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The effect of the length of delivery tubing to the anesthetic gas concentration

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Abstract: In this study, it was investigated whether the gas concentration delivered to the patient, shows changes depending on the length of the delivery tubing or not. The length of delivery tubing is important during performance tests of anesthesia vaporizer, because it may be shortened or extended if it is required. But its material type and its width does not change. To investigate the effect of length of delivery tubing, the performance test of anesthesia vaporizer may be performed for the tubes with different lenghts. In this study, for 3 different length of delivery tubing (A: 48cm, B: 100cm and C: 150cm), sevoflurane and isoflurane concentration measurements were performed. Because 5 different vaporizers were measured for each length of delivery tubing, totally 30 measurements (15 isoflurane and 15 sevoflurane) were performed. For the concentration measurements, PF301 Flow analyser (imt medical-Switzerland) and OR703 Multi Gas analyser (IRMA AX) were used. Measurement procedure were obtained from Inspection and Preventive Maintenance System (IPM) of Emergency Care Research Institute (ECRI). For sevoflurane; measurements were taken in the scale of 1%, 2%, 3%, 4%, 5%, 6% and 8%, whereas for isoflurane, were taken in the scale of 1%, 2%, 3%, 4% and 5%. Measurements were performed with an oxygen flow of 5L/min. The measurement results were investigated statistically and their mean and standard deviation were calculated. As a result, it was seen that, anesthesia vaporizers give concentrations close to each other, independently with the length of delivery tubing. There was no any gas absorption as like expected.

Keywords: Anesthesia, Anesthetic gas, Vaporizer, Sevoflurane, Isoflurane

1. Introduction

An anesthesia unit is a basic device that is used to dispense mixture of gases including anesthetic agents and to control ventilation during surgical operations. An anesthesia unit includes the gas connection, manometer, pressure valves, flowmeters, vaporizer, ventilator, monitor and delivery tubing. Anesthesia unit workflow is given in Figure 1.

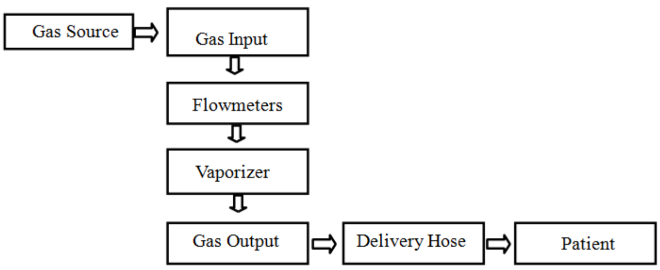

Figure 1. *Anesthesia unit workflow*

High pressure gas entering from gas sources to the anesthesia unit, is decreased to the appropriate pressure value by regulators. The adjustment of the gas with reduced pressure is administered via flow meter. An anesthesia vaporizer is used to evaporate liquid anesthetic agent and deliver a controlled amount to the patient. In vaporizer, a controlled amount of oxygen/medical gas mixture is added to the anesthetic liquid and the vaporizer changes it to a vapor, which then is delivered to the patient at a certain percentage. The percent of agent delivered is determined by the settings on the dial on the vaporizer that is set by the anesthetist.The most widely used anesthetic agents are isoflurane and sevoflurane. The gas output is where the oxygen/medical gas/anesthetic agent mixture exits the anesthesia machine to the breathing system. The anesthesia workflow is completed in the result of the transmission of the gas to the patient by using the delivery tubing.

The delivery tubing provides the gas transmission between the patient and the anesthesia equipment. It usually is a length of 1 meter. It is flexible and it has not more expansion capability. It has large-bores to decrease the resistance. The last part of the tubing is 22 mm wide and the average volume for 1 m is around 400 - 500 ml. Flow pattern is always turbulent.

Figure 2. *Anesthetic gas delivery tubing*

In literature, there are studies about the delivery system of anesthesia unit and the gas concentration changes in different environmental conditions [1-3]. In addition to them, some investigators have studied the anesthesia equipment problems and the human errors during the anesthesia [4-8]. The studies show that anesthesia errors generally are resulted from inaccurate anesthetic gas concentrations. In order to prevent gas concentration error, it is required to test vaporizer.

