

Risk Analysis Of Disorders Due To Isoflurane Exposure Among Healthcare Workers In The Operating Room: A Case Study At Ananda Women And Children Hospital

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Article Info	ABSTRACT
<p>Keywords: Isoflurane, PPE, Age, length of work, health problems.</p>	<p>Isoflurane is an inhalation anesthetic agent commonly used in clinical practice for the induction and maintenance of general anesthesia. Isoflurane has a depressant effect on the central nervous system, working by increasing the activation of inhibitory GABA receptors and reducing excitatory synaptic transmission. One of the key factors affecting the level of isoflurane exposure in the operating room is the room ventilation and air filtration system. Poor ventilation in the operating room can cause the concentration of anesthetic gases, such as isoflurane, to accumulate in the air, increasing the risk of exposure to health workers. Ineffective or inadequate ventilation systems may not be able to remove anesthetic gases released during surgical procedures, which can ultimately result in isoflurane exposure at hazardous levels. The purpose of this study was to identify and analyze the risk of health problems due to isoflurane exposure and to develop effective risk management to minimize the impact of isoflurane exposure on health workers in the operating room of RSIA Ananda and to analyze the existing operating room standards in the operating room of RSIA Ananda. The type of research that will be used in this study is quantitative research using a cross-sectional design. This study was conducted in the Operating Room of Ananda Mother and Child Hospital, Makassar from October to November 2024. The population and sample were all health workers on duty in the operating room of Ananda Mother and Child Hospital, which was 45 health workers. The results of this study indicate that of the 45 respondents who always use PPE and experience health problems such as nausea, which is 62.5% and with a P Value of 0.0612 > 0.05, have never been exposed to isoflurane and experience nausea as much as 37.5% with a P Value of 0.030 < 0.05, health workers who have worked for 1-5 years have a higher percentage of nausea, which is 66.7% with a P Value of 0.066 > 0.05. While the age group 25-34 years as many as 70.8% experience nausea with a P Value of 0.0590 > 0.05. The conclusion of the statistical analysis shows a significant relationship between the duration of isoflurane exposure and health problems in health workers, while the use of PPE, age and length of work do not have a significant relationship..</p>
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INTRODUCTION

The operating room is a special unit in the hospital that functions as a place to perform elective or acute surgical procedures. The operating room must be designed with high safety standards for both patients and health workers so that they are not included in factors that can cause accidents and occupational diseases. One of the medical actions in the operating room is anesthesia. Anesthesia is a chemical that can relieve pain during surgery. There are two types of anesthesia commonly used in the operating room, namely; 1). Injection anesthesia (intravenous), and 2). Inhalation anesthesia (inhalation). Inhalation anesthesia is a drug that can be in the form of gas and liquid that evaporates easily through anesthesia equipment or machines directly. Halothane, Enflurane, Isoflurane, Desflurane and Sevoflurane are anesthetics found in inhalation anesthesia.

Exposure to anesthetic gas for a long time can damage the human ability to give birth to healthy children which is caused by disruption of reproductive hormones. The effects of anesthetic gas on reproductive health not only affect women to be able to give birth to children at a productive age but can also affect male reproduction and can interfere with normal development both before and after birth (Fatimah & Wirjatmadi, 2023)

Isoflurane is an inhalation anesthetic agent commonly used in clinical practice for induction and maintenance of general anesthesia. Isoflurane has a depressant effect on the central nervous system, working by increasing the activation of inhibitory GABA receptors and reducing excitatory synaptic transmission (Miller et al., 2020). Isoflurane is an anesthetic gas used in Indonesia for general anesthesia purposes. This agent has a strong sedative effect, with better cardiovascular stability than other inhalation anesthetic agents (Ministry of Health of the Republic of Indonesia., 2023)

Anesthesia management without exposure to potentially hazardous environmental factors is impossible. Exposure to anesthetic gases in the operating room atmosphere cannot be avoided. A small amount of exhaust gas enters the operating room every time inhalation anesthesia is performed. In a study on the Relationship between Work Period, Frequency, and Duration of Exposure to Isoflurane Anesthesia and Fertility Disorders in Operating Room Nurses, which showed that there was a relationship between work period and fertility disorders ($0.00 < 0.05$) exposure to halogenated anesthetic gases, including isoflurane, it was concluded that it could cause reproductive health disorders, such as decreased fertility, in operating room care. High duration and frequency of exposure increase the risk of these disorders (Rika Handayani., 2019).

