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Original Study

Assessment of Genomic Instability in Operating Room Staff Using Cytokinesis Block Micronucleus Assay

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SUMMARY

Introduction: Anesthetic gases are the main pollutants in operating rooms (OR).
Aim: In this study, we explored the genomic instability and nuclear division index (NDI) in OR staff with prolonged exposure to low doses of waste anesthetic gases (WAGs).
Material and Methods: Study groups were: total 40 participants, 20 were OR staff (comprising 17 anesthesia technicians and three nurses from OR), while 20 that were not exposed to WAGs were assigned as control. The cytokinesis-blocked micronucleus assay (CBMN) was applied to assess genomic instability. Indicators of genomic instability were *micronucleus* (MN), *nuclear bud* (NBUD), and *nucleoplasmic bridge* (NPB). NDI was used as indicator of cell kinetic.
Results: The MN and NBUD average frequencies were significantly elevated in the operating room staff when compared to the respective controls ($p<0.001$, $p<0.005$). On the other hand, NPB and NDI showed no significant differences in both groups ($p>0.05$). Among the OR staff, a positive association in terms of correlation ($r=0.57$, $p<0.01$) is reported between age and MN frequency. Similarly, total years of service and MN frequency ($r=0.47$, $p<0.05$) were correlated. No differences in gender of operating room employees were found in MN, NPB, and NBUD frequencies ($p>0.05$).
Conclusion: Our results present no significant impact of WAG exposure on cell kinetics but significantly increased the frequency of MN and NBUD.

Keywords: Occupational Exposure, Operating Room Medical Stuff, Micronucleus, Nucleoplasmic Bridge, Nuclear Bud

INTRODUCTION

Operating room (OR) contamination with anesthetic gases is unavoidable, stemming from leaks in anesthesia systems and the gases exhaled by patients [1, 2]. These small amounts of volatile anesthetic gases are called waste anesthetic gas (WAG) [2]. ORs are working areas with many physical, chemical, and biological pollutants other than WAGs [3]. However, WAGs are the main pollutants in ORs [2]. Although systems designed to eliminate WAGs can reduce their presence and create a cleaner environment, they cannot completely remove these pollutants [4]. For this reason, millions of OR workers around the world, including doctors, nurses, and anesthesia technicians experience prolonged exposure to low doses of WAGs [2,5].

Anesthetic gases are quickly eliminated from the human body due to their low solubility [6]. However, reproductive health such

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as decreased fertility rate, increased incidence of miscarriage, congenital anomalies, and deterioration in sperm quality may be impacted during chronic occupational exposure to WAGs [7,8]. Additionally, it has been reported that WAG exposure stimulates oxidative stress [9,10], and increases the risk of infection [11]; many biomonitoring studies conducted with OR staff suggest a strong association between exposure to WAGs and genotoxic risk [11-14]. However, some other studies disagree and have reported no induction of genetic damage when exposed to WAGs [5,15].

The cytokinesis-blocked micronucleus assay (CBMN) is a reliable bioassay for DNA damage, biomarkers indicative of chromosomal instability are: micronucleus (MN), nucleoplasmic bridge (NPB), and nuclear bud (NBUD). MN represents either chromosome breakage or the loss of an entire chromosome, while NPB originates from the dicentric chromosome and nuclear bud (NBUD) represents gene amplification [16]. Previously genotoxicity after chronic exposure to WAGs have been demostrated using CBMN method and solely focused on MN frequency [6,14,17]. The rationale of the present study was to overcome the limited data scarcity on NBUD and NPB frequency assessments caused by WAG occupational exposures. Furthermore, conflicting evidence regarding whether WAG exposure causes genetic damage necessitated investigation of MN, NPB, and NBUD as indicators of genomic instability. Along this line, NDI values representing cytostatic effects, both in OR personnel and control groups were studied for comparison of results.

AIM

In this study, we explored the genomic instability and nuclear division index (NDI) in OR staff with prolonged exposure to low doses of waste anesthetic gases (WAGs).

