following subheadings under this section.

7.1 Ethical Approval

This study was approved by the Ethics Institution of the Gazi Yaşargil Training and Research Hospital **(dated 30.09.2022 and numbered 190).**

7.2 Informed Consent

There was no need for informed consent form to be obtained from participants for the study that they agreed to participate in the study.

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A Bibliometric Analysis of the Knowledge Structure of Reflective Learning in the Health Sciences**

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ABSTRACT

This research aims to identify the developmental patterns of reflective learning in the health sciences context and offer suggestions for future research in this field. Our dataset consists of 385 studies conducted between 1983 and 2023 in the Web of Sciences (WOS) database. In this study, bibliometric analysis techniques such as performance analyses, co-citation analysis, co-word analysis, and co-authorship analysis were employed. The results of the co-word analysis indicated that Cluster 1 emphasizes medical education, student performance, and skill development, showcasing that self-assessment and feedback are crucial components of reflective learning. Cluster 2 explores how health services shape student experiences and the impact of reflective learning on these experiences. Cluster 3 highlights the centrality of reflective learning in professional development and patient interaction. Clusters 4 and 5 elucidate the roles of knowledge, attitudes, and quality management in the reflective learning process. Clusters 6 and 7 underscore the critical importance of continuous improvement and patient safety within the context of reflective learning. In conclusion, the topic of reflective learning is garnering increasing interest in health disciplines, and further comprehensive analyses are needed to better understand the trend of this interest.

Keywords: Reflective learning, health, bibliometric analysis

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Sağlık Bilimlerinde Yansıtıcı Öğrenmenin Bilgi Yapısının Bibliyometrik Analizi

ÖZ

Bu araştırma, sağlık bilimleri bağlamında yansıtıcı öğrenmenin gelişim örüntülerini belirlemeyi ve bu alanda gelecekte yapılacak araştırmalar için öneriler sunmayı amaçlamaktadır. Veri setimiz Web of Sciences (WOS) veri tabanında 1983-2023 yılları arasında yapılmış 385 çalışmadan oluşmaktadır. Bu çalışmada performans analizi, ortak atıf analizi, ortak kelime analizi ve ortak yazarlık analizi gibi bibliyometrik analiz teknikleri kullanılmıştır. Ortak kelime analizinin sonuçları, Küme 1'in tıp eğitimi, öğrenci performansı ve beceri gelişimini vurguladığını, öz değerlendirme ve geri bildirimin yansıtıcı öğrenmenin önemli bileşenleri olduğunu göstermiştir. Küme 2, sağlık hizmetlerinin öğrenci deneyimlerini nasıl şekillendirdiğini ve yansıtıcı öğrenmenin bu deneyimler üzerindeki etkisini araştırmaktadır. Küme 3, mesleki gelişim ve hasta etkileşiminde yansıtıcı öğrenmenin merkeziliğini vurgular. Küme 4 ve 5, yansıtıcı öğrenme sürecinde bilgi, tutum ve kalite yönetiminin rollerini açıklamaktadır. Küme 6 ve 7, yansıtıcı öğrenme bağlamında sürekli iyileştirme ve hasta güvenliğinin kritik öneminin altını çizmektedir. Sonuç olarak, yansıtıcı öğrenme konusu sağlık disiplinlerinde giderek artan bir ilgi görmektedir ve bu ilginin eğilimini daha iyi anlamak için daha kapsamlı analizlere ihtiyaç vardır.

Anahtar Kelimeler: Reflektif öğrenme, sağlık, bibliyometrik analiz

1 Introduction

Reflective learning holds critical importance in health professionals' education, enhancing learners' capacity to learn from experiences and continually improve professional practice. Reflective learning is a process triggered by an experience, in which an individual internally examines and discovers a concern, creating meaning from their own perspective, clarifying, and resulting in a change in conceptual outlook [1, 2]. The reflective learning process can be examined in three stages: returning to the experience, dealing with emotions, and the processing stage. In the first stage, returning to the experience, students recall events and re-examine their reactions to those events. In the second stage, dealing with emotions, it enhances the student's self-awareness and helps to maintain their positive emotions while discarding the negative ones. In the final stage, the processing stage, events are interpreted and restructured by the student [3].

We believe that studying reflective learning in health sciences will have significant implications. Firstly, this concept is central to the education of professional groups in health sciences, such as medicine, nursing, and midwifery [1]. Therefore, the findings from analysing a dataset spanning forty years hold the potential to improve educational strategies and professional practices, ultimately contributing to better health outcomes in the health sciences. Secondly, this research highlights the importance of reflective learning in developing the knowledge, attitudes, and competencies necessary for quality management and continuous improvement in healthcare services [4]. Lastly, the study provides invaluable insights into academic outcomes and the effects on professional development and patient interactions, demonstrating that reflective learning is not just about academic results but also plays a crucial role in the broader context of healthcare practice and patient care [5, 6].

In this context, several studies examine reflective learning in health sciences. A systematic review by Mann, Gordon, and MacLeod (2009) highlighted the increasing importance of reflection in health sciences education. [1]. The work of Braun and Clarke (2006) on using thematic analysis in psychology aids in identifying themes that support the reflective learning process, enabling an in-depth analysis of student experiences within this process [7]. The main themes supporting the reflective learning process are self-Assessment and Awareness, Critical Thinking, Analysis of Errors and Successes, Personal and

Professional Development, Feedback and Communication, Effective Learning Strategies, the Role of the Educator, and Emotional Processing. The theme of Self-Assessment and Awareness encourages students to evaluate their learning processes and behaviours, enhancing their self-awareness and self-reflection skills.

Sandars (2009) and Boyd and Fales (1983), who address the use of reflective learning in medical education, emphasize the importance of this process, while Boud and Walker (1998) and de Rome et al. (1985) have drawn attention to the current challenges in promoting reflective learning in professional courses [8-11]. The work of Wong and Colleagues (1995) on reflective journals stands out as a significant tool in assessing students' levels of reflection [12]. Epstein (1999) and Epstein and Hundert (2002) have highlighted the importance of reflective practices in defining and evaluating mindfulness and professional competence [13, 14].

Gibbs (1988), who developed the 'learning by doing' approach, emphasizes the role of concrete experiences in developing reflective practices, while Pee and colleagues (2002) have pointed to the importance of using a structured worksheet in assessing students' written reflections [15, 16]. Aronson (2011) offered practical tips for teaching reflective learning at medical education levels, and Driessen et al. (2007), along with Sobral (2000), addressed the importance of evaluating students' learning achievements, self-confidence, and diagnostic abilities [5, 6, 17]. Wald and Reis (2010) focused on reflective writing and the development of reflective capacity, highlighting the critical importance of individuals' beliefs in their abilities in this process through Bandura's (1977) self-efficacy theory [18, 19]. Buckley and colleagues (2009) have presented a systematic review of the educational impact of portfolios on student learning [20]. This study on the educational effects of reflective journals and formative feedback emphasizes the importance of these methods in helping students understand and improve their involvement in learning processes. Dividing reflective practices into five categories has assisted students in enhancing the quality of these practices, and it has been observed that the quality of teacher-student relationships plays a significant role in this process. The research demonstrates that formative feedback contributes to students thinking more deeply, adding more meaning to their learning experiences. These results show the value of effectively using reflective practices and feedback in education [21]. The study conducted by MacAskill and colleagues (2023) thoroughly examines the diversity of reflective learning methodologies in medical education and how these methodologies contribute to the holistic development of students. Findings reveal that creative, reflective learning approaches significantly benefit recognizing multiple perspectives among students, fostering empathy, developing bilateral communication skills, and patient-centered care themes [22].

Considering these studies, it is evident that reflective learning has found a wide application in health education and the healthcare field. Consequently, some studies have examined the developmental patterns in the literature. These studies have been limited to topics in health education such as healthcare education [23], health profession education [1], and medical education [4] with no research presenting a holistic view of the field's development patterns. This research aims to identify the developmental patterns of reflective learning in the health sciences context and offer suggestions for future research in this field. The research seeks answers to several questions: i) Who are the most influential authors, journals, institutions, and countries in developing the reflective learning literature in the health field? ii) What are the emerging trend topics in reflective learning in the health field? iii) What developmental trends do the patterns of co-citation, co-authorship, and co-occurrence of terms in reflective learning in the health field show? In this context, the study contributes in two ways. Firstly, we provide a holistic perspective on the development patterns of reflective learning in health, offering insights that can guide scientists and students interested in the area. The presentation of the most influential sources, authors, journals, countries, and institutions mainly serves as a ready resource for those wishing to work in this field. Secondly, by showcasing the change patterns in the field, we provide information on which

concepts have emerged and receded, thus setting a roadmap for future research. The second part of the research presents the methodology section. The third part is dedicated to the findings of the research. Finally, the study is completed with the discussion and conclusion section.

2 Methodology

This research utilized bibliometric analysis techniques such as performance analyses, co-citation analyses, co-word analyses, and co-authorship analyses [24, 25]. The data for the research were obtained from the Web of Sciences (WoS) database. This database was chosen because it is widely used among management scientists and is considered the most influential database in the scientific community [26-30]. The data for the study were extracted from the database using the following search strategy. *Search strategy:* "reflective learning" (Topic) and Health Care Sciences Services or Nursing or Medicine General Internal or Psychology Multidisciplinary or Public Environmental Occupational Health or Psychology Educational or Dentistry Oral Surgery Medicine or Psychiatry or Primary Health Care or Health Policy Services or Psychology Applied or Pharmacology Pharmacy or Psychology Social or Rehabilitation or Ergonomics or Surgery or Dermatology or Clinical Neurology or Cardiac Cardiovascular Systems or Audiology Speech Language Pathology or Respiratory System or Obstetrics Gynecology or Anesthesiology or Psychology Developmental or Psychology Clinical or Psychology or Pediatrics or Neurosciences or Critical Care Medicine or Medicine Research Experimental or Medical Informatics or Emergency Medicine or Radiology Nuclear Medicine Medical Imaging or Psychology Experimental or Gerontology or Nutrition Dietetics or Oncology or Ophthalmology or Anatomy Morphology or Gastroenterology Hepatology or Geriatrics Gerontology or Medical Ethics or Psychology Psychoanalysis (Web of Science Categories) and News Item or Correction or Book Review or Letter or Meeting Abstract or Book Chapters or Proceeding Paper or Editorial Material (Exclude – Document Types)". After the data were extracted, analyses were conducted using Bibliometrix software. In the following section, the purpose of each analysis is explained, and the data obtained as a result of these analyses are presented.

3 Results

The findings are divided into two parts: performance analyses and scientific mapping analyses. The performance analyses included vital information, such as the number of publications and citations per year, the most prolific institution, author, country, and journals, and an analysis of trending topics. In the scientific mapping analyses, co-citation, co-occurrence, and co-author analyses were performed.

3.1 Performance Analysis

Performance analysis allows to identify the contribution of research components to a specific field [24]. The Figure 1 includes 385 documents focusing on 'reflective learning' in health disciplines between 1983 and 2023. The annual growth rate is observed to be 8.87%. This indicates that reflective learning is an emerging area of interest in health disciplines. The majority of the documents are articles (350), along with early access articles (6) and review articles (28). This shows that the bulk of the work in this area consists of original research. The small number of review articles may imply that the field is not yet consolidated.

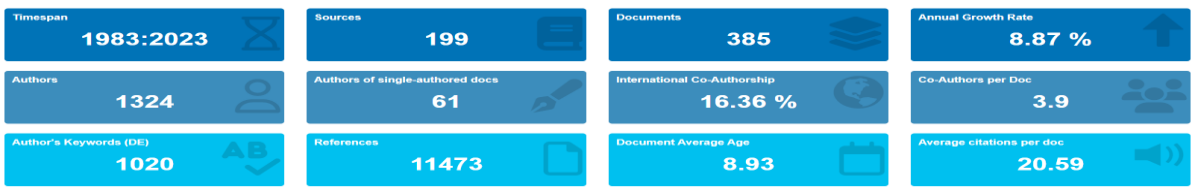

Figure 1: *Data Statistics*

The average number of citations per document is 20.59, which indicates the topic's significance and impact. With an average of 3.9 authors per document and 16.36% international collaboration, it can be said that there is a multidisciplinary and international approach in this field. Particularly in terms of health disciplines, these collaborations can be quite valuable. The abundance of keywords (1020) and Keywords Plus (659) indicates that the topic is addressed in various aspects. This suggests that reflective learning may have different applications and theoretical frameworks for health disciplines.

Figure 2 highlights the following elements: The number of publications has generally increased since 1983, with a notable rise after 2010. The highest number of publications was in 2023 (30 publications). Citation numbers have not been entirely correlated with the number of publications. For example, while 1204 citations were received in 2015, there were 23 publications in the same year. However, in 2021, 29 publications received only 77 citations. Recent Years: In the most recent years (2021-2023), the total number of citations has been relatively low despite the increase in publications. This may be due to the publications being more recent.

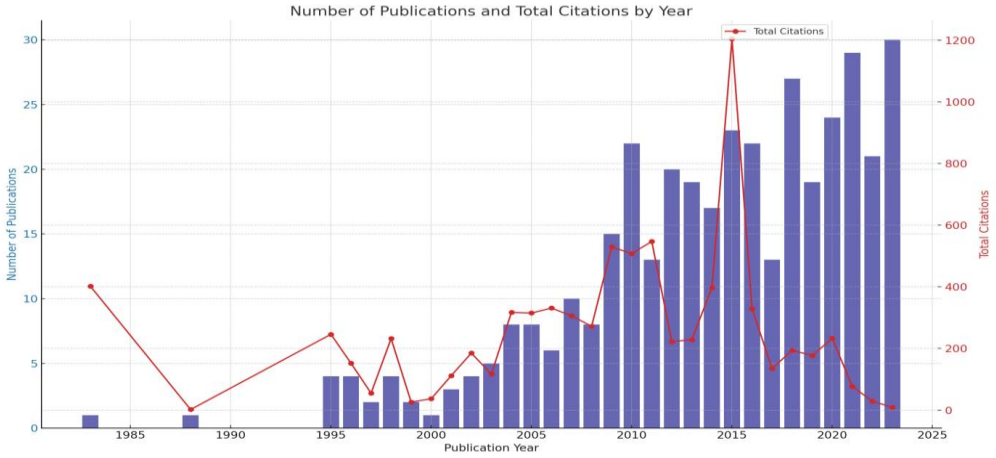

Figure 2: *Number of Publications and Citations by Years*

Table 1 lists the top 10 most cited articles. Upon detailed examination of the first four articles, we observe that some studies present a model of being aware of one's reflective learning styles and consciously choosing to use these styles [9]. Additionally, another study has defined an integrated conceptual framework named 'PEARLS' to foster excellence and reflective learning within the simulation [31]. Another research highlights the positive effects of general learning and specifically reflective learning styles on academic performance [32]. Yet another study has designed research from the perspective of the Iterative Reprocessing (IR) model, finding that a short-term intervention targeting reflection and rule use led to enhanced cognitive functionality, theory of mind, and corresponding changes in brain functions [33].

Table 1: *The 10 Most Cited Articles*

Articles	Total Citations	TC per Year	Normalized TC
Boyd EM, 1983, J Humanist Psychol	402	9,8	1
Eppich W, 2015, Simul Healthc	396	44	7,56
Komarraju M, 2011, Pers Indiv Differ	319	24,54	7,58
Zelazo Pd, 2015, Dev Rev	232	25,78	4,43
Wong FKY, 1995, J Adv Nurs	215	7,41	3,5
Joy S, 2009, Int J Intercult Rel	203	13,53	5,76
Wald HS, 2015, Acad Med	175	19,44	3,34
Kumagai AK, 2008, Acad Med	154	9,63	4,53
Lachman N, 2006, Clin Anat	154	8,56	2,79
Snadden D, 1998, Med Teach	129	4,96	2,22

Table 2 displays the publishing sources, institutions, regions, and authors that utilize reflective learning within the context of health sciences. Publishing Sources: It shows the journals that have published the most articles on reflective learning in health sciences. Institutions indicate how productive different academic institutions or universities are in this field. Regional frequency demonstrates the contributions of other regions to reflective learning. Productivity of authors shows the authors who have written the most articles and their publication counts. From this table, we can see that 'Medical Teacher' and 'Nurse Education Today' are among the leading journals in the field of health education, with 22 and 20 articles, respectively. These journals can be considered as one of the most significant sources in the field of health education. Among the most published universities are 'The University of Calgary,' 'The University of Ottawa,' and 'Maastricht University'.

Table 2: *Institutions, Authors, Countries and Journals with the Most Publications*

Journals	Articles	Institutions	Articles	Country	Frequency	Authors	Frequency
Medical Teacher	22	University of Calgary	18	USA	226	Eppich W	5
Nurse Education Today	20	University of Ottawa	18	UK	200	Branch WT	4
Medical Education	16	Maastricht University	12	Canada	130	Cheng A	4
Nurse Education in Practice	11	McGill University	12	Australia	120	Vachon B	4
Clinical Simulation in Nursing	9	University of Birmingham	9	China	49	Bion J	3
Journal of Advanced Nursing	8	University of California System	9	Netherlands	45	Bowie P	3
Journal of Dental Education	7	University of London	9	Spain	31	Brand G	3
Journal of Nursing Education	7	University of Melbourne	9	Germany	22	Chandrasekaran B	3
American Journal of Pharmaceutical Education	6	University of Toronto	9	South Africa	21	Chien WT	3
Journal of Continuing Education in the Health Professions	6	Feinberg School of Medicine	8	Sweden	21	Cress U	3

These universities are ranked in the top three with 18, 18, and 12 articles, respectively. It can be said that these universities play a significant role in the field of health education. The countries publishing the most are the 'USA,' 'UK,' and 'Canada.' These countries are ranked in the top three with 226, 200, and 130 frequencies, respectively. It can be stated that these countries are leaders in the field of health education. The most prolific authors include 'Eppich W,' 'Branch WT,' and 'Cheng A.' These are ranked in the top three with 5, 4, and 4 publications, respectively. These authors may have made significant contributions to the field of health education. This table indicates which institutions, countries, and authors are the most active in health education. This information can be a valuable resource for those who wish to conduct research in the field of health education.

