Ain Shams Journal of Forensic Medicine and Clinical Toxicology
January 2014, 22: 14-23

Evaluation of the Toxic Health Hazards in Female Nurses Chronically Exposed to Anaesthetic Gases

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Abstract **Background:** Volatile anaesthetics are the major pollutants in operating and recovery rooms of hospitals; where the health care personnel are exposed. Serious health effects may result from chronic exposure to low levels of anaesthetic gases inhalation. **Aim of The study**: The study was carried out to investigate the possible hepatic, renal, haematological and immune parameters alterations in a group of workers chronically exposed to volatile anaesthetic gases compared to a non-exposed control group. **Subjects and Methods**: Twenty-two operating room female nurses were recruited. The control group consisted of twenty-two non-exposed similar for gender and age. Each subject examined for **Hepatic function**: [levels of liver transaminases (Aspartate Aminotransferase (AST), alanine aminotransferase (ALT), Gamma-glutamyltransferase (GGT) and total Bilirubin]; **Kidney function**: [Blood urea nitrogen (BUN), serum creatinine]; **Haematological profile** [complete blood count (CBC)] and **Immune phenotyping of peripheral blood lymphocytes** measured by flow cytometry**. Results**: The exposed group showed an increased prevalence of headache, asthenia, gastritis, mouth herpes, allergic reactions, rhinitis, hypertension, arrhythmia, menstrual disorders, abortion, and infertility compared to control group. The hepatic and kidney function markers were highly significantly increased in exposed group compared to control. In addition, a statistically significant decrease in total white blood cells count (WBCs), Neutrophils percentage and a significant increase in lymphocyte percentage were found compared to control group. Furthermore, Cytotoxic T cell (CD8+/CD4-) and natural killer cells (NK) (CD19-/CD56+) percentages increased significantly, While percentages of T helper (CD8- /CD4+) cells and B lymphocytes (CD19+/CD 56-) significantly decreased compared to control group. There were non- significant difference in red blood cells count (RBC), haemoglobin, and platelet count. **In conclusion** female nurses chronically exposed to low level waste anaesthetic gases developed hepatic, renal, haematological and immune parameters alterations.

Introduction

Health workers are occupationally exposed to a variety of biological, physical and /or chemical factors. In operating and recovery rooms of hospitals, volatile anaesthetics are the major pollutants, where the subjects are exposed to low doses, for long periods of time (Gwak et al., 2011).

Anaesthetic gases contaminate the operating room due to anesthetic techniques as: induction of general anesthesia by mask, poorly fitting face mask, drop of liquid anesthetic during filling vaporizer, inaccurately underinflated endotracheal tube or laryngeal mask and flushing anesthesia circuit of residual gases. In addition, anesthesia machine delivery system and scavenging system play a role as maladjustment of hospital system vacuum or leaks (high-pressure hoses, nitrous oxide tank mounting, carbon dioxide absorbent canisters, low-pressure circuit) (Pothmann et al., 1991 and Yasny and White, 2012). Moreover, the exposure often exceeds set safety limits, especially in the case of paediatric anaesthesia (Raj et al., 2003). Furthermore, Waste anesthetic gases are also distributed in the exhaled air of patients recovering from anesthesia in recovery room (Li et al., 2002). The most commonly used inhaled anesthetic agents include two different classes of chemicals: nitrous oxide and volatile halogenated agents as halothane, methoxyflurane, enflurane, isoflurane, desflurane and sevoflurane. Nitrous oxide is supplied in a gas form. The halogenated agents are supplied as a liquid, which is then vaporized by the anesthesia machine into a gaseous state prior to its delivery to the patient (Shiraishi and Ikeda, 1990).

Previously, several epidemiological studies stated that serious health effects may result from chronic exposure to low levels of anaesthetic gases inhalation (Burm, 2003, Nilsson et al., 2005 and Sahin et al., 2011). The currently used volatile anaesthetics are degraded into potentially toxic products, that may cause hepatotoxicity, nephrotoxicity, haematological changes (Caciari et al., 2013) , increased prevalence of deaths from pancreatic, lymphoid and reticular-endothelial malignancies (Guirguis et al., 1990), peripheral neuropathy(Biró and Tompa, 2013), multiple sclerosis (Landtblom et al., 2006), impairment of fertility, spontaneous abortion and congenital defects (Shirangi et al., 2009 and Teschke et al.,2011).

