(average 5 months). In 14 of them the blood-pressure was maintained within reasonable limits.

Treatment failed to lower the blood-pressure to any significant extent in two in-patients. Three out-patients became rapidly refractory to the hypotensive effect of methylodopa.

Methylodopa was shown to be highly effective in the most severe cases of hypertension, but in some cases for only a short time.

The average effective dose in moderate and severe hypertension was 1.5 g. of methylodopa. Thiazide diuretics potentiated the hypotensive action.

The results obtained with guanethidine and methylodopa in the treatment of seven hypertensive patients are compared. It appeared that both drugs might be considered in the treatment of severe hypertension and that methylodopa was usually better tolerated.

Our results as regards the urinary excretion of catecholamines and metanephrine did not show any parallelism between the inhibition of the biosynthesis of noradrenaline and the blood-pressure reduction.

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"Recently C. P. Snow, the novelist, once a scientist, has described the phenomenon of two cultures. It is most often encountered, he writes, in our universities. Those devoted to science and those in the humanities no longer communicate with each other. Their cultures separate them and they speak different languages. They are unhappy and irritated when not left to themselves. But what Sir Charles Snow is describing is only one example of a much more general phenomenon prevalent to-day in society. Within science itself, separate groups have formed. Each uses a technical lingo incomprehensible to other groups. Even doctors of medicine use strange genteelisms and expertise in laboratory and hospital. When they talk to patients, or write reports, they continue to use it, as though hoping to impress someone. Or else they forget the fact that simpler diction would be better suited to humane purposes and to scholarly performance. The rancher, the business man, the technologist, the musician and even the beatnik and the crook have a language of their own. As the years pass, they find general communication increasingly difficult." (Professor Wilder Penfield, O.M., F.R.S., "Scholar's Use of Idleness," *Med. J. Aust.*, December 22, 1962.)

ASSESSMENT OF CONDENSER-HUMIDIFIERS WITH SPECIAL REFERENCE TO A MULTIPLE-GAUZE MODEL

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If a patient's upper respiratory tract is bypassed by means of an endotracheal tube or a tracheostomy the humidifying properties of this part of the tract are lost. If it is thought necessary to replace this loss by external means there are three main possibilities. Water droplets may be added to the inspired gas by means of a nebulizer; water vapour may be added by passing the inspired gas over heated water; or a "condenser-humidifier" may be used.

In general a condenser-humidifier is a device through which the patient's respirations pass and which contains some element of large surface area such as a multiple-bore tube (Toremalm, 1960) or wire gauze as in Walley's (1956) device, or in the instruments manufactured by Drägerwerk and by Messrs. Garthur (London) Ltd. During expiration warm moist gas from the patient passes through the relatively cool element; therefore the gas is cooled and the element is warmed, and water condenses out of the gas on to the element. During inspiration gas enters the device and in passing through the relatively warm wet element becomes warmed and humidified.

In principle, at least, by using a nebulizer or by passing inspired gas over heated water any desired humidity can be produced, because external supplies of water and heat or power are available. In a condenser-humidifier, however, no such external supplies are present and its performance must therefore be subject to some limits. The object of this investigation was to determine these limits for condenser-humidifiers in general and for the multiple-gauze condenser-humidifier manufactured by Messrs. Garthur (London) Ltd. in particular.

Fig. 1.—Condenser-humidifier manufactured by Messrs. Garthur (London) Ltd.

This multiple-gauze humidifier (Fig. 1) is similar in general design to the Dräger condenser-humidifier. The humidifying element consists of ten flat circular nickel-wire gauzes, 5 cm. in diameter, clamped together as a unit. This unit is housed in an aluminium-alloy container from which it can be removed for cleaning or replacement.

The dead space of the whole device is 17 ml. Its resistance is 0.1 cm. $H_2O/(l./sec.)$ at 0.5 l./sec.; this is small compared with the airway resistance (about 1 cm. $H_2O/(l./sec.)$) with which it will be in series in use.

