Medical Intelligence

Systemic and Pulmonary Changes with Inhaled Humid Atmospheres:

Clinical Application

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In the course of inhalation, man is physiologically able to take cold, dry atmospheric air, warm it nearly to body temperature, and saturate it with water vapor by the time it reaches the carina of the trachea. This is accomplished by an air-conditioning system that utilizes heat and moisture from the mucosal lining of the nasal turbinates, nasopharynx, and oropharynx. This ability is common to all mammals and other air-breathing animals. If the air-conditioning system is bypassed, such as might occur in a comatose patient breathing through a wide-open mouth or in a patient with a tracheostomy or endotracheal tube in place, the drying effect increases the viscosity of the mucus that forms a blanket overlying the mucosa of the tracheobronchial tree. Dahllöf and Yaglou pointed out that infants exposed to low humidity for long periods had unstable body temperatures, lost weight, and, in general, failed to thrive. Burch demonstrated that output and work of the heart increased in patients in warm humid environments as a result of heat retention and consequent increased demand on circulation to dissipate heat. He stressed the importance of this finding as it relates to patients with impaired cardiac reserves. More recently, O'Brien, Hansen and Smith showed that supersaturated, warm atmospheres significantly reduced the insensible water loss and hemoconcentration normally seen in the early newborn period.

Hazards of Artificial Humidification

Not long after the enthusiastic acceptance of the clinical use of humidified atmospheres, reports concerning its hazards appeared. Hoffman and Finberg noted a rise in *Pseudomonas* infections coincident with the increased use of high-humidity atmospheres in the care of newborns. Silverman pointed out the practical difficulties of preventing gross bacterial contamination of water used to produce high humidity. He postulated that the hazards of high humidity might outweigh intended benefits. Reinarz reported a tenfold increase in gram-negative necrotizing bacillary pneumonias in association with the introduction of inhalation therapy equipment that in-

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Received from The Johns Hopkins Hospital and University, Baltimore, Maryland. Accepted for publication August 12, 1968.
Table 1. Water Balance

<table>
<thead>
<tr>
<th>Description</th>
<th>Formula</th>
<th>Calculation</th>
<th>Result</th>
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</thead>
<tbody>
<tr>
<td>Daily water loss through ventilation in a 10-kg child</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventilatory volume 1.7 m³/24 hours</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Expired air temperature 32°C; expired water content 34 gm/m³</td>
<td>(34 - 34) × 1.7 = 0 gm/24 hours</td>
<td>0 gm/24 hours</td>
<td></td>
</tr>
<tr>
<td>A. Room air: t° 22°C; relative humidity 50 per cent</td>
<td>(34 - 9) × 1.7 = 42.5 gm/24 hours</td>
<td>42.5 gm/24 hours</td>
<td></td>
</tr>
<tr>
<td>(water content 9 gm/m³)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 per cent of daily fluid requirement (700 gm)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>B. Mist atmosphere (high density):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t° 22°C; water content 100 gm/m³</td>
<td>(100 - 34) × 1.7 = 112.2 gm/24 hours</td>
<td>112.2 gm/24 hours</td>
<td></td>
</tr>
<tr>
<td>gain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 per cent of daily fluid requirement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Heated vapor atmosphere:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t° 32°C; water content 34 gm/m³</td>
<td>(34 - 34) × 1.7 = 0 gm/24 hours</td>
<td>0 gm/24 hours</td>
<td></td>
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</tbody>
</table>

corporates large-capacity nebulizer units for humidification. He reasoned that the use of aerosolized water particles small enough to penetrate beyond the terminal bronchioles increased the hazard of depositing water-borne bacteria in the periphery of the lung and resulted in a high incidence of bronchopneumonia.

Harris and Riley⁹ expressed concern that infants treated with high-density mists might develop water intoxication. They quoted work done by Herzog,¹⁰ who had shown that small children exposed to ultrasonic mists may gain as much as 400 gm in 24 hours. Harris and Riley interpreted this to mean that infants might gain an amount of water equal to the total blood volume, and were surprised that complications from mist therapy in infants did not occur more often.

