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Original Article

Evaluation of the Approaches of the Anaesthesiologists on Maintenance of Anaesthesia Machines

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Abstract

Objective: In this study, we aimed to discuss the level of knowledge and approach on 'maintenance, calibration and cleaning of anaesthesia devices' among anaesthesiologists in Turkey.

Methods: A questionnaire was prepared with 21 questions based on the Google document system, and these questionnaires were sent to the anaesthesiologists via e-mail.

Results: Overall, 226 anaesthesiologists answered our survey. With respect to the maintenance and calibration, anaesthesiologists had sufficient information about the vaporizer and the carbon dioxide canister devices; however, information about the vital components, such as disassembly of the anaesthesia machine, flow sensor, oxygen sensor, battery and exhaust system, was insufficient. The cleaning and sterilization procedures were performed when the devices became dirty, and the bacteria filter was used only for the protection of the anaesthesia system. There was a lack of knowledge about how and which part of the anaesthesia device should be disinfected. In total, 85% of the survey participants were thinking of the need of additional education on anaesthesia machine maintenance.

Conclusion: It is observed that education about anaesthesia device maintenance, calibration and cleaning issues is obviously necessary for the anaesthesiology specialists in our country. We believe that it would be useful to highlight this issue to anaesthesia educational institutions and anaesthesia associations.

Keywords: Anaesthesia device, maintenance, calibration, hygiene

Introduction

Anaesthesia devices are devices that are used extensively and make contact with many different patients. The maintenance, calibration and cleaning of these devices are of vital importance. Today, anaesthesia devices are electronic and computerised and work with microprocessors, making their maintenance and cleaning more complex. Each model of anaesthesia device may have different parts and different characteristics of maintenance. The most common parts that show difference are the oxygen sensor, flow sensor, canister and waste gas systems. In fact, there are many mechanisms for the control of anaesthesia devices and equipment. These controls include the routine maintenance and calibrations performed by authorised service centres, weekly maintenance usually performed by the anaesthesia technician and daily checks. Checklists are often applied for these procedures or the maintenance is included in the automatic controls that are done by the device itself (1). However, the maintenance of the device may also be required because of reasons such as contamination or malfunction of the device. The anaesthesiologist and anaesthesia technician are responsible for the control of these parts at appropriate time intervals and for ensuring that the 6-month and annual maintenance requirements are met (2). If not well cleaned, all the respiratory equipment used in an operating room can lead to infection from patient to patient. Microorganisms, produced in any part of the breathing apparatus used, may spread to the lower respiratory tract with the aerosol effect and can lead to serious cases of infections (3). The cleaning and sterilisation of these parts vary depending on the brands and models.

In this survey study, we aimed to investigate the approaches and the level of knowledge of anaesthesiologists in Turkey about the 'maintenance, calibration and cleaning of the anaesthesia devices'.

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Methods

Our study has been prepared to measure the approaches of anaesthesiologists in terms of the 'maintenance, calibration and cleaning of anaesthesia equipment' through a multiple choice survey. Ethics Committee approval (Decision No. 2015/12–18) of the Çanakkale Onsekiz Mart University was received. Our survey consisted of 21 questions. Of the questions, 1 was about demographic data, 11 were about maintenance and calibration, 6 were about cleaning and sterilisation, 1 was about legal issues and 2 were about general opinions. While only 1 option could be checked in 15 of the questions, more than 1 choice could be selected in 6 of them (Appendix 1). The survey questions were electronically transmitted through the Google Document System (docs.google.com). All anaesthesiologists throughout Turkey were invited to online access via electronic mail. The Turkish Anaesthesiology and Reanimation Society was tasked to this purpose. An announcement was made to all members on 16 June 2015 by the association. The survey was open to access between 13 June 2015 and 3 July 2015. The data input was accepted only via the online system in the survey assessment. The obtained data were transferred to a spreadsheet on the Google Docs system. The numbers and percentages of the data were determined and interpreted.

Results

In our study, a total of 226 participations took place through the Google Document System between 13 June 2015 and 3 July 2015. The responses were assessed in 5 separate sections.

In demographic data: to the question of 'How long have you worked as an anaesthesiologist?', 69 people (30.5%) replied 0–5 years, 59 people (26.2%) replied 5–10 years, 50 people (22.1%) replied 10–20 years and 48 people (21.2%) replied 20–30 years.

