Disinfection of the East–Radcliffe ventilator

A bacteriological study of a modified picloxydine technique

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The decontamination of ventilators has always proved difficult, but in recent years five methods have been evolved: these are formalin vapour[1], ethylene oxide[2,3], nebulised alcohol[4] or hydrogen peroxide[5] and picloxydine foam (Resiguard)[6]. The last method is limited to ventilators which can be circulated on a closed circuit such as the East–Radcliffe machine.

Chemical disinfection requires the least elaborate apparatus and this paper describes a modification of the original method[6] using picloxydine foam and suggests a new method for detecting bacterial contamination in ventilators.

In order to monitor their method in 14 ventilators Meadows *et al.*[6] used a broth–soaked swab technique.

In the present series, 50 ventilators were disinfected and the opportunity was taken to compare the swab technique with a detailed bacteriological study using a semi–quantitative sampling technique and employing an improved culture medium, which was specially developed for the purpose.

METHOD

Disinfection technique

Resiguard is a multi–purpose disinfectant concentrate containing picloxydine digluconate, octylphenoxypolyethoxyethanol and benzalkonium chloride, which has already been adequately described[7]. For the disinfection of ventilators it is diluted 1 : 80 with water.

In the original procedure[6] the humidifier and carbon dioxide absorber and front and rear body panels were first removed from the East–Radcliffe ventilator. Once access to the interior of the machine had been achieved, the tubing to the pressure gauge was disconnected and the Wright respirometer was removed. The humidifier hoses were then connected together, the oxygen lead was spigotted, the negative pressure control was turned fully on and a reservoir bag was attached to the patient delivery tubing. A length of corrugated tubing was attached to the inlet port and picloxydine (diluted 1:80) was sucked up from a bucket by manually

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cycling the ventilator until fluid emerged from the outlet port. The distal end of the corrugated tubing was next attached to the outlet port and the ventilator was cycled by power on closed circuit for 20 minutes; the slowest speed was used with a full set of weights applied to the positive pressure bellows. At the end of 20 minutes, all the traps and hoses were removed and the ventilator was allowed to cycle for one hour to allow it to dry. Following this the power supply was disconnected, the electrical junction box was dried and the machine re-assembled.

We modified this method to simplify and shorten the procedure, and to avoid spillage of fluid on to the floor. A U-connector was placed between the two humidifier tubes and a polythene tube of wide bore, about 18″ long, with suitable connections, was attached between inlet and outlet ports. The polythene tube was considered preferable to corrugated rubber as it allowed easier drainage and visual confirmation that picloxydine was being cycled correctly. The Wright respirometer was left *in situ* but out of circuit, and the pressure gauge was isolated by disconnecting and spigotting the tube connecting it to the circuit. The tube was reached by inserting a hand into the machine from above, after the weights had been removed, the weight carrier moved as near to the fulcrum as possible and the bellows collapsed either by cranking the ventilator manually or by removing the gear sprocket and pushing the bellows down by hand.

Removal of the front of the machine was necessary only on the first occasion of disinfection with picloxydine in order to check that all internal connections were water-tight. Provided that these connections were water tight the inside of the machine remained dry and the electrical junction box did not need to be dried. Any leak is easily noticed when spillage from the underside of the ventilator occurs.

By the modified procedure the ventilator could be made ready for disinfection in about 1 minute. 1 pint (540ml) of picloxydine was poured into the proximal end of the polythene tubing used to connect inlet and outlet ports, which was temporarily disconnected at the outlet port for this purpose. As the fluid was poured in, the ventilator was cranked by hand. This was done either by two operators simultaneously, or by one pouring and cranking alternately, but with experience it was possible to add the entire 540ml of fluid before having to crank the machine. The connector tube was now reconnected to the outlet port and the ventilator cycled on the main supply for 30 minutes. At the end of this time the machine was emptied and dried by the following procedure:

(1) The ventilator was stopped at the end of the inspiratory phase, the reservoir bag disconnected and emptied into a suitable receptacle.