Modell¹¹,¹² became interested in parenchymal pulmonary changes and systemic changes brought about by inhalation of high-density mists. His interest may have been stimulated by the laboratory work of Johnson¹³ and Huber and Finley,¹⁴ which showed that irrigation of the tracheobronchial tree with amniotic fluid or physiologic saline solution caused loss of surfactant, altering pulmonary surface activity and increasing surface tension at the alveolar lining. Modell was unable to show that either short- or long-term exposure to ultrasonic mists caused changes in lung mechanics or in water or electrolyte balance. He did find a high incidence of bronchopneumonia in animals chronically exposed to high-density mists, especially when physiologic saline solution was used. Avery¹⁵ reasoned that since air in the lungs is always humidified by the upper airway, nothing is to be gained by the use of mist in maintaining ciliary activity. She warned that a mist environment might interfere with normal heat exchange and that such an imbalance might affect metabolism. Potential hazards of mist therapy can be divided into those with systemic significance and those that have direct effects on the lungs and airways.

Systemic Hazards

Two systemic problems in the use of high-density water aerosols are: 1) excessive absorption of water, leading to water and electrolyte imbalance; and 2) interference with mechanisms of heat loss from the respiratory tract that normally helps to regulate body temperature. These problems will be discussed as they would affect a child weighing 10 kg.

Water Balance (Table 1)

A 10-kg patient might be expected to have a total 24-hour ventilation of 1.7 m³. His daily maintenance water requirement would be approximately 700 gm. Breathing room air at a temperature of 22°C and a relative humidity of 50 per cent, the total water content of inspired air would be 9 gm/m³. Expired air has been shown by Cole¹⁶ to be at a temperature of 32°C and fully saturated with water vapor and will, therefore, have a water content of 34 gm/m³. Therefore, each m³ of air used in ventilation will remove 25 gm of water from the respiratory tract, and the child will lose 42.5 gm of water from his respiratory tract in 24 hours. This would amount to 6 per cent of his maintenance water requirement.

If the child were now placed in an atmosphere of dense mist generated by an ultrasonic nebulizer, water balance could be altered as shown in part B of table 1. With minimal balking in the humidifier chamber and delivery tubing, the inhaled total water content could be as much as 100 gm/m³. Assuming
that exhaled air continued to hold 34 gm of water per m$^3$ in the vapor phase (no water exhaled in droplet form), total water retention for 24 hours would be 112 gm. Since the child normally loses 42.5 gm from the respiratory tract, he would have a total retention of 155 g or 22 per cent of the daily fluid requirement. In the presence of severe renal disease, oral and parenteral fluids would have to be moderately restricted to nullify hazards of water intoxication and electrolyte derangement.

A different set of circumstances would exist if the child breathed air conditioned by a heated vapor humidifier. A humidifier of this type can deliver air at 32 C fully saturated with water vapor. The total water content offered to the patient would be 34 gm/m$^3$.

**Table 2. Heat Balance**

Daily heat loss through ventilation in a 10-kg Child Ventilatory volume 1.7 m$^3$/24 hours
Expired air temperature 32C; expired water content 34 gm/m$^3$

A. **Room air**: t$^*$ 22C; relative humidity 50 per cent (water content 9 gm/m$^3$)
   By warming inspired air:
   10C $\times$ 1.0$^*$ $\times$ 0.21** = 4.6 kcal
   By water vaporization:
   25 gm/m$^3$ $\times$ 1.7 m$^3$ $\times$ 0.58*** = 42.5 kcal
   Total heat lost in 24 hours = 47.1 kcal
   7.8 per cent of basal heat production (600 kcal)

B. **Mist atmosphere** (high density):
   t$^*$ 22C; water content 100 gm/m$^3$ (20 gm/m$^3$
   vapor; 80 gm/m$^3$ liquid)
   By warming:
   Inspired air 10$^*$ $\times$ 1.9 $\times$ 0.24** = 4.6 kcal
   Retained inspired water 15$^*$ $\times$ 1.7 $\times$ 66 gm = 1.7 kcal
   By vaporization: 14 gm $\times$ 1.7 $\times$ 0.58*** = 13.8 kcal
   Total heat loss in 24 hours = 20.1 kcal
   3.4 per cent of basal heat production

C. **Heated vapor atmosphere**:
   t$^*$ 32C; water content 34 gm/m$^3$
   By warming — none
   By vaporization — none
   Total heat lost from lungs in 24 hours — None

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* Weight of 1.7 m$^3$ of air in kg.
** Specific heat of air — kcal/kg.
*** Heat of vaporization of water — kcal/gm.

