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REVIEW ARTICLE

Exposição Ocupacional a Resíduos de Gases Anestésicos*

Occupational Exposure to Anesthetic Gases Residue

Carlos Rogério Degrandi Oliveira, TSA[1]

RESUMO
Oliveira CRD — Exposição Ocupacional a Resíduos de Gases Anestésicos.

JUSTIFICATIVA E OBJETIVOS: *Embora existam relatos negativos quanto aos efeitos da exposição prolongada a resíduos de gases anestésicos, há ainda muitas controvérsias. Dados contraditórios são encontrados na literatura, considerando-se a variabilidade nas respostas individuais a diferentes agentes. O objetivo deste trabalho foi apresentar revisão sobre a exposição ocupacional aos resíduos de gases anestésicos.*

CONTEÚDO: *São discutidos os resultados dos principais artigos sobre o tema, assim como causas de contaminação do ambiente cirúrgico, ventilação, exaustão, monitoração e dosagem dos resíduos de gases anestésicos. É dada ênfase às recomendações para a minimização dos efeitos imputados aos agentes inalatórios.*

CONCLUSÕES: *Mesmo nos trabalhos das forças-tarefas de renomadas instituições reguladoras internacionais nota-se certo grau de controvérsia sobre os efeitos da exposição ocupacional a resíduos de gases anestésicos. Observa-se estipulação de valores máximos para exposição ocupacional, porém com reconhecimento de que não existem indícios epidemiológicos de qualquer tipo de dano causado pela exposição a concentrações de gases anestésicos em locais onde as medidas-padrão de ventilação, exaustão e uso de equipamentos anestésicos estejam sendo observadas. No nosso meio essas medidas, na maioria das vezes, não são implementadas e quando o são, não corretamente fiscalizadas. Além disso, há que considerar diferenças entre as técnicas utilizadas e as condições de trabalho. Levando-se em conta a natureza multifatorial da exposição de profissionais da saúde, medidas devem ser tomadas para minimizar a exposição ocupacional aos agentes com conhecido ou provável potencial tóxico. A reivindicação por salas cirúrgicas mais bem equipadas, com sistemas de ventilação e exaustão adequados, bem como sua manutenção devem ser incentivadas.*

Unitermos: ANESTÉSICOS, Gasoso, Volátil; COMPLICAÇÕES: contaminação, poluição ambiental, risco profissional.

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1. Co-Responsável pelo CET da Santa Casa de Misericórdia de Santos; Membro da Comissão de Normas Técnicas e Segurança em Anestesia da Sociedade Brasileira de Anestesiologia; 2° Secretário da Sociedade de Anestesiologia do Estado de São Paulo

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*Endereço para Correspondência (**Correspondence to**):*
Dr. Carlos Rogério Degrandi Oliveira
Praça Dr. Hipólito do Rego, 7/11 — Embaré
11045-310 Santos, SP
E-mail: degrandi@bol.com.br

SUMMARY
Oliveira CRD — Occupational Exposure to Anesthetic Gasses Residue.

BACKGROUND AND OBJECTIVES: *Although the absence of negative effects of prolonged exposure to anesthetic gases residue has been reported, controversies on the subject still linger. Contradictory data on the variability in individual response to different agents can be found in the literature. The objective of this report was to present a review of occupational exposure to anesthetic gases residue.*

CONTENTS: *The results of the main articles on the subject, as well as the causes of contamination of the surgical environment, ventilation, exhaust system, monitoring, and dosage of anesthetic gases residues are discussed. Recommendations to minimize the supposed effects of inhalational agents are emphasized.*

CONCLUSIONS: *Even in task-forces studies of renowned international regulating institutions, there are some controversies on the risks of occupational exposure to anesthetic gases residue. Minimal values for occupational exposure are stipulated, but acknowledging the lack of epidemiological evidence of any type of damage caused by said exposure in places where standard measures of ventilation and exhaust systems and the use of anesthetic equipment are observed. In our country, most of the time those measures are not implemented and, when they are, they are not supervised properly. Besides, differences in techniques and working conditions have to be considered. Taking into consideration the multifactorial nature of the exposure of health care professionals, measures should be undertaken to minimize occupational exposure to agents with known or probable toxic potential. The demand for better equipped operating rooms, with adequate ventilation and exhaust systems as well as their maintenance should be stimulated.*

Key Words: ANESTHETICS, Gaseous, volatile; COMPLICATIONS: contamination, environmental pollution, professional hazards.

INTRODUÇÃO

As demonstrações convincentes das propriedades anestésicas do éter dietílico por William T.G. Morton, em 1846, foram consideradas os eventos mais significativos da história da Medicina. Pouco tempo depois o óxido nitroso e o clorofórmio também foram introduzidos e esses três anestésicos permaneceram na prática clínica por quase um século como opções únicas em anestesia inalatória. Em 1933, o ciclopropano e, em 1934, o tricloroetileno foram introduzidos no mercado e, posteriormente, uma série de anestésicos inalatórios halogenados. Desde os primórdios da anestesia o perigo dos anestésicos inalatórios tanto para o paciente quanto para as equipes cirúrgicas é conhecido. Ocasional-

A Holanda tem limite de 25 ppm para o óxido nitroso. A Itália, Suécia, Noruega e Dinamarca ajustaram para 100 ppm o nível de exposição limite para o óxido nitroso. As diferenças ilustram a dificuldade em ajustar padrões sem dados adequados [42].