3.2 Analysis of Trending (Prominent) Topics

When analysing Figure 3, several key findings emerge. The concepts of 'Reflection' and 'Reflective learning' are quite popular in health sciences, with frequencies of 39 and 65, respectively. On the other hand, concepts like 'Quality improvement' and 'Collaborative learning' are mentioned only five times, indicating less attention to these topics. General educational concepts like 'Learning' and 'medical education' have consistently evolved since older dates. They are mainly concentrated between the years 2006-2010. Concepts like 'Nursing' and 'training' have recently gained popularity, with median years close to 2021 and 2022. There is an imbalance between general concepts ('learning,' 'education') and more specific concepts ('nursing education,' 'experiential learning'). Specific concepts seem to have become popular more recently. There is a substantial body of literature on reflective learning ('reflection,' 'reflective practice,' 'reflective learning') with a trend that varies over time. Notably, 'reflective learning' has gained popularity since 2015.

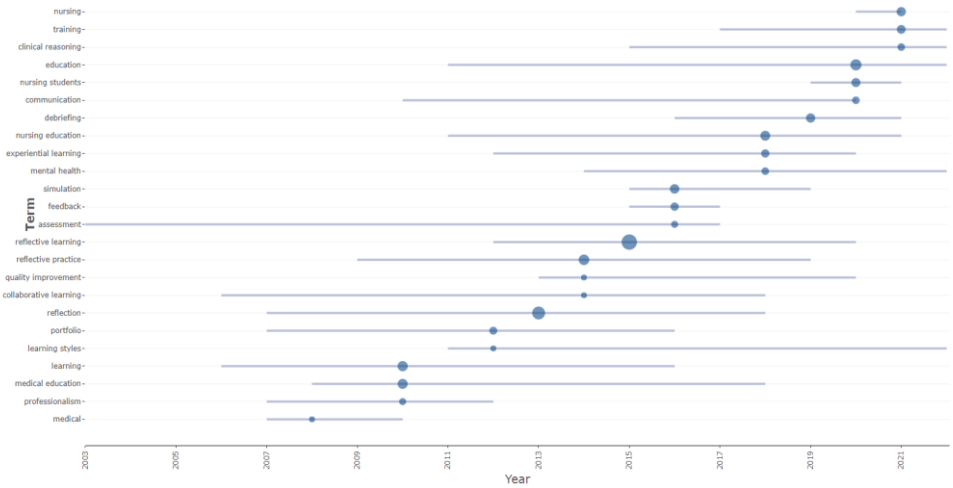

Figure 3: *Changes in Conceptual Patterns*

These findings indicate that reflective learning is significant in health sciences education. However, other areas in this field require attention; for instance, areas like 'quality improvement' or 'collaborative learning' may need more research and focus. Furthermore, reflective learning has evolved into more specific sub-topics (for example, 'reflective practice' or 'debriefing'). This suggests that we may need a more comprehensive understanding of how students and professionals can use different forms of reflection in their educational processes.

When examining the word cloud in Figure 4, it is observed that terms related to reflective learning and reflection are used more frequently in the context of health sciences. Alongside these terms, words such as education, reflective practice, medical education, and learning are used less frequently. Other terms like nursing education, informatics, simulation, nursing students, training, nursing, portfolio feedback, experiential learning, qualitative research, clinical reasoning, and mental health are also present but used much less frequently in health sciences.

Figure 4: *Word Cloud Analysis*

3.3 Science Mapping

Science mapping allows visualization of network relationships between research components. Different techniques exist, such as citation analysis, co-citation analysis, bibliography matching, common word analysis, and co-authorship analysis [28]. In this study, a review was conducted using co-citation analysis, co-word analysis, and co-authorship analysis techniques.

3.3.1 Co-Citation Analysis

Co-citation is the frequency with which two documents are cited together [34]. Co-citation analysis is used to create measures of similarity among documents, authors, or journals [30]. Üsdiken and Pasadeos (1995) have indicated that after all citations in a specific document are recorded, a list of all pairs of works cited in that document can be obtained, and by repeating this procedure for a large number of documents, frequencies of co-citations can be generated. In this case, a co-citation network is formed [35]. The co-citation network is represented by a line when multiple different documents cite two papers together. The strength of a co-citation depends on the number of sources citing both documents and is represented by the number or size of lines connecting the two papers [36]. Co-citation analysis can identify the most influential publications in a field [37]. The more citations two documents receive, the more similar their contents are considered to be [38].

Bibliography coupling refers to the similarity of the bibliographies of two different studies. [39]. However, mapping science frequently uses Co-citation Analysis [30]. Bibliographic coupling is considered a static analysis because it relies on the references in the related documents. In contrast, co-citation analysis is dynamic as it changes over time [38]. When two documents receive a high rate of citations, co-citation analysis can reveal which of these documents is considered more important by the researchers citing them. However, in bibliographic coupling, it is difficult to determine which document is more significant. This is both a strength and a weakness of co-citation analysis. While it contains high information for highly cited documents, it is unreliable for less cited niche expertise areas [30].

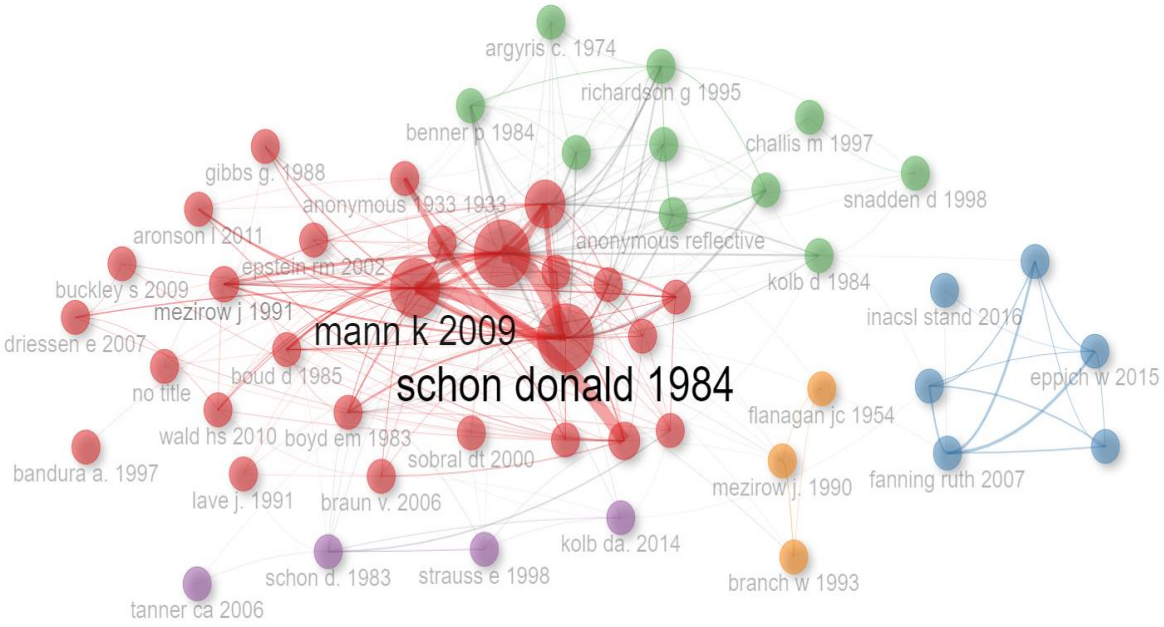

Figure 5: *Co-Citation Analysis Network Structure*

For the red cluster, Cluster 1, the theme will be 'Reflective Learning Processes and Practices.' The reason for selecting this theme is that the studies in Cluster 1 comprehensively examine how reflective learning is used in the education of health professionals and the impact of this process on student success, self-confidence, and professional competence.

Mann, Gordon, and MacLeod's (2009) study emphasizes the importance and effectiveness of reflective practices in health sciences education by presenting a broad literature review [1]. Braun and Clarke (2006) demonstrate the role of reflective thinking in interpreting qualitative data using thematic analysis [7]. Sandars' (2009) study provides a comprehensive guide on how reflective learning can be used in medical education [8]. Boyd and Fales (1983) discuss the critical role of reflective learning in the process of learning from experiences, while Boud and Walker (1998) and De Rome et al. (1985) address the challenges of promoting reflective learning in professional courses and changes in academic staff's perceptions of teaching and research [9-11]. Wong and colleagues' (1995) study presents a method for assessing the level of student reflections, and Epstein's (1999, 2002) works focus on mindful practices and the definition of professional competencies of health professionals [12-14]. The works of Gibbs (1988) and Pee et al. (2002) contribute to learning methodologies and the evaluation of student reflections [15, 16], while Aronson (2011) and the studies of Driessen et al. (2007) discuss methods of teaching reflective learning in medical education and the complex success of portfolios [5, 6]. Sobral (2000) and Wald and Reis (2010) focus on the assessment of students' diagnostic abilities and the development of reflective capacity in medical education [17, 18]. Lastly, Bandura's (1977) self-efficacy theory and the study of Buckley and colleagues (2009) on the educational effects of portfolios are significant components of this theme [19, 20]. These articles provide an in-depth look into how reflective learning can be integrated into health education, contribute to student development, and enhance professional competencies.

When examining the blue Cluster 2, we can see that the common theme of the articles in this group is 'Reflective Learning with Debriefing in Health Simulations.' This theme encompasses debriefing methods focused on enhancing learning and performance in the simulation-based learning process in health education. In health simulation training, debriefing refers to the process where students or professionals analyse the simulated scenarios they experience, reflect on their experiences, and integrate

what they have learned. Fanning and Gaba's (2007) study highlight the role of debriefing in simulation-based learning. This study reveals the importance of feedback in health simulations and how debriefing plays a critical role in the learning process [40]. Eppich and Cheng (2015) present the development and rationale of a blended approach named PEARLS, which is designed for use in healthcare simulation debriefing. This approach is a debriefing model that encourages learning and reflective thinking [31]. Rudolph et al.'s 2006 study discusses how collaborative offline reflection can be used to develop action science and inquiry skills. This demonstrates how the debriefing process can be effective in post-simulation and general health education [41]. Rudolph and colleagues' subsequent studies in 2007 and 2008 examined using debriefing as a formative assessment and how it can bridge performance gaps in medical education. These studies show how the debriefing process can be integrated with critical thinking and authentic inquiry [42, 43]. The common thread of these articles is the importance of debriefing processes in health simulations and how these processes can contribute to reflective learning. These works lay the foundation for developing and enhancing debriefing techniques in simulation-based training.

The green Cluster 3 focuses on 'Overall Reflective Learning.' This theme is based on reflections on how students and health professionals learn from their experiences and apply this learning in practice. Richardson and Maltby (1995) examine how students' reflections on their practices enhance their learning. This study shows how reflective learning helps students draw lessons from their experiences [44]. Atkins and Murphy (1993) review the existing literature on reflective practice and emphasize its significant role in student and practitioner professional development [45]. Johns (1995) discusses how reflective learning can be framed in nursing through Carper's Ways of Knowing. This work addresses the importance and application of reflective thinking in nursing education [46]. Powell (1989) investigates how reflective practice is implemented in nursing, highlighting the importance of reflection in professional practice [47]. Argyris and Schön (1974) address the relationship between theory and practice to enhance the effectiveness of professionals. Their work provides the theoretical foundations for reflective thinking [48]. Snadden and Thomas (1998) and Challis et al. (1997) explore the effectiveness of portfolio-based learning in general practitioner training and how this form of learning integrates with reflective practice. Portfolio-based learning is an educational approach where students or professionals create a portfolio to document their knowledge, skills, experiences, and personal development. This method, prevalent in health sciences and education fields, involves portfolios typically comprising various materials such as written work, projects, research, self-assessment, reflective writings, and practical experiences. These studies demonstrate the applicability and impact of reflective learning in professional education [49, 50]. These articles underscore the importance of reflective learning in health education and professional development, providing valuable insights into implementing reflective practices in nursing and general practitioner training. Together, under the theme of 'Reflective Learning,' these works highlight the significance of continuous learning and development in the education and practice of health professionals.

Based on the co-citation analysis data on reflective learning, the orange Cluster 4 can be named 'Dynamics of Reflective Practice in Professional Development.' This theme focuses on the deep, reflective processes professionals use in their practice and learning, encapsulating the essence of these works. Kolb et al. (2014) emphasize the importance of experiences in professionals' learning processes by addressing previous research and new directions in experiential learning theory. This study lays the groundwork for reflective learning, enabling individuals to enhance their ability to learn from personal experiences [51]. Schon (1983) explores how professionals think in action, highlighting the significance of reflective practice. This work focuses on developing professionals' abilities to analyze situations they encounter and learn from them [52]. Boud (2001) focuses on using journal writing to develop reflective practice. This approach plays a significant role in professional development by enabling individuals to

express their experiences in writing and engage in deep thinking during this process [53]. Lastly, Tanner (2006) presents a research-based model used in clinical judgment in nursing, emphasizing the role of reflective thinking in professionals' decision-making processes. This model demonstrates the importance of reflective thinking in complex decision-making situations and provides essential insights into how professionals can develop these skills [54]. These works deeply examine the role of reflective practice in professional development, clarifying the scope and significance of this theme.

The purple Cluster 5 has been named 'Critical Incident Technique and Transformation in Adult Education in the Reflective Learning Process.' This theme emphasizes the examination of critical incidents in the learning process and the importance of transformative approaches in adult education. Flanagan's (1954) work on the 'Critical Incident Technique' profoundly examines the process of learning from individuals' experiences and how this process is shaped by critical incidents [55]. Flanagan's study lays the foundations for reflective learning, contributing to analysing individuals' experiences and enhancing their ability to learn from these experiences. Mezirow (1990) developed the theory of transformative learning in adult education. This theory describes reaching knowledge by questioning individuals' experiences and assumptions [56]. Mezirow's work further deepens the role of critical incidents in the reflective learning process, enabling individuals to undergo significant personal and professional transformations. The study by Branch et al. (1993) examines the vital incidents encountered by third-year medical students and investigates their impact on the students' process of becoming doctors [57]. This study demonstrates how reflective learning can be applied in professional education and reveals how students can learn and practice more effectively in the face of critical incidents.

3.3.2 Co-occurence Analysis

Co-occurrence is used to provide a visual representation of a scientific field's structure and examine relationships between authors or journals. When direct similarity is applied to co-occurrence data, the aim is to normalize the data, that is, to correct for differences in the total number of occurrences or co-occurrences of objects [58]. This method summarizes the weighted inputs from the entire visual [59]. Thus, this analysis allows for determining the dynamics of science without any predefined definition of research themes [60]. Türkmendağ (2021) has noted the importance of this analysis in visualizing the literatüre [61]. Furthermore, Lis (2018) has stated that the clustering of keywords manually performed by authors would be highly subjective and flawed [62].

Based on the results of the co-occurrence analysis, the identified theme names and evaluations for each cluster within the context of health sciences and reflective learning indicate the existence of seven clusters. Cluster 1, colored red, has been named 'Education and Assessment.' The concepts in this cluster include medical education, model, performance, feedback, skills, competence, portfolios, self-assessment, science, nursing students, tools, behaviour, and confidence. This cluster encompasses fundamental concepts related to medical education and student performance. Concepts such as 'feedback' and 'self-assessment' represent the self-evaluation and feedback dimensions of reflective learning.

Cluster 2, colored blue, is grouped under 'Healthcare Services and Student Experience.' The key concepts in this cluster are education, students, care, experiences, perceptions, nurses, curriculum, healthcare service, impact, outcomes, thought, health, simulation, strategies, knowledge, self-reflection, stress, children, and internship. This cluster emphasizes how healthcare services shape students' experiences and perceptions, how this process can affect student care, and the importance of self-reflection. Concepts such as 'experiences,' 'perceptions,' and 'self-reflection' illustrate how reflective learning can enrich student experiences and highlight the role of this process in individual development.

Cluster 3, colored green, is named 'Professionalism and Patient Interaction.' The prominent critical concepts in this cluster are reflection, professionalism, and patience. This cluster emphasizes the interaction of health professionals with patients and how this interaction is shaped within the framework of professionalism. The concept of 'reflection' emerges as a critical component of reflective learning that supports professional development and strengthens patient interaction. In this context, how reflection can be integrated into professional practice to improve patient interactions is considered a significant topic.

Purple Cluster 4: 'Knowledge and Attitudes': The key concepts in this cluster can be listed as knowledge, program, attitudes, validity, and capacity. This cluster highlights the critical importance of knowledge and attitudes in the reflective learning process. The concepts of 'knowledge' and 'attitudes' are fundamental in shaping the learning process and developing an individual.

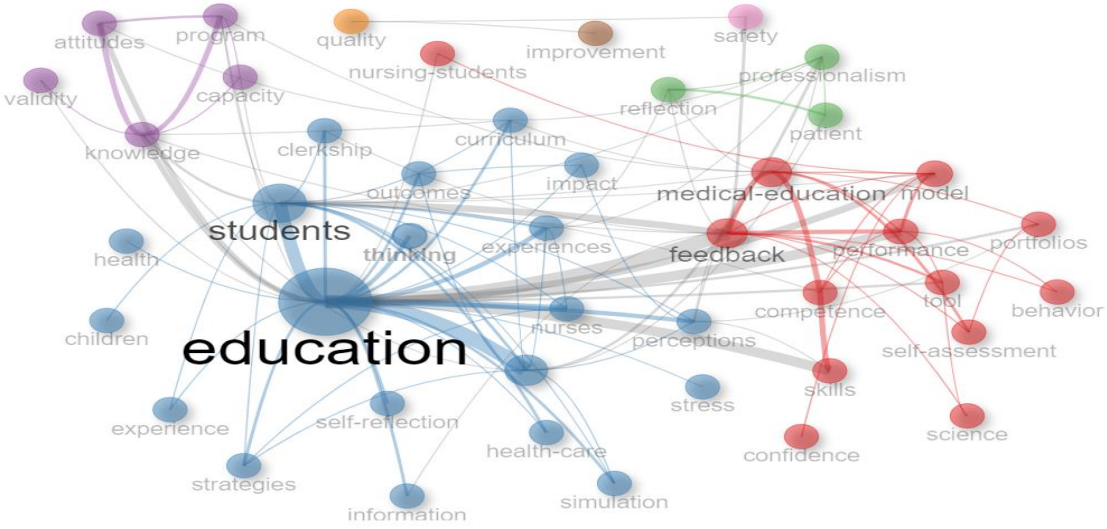

Figure 6: *Co-occurence Analysis Network Structure*

Orange Cluster 5: 'Quality Management': The key concept in this cluster is 'quality.' This concept implies that reflective learning processes can positively impact enhancing the quality of healthcare services. Quality management contributes to delivering healthcare services more effectively and efficiently, highlighting the significance of reflective learning processes. Brown Cluster 6: 'Continuous Improvement': Including 'improvement' as a key concept, this cluster emphasizes the critical importance of reflective learning in continuous improvement. Reflective learning enables an individual to continually develop and improve by leveraging their own experiences and knowledge. Pink Cluster 7: 'Patient Safety': The key concept in this cluster is 'safety,' indicating that reflective learning practices can positively affect patient safety. Reflective learning aids health professionals in evaluating their practices and enhancing patient safety. These clusters and evaluations reveal that reflective learning is a multifaceted and comprehensive subject in health sciences. The clusters highlight essential aspects of reflective learning, such as enhancing the quality of healthcare services, ensuring patient safety, and contributing to professionals' continuous development.