One of the key factors affecting the level of isoflurane exposure in the operating room is the room ventilation and air filtration system. Poor ventilation in the operating room can cause concentrations of anesthetic gases, such as isoflurane, to build up in the air, increasing the risk of exposure for healthcare workers. Ineffective or inadequate ventilation systems may not be able to remove anesthetic gases released during surgical procedures, which can ultimately result in hazardous levels of isoflurane exposure (Afra et al., 2020).

Poor ventilation also contributes to the uneven distribution of isoflurane in the operating room. When the ventilation system is unable to quickly remove the anesthetic gas from the

air, isoflurane can spread to areas outside the anesthesia zone and reach health care workers, even those who are not directly involved in the administration of anesthesia. This creates a wider risk of exposure among the entire medical team in the operating room (Müller-Wirtz et al., 2022).

However, in many cases the effectiveness of ventilation and air filtration systems is often not fully evaluated. Improper placement or suboptimal maintenance of air filtration systems can reduce their ability to remove anesthetic gases, increasing the risk of exposure. In addition, health workers' ignorance of the importance of maintaining these systems can also potentially worsen the situation (Mousavi et al., 2021).

Based on the background above, the objectives of this research are to identify and analyze the risk of health disorders due to isoflurane exposure and to develop effective risk management to minimize the impact of isoflurane exposure on health workers in the operating room of RSIA Ananda and to analyze the operating room standards in the operating room of RSIA Ananda.

METHODS

The type of research that will be used in this study is quantitative research using cross sectional. The independent variables are seen from the infrastructure factors: ventilation quality, use of PPE, and air filter systems, seen from the exposure factors: frequency of exposure and length of service, and seen from the supporting examination factors: laboratory and radiology examinations. And the research method uses Chi Square. This research was conducted in the Operating Room of Ananda Mother and Child Hospital, Makassar and was conducted from October to November 2024. The population and sample in this study were all health workers who worked in the operating room of Ananda Mother and Child Hospital, namely 45 health workers. Data collection was conducted using a structured questionnaire. Before data collection, a questionnaire test was conducted to determine the validity and reliability of the questionnaire used. As for the enumerators, they will first provide training, so that there is a common perception with the researchers. The data processing and analysis method is carried out in several stages, namely editing, coding entry and data clearing, then analyzed using univariate and bivariate analysis. The form of data presentation in this study can be in the form of images or tables accompanied by narration. The presentation of univariate tests is in the form of frequency distribution tables, while the presentation of data in bivariate tests is done in the form of cross-tabulation tables or crosstabs.

RESULTS AND DISCUSSION

Analysis of Research Results

Univariate Analysis

Univariate analysis is an analysis used in research that focuses on the exploration and description of one variable without being associated or connected to other variables. The purpose of univariate analysis is to provide an overview or description of the characteristics

of the data collected such as basic statistics, distribution and certain patterns of each variable studied. The results of univariate analysis in this study are as follows:

Table 4.1 Distribution of Respondents Based on Characteristics Health Workers in the Operating Room of RSIA Ananda

Respondent Characteristics (n)	(%)
Age (Years)	
25-34 Years	29 64.4
35-44 Years	16 35.6
Gender	
Male	5 11.1
Female	40 88.9
Length of Work	
1-5 Years	25 55.6
6-10 Years	17 37.8
>10 Years	3 6.7

Source: Primary Data, 2025

Table 4.1 above shows that based on age category, the largest number of respondents are in the 25-34 age range, 29 people (64.4%). While the smallest number of respondents are in the 35-44 age range, 16 people (35.6%). Based on gender category, the largest number of respondents are women, 40 people (88.9%). While there are 5 male respondents (11.1%). Then based on the length of service, the largest number of respondents were in the 1-5 years category with a total of 25 people (55.6%). While the smallest number of respondents were in the >10 years service category with a total of 3 people (6.7%).

