Blower-Driven Artificial Respirator for Large Animals

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General anesthesia depresses ventilation of large animals such as cattle and horses [4, 6, 7], and consequently, it sometimes requires assisted or controlled respiration. Although high-pressure oxygen or compressed air is used as a drive source in large animal respirators [1, 5, 8], these respirators have economic and ambulatory disadvantages. In this study, a portable artificial respirator was designed to overcome those problems, and the practical applicability was evaluated. The trial respirator consists of three separable units; the control unit, the drive unit, and the barrel for compression of a reservoir bag (respiratory bag). As a drive source we used a blower instead of conventional high-pressure oxygen or compressed air. Blowers are originally designed for sending air, and those with large airflow are easily obtainable, but those producing high wind pressure are comparatively rare. In our trial we used a high-speed blower with a universal motor driven by AC 100 V since it provides a comparatively high wind pressure and facilitates adjustability of wind pressure. This blower has the capacity of the maximum wind pressure of 160 cm H_2O as well as the maximum airflow of 2.2 m^3/min. The wind pressure of the blower was adjusted electrically by controlling the rotating speed, and the airflow was controlled by adjusting the throttle of the large valve for city water, which was installed between the blower and the barrel for compressing the reservoir bag. The barrel, made of stainless steel in a cylindrical shape, had a capacity of 50 *l* and the upper part of which was made of acrylate resins as to make the interior visible. The 20 *l* reservoir bag, commercially available for large animals, was used without modification. A specially-ordered and -made solenoid valve was used for the valve for expiration and inspiration (Figs. 1 and 2). This artificial respirator was so designed that it could operate as a time-cycle and pressure limit type. However, when the pressure limit was set at the maximum, the airway pressure was switched, without reaching the pressure limit, to expiration after air was supplied for a desired length of time. It could thus be also utilizable as a volume limit (determined by flow rate × inspiration time) type. The respiratory rate and the inspiration/expiration (I/E) ratio vary from 1 to 99/min and from 1:9 to 1:1, respectively. Alarms were also installed for warning abnormality in the respiratory circuit. In addition to that, the respirator was so facilitated that it would utilize high-pressure air or oxygen, if available.

The practical applicability of this respirator was tested in 5 adult Holstein cows. After premedication with

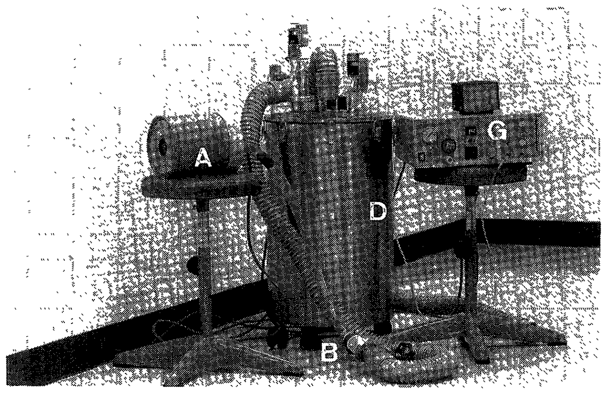

Fig. 1. An artificial respirator constructed for trial. A: Blower, B: Valve for adjusting the flow rate, C: Rotation controller of the blower, D: Barrel for compression of the reservoir bag, E: Inspiratory valve, F: Expiratory valve, G: Control unit equipped with alarms.

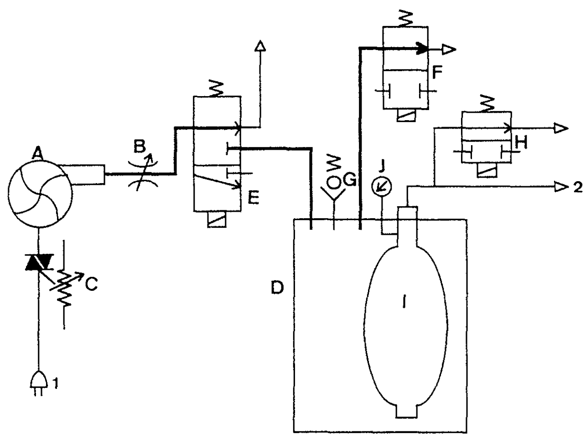

Fig. 2. Diagram of the respirator, A: Blower, B: Valve for adjusting the flow rate, C: Rotation controller of the blower, D: Barrel for compression of the reservoir bag, E: Inspiratory valve, F: Expiratory valve, G: Safety valve, H: Spill valve, I: Reservoir bag, J: Pressure meter. 1: To AC 100 V line, 2: To anesthetic circuit.

atropine and xylazine, anesthesia was introduced by intravenous injection of glyceryl guaiacolate and thiopental sodium. It was then maintained with halothane-oxygen through an endotracheal tube. They were retained by a right lateral recumbency. When the anesthesia was stabilized, controlled respiration was started. The flow rate in controlled respiration was so adjusted that the airway pressure would reach the set pressure at the time when the

Table 1. Changes in blood gases during controlled respiration in dairy cows

Inspiratory pressures (cmH_2O)	P_{aCO2} (mmHg)	P_{aO2} (mmHg)
0[a)]	55.5±7.7[b)]	319.2±138.1
10	60.3±0.1	452.9±148.5
15	50.5±3.8	352.9±181.7
20	34.4±3.6	404.7±147.4
25	31.4±1.6	449.5±218.2

a) Spontaneous breathing. b) Data are expressed as the mean±standard deviation.