3.3.3 Co-Author Analysis

In scientific studies, co-authorship manifests intellectual collaboration [63]. Co-authorship reflects stronger social ties compared to other measures of relatedness. This makes co-authorship particularly suitable for examining social networks. Moreover, since it includes information about authors' institutional affiliations and geographical locations, co-author analysis allows for reading collaboration issues at the levels of institutions and countries [30]. In Co-Authorship analysis, the centrality degree of

an actor is taken as a basis, and the social network in the field is visualized [64]. While similar to co-citation analysis, co-authorship analysis differs in that co-citation analysis is conducted based on citations to authors' works. In contrast, co-authorship analysis is based on authors' joint works.

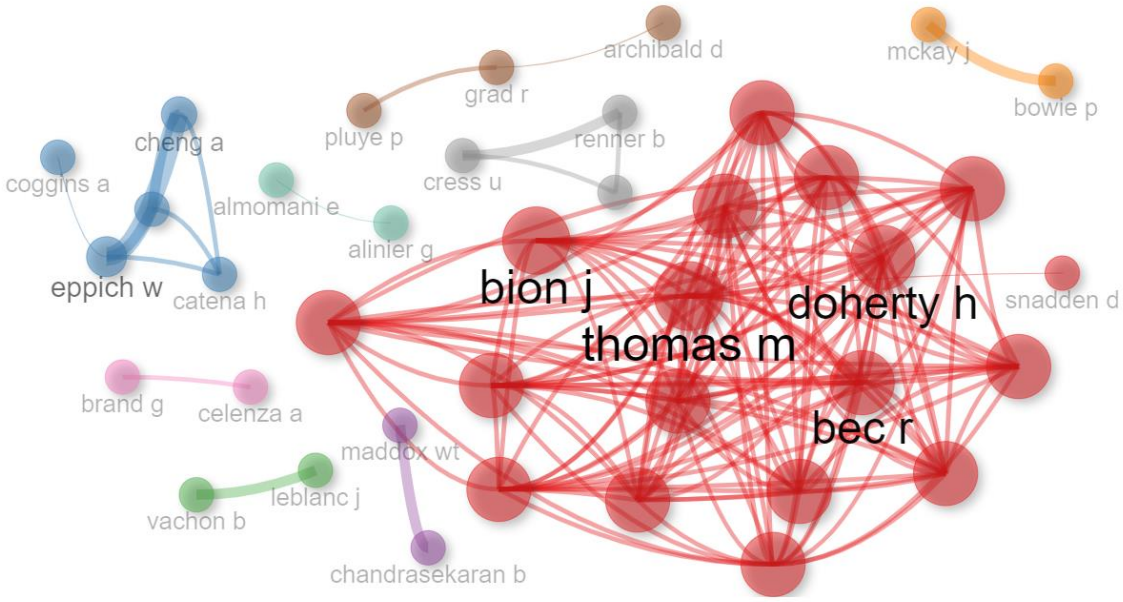

Figure 7: *Co-Author Analysis Network Structure*

Therefore, while co-citation analysis facilitates the identification of significant works, co-authorship analysis provides the opportunity to identify essential scientists [65]. On the other hand, a weakness of co-authorship analysis can stem from scientific fraud. Indeed, Katz and Martin (1997) have pointed out that not everyone named has contributed to the work, with some authors being added to studies for social reasons, and concepts such as honorary co-authorship exist [66]. The authors with the most co-authorship relationships are found in the red cluster, including Bion J., Thomas M., Doherty H., and Bec R. Subsequently, the authors addressing co-authorship cluster relationships are in the blue cluster, comprising Eppich W., Catena H., Coggins A., Cheng A.

4 Discussion

Reflective learning is an essential concept in education and teaching, and over time, it has manifested itself in various applications across different disciplines. Historically, our analysis suggests that reflective learning can be examined through three main periods representing themes from the earliest to the most recent studies. These periods demonstrate the evolution of reflective learning in education, its application in clinical and medical fields, and the integration of technology with reflective learning. The themes above highlight the historical changes and transformations in this area. In this discussion text, we will analyse the relationship of reflective learning with education, clinical and medical practices, and technology. We have named these three main period themes as the three main themes.

Reflective Learning in Education: Reflective learning is a strategy that enables students to learn from their experiences and develop their critical thinking skills. Studies titled 'Reflective Learning - The Key to Learning from Experience' and 'Reflective Learning as a Teaching Strategy for Critical Thinking' emphasize how this approach can transform students' thinking [9, 67]. Educators encourage students to process new information using their experiences and existing knowledge. This process allows students to learn more deeply and develop critical thinking skills.

Reflective Learning in Clinical and Medical Fields: In clinical and medical fields, reflective learning enables students and health professionals to draw lessons from their patient care experiences and transform these experiences into better practices [9]. Studies such as 'My Most Meaningful Patient' and 'Reflective Learning in a Patient Safety Course for Final-Year Medical Students' demonstrate how reflective learning is utilized in medical education [68, 69]. This approach allows medical students and healthcare workers to analyse their challenges and successes, integrating the knowledge and skills gained in the process into their clinical practices.

Technology and Reflective Learning: The role of technology in education is increasingly significant, and reflective learning occupies an essential place in this process. Studies like 'The Impact of Technology on Reflective Learning in Dental Hygiene Education' and 'Computer-assisted Reflective Learning: How Applications Can Promote Reflection in the Workplace' examine how technology supports reflective learning [70, 71]. Technology enables students and professionals to record, analyze, and more effectively share their experiences. Mainly, mobile applications and online platforms facilitate the reflective learning process and extend its reach to a broader audience.

Reflective learning is an approach that can be applied across a broad spectrum, from education to healthcare services and technology. Implementing this approach enables students and professionals to learn more deeply from their experiences and enhances their critical thinking skills [16]. Reflective learning is vital in supporting individuals' continual development and adaptation abilities, especially in the rapidly changing and evolving modern world [1].

Evaluation from the perspective of co-occurrence analyses: Based on the results of co-occurrence analysis in health sciences and reflective learning, the seven emerged clusters cover a wide range from education to patient safety. The first cluster focuses on the importance of feedback and self-assessment in medical education, while the second cluster addresses the impact of healthcare services education on student experiences [22]. The third cluster emphasizes professionalism and patient interaction, and the fourth cluster highlights the roles of knowledge and attitudes in the learning process. The fifth cluster discusses the contribution of quality management to reflective learning processes, while the sixth cluster points to the importance of continuous improvement processes. The seventh and final cluster foregrounds the role of patient safety in reflective learning processes.

The topics within each cluster offer significant insights into the future of health education and services. The evolution of educational processes from traditional methods to interactive and student-centered approaches, the adaptation of students and educators to these new methods, and efforts to maintain objectivity are becoming prominent. Additionally, health professionals' experiences in reflective learning processes influence their perception of patient care and professionalism, enhancing the human-centered aspect of healthcare services. Quality management and continuous improvement processes contribute to the efficiency and effectiveness of healthcare services. Each cluster plays a critical role in enhancing the quality of healthcare services and education, with a central focus on patient safety. The evaluation of these clusters demonstrates that reflective learning plays a versatile and comprehensive role in health sciences. Reflective learning is an indispensable tool in health sciences with its various aspects, such as improving the quality of healthcare services and patient safety, ensuring the continuous development of professionals, and enriching educational processes.

Evaluation in terms of co-citation analyses: The similarities and differences between the themes in the 'Three Main Periods' and 'Co-Citation Clusters' files can be summarized as emphasizing the importance of reflective learning and its various application areas:

Similarities: Focus on Reflective Learning Approaches: Reflective learning is emphasized in both files. The 'Three Main Periods' file focuses on the relationship of reflective learning with education, clinical

and medical practices, and technology, while the 'Co-Citation Clusters' file deals with themes such as reflective learning processes and practices, reflective learning with debriefing in health simulations, and reflective learning in general. These themes concentrate on integrating reflective learning in health education, student development, and enhancing professional competencies. Professional Development and Educational Practices: In both files, there is a focus on how professionals and students can learn from their experiences and how they can apply this learning in practice.

Differences: Specific Emphases and Methods: The 'Three Main Periods' file addresses specific themes, such as the integration of technology with reflective learning, while the 'Co-Citation Clusters' file includes a broader and more diverse range of sub-themes, such as the dynamics of reflective practice in professional development, the critical incident technique in the reflective learning process, and transformation in adult education. Relationship Between Practice and Theory: In the 'Co-Citation Clusters' file, the impact of reflective learning on health education is examined from a more theoretical and methodological perspective, whereas the 'Three Main Periods' file focuses on the practical integration of reflective learning with education, clinical and medical practices, and technology.

5 Conclusion

These comparisons show that both files have unique emphases and application areas regarding reflective learning. While the 'Co-Citation Clusters' file offers a broad theoretical framework, the 'Three Main Periods' file presents content more directed towards specific and practical application areas.

6 Research Limitations and Future Research

In bibliometric studies, co-citation, co-occurrence, and co-authorship analyses are commonly used methods, yet they also have certain limitations [24, 30, 72]. Firstly, these analyses often rely on publications from limited databases, which can affect the scope and reliability of the results. Therefore, future research could deepen analyses by integrating databases such as WoS and Scopus. Secondly, the diversity of research terms and concepts, language differences, and interdisciplinary terminological differences can limit the accuracy of the analysis [27, 28]. Thus, future research could replicate studies using different search strategies. Thirdly, analyses conducted within a specific timeframe may not reflect the latest developments in rapidly evolving fields. Therefore, it is crucial for future research to identify new development patterns in these areas through bibliographic coupling analysis.

Fourthly, focusing on highly cited works may lead to the oversight of lesser-known studies. The methodological limitations of co-citation, co-occurrence, and co-authorship analyses are confined to the quantitative assessment of relationships among publications, which may not fully represent the nature and context of these relationships. While these analyses reflect the current state of a research field, they do not consider the dynamics and changes over time, leading to limitations, especially in analysing new and rapidly evolving topics. Therefore, future research could focus on systematic literature reviews and qualitative analyses to perform in-depth analyses.

Fifthly, the contributions of reflective learning to various health science disciplines, such as nursing, medicine, and public health, can be systematically explored. In these studies, employing a mixed-methods approach to investigate how reflective practices affect clinical decision-making, interdisciplinary teamwork, patient outcomes, and the overall resilience and adaptability of healthcare professionals would be valuable. Finally, research could be designed to examine the integration of reflective learning into curricula and its impact on the preparedness of students transitioning to clinical settings. Additionally, these studies could investigate potential barriers to and facilitators of effective reflective learning in educational settings and professional practice.

7 Declarations

7.1 Study Limitations

The research utilized a limited database. The diversity of research terms and concepts, language differences and terminological differences across disciplines may limit the accuracy of the analysis. Articles from a specific time period were analyzed in the study. The most cited studies were included in the article.

7.2 Ackowledgements

There are no individuals or organizations other than the authors who contributed to this research.

7.3 Funding Source

No financial support was received for this research.

7.4 Competing Interests

This study has no conflict of interest.

7.5 Authırs Contributions

Buket ÖGET: All authors contributed equally.

Mehmet Nurullah KURUTKAN: All authors contributed equally.

Mehmet BAĞIŞ: All authors contributed equally.

8 Human and Animal Related Study

8.1 Ethical Approval

Since the article was written as a bibliometric analysis, no ethical approval is required in our study within the framework of ethical rules and policies.

8.2 Informed Consent

Since this study was a bibliometric analysis, informed consent was not required.

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The Use of Carbon Dioxide (Co2) Lasers in the Treatment of Vulvovaginal Atrophy Symptoms in Perimenopausal and Postmenopausal Women

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ABSTRACT

This study explores the efficacy of pixelated carbon dioxide (CO2) laser treatment in mitigating vulvovaginal atrophy symptoms among perimenopausal and postmenopausal women. This study examines the effectiveness of CO2 laser treatment in reducing vaginal discomfort for women experiencing menopause. With a cohort of 127 participants (mean age 47 ± 5 years), the researchers administered three sessions of vaginal CO2 laser treatment over three months. The primary evaluation metric was patient-reported satisfaction levels, aiming to assess the treatment's impact on alleviating symptoms associated with vulvovaginal atrophy, such as dryness, burning, and discomfort during intercourse. The findings revealed that 98% of the patients experienced significant symptom improvement three months post-treatment. Notably, 89% reported a resolution of sexual dysfunction due to vaginal dryness, and 96% indicated an end to discomfort and burning sensations. The satisfaction of the patients is extremely high, with 98% of the participants being satisfied with the results, and this satisfaction has persisted even after some time following the treatment. Furthermore, 95% of the women encountered no discomfort during the procedure, and any post-treatment complaints were mild and temporary, with a watery discharge being the most common. The study concludes that pixel CO2 laser treatment is a practical, painless, and efficient approach for addressing vulvovaginal atrophy symptoms, yielding high patient satisfaction rates. The study finds that using pixel CO2 laser treatment is a practical and painless way to help with symptoms of vaginal discomfort, and most patients are satisfied with the results.

Keywords: Genitourinary menopause, vaginal rejuvenation, urinary stress, collagen reshaping, sexual dysfunction, vulvovaginal atrophy, CO2 laser treatment

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Perimenopozal ve Postmenopozal Kadınlarda Vulvovajinal Atrofi Semptomlarının Tedavisinde Karbon Dioksit (Co2) Lazer Kullanımı

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ÖZ

Bu çalışma, perimenopozal ve postmenopozal kadınlardaki vulvovajinal atrofi semptomlarının hafifletilmesinde pikselize karbon dioksit (CO2) lazer tedavisinin etkinliğini araştırmaktadır. 127 katılımcı (ortalama yaş 47 ± 5 yıl) ile yürütülen araştırmada, üç ay boyunca üç seans halinde vajinal CO2 lazer tedavisi uygulanmıştır. Ana değerlendirme ölçütü, tedavinin vulvovajinal atrofiye bağlı semptomları, örneğin kuruluk, yanma ve cinsel ilişki sırasında rahatsızlık gibi belirtileri hafifletme etkisini değerlendirmek amacıyla hastaların bildirdiği memnuniyet seviyeleriydi. Bulgular, tedaviden üç ay sonra hastaların %98'inin önemli semptom iyileşmesi yaşadığını göstermiştir. Özellikle, %89'u vajinal kuruluğa bağlı cinsel işlev bozukluğunun çözüldüğünü, %96'sı ilişki sırasındaki rahatsızlık ve yanma hissinin sona erdiğini belirtmiştir. Hastaların memnuniyeti son derece yüksek olup, katılımcıların %98'i sonuçlardan memnun kalmış ve bu memnuniyet tedaviden bir süre sonra bile devam etmiştir. Ayrıca, kadınların %95'i işlem sırasında herhangi bir rahatsızlık hissetmemiş ve tedavi sonrası şikayetler hafif ve geçici olmuş, en yaygın şikayet prosedür sonrası gözlenen sulu akıntı olmuştur. Çalışma, piksel CO2 lazer tedavisinin, vulvovajinal atrofi semptomlarını ele almak için etkili, ağrısız ve verimli bir yaklaşım olduğu sonucuna varmış ve yüksek hasta memnuniyet oranları elde edilmiştir.

Anahtar Sözcükler: Ürogenital menopoz, vajinal gençleşme, idrar stresi, kollajen şekillendirme, cinsel işlev bozukluğu, vulvovajinal atrofi, CO2 laser tedavisi

1 Introduction

Vulvovaginal atrophy, common in perimenopausal and postmenopausal women, significantly affects their quality of life. This condition, marked by thinning and drying of vaginal tissue due to declining estrogen levels, has traditionally been treated with hormonal replacement therapies. However, concerns about side effects have led to interest in alternative approaches. Carbon Dioxide (CO2) laser therapy is emerging as an innovative and minimally invasive option with reduced side effects and quick recovery. This article explores the efficacy, safety, and benefits of CO2 laser treatment for managing vulvovaginal atrophy symptoms in perimenopausal and postmenopausal women, considering current scientific evidence [1,2].

In recent years, the widespread adoption of Fractionated CO2 Lasers, especially in aesthetics and gynecology, has revolutionized medical practices globally, including in our region. This preference is mainly due to their non-invasive nature, offering faster recovery and less discomfort compared to traditional surgeries. Fractionated CO2 Lasers precisely target damaged skin cells without affecting surrounding healthy areas, proving effective in cosmetic applications and gynecological treatments. These lasers are versatile, with minimal side effects, making them a pivotal component in the transition towards non-surgical healthcare options, showcasing the industry's commitment to innovative, patient-centered care [3-5].

Lasers are now used in aesthetic gynecology, especially for short-term non-invasive vaginal treatments. This offers an alternative to hormonal therapy, suitable for patients averse to hormones or with contraindications. Doctors increasingly prefer vaginal CO2 laser over long-term hormonal treatment for

conditions like vaginal atrophy and genitourinary syndrome in peri- and post-menopausal women, where estrogen deficiency impacts quality of life. In premenopause and menopause, decreasing estrogen levels lead to issues like vulvar and vaginal atrophy (VA), significantly affecting women's well-being, with 60% of postmenopausal women experiencing vaginal dryness [6-8].

The vaginal wall typically comprises stratified squamous epithelium with cytokeratin, including the stratum basale, suprabasal layer, and stratum corneum. Originating from the Müllerian layer during embryonic development, vaginal tissue migrates caudally to the endocervical canal. The tissue contains estrogen-sensitive glands with receptors for this hormone, crucial for maintaining standard vaginal wall structure [9].