There were a total of 11 questions in the maintenance and calibration issues section. The rate of those who gave the answer of 'once in 6 months and once in a year' was 62.4% to the question (question 2) related to how often anaesthesia device maintenance was performed by the authorised company. In the tenth question, the rate of those replacing the soda lime canister routinely was only 44.7% (Table 1). About the parts of the anaesthesia device (5th, 9th, 11th, 13th and 15th questions), while nearly half of the participants said that they had never disassembled an anaesthesia device, 21.2% said they did not know the place of the flow sensor, 32.7% said that they did not know the place of the oxygen sensor and 58.4% said that they did not check the battery. Almost everyone knew the location of the soda lime canister (Table 2). In the 16th and 17th questions related to the waste gas system, 63.7% of participants reported that routine inspection was not performed and 80.5% reported that they did not know about the flow of the waste gas system (Table 3). The vast majority of the participants were found to have knowledge about how to use the vaporiser (18th and 19th questions) (Table 4).

Table 1. Questions related to the frequency of maintenance of anaesthesia devices and the maintenance and calibration of the soda lime canister

Questions	Number	%
How often is the maintenance of the anaesthesia device performed in your organisation by the authorised companies?		
Weekly	1	0.4
Once in a month	8	3.5
Once in 3 months	19	8.4
Once in 6 months	65	28.8
Once a year	76	33.7
I do not have enough knowledge *	57	25.2
When do you consider replacing the soda lime canister? (Question for which more than 1 option can be selected)		
Routine replacement	101	44.7
With colour change	155	68.6
With the increase of $EtCO_2$ values	88	33.9
I do not have enough knowledge *	4	1.8

*Those who gave the answer 'I do not have enough knowledge' and did not answer

Table 2. Questions related to the maintenance and calibration of the parts of the anaesthesia device

Questions	Yes Number (%)	No Number (%)	Unanswered Number (%)
Have you ever disassembled anaesthesia device(s)?	111 (49.1)	110 (48.7)	5 (2.2)
Do you know the location of the soda lime canister?	224 (99.1)	0	2 (0.9)
Do you know the location of the flow sensor?	175 (77.4)	48 (21.2)	3 (1.4)
Do you know the location of the oxygen sensor?	150 (66.3)	74 (32.7)	2 (0.9)
Do you check the battery of the device?	89 (39.4)	132 (58.4)	5 (2.2)

There were a total of 6 questions about cleaning and sterilisation issues. Mostly, the anaesthesiologists performed the cleaning of the anaesthesia device by disassembling the parts (3rd Question) 'when it just got contaminated' (Figure 1). While the majority of the participants preferred to use the bacteria filter (6th question), it was understood that they thought the M. tuberculosis bacteria filter was not protective against viruses and fungus (7th questions) (Figure 2, 3). A variety of responses were given about which parts of the anaesthesia device that did not have direct contact with the exhaled breath of a patient needed to be disinfected (8 questions) after a patient with a contagious infection in the respiratory tract was operated upon (Figure 4). The most frequently marked

Table 3. Questions related to the maintenance and calibration of the waste gas system

Questions	Number	%
What is your procedure for control of the waste gas system? (Question for which more than 1 option can be selected)		
The deflation of the waste system balloon	33	14.6
Follow-up with negative flowmeter	44	19.5
Manual assessment of the negative pressure	28	12.4
We do not routinely check	144	63.7
How much is the negative flow of the waste gas system in your organisation?		
<10 L/min	19	8.4
10–35 L/min	18	8
35–70 L/min	6	2.7
>70 L/min	1	0.4
I do not have enough knowledge*	182	80.5

*Those who gave the answer 'I do not have enough knowledge' and did not answer

Table 4. Questions related to the maintenance and calibration of the vaporisers

Questions	Number	%
How is the calibration of the vaporisers performed in your organisation?		
By the anaesthesia technicians	12	5.3
By the biomedical employees	30	13.3
By the authorised firm	171	75.7
I do not have enough knowledge*	13	5.7
What is your transportation procedure for the vaporiser? (Question for which more than 1 option can be selected)		
There is no consideration about it	10	4.4
We carry the vaporiser perpendicularly	181	80.1
We put the device in T (transport) mode	121	53.5
We carry after it is fully discharged	19	8.4
I do not have enough knowledge*	23	10.2

*Those who gave the answer 'I do not have enough knowledge' and did not answer

answer about how to disinfect the flow sensor and oxygen sensor (12th and 14th questions) was 'I do not have enough knowledge' (Figure 5).