MATERIAL AND METHODS

Study groups and their members were: A total 40 participants, of which 20 were OR staff (comprising 17 anesthesia technicians and three nurses from OR) 20 were assigned in the control group. The control group consisted of 20 individuals who lived in the same region as the operating room workers, had no occupational exposure to genotoxic agents (pesticides, radiation, etc.), and had no chronic diseases. Additionally, the control group and the operating room staff group were matched in terms of age, gender, and smoking habits (Table 1). Ethical approval was obtained from Çanakkale Onsekiz Mart University Faculty of Medicine Ethics Committee (application number: 2022-106).

Informed consent was obtained from each participant. Subsequently, a 3 ml peripheral whole blood was drawn into a sterile heparinized tube. CBMN assay was applied on the day of sampling, according to Fenech [18]. In summary, a 0.5 ml representative whole blood sample was added to a culture mixture containing fetal calf serum, culture medium (Sigma, Germany), and phytohemagglutinin (PHA, Biological Industries, Israel). Incubation was at 37°C for 72 hours; cytochalasin-B (6 µg/ml, Sigma, Germany) was introduced at the 44-hour point. At the end of the 72-hour incubation, the harvest was attained by initially treating with cold hypotonic KCl solution (Merck, Germany); followed by three rinses with a cold methanol and acetic acid fixative (7:1, Merck, Germany). After each wash, the samples were rotated at 1200 RPM and the after the last wash, cells were resuspended and placed onto microscope slides, air-dried and stained with Giemsa solution (5%, Merck, Germany). Supernatants were discarded. One

Table 1. Demographic characteristics of the studied population

	Control group (n=20)	Operating room personnel (n=20)
Age (Mean)	30.4	31.5
Total working time (year)	-	10
Gender		
Male	6	7
Female	14	13
Smoking habit		
Smokers	8	12
Non-smokers	12	8

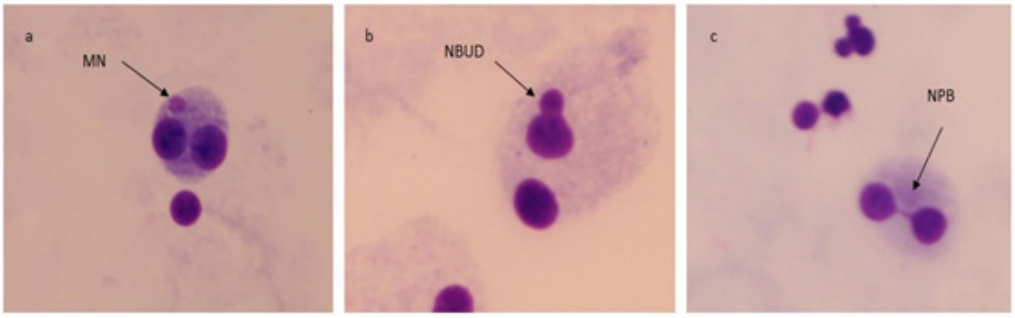

Figure 1. Binucleate lymphocytes with MN (a), NBUD (b), NPB (c)

