
**Myocardial Oxygen Extraction Rate under General Anesthesia**

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Yusa, T. and Obara, S. Myocardial Oxygen Extraction Rate under General Anesthesia. Tohoku J. exp. Med., 1981, 133 (3), 321-324 — Myocardial oxygen extraction rates (R) were measured in dogs anesthetized with eight kinds of anesthetic agents to study the balance between myocardial oxygen consumption and its supply under general anesthesia. The R value for basal anesthesia (pentobarbital), original neuroleptanesthesia (Thalamonal*), modified neuroleptanesthesia (droperidol and pentazocine), morphine anesthesia or halothane anesthesia was not significantly different from each other, and similar to those for conscious dogs reported by Merin or Spencer. On the other hand, the R values for ether anesthesia, methoxyflurane anesthesia and enfurane anesthesia were significantly lower than those for the above mentioned anesthesia. ——— cardiac oxygen consumption; coronary blood flow; cardiac metabolism; general anesthesia

The effects of anesthetic agents on coronary circulation have been studied by many investigators, and their experimental findings on coronary hemodynamic effects are mostly consistent. However, the most important problem is to elucidate whether myocardial oxygen supply during anesthesia sufficiently meets its consumption. To our knowledge, only a few reports dealing with this problem are available, and no definite result for each anesthetic agent has been reported (Saito et al. 1966a, b; Merin et al. 1976a).

We systematically studied the effect of anesthetic agents on the balance between oxygen supply and its demand in the heart by measuring myocardial oxygen extraction rate (R) in dogs.

**Materials and Methods**

Forty-eight healthy mongrel dogs weighing 10 to 14 kg were divided in eight groups and anesthetized with eight kinds of anesthetic agents respectively as follows:

**Intravenous anesthesia.** Basal anesthesia (Group 1) was induced by sodium pentobarbital 30 mg/kg, i.v., and a cuffed endotracheal tube was employed. Controlled respiration with pure oxygen was started with the aid of succinylcholine 1 to 2 mg/kg, i.m. to prevent spontaneous respiratory effort. Subsequently, catheters for blood sampling were placed in the coronary sinus and in the abdominal aorta.

Original neuroleptanesthesia (original NLA) (Group 2), modified NLA (Group 3) and morphine anesthesia (Group 4) were induced after the completion of cannulation under

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basal anesthesia as mentioned above. Thalamonal® 0.15 ml/kg (Group 2), a mixture of droperidol 0.375 mg/kg and pentazocin 1.5 mg/kg (Group 3) and morphine hydrochloride 1.0 mg/kg (Group 4) were injected, i.v., respectively.

Inhalation anesthesia. After endotracheal intubation with the aid of succinylcholine 1 to 2 mg/kg, i.m., dogs of the other four groups were anesthetized with 10% ether (Group 5), 1.5% methoxyflurane (Group 6), 2% halothane (Group 7) and 3% enflurane (Group 8) respectively in oxygen through a non-rebreathing respirator. In such high anesthetic concentrations, ether and methoxyflurane were inhaled for 3 hr, and halothane and enflurane for 2 hr. At the end of this period, cannulations for blood samplings were performed. Then the inspiratory anesthetic concentration was gradually decreased and adjusted to maintain its endotidal concentration within 1.0±0.1 MAC of each anesthetic agent (Eger et al. 1969).

During the experiment, ventilation was controlled to maintain the endotidal CO₂ concentration at about 5%, as measured by an infrared CO₂ analyzer. When cardiovascular stability had been achieved, arterial and coronary sinus blood samples were taken simultaneously, and analyzed for oxygen content with Lex-O₂-Con (Lexington Instrument Co.). Myocardial oxygen extraction rate (R) was calculated using the following formula:

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\text{Myocardial } O_2 \text{ extraction rate (R)} = \frac{\text{Coronary arterio-venous oxygen difference (vol %)}}{\text{Arterial blood oxygen content (vol %)}} \times 100
\]

**RESULTS**

Results are shown in Fig. 1. The mean±s.d. of each anesthetic group was: basal anesthesia, 74.9±8.4%; original NLA, 75.2±6.8%; modified NLA, 76.8±6.3%; morphine anesthesia, 77.7±4.1%; ether anesthesia, 54.8±7.4%; methoxyflurane anesthesia, 64.0±4.3%; halothane anesthesia, 74.5±2.4%; enflurane anesthesia, 67.6±5.2%.

![Fig. 1. Myocardial oxygen extraction rate (R) for various kinds of anesthesia. Vertical bars represent ±one standard deviation about the mean. Horizontal zone shows the limits of R value for conscious dogs reported by Spencer et al. (1950) and Merin et al. 1976b.](image-url)
No statistically significant differences were observed between any pair of R values for intravenous anesthesia and halothane anesthesia. On the other hand, the R values for ether anesthesia, methoxyflurane anesthesia and enflurane anesthesia were significantly lower than those for basal anesthesia or halothane anesthesia \((p<0.05)\). The difference between ether anesthesia and enflurane anesthesia was also significant \((p<0.01)\).

**DISCUSSION**

In the study on the balance between oxygen supply and its demand in the heart, several indices, including coronary sinus blood oxygen tension, coronary arterio-venous oxygen difference and excess lactate, have been used. Generally, arterio-venous oxygen difference has been measured to study the effects of anesthetic agent on the mode of myocardial oxygenation. This index, however, is not adequate to evaluate the myocardial oxygenation in the presence of variations in arterial blood oxygen content. On the other hand, myocardial oxygen extraction rate is found to be equal to the ratio of myocardial oxygen consumption to its supply, when the numerator and the denominator of the formula are multiplied by blood flow. Hence, it may be thought that R value remains to be a reasonable index of myocardial oxygenation even when there are relatively wide variations in arterial blood oxygen content. The rise in this index represents a decrease in relative oxygen supply to myocardium and the fall indicates an increase in the latter. R values for basal anesthesia, original NLA, modified NLA, morphine anesthesia and halothane anesthesia were not significantly different from each other, and they were similar to those for conscious dogs reported by Spencer et al. (1950) or Merin et al. (1976b). Accordingly it may be thought that these anesthesia do not disturb the mode of oxygen supply to the heart. Previously we reported that modified NLA using droperidol and pentazocine caused a significant dose-related increase in R value (Yusa and Iwatsuki 1974). This finding contradicts the present study, in which no significant difference was found between modified NLA and basal anesthesia. This discrepancy may be attributed to the following factors: 1) An ordinary clinical dose as used in the present study caused only a slight increase in R value, and 2) in the present study comparison was made between different groups in contrast to the previous study. The result that R value for halothane anesthesia was not significantly different from those for the other intravenous anesthesia and similar to those for conscious dogs coincides with other previous reports (Merin et al. 1976a; Yusa et al. 1977).

In contrast with these anesthesia R values for ether anesthesia, methoxyflurane anesthesia and enflurane anesthesia were significantly lower than those for intravenous anesthesia and halothane anesthesia. Previously we reported that the fall in R value associated with ether anesthesia is caused by the greater increase in coronary blood flow than in myocardial oxygen consumption, and that the fall in R value with methoxyflurane anesthesia is caused by more marked decrease in myocardial oxygen consumption than in coronary blood flow (Yusa et al.
1969, 1977). The fall in R value with enflurane anesthesia may be caused by greater decrease in myocardial oxygen consumption as methoxyflurane anesthesia, because the reduction in myocardial oxygen consumption with enflurane anesthesia has been shown by Merin et al. (1976b).

References