(2) The patient delivery tube was emptied.

(3) The water traps were emptied.

(4) The humidifier pipes underneath the machine were drained by disconnecting the U-connector.

(5) The machine was tilted forward through 30 degrees to drain fluid from the inlet side into the polythene connector. The connector tube was then drained by disconnecting at the outlet port.

(6) The hoses, U-connector and water traps were reconnected.

(7) The machine was then cycled for one further minute and operations 3 and 5 repeated.

(8) All hoses, water traps *etc.* were removed and the machine dried by cycling for one hour. This method of drainage allowed collection of approximately 500ml of the original 540ml, thus minimising the amount which sprayed on to the floor during drying.

Bacteriological techniques

(*a*) *Contaminating suspensions.* 18-hour nutrient broth cultures of various organisms were suspended in 540ml of 2 per cent Tween-80 solution and used as contaminating suspensions. A standard loop was used to inoculate 10^{-3}ml of the suspension and a 10^{-3} dilution of the suspension onto blood agar plates which were incubated at 37°C for 18 hours. Colony counts were performed.

(*b*) *Culture media for contaminating suspensions and all sampling fluids after circulation.* All suspensions were cultured on serum-lecithin-Tween-80 agar (SLT) which is composed of:

Blood agar base (Oxoid)	40gm
Tween-80	10ml
Water	950ml
Egg lecithin (in 50ml absolute ethanol)	5gm
Horse serum	40ml

The medium was prepared as follows: The blood agar base and Tween-80 were dissolved in the water, autoclaved at 15PSI and 121°C for 15 minutes and cooled to 45°C. The lecithin solution and horse serum were added aseptically and the mixture dispensed into sterile Petri dishes.

Procedure. SLT agar plates were inoculated with a standard loop as already described and in addition 10ml of fluid was filtered through an Oxoid membrane filter which was cultured on SLT agar. All plates were incubated at 37°C for 42 hours and colony counts performed.

SAMPLING TECHNIQUES AND RESULTS

In order to demonstrate the sensitivity of the semi-quantitative wash-out technique (*v.i.*) and to afford a comparison with conventional sampling methods, serum tipped swabs were used to sample some of the ventilators before disinfection. Swabs were taken from the outlet port, the outlet of the patient delivery tubing, the left (small) and right (large) water traps and the inlet pipe to the bellows.

Table 1 compares the results obtained by enumerating the viable organisms in the wash-out fluid with those obtained by swabbing multiple sites within the ventilators and demonstrates the greater sensitivity of the wash-out technique.

TABLE 1

Comparison of quantitative washout results with swabbing 5 sites in 17 ventilators

QUANTITATIVE CULTURE	SWAB CULTURE
10^9 *Alcaligenes bronchisepticus*	5 sterile
10^2 *Staph. aureus*+10^2 Coliforms	5 *Staph. aureus*
10^6 *Staph. aureus*	4 *Staph. aureus*+1 sterile
10^3 *Staph. aureus*+10^2 Bacillus sp.	2 sterile+3 Bacillus sp.
10^4 *Esch. coli*	2 sterile+3 *Esch. coli*
10^5 *Esch. coli*	2 sterile+3 *Esch. coli*
10^5 *Staph. aureus*+10^5 *Esch. coli*+10^7 Candida sp.	3 sterile+2 micrococci
10^3 *Staph. aureus*+10^2 *Esch. coli*+10^2 Bacillus sp.	5 sterile
10^3 *Staph. aureus*	5 sterile
10^7 *Ps. aeruginosa*+10^6 Candida sp.	3 *Ps. aeruginosa*+2 sterile
10^0 *Ps. aeruginosa*	5 sterile
10^3 *Ps. aeruginosa*	5 sterile
10^5 *Ps. aeruginosa*	4 sterile+1 *Ps. aeruginosa*
10^5 *Ps. aeruginosa*	3 sterile+2 *Ps. aeruginsoa*
10^5 *Ps. aeruginosa*	2 sterile+3 *Ps. aeruginosa*
10^5 *Ps. aeruginosa*	2 sterile+3 *Ps. aeruginosa*
10^6 *Ps. aeruginosa*	2 sterile+3 *Ps. aeruginosa*

Two series of experiments were then performed.