O tratamento dado pela legislação trabalhista brasileira ao assunto específico é omisso, não havendo nenhuma menção aos valores limites para exposição ocupacional aos gases anestésicos, tampouco recomendações a respeito de como proceder à monitoração ambiental ou sua periodicidade. A NR 15 (Norma Regulamentadora sobre atividades e operações insalubres) estipula alguns valores para exposição ocupacional a gases e vapores tóxicos, porém o único gás anestésico mencionado é o óxido nitroso, que é limitado apenas em doses asfixiantes. A NR32 (Norma Regulamentadora de segurança e saúde no trabalho em estabelecimentos de assistência à saúde) do Ministério do Trabalho é a que trata mais diretamente do assunto e mesmo em seus tópicos mais específicos ainda pode ser considerada pouco clara no que concerne ao tema. No entanto, dispõe que toda trabalhadora gestante só será liberada para o trabalho em áreas com possibilidade de exposição a gases ou vapores anestésicos após autorização por escrito do médico responsável pelo Programa de Controle Médico de Saúde Ocupacional (PCMSO), considerando as informações contidas no Programa de Prevenção de Riscos Ambientais (PPRA) [43]. Mesmo nos arquivos da força-tarefa da ASA dedicada ao tema nota-se certo grau de controvérsia na medida em que se observa a estipulação de valores máximos para exposição ocupacional, porém com o reconhecimento de que não há indícios epidemiológicos de qualquer tipo de dano causado pela exposição a concentrações de vapores/gases anestésicos em locais onde as medidas-padrão de ventilação, exaustão e uso de equipamentos anestésicos estejam sendo observadas. No nosso meio o grande problema é que essas medidas na grande maioria das vezes não são realizadas e, quando o são, não são fiscalizadas. Além disso, há que considerar as diferenças entre as técnicas utilizadas e as condições de trabalho. Assim, os profissionais estão expostos a uma quantidade variável de gases anestésicos, por períodos também variáveis.

Também os procedimentos radiológicos, o estresse, as longas horas de exposição aos produtos de limpeza usados na área cirúrgica são fatores que podem atingir o anestesiologista. Além disso, muitos compostos, incluindo álcool, fármacos e poluentes ambientais, podem agir como indutores de enzimas hepáticas, que podem determinar graves problemas.

Levando-se em conta a natureza multifatorial da exposição de profissionais da saúde, medidas devem ser tomadas para minimizar a exposição ocupacional a agentes químicos com conhecido ou provável potencial tóxico. Assim sendo, é possível prevenir, de forma efetiva, a ocorrência de efeitos danosos à saúde em tais profissionais. A reivindicação por salas cirúrgicas mais bem equipadas, com sistemas de ventilação e exaustão adequados, bem como sua manutenção, deve ser seguida [44].

Occupational Exposure to Anesthetic Gases Residue

Carlos Rogério Degrandi Oliveira, TSA, M.D.

INTRODUCTION

Convincing demonstrations of the anesthetic properties of diethyl ether by William T. G. Morton in 1846 were considered the most significant event in the history of medicine. Soon after, nitrous oxide and chloroform were also introduced, and those three anesthetics were used in clinical practice for almost a century as the only options of inhalational anesthesia. Cyclopropane and trichloroethylene were introduced in the market in 1933 and 1934, respectively, followed by a series of halogenated inhalational anesthetics. Since the beginning of anesthesia the dangers of inhalational anesthetics, both to patients and the surgical team, are known. Occasionally, patients develop toxicities, such as liver failure, after the use of chloroform, and the surgical teams were exposed to the risk of fire and explosion secondary to the use of ether and cyclopropane. Reports at that time showed that professionals exposed to surgical rooms with large amounts of anesthetic residues had chronic problems with multiple symptoms. In 1967, Vaisman published the results of a study conducted in the former Soviet Union, which evaluated health exams of 198 male and 110 female anesthesiologists [1]. They all used diethyl ether, nitrous oxide, and halothane in their daily practice. Again, a high incidence of symptoms like headache, fatigue, and irritability was noticed but, for the first time, adverse effects on human reproduction were analyzed. Eighteen of 31 pregnancies in the group of female anesthesiologists resulted in spontaneous abortion. That same year, Fink et al. demonstrated that nitrous oxide had adverse effects on mammal reproduction [2]. Rats, in particular, exposed to high concentrations of nitrous oxide had a high incidence of skeletal abnormalities. Although Vaisman did not include a control group and careful epidemiological analysis, his work along with the work of Fink inspired other studies on the adverse effects of anesthetic gases residue.

In 1981, the American Society of Anesthesiologists (ASA) published the booklet “Waste Anesthetic Gases in Operating Room Air: a Suggested Program to Reduce Personnel Exposure”, written by the ASA *ad hoc* committee on the effects of anesthetic gases residues on the health of operating room personnel [3].

Currently, the anesthesiology field in Brazil lacks studies and standards regulating this subject. The objective of this work was to present a review of occupational exposure to anesthetic gases residues and propose appropriate conducts based on the studies available in the literature.

MUTAGENIC EFFECTS AND ORGANIC TOXICITY

Despite negative reports on the mutagenic effects of anesthetic gases, the issue is still surrounded by controversies. Contradictory data, considering the variability of individual responses to different inhalational anesthetics, are found in the literature.

The results of those studies could be related to other environmental factors and not necessarily to exposure to anesthetic gases residues.

Some studies concluded that the inhalational anesthetics used currently are not potentially mutagenic [4,5]. Only the oldest anesthetics, such as trichloroethylene, fluroxene, and chloroform showed carcinogenic potential in rodents when administered in high concentrations [6,7].

Besides information on the carcinogenic potential, long-term studies on carcinogenesis provided researchers with resources and opportunities to evaluate toxicity in specific organs after chronic exposure to inhalational anesthetics. Even in the maximum tolerated dose, isoflurane, halothane, enflurane, and nitrous oxide did not show evidence of significant clinical or pathological damage of kidneys, liver, gonads or other organs [8-15]. Most significant studies in mammals were discussed in a large review [13]. In general, only nitrous oxide seems to be teratogenic experimentally. Elevated concentrations (50% to 75%) for 24 hours in pregnant mice during the period of organ formation and low concentrations (0.1%) in mice throughout pregnancy increased the incidence of visceral and skeletal abnormalities [14]. It is unlikely that those conditions would ever be reproduced in humans.

