原 著 (Original)

Effects of Volatile Anesthetics on Cervical Sympathetic Nerve Activity during Acute Hypoxemia or Hypercarbia in Dogs

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Abstract

The response of cervical symathetic nerve activity (CSA) to acutely induced hypoxemia and/or hypercarbia was studied in the absense and the presence of either halothane (H), enfulurane (E), isoflurane (I) or sevoflurane (S). Hypoxemia was produced by adding nitrogen to the inspired gas in amounts needed to decrease arterial oxygen saturation (SaO_2) at a rate of 6-9% per minute. Hypercarbia was produced by adding carbon dioxide in amounts needed to maintain end tidal carbon dioxide concentration ($F_{ET}CO_2$) at 10%. EEG, ECG, heart rate, arterial blood pressure, SaO_2, $F_{ET}CO_2$ and multifiber potentials of CSA were continuously monitored. CSA increased significantly in response to hypoxemia. The response of CSA was quantified as a function of SaO_2 in two ways: First, a threshold value of SaO_2 was determined at the SaO_2 value at which CSA increased 3% over the baseline level. Second, a reflex gain was determined by dividing the net increase in CSA by the degree of change in SaO_2 value. The threshold and gain were $92.0\pm1.8\%$ and -1.88 ± 0.14 (mean$\pm$SD), respectively, in the absence of volatile anesthetics. The threshold and gain significantly decreased in the presence of E, I and S at 1 MAC. They were $81.0\pm6.6\%$, -0.74 ± 0.21; $84.2\pm3.6\%$, -1.16 ± 0.08 and $86.2\pm4.4\%$, -0.94 ± 0.11 for E, I and S, respectively. Suppression of the responses of CSA was significantly greater with both E and S than with H and I ($p<0.05$). H at 1 MAC attenuated the gain but changes of threshold was not signifcant.

CSA also increased in response to acutely induced hypercarbia. The peak response was suppressed with increasing concentrations of volatile anesthetics.

These results may indicate that the depressant effects of E on CSA responses to acutely induced hypoxemia and hypercarbia was significantly greater than that of equipotent H or I.

Key words: Halothane, Enflurane, Isoflurane, Sevoflurane, Sympathetic Nervous System, Hypoxemia, Hypercarbia.

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Introduction

Sympathetic nervous system responds rapidly to both hypoxemia and hypercarbia[1]. In general, these responses appear to be the reflexes in nature via the chemoreceptors[2-4]. Acute hypoxemia or hypercarbia produce significant hemodynamic changes, e. g., peripheral vasoconstriction, increases in arterial blood presspure (ABP) and heart rate (HR)[5-7]. Moreover, because of their possibility to be dangerous complications during anesthesia, prompt recognition and treatment are essential.

General anesthetics depress sympathetic nervous system activity in both a type-dependent and dose-dependent fashion[8-12]. In addition, the magnitude of the response may differ with different general anesthetics. However, the threshold and extent of the response, as well as the quantitative relationships between cervical sympathetic nerve activity (CSA) and arterial oxygen saturation (SaO_2) or end tidal carbon dioxide concentration ($F_{ET}CO_2$) are not clear[13,14]. In this study, we investigated these relationships under conditions of acute hypoxemia and hypercarbia, as well as the comparative effects of four volatile anesthetics: halothane, enflurane, isoflurane and sevoflurane.