One question that was 'select all that apply' was about legal issues. While the number of those who considered the anaesthesia technician and the anaesthesiologist as the responsible partner was only 26 (11.5%), the total number of people who said that the medical firm and/or the hospital management had the responsibility was 92 (40.7%) (Figure 6).

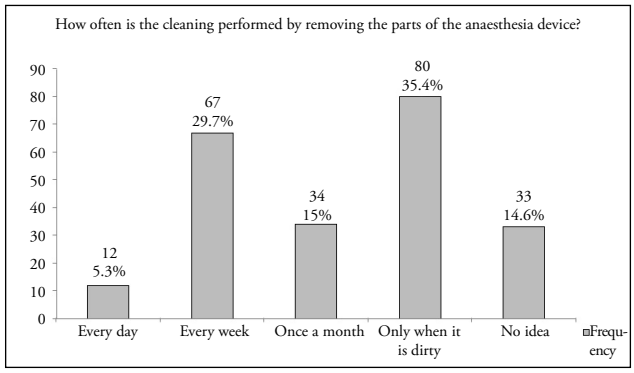


Figure 1. The cleaning and sterilisation question related to how often the cleaning is performed by removing the parts of the anaesthesia device

*Those who gave the answer 'I do not have enough knowledge' and did not answer.

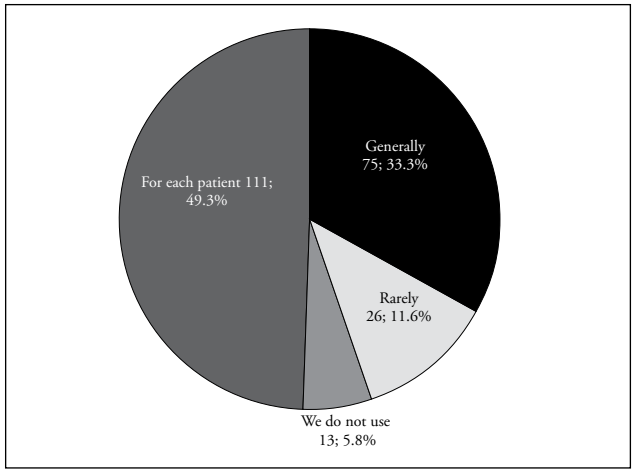


Figure 2. The cleaning and sterilizing question regarding the frequency of use of the bacteria filter

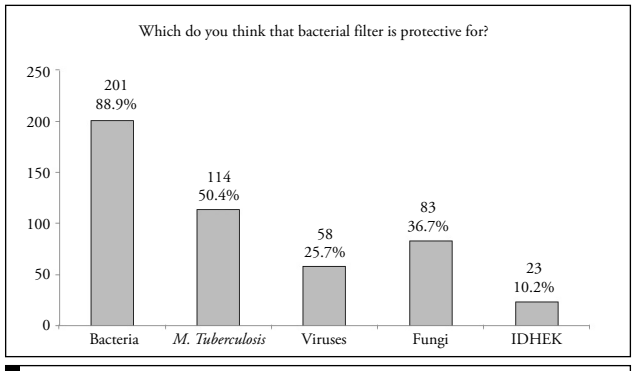


Figure 3. The cleaning and sterilisation question related to the pathogens for which the bacterial filter is protective. (Question for which more than 1 option can be selected)

*Those who gave the answer 'I do not have enough knowledge' and did not answer.