Although volatile anesthetics have been used for more than a century, their mechanisms of toxicity remain poorly understood, so it is a hot topic of research (Gross and Stern, 2014). Many studies supported the existence of oxidative DNA damages in lymphocytes of subjects exposed to nitrous oxide, halothane and isoflurane (Baysal et al., 2009, Izdes et al., 2010 and Wrońska-Nofer et al., 2012). In addition, previous experimental studies have unveiled the effect of anaesthetic gases on various immune parameters (Puig et al., 2002 and Colucci et al., 2003). In vitro exposure of human lymphocytes to anaesthetic gases such as halothane, isoflurane, enflurane and nitrous oxide decreased immune cell functions in a dose-dependent manner (Welch, 1984 and Woods and Griffiths, 1986). In anaesthetised patients during the postoperative period, Suppression of immune defence has been frequently reported. However, the results are transient, both inhaled and intravenous anaesthesia were given, and immune suppression may be a combined effect of surgery stress and anaesthesia (Inada et al.,2004; Ahlers et al., 2008 and Liu et al., 2011).

Many studies have investigated the immunological status of health workers chronically exposed to volatile anaesthetics in operating theatres (Bargellini et al., 2001, Casale et al., 2013 and Biró and Tompa, 2013). Indeed, studies are not easily comparable due to the heterogeneity of exposed groups, considerable differences in gas type and levels, a great variability in immune parameters examined and the methodology of the studies. Many aspects of the immune response have been evaluated with contradictory results, some studies have not found any changes in the investigated immune parameters (Karakaya et al., 1992) and both inhibition and stimulation have been reported depending on the cell type or function (Urner et al., 2011). In addition, Confounding factors related to lifestyles, namely smoking and alcohol consumption altered the measured immune parameters (Biró and Tompa, 2013).

Therefore, the aim of this study is to investigate the possible hepatic, renal, haematological and immune parameters alteration in a group of workers chronically exposed to anaesthetic gases compared to a control group of non-exposed subjects.

Materials and Methods

Subjects

The study was carried out on twenty-two operating room female nurses, who chronically exposed to waste anaesthetic gases without protective measures. Their results were compared to twenty-two healthy controls, not occupationally exposed to known substances, at Ain Shams University Hospitals. After institutional and ethical committee approval a preliminary meeting was organised to explain the purpose of the study, to answer questionnaire questions and informed consent from all exposed and control subjects were taken.

The questionnaire included information on age, smoking habit, alcohol consumption, type of anaesthetic gases and duration of exposure, exposure to X-rays, pre-occupational or current history of liver, renal, haematological, neurological, cardiovascular, reproductive and immunological disorders and intake of medications and contraceptive pills. The anaesthetic gases mainly used in the operating rooms were: (sevoflurane, isoflurane mixed with oxygen), in addition they were previously exposed to halothane and nitrous oxide, in past years.

In order to avoid the influence of the confounding factors, which could alter the immune parameters, all nurses are female and those older than 50 years were excluded (Peric et al., 1994 and Marttila et al., 2013). Moreover, subjects were excluded if they were active smokers (Biró and Tompa, 2013), exposed to X-rays (Caciari et al., 2012), alcohol drinkers (Romeo et al., 2007 and Burnham et al., 2013) or having pre-employment history of hepatic, renal, blood diseases or recent infection.

Laboratory parameters

A 10 ml venous blood sample was taken from each nurse and control subjects. The samples were processed to assess:

Hepatic parameters

Levels of liver transaminases (aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma-glutamyltransferase (GGT) were determined by colorimetric method according to Frankel and Gradwohl (1970) and total bilirubin was measured according to Suber (1994).

Kidney parameters

Blood urea nitrogen (BUN) and serum ceatinine were measured by colorimetric method according to Lawrence and Robert (1993). The assay kits were purchased from Alkane Company.

Haematological profile

Complete Blood Count (CBC) using coulter counter model M450 (coulter Electronics Ltd, Australia).