Table 4.2 Distribution of Respondents Based on Health Disorders Experienced by Health Workers in the Operating Room of Ananda Hospital

Health Disorders	(n)	(%)
Yes	36	80
No	9	20
Total	45	100

Source: Primary Data 2025

Based on table 4.2 above, it shows that out of 45 respondents, both male and female health workers, 36 (80%) health workers experienced health complaints while working in the operating room and 9 (20%) health workers did not experience health problems.

Table 4.3 Distribution of Respondents Based on Types of Complaints Experienced by Operating Room Staff While Working in the Operating Room of RSIA Ananda

Types of Complaints Experienced by Male and Female Health Workers	(n)	(%)
Headache	18	40
Nausea	24	53.3
Respiratory Disorders	3	6.7

Types of Complaints Experienced by Male and Female Health Workers	(n)	(%)
Total	45	100

Source: Primary Data 2025

Based on table 4.3 above, it shows that the majority of health workers experience nausea due to exposure to isoflurane, as many as 24 people (53.3%) of health workers in the operating room. While the minority of health workers experience respiratory problems due to exposure to isoflurane, as many as 3 people (6.7%) of health workers in the operating room.

Exposure to isoflurane is caused by the type of ventilation that is not installed in the operating room which causes the anesthetic gas to remain in the operating room and be inhaled by nurses, as well as the absence of a Scavenging system in the operating room.

Table 4.4 Distribution of Respondents Based on the Number of Children of Health Workers Before Working in the Operating Room of RSIA Ananda

Number of Children Before	(n)	(%)
0	23	51.1
1	10	22.2
2	10	22.2
3	2	4.4
Total	45	100

Source: Primary Data 2025

Based on table 4.4 above, it shows that the majority of 23 people (51.1%) of health workers did not have children before working in the operating room. There were 10 people (22.2%) of health workers who had 1 child before working in the operating room. There were 10 people (22.2%) of health workers who had 2 children before working in the operating room, while the minority were 2 people (4.4%) of health workers who had 3 children before working in the operating room

Table 4.5 Distribution of Responses Based on the Number of Children of Health Workers After Working in the Operating Room of RSIA Ananda

Number of Children After	(n)	(%)
0	30	66.7
1	11	24.4
2	2	4.4
3	2	4.4
Total	45	100

Source: Primary Data 2025

Based on table 4.5 above, it can be seen that there is a difference in the numbers from table 4.4 where health workers who do not have children after working in the operating room are 30 people (66.7%), health workers who have 1 child after working in the operating room are 11 people (24.4%), health workers who have 2 children after working in the operating

room are 2 people (4.4) and health workers who have 3 children after working in the operating room are 2 people (4.4%).

Table 4.6 Distribution of Respondents Based on the Number of Isoflurane Exposures in the Operating Room of Ananda Hospital

Number of Exposures	(n)	(%)
Never	9	20
1-2 Times	30	66.7
3-5 Times	6	13.3
Total	45	100

Source: Primary Data 2025

Table 4.6 above shows that respondents in the never-exposed group were 9 people (20%) health workers, respondents in the 1-2 times exposure group were 30 people (66.7%) health workers, while respondents in the 3-5 times exposure group were 6 people (13.3%) health workers.

Table 4.7 Distribution of Respondents Based on Length of Service In Health Workers in the Operating Room of Ananda Hospital

Period of Service	(n)	(%)
1-5 Years	25	55.6
6-10 Years	17	37.8
>10 Years	3	6.7
Total	45	100

Source: Primary Data 2025

Table 4.7 above shows that the majority of respondents have a work period of 1-5 years as many as 25 people (55.6%) health workers and a work period of >10 years as many as 3 people (6.7%) health workers. According to the Indonesian Ministry of Health (2022) health workers with a work period of more than 5 years have a risk of twice as high as those with a work period of less than 2 years.

Table 4.8 Distribution of Respondents Based on Duration of Exposure to Health Workers in the Operating Room of Ananda Hospital

Duration of Exposure	(n)	(%)
<4 Hours	4	8.9
4-6 Hours	4	8.9
6-8 Hours	35	77.8
>8 Hours	2	4.4
Total	45	100

Source: Primary Data 2025

Table 4.8 above shows that the duration of exposure to health workers has a proportion of exposure duration <4 hours and 4-6 hours has the same value, namely 4 people (8.9%), 6-8 hours exposure duration as many as 35 people (77.8%), while 8 hours exposure duration >

8 hours as many as 2 people (4.4%). Duration is the length of exposure time, the longer the exposure to risk factors to workers, the greater the possibility of workers to feel complaints. National Institute for Occupational Safety and Health (NIOSH) 2022, recommends the safe limit of isoflurane gas concentration in the air is 2 ppm for 8 hours of work. However, the duration of exposure exceeds this time, especially in environments with poor ventilation, can cause health problems.