Theory

First it is necessary to distinguish four different conditions of gas (see Fig. 2). (1) Expired gas: gas breathed out by the patient *before* it enters the condenser-humidifier. (2) Waste gas: gas breathed out by the patient *after* it has left the humidifier. (3) Fresh gas: gas from the room or from a cylinder of compressed gas before it enters the humidifier to be breathed in by the patient. (4) Inspired gas: gas breathed in by the patient from the humidifier.

FIG. 2.—Diagram of the gauzes and gas flows in a multiple-gauze condenser-humidifier. The symbols refer to the temperatures of the different elements.

A general theory, applicable to all types of condenser-humidifier, can now be developed as follows.

During expiration warm moist expired gas at temperature T_e and containing a fractional water-vapour concentration F_e enters the humidifier. In passing through the humidifier the gas gives up heat and moisture to the element of large surface area and leaves the humidifier to go to waste at some lower temperature T_w and containing the saturated water-vapour concentration at that temperature F_{ws} . During inspiration cooler and drier fresh gas enters the humidifier at temperature T_f and with water-vapour concentration F_f . In passing through the element it picks up heat and water vapour and then leaves the humidifier to be inspired by the patient at some temperature T_i and with some water-vapour concentration F_i .

If the inspired and expired tidal volumes are taken to be equal, and the changes of gas volume with temperature and humidity are neglected for the moment, the quantity of water vapour condensed during the expiration of one tidal volume V_T is $V_T(F_e - F_{ws})$; and the quantity evaporated during one inspiration is $V_T(F_i - F_f)$. Assume that the quantity evaporated is equal to the quantity condensed. (It cannot, in the long run, be greater although it may in some circumstances be less.) Then

$$F_i = F_e - F_{ws} + F_f \quad (1)$$

If account is taken of the changes of gas volume with temperature and humidity this becomes modified to

$$\frac{F_i}{1 - F_i} = \frac{F_e}{1 - F_e} - \frac{F_{ws}}{1 - F_{ws}} + \frac{F_f}{1 - F_f} \quad (2)$$

but for many purposes equation (1) is accurate enough and may be used to make the following important deductions.

1. The lowest temperature associated with the humidifier will be that of the fresh gas. Therefore the waste gas (that is, expired gas after it has passed through the humidifier) cannot be cooled below this temperature and the water-vapour concentration in it F_{ws} cannot be less than the saturated concentration F_{fs} at the fresh-gas temperature. The water-vapour concentration in the fresh gas F_f cannot be more than the saturated concentration F_{fs} . Therefore the maximum value of F_i is $F_e - F_{fs} + F_{fs} = F_e$. That is, the highest possible inspired concentration of water vapour is equal to the expired concentration, and this will be achieved only if the fresh gas is saturated with water vapour, and if the expired gas is cooled to the fresh-gas temperature before going to waste, and if all the water vapour condensed on the gauzes in expiration is evaporated in inspiration.

2. If the fresh gas is completely dry, as from a cylinder of compressed gas, the inspired concentration of water vapour must be less than the expired concentration to the extent of the concentration in the waste gas. This last must be at least as great as the saturated concentration at the temperature of the fresh gas and may be greater.

3. The inspired concentration may be further reduced by the amount of water evaporated being less than the amount condensed.

Just how far the inspired concentration falls short of the expired concentration depends on the particular values of temperature and water-vapour concentration of the expired and fresh gas and on the design of the humidifier.

For any condenser-humidifier in which the patient breathes through a number of flat gauzes in series the actual values of inspired concentration may be estimated as follows.

Since the waste gas is saturated with water vapour its concentration F_{ws} may be determined from tables if its temperature T_w is known. Therefore, for any given values of the water-vapour concentration in expired and fresh gas, F_e and F_f , if the temperature of the waste gas can be determined the inspired concentration F_i may be calculated. The waste-gas temperature may be determined if the following assumptions are made.

1. That the gauzes exchange heat only with the gas (and contained water vapour) passing through them and that they do not gain heat by conduction from the patient nor lose heat by conduction to the atmosphere. (These effects are probably small in the present device.)

2. That gas leaves a gauze at the same temperature as the gauze. (The gauzes in the present device are of a fine enough mesh for this to be very nearly true.)

3. That the amount of water evaporated from any gauze during inspiration is equal to the amount condensed during expiration. (The limited range of conditions in which the amount evaporated is less than the amount condensed is considered later.)

