

Development of a Software to Prevent Intravenous Medication Administration Error: An Observational Study

İntravenöz İlaç Uygulama Hatalarını Önlemeye Yönelik Yazılım Uygulamasının Geliştirilmesi: Gözlemsel Bir Çalışma

^{1b} Zilan BARAN^a, ^{1b} Esra AKIN^b, ^{1b} İsmail AKDAĞ^c

^aDepartment of Neurology, University of Health Sciences İzmir Tepecik Education and Research Hospital, İzmir, Türkiye

^bDepartment of Nursing, Division of Fundamentals of Nursing, İzmir Katip Çelebi University Faculty of Health Sciences, İzmir, Türkiye

^cDepartment of Electrical and Electronic Engineering, İzmir Katip Çelebi University Faculty of Engineering and Architecture, İzmir, Türkiye

ABSTRACT Objective: The purpose of the present study was to determine the wrong and missing application steps in intravenous (IV) medication administration of nurses using a software program developed to identify and prevent IV medication errors and to provide feedback in this respect. **Material and Methods:** The study was conducted in the observational type and was carried out in 2 stages. In the first stage, was developed the software to measure IV medication errors. In the second stage, the application was tested with the participation of 12 nurses between May-June 2021. According to the participant observation method, 124 IV medication applications were observed and the software was installed. After the data were collected, the nurses' incomplete IV medication administration steps were determined using software. The SPSS for Windows (version 25.0) was used for data analysis. **Results:** Considering the steps that nurses skipped most frequently in the process steps when they performed IV medication administration, it was found that 96.8% did not control the expiration date of the medications, 89.6% did not question the allergy history of the patient in the control step, 49.2% did not wash their hands in the preparation step, 86.3% did not make an explain to the patient in the application step, and 70.2% did not follow the patient in terms of complications in the evaluation step. **Conclusion:** The results of this study indicate that the developed software program can be used to identify and prevent medication errors.

ÖZET Amaç: Bu çalışmanın amacı, intravenöz (IV) ilaç hatalarını belirlemek ve önlemek için geliştirilen bir yazılım programı ile hemşirelerin IV ilaç uygulamalarındaki yanlış ve eksik uygulama adımlarını belirlemek, bu bağlamda geri bildirim sağlamaktır. **Gereç ve Yöntemler:** Çalışma gözlemsel tipte yürütülmüş ve 2 aşamada gerçekleştirilmiştir. İlk aşamada, Microsoft Visual Studio'da C# programlama kullanılarak IV ilaç hatalarını belirleyen yazılım geliştirilmiştir. İkinci aşamada ise Mayıs-Haziran 2021 tarihleri arasında 12 hemşirenin katılımı ile uygulama test edilmiştir. Katılımcı gözlem yöntemine göre toplam 124 IV ilaç uygulaması gözlemlenmiş ve Firebase gerçek zamanlı veri tabanına yüklenmiştir. Verilerin analizinde SPSS Windows (sürüm 25.0) programı kullanılmıştır. **Bulgular:** Hemşirelerin IV ilaç uygulamaları işlem basamaklarında en sık atladıkları adımlar değerlendirildiğinde; kontrol aşamasında %96,8'inin ilaçların son kullanma tarihini kontrol etmediği, %89,6'sının hastanın alerji öyküsünü sorgulamadığı, hazırlama aşamasında %49,2'sinin ellerini yıkamadığı, uygulama aşamasında %86,3'ünün hastaya açıklama yapmadığı, değerlendirme aşamasında %70,2'sinin komplikasyon yönünden hastayı takip etmediği saptanmıştır. **Sonuç:** Araştırmanın sonucunda, geliştirilen yazılım programının ilaç hatalarının belirlenmesi ve önlenmesine yönelik kullanılabilir olduğu belirlenmiştir.

Keywords: Medication errors; nursing; software; observational study

Anahtar Kelimeler: İlaç hataları; hemşirelik; yazılım; gözlemsel çalışma

Nurses play an important role in providing nursing care to improve and protect the health of individuals, families, and society, improving and increasing the quality of life, implementing a medical diagnosis and

treatment plan prepared by the physician, creating a safe and healthy environment, education, consultancy, research, management, quality improvement, cooperation, and communication.¹ Among which,

Correspondence: Zilan BARAN

Department of Neurology, University of Health Sciences İzmir Tepecik Education and Research Hospital, İzmir, Türkiye

E-mail: zilan.baran@outlook.com



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participating in the treatment plan and administering medications have an important place in nursing responsibilities.