Immune phenotyping of peripheral blood lymphocytes by flow cytometry

1 ml blood was mixed with EDTA. 100 µl of the blood sample was taken and divided in two Wassermann tubes, 50 µl in each, the tubes were incubated in dark at room temperature for 20 minutes with 5 µl of

monoclonal antibodies against surface antigens, and these monoclonal antibodies were labelled with Fluorescein Isothiocyanate (FITC) and Phycoerythrin (PE). The erythrocytes were removed by Lysing solution (Ammonium chloride based) incubated for 5-10 minutes in dark at room temperature. After washing with Phosphate Buffered Saline (PBS), a suspension with 500 µl of PBS was made and samples were analyzed within 4 hours after labelling. The studied antigens were: Helper T cells (CD4+), cytotoxic T cells (CD8+), Natural killer (NK) cells (CD 56+) and B lymphocytes (CD19+). The following monoclonal antibody combinations were used: in the first tube, CD4- FITC / CD8-PE; and in the second tube CD19-FITC / CD56. Helper T cells were characterized by CD8- /CD4+ phenotype, cytotoxic T cells by CD8+/CD4- phenotype, NK cells as CD19-/CD56+ phenotype and B lymphocytes were characterized as CD19+/CD 56- cells. Phenotypes are expressed as percentage of positive cells of a given lymphocyte subpopulation. All analysis was performed on a COULTER EPICS XL-MCL Flow Cytometry SYSTEM II Software (COULTER CORPORATION, Miami, Fl, USA).

Statistical analysis

Using PASS (power and sample size), it was calculated that a sample size of twenty-two per group will achieve 80% power to detect a mean difference between the exposed and control group with a significance level (alpha) of 0.05 using a two-sided two-sample t-test. The statistical analysis was performed using a standard SPSS (Statistical Package for Social Science) software package, version 17 (Chicago, IL). Data were expressed as (mean ± SD), numbers (%). Student's t-test was used to analyze the parametric data, and discrete variables were analyzed using chi-square test (χ^2), with $p < 0.05$ considered statistically significant (Taylor, 1990).

Results

Age of exposed nurses ranged from 31 to 40 years with mean 35.3 ± 4.6 years and the duration of exposure to anaesthetic gases ranged from 8 to 12 years with mean 9.8 ± 3.1 years. The control group was similar for gender and age.

After analysis of the questionnaire, an increased prevalence of headache (54.5 %), asthenia (41 %), gastritis (45.5 %), mouth herpes (22.7 %), allergic reactions (9.1 %), rhinitis (45.5 %), hypertension (18.1%), arrhythmias (31.8%), menstrual disorders (45.4%), abortion (18.2 %) and infertility (13.6%) appears in exposed groups compared to controls Table (1).

The blood levels of AST, ALT, GGT, and total Bilirubin, BUN, and creatinine were highly significantly increased in exposed group compared with the control group (Table 2 and 3).

Regarding CBC, there were non- significant difference in RBC count, Hb level, and platelet count in exposed compared to control group. While, a very highly significant decrease in total WBCs count, significant decrease in neutrophils percentage and significant increase in lymphocyte percentage was found in exposed group compared to control group as shown in Table (4).

As regard lymphocytes differential count: Cytotoxic T cell (CD8+/CD4-) percentage significantly increased and NK cells (CD19-/CD56+) percentage very highly significantly increased, while percentages of T helper (CD8- /CD4+) cells and B lymphocytes (CD19+/CD 56-) significantly decreased in exposed group compared to control group as shown in (Table 5) and (figures 1,2,3).

Table 1: Chi-square test comparing some health disorders in the control and exposed groups.

	Control Group n (%)	Exposed Group n (%)	p
Headache	3(13.6%)	12(54.5 %)**	<0.01
Asthenia	2(9.1 %)	9(41 %)*	<0.05
Gastritis	1(4.5%)	10(45.5%)*	<0.05
Mouth herpes	1(4.5%)	5(22.7 %)**	<0.01
Allergic reactions	0%	2(9.1 %)*	<0.05
Rhinitis	2(9.1%)	10(45.5 %)*	<0.05
Hypertension	3(13.6%)	4(18.1%)	>0.05
Arrhythmia	1(4.5%)	7(31.8%)*	<0.05
Menstrual disorders	1(4.5%)	10(45.4%)***	<0.001
Abortion	2(9.1%)	4(18.2 %)**	<0.01
Infertility	0%	3(13.6%)*	<0.05

**p < 0.05=statistically significant; **p < 0.01= highly significant; ***p < 0.001=very highly significant; p >0.05 = statistically non- significant.*

Table 2: Student's *t*-test comparing hepatic parameters [aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma-glutamyltransferase (GGT), and total Bilirubin] between the control and exposed groups.