4. The thermal capacity of the gauzes is large compared with that of a tidal volume of air, so that there is only a negligible fluctuation in temperature of any gauze throughout the respiratory cycle. (In fact, there is an appreciable temperature fluctuation in the gauzes in the present device.)

5. That the gauzes are thermally isolated from one another so that they do not exchange heat with one another except via the gas passing through them. (The only other simple assumption is that the gauzes are in such good thermal contact that they are all at the same temperature; such an assumption predicts a performance much inferior to that found experimentally with the present device.)

The humidifier may be represented diagrammatically as in Fig. 2. Consider the heat exchange between each of the gauzes and the gas. From assumption 3 the heat gained by any gauze as a result of condensation of water vapour during expiration will be exactly balanced by the heat lost in evaporating the same amount of water in the following inspiration. Therefore attention may be confined to the cooling and heating of the gases.

Consider the first gauze whose temperature is T_1 . During expiration gas arrives at this gauze at temperature T_e and leaves (assumption 2) at T_1 , and therefore delivers to the gauze an amount of heat $c(T_e - T_1)$, where c is the heat capacity of a tidal volume of gas. During inspiration gas arrives (from the second gauze) at T_2 and leaves at T_1 and therefore removes from the gauze an amount of heat $c(T_1 - T_2)$. Since the gauzes do not exchange heat with any other source (assumption 1) the heat gained from the cooling of the expired gas $c(T_e - T_1)$ must equal the heat lost in the warming of the fresh gas $c(T_1 - T_2)$. Therefore:

$$T_e - T_1 = T_1 - T_2$$

In the same way it may be shown that

$$T_1 - T_2 = T_2 - T_3 = T_3 - T_4 = \dots = T_n - T_f$$

where T_n is the temperature of the final or n th gauze. Therefore, for a humidifier containing n gauzes the temperature difference between the expired and fresh gases is divided into $n+1$ equal steps, and the temperatures of the inspired and waste gases, which equal those of the first and last gauzes, may be determined. With an infinite number of gauzes the waste-gas temperature would equal that of the fresh gas and the inspired-gas temperature would equal that of the expired gas. Even in the present device with 10 gauzes the temperature of the waste gas exceeds that of the fresh gas by only 1/11 of the difference between the expired- and fresh-gas temperatures:

$$T_w = T_f + (T_e - T_f)/11$$

Similarly, the temperature of the inspired gas is less than that of the expired gas by the same amount:

$$T_i = T_e - (T_e - T_f)/11$$

Since the difference between expired- and fresh-gas temperatures is normally of the order of 16 degC. the waste-gas temperature will be only about 1.5 degC. above that of the fresh gas. Remembering that the waste gas is always saturated with water vapour it will be seen that the concentration of water vapour carried to waste is little more than if the waste gas were cooled to the lowest possible temperature for a condenser-humidifier—that of the fresh gas. Detailed results are given in the results section.

Experiment

The performance of the present device was tested in the laboratory with the aid of a model lung (Fig. 3) and a ventilator.

During "inspiration" the one-way valves (1) allowed the inflating gas to go direct to the tank representing the lung compliance (2); during "expiration" the gas leaving the tank was forced to pass through the perforated tube (3) and to bubble through water at 37° C. This was done in an attempt to reproduce the humidity of expired gas. The tank and connecting tubing were heated and lagged to maintain a gas temperature of 37° C. and thus prevent condensation within the model. The perforated tube was mounted in a measuring cylinder, so that by stopping the ventilation

and turning the measuring cylinder to the upright position at intervals the rate of loss of water by evaporation could be determined. (A wire gauze (4) was included in the outlet tube from the measuring

FIG. 3.—The experimental arrangement. 1, One-way valves. 2, Tank representing compliance of lungs. 3, Perforated pipe with outlets under water in measuring cylinder. 4, Wire gauze to trap water droplets.

cylinder to trap any water droplets that were formed and return them to the cylinder.)

