Acta Medica Okayama

Volume 15, *Issue* 5 1961 *Article* 6

OCTOBER 1961

Studies on respiratory humidity. II. Humidity in anesthetic circuits and water loss via anesthesia systems

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Abstract

Through the use of an automatic photo tube dew-point hygrometer, the author succeeded in measuring dew point of gas flows continuously in anesthetic circuits. Simultaneous thermometries were done on the nasal or oral mucosa, on the respiratory gas flows in the anesthetic mask or the endotracheal tube, and on the gas in the inhaling conduit. Experiments were performed on ten adults patients undergoing various types of surgery under general inhalation anesthesia. Anesthetic technics were varied intentionally during the measurements. Thus, both absolute and relative humidities of exhaled and inhaled gases, and respiratory water and heat losses were calculated under various anesthetic conditions, and physiological and clinical considerations were discussed. The conclusions obtained from this research are as follows: (1) When a non-rebreathing system is applied, moisture content of exhaled gas is minimal, and respiratory losses of both water and heat are maximum. With a semi-closed circle method, according to decreasing fresh gas flows, the humidity of the inspiratory and expiratory gases becomes higher, and both heat and water losses through respiration are lessened. When a closed circle method, with carbon dioxide absorption, is employed, temperature and humidity of gas in the inhaling conduit are highest, and the expired gas offers the maximum temperature and moisture contenL Both water and heat losses from anesthesia become minimal when administered in a closed system. (2) While the water and heat that a patient loses through respiration increase with increasing breathing capacity, they are still small parts of the total water and heat losses of the patient. Water and heat losses via anesthesia systems are not so predominant in maintaining water balance and heat regulation of patients during anesthesia and surgery.

*PMID: 14497443 [PubMed - indexed for MEDLINE]

Acta Med. Okayama 15, — (1961)

STUDIES ON RESPIRATORY HUMIDITY

II. HUMIDITY IN ANESTHETIC CIRCUITS AND WATER LOSS VIA ANESTHESIA SYSTEMS

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Received for publication, February 25, 1961

The importance of the humidity of respiratory gases in clinical anesthesia has been well and widely recognized. In most books on anesthesia, statements such as the following are seen on this subjects: [1-3](1) Most gases used for anesthesia are supplied in the anhydrous condition. They dehydrate mucous membranes, unless they are well humidified. Adequate humidification of inhaling gases is very important to normal functioning of the respiratory tract. (2) Moisture is essential in the chemical reaction of carbon dioxide absorbents, which are used in rebreathing apparatuses. (3) Moisture facilitates the dissipation of electrostatic charges. (4) Humidity has immediate relations to the heat regulation and water balance of the human body.

However, on the quantitative measurement of humidity of gases in anesthetic circuits, there has been practically nothing but elementary assumptions, such as that gases in closed circle systems are uniformly saturated,[3] expiratory gases are always saturated with water vapor,[3-6] etc. Actual determination of the moisture content in anesthetic gas flows is not seen in the literature, probably due to a lack of adequate instruments. The author succeeded in practical hygrometry of expiratory and inspiratory gases under various anesthetic conditions with a photo tube dew-point hygrometer. The results of the clinical experiments, using this hygrometric technic, are described, and losses of water and heat via anesthesia systems are presented in this paper.

METHODS

The apparatus and method for measuring humidity of respiratory gases were described in detail in the previous paper,[7] Part I of this series of work. By the insertion of a photo tube dew-point hygrometer in the exhaling or inhaling side of an anesthetic circuit, the dew points of expiratory and inspiratory gases, which pass through the dew-point detecting chamber of the hygrometer, were automatically and continuously determined and recorded by means of an electronic recorder.

One-way valves for the prevention of back-flow of gases in the passages, as described in Part I, were replaced by the expiratory and inspiratory valves of an anesthetic circuit apparatus (Heidbrink and Dräger machines were used). The application of too many valves in an anesthetic circuit increases the respiratory resistance greatly. When the circuit was opened at the expiratory side, a long outlet pipe with a rubber-made directional valve was used for preventing a back-flow of the outside gas into the dew-point detecting chamber through the opening, so that a type of semi-open or non-rebreathing system was established in the passage. A Fink valve was used for establishing a non-rebreathing system, also.