EPIDEMIOLOGIC STUDIES IN HUMANS

Since the 1967 Vaisman report, several studies involving laboratorial exams of operating room professionals were conducted. The focus of those exams was always on the effects in the reproductive system and carcinogenesis, although other risks, such as liver and renal disorders were evaluated occasionally. Those studies seem to favor the possibility that the work in operating rooms represents an occupational risk. The most notable and influential study was conducted by the ASA, in 1974, on the effects of residual levels of anesthetic gases on individuals who worked continuously in operating rooms [16]. Approximately 73,000 members of different professional organizations including the ASA and the American Pediatric Academy were examined. Compared to women that were not exposed, women who had been exposed to anesthetic gases residues had an increased risk of spontaneous abortions, cancer, and liver and renal diseases, and their children had an increased risk of congenital abnormalities. Male anesthesiologists had an increased risk of liver disease and their children had an increased risk of congenital abnormalities. During the following decade, additional studies were undertaken. The results were somewhat consistent; some of them supported and others refuted occupational risks.

In light of the inconsistencies and different interpretations of the results, a commission of the ASA gathered epidemiologists and biostatisticians to evaluate the meaning of the studies on the risks of exposure to anesthetic gases. The report of the commission was published in 1985 as a special article on Anesthesiology [17]. Burning et al. analyzed 17 studies. After excluding studies without proper methodology, the remaining six studies were included in the result of the meta-analysis [18-22]. They indicated an increased risk, of up to 30%, of spontaneous abortion in women who worked in operating rooms and a similar increase in the risk of congenital anomalies in the children of physicians who had been exposed. They also indicated a 50% increase in the risk of liver disease and a 30% increase in the risk of renal disease. Finally, the study showed an increase in the risk of cervical cancer, but it did not increase the risk of any other cancer. Researchers noticed that all studies reviewed had flaws, including low response indices, inadequate information in non-receptive subjects, variable exposure to anesthetics, and lack of verification of the results. Researchers believed that it was unlikely that other retrospective studies would add useful and significant information and that further studies were necessary to determine whether the risks were really related to residues of anesthetic gases.

In 1985, the same year that Buring et al. issued their report, Tannenbaum and Goldberg published their own independent review of the literature on the effects of the exposure to anesthetic gases residue on the reproductive system [23]. Their conclusion was essentially the same and they also recommended that a prospective study with frequent and detailed monitoring of exposure levels and resulting events should be undertaken.

Additional revisions, including one by Ebi and Rice, reached the same conclusion [24-26]. Although epidemiological studies investigated professionals who worked in operating rooms, some involved dentist offices where nitrous oxide was used. Those two environments can be considerably different. Only in 1996 the American Dental Association recommended the elimination of anesthetic gases residues from dental offices, especially when nitrous oxide was used [27]. Due to the small size and the fact that many of those environments do not have an adequate exhaust system, extremely elevated concentrations of nitrous oxide, above 1,000 ppm are not rare. In one study three out of 20 dentists who were exposed to concentrations of up to 4,600 ppm had bone marrow abnormalities with leukocyte changes [28].

Under specific conditions, prolonged exposure to nitrous oxide can lead to depression of the activity of methionine synthetase and megaloblastic erythropoiesis [29].

In 1992 and in 1995, Rowland et al. published two studies suggesting a reduction in fertility and increase in the risk of spontaneous abortion among dental assistants exposed to nitrous oxide for more than three hours a week in environments without an exhaust system. Adverse reproductive effects were not detected in dental assistants who worked in environments with exhaust systems.

Maran et al. conducted studies that examined 11,500 females younger than 40 years who graduated from medical schools in the United Kingdom [32]. They collected occupational data, working habits, life style, and medical and obstetric history. The results indicate that female anesthesiologists did not have a higher incidence of infertility than other physicians. The incidence of spontaneous abortion and congenital abnormalities in their children was not related to the occupation of the mother, hours of exposure to the environment, or lack of an exhaust system. The incidence of cancer and neuropathies were also not related with the occupation.

CAUSES OF OPERATING ROOM CONTAMINATION

Chart I lists the main causes of operating room contamination by inhalational anesthetics gases. Leakage during the administration of inhalational anesthesia frequently involves technical problems. One of the most common situations is failure to turn off all flow control valves (oxygen, nitrous oxide, and air) or the vaporizer when the anesthetic system is disconnected from the patient. This usually occurs during intubation, but it can happen any time during anesthesia. An ill-fitting face-mask and especially during the management of difficult airways allows loss of gas. Similarly, many anesthesiologists "wash" the anesthetic system at the end of the procedure to speed up awakening. If this is done the flow should be directed to the exhaust system of the anesthesia device. Finally, if the patient was allowed to breath spontaneously during anesthesia, anesthetic gases residue should be removed from the operating room when disconnecting the patient from the circuit.

Filling up vaporizers with anesthetics can contaminate the room air. One milliliter of a liquid anesthetic agent evaporates to form approximately 200 ml of vapor at the temperature of the operating room.

Vaporizes are equipped with two types of filling systems. The key-indexed system tends to be associated with less spilling of the anesthetic agent than traditional funnel-fill systems (Figures 1, 2, and 3). The key-indexed filling system guarantees that virtually no liquid can be spilled during filling.