Two questions were evaluated about general issues. To the first question 'Have you read the manual of the anaesthesia device(s) that you use?', 56 (24.8%) people replied 'yes', 74 (32.8%) people replied 'no', 95 (42%) people replied 'partially' and 1 person (0.4%) did not answer. To the final question 'Do you think that you need training about the maintenance

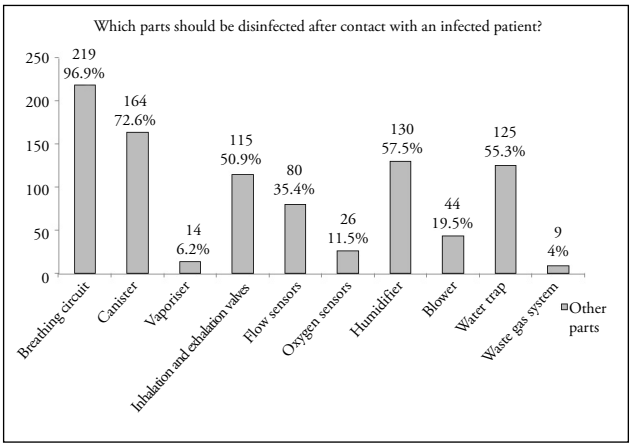


Figure 4. The cleaning and sterilisation question about which parts of the anaesthesia device need to be disinfected after contact with an infected patient. (Question for which more than 1 option can be selected)

* Inhalation and exhalation valves

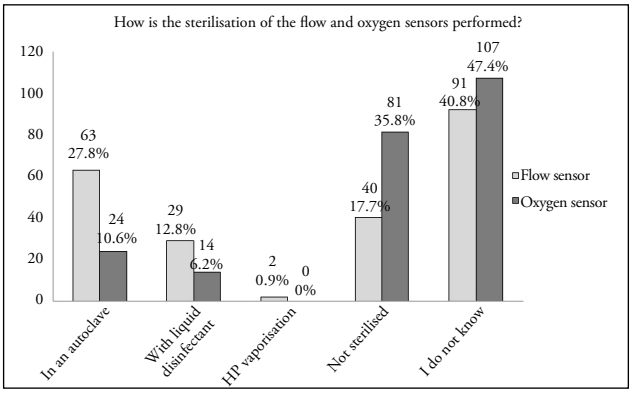


Figure 5. The cleaning and sterilisation questions about how to clear the flow and oxygen sensors after contact with an infected patient

*Hydrogen peroxide, †: Those who gave the answer 'I do not have enough knowledge' and did not answer.

of the anaesthesia device and equipment?', 192 people (85%) replied 'yes' and 34 people (15%) replied 'no'. Intergroup survey questions were examined according to the working year. However, the results obtained were quite heterogeneous.

Discussion

Modern anaesthesia devices are no longer simple units that deliver anaesthetic gases to patients; they have turned into computer-assisted professional units where precise adjustments and measurements can be executed. These devices are now named anaesthesia workstations. Nowadays, both anaesthesia-related mortality rates (4) and the incidence of death due to anaesthesia devices are low (5). However, faults associated with the device are more common than presumed. In the study of Bothner et al. (6), where the data of 96107 patients were evaluated, it was reported that an 'event' or a 'complication' was seen at a rate of 22% in anaesthesia applications. In this study, the incidence of complications related to anaesthesia equipment was detected as 0.4% and the incidence

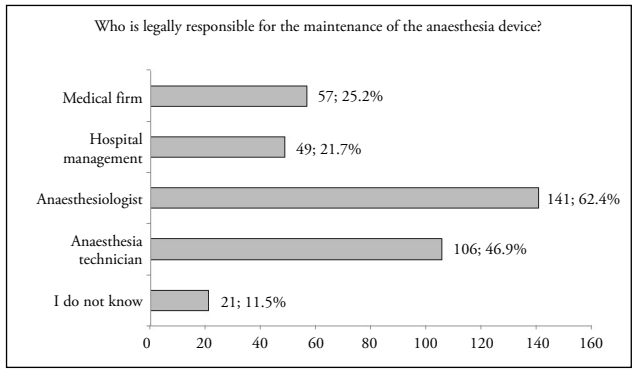


Figure 6. The question about who is legally responsible for the maintenance of the anaesthesia device. (Question for which more than 1 option can be selected)

depending on all medical equipment was found as 1.24% (6). In a study where 1000 anaesthesia accidents were evaluated through the notification system of anaesthesia accidents, it was reported that 395 incidents were found to be associated with the anaesthesia device and equipment (7).