When the measurement was done at the exhaling side for checking the humidity of expiratory gas, a guide-tube for introducing the exhaled gas into the hygrometer was heated throughout, so that dew formation on its wall was prevented. A slip joint and a Y-connector, which were attached to the endotracheal tube, were also heated to approximately 40°C. A Fink valve was heated with attached electric heaters in the event that it would be used. A specific chimney-piece with a rubber cushion was devised for mask breathing, the entire internal surface of which was kept slightly warmer than body temperature with a thermostatic electric heater. This device was specially designed with a small amount of dead sapce in it and also to facilitate thermometry of the exhaled gas with an installed thermocouple. Thus, the humidity of the expiratory gas was measured as it was in the same state as in the endotracheal tube, or the nasal and oral cavities. On the other hand, when the hygrometer was used in the inhaling side of the circuit, a guide-tube between the hygrometer and the human body was heated in the same manner, so that the humidity of the gases being inhaled became known. Respiratory water loss via anesthesia systems can be determined by calculating the difference of moisture contents between the expiratory and inspiratory gases.

Temperature measurements were taken at two different places in the anesthetic system, one in the endotracheal tube or in the anesthetic mask, and the other in the inhaling conduit. At these places, it was felt that untoward affection of the heat from the hygrometer apparatus would be very slight. The structure of the thermometric instruments (i. e. the copper-constantan thermocou ples) was described in Part I. Attention was paid to allow the thermocouples to indicate the correct temperature of gas flows without touching the walls, without being spoiled with splashed secretion or water droplets, without receiving heat radiation from the environment, etc.

Ten adult patients, who ranged in age from 26 to 64 years and underwent various kinds of surgery (four gastrectomies, four gut resections, one chordotomy and one ganglionectomy) under general inhalation anesthesia, were chosen for this study. Experiments were done for from one to five-hour duration in the operating rooms of the Second Surgical Department of Okayama University Medical School Hospital. While nitrous oxide was used mainly for anesthesia maintenance, various anesthetic technics were employed for each case.

RESULTS

Fig. 1 shows an example of hygrometric measurement during general inhalation anesthesia, when various anesthetic technics were used. A 47-year-old female (wt. 39.5 kg.) had a chordotomy in a prone position. Anesthesia was maintained mainly with nitrous oxide and oxygen through an intubated endotracheal tube, with an inflated cuff, connected to a Romulus Dräger anesthetic machine. Spontaneous respiration was maintained almost in a constant state;

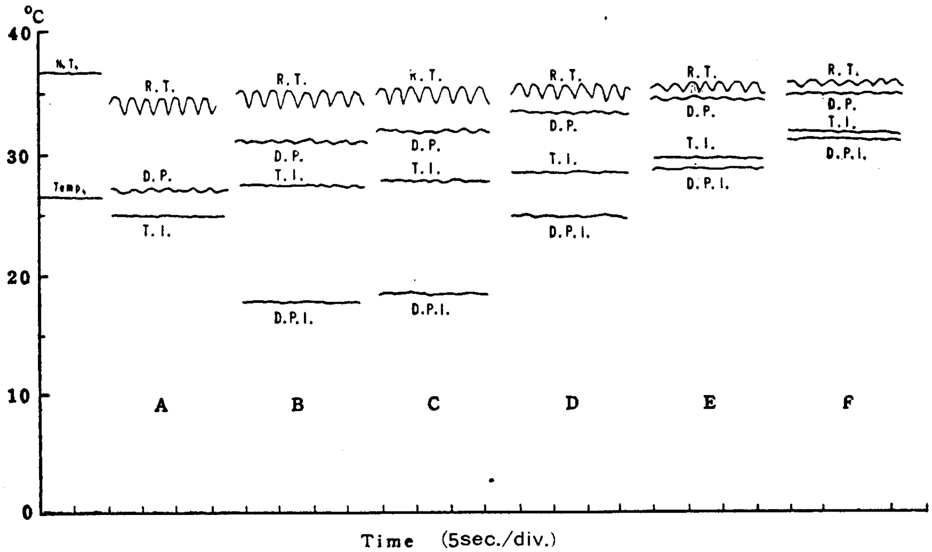

Fig. 1. Recordings of the hygrometric measurements during general inhalation anesthesia on a clinical case (Case 1, refer to text).