Chart 1 – Causes of Contamination of Operating Room [33]

- Failure to turn off flow control valves
- Ill-fitting masks
- Flushing of the respiratory circuit
- Filling of vaporizers
- Tracheal tubes without balloon
- Pediatric respiratory systems
- Side stream samples of gas analyzers
- Occlusion of the elimination system of the hospital (vacuum)
- Leak on the low-pressure circuit (CO_2 absorber reservoir), o-rings, and hoses

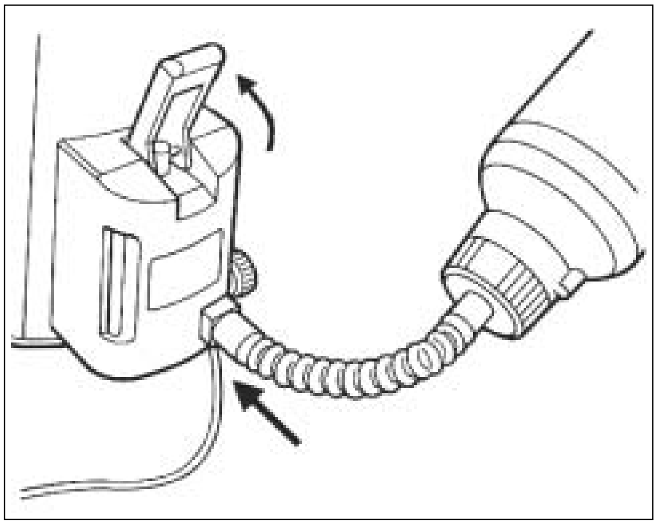

Figure 1 –Key-Indexed System for Inhalational Agents. The illustration of the Delta Vaporizer, Delta Fill type, was reproduced with permission of Penlon Ltd, Abingdon, UK.

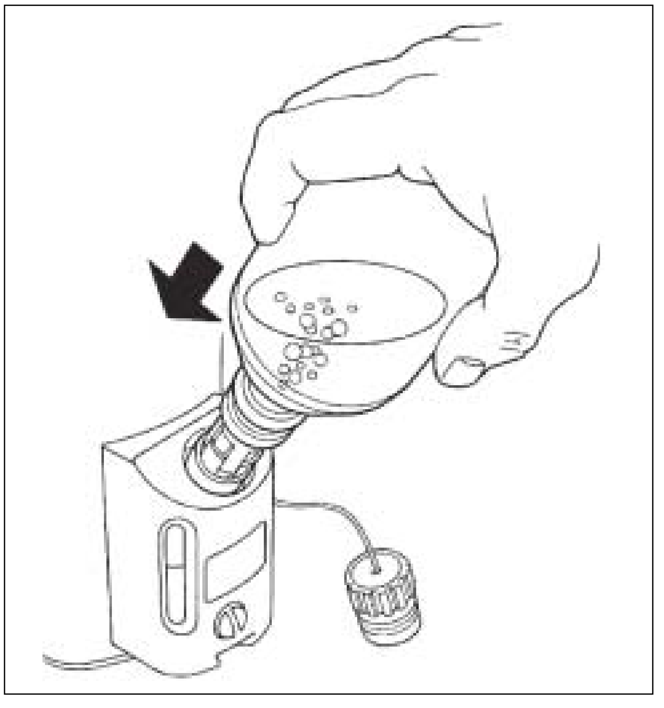

Figure 2 –Key-Indexed System for Inhalational Agents. The illustration of the Delta Vaporizer, Quick Fill type, was reproduced with permission of Penlon Ltd, Abingdon, UK.

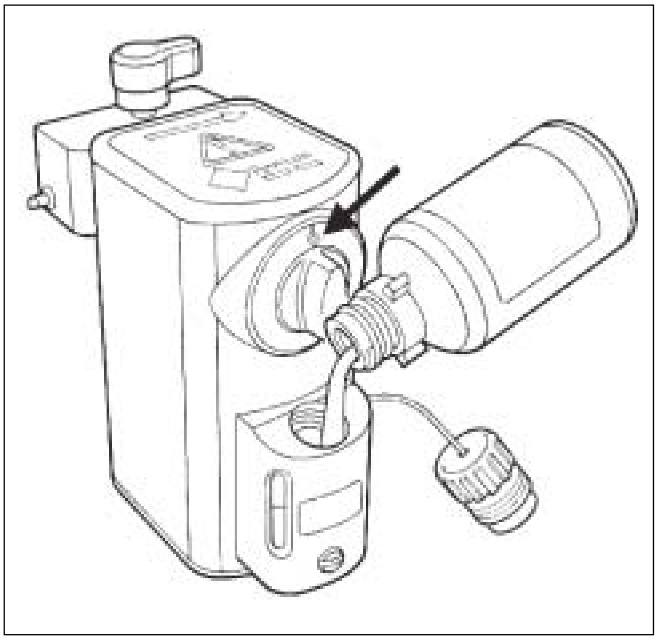

Figure 3 – Non-Specific Traditional System Type Funnel-Fill. The illustration of the Delta Vaporizer, Pour fill type, was reproduced with permission of Penlon Ltd, Abingdon, UK.

Pediatric anesthesia has specific problems regarding contamination of the operating room. The trachea of a child is usually entubated with a tube without balloon, which allows gas to escape. Specific circuits used in pediatric anesthesia do not have any possibility of exhaustion. The Mapleson D system extensively used in pediatric anesthesia eliminates large amounts of anesthetic into the operating room. Special modifications or additional elimination valves should be added to the system. Sidestream gas analyzers monitor the concentrations of exhaled CO_2 and anesthetics. Those devices usually aspirate between 50 and 250 ml of gas from the respiratory circuit per minute. After analysis, this gas sample should be directed to the exhaust system or returned to the respiratory system.

ANESTHESIA DEVICES AND EXHAUST SYSTEMS

Most anesthesia devices manufactured nowadays all over the world have an exhaust system for anesthetic gases residues. Those systems collect gases eliminated through the adjustable pressure limiting (APL) valve, pop-off valve, or pressure relief valve of the ventilator directing them to the residue elimination system.

Most connections to the exhaust system have a diameter of 19 mm, but 30 mm is the new international standard. Many devices with 30-mm connectors provide a 19-mm adapter.

Usually, all gases administered in the anesthetic circuit are eliminated by the residue exhaust system.

Anesthetic gases will only be released in the operating room if the exhaust system has leaks or if it receives more than it can handle. Therefore, checking the exhaust system should be one of the items in the general verification of the anesthesia equipment.