The model was then ventilated with a tidal volume of 500 ml. at a rate of 13/min. (total ventilation 6.5 l./min.) for periods of one to three and a half hours. (The tidal volume was monitored by a volumeter in the expiratory limb of the ventilator, but this read high and the true tidal volume was determined in a separate experiment by adjusting a calibrated piston pump to produce the same pressure swing in the model lung as occurred when the ventilator was used.)

Some experiments were conducted with the condenser-humidifier omitted from the circuit to establish the rate of water loss when the model "expired" directly to the atmosphere. Further experiments with the condenser-humidifier in circuit showed a smaller rate of water loss due to some of the expired water vapour being returned to the model in inspiration. To a first approximation the saving in water loss resulting from the introduction of the condenser-humidifier, divided by the water loss when the condenser-humidifier was omitted, gives the inspired concentration of water vapour as a fraction of the expired; but in fact a number of corrections were necessary as indicated below.

Results

In eight experiments in which the condenser-humidifier was omitted from the circuit the overall mean rate of water loss was 14.1 ml./hr. The ventilation of 6.5 l./min. was measured at a mean room temperature of 21.7° C. with the gas saturated with water vapour. Allowing for the higher temperature (37° C.) and water vapour content of the gas leaving the measuring cylinder, and assuming that water vapour behaves as a perfect gas and knowing that the fresh gas was dry (from a compressed-gas cylinder), it may be calculated that gas left the measuring cylinder 76% saturated with water vapour at 37° C.

In four experiments in which the condenser-humidifier was included in the circuit the overall mean rate of water loss was 6.7 ml./hr. This time the ventilation of 6.5 l./min. was measured, saturated at a mean room temperature of 19.6° C. Assume that, for a given ventilation, the measuring cylinder always raises the

humidity of the gas passing through it by 76% of the way from its incoming humidity (the humidity of inspired gas) to saturation at 37° C. Then, allowing for changes of temperature and humidity in different parts of the apparatus, and knowing that no condensation occurs within the "lung," it may be calculated that the humidity of the expired gas was 89% saturated at 37° C. and that of the inspired gas was equivalent to 55% saturated at 37° C. Therefore the inspired humidity was $55/89=62\%$ of the expired humidity.

Under the experimental conditions solution of equation (2) predicts that the inspired humidity would be 62% of the expired for an infinite number of gauzes or 58% for a 10-gauze humidifier of large heat capacity. Thus the present instrument appears to have performed better than theory would predict for a 10-gauze humidifier of large heat capacity. This can be attributed, at least in part, to experimental error; but since the discrepancy is in this direction it seems unlikely that the true performance of the present instrument after allowing for the limited heat capacity of the gauzes would be much below the theoretical one for the 10-gauze humidifier of large heat capacity.

Accordingly, equation (2) has been solved for a variety of conditions, both for this type of humidifier and for one with an infinite number of gauzes. The results are plotted in Fig. 4. The amount or concentration of water vapour in inspired gas is expressed as a percentage of the amount or concentration in expired gas. That is, the ordinate shows the percentage of the water contained in expired gas which is returned to the patient in inspiration. The remaining percentage of the water contained in expired gas is permanently lost from the respiratory tract (in the waste gas). The abscissa shows the temperature difference between expired gas and the fresh gas which enters the condenser-humidifier from the room or from a cylinder of compressed gas. The graph is valid when the expired gas is saturated

with water vapour at any temperature between 33 and 37° C. Combining the graph with Cole's (1953a, 1953b) results it seems that it should cover all conditions likely to be met in clinical practice.

The continuous lines are for a humidifier containing an infinite number of gauzes and the broken lines for one containing 10 gauzes of large heat capacity. The performance of the present device should be close to that indicated by the broken lines. (The cross-hatched area is explained below.) Curves are drawn for three different relative humidities of the fresh gas.

It will be seen that for an infinite-gauze humidifier when the relative humidity of the fresh gas is 100% (that is, saturated with water vapour) the inspired gas always contains as much water as the expired and there is no net loss of water from the respiratory tract.