MN - micronucleus
NBUD - nucleoplasmic bridge
NPB - nuclear bud

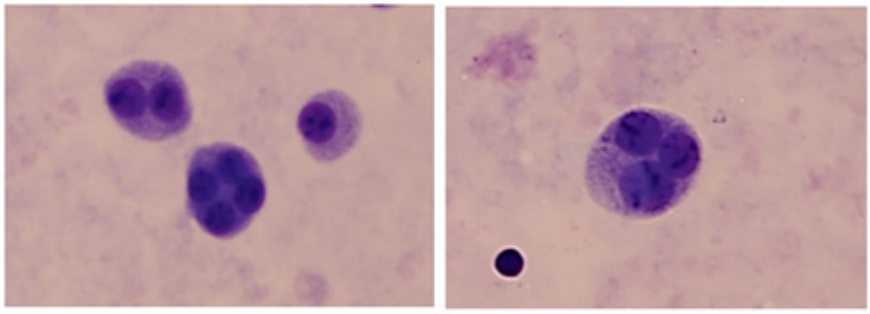

Figure 2. Lymphocytes with 1,2,3, and 4 nuclei

thousand binucleated cells per individual were assessed according to Fenech's criteria, and MN, NBUD, and NPB frequencies were determined [19] (Figure 1). Eastmond and Tucker's [20] protocol, based on cytostatic effect described by Fenech [16] was used for calculation of the nuclear division index (NDI), using the formula:

$$NDI= (M1+2\times M2+3\times M3+4\times M4)/N.$$

In this formula; M1, M2, M3, and M4 contain 1, 2, 3, and 4 nuclei, respectively (Figure 2). N is the number of cells evaluated. For determining NDI, 500 cells were evaluated for each donor.

Tests for normality distribution were conducted using the Kolmogorov-Smirnov and Levene's test: MN, NPB, NBUD, and NDI were the dependent variables and were log transformed before analysis. The nonparametric Mann-Whitney U test was used to assess differences between means of OR staff and the control group data. Furthermore, we explored the relationship among MN, NPB, NBUD, and NDI with age and working time using Pearson's correlation analysis. To evaluate the effects of various variables on MN, NPB, and NBUD formation across different models, we employed a general linear model with univariate analysis. All analyses were performed using SPSS version 19.0.0.

RESULTS

In this study, we examined the parameters of OR medical staff exposed to volatile gasses used during anesthesis. Table 2 reports levels of MN, NPB, NBUD, and NDI for the two groups used for comparison (exposed/non-exposed). The MN and NBUD average frequencies were significantly elevated in the OR staff when compared to those with the respective controls ($p<0.001$, $p<0.005$). Conversely, NPB and NDI showed no significant differences in both groups ($p>0.05$). Among the OR staff, a positive association in terms of correlation ($r=0.57$, $p<0.01$) are reported between age and MN frequency. Similarly, total years of service and MN frequency were correlated ($r=0.47$, $p<0.05$). No differences in gender of OR employees were recorded in MN, NPB, and NBUD frequencies ($p>0.05$). Furthermore, no notable differences in frequencies of

	Control group (Mean ± SD)	Operating room personnel (Mean ± SD)
MN	14.55 ± 4.9	27.9** ± 7.3
NPB	2.45 ± 2.0	1.60 ± 1.6
NBUD	3.50 ± 1.4	5.65* ± 5.6
NDI	1.1,66 ± 0.07	1.65 ± 0.04

Table 2. Results of cytokinesis-blocked micronucleus assay parameters

* - $p<0.005$
** - $p<0.001$
MN - micronucleus
NBUD - nucleoplasmic bridge
NPB - nuclear bud
NDI - nuclear division index

Table 3. MN frequency as dependent variable (Model 1)

MN - micronucleus
df - degrees of freedom associated with the source of variance
F - mean of square regression divided by the mean square residual
[a] - R Squared = 0.311 (Adjusted R Squared =0.230)

Tests of Between-Subjects Effects Dependent Variable: MN (Log transformed)					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	0.071[a]	2	0.035	3.841	0.042
Intercept	1.072	1	1.072	116.565	0<001
Smoking Habit * Age * Weekly work hours	0.071[a]	2	0.035	3.841	0.042
Error	0.156	17	0.009		
Total	41.251	20			
Corrected Total	0.227	19			

Table 4. NPB frequency as dependent variable (Model 2)

NPB - nuclear bud
df - degrees of freedom associated with the source of variance
F - mean of square regression divided by the mean square residual
[a] - R Squared = 0.036 (Adjusted R Squared = -0.077)