Since this is the same temperature and the same water content of exhaled air, he would retain 42 gm of water (6 per cent of his daily water requirement) due to the elimination of the respiratory tract as an outlet for water loss. This normally would be balanced easily by adequately functioning kidneys. Such a humidifier offers no liquid water to the tracheobronchial tree, but it does assure minimal loss of water from the physiologic mucous blanket.

**Heat Balance (Table 2)**

Under basal conditions, a 10-kg infant would generate approximately 600 kcal in 24 hours. Breathing room air at 22 C with 50 per cent relative humidity, he would lose 4.8 kcal in the process of warming inspired air. This is calculated by multiplying the temperature difference between inspired and expired air (taken as 32 C), the weight of 1.7 m$^3$ of air (24-hour ventilation for a 10-kg infant), and the specific heat of air. In addition he loses calories by humidifying inspired air. The inspired air is assumed to contain only 9 gm of water/m$^3$ (50 per cent relative humidity). Since exhaled air contains 34 gm/m$^3$, he loses 25 gm of water for every m$^2$ of air ventilated. Multiplying this factor by ventilatory volume and by the heat of vaporization of water gives the total amount of heat lost in overcoming the humidity deficit of environmental air, 42.5 kcal. Thus, this hypothetical child loses between 7 and 8 per cent of the total heat production through his lungs.

If he were now placed in an environment of dense water mist (part B of table 2) he would continue to lose 4.6 kcal in warming inspired air. In addition, he would lose 1.7 kcal in warming liquid water (66 gm) to body temperature. Also he would lose 13.8 kcal by vaporization, since of the 50 gm of liquid water/m$^3$ inspired, he needs 14 gm/m$^3$ to humidify the inspired air (air fully saturated at 22 C holds 20 gm of water/m$^3$, versus exhaled air which holds 34 gm/m$^3$ at 32 C). The total heat lost from the lungs breathing a mist atmosphere would be 20.1 kcal or 3.4 per cent of the total daily heat production. Over 90 per cent of total heat lost is lost by way of convection, radiation and conduction through the skin. If body environmental temperature
Table 3. Heat Retention in Hot, Humid Atmosphere

<table>
<thead>
<tr>
<th>Heat retention breathing hot (40°C), humid (60/gm/m³) atmosphere (10-kg infant with daily ventilation of 1.7 m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. By cooling inspired air:</strong></td>
</tr>
<tr>
<td>(40°C - 37°C) × 1.9 × 0.24** = 1.4 kcal</td>
</tr>
<tr>
<td><strong>B. By heat of condensation:</strong></td>
</tr>
<tr>
<td>(60/gm - 44/gm) × 1.7 × 0.58*** = 15.8 kcal</td>
</tr>
<tr>
<td>Total heat retained                                      = 17.2 kcal</td>
</tr>
<tr>
<td>Heat normally lost by                                 = 43.0 kcal</td>
</tr>
<tr>
<td>ventilation                                           = 60.2 kcal</td>
</tr>
<tr>
<td>Total heat gain in 24 hours                            = 60.2 kcal</td>
</tr>
</tbody>
</table>

*Weight of 1.7 m³ air.  
*Specific heat of air = kcal/kg.  
***Heat of condensation of water = kcal/gm.

is maintained in the normal comfortable range, the inhalation of such an atmosphere is unlikely to cause a serious derangement in heat exchange.