Series 1

Ventilators were taken directly from patients and sampled by circulating one pint (540ml) of 2 per cent Tween-80 in sterile distilled water for 30 minutes and then removing it from the machine for culture. The ventilators were then disinfected with picloxydine, dried and re-sampled with a further pint of 2 per cent Tween-80 in the same way.

Table 2 shows the results of sampling 21 ventilators, which had been taken directly out of service, before and after disinfection with picloxydine. Only aerobic spore-bearing organisms were recovered after disinfection.

Series 2

(1) A small sample of each contaminating suspension was retained for culture, and the remainder circulated in the ventilator for 5 minutes, drained from the machine and bacteriologically examined.
(2) 540ml of sterile 2 per cent Tween-80 solution was used to sample the machine by cycling for 30 minutes, draining the ventilator and examining the effluent bacteriologically.
(3) The machine was decontaminated with picloxydine solution.
(4) 540ml of sterile 2 per cent Tween-80 solution was used to sample the machine as before.

Table 3 shows the results of deliberately contaminating 31 ventilators and sampling before and after picloxydine disinfection. Again, only aerobic spore-bearing organisms were recovered after disinfection.

(5) A new East–Radcliffe ventilator which had never been exposed to ethylene oxide was used to demonstrate the residual action of the gas. It was contaminated, sampled and disinfected with picloxydine on 6 occasions and the wash-out results compared with those obtained from four ventilators which were contaminated and sampled within 4 hours of ethylene oxide sterilisation.

Table 4 compares samples obtained from ventilators which had been previously disinfected with ethylene oxide and subsequently cycled with air for at least 1 hour, with those obtained from the ventilator which had never been exposed to the gas. The recovery of organisms from those ventilators recently exposed to ethylene oxide was considerably less than that from the ventilator which had never been disinfected with ethylene oxide.

TABLE 2

Quantitative sampling of 21 ventilators taken directly out of service

NO. OF VENTILATORS	BEFORE PICLOXYDINE	AFTER PICLOXYDINE
3	Sterile	Sterile
5	Bacillus sp. (10–10^2)	Sterile
3	*Klebsiella aerogenes* (10^4–10^7)	Sterile
1	*Alcaligenes faecalis* (10^5)	Sterile
1	*Alcaligenes bronchisepticus* (10^2)	Sterile
1	*Proteus mirabilis* (10^5)+ *Klebsiella aerogenes* (10^5)	Sterile
1	*Staph. aureus* (10^3)+ Bacillus sp. (10^2)	Sterile
1	*Pseudomonas aeruginosa* (10^7)+ Candida sp. (10^6)	Sterile
1	*Alcaligenes faecalis* (10)+ Candida sp. (10)	Bacillus sp. (10^3)
1	*Alcaligenes faecalis* (10^3)	Bacillus sp. (10)
2	Bacillus sp. (10)	Bacillus sp. (1–10)
1	*Ps. aeruginosa* (10)+ Bacillus sp. (10)	Bacillus sp. (10^5)
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DISCUSSION

Disinfection technique

The simplified method of disinfecting an East–Radcliffe ventilator described in this paper, does not require the dismantling of the machine except on the first occasion on which picloxydine is used. It has proved more satisfactory to pour the picloxydine, rather than suck it, into the machine, and systematic drainage minimises spillage on to the floor. 1 pint (540ml) of picloxydine dilution has been found adequate, as larger quantities interfere with the smooth cycling of the machine.