Methods

Forty-eight mongrel dogs of either sex weighing between 9 and 15 kg were divided into eight groups of 6 dogs; each who were made either hypoxemic or hypercarbic during halothane (H), enflurane (E), isoflurane (I) and sevoflurane (S) anesthesia. Following tracheal intubation after induction of anesthesia with intravenous thiamylal (20 mg/kg), the lungs were mechanically ventilated to maintain $PaCO_2$ between 34 and 40 mmHg. During the surgical preparations, anesthesia was maintained with 0.5% H in oxygen. To reduce pain, 0.5% bupivacaine (a total of 6 m*l*) was administered subcutaneously prior to each skin incision. Each animal was paralyzed with pancuronium bromide (0.1 mg/kg/hr) to avoid movement secondary to artifacts during the recording of neural activity. Blood pressure was continuously monitored through a femoral artery catheter connected with a pressure transducer. Blood samples were obtained via the femoral artery catheter. Fluids and medications were administered through a femoral vein catheter. ECG, ABP and EEG (using bipolar implanted screw electrodes on the parietal region) were also monitored continuously. Esophageal temperature was maintained at 37±0.5°C using a heating pad and infrared lamp. SaO_2 was monitored using a fiberoptic catheter oximeter (Oximetrix, Opticath®) positioned into the aorta at the level of aortic arch, and $F_{ET}CO_2$ was monitored using a capnograph (Engström, Eliza duo analyzer®). These procedures and this study were approved by the Animal Research Committe of Hokkaido University School of Medicine.

The animal was prepared as follows. An incision was made on the anterior midline of neck and the vagosympathetic nerve trunk was exposed and dissected free of the surrounding tissue. The sheath around the central cut end of vagosympathetic nerve was removed and only sympathetic nerve was then placed on a bipolar silver wire electrode (hand-made), and immersed in a mineral oil pool. These procedures were done using a microscope. The multifiber action potentials of cervical sympathetic nerve activity (CSA) were monitored and recorded on a polygraph (NEC San-Ei, 365). CSA was band-filtered (pass band was 10-1000 Hz) using a 24 dB/octave filter prior to being recorded. All variables (CSA, EEG, ECG, ABP, SaO_2, $F_{ET}CO_2$) were recorded on an instrumentation tape recorder (TEAC, R-71). Stimultaneously, the variables were digitized at 800 samples/sec/channel (TEAC, PS-9030 A/D converter) and analyzed in real time using a HP9816S computer.

After the surgical procedures were completed, ketamine (1 mg/kg) was administered intravenously and halothane was stopped. Anesthesia was maintained through intravenous infusion of ketamine (0.5 mg/kg/hr) during the periods when data was collected in the absence of volatile anesthetics (control experiments).

Details of the procedures for recording and processing CSA have been previously reported[12] and are only briefly described here. The integrated sympathetic nerve activity for the i-th time period (ISA(i)) was computed by rectifying and numerically integrating a 3.125 second record of the compound action potential (2500 samples at 800 samples/sec.) The baseline ISA values during control period (ISA(cb)) were computed 60 minutes after the cessation of halothane as an average of 6 consecutive ISA values. A measure of CSA as a percentage fraction of the control baseline value of CSA was computed using the following equation:

$$CSA(i)=\frac{ISA(i)-ENL}{ISA(cb)-ENL}\times 100$$

where ENL is the estimated noise level. ENL is an estimate of the electronic noise in the data acquisition system and cannot be ignored because of the large amplification required for the detected action potentials. ENL was estimated by connecting a 150 kΩ resistor across the leads of bipolar amplifier, the signal level was assumed to correspond to zero neural activity[12]. The value of ENL was computed by rectifying and summing 3.125 seconds of the digitized data, the same process used to compute ISA(i).

Hypoxemia was induced by adding nitrogen to the inspired gas in amounts needed to decrease SaO_2 by 6 to 9% per minute. After SaO_2 reach 10%, the animal was administered 100% oxygen. Hypercardia was induced by adding carbon dioxide to the inspired gas in amounts needed to produce and maintain an $F_{ET}CO_2$ of 10%. At this condition, CSA response usually reached a plateau within 3 to 5 minutes and then the animal was administered 100% oxygen again. During above period, the ventilator settings remained unchaged.

All anesthetics were administered using calibrated vaporizers. We used 0.87%, 2.06%, 1.28% and 2.36% of H, E, I and S, respectively, as 1 MAC[15,16]. In selected experiments, gas samples collected at end-expiration were analyzed using a gas chromatograph (GC-12A, Shimadzu) to measure the actual level each anesthetic. The data collection, after each change in anesthetic concentration, required at least 30 minutes to perform. CSA responses to hypoxemia and hypercarbia were analyzed based on the following four parameters: 1) Base level: CSA value prior to either hypoxemic or hypercarbic maneuver; 2) Peak level: the maximum CSA value after stimulation; 3) Threshold: SaO_2 at which CSA increases to more than 3% above the base level (This definition of threshold was used so that a decrease in CSA response indicates a decrease in the threshold.); 4) Gain: the maximum change in CSA divided by the maximum change SaO_2. See Fig. 1 for a graphic description of each parameter.