Parameter	Control Group (n=22)	Exposed Group (n=22)	P
AST IU/L (Mean ±SD)	21.0±9.1	37.5±16.4***	<0.001
ALT IU/L (Mean ±SD)	28.1±7.6	41.3± 15.9***	<0.001
GGT IU/L (Mean ±SD)	26.75±21.30	38.4± 20.11***	<0.001
Total Billirubin mg/dl (Mean ±SD)	0.7±0.14	0.9±0.21*	<0.05

**p < 0.05=statistically significant; ***p < 0.001=very highly significant; SD=standard deviation.*

Table 3: Student's *t*-test comparing kidney parameters [blood urea nitrogen (BUN) and creatinine] between the control and exposed groups.

Parameter	Control Group (n=22)	Exposed Group (n=22)	P
BUN mg/dl (Mean ±SD)	20.6±8.1	35.9±14.7***	<0.001
Creatinine mg/dl (Mean ±SD)	0.6± 0.4	1.1±0.3*	< 0.05

**p < 0.05=statistically significant; ***p < 0.001=very highly significant; SD=standard deviation.*

Table 4: Student's *t*-test comparing haematological parameters [red blood cells count (RBCs), Haemoglobin (Hb), platelets count, total white blood cells count (WBCs), neutrophils percentage and lymphocytes percentage] between the control and exposed groups.

Parameter	Control Group (n=22)	Exposed Group (n=22)	P
RBC/mm³ (Mean ±SD)	5.1±0.7	4.9 ±0.9	>0.05
Hb g/dl (Mean ±SD)	12.0±0.92	11.5±1.22	>0.05
Platelets/mm³ (Mean ±SD)	313.54±17.6	306.77±16.25	>0.05
WBC/mm³ (Mean ±SD)	8.6±2.3	6.5±1.6***	<0.001
Neutrophils% (Mean ±SD)	62.0±3.85	52.3±7.1*	< 0.05
Lymphocytes% (Mean ±SD)	29.85 ±7.95	35.49±8.18*	< 0.05

**p < 0.05=statistically significant; **p < 0.01= highly significant; ***p < 0.001=very highly significant; p >0.05 = statistically non- significant; SD=standard deviation.*

Table 5: Student's *t*- test comparing percentages of total lymphocytes and lymphocyte subpopulations [T helper (CD8- /CD4+), cytotoxic T cells (CD8+/CD4-), the natural killer (NK) (CD19-/CD56+) and B lymphocytes (CD19+/CD 56-)] between the control and exposed groups.

Parameter	Control Group (n=22)	Exposed Group (n=22)	P
Total lymphocytes % (Mean±SD)	29.85 ±7.95	35.49 ±8.18*	< 0.05
Helper T cells (CD4) % (Mean±SD)	38.63± 2.12	30.32± 3.05*	< 0.05
Cytotoxic T cells (CD8+)% (Mean±SD)	33.64±1.8	40.5±4.15*	< 0.05
Natural killer (NK) cells (CD 56+)% (Mean±SD)	12.64± 0.95	18.91± 2.29***	<0.001
B lymphocytes (CD19+)% (Mean±SD)	5.93± 0.31	4.96±0.48*	< 0.05

**p < 0.05=statistically significant; ***p < 0.001=very highly significant; SD=standard deviation.*

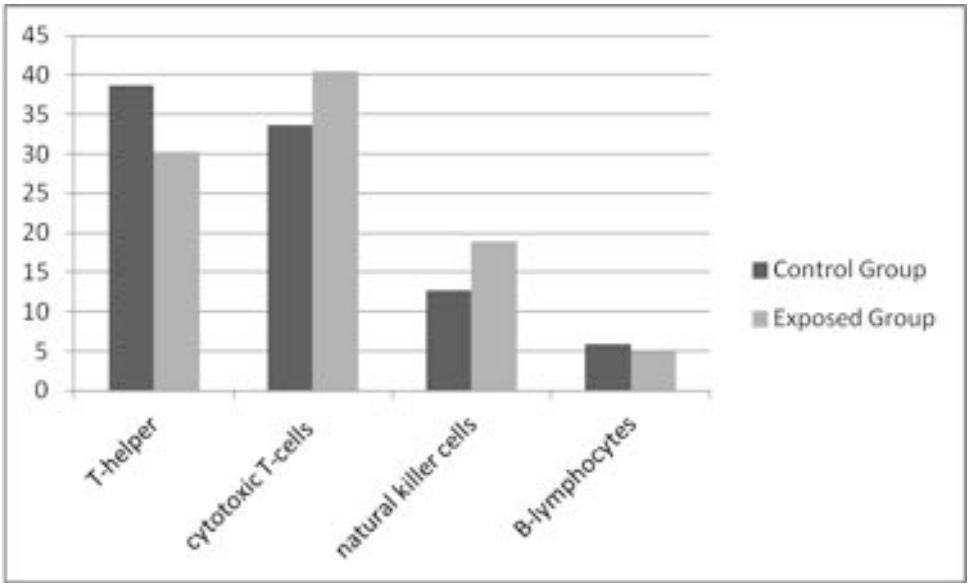

Figure 1: mean percentage of T-helper cells, cytotoxic T cells, natural killer cells and B lymphocytes between the control and exposed groups.