According to the American Society for Testing and Materials (ASTM) standard ASTM F1161-88, anesthesia vaporizers must be controlled [9]. The testing period of anesthesia vaporizers is 6 months because they are in high risk level [10]. Additional inspection and preventive-maintenance program is normally required to apply annually or semiannually [11,12]. According to the Inspection and Preventive Maintenance System of ECRI, the concentration should be ±0.3% vapor or ±10% of the selected value, whichever is greater.

During the performance tests of anesthesia vaporizer, the standard type tubing with standard material and standard width, are used. These parameters are not changed. But, the length may be changed according to the application conditions. The purpose of this study, is to investigate whether the length change does affect the measured concentration or not.

In this study, the gas concentration was tested by using the three different length of delivery tubing to investigate the effect of the length of the delivery tubing.

2. Method

In this study, for 3 different length of delivery tubing (A: 48cm, B: 100cm and C: 150cm), sevoflurane and isoflurane concentration measurements were performed. Because 5 vaporizers were measured for each length of delivery tubing, totally 30 measurements including 15 isoflurane and 15 sevoflurane were completed. For the concentration measurements, PF301 Flow analyser (imt medical-Switzerland) and OR703 Multi Gas analyser (IRMA AX) were used (Fig. 3).

Figure 3. *Flow analyser and OR703 [13]*

OR703 MultiGas analyser is the world's smallest and lightest Multi-Gas Sensor. It is integrated to the Flow analyser and it operates together with Flow analyser [13]. Both of them have calibration certificates to show their measurement accuracy. Measurement uncertainty was calculated as 0,033% concentration at a 95% level of confidence [14].

During measurements, the measurement procedure that are obtained from Inspection and Preventive Maintenance System (IPM) of Emergency Care Research Institute (ECRI) were applied [2].

For sevoflurane; measurements were taken in the scale of 1%, 2%, 3%, 4%, 5%, 6% and 8%, whereas for isoflurane, were taken in the scale of 1%, 2%, 3%, 4% and 5%. Measurements were performed with an oxygen flow of 5L/min. During each scale measurement, it was waited for gas stability at 3 minutes. After this, measurement results were recorded. From PF301 Flow analyser' screen, because the maximum, minimum and statistic values can be seen, only statistic data were recorded.

3. Results

The data obtained from 5 different sevoflurane vaporizers, firstly, were investigated statistically and their mean and standard deviation were calculated. Calculated data can be seen in Table 1.

Table 1. *Statistical data of sevoflurane vaporizers' concentration for 3 different length of delivery tubing (A: 48cm, B: 100cm and C: 150cm).*

%	Measured concentrations (%)					
	Mean Sevo A	**Std A**	**Mean Sevo B**	**Std B**	**Mean Sevo C**	**Std C**
1	0,88	0,04	0,83	0,05	1,18	0,11
2	1,93	0,05	1,87	0,06	2,30	0,07
3	2,92	0,11	2,77	0,16	3,31	0,14
4	3,84	0,10	3,75	0,06	4,00	0,06
5	4,73	0,22	4,74	0,16	4,97	0,11
6	5,61	0,15	5,69	0,05	5,92	0,10
8	7,23	0,18	7,58	0,22	7,60	0,14

As you see in Table 1, the output concentration data for A and B length are lower from the adjusted concentration.

Whereas vaporizers with C length give higher output concentrations from the adjusted value until 4% scale, lower concentration is essential at 5%, 6% and 8% scale. All data are within the tolerance values that are recommended by the international standards.

The relationship between the adjusted and the measured sevoflurane concentration data for 3 different length of delivery tubing can be seen in Figure 4.