Statistical analyses were performed using ANOVA between groups and Student's paired t-test within groups. A p-value of less than 0.05 was considered statistically significant.

Results

An example of data recorded during a control period is shown in Fig. 2. HR remained between 147 and 159 bpm, and mean arterial pressure (MAP) was maintained between 124 and 138 mmHg. The mean EEG frequency was approximately 15 Hz. CSA consisted of burst discharged which occurred 100 to 150 ms before R-wave of ECG. While the tonic level of CSA continuously changed, its variation remained within 10% of its mean value.

A typical CSA response to acute hypoxemia is

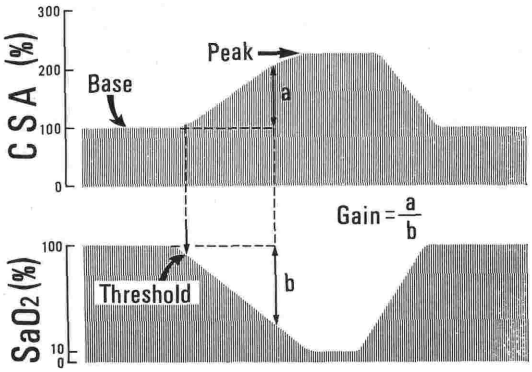

Fig. 1. Schematic illustration of the CSA analyses.
Base represents the steady CSA value before hypoxemia or hypercarbia induction. The CSA control value is 100%. Peak represents the maximum CSA value after hypoxemia or hypercarbia induction. Threshold means SaO_2 at which CSA rises more than 3% above the Base level. Gain is obtained by dividing maximum CSA increment by the maximum SaO_2 range.

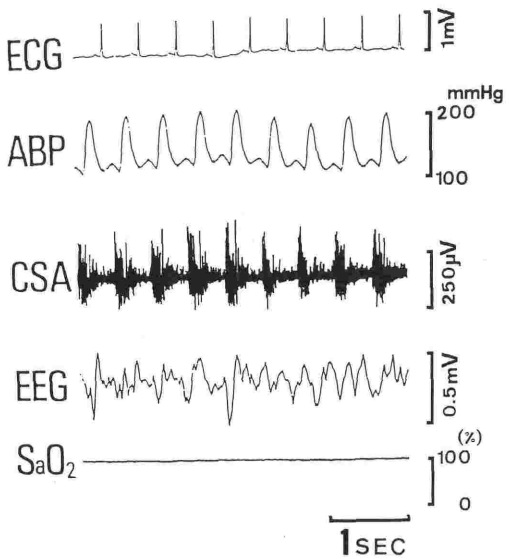

Fig. 2 An example of data recorded during a control period.
From top to bottom, the tracings are electrocardiogram (ECG), arterial blood pressure (ABP), CSA, electroencepharogram (EEG) and SaO_2. CSA produced burst-like discharges synchronized with the heart beats.