that is, the tidal volume was approximately three hundred cubic centimeters and respiratory rate was twenty-six per minute during the measurements. Measurements were done on the temperature of the nasal mucosa (N.T.), the temperature of the environmental air (Temp.), the temperature of the respiratory gas in the endotracheal tube (R.T.), the dew point of the expiratory gas (D.P.), the dew point of gas in the inspiratory conduit (D.P.I.) and the temperature of gas in the inspiratory conduit (T.I.). The mean values of those were estimated by means of leveling their respective wave-formed curves geometrically. In ***A***, 6 *l.*/min.

of nitrous oxide and 2 *l.*/min. of oxygen were given in a non-rebreathing technic. In ***B***, the same gas flows were administered in a semi-closed circle method with carbon dioxide absorption. In ***C***, ***D*** and ***E***, semi-closed methods were also used, administering different amoutns of gas and oxygen through the flowmeters: i. e., 3.5 *l.*/min. of nitrous oxide plus 1.5 *l.*/min. of oxygen in ***C***, 2.0 *l.*/min. of nitrous oxide plus 1.0 *l.*/min. of oxygen in ***D***, and 1.0 *l.*/min. of oxygen alone in ***F***. ***E*** shcws the determinations when 0.3 *l.*/min. of oxygen flow was used in a closed method with carbon dioxide absorption.

In ***A***, the patient was inspiring anhydrous anesthetic gas and oxygen, and both R. T. and D. P. are shown to be lower than in any others. This means that the amount of water vapor in exhaled gas is minimal when a non-rebreathing system is used. The relative humidity of the expiratory gas, calculated from the mean R. T. (34.5°C) and mean D. P. (27.0°C), is 65 per cent. (The mean R. T., which was applied here, must refer to the mean temperature of the expiratory gas, and it was estimated by means of leveling the upper halves of the R. T. waves.) In this case all of the moisture content of the expiratory gas must be derived from the human body, so that total respiratory water loss is determined directly from the D. P. Since 25.8 mg. of water is contained in one liter of gas, the dew point of which is 27.0°C, [8] respiratory water loss, via the non-rebreathing system, is calculated to be 12.4 grams per hour. Since the latent heat of water vaporization is 0.575 Cal.[9] at body temperature (N. T. in this case was 36.6°C), heat loss due to the same amount of water vaporization from the respiratory tract and lungs is 7.13 Cal. per hour. Since the specific heat of nitrous oxide and oxygen gases are 0.0004 Cal. /*l.* and 0.0003 Cal. /*l.*[10] respectively, heat loss in the human body, in raising the temperature of the mixture of 6 *l.*/min. of nitrous oxide and 2 *l.*/min. of oxygen from the mean T. I. (25.0°C) to R. T. (34.5°C), is calculated to be 1.71 Cal. per hour. It is known, therefore, that the total water loss by means of the anesthetic system ***A*** is 8.84 Cal. per hour. The heat for changing the temperature of the water vapor was found to be small enough to be negligible. Calculations can be done in the same way in the others. In ***B***, the relative humidity of the expiratory gas is 79.8 per cent (R. T.: 35.0°C and D. P.: 31.0°C), and that of the inspiratory gas is 56.2 per cent (T. I.: 27.5°C and D. P. I.: 18.0°C). Respiratory water loss is 8.5 grams per hour (calculation: (32.08—15.40) mg. $\times 8 \times 60$). The total heat loss via anesthesia system ***B*** is 6.24 Cal. per hour (calculation: for vaporization; 0.575 Cal. $\times$ 8.5, for warming gas; (0.0004 Cal. $\times 6 +$ 0.0003 Cal. $\times$ 2) $\times$ (35.0 —27.5) $\times$ 60). In ***C***, the relative humidities of the expiratory and inspiratory gases are 83.6 per cent and 58.1 per cent respectively. Respiratory water loss is 8.4 grams per hour (calculation: (33.84—16.33) mg. $\times 8 \times 60$), and total respiratory heat loss is 6.12 Cal. per hour (calculation: 0.575 Cal. $\times$ 8.4 plus

