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Effects of General Anaesthesia on the Middle Ear Pressure

Engin Deniz[1], Sevtap Hekimoğlu Şahin[1], Necdet Süt[2]

[1]Department of Anaesthesiology, Trakya University School of Medicine, Edirne, Turkey

[2]Department of Biostatistics, Trakya University School of Medicine, Edirne, Turkey

ORCID IDs of the authors: E.D. 0000-0002-1239-8402; S.H.Ş. 0000-0002-3223-531X; N.S. 0000-0001-6678-482X.

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Abstract

Objective: Inhalation agents can have different effects on the middle ear pressure (MEP). We aimed to investigate the effect of sevoflurane and desflurane, the agents used in patients who do not have any ear pathology and who undergo surgery under general anaesthesia, on MEP.

Methods: Fifty adult patients who were scheduled to undergo inguinal hernia and lower extremity surgery were included in our study. All patients were aged between 20 and 60 years and belonged to the American Society of Anesthesiologists (ASA) I-III class. Patients were divided into two groups, according to the inhalation agent administered for the surgery: sevofluran, Group S (n=25); and desfluran, Group D (n=25). Anaesthetic agents, intraoperative end tidal carbon dioxide and airway pressures were recorded. The MEP was measured for both ears preoperatively, at the intraoperative 5th, 10th, 15th minutes, and at the postoperative 10th and 30th minutes.

Results: The MEP at the intraoperative 10th minute was significantly higher in Group D compared to Group S. In Group D, the MEP increased significantly at the intraoperative 10th and 15th minutes, and postoperative 30th minute, compared to preoperative values. In Group S, the MEP increased significantly at the postoperative 10th minute, compared to preoperative values.

Conclusion: We found that desflurane increases the MEP during the intraoperative and postoperative period, compared to sevoflurane.

Keywords: Desflurane; middle ear pressure, sevoflurane

Introduction

Although there are no severe adverse effect of currently used anaesthetic agents on human body, it is known that they have a varying degree of impact on several systems (1, 2). Thus, studies showed that anaesthesia administration leads to changes in the middle ear pressure (MEP) (3, 4).

Anaesthetic agents preferred in the middle ear surgery can cause serious complications, such as changes in MEP, haemotympanum, serous otitis, temporary or permanent hearing loss, replacement of tympanic membrane graft and impairment of ossicular chain. Therefore, anaesthetic agents used in the middle ear operations should have a minimal impact on MEP (1).

There are several factors affecting MEP. Among these are the position of the patient, eustachian tube changes, strabismus surgery, mask pressure administered during the induction of anaesthesia, and hypo- and hyperventilation (1). In recent years, it has been reported that the gas exchange in the middle ear mucosa takes place between the middle ear cavity and submucosal connective tissue capillaries. Carbon dioxide (CO_2) can increase MEP by diffusing into the middle ear cavity as a result of rise in the partial CO_2 pressure (2). Therefore, when assessing the association of anaesthetic agents with MEP, it is crucial to evaluate all potential factors that could affect the MEP during surgery.

Studies reported that inhalation agents are more likely to affect MEP compared to intravenous anaesthetic agents. Our goal in this study was to describe the effect of inhalation agents, sevoflurane and desflurane, on MEP, when

Corresponding Author: Sevtap Hekimoğlu Şahin E-mail: sevtaphekimoglu@yahoo.com

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used in patients who did not have any ear pathology and underwent non-ear surgery under general anaesthesia.

