Differences in the Levels of Total Volatile Organic Compound (TVOC) and Formaldehyde in Cigarette Smoke and Electrocautery Produced Smoke in Orthopaedic Surgery at IGNG Ngoerah (Sanglah) Denpasar General Hospital

Rizki Zainuraditya, I Wayan Suryanto Dusak, I Ketut Suyasa, and I Gede Eka Wiratnaya

ABSTRACT

Introduction: In surgeons, electrosurgical surgical devices are gaining attention that stands out as one of the most useful and most widely used instruments. Thus, the instrument of electrical surgery is undoubtedly one of the most useful and most frequently used tools by surgeons. However, not many realize that the use of electrosurgery can produce smoke containing quite harmful gases such as TVOC such as benzene, nitrile, hydrocyanides and other hydrocarbons as well as Formaldehyde.

Methods: This study used a Crosssectional Observational research design with a control group, namely cigarette smoke, and a cautere smoke treatment group. Samples in the form of TVOC and formaldehyde levels were taken as a result of all cigarette smoke and cautereized smoke operating at IBS Sanglah Hospital in Denpasar. Then patients from each age level will be randomized using the Online Research Randomizer (randomizer.org) application. Then the levels of TVOC and formaldehyde are measured in the area of operation, and for cigarette smoke it is carried out using non-filtered cigarettes.

Results: In this study, the cigarette group had an average TVOC of 9.841 mg/m³ and formaldehyde of 1.197 mg/m³. Meanwhile, the average TVOC in the electrocauter group was 6.34 mg/m³ with the average formaldehyde contained in this study of 0.87 mg/m³. It was also found in the combined levels of TVOC and formaldehyde in the cigarette group of 5.51 mg/m³ which was greater than the electrocauter group of 3.60 mg/m³.

Conclusion: Levels of TVOC and formaldehyde in orthopedic surgical electrocauteric smoke are lower levels than cigarette smoke. The combined total level of electrocauteric smoke of TVOC and formaldehyde content in orthopedic surgery is lower than the combined total level of TVOC and formaldehyde content in cigarette smoke.

Keywords: Cigarette, electrocautery, formaldehyde, smoke, TVOC.

I. INTRODUCTION

In the world of surgeons, electrosurgical devices are gaining attention that stands out as one of the most useful and most frequently used instruments in surgical procedures with functions as coagulation (stopping bleeding), cutting tissues, and even separating each layer of tissue [1]. Thus, the instrument of electrosurgery is undoubtedly one of the most useful and most frequently used tools by surgeons [2]. Although it has a very vital function in the world of surgery, there are various injuries that can be caused by electrocautery. Most of the injuries caused by electrocauterers are related to thermal energy and what is commonly called thermal injury [3].

Another injury is an injury related to smoke produced by electrocauteral action. The production of smoke in surgical procedures is a gaseous product produced during surgical procedures. It is also known as aerosol, cauteric smoke, or plume diathermy [4]. During the surgical procedure, the heat of the diathermy causes the target cell membrane to rupture to its boiling point, and then produces smoke containing most of the moisture and then releases into the atmosphere of the operating room [5]. 77% of the particles inside the surgical smoke have a size of less than 1.1 μm with an average diameter of 0.07 μm. However, this content can also contain very high levels of ultrafine particles ranging from 10 nm to 1 μm. At sizes smaller than 5 μm, these particles are not filtered by surgical masks and can be inhaled by personnel in
the operating room [1]. The smoke released at the contact of the active electrode with the tissue contains various harmful elements, including TVOC (Total Volatile Organic Compound) gas, such as benzene, nitrile, hydrocyanide and other hydrocarbons, as well as Formaldehyde. Some of these are potentially carcinogenic [2], [3].

Most surgeons, operating room staff are unaware of the risk of the smoke risk. In general, the smoke resulting from surgical procedures is produced by cautery devices, laser ablation, ultrasonic scalpels, ‘High Speed Burr’, burrs and saws as a result of damage and evaporation of proteins from tissues and fats [6]. Smoke production from the electrocautery during surgical procedures consists of 95% water or steam and 5% cell debris in the form of particulate matter consisting of chemicals, blood, tissue particles, viruses and bacteria. The electrocauter creates particles with the smallest average aerodynamic size (0.07 μm), while laser tissue ablation creates larger particles (0.31 μm) [1].

