行政院國家科學委員會專題研究計畫　成果報告

低流量麻醉中各種污染氣體之定量、成因及對人體影響之探討(3/3)

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Title: Effects of Anesthetic Types, Concentrations and Gas Flow Rates on Carbon Monoxide Production During Low-Flow Anesthesia

<u>Aim of investigation</u>: To exclude the patients' physiological effects on carbon monoxide (CO) formation in the breathing circuit, this study was to investigate the effects of anesthetic types, concentrations and gas flow on CO production at two controlled carbon dioxide (CO_2) flow rates through mimic clinical low-flow anesthesia conditions.

<u>Methods</u>: A 2L-breathing bag and respiratory humidifier were equipped with the modified anesthesia system to simulate the human's lung. Pure CO_2 gas (99%) was injected into the breathing bag by a T-connector inserted in the inspiratory limb of Y-tube at controlled flow rate to simulate the expiratory CO_2 during the clinical conditions. As listed in Table 1, each testing condition was a various combination of 2 anesthetics (desflurane & isoflurane) with 3 different concentrations (0.5, 1, & 2 MAC), 2 CO_2 flow rates (200 & 400 ml/min), and 3 gas flow rates (0.2, 0.5, & 1 L/min). Each test was run for 2 hours and repeated 4 times. The mean of CO concentration was continuously measured by the electro-chemical monitoring system (Drager Pac III CO detection instrument, Drager, Inc., USA) every minute[1]. New soda limes were replaced and the anesthesia system was flushed by a high fresh oxygen flow till the zero CO reading was achieved before each experiment. Stepwise linear regression analysis was performed by SPSS 12.0 (SPSS Inc., USA) to evaluate the significant affecting factors of the CO concentrations in the breathing circuit. The stepwise criteria are the probability of F-to-enter ≤ 0.05, probability of F-to-remove ≥ 0.01. The adjusted r-square was reported.

Results: Table 2 shows the means and standard deviation of inspiratory CO time-weighted average at different test conditions. The results indicated that the CO concentration decreased as the airflow increased for both anesthetics. The stepwise linear regression result for the pooled data of two anesthetics is listed in Table 3. This model proofed that anesthetic type as well as the gas flow were the two significant factors affecting the mean CO concentrations. For the regression with desflurane data only, the model was:

$$CO\ (ppm) = 4.409 - 6.187(air\ flow) + 2.281(CO_2\ flow) \qquad adjusted\ r^2 = 0.412$$

Both models suggest the anesthetic concentration had no significant effect on the CO production.

Conclusions: The CO production varied with different types of anesthetics.[2] The regression with both anesthetic showed (Table 3) that the constant of anesthetic type was 1.786. This positive figure proofed that desflurane produced more CO than isoflurane did during the degradation process. This result did confirm the findings of former investigators that the amount of CO production in the following order (from highest to lowest): desflurane ≥ enflurane > isoflurane ≥ etc…[3] The gas flow is another significant factor affected the CO production. CO concentration would be diluted if more fresh air were brought into the breathing circuit. Increasing gas flow rates is an effective method of decreasing CO concentrations in the breathing circuit.

While considered the desflurane data only, the CO_2 flow became another significant factor. The higher CO_2 flow (400 ml/min), which simulated patients with heavier body weight, produced more CO. This did validate that the patient's physiological status such as body weight did affect the inspriatory amount of CO from our previous study.[1]

References

1. Tang CS, Fan SZ, Chan CC. Smoking status and body size increase carbon monoxide concentrations in the breathing circuit during low-flow anesthesia. Anesth Analg 2001; 92:542-7.

2. Woehlck HJ, Dunning MB III, Raza T, Ruiz F, Bolla B, Zink W. Physical factors affecting the production of carbon monoxide from anesthetic breakdown. Anesthesiology 2001; 94:453-6.

3. Wissing H, Kuhn I, Warnken U, Dudziak R. Carbon mononxide production from Desflurane, Enflurane, Halothane, Isoflurane, and Sevoflurane with dry soda lime. Anesthesiolog 2001; 95(5):1205-12.

Table 1. Combination of Experimental Conditions

Anesthetic	MAC	O_2 Flow Rate (L/min)	CO_2 Flow Rate (ml/min)
Desflurane	0.5	0.2	
	1	0.5	200
	2	1	
	0.5	0.2	
	1	0.5	400
	2	1	
Isoflurane	0.5	0.2	
	1	0.5	200
	2	1	
	0.5	0.2	
	1	0.5	400
	2	1	

Table 2. Results of CO Production [Mean (Standard Deviation), unit:ppm] for Different Test Condition

Anesthetic		CO_2 Flow Rate = 200 ml/min			CO_2 Flow Rate = 400 ml/min		
		O_2 Flow Rate (liter/min, LPM)					
	MAC	0.2 LPM	0.5 LPM	1 LPM	0.2 LPM	0.5 LPM	1 LPM
Desflurane	0.5	13.25(4.99)	6.25(0.96)	3.25(0.96)	18.25(8.18)	7.75(3.86)	4.00(3.16)
	1	9.50(4.43)	4.25(1.50)	0.50(1.00)	15.75(7.41)	8.00(5.60)	5.00(3.37)
	2	8.00(4.83)	4.75(1.26)	1.75(1.50)	12.00(8.76)	6.25 (4.19)	3.25(2.22)
		O_2 Flow Rate (liter/min, LPM)					
	MAC	0.2 LPM	0.5 LPM	1 LPM	0.2 LPM	0.5 LPM	1 LPM
Isoflurane	0.5	10.50(5.92)	4.50(3.11)	3.00(2.00)	5.75(1.50)	2.50(1.73)	2.25(1.50)
	1	12.75(4.65)	6.00(2.16)	2.50(1.73)	5.00(1.83)	2.75(3.20)	1.75(2.06)
	2	11.75(4.79)	5.75(2.06)	2.00(1.41)	4.25(1.50)	3.50(2.52)	2.00(2.45)

Table 3. Effects of Anesthetic Conditions on CO Concentrations in the Breathing Circuit by Stepwise Linear Regression Model

Dependent Variables	Predictors	Unstandardized Coefficients			Adj. r^2
		B	SE	p Value	
Mean CO (n = 144)	Constant	5.272	0.478	0.000	0.330
	Gas Flow (LPM)	-4.825	0.651	0.000	
	Anesthetic	1.786	0.429	0.000	

Mean CO = concentration (ppm); Adj. r^2 = adjusted R square; Anesthetic: 0 = Isoflurane, 1 = Desflurane.