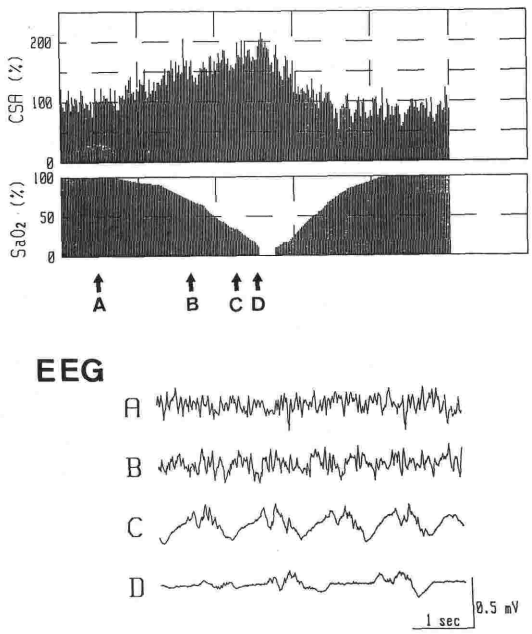

Fig. 3 CSA and EEG responses to acute hypoxemia in a control period.
CSA began to increase when SaO_2 fell below 93%. Maximum CSA reached 214%. Time scale: 5 min/div. Mean EEG frequency was around 15 Hz during control period (A). In spite of vigorous excitation of CSA under deep hypoxemia, mean EEG frequency decreased markedly when SaO_2 was below 70% (B) and was depressed markedly when SaO_2 was below 30% (C). EEG became isoelectric when SaO_2 was below 10% (D).

shown in Fig. 3. CSA increased rapidly when SaO_2 decreased below 93%. During this period, MAP and HP increased 44% and 9%, respectively (Table 1). In the control experiments, the peak level of CSA reached between 180 and 193% of the base level, the threshold values of CSA in response to hypoxemia were between 91.3 and 92.7%, and the gain values were between −1.94 and −1.82. There were no significant differenced in the control values between groups (Table 2).

EEG changed markedly with decreases in SaO_2. The mean frequency of EEG began to decrease when SaO_2 decreased below 70%, and

Table 1. Circulatory changes during acute hypoxemia.
All MAP increased significantly after the hypoxemic stimulation ($p<0.05$). MAP=mean arterial pressure. HR=heart rate. pre=before the hypoxemic stimulation. post=after the hypoxemic stimulation.

		MAP (mmHg)		HR (bpm)	
		pre	post	pre	post
Halothane	Control	147.5±15.1	193.8±7.8#	194.3±22.0	201.2±24.7
(n=6)	0.5 MAC	132.7±16.1	160.8±9.4#**	163±16.5	172.2±19.3*
	1 MAC	109.5±15.0*	137.8±22.4#**	142.8±23.9*	162.5±23.8#**
Enflurane	Control	156.2±12.9	192.7±19.5#	190.7±20.3	204±18.9
(n=6)	0.5 MAC	133.8±12.8*	148.3±13.2#*	178.7±23.0	184.2±16.7
	1 MAC	101.7±9.3**	111.7±13.7#**	142.3±22.8**	147±18.6**
Isoflurane	Control	142±28.5	184.8±27.9#	187.5±29.4	193.3±19.8
(n=6)	0.5 MAC	133.7±23.0*	157±20.0#*	158.3±15.0*	165.5±17.4*
	1 MAC	116.5±22.4**	128±15.6#**	133.7±22.3**	140.7±25.2**
Sevoflurane	Control	156.5±4.4	191.2±11.5#	188.8±16.7	204.2±16.2#
(n=6)	0.5 MAC	130.7±13.8*	141.8±12.6#*	148.3±22.0*	156.3±15.2*
	1 MAC	109.7±12.5**	122.2±10.5#**	127.7±19.7**	137.7±15.9#**

*: $p<0.05$ vs Control, **: $p<0.05$ vs 0.5 MAC, #: $p<0.05$ vs pre

Table 2. CSA response during transient hypoxemia.
All peak levels increased significantly compared to base levels ($p<0.05$). CSA=cervical sympathetic nerve activity.