Cigarette smoke has a toxic mixture and a carcinogenic content of more than 5,000 chemicals. The electronic database provides information regarding smoke components containing more than 2,200 harmful contents. The emission level in cigarette smoke that has been found is 542 components and with a risk value of inhalation in humans for 98 components [7]. Components with potential effects of carcinogenic, cardiovascular and respiratory disorders have been included, which are the three leading causes of death from cigarette smoke [4].

Substances contained in electrocautery and cigarette smoke can trigger viral infections and molecular signaling pathways that play an important role in the forerunner of the formation of a tumor and disruption of cell growth on the surface of squamous cells in the cervix. In some studies it has been found that infectious diseases Human Papilloma Virus (HPV), Human Immunodeficiency Virus (HIV), Hepatitis B Virus (HBV) are transmitted through smoke produced inside the operating room [8]. Among the harmful substances contained in the two fumes, there are 2 main harmful gas productions, including TVOC (Total Volatile Organic Compound) and Formaldehyde. Total Volatile Organic Compound (TVOC) is a compound that contains carbon and can evaporate at certain pressures and temperatures. TVOC is very dangerous and needs special attention. One of the reasons is that TVOC can react with nitrogen oxides and if exposed to sunlight it can form smoke or fog which can affect health and the environment and has a carcinogenic content [5]-[7].

Formaldehyde (FAL) is a colorless, flammable chemical, has a strong odor and is widely used by industry especially in the production of adhesives and binders for wood products, paper, glass wool and stone wool [9]. Formaldehyde is also widely used in the production of plastics and coatings, in textile finishing processes, in the manufacture of industrial chemicals and also as a disinfectant and preservative (formalin) in many applications in medical research and pathology laboratories as well as in morgues.

There is sufficient evidence that formaldehyde causes nasopharyngeal cancer in humans and as a result, formaldehyde is classified as a Class I carcinogen [8].

Until now, it is not known about the difference in TVOC and formaldehyde levels in the smoke produced by Electrocautery during the operating procedure in the orthopaedic field at IGNG Ngeorah Hospital (Sanglah), Denpasar, compared to TVOC and formaldehyde levels in cigarette smoke. Thus, the author has an interest in further researching the differences in TVOC and formaldehyde levels in Electrocautery smoke in Orthopaedic surgery at IGNG Ngeorah Hospital (Sanglah), Denpasar, with levels in cigarette smoke. By knowing the difference in TVOC and formaldehyde levels in the two smokes, researchers were able to find out whether TVOC and formaldehyde levels reached levels of harm to staff in the operating room, especially in the field of Orthopaedics

II. METHODS

A. Selection of Research Subjects

The study used a crosssectional observational research design with a control group, namely cigarette smoke, and a cautery smoke treatment group. Samples in the form of TVOC and formaldehyde levels were taken consequently from all cigarette smoke and cauterized smoke in surgery at the Central Surgical Installation of Sanglah Hospital, Denpasar. Measurement, observation, retrieval of materials is carried out gradually over a certain period of time. The sample size was calculated by the sample size formula for hypothesis testing against an average of two populations and obtained 24 samples per group. The exclusion criteria in this study were samples who were not patients with an operative action plan in the field of orthopaedics carried out at the Central Surgical Installation of Sanglah Hospital Denpasar. The patient does not agree to be carried out sampling during operative actions. Patients with infectious diseases (HPV, HIV and HBV) and metabolic disorders diseases. Patients who at the procedure of surgery do not use electrocautery.

All patients who underwent surgery in the field of orthopaedics using electrocautery at the Central Surgical Installation of Sanglah Hospital were put into a sample pool. Then patients from each age level will be randomized using the Online Research Randomizer (randomizer.org) application to determine samples. Patients who have met the inclusion criteria, are explained about the procedure for taking smoke as a result of the use of electrocautery. The patient has received an explanation of the research to be carried out and signed an informed consent sheet at the time after the explanation is carried out.

B. Sampling

Measurement of TVOC and formaldehyde levels in smoke resulting from the cauteryization process will be carried out using a DT-400P brand cautery machine with a cautery strength when using 50 W, measurement of levels in smoke will be carried out at each layer of the operating area (Subcutis, Fascia, Muscule). Measurements are carried out with a measuring device placed at a distance of 5 cm from the cauteryization area with a duration of 5-7 seconds from the electrocauterer so that a high proportion of smoke is obtained, and then the average value is taken [9], [10]. Measurement of TVOC and formaldehyde levels produced by cigarette smoke is carried out using non-filter cigarettes, with the Dji Sam Soe Super Premium brand with Nicotine levels of 2.3 mg and Tar 39 mg, then samples will be selected using randomization (as many as 24 samples). After obtaining a sample, the level measurement will be carried out by lighting a cigarette in a
closed room that has been adjusted (resembling the conditions and temperature of the operating room, which is 19-24 °C with a room humidity of 45-60%) using a detector. Measurements are made as long as the cigarette is lit and produces Sidestream smoke and then the cigarette will be smoked so that Mainstream smoke will form, then the device is approached to the source of smoke (both Sidestream and Mainstream smoke) with a distance of about 5-10 cm for 5-7 seconds, then the average value is taken [11].