Tests of Between-Subjects Effects Dependent Variable: NPB (Log transformed)					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	0.054[a]	2	0.027	0.321	0.730
Intercept	0.251	1	0.251	2.973	0.103
Smoking Habit * Age * Weekly work hours	0.054	2	0.027	0.321	0.730
Error	1.435	17	0.084		
Total	3.478	20			
Corrected Total	1.489	19			

Table 5. NBUD frequency as dependent variable (Model 3)

NBUD - nucleoplasmic bridge
df - degrees of freedom associated with the source of variance
F - mean of square regression divided by the mean square residual
[a] - R Squared = 0.096 (Adjusted R Squared = -0.011)

Tests of Between-Subjects Effects Dependent Variable: NBUD (Log transformed)					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	0.047[a]	2	0.024	0.901	0.425
Intercept	0.556	1	0.556	21.267	<0.001
Smoking Habit * Age * Weekly work hours	0.047	2	0.024	0.901	0.425
Error	0.444	17	0.026		
Total	13.157	20			
Corrected Total	0.491	19			

MN, NPB, and NBUD between smokers and non-smokers were found ($p>0.05$). A general linear model assessed the potential impacts of various factors on MN, NPB, and NBUD parameters. We found that smoking habits, age, and weekly work hours significantly affect MN frequency ($p<0.05$); on the other hand, NPB and NBUD were not significantly associated (Table 3, 4, and 5).

DISCUSSION

In this study, we explored the potential for WAGs to induce genomic instability and examined their effects on the NDI in OR staff chronically vulnerable to these gases. Our findings revealed MN and NBUD average frequency increases among the OR staff compared to the controls. However, NPB and NDI average frequencies were not different in both groups.

Genotoxicity potentials of volatile anesthetic gases were studied using various cytogenetic methods. For example, Hoerauf, Wiesner [21] determined that the level of sister chromatid exchange (SCE) in OR staff exposed to WAGs (nitrous oxide and isofluorane) were above that of controls, reporting exposure even at trace concentrations have the potential for genetic damage. Similarly, two studies utilizing comet assay for DNA destruction in OR staff found a significant increase in DNA damage levels such as comet tail length and mean percentage of DNA in the tail, when compared to controls [1,9]. Other studies employing the CBMN method also demonstrated a significant rise in MN frequencies due to WAG exposure compared to control groups [13,14,17]. These findings are compatible with our findings for MN. While these results do

not definitively clarify the molecular mechanisms behind the genotoxic effects of the inhalation anesthetics studied, we can propose a potential scenario. SCEs occur through the breakage of sister chromatids and their subsequent relocation at homologous loci during the S phase of the cell cycle [22]. Similarly, the comet assay is used both for single- and double-strand DNA breaks [23]; given that chromosome breakage is a primary mechanism of MN formation [16]. It is plausible that the clastogenic effects may underlie the genotoxic impact of prolonged WAG exposure. Two separate studies investigating oxidative stress among OR staff reported significant increases in lipid peroxidation, a biomarker for reactive oxygen species (ROS), compared to control groups. Additionally, a decrease in protective thiol groups was noted [10,24]. This suggests a possible reactive oxygen damage interference in genotoxicity linked to WAG exposure. No published data exist regarding the frequency of NBUD in OR personnel with chronic WAG exposure; however, we report mean NBUD frequency to be significantly higher among the OR staff. According to Fenech, one mechanism for NBUD formation is gene amplification [25], which can contribute to malignant transformations in human cells through the activation of oncogenes [26]. Thus, we propose that the increased frequency of NBUD associated with WAG exposure may be implicated in the pathogenesis of certain diseases. Moreover, several studies have documented elevated MN frequencies in patient populations with conditions such as diabetes [27], cancer [28-30], cardiovascular diseases [31], Parkinson's disease, and Alzheimer's disease [32]. For this reason, it is thought that increased MN frequency may be useful in the diagnosis/prognosis of some diseases [33].