Since exhaled air is normally at 32°C and fully saturated with water vapor, it is possible to eliminate the role played by the lungs as a heat exchanger by heating inspired air to 32°C and saturating it with water vapor (part C of table 2). There will be no loss of heat by either warming of inspired air or vaporization of water from the respiratory mucosa. Rashad 17 has shown that during surgical anesthesia body temperatures of infants can be controlled effectively with a heated-vapor humidifier which delivers gases heated to 32°C and saturated with water vapor.

A hazardous situation could be created by fully humidifying inspired air above body temperature (table 3). A 10-kg infant exposed to a fully-humidified atmosphere at 40°C would inhale a concentration of water, in vapor form, of 60 gm/m³. The temperature of exhaled air would be no lower than body temperature. Maximum heat absorption by cooling inspired air would be no greater than 1.4 kcal (a product of the difference between inspired and expired air temperature, the weight of air exchanged, and the specific heat of air). Exhaled air at 37°C would hold 44 gm of water in vapor form. Thus, 16 gm of water vapor would condense for every m³ of air exchanged. Multiplying the weight of water condensed, the daily ventilatory volume, and the heat of condensation of water gives the amount of heat retained by water condensation. Thus, this 10-kg infant would gain 17.2 kcal of heat through his respiratory tract in 24 hours. Since this patient normally loses 43 kcal by this avenue, he would experience a total 24-hour heat gain of 60.2 kcal, more than 10 per cent of the total maintenance heat production. This heat must be lost elsewhere if body temperature is to be kept in a normal range. The burden would fall on the cardiovascular system to increase circulation to the skin to provide for additional heat loss. Such a burden might be seriously hazardous to a child with poor cardiac reserve. If, unwittingly, the child were placed in a hot environment, all avenues of heat loss would be blocked, resulting in almost certain hyperpyrexia.

Pulmonary Changes

Hazard of Bacterial Contamination and Infection

The work of Moffet and his group 18 probably represents the most extensive study of the hazards of bacterial growth and infectivity associated with nebulization therapy. Using freshly distilled but unsterile water to fill their nebulizers, they found a high incidence of contamination of the units after clinical use. They were able to culture the same bacteria from the external noses of approximately 10 per cent of patients exposed to these units. However, of the 96 patients studied, none developed clinical disease that could be related to the water used or to the nebulizer units. Bacteria recovered from the nebulization units included Flavobacterium, nonpigmented Pseudomonas species, and organisms of the Pseudomonas-Alcaligenes group. The pathogenic enteric bacteria (E. coli and Proteus) were rarely found in the reservoir water or the mist fallout. In a controlled study, Shakoor 19 did not find any significant difference in the relative infectivity of a heated vapor humidifier known to provide sterile water vapor and ultrasonic nebu-
lizers. Using gas-sterilized nebulization equipment and filling the units with only sterile water or physiologic saline solution, he was able to obtain positive bacterial cultures from more than 40 per cent of the nebulizers after 72 hours of use. The organisms recovered were essentially those described by Moffet.18

PATHOLOGIC CHANGES

Huber and Finley 14 showed that irritation of the lungs with large volumes of physiologic saline solution resulted in marked alterations of the normal alveolar architecture. With electron microscopy, they found fragmentation of epithelial cells, interstitial edema, and alterations in the basement membrane. Shakoor 19 submitted tracheotomized animals to prolonged exposure to either ultrasonic mist or air fully humidified with water vapor. He found no difference between the pathological changes in the parenchymas and airway tissues of the two groups.

CHANGES IN SURFACE ACTIVITY

Animals chronically exposed to ultrasonically-generated mists of physiologic saline solution or distilled water were found by Shakoor 19 to have normal amounts of pulmonary surfactant. Similarly, Modell 20 was unable to demonstrate changes in pulmonary alveolar surface activity after acute or chronic exposure of experimental animals to high-density mists. These results are in contrast to those of Johnson 12 and Huber and Finley, 14 who showed that irrigating the lungs with physiologic saline solution removed pulmonary surfactant, resulting in excessive surface tension of the alveolar lining. It is likely that the discrepancy reflects differences in the amounts of saline solution that reach the periphery of the lung when the lungs are ventilated with a saline aerosol and when they actually are irrigated with saline solution. Ultrasonic generators can disperse in mist form nearly eight liters of water or saline solution in 24 hours. However, the information needed for clinical use of high-density mists must include the total water content of the aerosol that is actually inhaled and the site of deposition of the moist particles in the tracheobronchial tree.