Exposure with a duration of <4 hours causes mild symptoms such as dizziness, nausea, and fatigue. Exposure with a duration of 4-8 hours per day has a high risk of respiratory disorders and decreased concentration. While exposure with a duration of >8 hours per day has the potential for reproductive disorders, liver damage, and cumulative neurotoxic effects.

Table 4.9 Distribution of Respondents Based on Level of Exposure to Health Workers in the Operating Room of Ananda Hospital

Duration of Exposure	(n)	(%)
Very Low	6	13.3
Low	8	17.8
Moderate	19	42.2
High	12	26.7
Total	45	100

Source: Primary Data 2025

Table 4.9 above shows that the level of exposure of health workers in the operating room is mostly at a moderate level, namely 19 people (42.2%), while the level of exposure of health workers in the operating room is a minority at a very low level, namely 6 people (13.3%). The more often health workers are exposed to isoflurane gas, the greater the possibility of workers experiencing discomfort. According to NIOSH (2022), the frequency of exposure is a risk indicator that includes the number of exposure events and the duration per event in the context of the work environment. According to WHO (2023), exposure to chemicals such as anesthetic gases can affect the health of workers, depending on the duration, frequency, and concentration of exposure.

Table 4.10 Distribution of Respondents Based on the Use of PPE in Health Workers in the Operating Room of RSIA Ananda

Use of PPE	(n)	(%)
Always	28	62.2
Often	12	26.7
Sometimes	5	11.1
Total	45	100

Source: Primary Data 2025

Table 4.10 above shows that the majority of respondents always use PPE when in the operating room, namely 28 people (62.2%), while the minority of respondents sometimes use PPE, namely 5 people (11.1%). Improper use of PPE can harm the workers who wear it, even

more dangerous than not using PPE. The use of PPE such as N95 masks can reduce the risk of exposure to hazardous gases by blocking inhaled particles and anesthetic gases (CDC, 2022). In the operating room, compliance with the use of masks and respiratory protection is essential to protect healthcare workers from exposure to anesthetic gases such as isoflurane, which is known to have the potential to cause long-term health problems, including reproductive and respiratory disorders. In this context, compliance with the use of PPE also helps create a safer work environment and reduces the level of stress experienced by workers due to the potential dangers they face.

Braviat Analysis

Braviat analysis is an analysis method applied to two variables that are believed to have a relationship or correlation. The purpose of this bivariate analysis is to determine the relationship between the independent and dependent variables by presenting data in the form of cross tabulations, which will then be analyzed using the Chi-square Test. The results of the bivariate analysis in this study are as follows;

Relationship between Health Disorders and Use of PPE

Table 4.11 Relationship between Health Disorders and Use of PPE in the Operating Room of Ananda Hospital

Health Disorders	PPE						Total	<i>p- value</i>
	Always		Often		Sometimes			
	n	%	n	%	n	%		
Headache	10	55.6	5	27.8	3	16.7	18	100
Nausea	15	62.5	7	29.2	2	8.3	24	100
Respiratory Disorders	3	100	0	0	0	0	3	100
Total	28	62.2	12	26.7	5	11.1	45	100

Source: Primary Data 2025

Table 4.11 shows the relationship between the use of Personal Protective Equipment (PPE) and health disorders that experienced by health workers in the operating room of RSIA Ananda. Health problems such as headaches, from a total of 18 respondents who reported headaches, the majority (55.6%) or 10 people always use PPE, followed by (27.8%) or 5 respondents who often use PPE, and (16.7%) or 3 respondents who sometimes use PPE. Health problems such as nausea, recorded as many as (62.5%) or 15 people who experience nausea always use PPE, while as many as (29.2%) or 7 respondents often use PPE, and only (8.3%) or 2 respondents sometimes use PPE. As for health problems such as respiratory problems, shows all respondents (100%) or 3 respondents who reported respiratory problems when always using PPE, without any reporting when often or sometimes using PPE.