Methods

This single-centre, prospective study was conducted at Trakya University, Medical Faculty. After obtaining an approval from the institutional ethics board (Committee No: 2013/136, TÜTF-GOKAEK, Trakya University, 31.07.2013) and written informed consent, 50 patients aged between 20 and 60 years who according to the American Society of Anesthesiologists (ASA) had the class II–III physical status and were scheduled for elective inguinal hernia and lower extremity surgery under general anaesthesia in the supine position were enrolled in the study (ClinicalTrials.gov Identifier: NCT03100604). Preoperative baseline values were obtained by performing tympanometry prior to anaesthesia for each patient in supine position. Patients were divided into two groups according to the inhalation agent administered for the surgery: sevoflurane, Group S (n=25); and desfluran, Group D (n=25). Patients with deviated nasal septum, adenotonsillar hypertrophy, perforated tympanic membrane and middle ear pathology, and those who receive medications affecting MEP, were excluded from the study. The heart rate (HBR), arterial blood pressure and peripheral oxygen saturation (SpO_2) were monitored in patients who were taken into operating room. All patients were given intravenous propofol 2-3 mg kg^{-1}, fentanyl 1 mcg kg^{-1} and rocuronium 0.6 mg kg^{-1} for anaesthesia induction and were intubated. The endotracheal cuff pressure was adjusted between 26 and 30 cmH_2O. Maintenance of anaesthesia was provided with 2% sevoflurane in Group S, and 6%-9% desflurane in Group D, with a 50% air/oxygen mixture and fresh gas flow at 4 L min^{-1} in both groups. Tympanometric measurements were performed and recorded for each ear preoperatively, at intra-