(0.0004 Cal. ×3.5+0.0003 Cal. +1.5) × 8/5 × (35.2—28.0) ×60). In ***D***, the relative humidities of the expiratory and inspiratory gases are 89.5 and 81.4 per cent respectively. Respiratory water loss is calculated 6.5 grams per hour (calculation: (36.61—23.07) mg. × 8×60). Heat loss for vaporizing the same amount of water is 3.74 Cal. per hour. 1.23 Cal. is used in warming the gas mixture from the mean T. I. (28.5°C) to R. T. (35.5°C) in one hour (calculation: (0.0004 Cal. ×2+0.0003 Cal. ×1) × 8/3 × 7.0×60). Then, the total heat loss through the anesthesia system ***D*** is found to be 4.97 Cal. per hour. In ***E***, the relative humidity of the expiratory and inspiratory gases are 93.1 and 95.5 per cent respectively. Respiratory water loss is 4.8 grams per hour (calculation: (38.79—28.78) mg. ×8×60). Respiratory heat loss for one hour is 2.76 Cal for vaporizing 4.8 grams of water, and 0.88 Cal. for raising the temperature of the gas, which is considered to be almost pure oxygen in this case. The total heat lost through respiration amounts to 3.64 Cal. per hour. In ***F***, when a closed method was used, both expiratory and inspiratory gases were shown to be the most humidified and the warmest in these experiments. Their relative humidities are 94.6 and 97.2 per cent respectively. Respiratory water loss is 3.2 grams per hour, and total heat loss by the use of the closed circle system is 2.41 Cal. per hour (calculation: 0.575 Cal. ×3.2 plus 0.0003 Cal. ×8× (36.0—32.0) × 60). Thus, it is obvious that both water and heat losses via anesthesia systems decrease from ***A*** to ***F***, as seen in these experiments.

Data thus determined and calculated on the ten cases are summarized in Table 1. Each value in the table refers to the average of several determinations on each case. Average values, which were calculated from the data on corresponding determinations with same fresh gas inflows on the whole cases, are shown in Table 2.

DISCUSSION

Physiological problems on the humidity of respiratory gases are still far from being cleared. Several investigations which were previously attempted in this field (see the references in Part I[7]) vaguely described some ideas, mainly on the air-conditioning function of the respiratory tract, but did not offer any definite knowledge of the physiological relationship between respiratory function and humidity.

Since starting to utilize a photo tube dew-point hygrometer as an improved hygrometric instrument in biology, with success in recording dew point (absolute humidity) of respiratory gas flows precisely and continuously, attempts have been made to explore several questions on this subject. Since it is now clear that expired gas is not always or uniformly saturated with water vapor, as is conventionally considered to be so, and moisture contained in it must be derived

Table 1. Hygrometric and thermometric data on ten clinical cases under various types of general inhalation anesthesia, and calculated respiratory water and heat losses via the anesthesia systems.