The National Coordinating Council for Medication Error Reporting and Prevention defined medication errors as “Preventable events that may cause the patient to be harmed by the medication or take the wrong medication while the medication is under the control of the manufacturer, healthcare personnel, or patient.”² In the report that was published by the institute of medicine in 1999, it was reported that between 44,000 and 98,000 people died annually because of medication errors in the world, and medication errors rank 5th in the list of the 10 main causes of death in the same report.³ In this context, it is seen that medication errors cause great harm to the healthcare system.

Medication errors are the most common errors that nurses face throughout their professional lives, with a rate of 47%.⁴ The vast majority of medication errors occur because of the violation of rational medication administration principles. According to the data of the American National Learning and Reporting Center (2007), more than half (60%) of 60 thousand incorrect medication reports in 1 year are in the form of incorrect dose administration.⁵ According to the data of the Turkish Safety Reporting System (2016), medication administration errors are among the most common medical practice errors. According to the notification of medication errors of the T.C. Ministry of Health, the first 3 most common medication errors are; wrong dose request, wrong medication request, and wrong medication preparation.⁶

Intravenous (IV) medications are absorbed faster than other medications because they directly participate in the circulatory system. IV medication administration is of critical importance because it carries the riskiest side effects resulting from medication administration. IV medication errors are the most common type of medication error.⁷ It attracts attention to the subject because it affects patients, increases the cost of healthcare and hospital stays, causes complications, disturbs the comfort of patients, and decreases the trust in the healthcare staff.⁸

In the present study, based on the results and recommendations of previous studies conducted on

medication administration errors, the purpose was to determine the wrong and missing application steps in the IV medication administration of nurses using the software developed to identify and prevent IV medication errors and to provide feedback in this context.

MATERIAL AND METHODS

TYPE AND PLACE OF THE STUDY

The observational study was conducted in the intensive care unit (ICU) of a university hospital between May and June 2021. The observation method is used to describe in detail the behaviors that occur in any environment or institution, and there are 3 types participant, non-participant observation, and secret observation.^{9,10} In this study, the researcher performed tracking using the participant observation method in the clinic. The Strengthening the Reporting of Observational Studies in Epidemiology was used as the guide for the objective implementation of the observation method.^{11,12}

THE POPULATION AND SAMPLE OF THE STUDY

IV medication administrations applied by nurses (n=12) in the ICU for 2 months constituted the universe of the research. The sample of the study consisted of 124 IV medication administrations by nurses during 24-hour shift periods.

SELECTION OF THE PARTICIPANTS

Nurses working at least 6 months in the ICU who volunteered to participate in the study were included in the study. Isotonic, hypertonic, hypotonic solutions, osmotic diuretics, diuretics, analgesics, neuroleptics, antibiotics, proton-pump inhibitors, bronchodilators, and tramadol hydrochloride medication administrations of the nurses administered IV in the ICU were observed in the study.

VARIABLES OF THE STUDY

The dependent variable was the IV medication administration steps of nurses. The independent variables were age, sex, education level, years of professional experience, working duration in the ICU, having an intensive care certificate, working period, and medication administration times of nurses.

DATA COLLECTION

This study was conducted in 2 stages. In the first stage, was developed software to measure IV medication errors using the C# programming in Microsoft Visual Studio (Microsoft Inc., New Mexico, USA). The graphical user interface includes detailed IV medication administration steps in detail for each method. After the software was developed, it was submitted for approval by five experts and its final form was obtained in accordance with the feedback of 3 experts. In the second stage, the application was tested with the participation of 12 nurses.

The Firebase (Alphabet Inc., California, USA) real-time database was used as the database infrastructure in the software. Data were collected during the nurses' 24-hour shifts. Each nurse was observed in the context of IV medication applications that they performed during all treatment hours during 24-hour shifts. Since nurses are observed more than once, the interface includes work experience, intensive care experience, working hours, etc., which are thought to affect nurses' sociodemographic information and medication applications. By entering the information, the nurses were recorded by coding Nurse 1 and Nurse 2 ... Nurse 12 (Figure 1).

In the next stage, each IV medication administration process was tracked according to 5 categories: including control, preparation, application, evaluation, and registration (Figure 2).