Exhaust systems are classified as opened or closed reservoirs. In the closed reservoir system, gases are directed to the exhaust or tubing interface.

This system incorporates a positive pressure valve (pop-off valve) that prevents excessive pressure in the system, and one or more negative-pressure escape valves, which prevents application of excessive negative pressure to the system allowing room air to be incorporated into the system. The closed reservoir system has a reservoir bag to compensate for acute changes in the gas flow and exhaust ratios. Gases residues are directed from the exhaust system (interface or tubing) to the elimination system of the hospital.

The open reservoir system does not have valves and it uses a reservoir that remains in contact with the ambient air through several pores and, therefore, flows determined by positive and negative pressures develop freely. Once again, the tubing of the APL, pop-off valve, or ventilator valve directs residues to the opened system and the connections to the elimination system of the hospital.

The exhaust system and tubing are subjected to several potential problems. If the gases directed to the APL tubing or if ventilator valves are occluded, the patient might develop barotrauma. If the connection with the gases elimination system of the hospital is occluded, the residue is eliminated into the surrounding air through the positive pressure escape valve. If this valve is not operating properly, the patient could develop barotrauma.

Once gases residues leave through the tubing, they are directed to the elimination system of the hospital. This can be done via an active or passive mechanism. In the active system, residues are actively removed by applying vacuum to the system. A flow control valve allows adjustment in the amount of vacuum applied by the operator to the system. If the vacuum is not adjusted properly or if it is disconnected from the exhaust system residues will be released into the operating room. The reservoir bag of the exhaust system also works as a visual indicator if additional or inadequate amounts of vacuum are applied to the system. It is recommended to have a specific vacuum system for residues independent from the main vacuum system of the hospital.

In the passive system, a tube connects the exhaust system to the ventilation system of the operating room. This can only be done if the case of a non-recirculating ventilation system. Residues run through the exhaust system because the ventilation system of the room maintains a slightly positive pressure. The possibility of compression or occlusion of the elimination tubing, causing the residues to escape into the environment, would be the main risk of this system. The elimination tubing should not be placed on the ground and should be made of a non-compressible material. In the passive system, if the gas outlet of the hospital is obstructed by residue or ice, the gases will not be removed to the exterior. External atmospheric conditions can cause reversion of the flow of gases in this system.

An exhaust system should be used wherever anesthetic gases are used. It is the responsibility of each institution to organize and document the maintenance program and verify that all anesthetic equipment is working properly.

Reducing the exposure of anesthetic gases by using an exhaust system is currently widely accepted, although deleterious health effects have not been demonstrated. A properly working exhaust system will reduce residues to the recommended levels (25 ppm for nitrous oxide and 2 ppm for halogenated anesthetics).

An orientation program is recommended for all personnel working in areas where anesthetic agents are used. The program should include updated literature information on possible adverse effects on health and emphasis on attention to the maintenance of all equipment used. Although the current data do not demonstrate that residue concentrations are associated with all reported health hazards to exposed personnel working in areas with efficient exhaust systems, each institution should provide mechanisms to report all adverse health effects in areas exposed to anesthetic gases residues.

OTHER COMNTAMINATION SOURCES

Leaks in the high-pressure system represent another source of operating room contamination. The nitrous oxide high-pressure hose and cylinders can leak significant amounts of gas. If the nitrous oxide cylinder does not fit correctly the anesthesia equipment large amounts of nitrous oxide will leak into the air since cylinder pressure is usually around 45 atm. Any parts of the anesthesia equipment or circuit that does not fit properly will allow anesthetic gases in the room. This can occur in deformed or perforated plastic hoses, or if the rubber o-rings are worn out or deformed. If the lid of the vaporizer reservoir is not tightly closed, it might result in significant leaks. In general, any connection between two components of the system with rubber connectors can leak if it is deteriorated or misaligned. The reservoirs of the CO_2 absorber are typical examples. Leaks in the low-pressure system of the anesthesia equipment usually can be detected by careful verification. A leak in the continuous flow section can be identified connecting a sphygmomanometer bulb to the common gases outlet [34]. Leaks in the high-pressure system can be detected verifying the system or monitoring room air. Other sources of operating room contamination not under the direct control of the anesthesiologist include cryosurgery and the extracorporeal circulation equipment. Many cryosurgery units use nitrous oxide at a flow of up to 90 $L.min^{-1}$. If inhalational anesthetics are added to the extracorporeal circulation circuit, the gases should be removed from the room air. A specific exhaust system is used in both examples. If anesthetic gases are eliminated into the operating room, residue concentration is completely dependent on the ventilation system of the room. Surgical rooms need 15 to 21 air exchanges per hour, preferentially for fresh air[35]. The maintenance department of the hospital should verify on a regular basis whether air exchange in each room is adequate. Non-recirculating exchange replaces the air in the operating room continuously. This type of system decreases the concentration of anesthetic agents in the air faster than the recirculating type. The recirculating system adds some fresh air to the room air. The recirculating system is cheaper as far as heating and air conditioning costs are concerned.

MONITORING CONCENTRATIONS AND MEASURING ANESTHETIC GASES RESIDUES

Monitoring the levels of anesthetic gases residues in the surgical environment can help detect leaks. Using a sample of the air in the operating room when it is not being used is a useful method to monitor the levels of residues originated from intermittent leaks in the high-pressure system. An air sample is placed in an inert container, which will be sealed and sent to the laboratory for analysis. Another method indicates mean exposure as a function of time. In this method, a pump is used to collect air samples continuously at specific moments (usually every eight hours). This method allows one to know the mean exposure and it is normally used in research studies. Passive dosimeters similar to the ones used in environments exposed to radiation are available to monitor the exposure to some volatile anesthetics. They are designed to be sensitive to the air inhaled by the worker and operate for one to 168 hours. Dosimeters are removed from their package at the beginning of the exposure period and returned to the package at the end of the exposure period. The user should keep a record of the exposure period and, when sampling is completed, the dosimeter is identified with the name of the worker and the total time of exposure and sent to the laboratory. Lapel dosimeters are available for: halogenated anesthetic vapor, nitrous oxide, ethylene oxide, toluene, xylene, formaldehyde, acetic acid, hydrogen peroxide, ethanol, methyl ethyl ketone, isopropanolol, and methyl methacrylate.