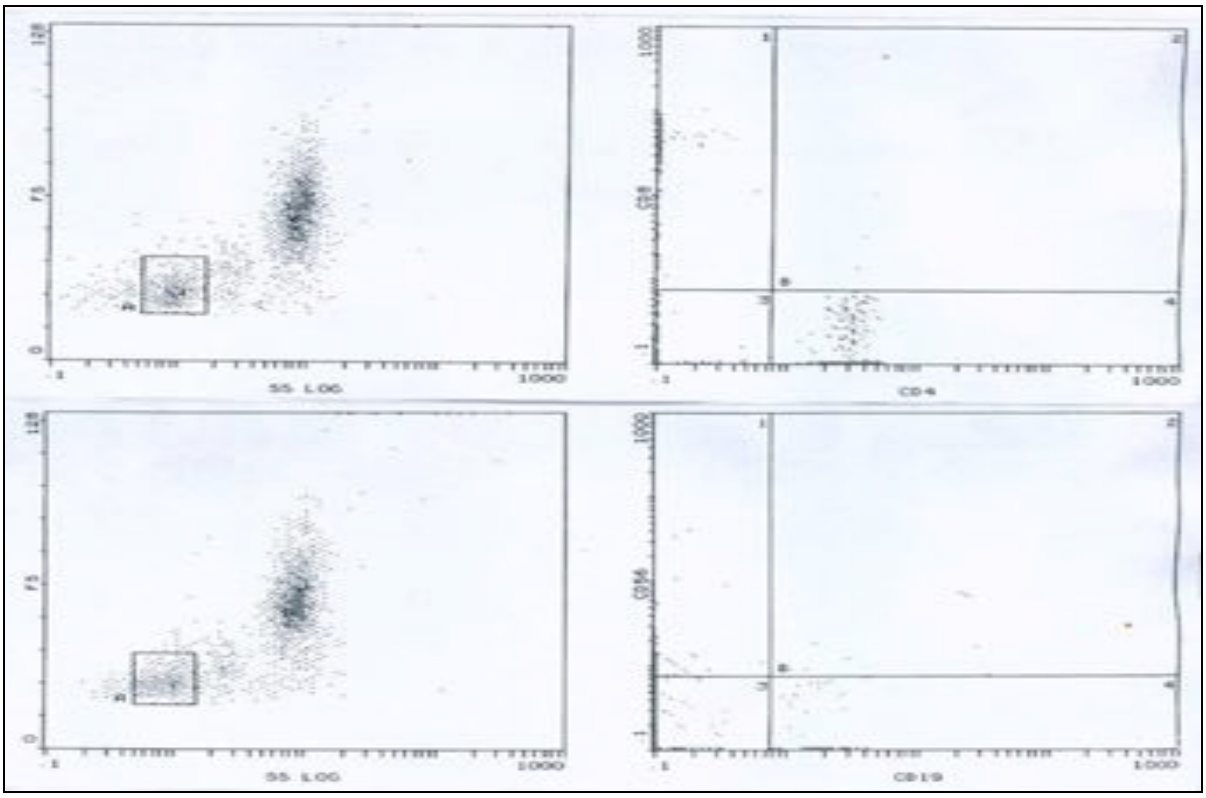

Figure 2: Flow cytometry report of a control showing gating of the lymphocytes followed by detection of the percentage of different type of cells; T cytotoxic cell (CD8+, CD4-) 36.0%, T helper cell (CD8-, CD4+) 41.4 %, Natural killer cell (CD 56+,CD 19-) 12.4 % and B lymphocyte (CD 56-, CD 19+) 7.42 %.