The steps followed by the nurse during IV medication administration, were marked with a button located at the interface (Figure 3). Then, the medication administration time of the observed medication administration and the study period were entered, notes were taken for the nurse's application process, and the follow-up was completed by selecting the nurse who performed the procedure via the interface (Figure 4).

All data were collected in Firebase. Nurses were observed in the intensive care setting during 24-hour shifts. At least 10 IV medication administrations by each participating nurse were observed and recorded in the software.

EVALUATION OF DATA

The data obtained in this study were analyzed using the SPSS for Windows 25.0 (IBM Inc., Chicago, USA). When the study data were evaluated, in addition to descriptive statistical methods (mean, standard deviation, median, frequency, and ratio), the one-way ANOVA test and student's t-test were used for comparisons of normally distributed parameters between the groups, and the Mann-Whitney U test was used for intergroup comparisons of non-normally distributed parameters. The Pearson chi-square test was used to compare qualitative data. The results were evaluated at a 95% confidence interval and significance level of $p < 0.05$.

FIGURE 1: Registration of nurses on the interface.

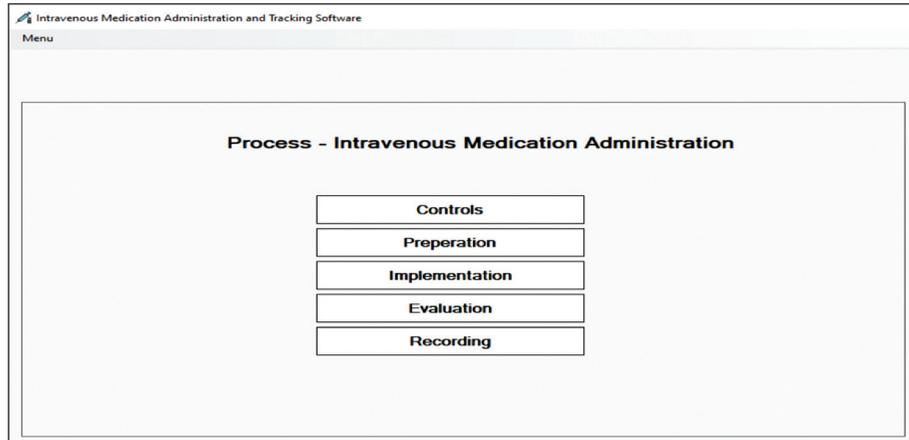


FIGURE 2: IV medication administration process.

IV: Intravenous.

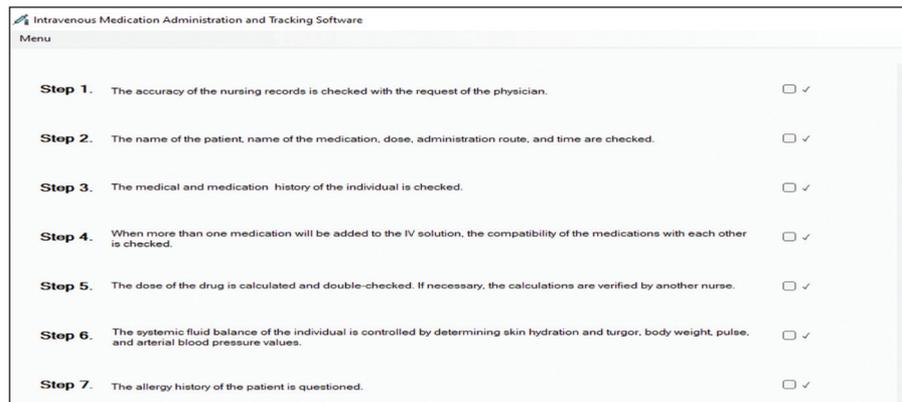


FIGURE 3: Steps of the preparation process in the software system.