“Trapped” gases are released and analyzed, and the results are given as ppm per hour of exposure.

Continuous sampling through the portable infrared analyzer, which collects and analyzes inhalational agents continuously, is the most convenient method to monitor environmental air. Those devices provide continuous readings of the concentrations of anesthetics in the air and they can be used to take the residues to the external environment. They can also calculate mean exposure by unit of time.

Carbon dioxide can be used as a marker to determine the quality of the air polluted by other gases [35]. The national Institute of Occupational Safety and Health (NIOSH), through standard method 62-1989, uses the relationship of airflow per person to determine the air quality in public buildings, since in this type of environment the source of contamination is related more to space occupation than with the internal volume. Ventilation of 10 $L.sec^{-1}$ per person is recommended for commercial buildings and 7.5 $L.sec^{-1}$ is recommended for schools and other buildings, which represents a maximal concentration of 800 and 1,000 ppm of CO_2, respectively [37,38]. The use of internal levels of CO_2 to determine ventilation is based on a simple relationship between the internal CO_2 concentration and ventilation.

CONCLUSION

An exhaust system should be present wherever anesthetic gases are administered, may it be in the operating room, office, radiology room, or radiotherapy room. With an exhaust system and proper gases management techniques, residues should be within the exposure limits recommended by regulating agencies. Professionals in post-anesthetic recovery rooms are also exposed; however, residues levels are lower than those in the operating room.

Charts II and III present the main recommendations of American occupational health agencies.

According to the recommendations of the American Institute of Architects, recent built medical installations should have systems that provide 15 to 21 air exchanges per hour [35]. The central vacuum system should be verified and tested every three months.

In 1996, The British Government Health Services Advisory Committee issued its recommendations, Anesthetic Agents: Controlling Exposure under the Control of Substances Hazardous to Health Regulations (COSHH), in which occupational exposure standards were established; approximately 100 ppm for nitrous oxide, 50 ppm for enflurane and isoflurane, and 10 ppm for halothane. Those levels were chosen because they are well below the levels in which they cause significant adverse effects in animals and represent levels for which there are no evidences that human health would be affected [41].

The Netherlands have a limit of 25 ppm for nitrous oxide. Italy, Sweden, Norway, and Denmark determined the level of exposure to nitrous oxide to 100 ppm. These differences illustrate the difficulty to set standards without adequate data [42].

Brazilian work legislation is deficient regarding this subject and it does not mention limits for occupational exposure to anesthetic gases or recommend how to monitor the environment and how often. NR 15 (Regulating Norm on unhealthy activities and operations) determined some limits for occupational exposure to toxic gases and vapors, but nitrous oxide is the only anesthetic gas mentioned, limited only to asphyxiating doses. NR 32 (Regulating Norm on safety and health on work in health care organizations) of the Labor Ministry treats the subject more directly, but even in its more specific topics it is not very clear regarding the subject. However, it determines that every pregnant worker will only be release to work in areas with possible exposure to anesthetic gases or vapors after written authorization from the physician responsible for the Programa de Controle Médico de Saúde Ocipacional (PCMSO – Occupational Health Medical Control Program), considering the information contained in the Programa de Prevenção de Riscos Ambientais (PPRA – Environmental Hazards Protection Program) [43]. Even in the archives

Chart 2 – Recommendations of the National Institute of Occupational Safety and Health (NIOSH) [39]

- Occupational exposure to halogenated anesthetics should not exceed 2 ppm, when used alone, or 0.5 ppm, when used in combination with nitrous oxide.
- Occupational exposure to nitrous oxide, when used as a single anesthetic agent, should not exceed the mean concentration of 25 ppm.
- Anesthesia equipment, respiratory systems, and T-tubes should have an effective exhaust mechanism to collect spilled anesthetic gases.
- The anesthetic gases residue elimination system should be tested before beginning anesthesia.
- Face masks should provide an effective seal to minimize gas leaks.
- Preferentially, vaporizers should be filled in a well-ventilated area and turned to the resting position when not in use.
- Low- and high-pressure components should be tested for leaks.
- Leaks in the low-pressure system (components of the respiratory system) should be less than 100 mL per minute at 30 cmH_2O. Leaks in the high-pressure system (cylinders/valve) should be controlled, with a maximal tolerance of 10 mL per minute.
- Anesthetic gases flow meters should not be opened before anesthetic induction. Flow meters can be disconnected or with the Y piece sealed when the respiratory circuit is disconnected from the patient after the administration of the anesthetic agent has begun.
- The reservoir bag should be emptied in the exhaust system before it is connected to the system.
- Appropriate measures to avoid spilling of anesthetics are necessary. Procedures should follow manufacturing and safety data furnished by the manufacturer. Individual protection equipment should be used when manipulating enflurane and desflurane, since chloroform residues are bioproducts of both agents.
- Air monitoring should be performed in every place with potential exposure of professionals to anesthetic gases residues.
- The results of air-sampling methods, places, dates, concentrations, and the results of leaking tests should be kept for at least 20 years.