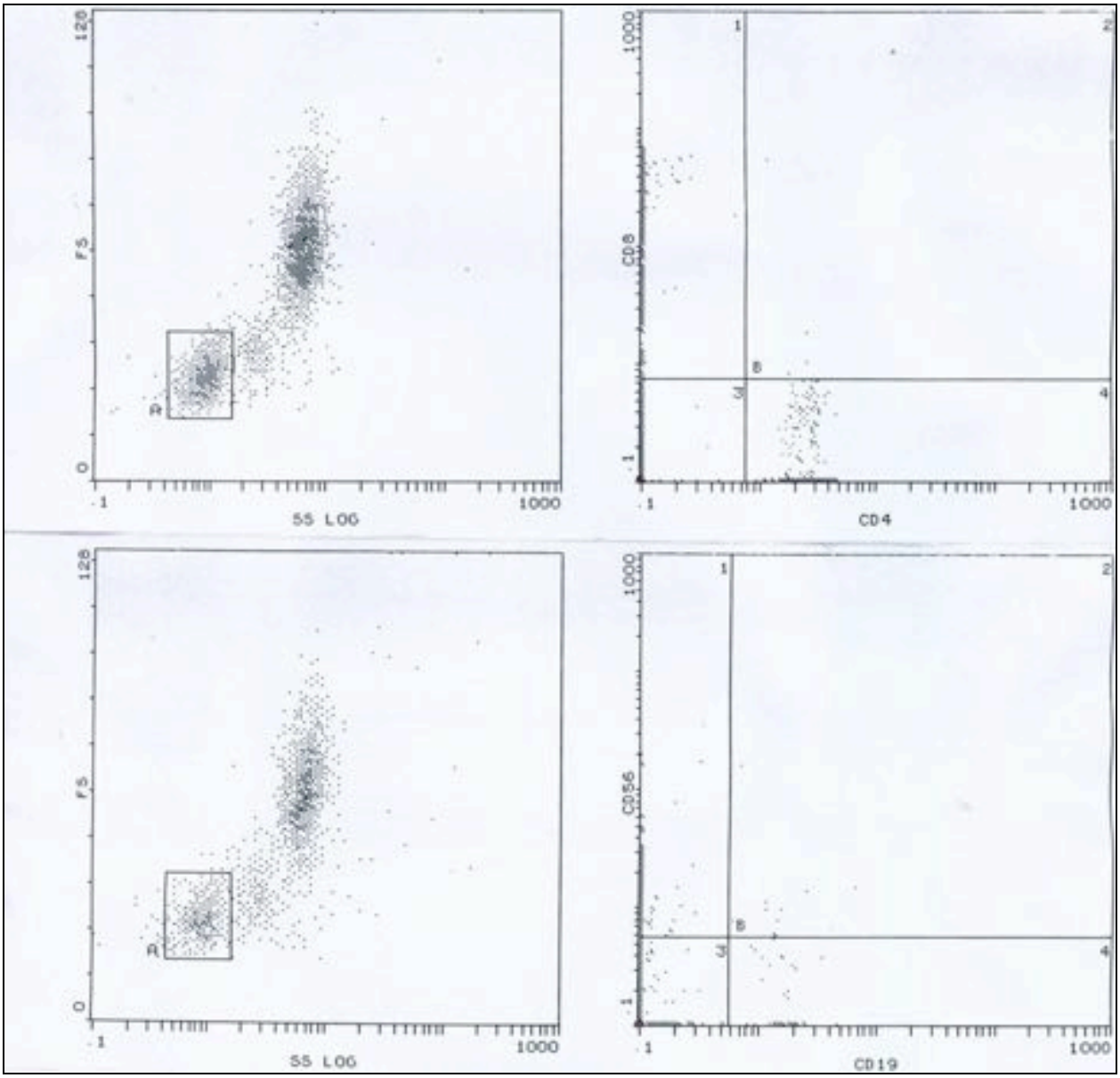

Figure 3: Flow cytometry report of anaesthetic exposed case showing gating of the lymphocytes followed by detection of the percentage of different type of cells; T cytotoxic cell (CD8+, CD4-) 39.9%, T helper cell (CD8-, CD4+) 27.9%, Natural killer cell (CD 56+,CD 19-) 32.4 % and B lymphocyte (CD 56-, CD 19+) 3.66 %.