The results of the Chi-square statistical test with a p-value of 0.612 indicates that there is no statistically significant relationship between the use of PPE and health disorders at the level of significance ($p > 0.05$). In other words, the use of PPE does not have a significant

correlation with the incidence of health disorders such as headaches, nausea and respiratory disorders in this study.

Relationship between Health Disorders and Frequency of Exposure

Table 4.12 Relationship between Health Disorders and Frequency of Exposure in the Operating Room of Ananda Hospital

Health Disorders	Exposure						Total	<i>p- value</i>
	Never		1-2 Times		3-5 Times			
	n	%	n	%	n	%		
Headache	0	0	15	83.3	3	16.7	18	100
Nausea	9	37.5	12	50	3	12.5	24	100
Respiratory Disorders	0	0	3	100	0	0	3	100
Total	9	20	30	66.7	6	13.3	45	100

Source: Primary Data 2025

Table 4.12 above shows the relationship between the frequency of exposure to anesthetic gas isoflurane with health problems experienced by health workers in the operating room of RSIA Ananda. The three types of health problems analyzed were headaches, nausea, and respiratory problems. Health problems such as headaches showed that no respondents experienced headaches in the category of never exposed. As many as (83.3%) or 15 respondents who were exposed 1-2 times reported headaches. Meanwhile, (16.7%) or 3 respondents who were exposed 3-5 times experienced headaches. Health problems such as nausea, as many as (37.5%) or 9 respondents in the category of never exposed reported experiencing nausea. The majority of respondents who were 84 exposed 1-2 times (50%) or 12 people reported experiencing nausea. Meanwhile, respondents who were exposed 3-5 times had a smaller proportion, namely (12.5%) or 3 people. Health disorders such as respiratory disorders, no health disorders such as respiratory disorders were reported in respondents in the category of never exposed and respondents who were exposed 3-5 times. However, as many as (100%) or 3 people from respondents who were exposed 1-2 times reported respiratory disorders. The p-value of 0.030 indicates that there is a statistically significant relationship between the frequency of isoflurane gas exposure and health disorders at the level of significance ($P < 0.05$). This indicates that increasing the frequency of exposure has the potential to increase the risk of health disorders.

Relationship between Health Disorders and Length of Work

Table 4.13 Relationship between Health Disorders and Length of Work in the Operating Room of Ananda Hospital

Health Disorders	Length of Work						Total	<i>p- value</i>
	1-5		6-10		>10			
	Years		Years		Years			
	n	%	n	%	N	%		
Headache	7	38.9	9	50	2	11.1	18	100
Nausea	16	66.7	8	33.3	0	0	24	100

Health Disorders	Length of Work						Total	<i>p- value</i>
	1-5		6-10		>10			
	Years	Years	Years	Years	Years	Years		
	n	%	n	%	N	%	n	%
Respiratory Disorders	2	66.7	0	0	1	33.3	3	100
Total	25	55.6	17	37.8	3	6.7	45	100

Source: Primary Data 2025

Table 4.13 above shows health disorders in health workers who worked for 6-10 years had a higher percentage of headaches (50%) or 9 people compared to health workers who worked 1-5 years (38.9%) and >10 years (11.1%). Health disorders in health workers who worked for 1-5 years had a higher percentage of Nausea (66.7%) or 16 people compared to health workers who worked 6-10 years (33.3%) and >10 years (0%). While health disorders in health workers who worked for 1-5 years had a higher percentage of respiratory disorders (66.7%) or 2 people compared to health workers who worked 6-10 years (0%) and >10 years (33.3%). The p-value of 0.066 indicates that there is a statistically significant relationship between the frequency of working hours and health problems at the level of significance ($P < 0.05$). This indicates the importance of the management of RSIA Ananda to pay attention to the health of health workers in the operating room, especially those who have worked for 1-5 years and more than 10 years. Prevention and intervention programs to reduce the risk of health problems need to be carried out to maintain the health and welfare of health workers.