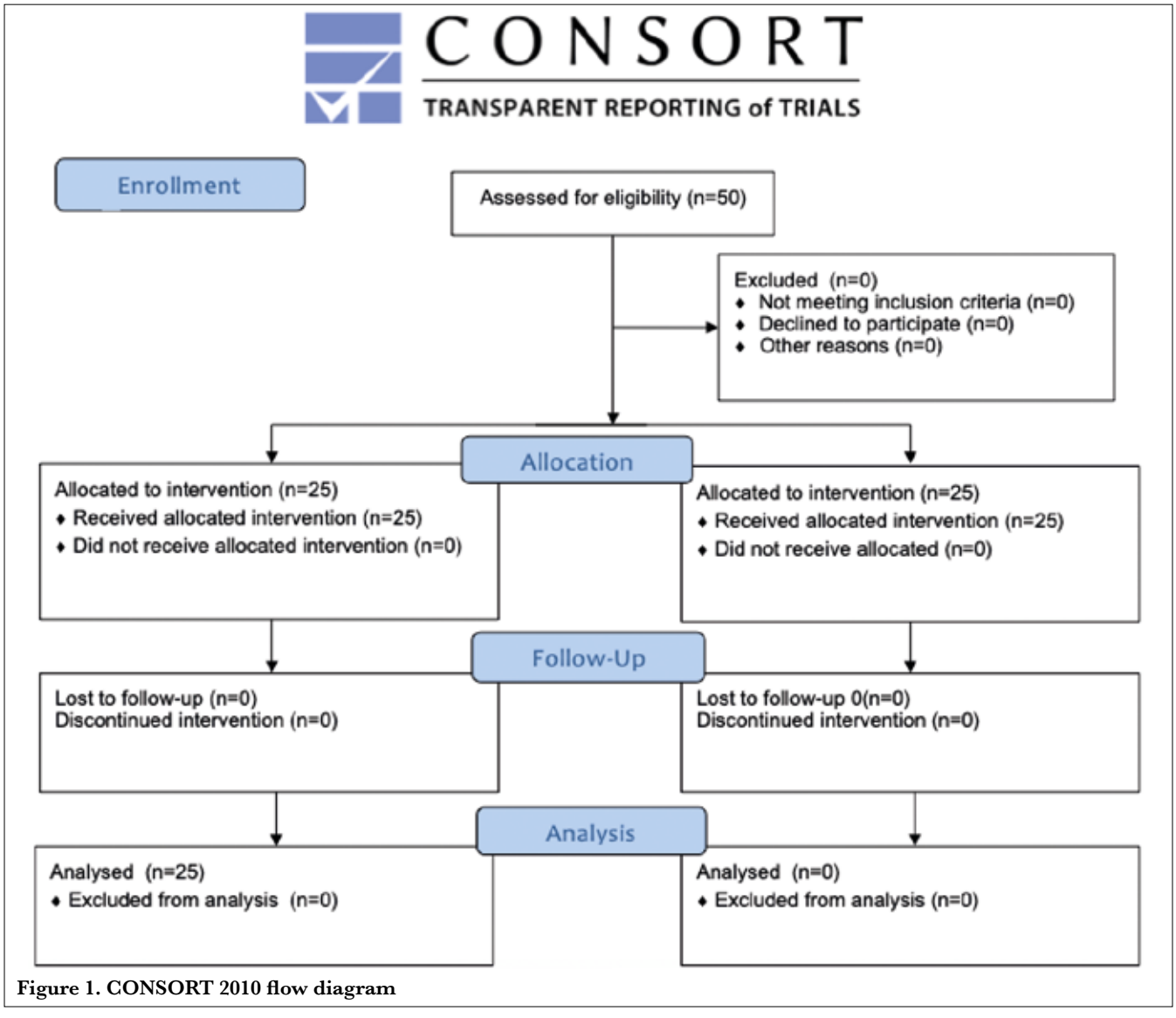

Figure 1. CONSORT 2010 flow diagram

operative 5th, 10th and 15th minutes and postoperative 10th and 30th minutes, using the MAICO MI 34 model tympanometry equipment. Normal MEP ranges between −200 and +200 decapascals (daPa). HBR, systolic blood pressure, diastolic blood pressure, mean blood pressure and SpO_2 values were recorded during the preoperative period, every 2 minutes during the first 10 minutes of the intraoperative period and during the postoperative period. Intraoperative anaesthetic and analgesic agents used during surgery, intraoperative end tidal CO_2 ($EtCO_2$) and airway pressure values, duration anaesthesia and surgery were recorded.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences version 15.0 (SPSS Inc.; Chicago, IL, USA) statistical program. The Mann-Whitney U test was used to evaluate demographic data such as the age and body weight, and parametric variables such as the mean arterial pressure and HBR. To detect a large effect size (d=0.8) in the MEP measurements between groups with an alpha level of 5%, and with a power of 80%, the sample size was calculated as 25 patients for each group. The ASA class and gender were assessed using the chi-squared analysis. The Mann-Whitney U test was used to evaluate data of ear measurements, and the Friedman and Wilcoxon tests were used for intra-group comparisons. Results were presented as (mean)±standard deviation. P-values <0.05 were considered to be statistically significant.

Table 1. Demographic and surgery data, and total fentanyl and propofol consumption by groups

	Group S (n=25)	Group D (n=25)	p
Age (year)	48.00±11.76	41.20±15.15	0.083
Gender (F/M)	3/22	3/22	1.000
ASA I/II/III	12/12/1	17/8/0	0.135
Weight (kg)	75.08±9.40	75.36±15.06	0.937
Height (cm)	172.24±7.07	170.80±7.63	0.492
Duration of anaesthesia (min)	64.40±19.49	71.40±20.44	0.215
Duration of surgery (min)	56.20±17.87	62.04±19.90	0.263
Total fentanyl consumption (mg)	52.00±20.31	51.00±15.28	0.840
Total propofol consumption (mg)	161.60±29.96	176.40±28.41	0.096

No significant differences were noted between the groups.
mean±standard deviation; n (%). ASA: American Society of Anaesthesiology

Results

Fifty patients were included in the study (Figure 1), and there was not any statistically significant difference between the groups in terms of age, gender, ASA scores, and body weight and height (Table 1). Difference in the duration of anaesthesia, duration of surgery and total amount of intravenous anaesthetic and analgesic consumption were not statistically significant (Table 1).

The MEP measured in left ear at the intraoperative 10th minute was found to be significantly higher in Group D, compared to Group S. The MEP values measured in the left and right ear were not significantly different preoperatively, intraoperatively at the 5th and 15th, and postoperative 10th and 30th minutes between the groups (Table 2, Figure 2).

The MEP measured in the left ear at intraoperative 5th and postoperative 10th minutes was significantly increased when compared to preoperative values in Group S. Left MEPs in Group D significantly increased at the intraoperative 10th, 15th and postoperative 30th minutes compared to the preoperative value (Table 2, Figure 2).