On the other hand, if the fresh gas is completely dry (0% relative humidity), as it will be if it all comes from a compressed-gas cylinder, the inspired gas contains much less water vapour. Here, as in nearly all circumstances, the performance of the 10-gauze humidifier is almost as good as that of one containing an infinite number of gauzes; for both it may be said that if the fresh gas is very warm, say 28° C. (82° F.), and the expired gas is at say 36° C. (temperature difference 8 degC.) the water content of inspired gas is only about 40% of that of expired gas and the remaining 60% is permanently lost from the respiratory tract. But if the fresh gas is cooler there is a bigger difference between the expired- and fresh-gas temperatures, and the water content of inspired gas is higher. Indeed, if the fresh gas were cooled to 0° C. the inspired water content would approach 90% of the expired, and yet, with the 10-gauze humidifier, the inspired-gas temperature would still be only about 3 degC. (one-eleventh of 36 degC.) below that of the expired gas.

If the fresh gas has a relative humidity of 50% (room air is not often drier than this) then for both types of humidifier the inspired gas contains at least 70% as much water as the expired for all normal circumstances. Again, the cooler the fresh gas the higher the water content of the inspired gas.

When the fresh gas is saturated with water vapour (100% relative humidity) an infinite-gauze humidifier prevents all loss of water from the respiratory tract. The exact performance of a 10-gauze humidifier in these circumstances is uncertain because the assumption that all the water that condenses on the gauzes during expiration is evaporated during inspiration is no longer valid. However, it can be shown from the present theory that the performance must lie somewhere in the cross-hatched area. The doubly cross-hatched area indicates a similar region of uncertainty when the fresh gas is at 50% relative humidity and more than 26 degC. below the expired temperature.

The results may be summarized in terms of the fate of each 10 ml. of water expired by the patient. (In normal quiet respiration this volume of water is expired in about half an hour.) If the fresh gas is at normal room temperature (25 to 17° C.) and completely dry (for example, all coming from a cylinder), then between 4 and 7 ml. is returned to the patient in the inspired gas and therefore between 6 and 3 ml. is permanently lost. If the fresh gas is mostly room air (of about 50% relative humidity) then 7 to 8.5 ml. is re-inhaled and only 3 to 1.5 ml. permanently lost. If the fresh gas is saturated with water vapour or if it is cooled to near freezing-

FIG. 4.—Theoretical values for the humidity of gas inspired from a condenser-humidifier when the expired gas is saturated with water vapour and at a temperature between 33 and 37° C., and for various relative humidities (R.H.) of the fresh gas. The ordinate may be read as the water vapour concentration, or as the water content of the inspired gas, both expressed as a percentage of the concentration or content of expired gas. Continuous lines are for a humidifier containing an infinite number of gauzes; broken lines for one containing 10 gauzes of large heat capacity. The cross-hatched area indicates an area of uncertainty in the performance of the 10-gauze humidifier (see text).

point then about 9 ml. is re-inhaled and only about 1 ml. permanently lost.

Discussion

From the above results it is evident that a condenser-humidifier can substantially increase the water content of inspired gas. Therefore it is worth while comparing its performance with that of the upper respiratory tract which it seeks to replace in a patient with a tracheostomy or an endotracheal tube.

Ingelstedt (1956) made instantaneous measurements of the temperature and humidity of air in the subglottic space throughout the respiratory cycle. He found that with nasal breathing both of rather dry room air (23.3° C., 30% relative humidity) and of cold air (2° C., 55% relative humidity), the inspired water content was about 83% of that expired. Therefore if the upper respiratory tract is to be completely replaced by a humidifier of any sort it should raise the water content of inspired gas to about 83% of that expired. (From Ingelstedt's measurements expired air in the subglottic space is saturated with water vapour at about 36° C.)

When a patient is breathing room air, at say 20° C., through a multi-gauze humidifier it can be determined from Fig. 4 that the humidifier will completely replace the upper respiratory tract if the relative humidity of the room air is at least 50%. Since room air is usually outdoor air which may have been warmed but has not been appreciably humidified this condition will normally be met except in very dry climates or when the outdoor temperature is below about 10° C.

If the patient is breathing dry gas from a cylinder the humidifier will form a complete replacement of the upper respiratory tract only if the gas is first moistened or else cooled to 8° C. or below. However, even if the dry gas is not pretreated in either of these ways the humidifier will still give a useful degree of humidification: 60% of the water expired by the patient will be returned to him in inspiration.