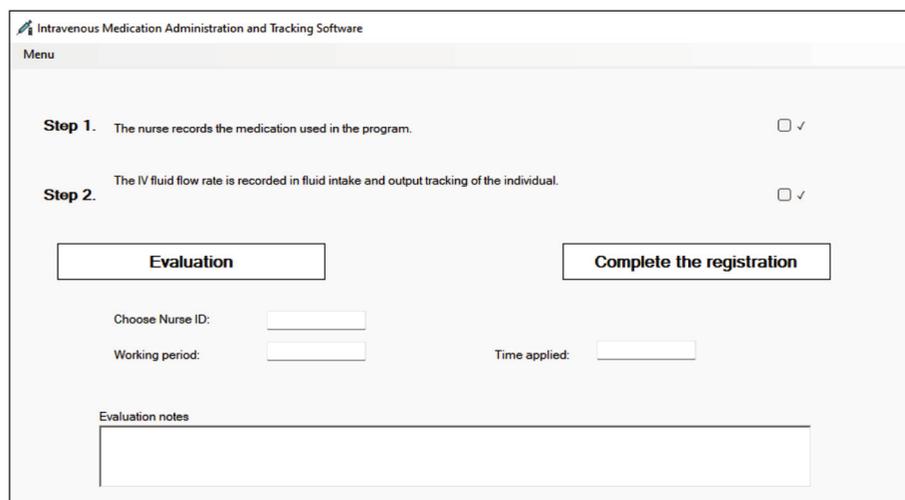


FIGURE 4: The process of completion of the tracking.

ETHICS

Ethics committee approval was obtained from the Non-Interventional Ethics Committee (date: April 29, 2021, decision and protocol no: 2021/04-0226) of the İzmir Kâtip Çelebi University for the conduct of the study. The principles of the Declaration of Helsinki complied with all stages of the research. The nurses who constituted the sample were informed that they would be observed during IV medication administration in line with the observational study design, which constituted the type of study, and their written consent was obtained.

RESULTS

When the data on the sociodemographic and descriptive characteristics of the nurses who participated in the study were examined, the mean age of the nurses was 37.5 ± 5.85 , 66.7% were male, 75% were married, 33.3% had children, 58.3% were associate degree graduates, the professional experience was 11.42 ± 4.34 years, and the duration of working experience in the ICU was 5.92 ± 2.91 years (Table 1).

When medication administrations are grouped according to time, 08.00-13.00 hours were taken as morning hours; 13.00-19.00 as afternoon hours; and 19.00-24.00 were taken as night hours.

When the descriptive statistics were examined, it was found that the mean scores were similar. Table 2 indicates that more observations were made at night. Errors were equally low when the deviations were not too high. Therefore, there was no significant difference between the number of correct IV medication administration steps and the time variable for nurses' medication administration.

When the relationship between averages of correct IV medication administration steps of nurses and the gender variable, education level, having an intensive care certificate, and overtime hours was examined, no significant differences were detected between the groups. When the relationship between the correct IV medication administration steps of nurses and the time of medication administration was examined, no significant differences were detected between the number of correct IV medication administration steps and the time variable of the medication administration of the nurses (Table 1, Table 2).

The correct implementation rates of the steps in the IV medication administration process for nurses are presented in Table 3.

There was a strong and positive relationship between the average number of correct medication administration steps of nurses and the variables of working experience and age (0.743^{**}), working experience and working experience in the ICU (0.681^*), and working experience in the ICU, and age (0.657^*) (Table 4).

TABLE 1: The distribution of the participating nurses according to descriptive characteristics.

Descriptive characteristics		n (12)	Cumulative percentage	Correct count	Mean-SD	Minimum-maximum
Gender	Female	4	33.3	17.36		
	Male	8	66.7	16.64		
Age		12			37.75 ± 5.85	25-43
Working experience		12			11.42 ± 4.34	1-17
Working experience in ICU		12			5.92 ± 2.91	1-10
Marital status	Single	3	25	17.23		
	Married	9	75	16.76		
Number of children	Yes	4	33.3	16.72		
	No	8	66.7	16.96		
Educational status	Assoc. Degree	7	58.3	17.10		
	Undergraduate degree	5	41.7	16.57		
Having intensive care certificate status	Yes	6	50	16.84		
	No	6	50	18.97		

ICU: Intensive care unit.

TABLE 2: The analysis of the relationship between the correct count of participating nurses and the hours of medication administration.

Correct count according to medication administration time	n	Mean	Standard deviation	Standard deviation	Confidence interval for mean (95%)		Minimum	Maximum
					Lower limit	Upper limit		
Morning	37	16.54	3.033	0.498	15.52	17.55	12.00	24.00
Afternoon	31	17.48	2.350	0.422	16.62	18.34	13.00	23.00
Night	56	16.78	3.102	0.414	15.95	17.61	8.00	23.00
Total	124	16.88	2.911	0.261	16.36	17.40	8.00	24.00

TABLE 3: Correct implementation rates of the steps in the IV medication administration process of nurses.