Table 2. The MEP of left and right ears values in the preoperative, intraoperative, and postoperative period

	MEP of right ears			MEP of left ears		
MEP (daPa)	Group S (n=25)	Group D (n=25)	p*	Group S (n=25)	Group D (n=25)	p*
Preoperative	−14.84±66.01	−29.52±49.04	0.778	−24.2±64.71	−24.52±34.32	0.509
Intraoperative 5 min	−10.52±90.23	−15.8±39.69	0.884	−21.76±64.86	−6.24±34.9	0.057
Intraoperative 10 min	−8.28±108.17	18.56±66.36	0.200	−27.36±59.35	5.72±58.17	0.043
Intraoperative 15 min	−8.96±104.88	10.72±72.55	0.485	−5.44±84.09	20.8±64.05	0.079
Postoperative 10 min	7.12±104.7	32.16±64.25	0.252	14.44±86.92	36.12±69.9	0.264
Postoperative 30 min	−19.32±92.73	−18.48±74.49	0.869	−3.28±69.89	−3.64±50.,83	0.938
p**	0.001	<0.001	p**	0.079	<0.001	

*Mann-Whitney U Test, **Friedman test according to preoperative measurements. p<0,05 statistically significant. MEP: middle ear pressure; mean±standard deviation

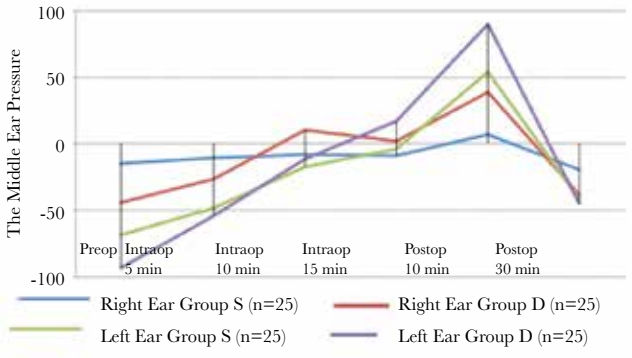

Figure 2. The MEP of the left and right ears values preoperatively, intraoperatively, and postoperatively in the sevoflurane and desflurane groups

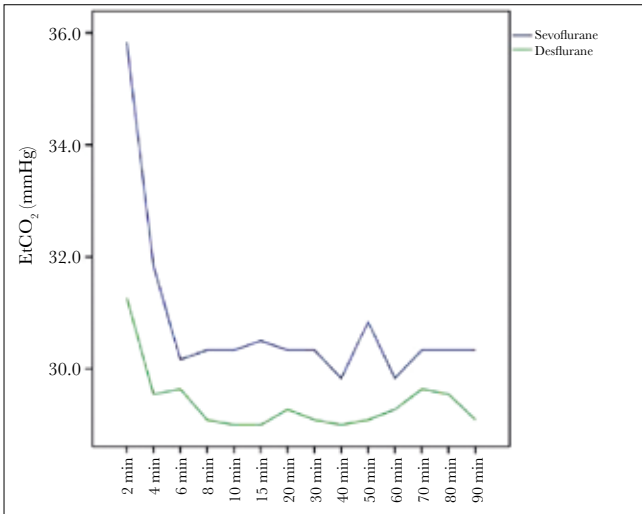

Figure 3. Comparison of the $EtCO_2$ values intraoperatively in the sevoflurane and desflurane groups

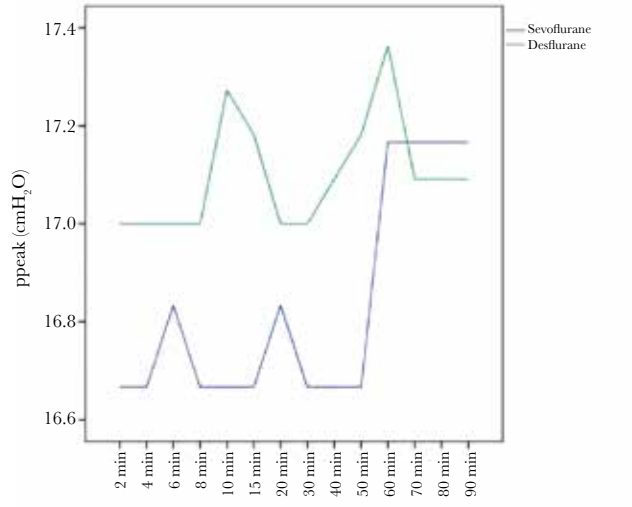

Figure 4. Comparison of P peak values intraoperatively in the sevoflurane and desflurane groups