Vaginal atrophy results from decreased estrogen in vaginal tissue during menopause, causing structural changes and disrupting physiological functions. In our study on postmenopausal women with low estrogen, we examined vaginal mucosa modifications after fractional CO2 laser treatment. Significant glycogen storage was observed in squamous layer epithelial cells, and the epithelial surface had a high glycogen content. Restoration, indicated by shed cells rich in glycogen, was observed. New extracellular matrix components, including activated fibroblasts, collagen, and ground substance, were synthesized in the lamina propria connective tissue. Connective tissue papillae and typical blood capillaries entering the papillae were also noted. Morphologically, Fractional CO2 Laser application demonstrated effectiveness in restoring vaginal mucosa structure and associated physiological trophic changes [5,10].

Introduced in 2014, Genitourinary Syndrome of Menopause (GSM) consolidates conditions like vulvovaginal atrophy, atrophic vaginitis, and urogenital atrophy. Recognized as a chronic disorder, GSM impacts the vulvovaginal area, sexual health, and the lower urinary system. Primarily affecting postmenopausal women due to reduced estrogen levels, symptoms can also occur in premenopausal individuals. Hormonal changes result in issues like vaginal dryness and dyspareunia. Laser therapy, a non-hormonal approach, utilizes a CO2 laser (10,600 nm) to coagulate vaginal tissue, inducing a healing response and promoting collagen and elastin production. Research consistently shows CO2 laser therapy's efficacy in alleviating GSM symptoms in postmenopausal women, even those not producing estrogen [11-13].

Gynecologic cancer treatment significantly affects sexual health and reproductive organ functionality, necessitating consideration of GSM in menopausal or medically induced menopausal women. GSM encompasses symptoms affecting the bladder, vulva, and vagina, with vulvovaginal atrophy (VVA) being a notable manifestation due to estrogen deficiency. VVA presents symptoms like vulvovaginal dryness, burning, dyspareunia, and urinary issues. Without intervention, these symptoms worsen over time. As survivorship increases, addressing sexual and overall quality of life becomes crucial. Various interventions for VVA include hormone replacement therapy, topical vaginal estrogens, selective estrogen receptor modulators (SERMs), and non-hormonal options like hyaluronic acid-containing products. Oral medications acting as SERMs provide an additional treatment avenue. These diverse approaches highlight the significance of holistic care in promoting the well-being of women post-gynecologic cancer treatment [14].

2 Methods

In preparing this article, formal approval was diligently sought and subsequently obtained from the Ethics Committee of Istanbul Gelisim University, per the requirements for conducting research involving human participants. This approval was granted on January 12, 2024, underscoring the research's adherence to the ethical standards and guidelines established for scientific investigation.

Through its comprehensive review process, the Ethics Committee of Istanbul Gelisim University issued an ethics approval with the decision number 2024.01.130. This step validates the research project's ethical integrity. It ensures compliance with the principles of respect, justice, and beneficence, reinforcing the commitment to uphold the highest standards of ethical conduct in academic research.

The study included a total of 127 patients, menopausal and perimenopausal women, who presented to the clinic with vaginal dryness, irritation, pain, or dyspareunia. The criterion for menopause to be considered is evaluated as the absence of menstruation for 12 consecutive months in the patient. Patients who had not undergone vaginal tightening surgery in the past year, who were not pregnant, who did not have acute or recurrent urinary tract infections, active genital infections, undiagnosed vaginal bleeding, or any severe or chronic illness that could interfere with hormonal function or work compliance were included in the study.

Fractional CO2 laser treatment was applied intravaginally to perimenopausal women. The energy level varied between 40-55-75 mJ, depending on the patient's pain tolerance. Before the procedure, a few drops of baby oil or liquid petroleum jelly were used on the laser probe to make it easier to insert into the introitus. Prior to starting the procedure, the vagina was wiped with a saline tampon. The vaginal probe was gently inserted into the vagina, lightly touching the cervix, and rotated 360 degrees within the vagina, applying laser at every 1 cm mark. The probe was slowly withdrawn, and a laser was applied until it reached the introitus according to the marks on the probe. The same procedure was repeated three times in the same session. Three more sessions were performed in the same manner at 4-week intervals. No anesthesia or analgesia was required for the patients. Patients were advised to avoid sexual activity for at least four days after treatment.

After six months, a significant reduction (98%) in symptoms and complaints was observed according to patients' self-reports. Statistically significant improvements were also noted in vaginal elasticity and the disappearance of vaginal dryness during follow-up visits after vaginal laser treatment ($P<0.05$).

Our study employed a state-of-the-art CO2 Pixel Laser Device, as depicted in Figure 1, to carry out the treatments under investigation. This device, renowned for its precision and effectiveness in delivering fractional CO2 laser therapy, was instrumental in facilitating the non-invasive procedures that formed the core of our research. Its utilization enabled us to meticulously target and treat the specific areas of concern, leveraging the device's advanced capabilities to achieve optimal outcomes.

Figure 1: *The CO2 Pixel Laser Device used in our study*

Within the framework of our study, we have incorporated visual documentation to illustrate the procedural methodology precisely, facilitating a more precise understanding and potential replication of the treatment processes. Figure 2, entitled "Intravaginal Application of Laser," depicts the direct application of laser treatment within the vaginal cavity, serving as a critical visual guide to the precise, non-invasive technique employed in our research. It is important to note that Figure 2 was sourced from open-access online platforms, ensuring that the image adheres to the principles of open-source utilization, thereby allowing for its ethical and unrestricted use in academic and research contexts.

Additionally, Figure 3, named "Vaginal Laser Application," extends the visual representation to encompass a broader perspective on the laser treatment's application within the vaginal area. In conjunction with Figure 2, this image offers a holistic view of the laser application technique, underlining the innovative approach adopted in leveraging laser technology for therapeutic interventions within our study. The integration of these images, particularly with Figure 2 being obtained from open-source online resources, emphasizes our commitment to transparency, ethical research practices, and the dissemination of knowledge within the scientific community.

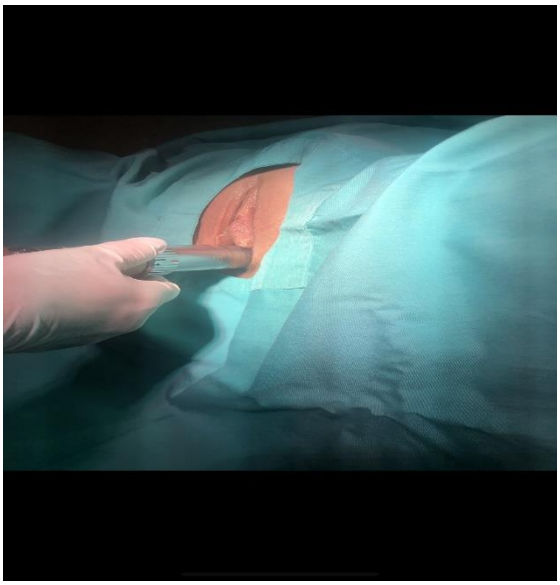

Figure 2: *Intravaginal application of Laser*

Figure 3: *Vaginal Laser Application*

3 Results

In our study, as detailed in Table 1, we analyzed data from a cohort of 127 patients, comprising 70 perimenopausal and 57 postmenopausal individuals, with ages ranging from 46 to 72 years (mean age 59 ± 5 years). These participants underwent a series of three vaginal CO2 laser treatment sessions over three months. The primary objective of our investigation was to evaluate the treatment's effectiveness, focusing specifically on patient satisfaction or dissatisfaction. This assessment was conducted three months following the completion of the final treatment session, aiming to provide a comprehensive overview of the outcomes associated with the CO2 laser therapy. The inclusion of this data in Table 1 not only facilitates a structured presentation of the demographic and treatment-related specifics of our patient group but also underscores the methodological approach adopted in gauging the therapeutic impact of the laser intervention.

Table 1: *Response of the Patients to the Satisfaction Survey According to Age Distribution*

Groups	Nu	Satisfaction Rate 3 Months After Last Procedure	P Value
Premenopause (70)	68	Satisfied (%98)	<0.0001
Postmenopause (57)	56	Satisfied (%98)	<0.0001
Total (127)	124	Satisfied (%98)	<0.0001

Three months after the last laser treatment, significant improvement was observed in 124 (98%) of the patients ($P<0.05$). Among the patients who were called for follow-up three months after the last treatment, 114 (89%) reported that their sexual problems related to vaginal dryness had disappeared, 122 (96%) reported that their complaints related to burning sensation due to vaginal dryness had ended, and 124 (98%) reported that they were satisfied with the treatment. Their satisfaction remained significant even one year after the treatment ($P<0.01$).

Most of the patients, 123 (95%), reported that they did not experience any discomfort or pain during the application and that the procedure was quick. After the treatment, the patients' vaginal complaints were mild and temporary, with the most common complaint being a watery discharge observed in 58 patients (45%) after the procedure.

After the last treatment, patients were called for a follow-up visit three months later, and a total of 127 (98%) out of all patients reported satisfaction with the treatment within 12 weeks. Only two patients (2%) reported being generally satisfied during the follow-up but requested one more session. Patients did not complain of pain during any stage of the treatment except for a very mild burning sensation. No complications occurred.

4 Discussion

CO2 lasers have gained widespread acceptance as a non-invasive treatment option in numerous medical centers for an extended period. This acceptance is attributed to their ability to induce a microthermal effect on tissues, thereby stimulating the activation of new fibroblasts within the submucosal tissue. Consequently, this process leads to an increase in collagen and elastin levels, contributing to tissue regeneration and overall improvement in the treated area.

In 2019, Pearson et al. [15] conducted a study where they explored the efficacy of vaginal CO2 laser treatment. The focus was on patients experiencing vaginal atrophy, particularly those with breast cancer, for whom hormonal treatment was deemed inappropriate. Their research aimed to provide an alternative therapeutic approach for this specific population, offering potential relief from symptoms associated with vaginal atrophy while ensuring safety and efficacy in the absence of hormonal intervention.

Vulvovaginal atrophy is a common problem in breast cancer patients, and many etiological factors are involved. Treatment in these patients is quite tricky, mainly because the use of estrogen is not generally recommended because it is a hormonal treatment. Many studies have reported that vaginal laser application improves atrophy symptoms in patients. In our study, an improvement in VVA symptoms and sexual function was observed in breast cancer patients to whom we applied vaginal laser as a treatment for vaginal atrophy. More randomized, sham-controlled studies are needed to evaluate this treatment further [15].

In a 2020 study by Adabi et al., the focus was on the impact of menopause on women, particularly how hormonal shifts and a decrease in estrogen lead to vaginal atrophy. The research aimed to assess how fractional CO2 laser treatments could improve post-menopausal women's quality of life by addressing the symptoms associated with estrogen-deficient vaginal atrophy. The findings revealed significant enhancements in the discomfort associated with sexual activity and reductions in patient-reported symptoms. Additionally, there was a noteworthy decrease in the occurrence of stress incontinence and improvements were observed across all evaluated vaginal indices. The study concluded that fractional CO2 laser therapy plays a significant role in mitigating vaginal atrophy and related urinary symptoms, offering a promising non-hormonal treatment option for affected women [16].

Fractional CO2 laser therapy has been recognized for its substantial benefits in improving vaginal health and reducing the symptoms of VVA, thereby enhancing sexual satisfaction among perimenopausal women. These positive outcomes have been maintained throughout a 24-week follow-up period. The procedure is noted for its quick execution and minimal discomfort for patients. Additionally, a comprehensive multi-center study in the United States, as reported by Arroyo [14], is currently in progress to assess the long-term effects of this treatment, looking up to 12 months after therapy, mainly focusing on postmenopausal women. This study seeks to provide deeper insights into the lasting advantages and potential effects of fractional CO2 laser therapy on the vaginal health and overall well-being of postmenopausal women.

Our research indicates that fractional CO2 laser therapy is a dependable approach for managing vaginal atrophy. Following the procedure, patients experienced no severe complications, and only a minor fraction reported slight adverse effects, which subsided spontaneously without medical intervention. The majority of discomfort encountered was due to the insertion and movement of the probe. Overall, patients expressed high satisfaction with the outcomes and indicated a willingness to undergo the laser treatment again if necessary [17].

In their article published in 2018, Scott Evan Eder and his colleagues applied vaginal CO2 Laser to 28 postmenopausal patients due to vaginal atrophy. They stated that Fractional CO2 lasers improved VVA and that CO2 laser treatment could be an effective treatment option for relieving the symptoms observed in postmenopausal patients [18].

In their 2024 publication, Lami et al. addressed the prevalent issue of severe VVA among breast cancer patients, for whom hormonal treatments are often deemed contraindicated. They highlighted a notable gap in the literature regarding using non-ablative CO2 laser therapy for this demographic. The primary objective of their research was to assess the efficacy, safety, and patient acceptability of non-ablative CO2 laser treatment in managing vulvovaginal atrophy. Through their investigation, Lami et al. reached a compelling conclusion that non-ablative CO2 laser therapy yields effective outcomes in alleviating symptoms of vulvovaginal atrophy, demonstrating its potential as a viable treatment option for breast cancer survivors facing this distressing condition [19].

We performed a 12-week treatment with a fractional CO2 laser and observed a significant reduction in VVA symptoms in postmenopausal women. However, we believe that further controlled studies are required to confirm the current data and evaluate the long-term effects of the laser procedure on vaginal tissues [1].

Fractional CO2 laser treatment causes thermal heat in submucosal tissue, resulting in edema and erythema, which leads to the formation of new collagen and rejuvenation and narrowing of the vaginal mucosa, greatly improving symptoms that significantly reduce the quality of life in menopausal women.

The decrease and loss of estrogen hormone effect in vaginal tissue causes vaginal atrophy and genitourinary symptoms. CO2 lasers can restore the pH of the vaginal mucosa by releasing glycogen and acidic mucins from the epithelium. Symptoms such as dryness and itching, dysuria, and recurrent infections can be reduced by providing the necessary glycogen to lactobacilli in the vagina.

Due to its non-hormonal nature, pain-free application, and swift treatment process, non-ablative CO2 laser therapy is increasingly favored by patients over alternative treatment modalities. This preference is attributed to its ease of use and minimal discomfort, positioning it as a more attractive and effective solution for addressing genitourinary symptoms in perimenopausal and menopausal patients. Both patients and physicians regard this therapy as a superior alternative, offering significant benefits in symptom reduction compared to other available treatments. Its appeal lies in its clinical efficacy and ability to enhance patient comfort and satisfaction, underscoring its value as a preferred choice in managing menopausal symptoms.

5 Conclusion

This study focused on the efficacy of Fractional CO2 laser therapy in treating GSM and vaginal atrophy, conditions severely affecting the quality of life in perimenopausal and menopausal patients. The results, observed over a 6-month follow-up period, showed highly favourable outcomes, with symptom improvement nearing completeness. The therapy demonstrated an expedited treatment timeline, lacked complications or pain, highlighting its safety and patient-friendly nature.

Conclusively, our study establishes the efficacy and safety of vaginal CO2 laser treatment for managing GSM symptoms in perimenopausal and postmenopausal women, achieving a remarkable 98% satisfaction rate post-treatment. Sustained satisfaction even a year after therapy, coupled with minimal discomfort during the procedure, positions CO2 laser treatment as a viable, non-invasive alternative to traditional hormonal therapies. The minimal and temporary side effects, mainly mild vaginal complaints, further affirm the safety of this approach. These promising results have prompted ongoing multi-center investigations to explore the long-term clinical outcomes of Fractional CO2 laser treatment, aiming to establish a robust body of evidence supporting its use as a reliable, non-invasive treatment for managing GSM and vaginal atrophy symptoms and improving the quality of life in menopausal patients.

6 Declarations

6.1 Study Limitations

This study's primary limitation lies in its reliance on patient-reported satisfaction levels to evaluate the effectiveness of vaginal CO2 laser treatment in perimenopausal and postmenopausal women. While patient satisfaction is an important outcome, the lack of objective measures or clinical assessments to corroborate these findings may limit the comprehensiveness of the results. Furthermore, the study's sample size of 96 participants, although sizable, may not fully represent the broader population affected by the conditions treated. Additionally, the treatment's efficacy was assessed over a relatively short duration of three months, which may not capture long-term outcomes or potential delayed side effects. Future research could benefit from incorporating objective clinical evaluations and longer follow-up periods to provide a more holistic understanding of the treatment's effectiveness

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There is no person or institution contributing to this research other than the authors.

6 3 Funding sources

No financial support was received for this research.

6.4 Authors' Contributions

Define the contribution of each researcher named in the paper to the paper.

6.5 Competing Interests

There is no conflict of interest in this study.

7 Human and Animal Related Study

This research did not involve any human or animal subjects.

7.1 Ethical Approval

In preparing this article, formal approval was diligently sought and subsequently obtained from the Ethics Committee of Istanbul Gelisim University, per the requirements for conducting research involving human participants. This approval was granted on the 1st of December, 2024, underscoring the research's adherence to the ethical standards and guidelines established for scientific investigation. Through its comprehensive review process, the Ethics Committee of Istanbul Gelisim University issued an ethics approval with the decision number 2024.01.130. This step validates the research project's ethical integrity. It ensures compliance with the principles of respect, justice, and beneficence, reinforcing the commitment to uphold the highest standards of ethical conduct in academic research.

7.2 Informed Consent

Informed consent form was obtained from all participants for the study that they agreed to participate in the study.