TABLE 3

Samples obtained from 31 deliberately contaminated ventilators before and after picloxydine

NO OF VENTILATORS	CONTAMINATING SUSPENSION	CULTURE BEFORE PICLOXYDINE	CULTURE AFTER PICLOXYDINE
2	10^8–10^{10} *Staph. aureus*	10^5–10^8 *Staph. aureus*	Sterile
2	,, ,, ,,	10^5–10^8 ,, ,,	10^2 Bacillus sp.
1	,, ,, ,,	10^8 ,, ,,	Sterile
1	,, ,, ,,	10^8 ,, ,, +10 Bacillus sp.	Sterile
1	,, ,, ,,	10 Bacillus sp.	Sterile
1	,, ,, ,,	10 *Esch. coli.*	Sterile
2	,, ,, ,,	Sterile	Sterile
1	10^8 *Staph. aureus*+10^8 *Ps. aeruginosa*	10 *Staph. aureus*+10^2*Ps. aeruginosa*	10 Bacillus sp.
1	,, ,, ,,	10 Bacillus sp.	10 Bacillus sp.
1	,, ,, ,,	10 *Staph. aureus*+*Ps. aeruginosa*+ 10 Bacillus sp.	Sterile
3	10^7–10^{10} *Esch. Coli*	10^6–10^7 *Esch. Coli*	Sterile
1	,, ,, ,,	10^5 ,, ,,	10^2 Bacillus sp.
1	,, ,, ,,	10 ,, ,, +10^2 Bacillus sp.	Sterile
1	,, ,, ,,	10^7 ,, ,, +10^7 Coliforms	10 Bacillus sp.
1	,, ,, ,,	10^2 Bacillus sp.	10^2 Bacillus sp.
1	10^7 *Alcaligenes bronchisepticus*	Sterile	Sterile
1	10^9 Candida sp.	10^7 Candida sp.	10 Bacillus sp.
1	10^9 Candida sp.	10^7 Candida sp.+10^5 *Esch. coli* +10^5 *Staph. aureus*	Sterile
7	10^{10}–10^{11} *Ps. aeruginosa*	10^2–10^7 *Ps. aeruginosa*	Sterile
1	10^{10}–10^{11} *Ps. aeruginosa*	Sterile	Sterile
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TABLE 4

Comparison of samples from ventilators recently exposed to ethylene oxide with those from a ventilator never exposed to ethylene oxide

VENTILATORS WITHIN 4 HOURS OF ETHYLENE OXIDE			VENTILATORS NEVER BEFORE EXPOSED TO ETHYLENE OXIDE		
NO.	CONTAMINATING SUSPENSION	SAMPLING FLUID	NO.	CONTAMINATING SUSPENSION	SAMPLING FLUID
1	10^9 *Staph. aureus*	Sterile	1	10^9 *Staph. aureus*	10^7 *Staph. aureus*
2	10^9 *Esch. coli*	10 *Esch. coli*	2	10^9 *Esch. coli*	10^9 *Esch. coli*
3	10^9 *Esch. coli*	Sterile	3	10^7 *Esch. coli*	10^5 *Esch. coli*
4	10^{10} *Ps. aeruginosa*	Sterile	4	10^{10} *Esch. coli*	10^7 *Esch. coli*
			5	10^9 *Staph. aureus*	10^6 *Staph. aureus*
			6	10^{10} *Staph. aureus*	10^6 *Staph. aureus*

A 2 pint jug proved convenient for collecting the picloxydine as it fits easily under the humidifier hoses and water traps.

If, after filling, the machine is insufficiently cycled by hand, the bellows will not rise and fall freely and the weights will bounce noisily when the mains supply is switched on. This difficulty is overcome by applying manual pressure to the positive pressure bellows for 5–6 cycles, which enables the fluid accumulated on the inlet side to disperse and the machine will then function normally. If the reservoir bag is held aloft, this also overfills the inlet side of the ventilator upsetting the movement of the positive pressure bellows as described. The best results are obtained when the reservoir bag is kept below the level of the ventilator.

During the disinfection of 52 ventilators, one developed a fault, a sticking valve, which might have been attributable to picloxydine.