From a theoretical point of view a condenser-humidifier should generally perform best when the element is thermally isolated from the surrounding air. The fact that the performance of the 10-gauze humidifier in the experiments (where it stood freely in the room air) was as good as predicted theoretically, indicates that the exchange of heat between the gauze element and the surrounding air was negligible. If any attempt were made at specially heating the gauzes the one most remote from the patient would share in the temperature rise and hence the water content of the waste gas would be increased, thereby reducing the water content of inspired gas. If the gauzes were specially cooled (except by cooling the fresh gas) the gauze nearest the patient would share in the drop in temperature and the water content of inspired gas would be reduced directly.

Other types of condenser-humidifier have been reported. Toremalm (1960) described two devices. In the first the active element consisted of 75 small stainless-steel tubes through which the patient breathed; in the second the element was formed of two strips of aluminium foil, one corrugated and one plain, rolled up like a roll of corrugated cardboard. From the dimensions of the devices, the thermal conductivity of aluminium and of steel, and the heat capacity of air it is possible to estimate the temperatures at the two ends of the tubes or foil and thus the waste and inspired

temperatures. Then equation (2) can be used to determine the inspired water content. Values have been calculated and found to agree quite well with Toremalm's experimental figures. In the one device the high thermal conductivity of aluminium and the short length (3 cm.) appear to prevent the development of any appreciable temperature difference between the ends. Therefore it behaves as a single gauze of large heat capacity. In the other device the lower thermal conductivity of steel and the greater length of the tubes (5 or 10 cm.) allow substantial temperature differences to develop between the ends, and the performance is correspondingly better; but it is still not as good as the theoretical value for a 10-gauze humidifier.

Walley's (1956) condenser-humidifier consisted of a strip of wire gauze rolled up like Toremalm's foil. Calculation suggests that its performance should be intermediate between the foil and tube devices of Toremalm. Walley's measurements certainly suggest that the performance is better than that of a single flat gauze, but the measurements are not sufficiently detailed to show how near it approaches the performance of a 10-gauze humidifier. It is to be expected, however, that for a given quantity of gauze the performance would be inferior to that of the multiple-gauze type, since in the latter the successive layers are in much poorer thermal contact.

It is important to realize that even the best condenser-humidifier (best from the humidification point of view) cannot do more than return to the patient all the water he expires; it can never add water to the respiratory tract. Suppose a patient has breathed, or been ventilated, through a tracheostomy for some time without a humidifier and that as a result the trachea has become very dry. If a condenser-humidifier is then added to the circuit the trachea will be moistened only as fast as the local secretion of water permits. On the other hand, if liquid water is injected or a very high humidity is generated in the inspired gas by means of a nebulizer or hot-water humidifier, the trachea may be moistened much more quickly. However, once the trachea has been restored to a normal state the use of a condenser-humidifier should serve to keep it so, at least if the conditions are such that it can completely replace the humidifying powers of the upper respiratory tract.

An incidental advantage of condenser-humidifiers is as follows. The patient's expirations are saturated with water vapour at a temperature well above that of the room, and therefore when no humidifier is used copious condensation occurs in the expiratory circuit. The effect may be worse when a hot-water humidifier or a nebulizer is used. However, when a condenser-humidifier is used the fact that some of the expired water vapour is returned to the patient means that less emerges into the breathing circuit. With a multiple-gauze humidifier the waste gas is saturated with water vapour at only a little above room temperature so that very little condensation occurs. Thus valves and ventilation meters, whose performance may be impaired by condensed water, can be run for longer periods without attention.

In clinical use mucus may become deposited in the gauzes or in the tubes of Toremalm's devices. With the present 10-gauze humidifier it has not been possible to remove mucus by simple washing (although an ultrasonic cleaner might be more successful), and presumably similar difficulties would be encountered with the other

types of condenser-humidifier. If the gauze element is sterilized it will be safe to reuse it from a bacteriological point of view, but the resistance to breathing will be increased and the humidifying power will be decreased so that in time it may need to be replaced on these grounds.