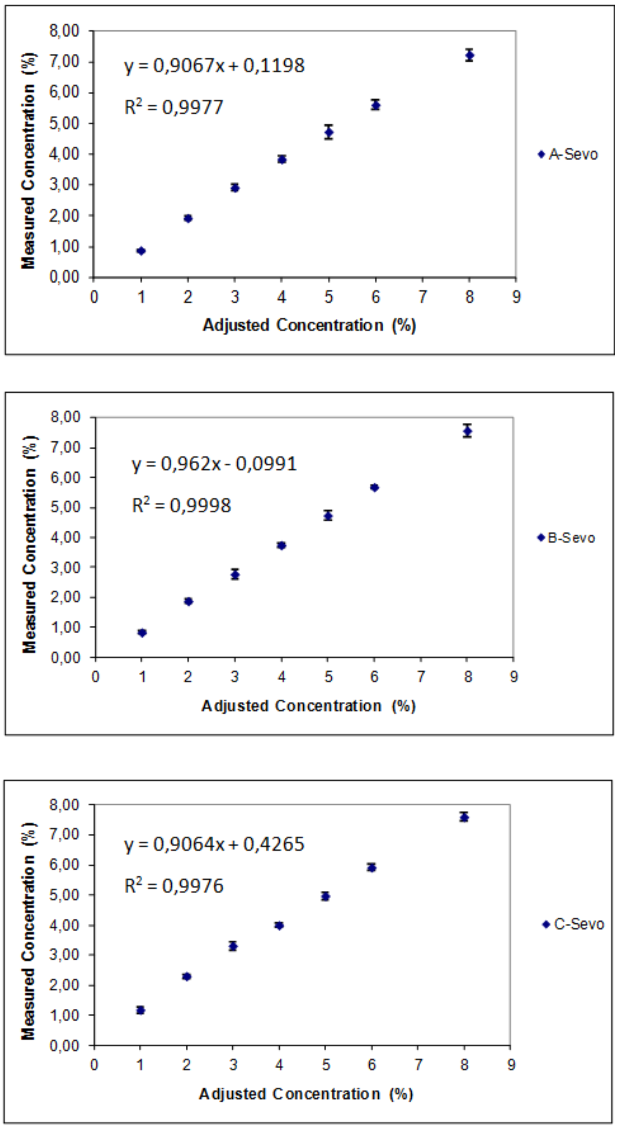

Figure 4. *Adjusted and measured concentration data for sevoflurane for 3 different length of delivery tubing (A: 48cm, B: 100cm and C: 150cm).*

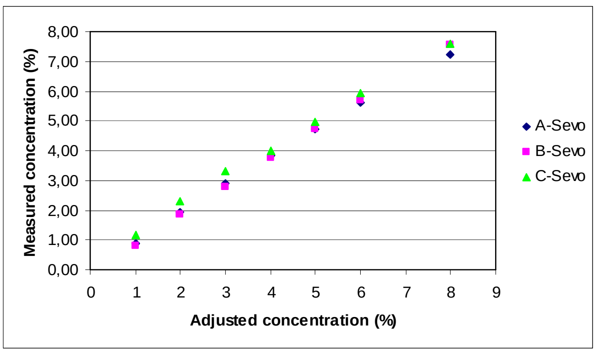

Figure 5. *Comparison of sevoflurane gas concentrations for 3 different length of delivery tubing (A: 48cm, B: 100cm and C: 150cm).*

When the data groups were placed in the same graphic (Figure 5), the vaporizers with A and B length shows the approximate values especially in the first 5 scales Although C vaporizers give higher values in the first 3 scales, it approaches to the other vaporizers' values in 4%, 5% and 6% scale.

Secondly, the isoflurane data obtained from 5 different vaporizers were investigated statistically and their mean and standard deviation were calculated. Calculated data can be seen in Table 2.

Table 2. *Statistical data of isoflurane vaporizers' concentration for 3 different length of delivery tubing (A: 48cm, B: 100cm and C: 150cm)*

%	Measured concentrations (%)					
	Mean Iso A	**std A**	**Mean Iso B**	**std B**	**Mean Iso C**	**std C**
1	1,21	0,11	1,01	0,13	1,08	0,11
2	2,12	0,19	1,82	0,14	2,09	0,07
3	3,04	0,24	2,70	0,13	3,09	0,11
4	3,91	0,34	3,72	0,07	4,04	0,09
5	4,78	0,24	4,71	0,09	4,87	0,29

As you see in Table 2, the output concentration data for B length are lower from the adjusted concentration. The output concentrations for vaporizers with A length, are measured as higher than the adjusted concentration until the 4% scale. C vaporizers give approximately the same values (measured concentrations equal to the adjusted concentration approximately) except for 5% scale.