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Yoğun Bakım Hemşirelerinin Kas İskelet Sistemi Ağrılarının İncelenmesi

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ÖZ

Araştırma, yoğun bakım ünitesinde çalışan hemşirelerin kas iskelet sistemine ilişkin ağrı yaşama durumları ve etkileyen faktörleri incelemek amacıyla yapıldı. Tanımlayıcı ve kesitsel tipte gerçekleştirilen araştırmaya, 08.01.2021-01.03.2021 tarihleri arasında İstanbul'da bir Eğitim ve Araştırma Hastanesi erişkin düzey Yoğun Bakım Ünitelerinde çalışan 90 hemşire dahil edildi. Veriler "Tanıtıcı Bilgi Formu" ve "Genişletilmiş Nordic Kas-İskelet Sistemi Anketi" kullanılarak elde edildi. İstatistiksel değerlendirmede tanımlayıcı istatistiksel metodlar, tek yönlü Anova, Kruskal Wallis, Pearson Ki-Kare ve Fisher-Freeman-Halton testi kullanıldı. Hemşirelerin %17.8'inde tanısı konulmuş kas-iskelet sistemi hastalığı bulunmaktadır. Ağrı şiddetleri 0 ile 10 puana aralığında değişmekte olup, ortalama 4.04±2.51'dir. Kas-iskelet sistemini olumsuz etkileyebilecek ilk üç hareketler olarak; hemşirelerin %42.2'si hastaya pozisyon vermek, %21.1'i hastayı yukarı çekmek ve %17.8'i hastaya bakım yapmak olarak belirtti. Hemşirelerin %88.9'unda (n=80) son 12 ay süresince herhangi bir zamanda acı, ağrı, rahatsızlık saptandı ve %36.7'sinde 1-3 bölgede, %36.7'sinde 4-6 bölgede görüldüğü belirlendi. Hemşirelerin, yarıdan fazlasının son on iki ay süresince herhangi bir zamanda ağrıdan dolayı işi engelleme durumu tespit edildi.

Anahtar Kelimeler: Yoğun bakım hemşiresi, kas iskelet sistemi, ağrı.

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Investigation of Musculoskeletal System Pain in Intensive Care Nurses

ABSTRACT

This study was planned to examine the musculoskeletal pain experience of intensive care nurses and the affecting factors. The population of the study consisted of nurses working in a training and research hospital intensive care unit between January 8, 2021, and March 1, 2021. A total of 90 nurses who accepted to participate in the study and filled out the data collection forms completely formed a sample. Data were obtained using the "Descriptive Information Form" and the "Extended Nordic Musculoskeletal Questionnaire". As a result of the research17.8%of the nurses had a diagnosed musculoskeletal disease. Pain severity ranges from 0 to 10, with an average of 4.04±2.51. According to the results, there are some questions that asked of nurses about the first movements that may adversely affect the musculoskeletal system: nurses replied that %42.2 give a position to patients, %21.1 pull over to patients in bed, and, %17.8 provide nursing care to patients. Pain, pain and discomfort were detected in 88.9% (n=80) of the nurses at any time during the last 12 months and it was determined that it was seen in 1-3 regions in 36.7% and in 4-6 regions in 36.7%. More than half of the nurses were found to be obstructed due to pain at any time during the last twelve months.

Keywords: Intensive care nurse, musculoskeletal system, pain.

1 Giriş

Sağlık hizmetleri, iş sağlığı ve güvenliği açısından önemli riskler içeren çalışma alanlarından biridir. Başta hastaneler olmak üzere sağlığın birçok alanında çalışanların sağlığını olumsuz yönde etkileyen birçok risk faktörü bulunmaktadır [1,2].

Yapılan iş ile çalışan arasında uyumu sağlayan ergonomi basitçe; işçiye uyacak araçları, ekipmanı, çalışma ortamını ve görevleri işçiye uygun olarak tasarlayarak, daha akıllıca çalışmanın bir yoludur [3]. Ulusal İş Sağlığı ve Güvenliği Enstitüsü (NIOSH) tarafından hastanelerdeki ergonomik riskler; uygun olmayan çalışma duruşunda çalışma ve oturma, uzun süreli ayakta kalma, ağır ekipman ve hastaların taşınması ve transferleri esnasında oluşabilecek riskler olarak tanımlanmıştır [4,5].

Ergonomik risk derecesi ve risklerden etkilenme, hemşirelerin çalışma alanlarına göre farklılık göstermektedir. Yoğun bakım üniteleri, ergonomik riskler açısından yüksek riskli çalışma alanları olarak tanımlanmaktadır [6]. Yoğun bakım ünitelerinde hastaların gereksinimlerinin tamamına yakını hemşireler tarafından karşılanmaktadır ve bu ünitelerde hemşirelerin iş yükü ve ayakta durma süreleri oldukça fazladır. Bu alanda çalışan hemşireler, itme, çekme, kaldırma ve eğilme gibi hareketleri tekrarlamalı olarak ve çok sayıda yapmaktadırlar. Bu nedenle, KİS sorunları kolaylıkla oluşabilmektedir [7,8,9].

Ergonomik riskler yaygın olarak kas iskelet sistemi (KİS) ile ilgili sağlık sorunlarına yol açmaktadır [10,11]. Sağlık çalışanlarında kas-iskelet sorunları; iş verimliliğini azaltır, sağlık kurumunun ekonomik kaybına, kazaların artmasına ve bakım verilen kişilerin doğrudan risk almasına neden olur. Çalışanın, çalışma ortamındaki sağlığı sadece kendisini değil hizmet verdiği kişileri de etkiler. Aynı zamanda, hizmet verenin sağlığı, yaşam kalitesinin artmasında da etkilidir [12].

Bu bağlamda çalışma, yoğun bakım ünitesinde çalışan hemşirelerin kas iskelet sistemine ilişkin ağrı yaşama durumlarını ve etkileyen faktörleri incelemek amacıyla yapıldı.

2 Metodoloji

2.1. Araştırmanın tipi ve örneklemi

Tanımlayıcı ve kesitsel tipte yapılan araştırmanın evrenini İstanbul'da bir Eğitim ve Araştırma Hastanesi Yoğun Bakım Ünitelerinde 08.01.2021 – 01.03.2021 tarihleri arasında çalışan 135 hemşire oluşturmuştur. Erişkin Yoğun Bakım, Nöroloji Yoğun Bakım, Kardiovasküler Cerrahi Yoğun Bakım, Beyin Cerrahi Yoğun Bakım, Post-Op Cerrahi Yoğun Bakım, Koroner Yoğun Bakım olmak üzere altı yetişkin yoğun bakım ünitesi çalışmaya dahil edildi. Evrenin tamamına ulaşılamadığı takdirde minimum örneklem sayısı kullanılarak n = 87 hemşire olarak hesaplandı.

Bu bağlamda, çalışmaya katılmayı kabul eden ve veri toplama formlarını eksiksiz dolduran toplam 90 hemşire örneklemi oluşturdu. Veri toplama dönemi süresince, 10 hemşire yıllık izinde, 5 hemşire raporlu, 20 hemşire çalışmaya katılmayı kabul etmemesi nedeniyle araştırmaya dahil olamadı. Bu durum, evrenin tamamıma ulaşmamıza engel olarak; 90 hemşirenin verileri alınarak çalışmanın yürütülmesine neden oldu.

2.2. Veri Toplama Araçları

Veriler 'Tanıtıcı Bilgi Formu' (Ek 1) ve 'Genişletilmiş Nordic Kas-İskelet Sistemi Anketi' (Ek 2) kullanılarak elde edildi.

Tanıtıcı Bilgi Formu; araştırmacı tarafından literatür incelemesi doğrultusunda [2, 12, 13] hazırlanmış olup; hemşirelerin demografik bilgilerini, sağlık-hastalık durumları, egzersiz durumu, sigara kullanım durumu, mesleki çalışma durumu ve şartları gibi bilgileri sorgulayan toplam 36 sorudan oluşmaktadır. Ağrı şiddeti ağrı skalası kullanılarak değerlendirildi. Bu değerlendirmede 0-10 arasında değişen ağrı ortalama puanları verilmektedir. Buna göre "0" ağrının olmadığını belirtirken ortalama değerinin 1-4 olması hafif, 5-6 olması orta şiddette, 7-10 olması ise şiddetli ağrıyı ifade etmektedir.

Genişletilmiş Nordic Kas İskelet Sistemi Anketi (GNKİSA); standardize edilmiş sorularla bel, boyun, omuz ve genel kas-iskelet yakınmalarının değerlendirilmesini amaçlamaktadır. GNKİSA ile, vücudun haritalandırılarak işaretlenmiş dokuz bölgesinde (boyun, omuzlar, sırt, dirsekler, el bilekleri/eller, bel, kalçalar/uyluklar, dizler, ayak bilekleri/ayaklar) kas iskelet sistemi ağrılarını değerlendirilir. Değerlendirmede, son 12 ay içerisinde herhangi bir zamanda bu bölgelerde bir sorun (acı, ağrı, rahatsızlık) olup olmadığı, son 12 ay içerisinde herhangi bir zamanda ağrıdan dolayı olağan işi (evde ya da ev dışında) yapmayı engelleyip engellemediği ve son yedi gün içerisinde herhangi bir zamanda ağrının olup olmadığını sorgulamaktadır. Yanıtlar evet/hayır seçeneklerinden oluşmaktadır. Sorulara verilen yanıtlarda 'Hayır' cevabı için sıfır puan, 'Evet' cevabı için bir puan olarak değer verilir. Testin kesme sınırı yoktur veya alınan toplam puanlar üzerinden istatistiki analizler yapılamamaktadır. İlk olarak Kuorinka et al., (1987) [14] tarafından geliştirilen ve Dawson et al., (2009) [15] tarafından genişletilmiş versiyonun geçerlik ve güvenirlik çalışması yapılmıştır. Türkçe uyarlamasını Kahraman, Göz ve Genç (2016) [16] tarafından yapılmış ve Cronbach's alfa katsayısı 0.896 olarak bulunmuştur. Araştırmada ölçek Cronbach's alfa katsayısı 0.898 olarak bulundu.

2.3. Uygulama

Veriler, hemşirelerin işlerini aksatmayacak biçimde zaman ayarlaması yapılarak ve anketleri kendilerinin doldurması istenerek araştırmacı tarafından elde edildi. Çalışmanın güvenilirliği açısında ünitede beklenilerek anketler toplandı.

2.4. Verilerin Değerlendirilmesi

İstatistiksel analizler için NCSS (Number Cruncher Statistical System) (Kaysville, Utah, USA) programı kullanıldı. Çalışma verileri değerlendirilirken, tanımlayıcı istatistiksel metodlar (ortalama, standart sapma, medyan, frekans, oran, minimum, maksimum) kullanıldı. Nicel verilerin normal dağılıma uygunlukları Kolmogorov-Smirnov, Shapiro-Wilk testi ve grafiksel değerlendirmeler ile sınandı. Normal dağılım gösteren üç ve üzeri grupların karşılaştırmalarında tek yönlü Anova Test; normal dağılım göstermeyen üç ve üzeri grupların karşılaştırmalarında ise, Kruskal Wallis test ve ikili karşılaştırmalarında Bonferroni Dunn test kullanıldı. Nitel verilerin karşılaştırılmasında ise, Pearson Ki-Kare testi ve Fisher-Freeman-Halton Exact testi kullanıldı. Anlamlılık en az $p<0.05$ düzeyinde değerlendirildi.

3 Bulgular ve Tartışma

3.1. Bulgular

Hemşirelerin %58.9'u kadın, %70.0'i 26-35 yaş aralığında, %74.4'ü bekar ve %80.0'i lisans mezunudur. Beden kitle indeksi değerlendirildiğinde, ortalama 23.81±3.07 kg/m2 olduğu belirlenmiştir. Hemşirelerin mesleki deneyimlerine ilişkin özelliklerinin dağılımı Tablo 2'de yer almaktadır. Hemşirelerin, %48.9'u 4-10 yıldır hemşire olarak çalıştığını ve %47.8'i 1-3 yıldır yoğun bakım hemşiresi olarak çalıştığını belirtmiştir. Hemşirelerin %96.7'sinin 08-16/16-08 saatleri arasında olmak üzere vardiyalı olarak çalı-çalıştıkları saptanmıştır. Haftalık çalışma süreleri 40 ile 72 saat arasında değişmekte olup; ortalama 45.91±6.64 saattir.

Hemşirelerin %66.7'si ergonomik risklere yönelik eğitim programına katılmadığını ifade etmiştir. Çalışma ortamında kas-iskelet sistemini olumsuz etkileyebilecek ilk hareketler sorulduğunda; hemşirelerin %42.2'si hastaya pozisyon vermek, %21.1'i hastayı yukarı çekmek, %17.8'i (n=16) hastaya bakım yapmak yanıtını vermiştir. Çalışma sırasında kas-iskelet sistemini olumsuz etkileyebilecek ikinci hareketler sorulduğunda ise; hemşirelerin %22.2'si hastaya pozisyon vermek olarak belirtmiştir (Tablo 1).

Tablo 1: *Hemşirelerin Ergonomik Risklere İlişkin Deneyimleri (N=90)*

		n	%
Ergonomik risklere yönelik eğitim programına katılma	**Evet**	30	33.3
	Hayır	60	66.7
Çalışma sırasında kas-iskelet sistemini olumsuz etkileyebilecek hareketler (ilk etki)	**Hastaya pozisyon vermek**	38	42.2
	Hastayı yukarı çekmek	19	21.1
	Hastaya bakım yapmak	16	17.8
	Diyaliz sıvılarını değiştirmek	5	5.6
	Hastayı mobilize etmek	5	5.6
	Diğer	7	7.8
Çalışma sırasında kas-iskelet sistemini olumsuz etkileyebilecek hareketler (ikinci etki)	**Hastaya pozisyon vermek**	20	22.2
	Hastayı yukarı çekmek	8	8.9
	Hastaya bakım yapmak	13	14.4
	Diyaliz sıvılarını değiştirmek	17	18.9
	Hastayı mobilize etmek	9	10.0
	Diğer	23	25.6

Hemşirelerin, %17.8'inde tanısı konulmuş kas-iskelet sistemi hastalığı bulunduğu saptanmıştır. Görülen kas-iskelet sistemi hastalıklarının türleri incelendiğinde; %56.3'ü (n=9) fıtık olduğunu belirtmiştir (Tablo 2).

Tablo 2: *Hemşirelerde Görülen Kas-İskelet Sistemi Hastalıklarına İlişkin Özellikler*

		n	%
Tanısı konulmuş kas-iskelet sistemi hastalığı	**Evet**	16	17.8
	Hayır	74	82.2
Görülen kas-iskelet sistemi hastalıkları (n=16)	**Lomber disk hernisi**	3	18.8
	Fıtık	6	37.5
	Kifoz	1	6.3
	Kireçlenme	1	6.3
	Patella kondromalazi	1	6.3
	Servikal lordoz düzleşmesi	1	6.3
	Skolyoz	1	6.3
	Bilinmiyor	2	12.5
Görülen kas-iskelet sistemi hastalıklarının tanı konma süresi (n=16)	**0-1 yıl**	3	18.8
	1-3 yıl	4	25.0
	3-5 yıl	1	6.3
	5-10 yıl	6	37.5
	≥ 10 yıl	2	12.5
Görülen kas-iskelet sistemi hastalıklarının türü (n=16)	**Omurga hastalıkları**	2	12.5
	Fıtık	9	56.3
	Kireçlenme	1	6.3
	Diğer	4	25.0

Hemşirelerin algıladıkları ağrı ve ağrının etkilerine ilişkin özelliklerin dağılımları Tablo 3'de verilmiştir.

Hemşirelerin, son bir ay içerisinde ve çalışma gününün sonunda bel, sırt, kol, omuz, bacak ya da ayakta ağrı, sızı ya da rahatsızlık hissetme durumları incelendiğinde;%48.9'unun ara sıra, %20.0'sinin her zaman olarak ifade ettiği saptanmıştır. Hemşirelerin algıladıkları bu ağrının şiddeti ise, 0 ile 10 puan arasında değişmekte olup, ortalama 4.04±2.51'dir.

Hemşirelerin, %35.6'sı yaşadığı şikayetlerle baş etmek için ağrı kesici/kas gevşetici ilacı aldığı, %48.9'u ağrı devam ederken işe gittiğini belirtmiştir. Hemşirelerin, %43.3'ünün genel anlamda algıladıkları sağlık durumları iyi olarak belirlenmiştir (Tablo 3).

Tablo 3: *Hemşirelerin Algıladıkları Ağrı ve Ağrının Etkilerine İlişkin Özellikleri (N=90)*

		n	%
Çalışma saatleri dışında evde bakım verme yükümlülüğü olma durumu	**Hiç ya da nadiren**	60	66.7
	Ara sıra	23	25.6
	Sık sık	5	5.6
	Her zaman	2	2.2
Egzersiz yapma durumu	**Hiç yapmıyor**	24	26.7
	Ayda en az bir kez	32	35.6
	Haftada üç kez	17	18.9
	Haftada en az bir kez	13	14.4
	Her gün	4	4.4
Son bir ay çalışma gününün sonunda bel, sırt, kol, omuz, bacak ya da ayakta ağrı, sızı ya da rahatsızlık hissetme	**Hiç ya da nadiren**	11	12.2
	Ara sıra	44	48.9
	Sık sık	17	18.9
	Her zaman	18	20.0
Ağrı şiddeti	*Min-Mak (Medyan)*	0-10 (4)	
	Ort±Ss	4.04±2.51	
Ağrı, sızı, rahatsızlıktan dolayı doktora gitme	**Evet**	20	22.2
	Hayır	70	77.8
Ağrı, sızı, rahatsızlığın çalışmaya etkisi olma durumu	**Evet**	39	43.3
	Hayır	51	56.7
Görülen ağrı, sızı, rahatsızlığın etkisi (n=39)	**Ağrı ile çalışma**	2	5.1
	Ayakta durmada zorluk	1	2.6
	Bacak ve bilekte ağrı	1	2.6
	Çalışma hızının azalması	1	2.6
	Hareket edememe	1	2.6
	Hareket kısıtlılığı	3	7.7
	Yeterli istirahat edememe	1	2.6
	Yorgunluk	2	5.1
	Yürümekte zorluk	1	2.6
	Zor hareket etme	1	2.6
	Bilinmiyor	25	64.1
•Ağrı, sızı, rahatsızlığın etkisi	**İstirahat alıp, işe gitmeme**	1	1.1
	İlaç kullanımı	32	35.6
	Ağrı devam ederken işe gitme	44	48.9
	Diğer	1	1.1
Genel anlamda sağlık durumu	**Kötü**	1	1.1
	Orta	34	37.8
	İyi	39	43.3
	Çok iyi	16	17.8

•*Birden çok seçenek işaretlenmiştir*

Hemşirelerin, son 12 ay süresince herhangi bir zamanda %36.7'sinin boynunda, %41.1'inin omzunda, %6.7'sinin dirseklerinde, %37.8'inin el bilekleri/ellerinde, %67.8'inin sırtında, %65.6'sının belinde, %27.8'inin kalçalar/ uyluklarında, %41.1'inin dizlerinde, %53.3'ünün ayak bileği/ ayaklarında acı, ağrı, rahatsızlık algıladıkları saptanmıştır. Hemşirelerin, son 12 ay süresince herhangi bir zamanda %32.2'si belindeki ağrıdan dolayı olağan işlerini engellendiğini belirtmiştir (Tablo 4).