Relationship between Health Disorders and Age

Table 4.14 Relationship between Health Disorders and Age of Health Workers in the Operating Room of RSIA Ananda

Health Disorders	Age				Total	<i>p- value</i>	
	25-34		35-44				
	Years	Years	Years	Years			
	n	%	n	%	n	%	
Headache	10	55.6	8	44.4	18	100	0.590
Nausea	17	70.8	7	29.2	24	100	
Respiratory Disorders	2	66.7	1	33.3	3	100	
Total	29	64.4	16	35.6	45	100	

Source: Primary Data 2025

Table 4.14 above shows the relationship between health disorders and age of health workers in the operating room RSIA Ananda. In the headache category, the 25-34 age group experienced the most headache complaints, as many as (55.6%) or 10 respondents. While in the 35-44 age group, there were (44.4%) or 8 respondents who complained of headaches. As many as (70.8%) or 17 respondents from the 25-34 age group experienced nausea. While in the 35-44 age group, only (29.2%) or 7 respondents reported nausea. In the 25-34 age

group, there were (66.7%) or 2 respondents who experienced respiratory problems. While in the 35-44 age group, only (33.3%) or 1 respondent experienced respiratory problems. The p-value of 0.590 indicates that there is no statistically significant relationship between the age of health workers and health disorders at the level of significance ($p > 0.05$).

Discussion

After conducting a study on 45 health workers who work in the operating room of RSIA Ananda Makassar, several significant findings were found. Based on the results of the bivariate analysis, there are variables that are related to health disorders, namely frequency of exposure and length of work. On the other hand, variables that do not show a relationship to health disorders are the use of personal protective equipment (PPE) and the age of health workers in the operating room. Furthermore, to discuss the research results after the data has been processed and presented, a more detailed explanation will be presented as follows:

Relationship between Health Disorders and the Use of PPE

Based on the results of the study, in table 4.11 which shows that there is no statistically significant relationship between the use of PPE and health disorders (headaches, nausea, and respiratory disorders) at the level of significance ($p > 0.05$) obtained a p-value of 0.612. This indicates that although there are health workers who experience health disorders, these incidents are not directly correlated with the frequency of PPE use. In other words, other factors may have a greater influence on the occurrence of health disorders, such as work environment conditions, types of chemical exposure, levels of work stress, or duration of exposure.

The results of this study indicate that even though personal protective equipment (PPE) has been used, there is still a risk of health disorders that may be caused by other factors. These factors include the duration of exposure to anesthetic gas, the effectiveness of ventilation in the operating room, and individual characteristics such as personal sensitivity levels.

Studies show that non-compliance in the use of Personal Protective Equipment (PPE) can increase the risk of exposure to hazardous substances, which in turn can result in diseases, both acute and chronic. For example, health workers who do not comply with the use of masks in the operating room are at risk of exposure to anesthetic gases such as isoflurane, which have the potential to cause reproductive health problems and other health risks. In line with previous research conducted by Rohimah (2020), there are indications that the variables of knowledge and attitudes towards the use of Personal Protective Equipment (PPE) do not always have a significant relationship with a decrease in health problems. On the contrary, external factors such as work environment conditions and levels of exposure to hazards have a greater influence on these results. In addition, according to the theory of work ergonomics explained in the book "Ergonomics and the Work Environment" (2023), the use of PPE is a crucial step in protecting health workers from various risks related to occupational hazards, such as exposure to chemicals, microorganisms, and hazardous particles in the air. However, the effectiveness of PPE in preventing health problems is not only determined by

the frequency of use, but also by the type of PPE used, the level of compliance with its use, and the existing work environment conditions.

Research conducted by David et al. (2024) also showed that even though 60.4% of respondents had used complete PPE, cases of hypertension still occurred. Bivariate analysis in the study indicated that there was no significant relationship between the use of PPE and the incidence of hypertension.

Theoretically, the use of Personal Protective Equipment (PPE) aims to protect workers from potential hazards that may be present in the work environment. However, the effectiveness of the use of this PPE is influenced by various factors, such as the level of worker compliance in using PPE, the quality and suitability of the PPE used, and the existing work environment conditions. Therefore, although the use of PPE is important, a holistic approach is needed that includes improving working conditions and education for workers to minimize the risk of health problems.

The researchers also found that the ventilation conditions in the operating room of Ananda Hospital were not equipped with a ventilation system and lighting system, which is one of the factors that influences health problems experienced by officers, even though they have used Personal Protective Equipment (PPE) while in the operating room. The researchers observed that the cooling system installed in the operating room of Ananda Hospital uses AC, which results in the air in the operating room not being replaced periodically and only circulating in the room.