Chart 3 –Occupational Safety and Health Administration (OSHA) Recommendations [40]

- Occupational exposure to halogenated anesthetics should not exceed 2 ppm. When those agents are used in combination with nitrous oxide, levels of 0.5 ppm are acceptable. When nitrous oxide is used as a single agent, it should be controlled so professionals are not exposed to mean concentrations of 25 ppm during anesthesia.
- An effective exhaust system should contain a device to collect excess vapor from respiratory systems and a ventilation system to carry anesthetic gases out of the operating room with a method that limits variations in positive and negative pressures in the respiratory system.
- Maintenance of the anesthetic equipment should be made by the authorized assistance every three months, to keep gas leaks to a minimum, and provide the necessary training to help professionals recognize the practices that decrease the risk of unnecessary exposure to anesthetic gases residues.
- Gas leaks should be kept to a minimum, avoiding opening the nitrous oxide flow meter and the vaporizer before the circuit is connected to the patient, and maintain the flow of oxygen until the exhaust system is leveled.
- Sampling procedures to evaluate the concentrations of anesthetic residues in the air should be performed every three months in each site. Monitoring should include testing the equipment for leaks, sampling the air, and real-time sampling of the gas in the reservoir bag. Ventilation and used air conditioning systems should be inspected and tested at regular intervals to guarantee that complete air exchange of the operating rooms are done at least 15 times per hour.

of the ASA task-force dedicated to the subject a certain degree of controversy regarding the norm stipulating maximal levels of occupational exposure can be noticed, but it acknowledges the lack of epidemiological evidence on any type of damage caused by exposure to concentrations of anesthetic vapors/gases in places where standard ventilation and exhaust measures and the use of anesthetic equipment are followed. In our country, usually those measurements are not done and when they are they are not supervised. Besides, the differences in techniques and working conditions have to be considered. Thus, professionals are exposed to uneven amounts of anesthetic gases for variable periods.

Radiological procedures, stress, and prolonged exposure to cleaning products used in operating rooms can also affect anesthesiologists. Furthermore, several compounds including alcohol, drugs, and environmental pollutants can act as hepatic enzymes inductors, which can cause serious problems.

Considering the multifactorial nature of the exposure of health care professionals, measures to minimize the occupational exposure to chemical agents with known or probable toxic potential should be taken. Therefore, it is possible to effectively prevent health damage. The demand for better equipped operating rooms, with adequate ventilation and exhaust system, as well as their maintenance, should be met [44].

REFERÊNCIAS — *REFERENCES*

01. Vaisman AI — Working conditions in the operating room and their effect on the health of anesthetists. Eksperiment Khirurg Anesteziol, 1967;12:44-49.
02. Fink BR, Shepard TH, Blandau RJ — Teratogenic activity of nitrous oxide. Nature. 1967;214:146-148.
03. American Society of Anesthesiologists — Waste Anesthetic Gases in Operating Room Air: a Suggested Program to Reduce Personnel Exposure. Park Ridge, IL, American Society of Anesthesiologists, 1981.
04. Baden JM, Simmon VF — Mutagenic effects of inhalational anesthetics. Mutat Res. 1980;74:169-189.
05. Eger EI II, White AE, Brown CL et al. — A test of the carcinogenicity of enflurane, isoflurane, halothane, methoxyflurane, and nitrous oxide in mice. Anesth Analg, 1978;57:678-694.
06. Chloroform as an ingredient of human drug and cosmetic products. Federal Register. 14:15026. DHEW, FDA, 1976.
07. National Cancer Institute — Carcinogenisis bioassay of trichloroethlene. Carcinogenesis technical report series. No. 2: CAS No. 79-01-6. National Cancer Institute, 1976.
08. Baden JM, Kundomal YR, Mazze RI et al. — Carcinogen bioassay of isoflurane in mice. Anesthesiology, 1988;69:750-753.
09. Baden JM, Kundomal YR, Luttropp ME Jr et al. — Carcinogen bioassay of nitrous oxide in mice. Anesthesiology, 1986;64: 747-750.
10. Baden JM, Egbert B, Mazze RI — Carcinogen bioassay of enflurane in mice. Anesthesiology, 1982;56:9-13.
11. Baden JM, Mazze RI, Wharton RS et al. — Carcinogenicity of halothane in Swiss/ICR mice. Anesthesiology, 1979;51:20-26.
12. Coate WB, Ulland BM, Lewis TR — Chronic exposure to low concentrations of halothane-nitrous oxide: Lack of carcinogenic effect in the rat. Anesthesiology, 1979;50:306-309.
13. Rice SA, Fish KJ — Reproductive and Developmental Toxicity of Anesthetics in Animals, em: Anesthetic Toxicity. New York, Raven, 1994;157-174
14. Shepard TH, Fink BR — Teratogenic activity of nitrous oxide in rats, em: Toxicity of Anesthetics. Baltimore, MD, Williams and Wilkins, 1968;308-323.
15. Vieira E, Cleaton-Jones P, Austin JC et al. — Effects of low concentrations of nitrous oxide on rat fetuses. Anesth Analg, 1980;59:175-177.
16. American Society of Anesthesiologists Ad Hoc Committee on the Effect of Trace Anesthetics on the Health of Operating Room Personnel — Occupational disease among operating room personnel: A national study. Anesthesiology, 1974;41:321-340.
17. Buring JE, Hennekens CH, Mayrent SL et al. — Health experiences of operating room personnel. Anesthesiology, 1985;62: 325-330.
18. Knill-Jones RP, Rodrigues LV, Moir DD et al. — Anaesthetic practice and pregnancy. Controlled survey of women anaesthetists in the United Kingdom. Lancet. 1972;1:1326-1328.
19. Rosenberg P, Kirves A — Miscarriages among operating theatre staff. Acta Anaesthesiol Scand, 1973;53:37-42.
20. Axelsson G, Rylander R — Exposure to anaesthetic gases and spontaneous abortion: Response bias in a postal questionnaire. Int J Epidemiol, 1982;11:250-256.