		Base (%)	Peak (%)	Threshold (%)	Gain (△%/△%)
Halothane	Control	100	192.7±23.2	92.3±1.5	−1.94±0.20
(N=6)	0.5 MAC	83.2±6.8*	127.7±5.5*	90.3±3.9	−1.52±0.11*
	1 MAC	66.8±11.8**	113.8±18.5*	89.2±3.4	−1.16±0.16**
Enflurane	Control	100	183.3±6.6	92.0±1.7	−1.84±0.09
(N=6)	0.5 MAC	63.2±10.1*ab	109.0±20.2*	88.0±2.5*	−1.18±0.14*a
	1 MAC	31.0±5.8**ab	60.0±13.6**ab	81.0±6.6**a	−0.74±0.21**ab
Isoflurane	Control	100	181.1±8.0	92.7±2.0	−1.92±0.17
(N=6)	0.5 MAC	81.5±12.5*	120.8±14.8*	88.0±2.2*	−1.34±0.20*
	1 MAC	67.0±11.0**	97.3±13.9**	84.2±3.6*a	−1.16±0.08*
Sevoflurane	Control	100	180.3±19.0	91.3±2.1	−1.82±0.12
(N=6)	0.5 MAC	66.3±10.1*ab	98.6±19.2*a	89.8±2.0	−1.26±0.16*a
	1 MAC	43.7±10.9**ab	70.8±18.1**ab	86.2±4.4**	−0.94±0.11**ab

*: $p<0.05$ vs Control, **: $p<0.05$ vs 0.5 MAC
a: $p<0.05$ vs Halothane, b: $p<0.05$ vs Isoflurane

the slow wave (at approximately 0.8 Hz) become the dominant component when SaO_2 decreased below 30%. When SaO_2 was below 10%, EEG became nearly isoelectric. In the presense of volatile anesthetics, CSA decreased and reached a new steady state which was taken to be the new base level for the purposes of next study. The base levels at 0.5 MAC

were significantly lower than the control values, and the base levels at 1 MAC were significantly lower than the 0.5 MAC values for all groups. When the volatile anesthetics at the same MAC were compared, the relative decreases in the base levels were as follows: E>S>I>H, with levels during E and S depressed more than with H or I ($p<0.05$, see Table 2).

The peak response of CSA to acute hypoxemia was attenuated in the presence of volatile anesthetics. At 0.5 MAC, the peak levels were significantly reduced in all groups when compared with the control values. When the anesthetic level was increased to 1 MAC, the peak levels were significantly lower than at 0.5 MAC in all groups except H (Table 2). For 0.5 MAC, the peak level using S was significantly less than using H, and for 1 MAC, the peak levels using E or S were significantly lower than that using H or I. The magnitude of the depressant effect followed this approximate order: E=S>I>H.

The threshold remained unchanged in the H group, but was significantly reduced in the remaining groups (and especially in E). The gain was also significantly reduced in each group. Overall, the depressant effects of E and S on CSA responses were much stronger than those of H and I (Table 2).

In contrast with the hypoxemic study, CSA changed very slowly as $F_{ET}CO_2$ gradually increased. This prevented the computation of a threshold and gain for this portion of the study. A typical CSA response to acute hypercarbia is shown Fig. 4. CSA increased 144% of the control value three minutes after the beginning of the administration of carbon dioxide.

In the control experiment, MAP and HR increased an average of 15% and 4%, respectively for all groups (Table 3). The peak levels of CSA were between 130 and 138% of the base level, and there were no significant differences in peak levels between the groups (Table 4).

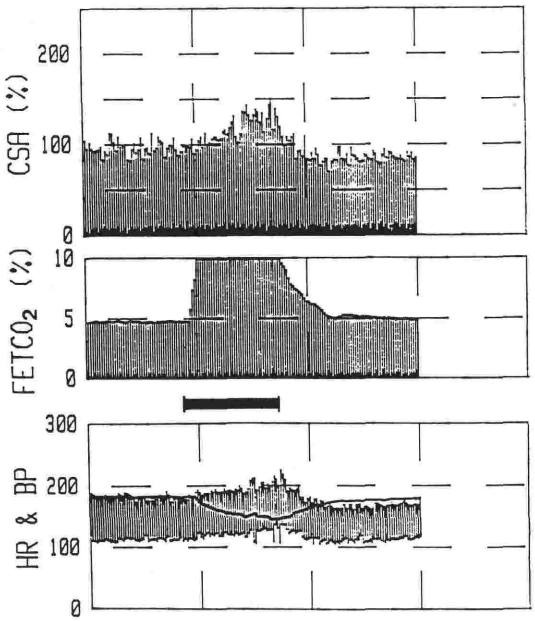

Fig. 4. CSA response to acute hypercarbia during a control period.
CSA increased to 144%, 3 minutes after the transient carbon dioxide stimulation. The period of hypercarbic stimulation is shown as the solid bar. Time scale: 5 min/div.