Steps to be applied in all procedures (n=124)		n	Rate of correct application
Control step	The accuracy of the nursing records was verified upon the request from the physician.	120	96.7%
	The name of the patient, name of the medication, dose, administration route, and time were checked.	114	91.9%
	The medical and medication history of each individual was checked.	113	91.1%
	When more than one medication was added to the IV solution, the compatibility of the medications was checked.	112	90.3%
	The systemic fluid balance of an individual was controlled by determining skin hydration and turgor, body weight, pulse, and arterial blood pressure values.	70	56.4%
	The allergy history of the patient was assessed.	13	10.4%
	The expiration date of medication was checked.	4	3.2%
Preparation and implementation step	The hands were washed or disinfected when preparing medication.	63	50.8%
	The hands were washed before administration of medication.	4	3.2%
	Gloves were worn.	68	54.8%
	The individual was informed of IV medication administration and why the medication was administered.	17	13.7%
Evaluation step	The IV infusion site was based on signs and symptoms of infiltration or phlebitis, and the patency of the IV catheter was determined.	66	53.2%
	The response of the individual to fluid therapy was evaluated using the signs of fluid-electrolyte imbalance, vital signs, and laboratory findings.	120	96.7%
Recording step	The patient was observed for possible complications.	37	29.8%
	The nurse recorded the medications used in the program.	121	97.5%
	The IV fluid flow rate was recorded during the fluid intake and output tracking of the individual.	119	95.9%

IV: Intravenous.

TABLE 4: The correlation analysis of the averages of correct IV medication administration steps of nurses in all procedures and age, working experience, and working experience in ICU.

Correlation		Number of correct items	Age	Working experience	Working experience in the ICU
General average of correct IV medication administration step	Pearson correlation	1	0.193	0.096	-0.317
	Sig. (2-tailed)		0.548	0.766	0.316
	n	12	12	12	12
Age	Pearson correlation	0.193	1	0.743**	0.657*
	Sig. (2-tailed)	0.548		.006	0.020
	n	12	12	12	12
Working experience	Pearson correlation	0.096	0.743**	1	0.681*
	Sig. (2-tailed)	0.766	0.006		0.015
	n	12	12	12	12
Working experience in ICU	Pearson correlation	-0.317	0.657*	0.681*	1
	Sig. (2-tailed)	0.316	0.020	0.015	
	n	12	12	12	12

*p<0.05; **p<0.01; IV: Intravenous; ICU: Intensive care unit.

DISCUSSION

When the 124 IV medication administrations of the nurses in the study group were examined, the expiration date of the medications was not checked in 96.8% of the administrations, and the allergy history of the patient was not questioned in 89.6% of the controls; 49.2% skipped the hand washing/disinfection step during the preparation step; 96.8% did not wash their hands during the application step; no explanation was given to the patient in 86.3%, and 70.2% skipped the step of following the patient in terms of complications of IV medication administration.

In a study conducted by Çevik et al., 32.7% of senior nursing students did not check the expiration dates of medications.¹³ If interpreted from the point of view of the nurses in the clinic, it can be considered that they do not check the expiration dates because they know that the medications are checked at certain intervals and because they are using certain medications in the clinics. In addition, when it is considered that the patient circulation was slow in the clinic where the nurses worked and looked after the same patients for a long time, it can be understood why the nurses did not question the allergy history of their patients. Contrary to the results of the present study, in a study that was conducted by Vural et al., it was reported that the majority of nurses (76.6%) questioned both food and medication allergies.¹⁴

Similar to the present study, in a study that was conducted by Mendes et al. in which 303 observations were made to determine the types and frequency of errors in medication preparation and administration, the primary errors regarding the preparation and administration of IV medications were found to be the lack of hand hygiene in medication preparation and administration and the lack of asepsis of the materials used for infusion.¹⁵ Gürol Arslan et al. in a study in which medications administered through a central venous catheter were observed, it was also determined that 87.8% of nurses did not maintain hand hygiene.¹⁶

In this context, it is possible to argue that nurses do not act in line with aseptic techniques when preparing medications.