Water Content and Distribution of Inhaled Mists

WATER CONTENT OF INHALED MISTS

Air distal to the carina normally holds 44 gm of water/m² of air, all in the vapor phase. Thus, inspiration of air in which the total water content is less than 44 gm/m² normally would necessitate vaporization of water from the mucosal surface at the proximal airway to make up the deficit. However, with inspiration of a mist, because of the size of the suspended particles and the enormous surface area provided at the air-water interface the humidity deficit will preferentially be made up by vaporization of particulate water. Thus, a water aerosol that has a total water content of less than 44 gm/m² will have water transformed from a particulate liquid form to a molecular vapor form in the course of being warmed to body temperature. The inhalation of such an aerosol, therefore, will provide no water droplets beyond the most proximal part of the upper airway. Sara 10 has shown that unheated venturi nebulizers deliver aerosols with total water contents of less than 30 gm/m². The Croupette* provides an atmosphere that contains only 15 to 20 gm of water/m². Obviously, the mists manufactured by these units will be completely vaporized by the time the inhaled air reaches the upper trachea. Using submersion heaters and taking the temperature of the reservoir water to 34 C will bring the total water content of the delivered aerosols to 38 to 40 gm/m². It should be realized that at room temperature the aerosols that emanate from the delivery tubes of these heated units appear as thick mists, yet, even if we assume no baffling to occur in the nose, none of the water will exist in a liquid form beyond the carina. An ultrasonic nebulizer capable of delivering a mist with a water content of more than 100 gm/m³ from the delivery tubing will provide an aerosol of only 35 to 40 gm of water/m² when the mist is introduced into an enclosure the size of an oxygen tent. This concentration, determined by Shakoor, 18 was probably the concentration used by Modell 12 in his mist chambers.

* Croupette humidity and oxygen tent. Air-Shields, Inc.
DISTRIBUTION OF INHALED MIST PARTICLES

It is generally accepted that more than 50 per cent of particles 1.0 to 2.0 microns in diameter, inhaled through the nose or mouth, can penetrate beyond the terminal bronchioles.21 Although early reports claimed that mist particles generated by ultrasonic nebulizers were largely in the range of 0.8 to 1 micron in diameter,22,23 Wolfsdorf and Swift24 measured the median diameter of aerosol particles from the DeVilbiss 900 ultrasonic humidifier and found them to average 5.5 microns. These investigators tagged the ultrasonically-suspended particles with radioactive technetium and followed the distribution of the radioactivity through the respiratory tract with scintillation counters. More than 80 per cent of the radioactivity remained in the anterior nares. Furthermore, having the subject breathe normally through the mouth failed to alter the distribution of the activity between the upper and lower respiratory tract. To further confuse the picture of distribution of inhaled water, West and Dollery25 labeled water molecules with $^{18}$O, and had volunteers inhale the tagged water in vapor form. They were unable to demonstrate any activity beyond the mid-trachea. Most of the activity was in the mouth and nose.

Although a great deal has been written about the deposition sites of inhaled particulate matter, it is important to realize that most of the work has been done by studying distribution of inhaled dust particles.26,27,28 In contrast, water particles are subject to infinite vicissitudes in their travel through the tracheobronchial tree, and there is little information to suggest were such particles of any given size will deposit. Application of data derived from studies of inhaled dust aerosols could lead to erroneous assumptions about the clinical effects of nebulized water or saline solution.