Case No. 1. age 2. sex 3. body weight 4. room temp. 5. nasal temp.	Anes. tech.	N_2O+O_2 (*l.*/min.)	R. T. (°C)	D. P. (°C)	R. H. (%)	T. I. (°C)	D. P. I. (°C)	R. H. I. (%)	H_2O -loss (g./hour)	Heat-loss (Cal./hour) Vapr.	Warm.	Total	Remarks Min. -vol. (*l.*)	CR & Mask
Case 1	N. R.	6 +2	34.5	27.0	65.0	25.0	—	—	12.4	7.13	1.71	8.84	8.0	
1. 47 yrs.	S. C.	6 +2	35.0	31.0	79.8	27.5	18.0	56.2	8.5	4.89	1.35	6.24	〃	
2. female	S. C.	3.5+1.5	35.2	32.0	83.6	28.0	19.0	58.1	8.4	4.83	1.29	6.12	〃	
3. 39 5 kg.	S. C.	2 +1	35.5	33.5	89.5	28.5	25.0	81.4	6.5	3.74	1.23	4.97	〃	
4. Temp. 26.7°C	S. C.	1	35.9	34.6	93.1	29.8	29.0	95.5	4.8	2.76	0.88	3.64	〃	
5. N. T. 36.6°C	Cl.	0.3	36.0	35.0	94.6	32.0	31.5	97.2	3.2	1.84	0.57	2.41	〃	
Case 2	N. R.	6 +2	33.6	25.5	62.8	22.5	—	—	11.4	6.56	2.00	8.56	8.0	
1. 37 yrs.	S. C.	6 +2	36.0	31.0	75.6	24.0	19.8	77.4	7.7	4.43	2.16	6.69	8.8	CR
2. male	S. C.	3.5+1.5	35.5	32.0	82.2	28.2	21.0	65.1	6.0	3.45	1.05	4.50	6.5	CR
3. 49.0 kg.	S. C.	2 +1	36.3	32.5	81.0	29.3	23.0	68.9	5.5	3.16	1.02	4.18	6.5	CR
4. Temp. 23.0°C	Cl.	0.5	36.8	33.6	83.8	29.5	26.5	83.9	4.1	2.35	0.79	3.14	6.0	CR
5. N. T. 37.0°C	Cl.	0.4	36.8	34.0	85.7	29.8	29.0	95.5	3.7	2.13	0.76	2.89	7.0	CR
	S. C.	3.5+1.5	32.7	27.1	72.1	27.4	21.0	68.2	3.3	1.90	1.28	4.18	7.2	Mask
Case 3	N. R.	6 +2	34.3	25.5	60.3	22.0	—	—	10.8	6.21	2.21	8.43	7.6	
1. 63 yrs.	S. C.	4 +1.5	36.2	31.8	78.3	26.8	18.8	61.6	8.3	4.77	1.72	6.49	8.0	CR
2. female	S. C.	2 +1	36.3	32.1	79.2	30.6	28.9	90.7	2.6	1.50	1.00	2.50	8.0	
3. 47.0 kg.	Cl.	0.4	36.8	35.5	93.1	32.0	31.5	97.2	3.7	2.13	0.90	3.03	8.0	
4. Temp. 22.5°C	S. C.	2 +1	35.8	30.0	72.2	29.8	27.0	85.0	2.2	1.27	1.06	2.33	8.0	Mask
5. N. T. 37.2°C														
Case 4														
1. 30 yrs.	N. R.	5 +2	32.8	24.0	59.9	20.0	—	—	9.2	5.29	2.00	7.29	6.8	
2. male	S. C.	3.5+1.5	35.9	31.6	78.6	24.6	21.7	83.9	5.9	3.39	1.76	5.15	7.0	CR
3. 41.0 kg.	Cl.	0.4	36.0	35.4	96.7	33.2	32.7	97.2	2.4	1.38	0.37	1.75	7.2	CR
4. Temp. 21.0°C	S. C.	3.5+1.5	34.0	29.2	76.1	23.8	20.4	81.3	3.7	1.99	0.95	2.94	5.5	Mask
5. N. T. 36.7°C														
Case 5	N. R.	6 +2	33.3	25.8	64.9	23.2	—	—	10.8	6.21	1.92	8.13	8.0	CR
1. 45 yrs.	S. C.	6 +2	34.5	29.2	74.0	24.5	17.2	63.9	6.1	3.51	1.58	5.09	7.0	CR
2. male	S. C.	3.5+1.5	34.8	31.0	80.8	26.6	23.6	83·6	4.1	2.36	1.09	3.44	6.0	
3. 57.0 kg.	S. C.	2 +1	35.2	32.9	88.0	27.1	24.6	86.2	4.7	2.70	1.07	3.77	6.3	CR
4. Temp. 24.5°C	Cl.	0.4	36.1	35.4	96.2	32.7	32.5	98.9	2.6	1.50	0.37	1.87	6.0	
5. N. T. 37.2°C	S. C.	3	34.0	31.0	84.4	26.6	24.1	86.2	4.7	2.70	1.03	3.73	7.7	Mask