Measurement of isoflurane gas concentration in the operating room of Ananda Hospital could not be carried out due to uneven air flow in the operating room, where the Laminar Flow system did not function optimally. This resulted in the distribution of isoflurane gas being non-uniform, in accordance with the reference basis of ASHRAE (2021) in "Ventilation Standards for Operating Rooms."

The researcher also observed periodic examinations at Ananda Hospital, which included SGOT, SGPT, Urea, Creatinine, and Thorax X-rays, which are generally carried out routinely once a year for Ananda Hospital employees. The results of the examination of health workers in the operating room of Ananda Hospital showed normal values for all parameters examined.

It is important to conduct a more in-depth evaluation of the quality and type of Personal Protective Equipment (PPE) used, as well as work environment factors such as ventilation systems and levels of anesthetic gas exposure. Recommendations that can be submitted include increasing the effectiveness of PPE, monitoring work environment conditions, and a holistic approach that considers other risk factors that can affect the health of officers.

Relationship between Health Disorders and Exposure Frequency

Based on table 4.12, it shows that there is a statistically significant relationship between the frequency of isoflurane gas exposure and health disorders at the level of significance ($p < 0.05$) while the p -value is 0.030. This indicates that increasing the frequency of exposure has the potential to increase the risk of health disorders.

The results of the analysis showed a significant relationship between the frequency of isoflurane gas exposure and health disorders experienced by medical personnel in the operating room of Ananda Hospital. Respondents who were exposed to isoflurane gas with a frequency of 1-2 times showed a higher prevalence of health disorders, especially in the form of headaches and nausea.

It is interesting to note that respondents who were exposed with a frequency of 3-5 times actually showed a lower proportion of disorders. This may be influenced by the smaller number of respondents in this category, or the presence of physiological adaptation among certain individuals.

Headache is one of the most common health disorders, especially in individuals exposed to 1-2 times. The cause is likely related to the toxic effects affecting the central nervous system. Although nausea is also frequently reported, the number of complaints related to nausea tends to be less than that of headaches. In contrast, respiratory disorders show the lowest prevalence rate, indicating that the impact of isoflurane gas is more influential on the nervous system than the respiratory system.

Health problems such as headaches, nausea, and respiratory problems experienced by health workers can be caused by exposure to anesthetic materials, one of which is isoflurane. Isoflurane is a volatile anesthetic that, if exposed for a long period of time or at high concentrations, can cause adverse side effects, especially on the central nervous system, respiratory system, and digestive tract. Based on the latest occupational toxicology theory in 2022, chemicals that are often found in medical environments have the potential to affect individual health, especially if not balanced with adequate precautions or use of Personal Protective Equipment (PPE).

In addition, previous studies also provide support for the results obtained. For example, a study conducted by Wang et al. (2023) showed a significant relationship between the frequency of exposure to volatile anesthetics in the operating room and complaints of nausea and headaches in health workers. The study emphasized the importance of ventilation control, the use of appropriate personal protective equipment (PPE), and limiting the duration of exposure as mitigation measures to prevent adverse health impacts.

The researchers also observed periodic examinations at the Ananda Hospital, which included SGOT, SGPT, Urea, Creatinine, and Thorax X-ray examinations, which are generally carried out routinely once a year for employees of the Ananda Hospital. The results of the examination of health workers in the operating room of the Ananda Hospital showed normal values for all parameters examined.

These results underscore the significance of implementing effective risk management policies in hospital institutions. Risk management must ensure that regular evaluations are carried out on operating room conditions, including ventilation systems, monitoring of anesthetic levels, and training in the use of personal protective equipment (PPE) to reduce potential health risks.

Relationship of Health Disorders with Length of Work

Based on Table 4.13, a p-value of 0.066 was obtained, indicating a statistically significant relationship between the frequency of length of work and health disorders at the level of significance. The results of the study showed a significant relationship between health disorders and duration of work in health workers in the operating room. Longer working duration tends to increase the risk of health disorders, such as headaches, nausea, and respiratory disorders. These factors are thought to be caused by continuous exposure to chemicals in the work environment (such as isoflurane), psychosocial stress, and increased physical fatigue as working time increases.