Fenech describes NPB as an indicator of dicentric chromosomes resulting from the misrepair of chromosome breaks or telomere end fusion [25]. In our study, we found no significant differences in mean NPB values between the OR staff and the controls. In this context, we may suggest two scenarios: a) chronic exposure to WAG does not stimulate the NPB formation mechanisms outlined above; b) according to Fenech breaking NPBs plays a role in the formation of NBUD and MN [16,25]. Therefore, while the MN and NBUD frequencies increased as a result of the breaking of NPBs formed by WAG exposure, the NPB frequency may not have a significant increase. A study by Lewińska, reported that WAG exposure in OR staff did not significantly change NDI [13]. Similarly, we did not determine a statistically significantly decrease in NDI value of the OR staff. Thus, we conclude that occupational exposure to WAGs does not impact cell cycle kinetics.

This study has few limitations. First, the number of participants could be higher, which might be a limitation to statistical evaluations. Second, individual levels of WAG exposure cannot be determined accurately. Therefore, we used working hours per week and total years of service in the OR as indicators of WAG exposure. Among the OR personnel, we found a positive correlation between total working time, likely indicative of cumulative WAG exposure, and MN frequency ($r=0.47$, $p<0.05$). Additionally, general linear models indicated that smoking habits, age, and weekly working hours have a high correlation with MN frequency ($p<0.05$).

CONCLUSION

This study demonstrates that CBMN assay is a reliable, repeatable method for assessing the effects of occupational long-term WAG exposure at the genomic level. Our results present no effect of WAG exposure on cell kinetics but reveal a significant increase in the frequency of MN and NBUD". Therefore, we suggest that it is crucial to minimize long-term occupational WAG exposure and that regular checks of waste anesthetic gas scavengers and central climate control equipment in ORs are essential to minimize WAG concentration in the ambient air. We suggested that future studies should be designed with larger cohorts to further validate our observations.

CONFLICT OF INTEREST

All authors declare no conflict of interest.

ACKNOWLEDGEMENT

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Procena genomske nestabilnosti kod osoblja u operacionoj sali pomoću mikronukleusnog eseja blokade citokineze

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KRATAK SADRŽAJ

Uvod: Anestetički gasovi su glavni zagađivači u operacionim salama (OR).
Cilj: U ovoj akademskoj studiji istraživana je genomska nestabilnost i indeks nuklearne deobe (NDI) kod OR osoblja sa produženom izloženošću niskim dozama otpadnih anestetičkih gasova (WAG).
Materijal i metode: U akademskoj studiji, istraživana grupa sastojala se od 40 učesnika, od kojih je 20 činilo OR osoblje (17 tehničara anestezije i tri sestre iz OR), dok je 20 učesnika koji nisu bili izloženi WAG gasovima činilo kontrolnu grupu. Test Mikronukleusni esej blokade citokinaze (CBMN) primenjen je za procenu genomske nestabilnosti. Pokazatelji genomske nestabilnosti bili su *micronucleus* (MN), *nuclear bud* (NBUD), i *nucleoplasmic bridge* (NPB). NDI korišćen kao indikator ćelijske kinetike.
Rezultati: Srednja učestalost MN i NBUD bila je značajno povećana kod OR osoblja u poređenju sa odgovarajućim kontrolama ($p<0.001$, $p<0.005$). S druge strane, NPB i NDI nisu pokazali značajne razlike između grupa ($p>0.05$). Među OR osobljem, zabeležena je pozitivna korelacija ($r=0.57$, $p<0.01$) između starosti i učestalosti MN. Takođe, broj ukupnih godina službe i učestalost MN bile su u korelaciji ($r=0.47$, $p<0.05$). Nisu zabeležene razlike u učestalostima MN, NPB i NBUD između muškaraca i žena zaposlenih u OR-u ($p>0.05$).
Zaključak: Naši rezultati ne pokazuju značajan uticaj izloženosti WAG gasovima na ćelijsku kinetiku, ali značajno povećavaju učestalost MN i NBUD.

Ključne reči: profesionalna izloženost medicinskog osoblja, micronucleus, nucleoplasmic bridge, nuclear bud

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