I/E ratio was 1:2. The maximum airway pressure was changed to 10, 15, 20 and 25 cmH_2O every 15 minutes. The respiratory rate was 10/min.

Spontaneous respiration and "Fighting" were observed during the introduction of the maximum airway pressure of 10 cmH_2O, however, spontaneous respiration disappeared after the introduction of the maximum airway pressure of 15 cmH_2O and more. The optimum ventilation as indicated by $Paco_2$ was obtained under the condition of the maximum airway pressure of 20 cmH_2O (Table 1). It was further found that the adjustment of air flow rate was somewhat difficult and the operating sound was relatively noisy. The practical applicability of the prototype artificial respirator was confirmed.

Yasuda *et al.* [9] and Ogasawara *et al.* [3] reported a bellows type respirator which is compact and economical, however, most of the commercially available respirators consume a large amount of oxygen for operating the machine itself. Therefore, in the case of anesthesia in the outdoors, several oxygen cylinders should be carried out only for the use of anesthesia but also for operating a respirator. It also possesses a problem from the viewpoint of safety. If the compressed air by means of a compressor is used as a drive source, the problem of running cost may be resolved. In this case, however, a large equipment expense will follow and ambulation of a large air compressor is impracticable. This, then, precludes the utilization in the field. We have, therefore, planned the use of a small blower as a power source.

Moore *et al.* [2] reported a respirator for large animals using an electric vacuum cleaner in 1946. Although it is unknown whether the respirator of this type is still in use or not, such a respirator holds some structural problems as far as the report concerned, namely, I/E ratio is fixed at 50%; airway pressure is controlled by closing an exhaust tube with a screw-clamp and adjusting a leak of air; and expiration is done through a clamped exhaust tube. On this system, change in output of a blower directly influences airway pressure since the airway pressure is decided by air circuit resistance, flow of air to be sent, and resistance at a clamp. When a resistance at the clamp is increased so as to raise the airway pressure, expiratory resistance is also increased.

In our device, I/E ratios are variable by the installation of electronic-controlled valves, and expiratory resistance is low since the diameter of expiration valve is large. Besides, the airway pressure is detected electrically, and valves are controlled according to its signal. So the maximum airway pressure is not influenced by the change in output of the blower, as far as the output of the blower is large enough.

On the other hand, the blower system of our respirator has some problems that should be modified in the future; the blower's rotating noise and exhaust sound from valves are comparatively large, and the adjustment of flow is rather difficult compared with the system using compressed gas because it is impossible to adjust independently wind pressure and flow due to the characteristics of a blower.

Although the respirator for large animals constructed for trial in this experiment still requires further improvement as mentioned above, it is small in size, easily transportable, highly practicable besides being economical with low running cost. This respirator is, therefore, considered useful, especially in the management of respiration at ill-equipped facilities such as in open fields.

REFERENCES

1. Beerwinkle, K. B. and Witzel, D. A. 1976. *Vet. Anes.* 3: 110–115.
2. Moore, A. G., McCrady, J. D., Vasku, J., Geddes, M. E., and Hoff, H. E. 1964. *Southwest Vet.* 18: 22–24.
3. Ogasawara, S., Takase, S., Kawamura, S., and Yasuda, S. 1971. *Jpn. J. Vet. Anesth.* 2: 41–46 (in Japanese).
4. Skarda, R., Baches, G., and Fackelman, G. E. 1974. *Vet. Med. Small Anim. Clin.* 69: 754–760.
5. Smith, M. 1971. *Nord. Vet. Med.* 23: 537–547.
6. Sobti, V. K., Prasad, B., and Rama Kumur, V. 1987. *J. Vet. Med.* A34: 465–475.
7. Tagawa, M. and Ejima, H. 1988. *Jpn. J. Vet. Anesth.* 19: 31–34 (in Japanese with English summary).
8. Thurmon, J. C., Menhusen, M. J., and Hartsfield, S. M. 1975. *Vet. Anes.* 11: 34–39.
9. Yasuda, S., Nisikawa, H., Murakami, D., Sugeno, H., Fujii, Y., and Ogasawara, S. 1959. *Jpn. J. Vet. Med. Assoc.* 12: 487–494 (in Japanese with English summary).