Adverse events occurring in anaesthesia applications are divided as preventable and unpreventable situations. The situations that occur, despite actions that are consistent with the standards of operation, are considered complications and the physicians are often not regarded as responsible (8). However, there are studies reporting that 75% of the cardiac arrests during the intervention can be prevented (9) and 12% of these situations result from faults related only to anaesthesia devices (10). While the responsibility of the maintenance of anaesthesia equipment has legally been given to the anaesthesia technician, the follow-up of this is the duty of anaesthesiologist (2). In the survey we conducted, while 11.5% of the anaesthesiologists considered it as the mutual responsibility of the anaesthesia technician and the anaesthesiologist, the rate of those who said that it was the responsibility of the anaesthesiologist was 62.4% and the rate of those who said it was the responsibility of the anaesthesia technician was 46.9%. In a forensic study performed by Gündoğmuş (11), it was reported that anaesthesia and resuscitation experts are responsible for 'doing all the controls of the patient during anaesthesia and surgery or having the technicians subject to themselves to do, as well as the provision, maintenance, preservation and the consumption of all kinds of devices, equipment, medicine and sanitary materials'. The anaesthesiologist and technicians are punished equally in the lawsuits of deaths caused by device and equipment issues (11). Legally, it is understood that the maintenance that the companies do, and therefore, the hospital management, cannot be held responsible for the problems that occur in patients. However, 40% of the respondents in our survey think that it is the responsibility of the medical companies and the hospital management.

Today, complications have been decreasing thanks to a variety of sensors and automatic control systems from advances in technology (12). Nevertheless, it is obvious that these systems are not adequate for providing the patients with safety. Dosch (13) showed that the automatic controls of the devices gave different reactions in the study where he examined the response of different anaesthesia devices to breathing circuit obstructions. It has also been emphasised, in a different case report, that automated systems are inadequate for identifying the errors that occur in the patient and controls performed by physicians are still safest (14). These studies demonstrate that professionals should know the features of the devices that they use.

In our country, 16 brands and 60 models of anaesthesia devices are sold (15, 16). New ones are being added to this list every day. Each model of anaesthesia device may have different parts and different maintenance characteristics. For example, while the oxygen sensors of some of these devices are disposable, sensors of some devices are suitable for reuse. In this case, the regular maintenance of the sensors is required. In our survey, while anaesthesiologists have sufficient knowledge about the vaporiser and carbon dioxide canister, they do not have enough knowledge about how to disassemble the anaesthesia device and about pieces of vital importance such as the flow sensor, oxygen sensor, batteries and waste gas system.

In their study, Dutoit et al. (17) mentioned an interference of the oxygen sensor of an anaesthesia device with another oxygen sensor in the same view. Similarly, troubles depending on the flow sensor failure during the operation were reported (18). In our survey, 21.2% of the participants said they did not know the place of the flow sensor and 32.7% said they did not know the place of the oxygen sensors. This can lead to serious troubles in the daily work of the anaesthesiologists.

In our country, despite all the technological advances and preventive actions, power outages may still occur in operating rooms. According to the guidelines issued by the Ministry of Health, each operating room is to have an uncut power supply (UPS) and each anaesthesia device is to have its own battery. These batteries should provide sufficient time for the operation of the device until power is restored (19). Additionally, anaesthesia devices operating only on battery power were shown to lead to changes in the ventilation parameters, albeit minimal (20). However, it is observed in our survey that only 39.4% of the anaesthesiologists check whether or not the device will work on battery only.

Anaesthesia waste gas systems are divided into two: active (vacuum systems) and passive (direct external exhaust systems). If the waste gas system does not work, the level of free nitrous oxide should not exceed 25 ppm and the volatile anaesthetics level should not exceed 2 ppm in the operating rooms according to international standards (21). It is understood in our survey that anaesthetists use different methods to determine whether or not the waste gas system works. In addition, 80.5% of respondents said that they did not know the negative flow of the waste gas system. The waste gas flow is 35–75 L/min in the systems used today. In fact, there are studies that demonstrate that a flow of 10-35 L/min or lower is actually sufficient. It was reported that waste gas discharge should be, at least, equal to the fresh gas flow and high negative pressures were unnecessary during the use of mechanical ventilation (22). It is also possible that excessive negative pressure causes the discharge of the blower and excessive consumption of volatile agents.

