

patients who have impaired autoregulation due to intracranial pathology, a more pronounced reduction of CBF may occur than that found in our study. Therefore, MAP must be carefully maintained in these patients. The present result does not mean that diazepam is unsuitable for neurosurgical anesthesia. In fact, Phirman and Shapiro⁷ stated that prior induction of anesthesia with diazepam and thiopental was capable of blocking an increase in ICP due to nitrous oxide, suggesting the usefulness of this combination in those patients with decreased intracranial compliance. In summary, a clinical dose of diazepam does not increase ICP.

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Evaluation of a Disposable Humidifier for Use during Anesthesia

D. B. WEEKS, M.D.*

The provision of humidity during prolonged endotracheal anesthesia has been recommended to prevent changes in ciliary cellular morphology and activity and in pulmonary mechanics.^{1,2} The method employed should reproduce the natural process and provide inspired humidity at temperatures to which the upper trachea is accustomed.¹ This paper reports a laboratory and clinical investigation of the Servo Humidifier[®] 150† with a disposable element, which appears to satisfy these physiologic needs.

MATERIALS AND METHODS

The Servo Humidifier[®] 150 (SH 150), a condenser humidifier that has a heat and moisture trap (cellu-

lose sponge) in addition to a heat and moisture screen (synthetic felt), is designed to be placed between the endotracheal tube and the breathing circuit of an anesthetic or ventilator system (fig. 1). To measure the efficiency of the SH 150, an experimental system was designed, consisting of a previously reported patient model³ and a miniature circle⁴ (fig. 2). The components of the experimental system consisted of a patient model (1, fig. 2) that produced effluent air at 32-34° C at 100 per cent relative humidity (RH; the normal moisture content and temperature of exhaled air¹), and a miniature circle (2, fig. 2) that isolated inspiration from expiration between the patient model's airway and the anesthesia system (4, fig. 2). The miniature circle was necessary to study humidity during the inspiratory phase of the SH 150, which operates on a to-and-fro principle.⁴ Temperatures of the room, exhaled air from the patient model (1C, fig. 2), air from the inspiratory (2U, fig. 2) and expiratory (2W, fig. 2) limbs of the miniature circle, and the area (2X, fig. 2) between the SH 150 and the miniature circle were measured with a Yellow Springs

* Associate Professor of Anesthesia.

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Address reprint requests to Dr. Weeks.

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† Siemens-Elma Ventilator System, 1765 Commerce Drive, Elk Grove Village, Illinois 60007.

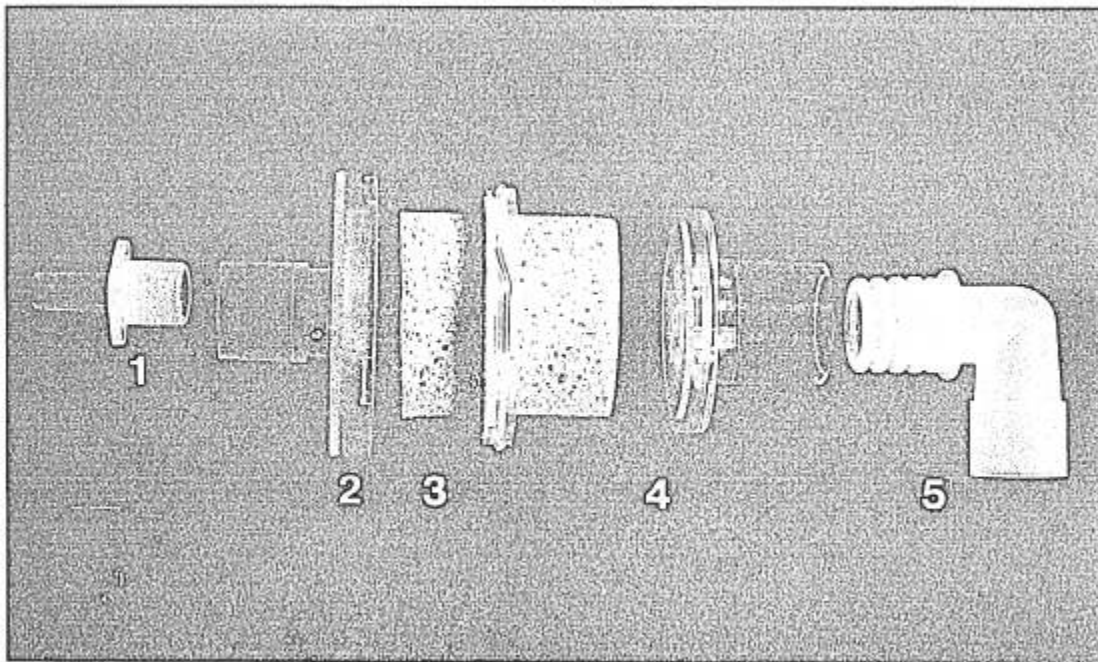


FIG. 1. The Servo Humidifier[®] 150. Each component of the system is marked by a different number. (1 = the endotracheal tube adapter; 2 = SH 150 housing top; 3 = SH 150 disposable insert; 4 = SH 150 housing; and 5 = Rackow elbow.)

recorder[‡] and matched thermistors. Humidity was measured by a hygrosensor and housing⁵ (2Y, fig. 2) placed in the inspiratory limb of the miniature circle.