Benefits of Humidification and Mist Therapy

In contrast to the enormous effort that has been exerted in perfecting techniques of aerosolization and in the study of aerosol deposition, little objective evidence has appeared in the medical literature to show clinical efficacy in the use of mist therapy. Bang and Bang29 demonstrated the untoward effects of dehydration on ciliary function and on movement of mucus in the upper airway. Viscosity of sputum was decreased by two-thirds in a study by Blanshard30 when the oral intake of fluid was tripled. There is no reason to doubt that water content and viscosity of the mucus overlying the respiratory mucosa will be affected adversely by general body dehydration and by exposure of the airway to dry gases. What is not known, and about which there is considerable dispute, is what benefits may be expected from exposing patients with respiratory problems to inhaled atmospheres of mist. Miller31 visualized the basic problems in patients with chronic inflammatory airway disorders as the accumulation of large quantities of secretions and exudate, which impair ventilation and lead to recurrent infection. His aim in aerosol therapy is to provide a fluid vehicle to liquefy these secretions so that they may be mobilized for evacuation by ciliary activity or by coughing. He points out that to deposit large quantities of liquid in the tracheobronchial tree aerosols must be heated to above body temperature, allowing for condensation and rainout along the airway mucosa as the inhaled air is cooled.

A study by Kelsch32 of the use of mist therapy in lower respiratory tract infections failed to show any significant difference in the durations of physical signs or hospital courses in patients treated with mist therapy and those who were not. The authors used the Air-Shields Croupette to provide the mist. As pointed out above, Sara33 has shown that the maximum total water content supplied by this unit is 20 gm of water/m2 of air. Thus, it would have been impossible for the mist particles offered to Kelsch’s patients to have passed much beyond the nasopharynx in liquid form. Patients with cystic fibrosis benefited from mist therapy in a long-term study by Matthews.34 The addition of mist therapy to an otherwise comprehensive treatment program resulted in significant decreases in functional residual capacity and residual volume and increases in maximum breathing capacity.
Conclusions and Recommendations

In the use of humidification or nebulization equipment, a favorable environment for the growth of certain bacteria is created. Whether these bacteria are presumed to be pathogens or nonpathogens (a feature largely dependent on individual host factors), their presence must be considered undesirable and hazardous to the patient. Growth of bacteria and colonization in the patient will be controlled by the application of principles long accepted in the field of surgery and taught in classrooms of microbiology. Bacteria grow only when provided with nutrient, hence all equipment must be meticulously cleansed with soap and water, thoroughly rinsed, and dried. All humidification or nebulization equipment that comes into contact with water and forms a common pathway with the patient must be sterilized prior to use. This includes reservoir bottles, nebulization cups, delivery tubing and adapters. Each item should be changed daily with sterile replacements. Ethylene oxide sterilization is recommended, although its use dictates that the equipment be aerated for at least 24 hours following sterilization. This necessitates much larger capital expenditures for equipment to maintain adequate inventories. Only sterile distilled water or physiologic saline solution is to be used to fill the units, and aseptic techniques must be followed assiduously in changing tracheostomy tubes and in carrying out tracheal suctioning. It has been shown that copper-wire mesh used in conjunction with a heated vapor humidifier will effect a sterile output of fully humidified gases. As a final check on bacterial control, periodic cultures of bacteria on all nebulization and humidification equipment should be made by a competent bacteriology staff. In the event a patient develops pulmonary infection while receiving nebulization therapy, the staff should investigate thoroughly any etiologic role the equipment may have played.

There is no evidence that lung tissue is damaged by exposure to high-density mist atmospheres of water or physiologic saline solution. Even when ultrasonically-suspended mist was inhaled directly into the trachea for prolonged periods, Shakoor was unable to demonstrate changes in surfactant activity, pulmonary mechanics, or the histologic appearance of the exposed lung tissue. However, the clinical use of such high-density mist introduced through a tracheostomy or endotracheal catheter results in the accumulation of large amounts of both water and secretions that require frequent tracheal aspiration. This, of course, provides repeated opportunities for introduction of infection into the tracheobronchial tree.

With an intact proximal airway and an environmental temperature that does not exceed normal room temperature, hazards of water intoxication or heat imbalance from mist therapy are virtually nonexistent. Even if the highly developed baffling systems of the nasal and oral passages are ignored, the amount of water retention from the most efficient mist generator would make up only a fraction of that needed for total body fluid maintenance. More than 90 per cent of man's total heat loss normally occurs through the skin by convection, conduction and radiation. Provided these mechanisms are not rendered ineffective by high environmental temperature, only a small additional circulatory effort would be needed to compensate for the disrupted avenue of heat loss from the respiratory tract.