The peak levels of CSA response with 0.5 MAC were decreased significantly compared with the control levels in all groups, and those with 1 MAC were depressed significantly compared with those of 0.5 MAC in all groups (Table 4). In comparisons between the same MAC, the peak level using E decreased significantly when compared with the peak level using H (at 0.5 MAC) and using H or I (at 1 MAC).

Discussion

Few reports quantitatively describe the response of sympathetic nervous system to acute hypoxemia and hypercarbia and fewer reports describe the effects of volatile anesthetics on these conditions[9,13]. To eastablish a control change of CSA tone, we used ketamine (0.5 mg/kg/hr iv infusion) as a basal anesthetic since this agent has been reported to have little effect on autonomic ner-

Table 3. Circulatory changes during acute hypercarbia.
Only MAP of the control measurement increased significantly after the hypercarbic stimulation ($p<0.05$). pre=before the hypercarbic stimulation. post=after the hypercarbic stimulation.

		MAP (mmHg)		HR (bpm)	
		pre	post	pre	post
Halothane	Control	152.3±19.7	169.7±25.6#	186.8±25.1	195.3±25.8
(n=6)	0.5 MAC	133.2±18.9*	140.2±20.4*	163.2±24.0	160.3±23.1*
	1 MAC	114.3±14.7**	120.3±16.4**	144.6±24.9*	140.5±19.1*
Enflurane	Control	144.5±9.8	169.7±25.2#	180.9±21.7	191.8±20.1
(n=6)	0.5 MAC	131.5±4.5*	137.3±11.6*	169.7±10.5	169±14.0
	1 MAC	104.8±10.3**	108.6±11.4**	134.3±5.6**	136.7±7.9**
Isoflurane	Control	142.3±14.0	161.8±17.9#	188.2±21.4	193±26.8
(n=6)	0.5 MAC	136.2±11.1*	142.2±14.9*	155.8±16.9*	155.5±21.0*
	1 MAC	119.3±7.7**	127.8±14.6*	131.8±20.9*	131.5±15.1**
Sevoflurane	Control	147.5±19.6	176±19.0#	189.5±29.3	196.7±22.5
(n=6)	0.5 MAC	140.5±16.3*	143.8±16.2*	153.3±25.0	161±25.0*
	1 MAC	111.5±13.5**	117.3±16.8**	127.2±22.7*	122.7±20.3**

*:$p<0.05$ vs Control, **:$p<0.05$ vs 0.5 MAC, #:$p<0.05$ vs pre

Table 4. CSA response during transient hypercarbia.
All peak levels except isoflurane control increased significantly compared to base levels ($p<0.05$).

		Base (%)	Peak (%)
Halothane	Control	100	129.5±15.6#
(n=6)	05 MAC	84.7±4.1*	103.2±9.3*#
	1 MAC	68.3±4.7**	75.0±11.4**
Enflurane	Control	100	132.8±23.8#
(N=6)	0.5 MAC	78.7±3.1*[a]	87.0±8.9*[a]
	1 MAC	50.7±6.8**[ab]	51.8±15.0**[ab]
Isoflurane	Control	100	137.0±34.3
(N=6)	0.5 MAC	84.7±9.9*	96.2±14.9*#
	1 MAC	70.3±7.0**	76.7±7.2**
Sevoflurane	Control	100	137.7±22.0#
(N=6)	0.5 MAC	78.8±11.3*	101.5±20.0*#
	1 MAC	55.5±18.5**	63.2±20.1**

*:$p<0.05$ vs Control, **:$p<0.05$ vs 0.5 MAC, #:$p<0.05$ vs Base
[a]:$p<0.05$ vs Halothane, [b]:$p<0.05$ vs Isoflurane

vous system activity at the dose used in our study[12].