Tablo 4: *Hemşirelerin Genişletilmiş Nordic Kas İskelet Sistemi Anketine Verdikleri Cevapların Dağılımı (N=90)*

	Son 12 ay süresince herhangi bir zamanda acı, ağrı, rahatsızlık oldu mu?				**Son 12 ay süresince herhangi bir zamanda ağrıdan dolayı olağan işinizi (evde ya da ev dışında) engelledi mi?**				**Son 7 gün süresince herhangi bir zamanda ağrı oldu mu?**			
	Evet		**Hayır**		**Evet**		**Hayır**		**Evet**		**Hayır**	
Bölgeler	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Boyun	33	36.7	57	63.3	14	15.6	76	84.4	18	20.0	72	80.0
Omuzlar	37	41.1	53	58.9	12	13.3	78	86.7	22	24.4	68	75.6
Dirsekler	6	6.7	84	93.3	4	4.4	86	95.6	3	3.3	87	96.7
El bilekleri/ eller	34	37.8	56	62.2	14	15.6	76	84.4	16	17.8	74	82.2
Sırt	61	67.8	29	32.2	27	3.0	63	70.0	40	44.4	50	55.6
Bel	59	65.6	31	34.4	29	32.2	61	6.8	40	44.4	50	55.6
Kalçalar/ uyluklar	25	27.8	65	72.2	11	12.2	79	87.8	13	14.4	77	85.6
Dizler	37	41.1	53	58.9	13	14.4	77	85.6	22	24.4	68	75.6
Ayak bileği/ ayaklar	48	53.3	42	46.7	21	23.3	69	76.7	29	32.2	61	67.8

Tablo 5. *Hemşirelerin Genişletilmiş Nordic Kas İskelet Sistemi Anketi Sorgusuna Göre Ağrı Görülme Durumlarının Dağılımı (N=90)*

			n	**%**
Son 12 ay süresince herhangi bir zamanda acı, ağrı, rahatsızlık oldu mu?	**Ağrı**	**Yok**	10	11.1
		Var	80	88.9
	Ağrı bölge sayısı	**Yok**	10	11.1
		1-3 bölge	33	36.7
		4-6 bölge	33	36.7
		7-9 bölge	14	15.6
Son 12 ay süresince herhangi bir zamanda ağrıdan dolayı olağan işinizi engelledi mi?	**Ağrı**	**Yok**	41	45.6
		Var	49	54.4
	Ağrı bölge sayısı	**Yok**	41	45.6
		1-3 bölge	33	36.7
		4-6 bölge	12	13.3
		7-9 bölge	4	4.4
Son 7 gün süresince herhangi bir zamanda ağrı oldu mu?	**Ağrı**	**Yok**	29	32.2
		Var	61	67.8
	Ağrı bölge sayısı	**Yok**	29	32.2
		1-3 bölge	37	41.1
		4-6 bölge	19	21.1
		7-9 bölge	5	5.6

Hemşirelerin %88.9'unda son 12 ay süresince herhangi bir zamanda acı, ağrı, rahatsızlık saptanmış ve %54.4'ünde son 12 ay süresince herhangi bir zamanda ağrıdan dolayı olağan işi engelleme durumu, %67.8'inde de son 7 gün süresince herhangi bir zamanda ağrı saptanmıştır (Tablo 5).

Tablo 6: *Hemşirelerin Demografik ve Mesleki Özelliklere Göre Son 12 Ay Süresince Ağrı Görülme Oranlarının Karşılaştırılmasına İlişkin Dağılımı (N=90)*

		Son 12 ay süresince ağrı			
		Ağrı yok (n=10)	**1-3 bölgede ağrı (n=33)**	**≥ 4 bölgede ağrı (n=47)**	
		n (%)	**n (%)**	**n (%)**	***P***
Demografik Özellikler					
Cinsiyet	**Erkek**	6 (60.0)	15 (45.5)	16 (34.0)	*0.259*
	Kadın	4 (40.0)	18 (54.5)	31 (66.0)	
Yaş (yıl)	**≤ 25 yaş**	2 (20.0)	5 (15.2)	16 (34.0)	*0.148*
	> 25 yaş	8 (80.0)	28 (84.8)	31 (66.0)	
BMI (kg/m^2)	*Min-Mak (Medyan)*	17.7-31.1 (23.1)	19.3-28.7 (23.5)	16.3-31.1 (23.7)	*0.846*
	Ort±Ss	24.14±4.08	23.96±2.49	23.64±3.26	
Eğitim durumu	**SML**	3 (30.0)	4 (12.1)	2 (4.3)	*0.111*
	Ön lisans	1 (10.0)	0 (0)	2 (4.3)	
	Lisans	6 (60.0)	27 (81.8)	39 (83.0)	
	Yüksek lisans	0 (0)	2 (6.1)	4 (8.5)	
Medeni durum	**Evli**	2 (20.0)	12 (36.4)	9 (19.1)	*0.202*
	Bekar	8 (80.0)	21 (63.6)	38 (80.9)	
Çocuk varlığı	**Yok**	9 (90.0)	28 (84.8)	45 (95.7)	*0.205*
	Var	1 (10.0)	5 (15.2)	2 (4.3)	
Mesleki Özellikler					
Hemşirelik deneyim süresi (yıl)	**< 4 yıl**	3 (30.0)	12 (36.4)	25 (53.2)	*0.205*
	≥ 4 yıl	7 (70.0)	21 (63.6)	22 (46.8)	
Yoğun bakım deneyim süresi (yıl)	**0-1 yıl**	2 (20.0)	3 (9.1)	9 (19.1)	*0.215*
	1-3 yıl	2 (20.0)	17 (51.5)	24 (51.1)	
	≥ 4 yıl	6 (60.0)	13 (39.4)	14 (29.8)	
Bulunduğu kurumdaki çalışma süresi (yıl)	**0-1 yıl**	1 (10)	3 (9.1)	6 (12.8)	*0.233*
	1-3 yıl	3 (30)	19 (57.6)	30 (63.8)	
	≥ 4 yıl	6 (60)	11 (33.3)	11 (23.4)	
Haftalık çalışma süresi (saat)	**≤ 45 saat**	4 (40.0)	19 (57.6)	24 (51.1)	*0.606*
	> 45 saat	6 (60.0)	14 (42.4)	23 (48.9)	

Çalışmada hemşirelerin cinsiyet, yaş, BKİ değeri, medeni durum, mesleki deneyim süresi, yoğun bakım deneyim süresi ve haftalık çalışma süresinin son 12 ay süresince ağrı görülme oranı ile arasında istatistiksel olarak anlamlı fark saptanmamıştır (p>0.05), (Tablo 6).

3.2. Tartışma

Çalışmada hemşirelerin, %17.8'inde tanısı konulmuş kas-iskelet sistemi hastalığı bulunmaktadır. Görülen kas-iskelet sistemi hastalıklarının türleri incelendiğinde; %12.5'inde omurga hastalıkları, %56.3'ünde fıtık, %6.3'ünde kireçlenme ve %25.0'inde diğer hastalıklar görülmektedir. Gül ve ark., (2014) [12] çalışmasında da, hemşirelerin sıklıkla; boyun, omuz, dirsek, el/el bileği, sırt, bel, kalça/uyluk, diz ve ayak/ayak bileği ağrısı yaşadığı saptanmıştır. Sezgin (2012) [2] çalışmasında, yoğun bakım hemşirelerinde; boyun bölgesinde %30.3, omuz bölgesinde %33.7, sırt bölgesinde %44.6, bel bölgesinde %58.8 ve bacak bölgesinde %64.4 oranında ağrı olduğu görülmüştür. Smith et al., (2004)

[17] çalışmasında ise, hemşirelerde bel ağrılarının %56.0, boyun ağrılarının %45.0, omuz ağrılarının %45.0 ve sırt ağrılarının %37.0 oranında olduğu belirtilmiştir. Şirzai ve ark., (2015) [18] hastane çalışanları ile yaptıkları çalışmasında; boyun %47.6, omuz %33.3, sırt %44.5, dirsek %13.3 ve el bileği/el ağrılarının %22.9 yaşandığı bildirilmiştir. Güler ve ark., (2015) [5] çalışmalarında, hemşirelerin %73.3'ünün alt ekstremitelerde, %15'inin sırt, %10'unun bel ve %1.7'sinin üst ekstremitelerde ağrı yaşadığı görülmüştür. Çalışma sonucumuz literatür ile uyumludur. Tüm çalışma bulguları değerlendirildiğinde, yoğun bakım ünitesinde çalışan hemşirelerinin kas iskelet sistemine bağlı ağrı deneyimleme oranının yüksek düzeyde olduğu ifade edebiliriz.

Çalışmada, hemşirelerin algıladıkları ağrı şiddetleri 0 ile 10 arasında değişmekte olup, ortalama 4.04±2.51'dir. Hemşirelerin %43.3'ü bu ağrı, sızı, rahatsızlığın çalışma performansına olumsuz etkisi olduğunu ifade etmiştir. Yang et al., (2018) tarafından yapılan çalışmada, yoğun bakım hemşirelerinde bel ağrısı %80.1, boyun ağrısı %78.6 ve omuz ağrısı %70.4 oranında bildirilmiştir. Younan et al. (2019) [20] 2852 hemşire ile yürüttüğü çalışmada, kas iskelet sistemi rahatsızlıklarının %11 oranında işe devamsızlığa neden olduğu, %35'inin doktor tedavisi gerektirdiği saptanmıştır. Yapılan çalışmalarda işle ilişkili kas iskelet sistemi rahatsızlıklarına bağlı hastalık izni, çoğunlukla sırt, boyun, ayak bileği ve diz semptomlarıyla ilişkili olarak tespit edilmiştir [21]. Genevay et al., (2011) [22] tarafından sağlık çalışanları ile yapılan çalışmada, omurga kaynaklı ağrıların çalışanların %15.7'sinde işe devamsızlığa yol açtığı gösterilmiştir. Ayrıca çalışmalar birçok iş gününde de hemşirelerin bel ağrısından yakınmasına rağmen çalışmaya devam ettiğini göstermektedir [23, 24]. Çalışma bulgumuz benzer çalışma bulgularından farklılık göstermekle birlikte yakın olduğunu da söyleyebiliriz. Araştırma sonuçları, hemşirelerin kas iskelet sorunları yaşama durumunun önemli düzeyde olduğunu göstermektedir.

Çalışmada, hemşirelerin son 12 ay süresince herhangi bir zamanda acı, ağrı, rahatsızlık gördüğü bölgeler %67.8'sinin sırtında, %65.6'sının belinde, %53.3'ünün ayak bileği/ ayaklarında, %41.1'inin omzunda, %41.1'inin dizlerinde, %37.8'inin el bilekleri/ellerinde, %36.7'inin boynunda, %27.8'inin kalçalar/ uyluklarında, %6.7'sinin dirseklerinde acı, ağrı, rahatsızlık hissettiği bulunmuştur. Kas iskelet sistemi ile ilişkili ağrıyı inceleyen çalışmalarda, fiziksel aktivite düzeyi ile bel ağrısı arasında ilişki bulunduğu [25], uygun pozisyonda durmamanın boyun, omuz, sırt ve el bileği ağrısı açısından, bir pozisyonda uzun süre durarak çalışmanın da omuz ağrısı açısından risk faktörü olduğu tespit edilmiştir. Pınar (2010) çalışmasında ise, hemşirelerin son 12 ay süresince kas iskelet sistemi rahatsızlığı yaşama prevalansının %79.5 olduğu belirtilmiştir [26]. Bu bulgulara dayanarak, yoğun bakım ünitelerinde çalışan hemşirelerin en çok kas iskelet sistemi ağrılarını sırasıyla sırt ve bel bölgesinde deneyimlediğini söyleyebiliriz.

Çalışmada, hemşirelere kas-iskelet sistemini olumsuz etkileyebilecek ilk hareketler sorulmuş; hemşirelerin %42.2'si hastaya pozisyon vermek yanıtını vermiştir. Hemşirelik hastaların taşınması, pozisyonlanması, tekrarlayan eğilme ve dönme hareketlerinin yapılması, ekipman taşınması ve uzun süreler ayakta çalışılması gibi yüksek fiziksel aktivitenin gerekli olduğu mesleklerden biridir. Bu tür günlük görevler, hemşirelerde kronik mesleki yorgunluk ve işe bağlı kas-iskelet sistemi rahatsızlıkları gelişme riskini arttırmaktadır [27, 28]. Güler ve ark., (2015) [5] ergonomik şartlar ve hemşirelerdeki kas iskelet sistemi problemleri ile ilgili olarak yaptıkları çalışmada, hemşirelerin hasta yatağının başındaki tıbbi araç-gereç ve malzemelere erişirken, hastayı kaldırma-taşıma aktivitelerinde ve hastaya egzersiz yaptırma aktivitelerinde zorlandığı; pozisyon verme, monitöre erişme, hasta kıyafetini değiştirme, hastaya sürgü verme işlemlerinde ise zorlanmadıkları belirtilmiştir. Şirzai ve ark., (2015) [18] evde geçen sürenin yeterli olmamasının (sırt ağrısı için), işi bitirmek için fazladan zaman harcamanın (dirsek ağrısı için), işinde zor görevler yapmanın (sırt ve dirsek ağrısı için), iş ortamının elverişli olmamasının (sırt bölgesi ağrısı için) ağrı açısından risk faktörü olduğunu belirtmiştir. Kas iskelet sistemi bozukluğu gelişimde günde 12 saatten uzun süreli çalışıyor olmak, haftada 40 saatten fazla çalışıyor olmak, haftada

birden fazla gece vardiyasında çalışıyor olmak mesleksel risk faktörleri arasında gösterilmiştir [24, 28]. Koohpayehzadeh et al., (2016) [29], hemşirelerde boyun ağrısının haftalık çalışma saati ile ilişkisiz olduğunu bildirmişlerdir. Skela-Savič et al., (2017) [30] vardiya saatlerindeki artış, çalışan hemşire sayısının gerekenden az olması ile bel ağrısı sıklığının arttığını göstermişlerdir; buna karşın aylık fazla mesai saatleri, aylık gece vardiyası sayısı, iş günü başına düşen hasta sayısı gibi faktörler ile bel ağrısı arasında anlamlı bir ilişki bulamamışlardır. Çalışma bulgumuz ile benzer çalışma sonuçları benzerlik göstermektedir.

4 Sonuçlar

Sonuç olarak; yoğun bakımda çalışan hemşirelerin ağrıyı deneyimleme oranları yüksektir. Çalışma sırasında kas-iskelet sistemini olumsuz etkileyebilecek ilk hareket hastaya pozisyon vermek olarak değerlendirilmektedir. Bu durumlar göz önüne alınarak; hemşirelerin kas-iskelet sistemini etkileyen risk faktörleri ve hissedilen ağrı açısından düzenli olarak değerlendirilmesi, kaliteli bakım için vücut mekaniğinin doğru kullanılması, yoğun bakım ünitesinde çalışma koşullarının ergonomik tasarımı, yeterli dinlenme sürelerinin ayarlanması oldukça önemlidir. Çalışma ortamındaki risk faktörlerini azaltmak için hemşirelere eğitim verilmesi ve farkındalık oluşturulması sağlığın korunması açısından yarar sağlayacaktır. Kas-iskelet sistemini etkileyebilecek fiziksel risk faktörlerinin ve koruyucu önlemlerin etkinliğinin değerlendirildiği büyük örneklem gruplu ve izlem çalışmalarına gereksinim duyulmaktadır.

5 Beyanname

5.1 Çalışmanın Sınırları

Araştırmadan elde edilen bulgular sadece uygulandığı hastanedeki hemşireleri genellenebileceği için, araştırmanın yapılacağı hastanedeki hemşireler ile sınırlıdır. Araştırmada hemşirelerin ağrı düzeyi, kullanılan ölçeğin ölçtüğü değerlerle sınırlıdır.

5.2 Finansman Kaynağı

Çalışmanın giderleri, araştırmacılar tarafından karşılanmıştır.

5.3 Çıkar Çatışması

Bu yayında herhangi bir çıkar çatışması yoktur.

5.4 Yazarların Katkıları

Sorumlu Yazar Azime KARAKOÇ KUMSAR: Makale için fikir ya da hipotezin oluşturulması, gereç ve yöntemlerin planlanması, metin düzenlenmesi, eleştirel okuma.

Yazar Sedef GÖK GEÇER: Makale için fikir ya da hipotezin oluşturulması, gereç ve yöntemlerin planlanması, verilerin düzenlenmesi ve analizi, literatür taraması, metin yazımı.

6 İnsan ve Hayvanlarla İlgili Çalışma

6.1 Etik Onay

Helsinki Deklarasyonu Prensipleri'ne uygun davranılarak; verileri toplamadan önce bir üniversitenin Girişimsel Olmayan Araştırmalar Etik Kurulu'ndan onay (Karar No: 2019/35-16) alındı. Etik kurul

onayını takiben çalışmanın yürütülmesi için İstanbul İl Sağlık Müdürlüğü'ne bağlı olarak hastanede çalışmanın uygulanabilmesi için ile kurum izni alındı.

6.2 Bilgilendirilmiş Onam

Araştırmamızda veri toplama aşamasında gönüllülük, özerklik/bireye saygı, mahremiyet ve eşitlik ilkeleri göz önüne alınarak hemşirelere araştırmanın amacı sözlü ve yazılı olarak onam formuyla aktarıldı. Araştırmaya katılan hemşirelere alınan bilgilerinin gizliliği hakkında bilgi verildi.