The device used to take samples of both cauterized smoke and cigarette smoke in this study used the metal-oxide semiconductor (MOS) method which works by absorbing oxygen at the end of the dioxide which then forms a layer. When the sensor detects the presence of a gaseous compound, an oxidation reaction will occur so that the resistance of the sensor is reduced. The tool screen will then show the readings of the TVOC and formaldehyde compound levels [12].

C. Data Analysis

All statistical analysis is carried out using the software program SPSS for Windows (Version 22; IBM Corp, Armonk, NY, USA). For data on the characteristics of patients who entered the study, descriptive analysis was carried out such as mean (standard deviation), frequency, median (inter-quartile) and nominal data presented in the form of frequency data. For numerical data, the Shapiro-Wilk normality test is carried out, if the data is not normally distributed, then to be able to test the hypothesis assuming the normal distribution can be transformed using logistic transformation. For inferential tests, data calculations using the Chi-square method are used. Homogeneity test with Laverne's test and One-way ANOVA to determine the difference between the treatment and control groups, with a confidence interval value (IK) of 95%. The meaningfulness of the TVOC and formaldehyde levels in the electrocautery action using the same type of electrocautery generator (DT-400P), the same electrocauteric active (Alphamed), and the same magnitude (50 W) at each operating action. The average and standard deviation of TVOC and formaldehyde levels in the electrocautery group and the cigarette smoke group were 18.77 ± 0.005 and 5.51 ± 4.40, while the TVOC levels in the electrocautery group and the cigarette smoke group were 17.75 and 31.25 with a statistically meaningful P value = 0.000.

III. RESULTS

This study used samples of substances containing substances in cigarette smoke and substances in smoke from electrocautery actions. All samples have been randomized and measured at TVOC and Formaldehyde levels. The electrocautery procedure was performed at the Central Surgical Installation of Sanglah Central General Hospital. The distribution of characteristics of the subject of the study can be seen in Table I.

This study used two groups, namely, the TVOC content group and formaldehyde measured from cigarette smoke and the group measured from smoke from electrocautery action. On electrocautery action using the same type of electrocauteric generator (DT-400P), the same electrocauteric active (Alphamed), and the same magnitude (50 w) at each operating action. The average and standard deviation of TVOC and formaldehyde levels in the cigarette smoke group was 9.841 ± 0.769 on TVOC and 1.197 ± 0.246 in formaldehyde, while in the electrocautery action group it had an average and standard intersection of 0.87 ± 0.428 in formaldehyde and 6.34 ± 3.525 on TVOC. The average and standard deviation at the combination of TVOC and formaldehyde levels was 4.56 ± 4.16.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N (%)</th>
<th>Average ± Of Raku Interchange</th>
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<tbody>
<tr>
<td>Electrocauter Generator Type (DT-400P)</td>
<td>100 (%)</td>
<td></td>
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<tr>
<td>Active Type of Electrocautery Electrode (Alphamed)</td>
<td>100 (%)</td>
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<tr>
<td>Large Electrocauteric Voltage (50 W)</td>
<td>100 (%)</td>
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The research variables in the case and control groups were carried out normality tests with the saphiro-wilk test (Table II), because the number of samples was less than 50 and aimed to find out whether the research data were normally distributed or not. In the normality test with saphiro-wilk, it was found that the variables that had a normal distribution were age variables and formaldehyde levels in the electrocautery group with values in the age variable P = 0.490 and in the variable formaldehyde levels P = 0.139, while variable levels of TVOC and formaldehyde in cigarette smoke and TVOC in electrocautery actions were not normally distributed.