The baroreflex of aortic arch, normally activated by an increase in blood pressure, did not affect the affrent or efferent pathways, since the cervical portion of vagus nerves had been severed bilaterally. The baroreflex of carotid sinuses, which is mainly activated by a decrease in intraluminal pressure of carotid sinuses[17,18], had a negligible effect on CSA, since arterial blood pressure did not significantly decrease during this study. Therefore, CSA changes

noted during this study were assumed to be due to chemoreceptor activity in response to hypoxemia and/or hypercarbia.

The threshold of CSA response to hypoxemia during control periods was at SaO_2 92%, which corresponded to a PaO_2 of 70 mmHg. At this level of hypoxemia, clinical signs, such as dyspnea and an increase in heart rate, may be observed in a conscious human. If the depressant effect of halothane at 0.5 MAC is determined as 1, then the depressant effects of enflurane, sevoflurane and isoflurane are 2.19, 2.01 and 1.10, respectively. If the effect of halothane at 1 MAC is determined as 1, then the effects of enflurane, sevoflurane and isoflurane are 2.78, 1.70 and 1.00, respectively. This suggest that MAC, which is widely used as a measure of physiological effect of anesthetics, does not consistently correspond to the degree of the depressant effects of different volatile agents on sympathetic nerve activity.

In the presence of volatile anesthetics, both the threshold and the gain of CSA decreased in a dose-dependent fashion. With 1 MAC of enflurane, for example, the base level of CSA decreased to 30% of the control value, while the threshold was 81% and the gain was −0.74. Therefore, not only the cardiovascular control ability of sympathetic nervous system under resting condition, but also its rapid responsiveness to hypoxemia seems to decrease markedly under general anesthesia with volatile anesthetics.

Ponte, et al. measured the carotid body chemoreceptor activity during hypoxemia and hypercarbia in the presence of 0.5 to 1% of halothane, enflurane and isoflurane in cats and rabbits[19]. They showed that all of these volatile anesthetics had a direct inhibitory effect on the peripheral chemoreceptor sites. This indicates that the depressant effects of volatile anesthetics on CSA reponse to acute hypoxemia may be responsible to the attenuation of a peripheral chemoreflex as well as the depression of central nervous system.

There are reports in the literature on the response of sinus nerve to hypoxemia and hypercarbia during halothane anesthesia in cats[13,14] and during halothane, isoflurane, thiopentone, etomidate and propofol anesthesia in rabbits and cats[19,20]. They suggested that the effects of hypoxemic stimulation is stronger than that of hypercarbic stimulation, suggesting that the reflex response to hypoxemia was more impotant.

However, most arterial blood gas disorders encountered in clinical practice are caused by an underlying preoperative respiratory complication or by intraoperative ventilation problems. In either case, hypoxemia or hypercarbia rarely occurs alone, but rather combined with one other in varying proportions. It is important to determine if the combined stimulation of hypoxemia and hypercarbia will affect CSA response in an additive or synergistic manner. To examine this point, the animals first inspired 10% carbon dioxide in the presence of 0.5 MAC enflurane. After CSA response reached a plateau, the animals received a hypoxemic stimulation. While the peak level reached 132% during hypercarbia alone, it reached 164% when hypercarbia was mixed hypoxemia (Fig. 5). When the stimulation was performed in the reverse order, the CSA peak level reached 159% during hypoxemia, but decreased slightly to 151% during the mixing of hypoxemia and hypercarbia. These results suggest that hypoxemia may act in an additive manner on CSA response when hypercarbia precedes hypoxemia but the response to hypercarbia is unclear because of the predominance of hypoxemia when the order of occurrences is reversed.