Temperature and humidity measurements were taken before the SH 150 was connected to the patient model and at 5-min intervals thereafter, for a period of 25 min. After calibration control measurements were obtained, the patient model and the miniature circle were ventilated with a nonbreathing valve driven by a Bird Mark VII ventilator, which delivered an arid air mixture. After control periods of 10 min, the SH 150 was inserted (3, fig. 2) between the miniature circle and the anesthesia system (4, fig. 2), and the measurements were repeated. Tidal volume was 800 ml and the respiratory rate was 8 per min.

Ten laboratory trials were performed, a fresh disposable insert being used for each trial. The SH 150 was tested clinically during routine surgical procedures by measuring airway temperature during inspiration and expiration, first without and then with the SH 150 in the system. A Yellow Springs 520 series thermistor with a response time of 0.1 s was placed between the endotracheal tube adapter and the Rackow elbow or, when the SH 150 was being evaluated, between the endotracheal tube adapter and the SH 150.

The anesthesia apparatus used was a semiclosed circle absorber (SCCA) system. Tidal volumes were 10 ml/kg and respiratory rates were 8 to 10 per min. The inspiratory phase was deliberately prolonged to ensure adequate plateau readings. Humidity measurements were not obtained in the operating room.[§]

Fifteen evaluations were made in six adult patients free of overt pulmonary disease and requiring endotracheal anesthesia. Sufficient time elapsed between each evaluation in a patient for all values to return to control levels. A fresh insert was used for each evaluation. Premedication, including belladonna alkaloids, was allowed. Enflurane, nitrous oxide, and oxygen with intravenous anesthetics were used as indicated. Fresh gas was administered at 4 L/min by the SCCA system. In addition to airway temperatures at the endotracheal tube adapter, temperatures in the room, the esophagus, and the inspired gases at the Y-piece of the SCCA system were recorded, as was room RH.

[§] From previous work¹ and the laboratory portion of this study, it was evident that the SH 150 would provide inspired humidity in the SCCA system equal to or greater than that it provided in the laboratory model, which used a nonbreathing system and gases of extremely low humidity. Omission of the miniature circle in the operating room allowed more accurate assessment of airway temperatures with the rapid response thermistor being placed close to the endotracheal tube adapter.

[‡] Yellow Springs Industries Co., P. O. Box 279, Yellow Springs, Ohio 45387.

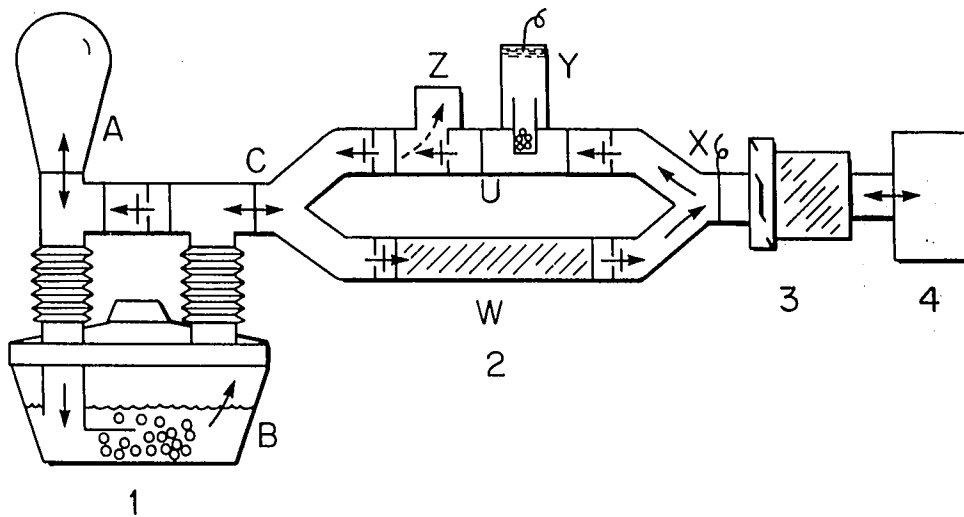


FIG. 2. An experimental system designed to measure the efficacy of the SH 150. The various components of the system are labeled in the figure. (1 = patient lung model; 1A = reservoir bag simulating the lung to provide exhaled tidal volumes; 1B = a water bath humidifier to provide the exhaled tidal volume with saturated gases at 32° C; 1C = model airway simulating endotracheal tube outlet; 2 = miniature circle; 2U = inhalational limb; 2W = exhalational limb heated to 32° C which splits exhalational gases from inhalational gases; 2X = rapid response thermistor which measures end inspired gas temperature; 2Y = hygrosensor to measure humidity and temperature of gas in the inhalational limb; 2Z = one-way valve which insures against contamination of hygrosensor by exhaled gases; 3 = SH 150; 4 = anesthesia system; nonbreathing system in the laboratory, SCCA in the operating room.)

Data were recorded on prepared flow sheets by anesthetists who were uninformed of the significance of the recordings. The Student's *t* test was used to calculate significance of the data.