<table>
<thead>
<tr>
<th>Variable</th>
<th>P-value</th>
<th>Information</th>
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<tbody>
<tr>
<td>Cigarette TVOC Levels</td>
<td>0.000</td>
<td>Not normally distributed</td>
</tr>
<tr>
<td>Formaldehyde Levels of Cigarettes</td>
<td>0.019</td>
<td>Normally Distributed</td>
</tr>
<tr>
<td>Electrocauter TVOC Levels</td>
<td>0.001</td>
<td>Not normally distributed</td>
</tr>
<tr>
<td>Electrocauter Formaldehyde Levels</td>
<td>0.036</td>
<td>Not normally distributed</td>
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<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Average</th>
<th>P</th>
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<tbody>
<tr>
<td>Formaldehyde Levels</td>
<td>24</td>
<td>18.77</td>
<td>0.005</td>
</tr>
<tr>
<td>Cigarette Smoke Group</td>
<td>24</td>
<td>30.32</td>
<td></td>
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<tr>
<td>TVOC Levels</td>
<td>24</td>
<td>17.75</td>
<td>0.000</td>
</tr>
<tr>
<td>Electrocauter Group</td>
<td>24</td>
<td>31.25</td>
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The inferential statistical tests used in this study are those that can be assessed in Table III. The results of the analysis above found that the average formaldehyde levels in the electrocautery and cigarette smoke groups were 18.77 and 30.32 with a meaningful meaning of the P value = 0.005, while the TVOC levels in the electrocautery group and the cigarette smoke group were 17.75 and 31.25 with a statistically meaningful P value = 0.000.

IV. DISCUSSION

According to the classification of The International Agency for Research on Cancer (IARC), a cigarette sap contains many compounds that are carcinogenic [13]-[17]. The content of cigarette smoke includes TVOC which is a

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volatile organic compound consisting of benzene, ethylbenzene, and styrene and formaldehyde [13]. Formaldehyde is a small volatile and highly reactive molecule and has been reclassified by IARC as a Group 1 carcinogen, i.e. ‘carcinogenic for humans’ [18]. TVOC and formaldehyde can be found on mainstream or sidestream smoke [14].

In this study, the cigarette group had an average TVOC of 9.841 mg/m³ and formaldehyde of 1.197 mg/m³. TVOC constitutes the smallest fraction of cigarette smoke (by weight) which is the main source of exposure to many toxic volatile compounds and has been proposed as the most dangerous fraction of cigarette smoke [19], [20]. Formaldehyde is known to be produced from the saccharides contained in tobacco, such as sugar and cellulose, which are naturally and are also added as a blending ingredient of cigarettes in some countries for taste reasons [14]. Formaldehyde content in mainstream cigarette smoke has been reported in the range of 1.3 μg in filtered cigarettes to 283 μg in unfiltered cigarettes [15]. Formaldehyde is also found in sidestream smoke. The ratio of formaldehyde content in sidestream smoke ranges from 36.5 for unfiltered cigarettes [14], [15].

Electrocautery is an important tool in surgery [16]. The tool is used to dissect tissues and coagulation of blood vessels to prevent the large amount of blood loss and reduce the time of operation. The electrocauter reaches coagulation by the transfer of electro-surgical energy to the tissues of the electrocautery device, the evaporation of the cellular fluid and the rupture of the cellular membrane [21]. This event causes the release of heat that can burn proteins and other organic matter in the cell. The burning of cellular material causes the scorching of cells that can produce surgical fumes. Surgical smoke consists of 95% moisture and 5% particles. Particulate matter consists of chemicals, blood and tissue particles, viruses, and bacteria [16].

In this study, the average TVOC in the electrocautery action group was found to be 6.34 mg / m³. Reference [17] found a fairly high concentration of harmful TVOCs during breast surgery of 9.953 mg/m³ and further indicated that a higher electrocautery power (> 27.5 watts) would result in a higher TVOC concentration. Another study by [18] found TVOC levels ranged from 0.7 to 3.27 μg/m³. Different things were found in the study by [16] where in the study on the evaluation of exposure to formaldehyde, PM 2.5, and volatile organic compounds in this surgical procedure, it was not found that there was a TVOC (benzene and toluene), this was because the detection limits of the analysis method (reporting limit) for benzene and toluene were 0.0010 and 0.0100 mg, respectively.

TVOC compounds, one of which consists of benzene, are very harmful to health, and are considered myelotoxic, leukemogenic, neurotoxic, carcinogenic and mutagenic, even at low concentrations [22]. Repeated and prolonged exposure can cause benzene poisoning and provoke various complications, including irritation of the ocular and respiratory mucous membranes, pulmonary edema, hematological abnormalities, chromosomal changes in lymphocytes and bone marrow cells, and toxic effects on the central nervous system depending on the amount absorbed, causing drowsiness, headache, tachycardia, convulsions, loss of consciousness and death. Benzene compounds can also trigger non-Hodgkin’s lymphoma [7], [20].