21. Spence AA, Knill-Jones RP — Is there a health hazard in anaesthetic practice? Br J Anaesth, 1978;50:713-719.
22. Cohen EN, Bellville JW, Brown BW Jr — Anesthesia, pregnancy, and miscarriage: A study of operating room nurses and anesthetists. Anesthesiology, 1971;34:343-347.
23. Tannenbaum TN, Goldberg RJ — Exposure to anesthetic gases and reproductive outcome. A review of the epidemiologic literature. J Occup Med, 1985; 27:659-668.
24. Spence AA — Environmental pollution by inhalation anaesthetics. Br J Anaesth, 1987;59:96-103.
25. Friedman JM — Teratogen update: Anesthetic agents. Teratology, 1988;37:69-77.
26. Ebi KL, Rice SA, Fish KJ — Reproductive and developmental toxicity of anesthetics in humans. Em: Anesthetic Toxicity. New York: Raven, 1994;175-198.
27. American Dental Association — Guidelines for the Use of Conscious Sedation, Deep Sedation and General Anesthesia for Dentists. Chicago, American Dental Association, 1996.
28. Sweeney B, Bingham RM, Amos RJ et al. — Toxicity of bone marrow in dentists exposed to nitrous oxide. Br Med J, 1985; 291:567-569.
29. Helfenstein E — Farmacodinâmica dos Anestésicos Inalatórios, em: Cangiani LM, Posso IP, Potério GMB et al. — Tratado de Anestesiologia, 6ª Ed, São Paulo, Atheneu, 2006;791-802.
30. Rowland AS, Baird DD, Weinberg CR et al. — Reduced fertility among women employed as dental assistants exposed to high levels of nitrous oxide. N Engl J Med, 1992;327:993-997.
31. Rowland AS, Baird DD, Shore DL et al. — Nitrous oxide and spontaneous abortion in female dental assistants. Am J Epidemiol, 1995;141:531-538.
32. Maran NJ, Knill-Jones RP, Spence AA — Infertility among female hospital doctors in the UK. Br J Anaesth, 1996;76:581.
33. American Society of Anesthesiologists, Committee on Occupational Health of Operating Room Personnel — Waste Anesthetic Gases — Information for Management in Anesthetizing Areas and the Postanesthesia Care Unit, 2004.
34. Torres MLA, Carlos RV — Aparelhos de Anestesia: Componentes e Normas Técnicas, em: Cangiani LM, Posso IP, Potério GMB et al. — Tratado de Anestesiologia, 6ª Ed., São Paulo, Atheneu, 2006;163-175.
35. American Institute of Architects: Guidelines for Construction and Equipment of Hospitals and Medical Facilities. Washington, DC, 1992.
36. Almeida FV, Alberici RM, Braga FS et al. — Contaminação atmosférica num centro cirúrgico por compostos orgânicos voláteis e dióxido de carbono. Rev Bras Anestesiol, 1999;49:190-195.
37. Marshall JW — Health care ventilation standard: Air change per hour or CFM/patient? ASHRAE J, 1996;38:27-30.
38. Turiel I, Rudy JV — Occupant-generated CO_2 as an indicator of ventilation rate. ASHRAE Transactions, 1982;88:197-210.
39. Criteria for a Recommended Standard: Occupational Exposure to Waste Anesthetic Gases and Vapors. DHEW (NIOSH) Publication No. 77-140. U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Cincinnati, OH, 1977.
40. Hazard Communication Standard. OSHA Publication. 1910.1200. U.S. Department of Labor, 1985.
41. Health Services Advisory Committee — Anaesthetic agents: Controlling exposure under COSHH. Suffolk, Health and Safety Executive, 1995.
42. Gardner RJ — Inhalation anaesthetics — exposure and control: A statistical comparison of personal exposures in operating theatres with and without anaesthetic gas scavenging. Ann Occup Hyg, 1989;33:159-173.
43. Ministério do Trabalho e Emprego — Portaria MTE n.° 485 — NR 32 — Segurança e Saúde no Trabalho em Serviços de Saúde, de 11 de novembro de 2005 (DOU de 16/11/05 — Seção 1).
44. Chinelato AR, Froes NDTC — Efeitos genotóxicos em profissionais expostos aos anestésicos inalatórios. Rev Bras Anestesiol, 2002;52:79-85.

RESUMEN

Oliveira CRD — Exposición Ocupacional a Residuos de Gases Anestésicos.

JUSTIFICATIVA Y OBJETIVOS: *Aunque existan relatos negativos, en cuanto a los efectos de la exposición prolongada a residuos de gases anestésicos, todavía existen muchas controversias. Encontramos datos contradictorios en la literatura, considerándose la variabilidad en las respuestas individuales a diferentes agentes. El objetivo de este trabajo, fue el de presentar una revisión sobre la exposición ocupacional a los residuos de gases anestésicos.*

CONTENIDO: *Se discuten los resultados de los principales artículos sobre el tema, como también las causas de contaminación del ambiente quirúrgico, ventilación, extracción, monitorización y dosificación de los residuos de gases anestésicos. Se le da énfasis a las recomendaciones para la minimización de los efectos imputados a los agentes inhalatorios.*

CONCLUSIONES: *Incluso con los trabajos de los contingentes de renombradas instituciones reguladoras internacionales, notamos un cierto grado de controversia sobre los efectos de la exposición ocupacional a residuos de gases anestésicos. Observamos la estipulación de valores máximos para la exposición ocupacional, sin embargo, también se reconoce, que no existen indicios epidemiológicos de ningún tipo que refieran un daño causado por la exposición a concentraciones de gases anestésicos en locales donde las medidas estándar de ventilación, extracción y el uso de equipos anestésicos estén siendo observadas. En nuestro medio, esas medidas, en la mayoría de los casos, no se implementan, y cuando se implementan, no están correctamente inspeccionadas. Por añadidura, hay que considerar las diferencias entre las técnicas utilizadas y las condiciones de trabajo. Teniendo en cuenta la naturaleza multifactorial de la exposición de profesionales de la salud, algunas medidas deben ser tomadas para minimizar la exposición ocupacional a los agentes con conocido o probable potencial tóxico. Debemos estimular la reivindicación por salas de cirugía con mejores equipamientos, con sistemas de ventilación y extracción adecuados, y también su mantenimiento.*