Discussion

After analysing the questionnaire, the exposed personnel showed significant increase in prevalence of headaches, asthenia, gastritis, mouth herpes, allergic reactions, rhinitis, hypertension, arrhythmia, menstrual disorders, abortion and infertility compared to the control group. These results were in agreement with Tannenbaum and Goldberg (1985), Talamanca (2000) and Patelarou et al. (2012). Previously, a study of Lucchini et al. (1996) proved that chronic exposure to low levels of anaesthetic gases causes an impairment of neurobehavioral performance, which was explained by interference with the dopaminergic system. Generally volatile anaesthetics cause formation of reactive oxygen species that could be involved in pathogenesis of reproductive, cardiovascular, neurological, immune and pulmonary toxicities (Kovacic and Somanathan, 2011).

The present study showed altered liver and kidney parameters in exposed nurses compared with controls. These results were in agreement with previous experimental studies where the presence of hepatotoxicity and nephrotoxicity by sevoflurane and isoflurane has been detected in animals (Gonsowski et al., 1994, Kandel et al., 1995 and Arici et al., 2013). On the other hand, Elena et al. (2003) observed that sevoflurane-treated animals showed no evidence of histological changes or alteration in hepatic or renal function. Other studies on patients and health care workers exposed to different anaesthetic gases, statistically significant increases in AST, ALT, GGT, total bilirubin and serum creatinine has been demonstrated (Sahin et al., 2011, Toprak et al., 2012, Caciari et al., 2013 and Casale et al., 2013).

The liver is one of the main body organs performing drug metabolism. Hepatic cells, during their

metabolic functions, continuously produce reactive oxygen species. They are reduced to other forms of oxygen by mitochondria; this process may be deficient in non healthy liver or when the liver is exposed to an extraordinary unwanted burden of toxins (Gottschalket et al., 2012). This oxidant damage would disturb many parts of the cell structure in hepatocytes leading to apoptosis (Malhi and Gores, 2008). During the recent years, it has been demonstrated in a great number of studies that most current anaesthetic volatile agents (like halothane, isoflurane, desflurane and sevoflurane), have been labelled as having apoptotic properties in animal studies, exerting their effect in a dose-dependent manner (Dabbagh and Rajaei , 2013).

Furthermore, for unknown reasons the liver proteins altered by anaesthetic gases, seem to be seen as non-self by the immune system of the patient. This process may induce an auto-lymphocyte-mediated immune reaction against the liver (Martin, 2005). That was demonstrated previously by the presence of significantly elevated levels of lymphocytes and auto-antibodies associated with hepatic injury in a group of paediatric female anaesthetists (Njoku et al., 2002).

These results are in agreement with the present study Immune-phenotyping results; that showed a highly significant decrease in total WBCs count and neutrophils percent. While a significant increase in percentages of total lymphocytes cells was observed. Percentage of cytotoxic T cell and NK increased significantly. While percentages of T helper cells and B lymphocytes significantly decreased in exposed group compared to control group.

The role of the cytotoxic T cell is to monitor all the cells of the body, ready to destroy any cell considered a threat to the integrity of the host; for example, cytotoxic T cells kill virally infected cells, preventing them from being the source of more viral pathogen. Moreover, they are thought to provide some degree of protection against spontaneous malignant tumours, by virtue of their ability to detect quantitative and qualitative antigenic differences in transformed cells (Andersen et al., 2006). As regard the role of NK cells, they are analogous to cytotoxic T cells as they provide rapid responses, in the absence of antibodies and major histo-compatibility complex, to virally infected cells and respond to tumour formation. This role of NK cells is critical for immune success particularly because T cells are unable to recognize pathogens in the absence of surface antigens. Tumour cell detection results in activation of NK cells and consequent cytokine production and release (Poggi and Zocchi , 2014).

Available literature data regarding immunotoxicityare are relatively scarce and conflicting. In accordance, Casale et al. (2013) study on exposed workers showed that the lymphocytes percentage was above the normal range and values of neutrophils granulocytes was below the normal range. In addition, Bargellini et al. (2001) study of chronic exposure to trace amounts of Nitrous oxide and Isoflurane in a group of relatively young anaesthetists, showed decrease of percentages of T helper lymphocytes, while neither other lymphocyte subpopulations nor cytotoxic activity of NK cells was affected by the exposure to anaesthetic gases . In Bargellini's study the observed imbalance in immune cell composition may be regarded as the result of an exposure which was not heavy, due to the scavenging systems of the theatres, and was limited to nitrous oxide and isoflurane, two of the less toxic anaesthetic gases.