Meanwhile, the average formaldehyde in the electrocautery action group found in this study was 0.87 mg/m³. In the research of [21] with the type of surgery in the field of otorhinolaryngology, the concentration of formaldehyde was found to be high at 1.51 ppm (1.85 mg/m³) and had the highest levels detected at the end of the operation. This is estimated to be an accumulation of residues from previous operations. The hectic operating schedule cuts preparation time between operations which also shortens air circulation time [21]. On the other hand, [16] found that the levels of formaldehyde detected were well below the standard figures according to the Occupational Safety and Health Administration (OSHA) in liver sarcoma resection surgery. Based on the standards set by OSHA, the permissible exposure limit is from 0.75 ppm (0.921 mg/m³) to an 8-hour time-weighted average. The detection limit of the analysis method (reporting limit) is 0.050 μg/sample [16].

Formaldehyde is one of the common compounds found in surgical fumes. According to the IASR, formaldehyde has been classified as carcinogenic in humans [21], [22]. The threshold value for indoor formaldehyde concentrations is 0.1 mg/m³. Short-term exposure can cause eye irritation, nausea, vomiting, headache, weakness, edema, dizziness, fatigue and chest tightness. Long-term exposure in humans may be associated with a higher incidence of cancers such as leukemia and may even result in fetal malformations in pregnant women [22], [23].

The level of exposure to surgical smoke tends to differ in some surgical procedures. Research on TVOC and formaldehyde levels in orthopaedic surgery so far is still scant. In this study, TVOC and formaldehyde levels were found to be high in Total Knee Replacement (TKR) surgery and spine division surgery [24]. The number of TKR surgical procedures in this study amounted to one operation while the surgical procedures in the spine division were 5 operations [25]. In TKR Surgery, TVOC levels were obtained at 9.99 mg/m³ and formaldehyde levels of 1.53 mg/m³, while in spine division surgery, TVOC levels were obtained at 9.99 mg/m³ with formaldehyde levels of 1.34 mg/m³. In contrast, TVOC and formaldehyde levels were obtained at least in the type of MINIPLATE ORIF surgery in coronary neglected fracture with TVOC levels of 0.97 mg/m³ with formaldehyde levels of 0.11 mg/m³. Many TVOC compounds found in smoke are produced by the combustion of cigarettes or car fuel. The smoke resulting from the use of electrocautery is also a product of combustion [16].

In this study, it was found that there was an average difference between TVOC and formaldehyde levels in two groups with the cigarette smoke group having a higher average compared to electrocautery action. This shows that the levels of TVOC and formaldehyde in the crown smoke are greater than the electrocautery action with an average TVOC content of 9.8418 mg/m³ and an average formaldehyde level of 1.197 mg/m³. Despite the differences in the mean of the two sample groups, long-term exposure to TVOC and formaldehyde had a fairly pronounced clinical impact. In the study by Jadhav, TVOC was found in gas samples obtained from ten patients after the use of electrocautery in one study, and compounds such as benzene, ethylbenzene, styrene,
toluene, heptane, and methylpropene were present in gas samples at low concentrations [16], [26].

Headache is the most prominent symptom reported in a survey conducted among 36 doctors (surgeons and anesthesiologists) and 45 nurses [26], [27]. In previous study from Mexico, surgeons and anesthesiologists reported eye irritation as the most commonly experienced symptom [28]. These adverse health effects can be well managed by installing high-quality engineering controls [23]. The ventilation system plays an important role to influence the concentration of surgical smoke. Although some hospitals have installed smoke extraction systems or ventilation systems in operating rooms, there are still many hospitals that are not aware of the use of suitable smoke extraction facilities [21]. In Michaels’ research survey, only 52% of hospital respondents and 65% of outpatient respondents reported using a suction system to catch surgical smoke. Some strategies that can be done include preparing an effective operating room, ventilation system, wearing a surgical mask or N95 mask, and using a PTFE-coated knife [21], [24].