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Integrative Artificial Intelligence in Regional Anesthesia: Enhancing Precision, Efficiency, Outcomes and Limitations

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ABSTRACT

Artificial intelligence (AI) has made remarkable progress in various domains, outperforming human capabilities in many areas. It is no surprise that AI is being increasingly used in healthcare practices, including regional anesthesia. Recent advancements in AI have enabled its integration into the field of regional anesthesia, promising to enhance precision, efficiency, and patient outcomes. By utilizing machine learning algorithms and predictive analytics, AI has the potential to revolutionize the way regional anesthesia procedures are conducted and managed. Ultrasound-guided regional anesthesia (UGRA) significantly enhances the success rates of regional blocks while mitigating complication risks. This review scrutinizes the burgeoning role of artificial intelligence (AI) in UGRA, detailing its evolution and pivotal function in optimizing sonographic imaging, target delineation, needle guidance, and local anesthetic administration. AI's support is invaluable, particularly for non-experts in training and clinical practice and for experts in educational settings. By systematically analyzing the capabilities and applications of AI in regional anesthesia, we assess its contribution to procedural precision, safety, and educational advancement. The findings reveal that AI-assisted UGRA not only bolsters the accuracy of anatomical identification, thus improving patient safety, but also standardizes the quality of care across varying expertise levels. The integration of AI into UGRA emerges as a transformative influence in anesthesiology, promising to reshape the domain with enhanced precision, efficiency, and patient-centered care.

Keywords: Regional anesthesia, artificial ıntelligence, ultrasound-guided blocks, machine learning, predictive analytics

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Rejyonel Anestezi Uygulamalarında Bütünleşik Yapay Zeka: Duyarlılığın, Verimliliğin, Sonuçların ve Sınırlamaların İyileştirilmesi

ÖZ

Yapay zeka (YZ), birçok alanda insan yeteneklerini aşan olağanüstü ilerlemeler kaydetmiştir. YZ'nin, rejyonel anestezi de dahil olmak üzere sağlık uygulamalarında giderek daha fazla kullanılıyor olması şaşırtıcı değildir. Yapay zekadaki son gelişmeler, rejyonel anestezinin alanına entegrasyonunu mümkün kılmış ve hassasiyeti, verimliliği ve hasta sonuçlarını artırmayı vaat etmektedir. Makine öğrenimi algoritmaları ve tahmine dayalı analitikleri kullanarak, YZ'nin rejyonel anestezi prosedürlerinin yürütülme ve yönetilme biçimini devrim niteliğinde değiştirme potansiyeli bulunmaktadır. Ultrason eşliğinde yapılan rejyonel anestezi (UGRA), rejyonel blokların başarı oranlarını önemli ölçüde artırırken komplikasyon risklerini azaltmaktadır. Bu derleme, UGRA'daki Yapay Zeka'nın (YZ) artan rolünü detaylandırarak, sonografik görüntülemenin, hedef belirlemenin, iğne rehberliğinin ve lokal anestezik uygulamanın iyileştirilmesindeki kritik işlevini ve evrimini incelemektedir. Özellikle eğitimdeki uzman olmayanlar ve klinik uygulamada, ayrıca eğitim ortamlarındaki uzmanlar için YZ desteği paha biçilmezdir. Rejyonel anestezi alanındaki YZ'nin yeteneklerini ve uygulamalarını sistematik olarak analiz ederek, prosedürel hassasiyete, güvenliğe ve eğitsel ilerlemeye katkısını değerlendiriyoruz. Bulgular, YZ destekli UGRA'nın sadece anatomik tanımlamanın doğruluğunu artırarak hasta güvenliğini iyileştirmekle kalmayıp, aynı zamanda farklı uzmanlık seviyeleri arasında bakım kalitesini standartlaştırdığını ortaya koymaktadır. YZ'nin UGRA'ya entegrasyonu, artırılmış hassasiyet, verimlilik ve hasta odaklı bakım ile anestezi alanını dönüştürme vaadi taşıyan bir etki olarak ortaya çıkmaktadır.

Anahtar Kelimeler: Rejyonel anestezi, yapay zeka, ultrason eşliğinde bloklar, makine öğrenimi, tahmine dayalı analitik

1 Introduction

1.1 The Future of Anesthesia: The Artificial Intelligence Revolution

Artificial intelligence (AI) has shown remarkable progress in various domains, surpassing human performance in many areas. It is no surprise that AI is being increasingly utilized in healthcare practices, including regional anesthesia. Recent advancements in artificial intelligence have paved the way for its integration into the field of regional anesthesia, promising to enhance precision, efficiency, and patient outcomes. By leveraging machine learning algorithms and predictive analytics, AI has the potential to revolutionize the way regional anesthesia procedures are conducted and managed.

One of the key areas where AI has an impact is preoperative planning. With access to a wealth of patient data and diagnostic imaging, AI-powered systems can assist anesthesiologists in developing personalized anesthesia plans tailored to each patient's unique anatomical and physiological characteristics. This level of customization can lead to more precise administration of regional anesthesia, minimizing the risk of complications, and improving overall patient safety and satisfaction.

AI can play a crucial role in intraoperative monitoring and decision-making. By continuously analyzing real-time patient vital signs, AI algorithms can alert healthcare providers to any deviation from expected norms, enabling early intervention and proactive management of potential complications during regional anesthesia procedures [1].

AI can also contribute to postoperative care and recovery in addition to optimizing the delivery of

regional anesthesia. Predictive modelling and risk stratification algorithms can aid in identifying patients at a higher risk of postoperative complications, allowing for targeted interventions and proactive post-anesthesia monitoring.

The trajectory of anesthesiology is increasingly being informed by the integration of artificial intelligence (AI), with innovations that enhance procedural precision and optimize patient outcomes. As Singhal et al. elucidated, AI's predictive analytics and machine learning capabilities are revolutionizing preoperative planning and personalized care strategies for regional anesthesia [2]. Pham FM and colleagues highlighted AI's transformative role of AI in intraoperative monitoring, where real-time data interpretation is pivotal for proactive patient management [3]. Garg and Kapoor underscored the utility of AI in postoperative recovery, providing a framework for risk stratification and predictive modelling that promises to refine post-anesthesia care [4].

Lopes et al. underscored the necessity for clinicians to engage with AI's evolution of AI, leveraging its capabilities to elevate care standards under regional anesthesia [5]. Mathur and Burns' discussion on critical care interventions reflects the broader implications of AI, illustrating its potential for enhancing patient safety and care efficiency [6]. Singam's comprehensive review corroborates the integral role of AI in advancing anesthesia practices, reiterating the importance of staying abreast of technological progress [7].

Komorowski and Joosten provide insight into AI's current methodologies and their practical applications within anesthesiology, underscoring the significance of continuous innovation [8]. Sönmez highlighted emergent technologies in emergency medicine, drawing parallels to potential AI harbors for critical, time-sensitive interventions [9]. Viderman et al. contributed to the discourse with a scoping review that focused on AI's application of AI in ultrasound-guided regional anesthesia, suggesting a scope for its expansion into other areas of anesthetic practice [10].

Hashimoto et al. delve into the current techniques and clinical applications of AI, discussing the technology's limitations and the imperative for ongoing research to overcome these challenges [11]. Finally, Singh and Nath presented a narrative review of AI's intersection with anesthesia, advocating for a narrative that is cognizant of AI's evolving capabilities and the subsequent impact on anesthesia delivery [12].

1.2 Improving Efficiency Through Artificial Intelligence in Anesthesia

In addition to its role in enhancing precision, artificial intelligence holds great potential for improving the efficiency of anesthesia procedures. By leveraging AI-powered predictive analytics and machine learning algorithms, healthcare providers can streamline various aspects of anesthesia delivery, ultimately leading to a more efficient use of resources and improved patient care.

One area where AI can significantly improve efficiency is optimization of the anesthesia workflow. AI algorithms can analyze vast amounts of data to identify patterns and trends, thereby enabling anesthesiologists to optimize the scheduling of procedures, resource allocation, and workflow management. This can lead to reduced waiting times for patients, optimized utilization of operating room resources, and improved overall efficiency in delivering regional anesthesia services [1].

Furthermore, AI-driven decision support systems can assist anesthesiologists in making real-time clinical decisions and improving the efficiency of intraoperative management. By continuously analyzing patient vital signs and integrating real-time data from various monitoring devices, AI can

provide valuable insights and recommendations to healthcare providers, enabling prompt and informed decision-making during anesthesia procedures. This not only enhances the efficiency of patient care but also contributes to improved patient safety and outcomes.

AI-powered predictive modelling and risk stratification can aid in optimizing postoperative care and resource allocation. By identifying patients at a higher risk of postoperative complications, healthcare providers can allocate resources more efficiently, ensuring targeted interventions and proactive monitoring for those who need them the most. This proactive approach can lead to improved outcomes, reduced healthcare costs, and greater overall efficiency in the delivery of post-anesthesia care.

As healthcare practitioners continue to integrate AI into regional anesthesia practices, the potential for improving efficiency and resource utilization is significant. By staying informed about the latest advancements and possibilities in AI-driven anesthesia, practitioners can harness the full potential of these technologies to optimize efficiency, improve patient care, and elevate the standards of healthcare delivery. To fully realize the promise of AI in healthcare practice, it is imperative that healthcare practitioners, researchers, policymakers, and technology specialists continue to collaborate and innovate in the field of AI-driven anesthesia. Collaboration between healthcare practitioners, researchers, policymakers, and technology specialists is crucial for advancing the integration of AI into regional anesthesia practices and ensuring that it aligns with the evolving needs of patient care.

Moreover, the potential of AI in anesthesia goes beyond precision and efficiency; it also extends to the realm of education and training. Virtual reality simulations powered by AI algorithms can provide immersive and interactive training experiences for anesthesiology students and practitioners. These simulations can replicate complex anesthesia scenarios, allowing individuals to practice critical decision-making and procedural skills in a safe and controlled environment. By integrating AI-driven virtual reality training into anesthesia education, healthcare practitioners can enhance their skills and readiness to deliver high-quality care, ultimately contributing to improved patient safety and outcomes.

In conclusion, the integration of artificial intelligence into regional anesthesia practices holds immense promise for enhancing precision, improving efficiency, and advancing education and training in the field of anesthesiology. As AI technology continues to evolve, healthcare practitioners must remain proactive in staying informed and embracing the potential of these innovations to elevate the standard of care and ultimately benefit patients. Embracing this collaborative and forward-thinking approach will ensure that the integration of AI in anesthesia remains patient-centered and aligned with the broader goals of enhancing healthcare delivery.

1.3 AI's Role in Improving Anesthesia Outcomes

Artificial intelligence is poised to revolutionize the landscape of anesthesia outcomes through its multifaceted applications, spanning from precision in administration to postoperative care, and even extending to education and training. In the realm of anesthesia outcomes, AI's potential for AI is evident in its ability to enhance precision during anesthetic procedures. By integrating AI into regional anesthesia practices, healthcare practitioners can leverage its power to tailor administration precisely, minimizing the likelihood of complications and leading to improved patient safety and satisfaction. Furthermore, AI's role of AI in intraoperative monitoring is indispensable for ensuring the precision and efficiency of anesthesia procedures. Real-time analysis of patients' vital signs using AI algorithms allows for early intervention and proactive management of potential complications, contributing to improved patient outcomes [13].

However, AI's impact of AI on AI transcends the delivery of anesthesia and extends to postoperative care and recovery. Predictive modeling and risk stratification algorithms, driven by AI, have the capability to identify patients at a higher risk of postoperative complications. This timely insight facilitates targeted interventions and proactive monitoring, thereby contributing to the overall precision and efficiency of anesthesia procedures and ultimately leading to improved patient recovery and satisfaction.

In addition to enhancing precision, AI also holds great promise for improving the efficiency of anesthesia procedures. Its application in predictive analytics and machine learning can streamline various aspects of anesthesia delivery, leading to more efficient use of resources and improved patient care. AI algorithms can analyze vast amounts of data to optimize the scheduling of procedures, resource allocation, and workflow management, resulting in reduced waiting times for patients and overall improved efficiency in delivering regional anesthesia services [14].

Moreover, AI-driven decision support systems can assist anesthesiologists in making real-time clinical decisions, thereby improving the efficiency of intraoperative management. By continuously analyzing patient vital signs and integrating real-time data from various monitoring devices, AI can provide valuable insights and recommendations to healthcare providers, enabling prompt and informed decision-making during anesthesia procedures.

Furthermore, the potential of AI in anesthesia extends beyond precision and efficiency; it also plays a significant role in education and training. AI-driven virtual reality simulations can provide immersive and interactive training experiences for anesthesiology students and practitioners, allowing them to practice critical decision-making and procedural skills in a safe and controlled environment.

In conclusion, the integration of AI into regional anesthesia practices not only holds significant promise for precision and efficiency but also for education and training, ultimately benefiting patients and elevating the standard of care in healthcare delivery. As AI technology continues to evolve, healthcare practitioners must remain proactive in embracing innovations to improve patient outcomes and enhance healthcare delivery.

The application of artificial intelligence in the field of anesthesia has the potential to initiate a paradigm shift in the future of patient care, precision in procedures, and healthcare delivery. As technology continues to advance, the integration of AI into anesthesia practices could bring about a transformative change in the way anesthesia is practiced.

One of the most promising aspects of AI in anesthesia is its ability to enhance the precision and personalization of anesthetic procedures. AI algorithms can adapt and tailor anesthesia administration with unprecedented accuracy through analysis of vast datasets and real-time patient information. This personalization not only minimizes the risk of complications but also allows for a more precise and customized approach to patient care. By leveraging AI-driven precision, healthcare providers can significantly improve patient safety, satisfaction, and ultimately, clinical outcomes.

1.4 Empowering Clinical Decision-Making and Continuous Learning

Another transformative aspect of AI in anesthesia is its capacity to empower clinical decision-making and facilitate continuous learning among healthcare providers. AI-driven decision support systems can analyze complex data in real-time, providing invaluable insights and recommendations to anesthesiologists during procedures. By integrating data from various monitoring devices and

leveraging machine learning algorithms, AI can facilitate prompt, informed, and proactive decision making, ultimately enhancing the efficiency and precision of intraoperative management.

Furthermore, AI's role of AI in continuous learning extends to its applications in education and training. Virtual reality simulations powered by AI can offer immersive and interactive experiences to anesthesiology students and practitioners. These simulations provide a safe environment for practicing critical decision-making and procedural skills, ultimately contributing to the ongoing professional development and competency of healthcare providers in the field of anesthesia.

As the AI revolution unfolds, the future of anesthesia is marked by collaborative and adaptive healthcare delivery. The integration of AI into anesthesia practices necessitates a collaborative approach in which healthcare practitioners and AI technologies work in tandem to optimize patient care and outcomes. By embracing AI-driven innovations, healthcare facilities can adapt to a rapidly evolving healthcare landscape, ensuring that the delivery of anesthesia remains patient-centered and aligned with the broader goals of enhancing healthcare delivery.

In conclusion, the future of anesthesia is intricately intertwined with the potential of artificial intelligence to revolutionize precision, efficiency, education, and training in the field of anesthesiology. As AI continues to advance, its impact on anesthesia outcomes and healthcare delivery will undoubtedly shape a new era of patient-centered care and clinical excellence. Embracing this AI revolution in anesthesia requires a proactive and collaborative mindset, in which healthcare providers leverage AI's capabilities to optimize patient care, improve clinical outcomes, and elevate the standard of healthcare delivery.

1.5 The Impact of Artificial Intelligence on Regional Anesthesia Practices

The integration of AI into regional anesthesia practices has the potential to revolutionize precision, efficiency, education, and training, thus reshaping the landscape of patient care and clinical excellence in anesthesiology. AI algorithms can analyze extensive datasets and adapt to anesthesia administration in real time, leading to a highly personalized approach tailored to the unique needs of each patient. This fine-tuned precision not only minimizes the occurrence of complications but also ensures customized and optimal delivery of anesthesia. Consequently, health care providers can deliver safer and more effective care, thereby enhancing patient safety and satisfaction.

1.6 Predictive Analytics and Early Intervention

AI's potential of AI in regional anesthesia extends to predictive analytics and real-time interventions. By continuously monitoring patients' vital signs and integrating data from diverse sources, AI can predict potential complications and enable early intervention. This predictive approach to patient care has the potential to mitigate risks, improve recovery outcomes, and elevate the standards of anesthesia procedures across healthcare facilities. With AI's support, healthcare providers can proactively address potential issues, leading to better patient outcomes and an overall improvement in the quality of care.

The impact of AI on regional anesthesia also encompasses the optimization of resource utilization and workflow management. Through machine learning and predictive analytics, AI algorithms can optimize scheduling, streamline resource allocation, and coordinate workflow, ultimately enhancing the efficiency of anesthesia delivery. This optimization not only leads to improved patient satisfaction but also ensures that healthcare facilities can maximize their operational capacity and resource allocation. A thorough analysis of historical data and real-time variables by AI can predict patient flow, optimize

scheduling, and allocate resources effectively, ultimately leading to reduced waiting times for patients and improved operational efficiency in delivering regional anesthesia services.

The advent of AI in regional anesthesia represents a significant shift towards precision and efficiency in patient care. Studies such as Bowness et al. revealed variability in the interpretation of solo-anatomical structures, suggesting that AI may standardize identification and support less experienced practitioners [15]. The potential of AI to enhance pediatric regional anesthesia, as explored by Bersenev et al., further exemplifies its role in expanding access to sophisticated anesthetic techniques 13). The application of AI in ultrasound image interpretation, validated externally by Bowness et al., demonstrated improved accuracy in non-expert scans, underscoring the utility of AI in clinical settings [16] (Table 1).

Table 1*: Summary of Key Studies on AI Integration in Regional Anesthesia*

Study Reference	**Focus Area**	**Methodology**	**Key Findings**
Bowness et al., 2023	AI vs. human experts in ultrasound identification	Comparative analysis among experts with AI comparisons	AI shows similar pattern of agreement with human experts, with variance across structures
Bersenev et al., 2023	Pediatric regional anesthesia with diode-laser cyclophotocoagulation	Clinical case description	Effective in stable children, reduces cognitive disorder risks
Bowness et al., 2021	Utility of AI in ultrasound-guided regional anesthesia	Pilot study with anesthetists assessing AI device's impact	Positive feedback from non-experts, AI viewed positively for learning and training
Bowness et al., 2023 (External Validation Study)	AI's accuracy in ultrasound-guided regional anesthesia	External validation study evaluating AI's accuracy	AI identified structures correctly in most cases, perceived to reduce risk of needle trauma
Bowness et al., 2023 (Impact Study)	AI's impact on ultrasound imaging by non-experts	Comparative study with/without AI assistance	AI improved correct block view acquisition and structure identification

1.7 Empowering Clinical Decision-Making through AI

AI plays a transformative role in empowering clinical decision making and facilitating continuous learning among healthcare providers. Decision support systems driven by AI can analyze complex data in real-time, providing invaluable insights and recommendations to anesthesiologists during procedures. By incorporating data from various monitoring devices and applying machine learning algorithms, AI can facilitate prompt, informed, and proactive decision making, ultimately enhancing the efficiency and precision of intraoperative management. AI-driven simulations also offer immersive and interactive experiences for anesthesiology students and practitioners, providing a safe environment for honing critical decision-making and procedural skills. Through these simulations, health care providers can continuously refine their skills and competencies, ultimately contributing to the delivery of high-quality care.