Summary and Conclusions

A theory has been developed to describe the performance of condenser-humidifiers in general and extended to cover more fully the type in which the patient breathes through a number of flat wire gauzes in series. An example of the "multiple-gauze" type, containing 10 gauzes, manufactured by Messrs. Garthur (London) Ltd., has also been tested experimentally; the results agreed with the theory.

Condenser-humidifiers can produce a substantial degree of humidification of inspired air in all normal circumstances by returning to the patient water vapour breathed out in expiration. They perform best when the fresh gas entering the humidifier from the room, or from a cylinder of compressed gas, is cold and damp

rather than hot and dry. If a patient with a tracheostomy or an endotracheal tube is breathing fairly moist cool room air a good condenser-humidifier can completely replace the humidifying properties of the upper respiratory tract.

The multiple-gauze type of condenser-humidifier appears to be the best design from a theoretical point of view and the 10 gauzes of the Garthur device give a performance close to the best possible for a condenser-humidifier. The device made by Drägerwerk with 15 gauzes should be marginally better.

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ABOLITION OF STAPHYLOCOCCAL CROSS-INFECTION IN A THORACIC SURGICAL WARD

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Cross-infection due to *Staphylococcus pyogenes* is still common, and numerous suggestions have been made by different workers to combat it. It is clear from most of their reports that, although the cross-infection rate was reduced, complete eradication was not achieved. The idea of dealing with hospital cross-infection on an epidemiological basis by eliminating the nasal reservoir of staphylococci, using an antibiotic dust in the form of droplet nuclei, was first suggested by Elek and Fleming (1960a, 1960b). The same approach was used later by means of an individual antibiotic spray by Stratford, Rubbo, Christie, and Dixon (1960) and Barber and Warren (1962) with encouraging results. Individual spraying requires assiduous application and continuous vigilance. Our experience with the original method of Elek and Fleming shows that cross-infection can be eliminated by a very simple approach, and we would like to report our experience with methicillin spraying in a thoracic surgical ward, where the risk of cross-infection was especially high.

Past History of Infection in the Ward

This ward, standing on its own and connected with other wards by open corridors, had a high cross-infection rate in the past and was closed twice for this reason. During its first closure in 1958, when the cross-infection rate was 18%, the ward was modernized and the number of side wards was increased, with partitioning up to ceiling height.

The following preventive measures were introduced—some at the time of reopening, some later, when the cross-infection rate was rising again. (1) Broom-sweeping was discontinued and suction machines were introduced for ward-cleaning. (2) All blankets were replaced by open-weave broadloom cotton blankets, and were changed once a week on the beds of infected patients. Sheets were changed daily for these patients. The linen was carefully collected into closed bins and

no counting of linen took place in the ward. (3) All dressings were collected into paper bags and put into bins with self-closing lids. (4) The clinically infected cases were isolated in the side wards and barrier-nursed. Furthermore, when space permitted, this included patients with infected sputa. (5) Nasal swabs were taken regularly from nursing and medical staff, and those with even minor skin sepsis were excluded from duty. (6) As a nasal prophylaxis, "naseptin" was administered to all patients from the time of admission twice daily, under the supervision of the ward sisters. (7) Such antibiotics were given as were indicated by the results of the sensitivity tests on the infecting organisms.

In spite of all these measures, although the cross-infection rate was low for a time after the reopening of the ward, it slowly rose, culminating in a fatal case of staphylococcal septicaemia in April, 1960, which led to the second closure of the ward for 11 weeks. It was reopened again and once more the cross-infection rate gradually rose (the incidence of cross-infection before and after the second closure is shown in Figs. 1 and 2). It was at this time that the trial of methicillin spraying was begun in the middle of December, 1960.

Method

The spray, a "spraydex" window-cleaning bottle-and-spray, containing a solution of 10 g. of methicillin ("celbenin") in 200 ml. of tap-water was used. This solution was made up freshly each morning and was kept at 4° C. between use. At each use approximately 1.5 ml. of this solution was sprayed in the air above the bed of each patient and also in the treatment rooms. This procedure was carried out four times a day at four-hourly intervals.

In the first six months of the trial methicillin was also given parenterally to each patient operated on, beginning on the morning of operation and continuing for five days. The dosage was 1 g. four-hourly for two days