In Group S, the right MEP significantly increased at the postoperative 10th minute, compared to preoperative value (p=0.002), while it significantly decreased at 30th minute. Right MEPs in Group D significantly increased at intraoperative 5th, 10th, 15th, and postoperative 10th and 30th minutes compared to the preoperative value (Table 2, Figure 2).

The average $EtCO_2$ levels at intraoperative 10th, 15th and 30th minutes were significantly higher in Group S, compared to Group D (Figure 3).

When the average airway pressures of the patients were compared within the groups, it was found that there was not any statistically significant difference in both the S and D Groups (Figure 4).

Discussion

In this study, we compared the effect of sevoflurane and desflurane inhalation agents used for the maintenance of anaesthesia on MEP in patients who underwent inguinal hernia and lower extremity surgery. We found that the left ear MEP measured at the intraoperative 10th minute was significantly higher in Group D, compared to Group S. We believe that the absence of statistically significant difference between the two groups in terms of haemodynamic and demographic data is rather important in correct demonstration of the effects of sevoflurane and desflurane on MEP.

The position of the patient, inhalation and intravenous anaesthetic agents and airway pressures influence the MEP in middle ear operations. Although it has been reported that the rate of hearing loss following general anaesthesia is low and most of such cases are reversible, it should be kept in mind that this can be permanent damage (5, 6).

The partition coefficient of a substance refers to its solubility in the air, blood and tissue. The lower blood gas partition in an inhalation agent, the higher its solubility in the blood, hence its arrival to the brain and its diffusion from alveoli into the blood is more expeditious (7, 8). Therefore, a substance with low blood solubility can pass faster through the middle ear cavity, and after the cessation of gas administration to the patient, clearance of the gas from the middle ear cavity can occur more rapidly. This in turn leads to rapid changes in MEP. In their studies, Sade et al. (7, 8) found that the middle ear mucosa-mediated gas diffusion occurs proportional to diffusion coefficients of the gases, and gas composition in the middle ear resembles that of venous blood. Blood gas partition of the volatile anaesthetic agents are 0.42 for desflurane and 0.65 for sevoflurane. In our study, although we found that the left ear MEP measured at the intraoperative 10th minute is significantly higher in Group D, it was concluded that

the right and left ear MEPs in both groups were similarly increased, compared to control values. We believe that this result arises from the fact that blood gas partition coefficients of sevoflurane and desflurane are closer to each other than other inhalation agents.

Change in the body position is another factor affecting MEP. The impact of surgical interventions performed in different positions on the cerebral blood flow and intracranial pressure is well known (9, 10). It has been shown that the MEP increases as the body position is changed from Fowler's to the supine position. This condition is explained by an increase of the jugular pressure in the supine position compared to Fowler's position (1). An increase in the jugular pressure leads to volume increment in the middle ear mucosa. An increase in the congestion also influences MEP (1). All surgical procedures were performed in the supine position, and the baseline MEP and all other parameters were measured in the supine position, minimising the effect of the position on the MEP. No position change was attempted during surgery.

It is generally known that respiratory changes have impact on MEP. Ikarashi (11) formed two groups in a study conducted on healthy volunteers. Participants in the first group were asked to hypoventilate first, and then they hyperventilated and later hypoventilated again. Cases in the second group were asked to hyperventilate first and then hypoventilate and later hyperventilate again. Hypoventilation was done with as few as possible and superficial respirations, while hyperventilation was done with rapid and deep respirations, and the gas analysis was performed in the individuals in both groups. Partial CO_2 pressure ($PvCO_2$) in venous blood was 56.2 mmHg, and MEP was 64 daPa initially. At the moment when hypoventilation was stopped and hyperventilation started, $PvCO_2$ was measured at 60.8 mmHg, and MEP was 49 daPa. A drop in MEP occurred as hyperventilation continued. At the end of the hyperventilation, $PvCO_2$ was 28 mmHg, and MEP was −46 daPa. It was shown that MEP increased with hypoventilation and decreased with hyperventilation (11). Due to vascularity of the mucosa in the middle ear cavity and diffusion characteristics of the gas, MEP can be affected by the changes in the tympanomastoid cavity volume. When a shift occurs in the amount of the gas in the middle ear, mastoid structure works as a buffer to minimise the pressure changes (12).