In the realm of research and innovation, Moka and Bowness discussed the potential roles of AI and robotics, and proposed synergies that could redefine the standards of care in regional anesthesia [17]. McKendrick, Yang, and McLeod highlight the integration of AI and robotics, suggesting a pivotal role in advancing anesthesia practices [3]. These collective insights from recent literature underscore the transformative impact of AI in the field, advocating a proactive approach from healthcare professionals to assimilate these advancements into practice for improved patient care and educational training within

the field of anesthesiology.

1.8 Optimizing Regional Anesthetic Protocols with Artificial Intelligence

The integration of artificial intelligence into anesthesia practices holds promise for optimizing anesthetic protocols to a remarkable degree. By harnessing the power of AI, healthcare practitioners can revolutionize the customization of anesthetic protocols and tailor them to individual patient needs with unprecedented precision and personalization.

AI's capacity of AI to analyze vast quantities of patient data, including medical history, genetic predispositions, and real-time physiological parameters, enables the creation of tailor-made anesthetic protocols. This individualized approach not only enhances patient safety but also contributes to more effective and efficient anesthesia delivery, considering unique patient characteristics and potential risk factors.

Furthermore, AI's predictive modelling capabilities can forecast patient responses to specific anesthetic agents and dosages, allowing for the optimization of protocols to minimize adverse reactions and maximize positive outcomes. The ability of AI to adapt in real time based on patient feedback during anesthesia procedures ensures that protocols can be promptly adjusted to ensure the most favorable patient response, further enhancing safety and effectiveness.

In addition, AI-driven decision support systems can assist healthcare practitioners in making real-time clinical judgments and optimizing the management of anesthesia delivery and postoperative care. By integrating AI into anesthetic protocols, healthcare providers can streamline the decision-making process, leading to more efficient resource utilization, and ultimately improving patient care and satisfaction.

The potential of AI in optimizing anesthetic protocols extends beyond the realm of individual patient care, and encompasses the opportunity to refine population-based protocols based on aggregated data and trends. AI's ability of AI to analyze large datasets can identify patterns and best practices, leading to the establishment of standardized protocols that are continuously refined to reflect the latest evidence and outcomes, ultimately benefiting patient populations.

The incorporation of Artificial Intelligence (AI) into anesthetic practices significantly enhances the calibration of regional anesthetic protocols. Leveraging AI's computational prowess, healthcare providers can revolutionize protocol personalization, achieving a level of precision and customization that was previously unattainable. Such advancements have the potential to significantly increase the safety and efficacy of anesthetic delivery in response to the unique physiological and genetic profiles of each patient [16, 18].

The ability of artificial intelligence to assimilate and interpret expansive datasets, including medical histories, genetic markers, and real-time physiological readings, facilitates the formulation of bespoke anesthetic strategies. This individual-centric approach is a paradigm shift from the one-size-fits-all methodology, enhancing patient safety and bolstering the effectiveness of anesthetic management by accommodating individual patient idiosyncrasies and associated risk elements [19].

AI predictive modelling techniques have been shown to reliably forecast patient reactions to specific anesthetic agents and dosages, which is instrumental in mitigating adverse reactions and optimizing therapeutic outcomes [20]. The ability of AI systems to assimilate real-time feedback and dynamically

adjust protocols during anesthetic administration is critical for securing optimal patient responses, thereby elevating both safety and procedural efficacy.

AI-augmented decision support systems provide substantial aid to clinicians in making informed, real-time clinical judgments. Such systems optimize the management of anesthetic administration and postoperative care, enhance the decision-making process, and optimize resource allocation, ultimately leading to improved patient care and satisfaction [21].

Beyond individual patient care, AI's potential of AI extends to refining population-based anesthetic protocols derived from aggregated data analyses and trending patterns. This facilitates the establishment of evidence-based standardized protocols that evolve in tandem with the latest research findings and patient outcomes, thereby benefiting larger patient cohorts [22].

The integration of AI in the realm of regional anesthesia represents a significant leap forward in medical practice, with AI's analytical capabilities synergizing with the intricate demands of anesthetic management to elevate overall patient care quality. The trajectory of regional anesthetic protocols is inextricably linked to AI's innovative advances, signaling a new epoch in the pursuit of superior patient outcomes and healthcare excellence [1].

1.9 Collaborative Healthcare Delivery in the AI Era, Harnessing the Full Potential of AI in Healthcare Practices

As the AI revolution unfolds, the future of regional anesthesia is characterized by collaborative and adaptive healthcare delivery. Collaboration between healthcare practitioners and AI technologies is essential for optimizing patient outcomes and enhancing healthcare delivery. It is crucial for healthcare providers to embrace these AI-driven innovations to ensure that the delivery of anesthesia remains patient-centered and aligned with the broader goal of improving healthcare delivery outcomes.

The potential of AI in anesthesia practice extends beyond the immediate delivery of care to the realm of education and training. The integration of AI-driven virtual reality simulations provides an immersive and interactive platform for anesthesiology students and practitioners to refine their decision-making and procedural skills in a simulated environment. This innovative approach to training not only enhances the skills and readiness of healthcare practitioners, but also contributes to improved patient safety and outcomes.

As the landscape of AI-driven anesthesia continues to evolve, healthcare practitioners, researchers, policymakers, and technology specialists must collaborate and innovate. By fostering collaborative efforts, the integration of AI into regional anesthesia practices can align with the evolving needs of patient care, ultimately elevating the standard of healthcare delivery.

The development of guidance techniques by Wu and Wang also illustrated AI's past, present, and future influences of AI in the domain [20]. The use of AI algorithms in combination with ultrasound for nerve blocks in surgery, as Fan et al. investigated, showed its impact during and after surgery [21]. In essence, the integration of AI is poised to augment regional anesthesia practices significantly, offering a trajectory towards more informed, precise, and patient-tailored anesthetic care.

The continuous advancement of AI in regional anesthesia practice presents a wealth of opportunities for precision, efficiency, and education in the field of anesthesiology. It is imperative for healthcare practitioners to remain proactive in staying informed about the latest developments in AI-driven

anesthesia and embrace the full potential of these technologies to optimize patient care and contribute to the advancement of healthcare delivery.

The integration of AI into regional anesthesia practices not only holds significant promise for precision and efficiency but also for education and training, ultimately benefiting patients and elevating the standard of care in healthcare delivery. As AI technology continues to evolve, healthcare practitioners must remain proactive in embracing innovations to improve patient outcomes and enhance healthcare delivery.

Table 2 provides a brief review of pivotal clinical trials and case studies that explore the nuanced interplay between artificial intelligence (AI) and specialized techniques in regional anesthesia. Each entry in the table methodically distils a unique investigation, ranging from the efficacy of AI in enhancing solo-anatomical precision to its role in risk mitigation and training enhancement. This collation serves not only as a testament to the progressive integration of AI into clinical practice but also as a touchstone for ongoing research in the domain, encapsulating the multifaceted impacts on patient care and clinical outcomes.

Table 2: *Review of Clinical Trials and Case Studies on the Integration of AI and Specialized Regional Anesthesia Techniques*

Study Title	**Focus**	**Methodology**	**Key Outcomes**	**Publication Date**
Variability between human experts and artificial intelligence in identification of anatomical structures by ultrasound in regional anesthesia [15]	Comparison of AI and human expert consistency in identifying sono-anatomical structures	Comparative analysis among 19 experts annotating ultrasound videos, with AI comparisons	Similar patterns of agreement between human experts and AI, with variance among different structures	October 2023
Possibilities of using regional anesthesia with diode-laser transscleral cyclophotocoagulation in children [19]	Regional anesthesia in pediatric ophthalmic surgery	Description of clinical cases	Effective in emotionally stable children, reduces cognitive disorder risks	August 6, 2023
A pilot study to evaluate the utility of assistive artificial intelligence in ultrasound-guided regional anesthesia [23]	Utility of AI in enhancing ultrasound-guided regional anesthesia (UGRA)	Pilot study with 30 anesthetists collecting 240 scans, assessing AI device's impact on identifying sono-anatomical structures	Positive feedback from non-experts in 45.8% of instances, with experts noting potential increased risk in 3.0% of cases. Device viewed positively for learning and training support.	September 2021
Assistive artificial intelligence for ultrasound image interpretation in regional anesthesia: an external validation study [16]	Accuracy and influence of AI on risk assessment in UGRA	External validation study with 720 videos across nine anatomical regions, evaluating AI's accuracy and its perceived impact on reducing adverse events or block failure	AI identified structures correctly in 93.5% of cases. Highlighting judged to reduce risk of unwanted needle trauma in most cases and to reduce risk of block failure in 81.3% of scans.	January 2023
Evaluation of the impact of assistive artificial intelligence on ultrasound scanning for regional anesthesia [18]	AI's impact on ultrasound image acquisition and interpretation by non-experts	Comparative study with 21 anesthetists performing scans with and without AI assistance	AI assistance improved correct block view acquisition (90.3% vs. 75.1%) and correct identification of structures (88.8% vs. 77.4%)	March 2023

1.10 The Role of Artificial Intelligence in Enhancing Patient Safety and Refining Anesthesia Techniques

As the field of anesthesia continues to evolve, the integration of artificial intelligence has become increasingly pivotal in enhancing patient safety and refining anesthesia techniques. AI's multifaceted applications encompass precision in administration, postoperative care, patient recovery, and education and training, marking a paradigm shift in the landscape of anesthesia outcomes.

In the realm of anesthesia outcomes, AI's impact on AI is most pronounced in its capacity to elevate precision during anesthetic procedures. By harnessing the power of AI in regional anesthesia practices, healthcare practitioners can fine-tune administration with unparalleled accuracy, thereby minimizing the likelihood of complications, and ultimately improving patient safety and satisfaction. Real-time analysis of patient vital signs, facilitated by AI algorithms, enables early intervention and proactive management of potential complications, significantly contributing to improved patient outcomes.

Artificial intelligence (AI) in regional anesthesia represents a pivotal shift towards safeguarding patient well-being and enhancing the precision of anesthetic delivery. The adoption of technology in the medical field underscores a commitment to patient-centric care, leveraging AI’s analytical process of AI to minimize procedural risks and bolster postoperative recovery.

Groundbreaking research, as presented by Bowness et al., affirmed AI's instrumental role of AI in refining ultrasound-guided regional anesthesia techniques. Their study elucidated how AI assistance facilitates accurate identification of anatomical landmarks, which is crucial for the precision of nerve blocks and overall patient safety [16, 24]. This is corroborated by Hewson and Bedforth, who advocate AI's capability to bridge the gap in ultrasound-guided procedures [25].

Table provided an overview of AI applications within the scope of regional anesthesia, exploring its current utility and the limitations that necessitate further development [26]. Bersenev et al. expanded AI applications in pediatric care, underscoring the versatility and adaptability of the technology [19]. Feinstein et al. project a transformative impact on remote patient monitoring, heralding a new era of medical oversight [22].

AI’s impact on anesthesia transcends procedural assistance; it encapsulates a holistic approach to patient care. Fan et al. demonstrated that AI algorithms can enhance the management of general anesthesia in conjunction with nerve blocks in complex surgical procedures [21]. James et al. extended this application to trauma patients, where AI-assisted regional anesthesia improved outcomes in acute settings [27].

The collective insights from these studies articulate an increasingly data-driven, patient-specific, and outcome-oriented vision of anesthesiology. AI’s integration into regional anesthesia is not merely an enhancement of existing practices, but a transformative process that redefines the standards of care. Balavenkatasubramanian et al. reiterate the importance of AI in regional anesthesia, focusing on its evolving role in clinical practice [1].

In this context, AI serves as both a facilitator and a catalyst for change, and its algorithms and machine learning models imbue clinicians with tools that predict, adapt, and respond to patient needs with unprecedented accuracy. Karmakar et al. captured this sentiment by highlighting the synergistic potential of AI and robotics in anesthesia, signaling a future in which technology and human expertise coalesce to deliver optimal patient care [13, 14].

As AI continues to integrate into clinical workflows, it demands an ethos of continuous learning and adaptation from health care providers. The potential to optimize anesthesia outcomes, personalize patient care, and enhance safety. With ongoing advancements in AI technology and its integration into clinical practice, the possibilities for enhancing patient safety and refining anesthesia techniques continue to expand. Proactive adoption and utilization of AI in anesthesia practices are essential for elevating the standard of care and enriching the overall patient experience.

As the landscape of healthcare continues to evolve, the integration of AI in anesthesia techniques will play a pivotal role in shaping the future of patient care. The potential of AI to optimize anesthesia outcomes, personalize patient care, and improve overall safety and satisfaction underscores its significance in revolutionizing the field of anesthesia. With the ongoing advancements in AI technology and its integration into clinical practice, the possibilities for further enhancing patient safety and anesthesia techniques are limited. The proactive adoption and utilization of AI in anesthesia practice holds the key to elevating the standard of care and ultimately enriching the overall patient experience.

1.11 The Limitations of Artificial Intelligence in Regional Anesthesia

The integration of artificial intelligence (AI) in ultrasound-guided regional anesthesia (UGRA) offers remarkable advancements but is accompanied by intrinsic limitations. Although beneficial, the accuracy of AI-assisted sono-anatomical identification is not absolute and may occasionally present inaccuracies, risking procedural precision. Clinicians' expertise remains irreplaceable, with AI designed to augment rather than substitute professional judgment. The reliance on high-quality, diverse datasets for algorithm training is critical because data biases can lead to misleading AI interpretations. Moreover, the ethical and legal implications of AI deployment in clinical settings necessitate the establishment of robust guidelines. The financial and training requirements for AI implementation along with the necessity for continual updates present additional constraints. Finally, the seamless integration of AI technologies into the existing healthcare infrastructure poses logistical challenges, emphasizing the need for deliberate and informed adoption strategies to maximize clinical efficacy and patient safety [26]. To detail:

1. **Inherent Limitations of AI Technology:** While AI can significantly enhance the accuracy of identifying sono-anatomical structures and improve needle tracking, it is not infallible. AI systems may sometimes incorrectly highlight anatomical structures, which could potentially lead to an increased risk of nerve injury or vascular trauma if relied upon without adequate clinician supervision.

2. Dependence on Data Quality: The effectiveness of AI in UGRA relies heavily on the quality and diversity of the data used to train the algorithms. Biases in the training data can lead to inaccuracies in AI interpretation, affecting their reliability and clinical applicability.

3. Interpersonal Variability: While AI can help reduce interpersonal variability in ultrasound imaging interpretation, this variability can also be a limitation. The unique judgement and experience of clinicians cannot be entirely replicated by AI, which means that AI tools should support rather than replace clinician judgement.

4. Risk of Overreliance: The potential risk of clinicians becoming overly reliant on AI tools could diminish their skills in ultrasound imaging and interpretation. Evidence warns against complacency that may arise from the perceived ease of use and accuracy of AI technologies.

5. Ethical and Legal Considerations: The integration of AI into clinical practice raises ethical and legal questions, especially regarding responsibility for misdiagnoses or procedural complications when AI tools are used. Therefore, clear guidelines and standards are required to address these concerns.

6. Cost and Accessibility: The adoption of AI technologies in regional anesthesia may be limited by the cost of AI devices and software, as well as the need for specialized training to use them effectively. These factors could limit the access to AI benefits in regions with fewer resources.

7. Need for Continuous Updates and Maintenance: AI systems require continuous updates to incorporate the latest clinical guidelines and research findings. Ensuring that AI tools remain current with medical knowledge and practice requires ongoing investment.

8. Technological Integration Challenges: Integrating AI tools into existing healthcare systems and workflows can be both complex and disruptive. The logistical challenges of incorporating AI into clinical practice, including its compatibility with existing medical devices and electronic health records, were discussed.

In summary, the burgeoning field of AI within the realm of ultrasound-guided regional anesthesia presents both unprecedented opportunities and notable challenges. The potential for AI to err in sono-anatomical delineation, although infrequent, mandates the ongoing vigilance and preservation of clinician acumen. Reliance on robust, unbiased datasets for algorithmic training, continuous technological updates, and the imperative for interdisciplinary collaboration are critical for the translation of AI's potential for clinical success. As we navigate the complexities of integrating AI into healthcare, the development of stringent ethical frameworks and legal provisions is essential. The financial implications and infrastructural demands of these technologies underscore their need for equitable and judicious deployment. The future of AI in regional anesthesia is contingent upon a confluence of innovation, empirical scrutiny, and steadfast commitment to patient-centered care [1, 17, 26].

2 Declarations

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There is no person or institution contributing to this research other than the authors.

2.2 Funding source

No financial support was received for this study.

2.3 Authors’ Contributions

Dr. KARA GÖRMÜŞ contributed in developing ideas or hypotheses for the research and/or article, planning the materials and methods to reach the results, taking responsibility for the experiments, organizing and reporting the data, taking responsibility for the explanation and presentation of the results, taking responsibility for the literature review during the research, taking responsibility for the creation of the entire manuscript or the main part, reworking not only in terms of spelling and grammar but also intellectual content or other contributions

2.4 Competing Interests

The authors have no conflicts of interest to declare.

3 Human and Animal Related Study

If the work does not involve the use of human/animal subjects, each manuscript should contain the following subheadings:

3.1 Ethical Approval

This study exclusively utilizes publicly available data obtained from open web platforms and, as such, is deemed exempt from formal ethical review processes. However, the research methodology was carefully designed to adhere to the principles of ethical research conduct, respecting the privacy and confidentiality of the data sources.

3.2 Informed Consent

There was no need for informed consent form to be obtained from participants for the study that they agreed to participate in the study.

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