Furthermore, Biró and Tompa (2013) examined the health personnel exposed to anaesthetic gases and found a significant elevation of activated cytotoxic T cells and the activation of lymphocytes in exposed personnel without protective measures compared to personnel with protective measures. Moreover, in anaesthetic personnel who previously exposed to very high concentrations of halothane and nitrous oxide, B lymphocytes numbers and percentages decreased significantly, T helper lymphocyte percentage were increased significantly and NK cells percentage decreased significantly during exposure (Peric et al.,1991). Indeed, T helper lymphocytes have a prominent action on B cell activation, and their depletion could be followed by a progressive suppression in B cell number and activity (Bargellini et al., 2001). On the other hand, other reports could not find any effect on lymphocyte counts (Atallah et al., 1991 and Karakaya et al., 1992). These studies and the present one, show that the exposing agent and the exposure level cause the differences in findings.

In conclusion, female nurses chronically exposed to low levels of waste anaesthetic gases developed hepatic, renal, haematological and immune parameters alterations.

It is recommended to minimise occupational exposure by usage of suitable protective measures, thus effectively preventing delayed effects on health. Further studies are needed for determining the appropriateness of periodic check-ups of immune functions and the most efficient and cost-effective ways of monitoring immune functions in health workers exposed to anaesthetic gases for detecting early changes in the immune system.

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الملخص العربي

تقييم المخاطر الصحية السمية الناتجة من تعرض الممرضات المهني المزمن للغازات المخدرة

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الخلفية: تعتبر غازات التخدير من الملوثات الرئيسية في غرف العمليات وغرف الإنعاش في المستشفيات، حيث يتعرض العاملون لجرعات منخفضة من غازات التخدير لفترات طويلة من الوقت. و قد يؤدي ذلك لأضرار صحية خطيرة آثر التعرض المزمن لمستويات منخفضة من استنشاق غازات التخدير.والهدف من هذه الدراسة هو التحقق من احتمالات التأثيرات على الكبد والكلى و الدم و المناعة في مجموعة من العاملين بالرعاية الصحية المعرضين لغازات التخدير مقارنة بالمجموعة الضابطة للعاملين الغير معرضين لغازات التخدير. **الطريقة**: تمت مقارنة نتائج عدد ٢٢ ممرضه عمليات من المعرضات لغازات التخدير بالمجموعة الضابطة المكونة من ٢٢ ممرضه من الأصحاء غير المعرضات في عملهن لغازات التخدير في نفس السن والنوع. وخضعت كل عامله لعمل اختبار مستويات إنزيمات الكبد ووظائف الكلى و تعداد خلايا الدم الكامل وتحليل نوعي للخلايا الليمفاوية المناعية في الدم بطريقة التدفق الخلوي. **النتائج**: أظهرت المجموعة المعرضة زيادة انتشار الصداع و الوهن و التهاب المعدة و هربس الفم و الحساسية و حساسية الأنف و ارتفاع ضغط الدم و عدم انتظام ضربات القلب و اضطرابات الدورة الشهرية والإجهاض والعقم مقارنة بالمجموعة الضابطة. أثبتت وظائف الكبد ووظائف الكلى زيادة إحصائية كبيرة في المجموعة المعرضة مقارنة بالمجموعة الضابطة.كما أثبت تعداد خلايا الدم الكامل نقصا إحصائيا ملحوظا في عدد كرات الدم البيضاء و انخفاض النسب المئوية لخلايا النيوتروفيل و زيادة النسب المئوية للخلايا الليمفاوية في المجموعة المعرضة مقارنة بالمجموعة الضابطة. كما أثبتت الدراسة زيادة إحصائية كبيرة في النسب المئوية لنوع الخلايا الليمفاوية المناعية T NK cells (CD19-/CD56+) وكذلك خلايا Cytotoxic T (CD4+CD8/) في المجموعة المعرضة مقارنة بالمجموعة الضابطة، بينما انخفضت النسب المئوية لنوع الخلايا الليمفاوية المناعية T helper (CD8- /CD4+) cells and B lymphocytes CD19+/CD 56-) إلى حد كبير في المجموعة المعرضة مقارنة بالمجموعة الضابطة. بينما لم يتواجد فروق ملحوظة في عدد كرات الدم الحمراء أو الهيموجلوبين أو الصفائح الدموية. **الاستنتاج**: تشير النتائج إلى أن تعرض الممرضات المهني المزمن لجرعات منخفضة من غازات التخدير يمكن أن يحدث أثرا سميا في بعض القياسات الكبدية والكلوية والدموية و المناعية.

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