The calibration of the vaporisers is a very delicate job and should be performed only by the manufacturers (23). Most of the anaesthesiologists reported information consistent with this opinion in our survey. There are some issues to be considered during the transportation of the vaporisers. As a result of moving the vaporiser sideways while it is full, anaesthetic agent may pass through the air channels in the liquid state and thus, it may lead to patient exposure to high concentrations of the anaesthetic agent. Therefore, a special transport mode has been developed by several firms. Most of the anaesthetists held the vaporiser in an upright position during transportation and/or put the device in the transport mode and some of them preferred to discharge the vaporiser completely.

As to the cleaning of the anaesthesia equipment, 35.4% of respondents reported that cleaning was performed only when the device became contaminated and 14.6% of them did not have enough knowledge on the subject. In fact, infection is known to spread via staff and equipment in the field of anaesthesia (24). Microorganisms reproducing in any part of the ventilators may spread to the lower respiratory tract through the aerosol effect and can lead to serious infections (3). The anaesthesiologists usually used the bacteria filter for preventive purposes, but they thought that it was not sufficiently protective against M. tuberculosis, fungi and viral infections in particular. Theoretically, bacteria filters exhibit very good protective properties against bacteria as well as fungi and viruses (25). Nevertheless, they have not been proved to be effective in the prevention of ventilator-associated pneumonia (26). There are studies that show that using the filter statistically reduced the rate of contamination, but reproduction was shown to occur in a rate as high as 33.9% in the samples taken after the use of filters (27).

A variety of answers were given in our survey about which parts should be disinfected after contact with an infected patient. Although the topic of whether or not an anaesthesia device increases ventilator-associated pneumonia is controversial in the studies performed, all of the device parts that come in contact with the expiratory air must be disassembled and sterilised after patients known to have contagious respiratory infections (28). In our survey, the anaesthesiologists answered the question on which parts needed to be

disinfected in accordance with the literature. However, the matter of how and which parts to disinfect shows differences among devices. Plastics are used in most of today's anaesthesia equipment. Some of these materials can be sterilised in an autoclave at a medium temperature (≤134°C) under high pressure. Breathing circuits, soda lime canister, bellow jar, water trap and humidifier can be given as examples. However, it is necessary to implement a specific procedure for the parts containing electronic circuitry (3, 29). For example, components such as the flow and oxygen sensors should be kept in disinfectants similar to glutaraldehyde or OPA by leaving electronic circuits outside. From our survey, participants only had knowledge about the sterilisation plastic parts such as the soda lime canister, but they did not have enough knowledge about the disinfection of sensitive components such as the flow sensor and the oxygen sensor. If the parts of the devices are not disassembled and appropriate sterilisation techniques are not performed, the parts and sensors may get damaged. For this purpose, both anaesthesia technicians and anaesthesiologists should carefully examine the user guides of all devices. Unfortunately, only 24.8% of the participants in our survey expressed that they had completely read the manual of the device they used.

At the end of the survey, 85% of respondents gave the answer 'yes' to the question 'Do you think that you need training about the maintenance of the anaesthesia devices and equipment?'

Conclusion

In our country, it is obvious that anaesthesiologists need training on the issues of maintenance, calibration and cleaning of anaesthesia devices. We believe that the institutions and anaesthesia associations that provide specialty education should act immediately.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Çanakkale Onsekiz Mart University School of Medicine (Decision No: 2015/12-18).

Informed Consent: This research is an survey on internet for anesthesiologists.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – U.A.; Design – U.A., H.B.A.; Supervision – H.T., M.E., H.Ş.; Resources – T.Ş., H.A.K., T.D.; Data Collection and/or Processing – U.A., H.B.A.; Analysis and/or Interpretation – U.A., H.B.A.; Literature Search – T.Ş., H.A.K., T.D.; Writing Manuscript – U.A., H.B.A.; Critical Review – H.T., M.E., H.Ş.