Weiskopf, et al.[21], studied the comparative effects of degrees of hypoxemia with without hypercarbia on the respiratory response in conscious, as well as anesthetized (1.1% halothane) dogs. Their results agree with the first part of our results in that the combined stimulation of

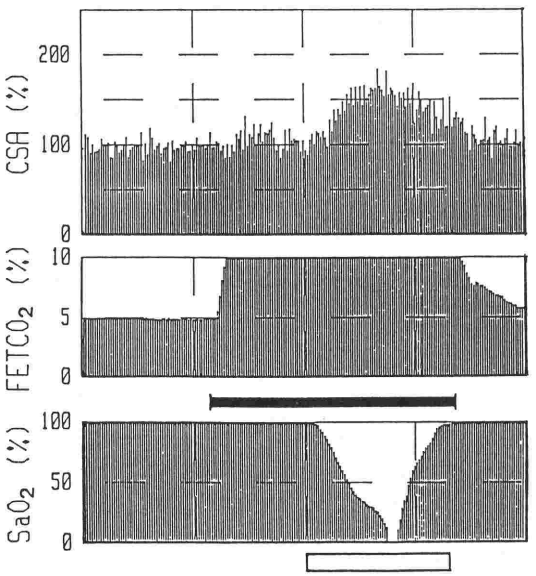

Fig. 5. Effect of acute hypercarbia-hypoxemia on CSA response.
During 0.5 MAC of enflurane anesthesia, acute hypoxemia was induced following the hypercarbic state. CSA response increased from 132% to 184%. Solid bar: hypercarbic stimulation. Open bar: hypoxemic stimulation. Time scale: 5 min/div.

hypoxemia and hypercarbia acted additively on CSA response. We speculate that the lack of increase in CSA response when hypercarbia preceded hypoxemia may be attributed to the strength of preceding hypoxemia. Hypoxemia depressed the central reflex pathway so that the responsiveness of reflex pathway to following hypercarbia was reduced[22,23].

The followings were suggested as to the quantitative effects of halothane, enflurane, isoflurane and sevoflurane on CSA response to hypoxemia and/or hypercarbia in dogs: First, various behaviorally equipotent volatile anesthetics depressed CSA response to acute hypoxemia or hypercarbia to various degrees. Enflurane depressed CSA by the largest amount, followed by sevoflurane, isoflurane and halothane. Second, CSA response to acute hypoxemia was more than twice the response to acute hypercarbia. Third, the combined stimulation of hypoxemia and hypercarbia appeared to act additively on CSA response. Finally, out data indicate that the depressant effects of volatile anesthetics on CSA responses to acute hypoxemia and hypercarbia can depress the control activity of autonomic nervous system in response to hypoxemia and hypercarbia and so conceal the manifestation of clinical signs of hypoxemia and/or hypercarbia.

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急性低酸素および高炭酸血症下のイヌ頸部交感神経活動に及ぼす吸入麻酔薬の影響

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急性低酸素血症および高炭酸血症の頸部交感神経活動 (CSA) に及ぼす影響，およびこれに対する4種類の吸入麻酔薬—ハロセン（H），エンフルレン（E），イソフルレン（I），セボフルレン（S）—の抑制効果について定量的に検討した．

CSA，脳波，心電図，心拍数，動脈圧，動脈血酸素飽和度 (SaO_2) および呼気終末炭酸ガス濃度 ($F_{ET}CO_2$) を連続的にモニタリングした．SaO_2 を6～9%/分の速度で下降させて得られた急性低酸素血症に対して CSA は著明に増加した．CSA の反応は SaO_2 との関係から以下の2つの方法により評価した．①CSA が基礎値より3%以上増加し続ける時点の SaO_2（閾値）および② SaO_2 の低下に対する CSA の増加の傾き（利得）．対照において，それぞれ92±1.8%と−1.88±0.14（平均±標準偏差）であった．H，E，I およびSの 1MAC 投与下において，各々89.2±3.4%と−1.16±0.16，81±6.6%と−0.74±0.21，84.2±3.6%と−1.16±0.08および86.2±4.4%と−0.94±0.11であった．1MAC のEとSは，HとIに比べ有意に CSA の反応を抑制した ($p<0.05$)．

二酸化炭素を加えることによって得られた高炭酸血症に対しても CSA は著明に増加した．反応の極値は，吸入麻酔薬の濃度の上昇に伴い抑制された．

以上のことから，急性低酸素および高炭酸血症に対する CSA 反応に及ぼすEの抑制効果は，等力価のHやIと比べて有意に強いことが示唆された．