It must be stressed, however, that if a patient is placed in a high environmental temperature, the respiratory tract would have to play a greater role in dissipation of body heat. Should this avenue of heat loss also be blocked by breathing a humid or mist atmosphere, all mechanisms for balancing heat production would be frustrated. A heavy demand would be placed on the cardiovascular system to circulate heat, but with no means of disposal the result would be heat retention and hyperpyrexia.

As stated above, there is little objective evidence to verify the efficacy of mist therapy. Nevertheless, a vast amount of clinical literature and basic principles of water behavior help to define rational uses and expected benefits of humidification and water mist in respiratory therapy. Three reasonable uses of humidity or mist are: 1) to humidify inspired air or therapeutic gases that bypass the normal humidifying mechanisms of the nose and
throat; 2) to deposit liquid water in the airways and thereby aid in mobilization and evacuation of retained secretions; 3) to provide greater patient comfort by the prevention of mucosal drying of inflamed or congested proximal airways.

There is no question of the necessity of humidifying air inspired by patients with fresh tracheostomies or in whom endotracheal catheters are left in place. Techniques of humidification should offer to the trachea a water content equivalent to at least 70 per cent of that normally supplied by the proximal air passages. Thus, the minimum acceptable water content to be delivered into the trachea in either vapor or liquid (mist) form, should be 30 gm./m². Heated vapor humidifiers and heated jet nebulizers supply this concentration of water. Aside from ultrasonic nebulizers, cold steam or unheated nebulizers cannot meet this demand. The common bubble humidifier is dangerously inadequate and is best removed from the hospital inventory.

Water can be deposited in a dispersed particulate form distal to the carina by either inhalation of high-density mist or inhalation of air heated above body temperature and saturated with water vapor. For inhaled mist to pass beyond the carina, there must be minimal baffling in the proximal airways. This is not possible with nasal breathing, and only possible with oral breathing by using a large-bore mouthpiece and by a conscious effort on the part of the patient to maximally retracted his oral and pharyngeal soft tissues. For significant liquid deposition to occur beyond the trachea (where inhaled air reaches body temperature), the water content of the mist must exceed 44 gm/m³. Only ultrasonic nebulizers and highly efficient heated jet nebulizers are capable of suspending a liquid aerosol of such magnitude. For maximal deposition in the distal bronchi, the mist would have to be directed into either an endotracheal catheter or a tracheotomy cannula. Occasionally, in patients with severe obstructive airway disease who are markedly affected by the retention of thick, mucoid secretions, it is feasible and highly effective to use a combination of endotracheal intubation, mechanical ventilation and high-density mist. We have repeatedly seen dramatic responses to such aggressive management, manifested by considerable improvement in ventilatory flow rates and, subjectively, by alleviation of respiratory distress.

The deposition of water as a precipitate (dew) can be accomplished by inhalation of preheated (above body temperature), fully saturated air. Precipitation occurs as the inhaled air is cooled to body temperature. This technique is generally feasible only when a tracheostomy or endotracheal catheter is in place; patients object to the oppressive feeling of inhaling hot humid air through their noses or mouths.

Patients with upper respiratory tract infections are more comfortable if allowed to breathe well-humidified air. There is no good evidence that the ultimate outcomes or duration of such diseases are favorably altered by mist therapy. However, it seems reasonable to assume that decreasing vaporization of water from the mucosal surface results in more favorable mucus viscosity that facilitates the evacuation of bacterial debris and inflammatory exudate. The deposition of exogenous water on the nasal mucosa will result in a ready supply of water to fulfill the physiologic demands for vaporization. Sufficient humidification for this purpose will be provided by unheated jet or spinning-disk nebulizers in combination with a croup tent or face tent. These techniques are well tolerated by patients even for long periods.

References

CHANGES WITH INHALED HUMID ATMOSPHERES