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Appendix 1. Survey form

1) How long have you worked as an Anaesthesiologist?
- o 0–5 years
- o 5–10 years
- o 10–20 years
- o 20–30 years

2) How often is the maintenance of the anaesthesia device performed by the 'authorised firm' in your organisation?
- o Daily
- o Weekly
- o Once in 3 months
- o Once in 6 months
- o Once a year
- o I do not have enough knowledge *

3) How often is the cleaning performed by anaesthesia professionals in your organisation (except for times after active contamination) by removing the parts of the anaesthesia device?
- o Daily
- o Weekly
- o Once in a month
- o Only when they get contaminated
- o I do not have enough knowledge

4) Who do you think is legally responsible for the maintenance and control of the anaesthesia device and equipment? (More than 1 option can be selected)
- o Medical firm
- o Hospital management
- o Anaesthesiologist
- o Anaesthesia technician
- o I do not have enough knowledge

5) Have you ever disassembled the anaesthesia device(s) that you use?
- o Yes
- o No

6) Do you use bacteria filters in your institution?
- o We use for each patient
- o We generally use
- o We rarely use
- o We do not use

7) What do you think that the bacteria filter is protective against? (More than 1 option can be selected)
- o Bacteria
- o M. tuberculosis
- o Viruses
- o Fungi
- o I do not have enough knowledge

8) Which parts of the anaesthetic device should be sterilised after surgery of a patient with a contagious infection in the respiratory tract? (More than 1 option can be selected)
- o Breathing circuit
- o Canister
- o Vaporiser
- o Inhalation and exhalation valves
- o Flow sensors
- o Oxygen sensor
- o Humidifier (humidifier)
- o Blower
- o Water trap
- o Waste gas system

9) Do you know the location of the soda lime canister in the anaesthesia device(s) that you use?
- o Yes
- o No

10) When do you consider replacing the soda lime canister? (More than 1 option can be selected)
- o Routine daily/weekly replacement
- o Replacement upon colour change
- o Replacement when the EtCO2 values rise
- o I do not have enough knowledge

11) Do you know the location of the flow sensor in the anaesthesia devices(s) that you use?
- o Yes
- o No

12) How do you clean the flow sensor in the anaesthesia devices you use after contact with an infected patient?
- o It is removed and sterilised in an autoclave (in the appropriate temperature and duration in accordance with the user guide).
- o It is removed and sterilised with liquid disinfectants (keeping in solutions like glutaraldehyde, OPA and others for the appropriate time).
- o Hydrogen peroxide is vaporised through the respiratory system.
- o The flow sensor is not a part that is removed and sterilised
- o I do not have enough knowledge

13) Do you know the location of the oxygen sensor in the anaesthesia devices(s) that you use?
- o Yes
- o No

14) What is your maintenance procedure for the oxygen sensor in the anaesthesia device(s) that you use after contact with an infected patient?
- o It is removed and sterilised in an autoclave (in the appropriate temperature and duration in accordance with the user guide).
- o It is removed and sterilised with liquid disinfectants (keeping in solutions like glutaraldehyde, OPA and others for the appropriate time).
- o Hydrogen peroxide is vaporised through the respiratory system.
- o The oxygen sensor is not a part that is removed and sterilised
- o I do not have enough knowledge

15) Do you routinely control 'how long the anaesthesia device you use works only with battery' during power outage?
- o Yes
- o No

16) How do you control the operation of the waste gas systems of the anaesthesia devices(s) that you use?
- o Deflation of the ventilation balloon of the waste gas system.
- o Follow-up with a negative flowmeter of the waste gas system
- o Manual evaluation through the hose of the waste gas system.
- o I do not have enough knowledge

17) What is the negative flow pressure of the waste gas system in your institution?
- o < 10 L/min
- o 10–35 L/min
- o 35–70 L/min
- o 70 L/min
- o I do not have enough knowledge

18) How is the calibration of the vaporisers performed in your organisation?
- o By the anaesthesia technician
- o By the biomedical employees of the hospital
- o By the authorised firm
- o I do not have enough knowledge

19) How do you transport the vaporiser? (More than 1 option can be selected)
- o There is no consideration about it
- o We pay attention to keeping the vaporiser perpendicular.
- o We put the device in T (transport) mode in appropriate vaporisers
- o We carry after it is fully discharged
- o I do not have enough knowledge

20) Have you read the user guide of the anaesthesia device(s) that you use?
- o Yes
- o No
- o partially

21) Do you think that you need training on the maintenance of anaesthesia devices and equipment?
- o Yes
- o No

Appendix 1: Survey Form