In another study, Ikarashi and Tsuchiya (2) examined the changes occurring in MEP during hyperventilation and hypoventilation in patients with ear symptoms such as tinnitus and hearing loss. In this study, $EtCO_2$ was measured instead of the blood gas analysis, and similar results were found; $EtCO_2$ and MEP increased during hypoventilation, and they decreased during hyperventilation. We recorded $EtCO_2$ and airway pressure values in all patients to abolish or notice the changes that could arise from hyperventilation or hypoventilation, and we statistically analysed these findings. We did not find any significant differences between two groups. Besides, our study is the first study in which the airway pressure was recorded, and MEP was assessed in line with the literature. Volatile anaesthetic agents diffuse from the eustachian tube or circulation into the middle ear through insufflations and cause changes in MEP. These alterations in MEP during surgery can lead to tympanic membrane rupture, replacement of tympanic membrane graft, haemotympanum. and temporary or permanent hearing loss (13). Ozturk et al. (4) analysed the MEP measurements in 19 boys, who received desflurane for circumcision, and concluded that desflurane increased MEP. They reported that compared to control values, the average MEP values increased at 5^{th}, 10^{th} and 15^{th} minutes after desflurane initiation, and MEP was higher than the control value at the 10^{th} minute following cessation of desflurane. These results were similar to our study, but unlike us, the authors applied the laryngeal mask to child patients, and duration of the operation was not reported by the authors. It should not be overlooked that the laryngeal mask would have an impact on MEP.

Similar to our study, Duger et al. (14) investigated the effect of desflurane and sevoflurane on MEP in 60 patients. They showed that sevoflurane and desflurane increased MEP compared to baseline values. However, when these two agents were compared, a smaller increase was observed with sevoflurane than with desflurane. Authors claimed that sevoflurane was safer than desflurane in the middle ear surgery. Differently from this study, we statistically analysed $EtCO_2$, airway pressure, and used intravenous anaesthetic and analgesic agents, which we believed to be associated with the MEP. To abolish the influence of cuff pressure on the MEP, endotracheal cuff pressure was adjusted between 26 and 30 cmH_2O. There was not any significant difference between the groups with regard to a total amount of intravenous anaesthetic and analgesic consumed. Similar to other studies, we found that MEP at the intraoperative 10th minute was significantly higher in Group D compared to Group S. We detected that MEP increased significantly at intraoperative 10^{th} and 15^{th} minutes and postoperative 30^{th} minutes, compared to preoperative values in Group D. However, MEP increased significantly at the postoperative 10^{th} minute, compared to preoperative in Group S.

Conclusion

We demonstrated that desflurane increased MEP more than sevoflurane. However, there was not any significant postoperative difference. We think that since an increase in the MEP can lead to complications, sevoflurane can be administered more safely in the middle ear surgery with $EtCO_2$ and airway pressure monitorisation, and further studies with a larger number of patients would enrich our research.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Trakya University School of Medicine (2013/136, TÜTF-GOKAEK).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – S.H.Ş.; Design – S.H.Ş., E.D.; Supervision – S.H.Ş., E.D., N.S.; Resources – E.D., S.H.Ş.; Materials – S.H.Ş.; Data Collection and/or Processing – E.D., N.S.; Analysis and/or Interpretation – S.H.Ş., E.D., N.S.; Literature Search – E.D., S.H.Ş.; Writing Manuscript – E.D., S.H.Ş.; Critical Review – S.H.Ş., E.D., N.S.; Other – S.H.Ş., E.D., N.S.

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Conflict of Interest: The authors have no conflicts of interest to declare.

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