Case 6.	N. R.	6 +2	33.5	24.0	57.6	22.3	—	—	9.5	5.46	2.02	7.48	8.0	CR
1. 33 yrs.	S. C.	3.5+1.5	36.2	31.8	65.9	25.4	22.0	81.5	6.4	3.78	1.82	5.60	7.6	CR
2. male	S. C.	2 +1	36.6	32.1	77.8	25.9	24.2	90.4	4.6	2.65	1.01	3.66	6.4	CR
3. 38.2 kg.	Cl.	0.4	36.2	35.5	96.2	32.0	31.5	97.2	3.8	2.19	0.48	2.67	6.4	CR
4. Temp. 23.5°C	N. R.	5.5+2	32.3	23.2	58.8	22.6	—	—	9.4	5.41	1.63	7.04	7.5	Mask
5. N. T. 36.8°C														
Case 7.	N. R.	6 +3	33.0	18.3	41.8	24.3	—	—	8.5	4.89	1.72	6.61	9.0	CR
1. 54 yrs.	S. C.	6 +2	36.1	25.0	53.0	24.8	12.6	46.7	5.7	3.28	2.07	5.35	8.0	CR
2. male	S. C.	4 +2	36.8	26.1	54.4	24.9	18.0	65.6	4.9	2.82	2.36	5.18	9.0	CR
3. 47.0 kg.	S. C.	2 +1	37.2	29.6	65.3	24.9	19.8	73.4	4.5	2.59	1.51	4.10	5.6	
4. Temp. 24. 1°C	S. C.	1	37.1	32.4	77.0	27.8	23.0	75.2	3.9	2.24	1.00	3.24	6.0	
5. N. T. 37.8°G														
Case 8.	N. R.	4 +3	33.3	24.0	58.3	20.5	—	—	9.2	5.29	1.72	8.01	7.0	
1. 32 yrs.	S. C.	4.5+1.5	35.2	24.2	53.1	22.2	17.8	76.2	4.1	2.36	2.94	5.30	9.6	CR
2. female	S. C.	3.5+1.5	35.4	26.8	61.2	24.1	20.7	81.3	3.2	1.81	1.76	3.60	7.0	CR
3. 39.5 kg.	N. R.	4 +2.5	32.4	23.5	59.5	20.5	—	—	7.9	4.54	1.68	6.22	6.5	Mask
4. Temp. 21. 3°C														
5. N. T. 36.5°C														
Case 9.	S. C.	4 +2	34.3	30.1	79.9	24.2	20.0	77.4	5.6	3.22	1.56	4.78	7.0	
1. 51 yrs.	S. C.	3.5+1.5	35.5	31.1	78.1	27.7	20.8	66.1	7.0	4.03	1.44	5.47	8.4	CR
2. female	Cl.	0.3	35·7	32.5	83.5	29.5	26.4	83.9	3.3	1.90	0.78	2.68	7.0	
3. 42.8 kg.	S. C.	6 +2	36.1	29.9	70.6	25.4	17.0	59.8	8.0	4.60	1.93	6.53	8.0	Mask
4. Temp. 25.0°C														
5. N. T. 36.7°C														
Case 10.	N. R.	6.5+2	31.6	27.5	78.9	21.2	—	—	12.7	7.84	1.87	9.71	8.0	
1. 42 yrs.	S. C.	6 +2	32.3	29.8	86.7	22.4	17.6	74.3	7.2	4.14	1.80	5.91	8.0	CR
2. male	S. C.	3.5+1.5	33.3	31.2	88.8	26.8	24.0	84.7	5.1	2.96	1.15	4.11	8.0	CR
3. 60.0 kg.	S. C.	2 +1	34.9	31.8	84.0	29.6	26.8	85.0	3.8	2.18	0.93	3.11	8.0	CR
4. Temp. 21.2°C	S. C.	1	34.6	32.9	90.9	29.6	27.2	87.0	4.4	2.53	0.72	3.25	7.0	Mask
5. N. T. 37.5°C														

Note: ***Anes. tech.***: Anesthesia technics used; ***N. R***: Non-rebreathing, ***S. C.***: Semi-closed circl., with carbon dioxide absorption, ***Cl.***: closed circl., with carbon dioxide absorption. ***N_2O+O_2***: Fresh gas inflows of nitrous oxide and oxygen (liter per minute). ***R. T.***: Temperature of respiratory (expiratory) gas (refer to text). ***D. P.***: Dew point of expiratory gas. ***R. H.***: Relative humidity of expiratory gas. ***T. I.***: Temperature of gas in the inspiratoy conduit. ***D. P. I.***: Dew point of gas in the inspiratory conduit. ***R. H. I.***: Relative humidity of inspiratory gas. ***H_2O-loss***: Respiratory water loss (grams per hour). ***Heat-loss, Vapr., Warm., Total***: Heat loss for water vaporization, for gas warming, total respiratory heat loss (Cal. per hour). ***Remarks, Min.-vol.***: Respiratory minute volume (liter per minute). ***CR***: Controlled respiration (otherwise, spontaneous or assisted respiration). ***Mask***: Mask breathing (otherwise, endotracheal anesthesia).

Table 2. Average values on the whole cases, by means of different anesthesia technics.