Health workers who have working hours of more than eight hours per day or more than 40 hours per week tend to have a higher risk of experiencing health disorders when compared to those who work for a shorter duration. Based on table 4.13, health workers who have work experience between 6-10 years experience headaches with a percentage of 50%. On the other hand, officers who have work experience between 1-5 years recorded a percentage of 38.9%, while officers with > 10 years only recorded 11.1%.

Regarding nausea disorders, officers who work with 1-5 years of experience showed a percentage of 66.7% (16 individuals), which is higher than officers who have 6-10 years of experience, which only reached 33.3%. There were no individuals from the group of officers with > 10 years of work experience who experienced nausea disorders.

Furthermore, for respiratory disorders, the group of officers with 1-5 years of experience recorded a figure of 66.7% with 2 individuals diagnosed, while in the group of officers with 6-10 years of experience there were no cases, and the group of officers with >10 years of experience recorded a percentage of 33.3%.

According to the latest work ergonomics theory (2023), long working duration has the potential to increase physical and mental workload, which can ultimately contribute to the emergence of health problems. Fatigue caused by continuous work can result in decreased body function and slow down the recovery process from exposure to hazardous materials in the work environment. Grandjean (2022) states that health problems experienced due to work, such as headaches and nausea, are one indicator that the duration of work has exceeded the physiological capacity of the worker.

In addition, in line with this study, the opinion expressed by Smith et al. (2023) states that the duration of work has a direct relationship with the risk of health disorders, due to increased exposure to risk factors in the work environment, such as inadequate ventilation and lack of rest time. The working environment in the operating room, which contains volatile anesthetics such as isoflurane, also increases the potential risk for workers who have long working hours. Meanwhile, according to Johnson et al. (2022) stated in their study that the duration of work that exceeds eight hours per day has a significant contribution to increasing symptoms such as nausea, dizziness, and fatigue in medical personnel. This is due to the imbalance between the level of exposure they face at work and the capacity to rest.

Researchers also conducted observations on periodic examinations at Ananda Hospital, which included SGOT, SGPT, Urea, Creatinine, and Thorax X-rays, which are generally carried

out routinely once a year for employees of Ananda Hospital. The results of the examination of health workers in the operating room of Ananda Hospital showed normal values for all parameters examined.

The results of this study confirm that the management of work duration plays an important role in minimizing the risk of health problems in health workers. Interventions that are carried out, such as job rotation, adequate rest time management, and control of risk factors in the work environment—including ventilation and anesthetic levels—are crucial steps in mitigating health risks caused by long work durations.

Relationship between Health Disorders and Age

Based on Table 4.14, a p-value of 0.590 was obtained, indicating that there was no statistically significant relationship between the age of health workers and health disorders at the level of significance ($p > 0.05$). In theory, age is often associated with physiological changes that affect the body's resistance to risk factors in the workplace. However, in this context, there are likely other factors, such as duration of exposure, level of work stress, and compliance with the use of personal protective equipment (PPE), which have a more dominant influence compared to the age factor.

The theory that is in line with the results of this study is the occupational health theory put forward by Smith et al. (2023) which explains that the age of workers is not the main determinant in assessing the risk of health problems in high-risk work environments. Other factors, such as work environment conditions, exposure to hazardous materials, and work habits, have a more significant role in determining the health risk compared to age alone. Meanwhile, according to Wang et al. (2023), research shows that the relationship between age and health problems in high-risk work environments is often insignificant, because the risk is more influenced by the duration of exposure and the level of worker protection.

The insignificant relationship between worker age and the risk of health problems in the operating room indicates that health factors are more influenced by other variables, such as exposure to anesthetics, use of personal protective equipment (PPE), and work stress levels. This finding emphasizes the importance of implementing comprehensive preventive measures in the work environment, regardless of the age of the worker. These measures include improving ventilation quality, training on the dangers of chemical exposure, and implementing good work protocols.

CONCLUSION

The conclusion of this study based on Statistical analysis shows a significant relationship between the duration of isoflurane exposure and health disorders in health workers. Long-term exposure increases the risk of respiratory, nervous system, and reproductive disorders. While the variables of PPE, length of work and age do not have a significant relationship.

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