In the study of Kim and Bates, which reported similar results to the present study, only 45.6% of the nurses confirmed the medication by looking at the vial for at least one second, 6.5% checked the name of the patient with their wristband, and 4.5% washed their hands before and after the medication administration.¹⁷

In the present study, no significant differences were detected between the nurses' gender and marital status variables and their correct application numbers. By evaluating this result, it is possible to argue that there is no relationship between nurses being male-female or married-single and doing the right application. In the study of Özen et al., female nurses were found to make fewer mistakes.¹⁸ Cebeci et al. reported that there were no relationships between the tendency of nurses to make medical mistakes and their gender and marital status.¹⁹

No differences were detected between the education levels and intensive care certificates of the nurses who participated in the study and their correct application numbers. In the study of Márquez-Hernández et al., no significant differences were detected between the professional experience of nurses and the places they worked and medication errors.²⁰ However, in the study of Manias et al., it was reported that more medication errors were detected in intensive and complex treatment centers.²¹ In Muroi et al.'s study, it was reported that more medication errors might be faced in ICU.²² Campino et al. argued that professional medication training among employees could reduce medication errors.²³

A positive relationship was detected between age, working experience, and working experience in the ICU and the correct number of nurses who were included in the study. In this context, it is possible to argue that nurses make fewer mistakes as their work experience increases. Similarly to the results of the study, the age, educational status, and work experience of nurses.²⁴⁻²⁶ Contrary to this result, Aygin et al. argued that there was no relationship between the working experiences and making mistakes of nurses.²⁷

The nurses were observed at different treatment hours under 24-hour shift conditions within the scope

of the study. When the treatment hours were examined in the morning, afternoon, and night, no significant differences were detected between the treatments applied the nurses during the day and night. Contrary to this study's results, some studies argue that nurses make more mistakes during the shift night work period.¹⁸⁻²⁸ Some studies report that nurses make more medication errors during the morning shift or at night.²⁹⁻³¹ It is believed that the main reason why the study results differ from the literature is the small sample group in the study.

No significant differences were detected between the total working hours of nurses and the average number of correct medication administration steps of nurses in the present study. When the literature is examined, it is stated that the increase in nurses' workload and working hours also increases medication errors.²⁹⁻³³ In the study conducted by Berdot et al., it was reported that long-term work and night shifts could increase errors.³² It was mentioned in the study of Er and Altuntaş that long and overtime working hours, lack of professional knowledge and skills, and inexperience of nurses would cause medical errors.³³

In a study that was conducted by Koçak and Yaman, it was reported that 44% of nurses made a medication error and 81.5% witnessed a medication error made by a healthcare staff other than themselves.²⁸ In the study of Top and Çam, it was reported that more than half of the nurses made medication errors, and the most important factor that contributed to these errors was the inexperience of the staff.³⁴ Similarly, in the study of Manav and Başer, 48.9% of the nurses said that they made a medication error and witnessed their colleagues making a medication error at least once.³⁵ The fact that nurses performed many IV medication administration steps incompletely or incorrectly in the study is similar to the results of the literature.

LIMITATIONS OF THE STUDY

Since the study had an observational design, awareness of the nurses being observed was among the limitations of the study. Due to the coronavirus disease-2019 pandemic, which has affected the entire

world since March 2020, data collection was limited to one clinic because of the interruption of the legal permissions of the study due to security measures. Therefore, the results of the study depend on the IV medication administration of the nurses in the clinic where the study was conducted, and it is not possible to generalize these results.

CONCLUSION

The results showed that the developed software system could be used for the detection and prevention of medication errors. It was also seen that nurses face many medication errors during the treatment process. It is extremely important to prevent medication errors, ensure patient safety and prevent unwanted events. It is observed that the applications developed to prevent medication errors are effective but the number of them is not adequate. For this reason, it is critical to develop institutional policies and increase the quality of in-service training to prevent medication errors.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: Zilan Baran, Esra Akın; **Design:** Zilan Baran, Esra Akın; **Control/Supervision:** Esra Akın; **Data Collection and/or Processing:** Zilan Baran, Esra Akın; **Analysis and/or Interpretation:** Zilan Baran; **Literature Review:** Zilan Baran; **Writing the Article:** Zilan Baran, Esra Akın; **Critical Review:** Zilan Baran, Esra Akın, İsmail Akdağ; **References and Fundings:** Zilan Baran; **Materials:** Zilan Baran, İsmail Akdağ.

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