Anes. tech.	N_2O+O_2 (l./min.)	R. T. (°C)	D. P. (°C)	R. H. (%)	T. I. (°C)	D. P. I. (°C)	R. H. I. (%)	H_2O -loss (g./hour)	Heat-loss (Cal./hour) Vapr.	Warm.	Total
N. R.	6 +2	33.8	25.6	62.1	23.6	—	—	11.0	6.31	1.97	8.29
S. C.	6 +2	34.8	29.2	73.8	24.6	17.0	63.7	7.0	4.05	1.79	5.86
S. C.	3.5+1.5	35.2	30.9	77.4	26.4	21.6	75.5	5.8	3.33	1.42	4.75
S. C.	2 +1	36.0	32.1	80.7	28.0	24.6	82.3	4.6	2.65	1.11	3.76
Cl.	0.4	36.3	34.6	92.5	31.3	30.2	93.9	3.4	1.93	0.63	2.56

Note: Refer to the note in the Table 1 for abbreviations in this table.

the respiratory surface of lungs (and of the respiratory tract) by means of the respiratory exchange, it is felt that the humidity of expired gas varies under the influence of respiratory states; i. e., respiratory frequency and volume in relation to pulmonary function. It must be correlated directly with the efficiency of respiratory ventilation, while there are a number of intrinsic and extrinsic factors which influence the relationship, together and in a complex fashion. They are the temperature and humidity of the inspired gas, temperature of the human body, conditions of the respiratory tract or respiratory dead space, etc. Some such problems are being investigated and will be reported elsewhere, although further extensive research is needed to clarify the details. However, the following statements seem to be justified in the light of the research to this point. These facts are believed necessary as basic knowledge for understanding the data in the present research.

(1) When inspired gas is anhydrous, expired gas contains minimum moisture. As the humidity of inspired gas increases, the humidity of expired gas also increases.

(2) The humidity of expired gas increases when respiration is deep and slow. Rapid and shallow respiration make the humidity lower in the expired gases.

Anesthesia provides specific and atypical conditions in human respiration. Various additional factors must be considered on the hygrometric determinations in anesthesia systems. The chemical reaction of carbon dioxide absorbents, which produces heat and water, and temperature and wetness of the internal surface of conduits, a bag, connectors etc., are very influential factors on the humidity of gases in the anesthetic circuit, and their states are constantly changing during application. Therefore, a wide range of variations in the data are unavoidable. In this article, the subjects are limited mainly to the clinical importance, and relative humidities in the exhaling and inhaling circuits, respiratory water and heat losses are calculated in relation to the amount of gas flow administered in the non-rebreathing, simi-closed and closed methods. Both water and heat losses through respiration are relatively small in comparison with those through other routes during surgery.[3,11,12] Therefore, it is not believed that their effects on the water balance and heat regulation of a patient under anesthesia and/or surgery are so predominant,

SUMMARY AND CONCLUSIONS

Through the use of an automatic photo tube dew-point hygrometer, the author succeeded in measuring dew point of gas flows continuously in anesthetic circuits. Simultaneous thermometries were done on the nasal or oral mucosa, on the respiratory gas flows in the anesthetic mask or the endotracheal tube, and on the gas in the inhaling conduit. Experiments were performed on ten adults patients undergoing various types of surgery under general inhalation anesthesia. Anesthetic technics were varied intentionally during the measurements. Thus, both absolute and relative humidities of exhaled and inhaled gases, and respiratory water and heat losses were calculated under various anesthetic conditions, and physiological and clinical considerations were discussed.

The conclusions obtained from this research are as follows:

(1) When a non-rebreathing system is applied, moisture content of exhaled gas is minimal, and respiratory losses of both water and heat are maximum. With a semi-closed circle method, according to decreasing fresh gas flows, the humidity of the inspiratory and expiratory gases becomes higher, and both heat and water losses through respiration are lessened. When a closed circle method, with carbon dioxide absorption, is employed, temperature and humidity of gas in the inhaling conduit are highest, and the expired gas offers the maximum temperature and moisture content. Both water and heat losses from anesthesia become minimal when administered in a closed system.

(2) While the water and heat that a patient loses through respiration increase with increasing breathing capacity, they are still small parts of the total water and heat losses of the patient. Water and heat losses via anesthesia systems are not so predominant in maintaining water balance and heat regulation of patients during anesthesia and surgery.

ACKNOWLEDGEMENT

The author gratefully acknowledges the guidance of Prof. Terutake SUNADA for this research. He also wishes to express his appreciation to Dr. Bruce L. DOUGLAS for his help in editing the final manuscript.

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