By observing the measurement results, it was seen that all vaporizers were appropriate to the international standards because their errors are within the tolerance values [2].

The relationship between the adjusted and the measured isoflurane concentration data for 3 different length of delivery tubing can be seen in Figure 6.

When the data groups were placed in the same graphic (Figure 7), the vaporizers with A and C length shows the approximate value especially in all 5 scales. Although C vaporizers give same values in the first scale, it differs from the other vaporizers' values in other scales.

4. Conclusion

In this study, the effect of the delivery tubing to the anesthetic gas concentration was investigated. When the results of the measurements for 3 different length are compared, it is seen that there is no any significant difference between them and that the existing differences can be ignored. The existing different values are within tolerance values defined for performance testing of vaporizator. Depending on the length of the delivery tubing, the changes occurring in the gas absorption values were observed to be very small.

It is understood from this study that the gas concentration delivered to the patient will not change even if the length of the delivery tubing changes. It was observed that the shorted or the added tubing will not vary the amount of gas administered to the patient.

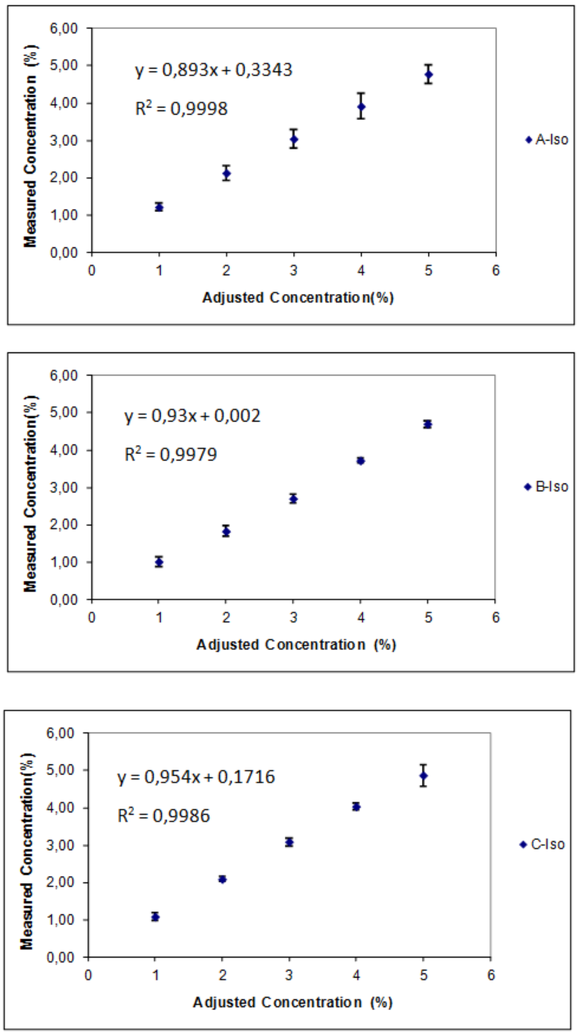

Figure 6. *Adjusted and measured concentration data for isoflurane for 3 different length of delivery tubing (A: 48cm, B: 100cm and C: 150cm).*

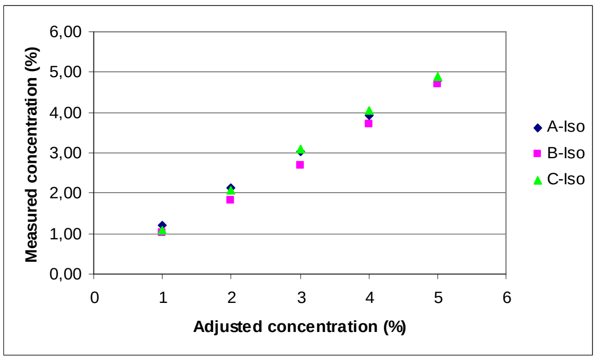

Figure 7. *Comparison of isoflurane gas concentrations for 3 different length of delivery tubing (A: 48cm, B: 100cm and C:*

Acknowledgements

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