RESULTS

Before the SH 150 was placed in the laboratory system, RH was not recordable (less than 38 per cent). After the SH 150 was placed in its position of function (3, fig. 2), RH increased with the first breath and reached plateau peak values in the inspiratory limb of the miniature circle within 15 min. The mean RH value for ten trials at 15 min each was 97.5 per cent (range: 95–99 per cent). Mean temperature in the hygrosensor housing during inspiration increased 1.3° C over ambient temperature after the SH 150 was interposed in the experimental system. At the same time intervals, temperature between the miniature circle and the SH 150 (2X, fig. 2) increased 4.2° C above ambient temperatures. Therefore, a 2.9° C heat loss during transit through the 20-ml volume distance between the hygrosensor housing in the miniature circle and the SH 150 was measured. That loss was verified both by using matched thermistors, and by rapidly switching the 520 thermistor between the two points. Room temperature in the laboratory averaged 24.7 ± 0.6° C. Those RH and temperature values represent a calculated actual moisture content during

inspiration of 24 mg of water per liter minute ventilation (mg/L) in the hygrosensor (2Y, fig. 2), and 28 mg/L at the SH 150 (2X, fig. 2).

Measurement of temperature during endotracheal anesthesia resulted in the following information. Temperature measured by the thermistor located between the endotracheal tube adapter and the SH 150 during inspiration ranged from 28.7–31.9° C (mean 30° C) and represented an increased heat gain of 8° C above the temperature recorded from the inspiratory limb of the SCCA system. Room temperature averaged 21.5° C, which was 0.7° C below the mean inspiratory temperature of the SCCA system. Interposing the SH 150 in the anesthesia circuit increased mean inspired airway heat from 24 to 30° C ($P < 0.001$) at the endotracheal tube adapter. This represented an inspired humidity of approximately 30 mg/L (based on 97.5 per cent RH). Mean exhaled gas temperature also increased from 29 to 32° C ($P < 0.001$).

DISCUSSION

Certain guidelines have now been established concerning replacement humidification during endotracheal anesthesia. Ciliated cellular morphologic conditions and function of the respiratory tract are preserved during exposure to humidity of no less than 14 to 22 mg/l, while alterations in lung mechanisms

are prevented when humidity of 17–30 mg/L is supplied.¹ Present anesthesia systems provide only marginal moisture replacement and may cause measurable physiologic and anatomic deficits after varying periods of use in the absence of humidification.^{1,2}

The SH 150 appears to satisfy recommended inspired humidity replacement in both nonrebreathing and SCCA systems. Because the SH 150 provided maximum RH with both the nonrebreathing and the SCCA systems, additional humidity was not necessary from CO₂-soda lime reaction.⁴ The performance of the SH 150 was remarkable in that, after 3 min, mean RH was greater than 93.8 per cent and had reached a plateau of 97.5 per cent at 15 min. Because of the reproducible laboratory results, humidity measurements using the miniature circle were not obtained during the clinical trials using the SCCA system.⁴ Rather, humidity was calculated at recorded inspiratory temperatures, assuming a 97.5 per cent RH.

The major advantage of the SH 150 over other commercially available heat and moisture exchangers reported in the literature, is that the SH 150 provides a higher inspired humidity at warmer temperatures. With nonrebreathing systems, the SH 150 provided an RH of 97.5 per cent at 29° C, compared to an RH of 34 per cent at 26.5° C,⁶ and an RH of 61 per cent at 26° C,⁷ provided by another heat and moisture exchanger. This efficiency is attributed to the heat sink of the SH 150, which is a cellulose sponge.³ Another advantage of the SH 150 is its inexpensive disposable exchange elements, which cost approximately the same as a disposable endotracheal tube. These elements may be used for 24 hours, and they are safer than reusable screens, which must be cleaned and sterilized with great care. The plastic housing for the disposable elements may be sterilized after each usage by autoclaving or cold sterilization. Finally, the SH 150 requires no power source, and it is readily adaptable to any standard anesthesia system.

Precautions in the use of the SH 150 pertain to deadspace and resistance. The SH 150 has a deadspace of 90 ml and a pressure drop across the unit of 0.4 cm/H₂O at a flow rate of 0.5 L/s. Therefore,

the manufacturer recommends the use of the SH 150 in patients who require a tidal volume range of 300–1500 ml. A unit for pediatric use is available, but has not been tested on the protocol reported here. Sufficient force may be generated by the patient whose trachea is intubated during “coughing”⁸ to acutely produce mucus within the SH, thereby causing a marked increase in airway resistance. Usual care in clinical monitoring should detect that unusual occurrence. Prewetting the sponge before inserting it is not recommended by the manufacturer, and the author has observed that prewetting does not increase humidity. Although the SH 150 does meet the physiologic humidity replacement requirements, it cannot provide therapeutic humidity in supersaturated form for liquifying secretions, and waterbath humidifiers may be indicated for that purpose.⁹

Our anesthetists frequently use the SH 150 for adult patients requiring endotracheal anesthesia and find it a useful, inexpensive, easily applied device for humidifying inspired gases.

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