Schultz suggested that a central evacuation system should be installed in the operating room of the hospital, and a control panel should be set up to regulate the flow rate and dissipate large amounts of air in the operating room. The smoke extraction system should have a High Efficiency Particulate Air filter (HEPA filter), which has the best effect as a smoke extraction system. The minimum effect of this filter is 99.97% to remove particles of 0.3µm in size and 99.99% to remove particles of 0.5 µm, which can ensure that microparticles and microorganisms are effectively removed. An Ultra Low Penetration Air Filter (ULPA filter) that can filter particles 0.1–0.2 µm with a filtration efficiency of up to 99.999% can also be considered. In addition, the combination of a HEPA or ULPA filter with activated carbon that can remove about 85% of the VOC compounds in the surgical smoke must be ready for use [25].

The diameter of particles in surgical smoke ranges from tens of nanometers (nm) to several microns (µm) [29]. It is recommended that health workers in medical institutions wear respiratory protective equipment for their own health. Lewin et al reported that the use of personal protective equipment was still low in the operating room. In addition, studies by [21] reported that only 5% of surgeons used N-95 respirators or other NIOSH-approved respirators and the rest used surgical masks. A study by [26] suggested that face masks that meet international standards, such as N95, provide better respiratory protection than surgical masks. Surgical masks can provide protection against particles 5 µm and above but do not provide protection against microorganisms measuring less than 5 µm [27].

The masks recommended for use in operations are made of three layers [28]. The outermost layer has the function of preventing dust and water from entering the mask. The middle and deep layers have the function of absorbing moisture and droplets from the mouth and nose. Where it can effectively block more than 90% of the 5 µm particles, but not for particles measuring 0.3 µm [26].

The Society of American Gastrointestinal and Endoscopic Surgeons and the European Association of Endoscopic Surgery recommend the use of tissue-cutting electronic devices such as electrocautery juxtaposed with surgical smoke evacuation devices to reduce smoke exposure to medical personnel in the operating room. However, until now there is no electrocautery device that is equipped with a smoke evacuation device (suction) directly in one tool at a time [28]. Therefore, [29] put forward the idea of combining electrocautery with suction.

The tools needed in its manufacture include suction tubes, electrocautery, sterile strips, and scissors. The way to make it is to cut/make a hole at the end of the suction hose which is continued by inserting the electrocautery tip at the end of the suction hose then fixing the hose using a sterile strip. However, care needs to be taken when positioning the suction hose when fixed so that the cautery end does not contact with the suction hose to avoid burning the hose when used. With this modification, it is hoped that the smoke produced when performing surgery will be directly sucked through the suction hose that has been connected to the electrocautery tip so as to minimize smoke exposure to medical personnel on duty [29].

In addition to using a combination of electrocautery with suction, another effort that can be made to reduce smoke exposure for medical personnel in the operating room is to reduce the production of surgical smoke itself [22], introduced the idea of the use of a combination of electrocautery with irrigation systems using infusion fluids [21]. This aims to reduce the formation of smoke due to the thermal effect resulting from the use of electrocautery by using irrigation techniques, minimizing excess tissue adhesions on the electrocautery to increase the effectiveness of the use of electrocauteries and indirectly reduce the production of excess smoke on the operating table. Tools and materials that can be used in its manufacture include bipolar electrocautery, sterile strips, infusion fluids (NaCl 0.9%), infusion hoses, and scissors. The stage in making it is cut at the end of the infusion hose by removing the rubber part and then on the other side it is inserted into the infusion fluid [30]. Fixation of the end of the infusion hose is carried out using sterile strips on the outer side of the end of the electrocautery. In its use for a year, it was reported that using a combination of electrocautery and infusion fluid simultaneously resulted in a decrease in tissue adhesion/adhesion, tissue scorching, the formation of surgical fumes, and enhancing the coagulation effect of tissues [28]-[30].

The limitations in this study include the condition when the study was carried out in period, which resulted in limited variations of the operations used as samples in this study, less homogeneous samples and difficulties in sampling, especially the distance of measuring devices to the sterile area of the operation, so that it is likely to affect the results of the study.

V. CONCLUSION

TVOC and formaldehyde levels in electrocautery smoke in orthopaedic surgery have lower levels than levels in cigarette smoke. The combined total content of TVOC and formaldehyde levels in electrocautery smoke in orthopaedic surgery is lower than the combined total content of TVOC
and formaldehyde in cigarette smoke. The advice that can be given is that operators of surgical actions are expected to wear adequate PPE (Masks) to reduce exposure to body smoke, and innovations for the manufacture of cauteries accompanied by connected suction, which can help reduce smoke exposure to operators.

**CONFLICT OF INTEREST**

Authors declare that they do not have any conflict of interest.

**REFERENCES**