Bacteriological assessment

The circulation of a solution of Tween–80 for sampling the East–Radcliffe ventilator for bacterial contamination, ensures that every part of the interior of the machine is washed, whilst Tween–80 in exerting its detergent action, neutralises the residual action of the quaternary ammonium constituent of picloxydine and assists in eliminating false negative cultures.

Subsequent culture of large quantities (10ml) of the wash–out fluid on a neutralising medium, such as that described, enables small numbers of organisms to be detected and the degree of bacterial contamination to be roughly estimated. In addition, the wash–out technique has proved far more sensitive than conventional swabbing, which often resulted in sterile cultures despite gross contamination of the ventilator (table 1).

In the first series of 21 ventilators taken from patients, ten were found to be sterile or to be contaminated only with aerobic spore–bearing organisms before disinfection with picloxydine (table 2). Ventilators were therefore deliberately contaminated with large numbers of known bacteria. Nevertheless, culture of the wash-out fluid resulted in little or no growth of bacteria in those ventilators which had been recently disinfected with ethylene oxide (table 3). It is well known that ethylene oxide is absorbed by rubber and plastic materials. It was therefore concluded that either the ethylene oxide was exerting a marked residual action or that the wash–out sampling technique was unsatisfactory. A new East–Radcliffe ventilator which had never been disinfected with ethylene oxide was contaminated, sampled and disinfected with picloxydine on several occasions.

The recovery of organisms from this ventilator was considerably better than that in those which had recently been exposed to ethylene oxide, thus suggesting that there may be a significant residual action of ethylene oxide. Even with this ventilator a large percentage of the contaminating organisms was not recovered. The reasons for this loss are not understood and are at present being investigated.

Picloxydine in common with most other disinfectants, is inactive against spores and on several occasions aerobic spore formers were isolated from disinfected ventilators. While such organisms are normally non–pathogenic for man, on rare occasions they have been incriminated as pathogens in patients with terminal illnesses.

Ethylene oxide sterilisation requires a separate room with special ventilation, storage space for the ethylene oxide cylinders and the removal of each ventilator from service for 24 hours. In addition the method is relatively expensive, costing about seven shillings per ventilator, the gas is toxic and must be mixed with carbon dioxide in order to avoid explosions. It is, however, probably the most convenient method in a large hospital, which has the space, labour and facilities available and which is well supplied with ventilators. It is suitable for sterilising most makes of ventilators in common use.

When using formaldehyde to sterilise ventilators, a separate room is not essential but is desirable because the formaldehyde vapour and ammonia which is the neutralising agent, escape into the atmosphere. No cylinder storage space is needed but the ventilators are kept out of service for 24 hours.

The main disadvantage of picloxydine disinfection is that it requires the presence of the operator for most of the first half hour and the number of ventilators to which he can efficiently attend is limited. With ethylene oxide sterilisation the ventilators are simply exposed to the gas for 24 hours. It is also difficult to avoid spillage of picloxydine on to the floor, though the amount of spillage can be considerably reduced by careful drainage. However, it is desirable to have a waterproof floor or a shallow tray beneath the machine. Picloxydine is suitable for disinfecting only those machines that can be cycled on a closed circuit.

The picloxydine method of disinfection requires no special room or equipment. It is inexpensive, costing about threepence per ventilator and the whole process is completed in one and a half hours. It also removes dirt and debris from the machine.

It is well suited for the disinfection of ventilators in situations where facilities for ethylene oxide sterilisation are not available, or where speed is essential.

SUMMARY

A modified technique for satisfactorily disinfecting the East–Radcliffe ventilator with picloxydine is described.

Random swabbing of the machine was found to be an inaccurate method of detecting bacterial contamination and an improved method is described.

Picloxydine disinfection is cheap, quick and well suited for hospitals where there are no facilities for ethylene oxide sterilisation.

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References

1 SYKES, M. K. (1964). Sterilizing mechanical ventilators. *Br. med. J., i,* 561

2 BISHOP, C., POTTS, M. W., and MOLLOY, P. J. (1962). A method of sterilization for the Barnet respirator. *Br. J. Anaesth., 34,* 121

3 BISHOP, C., ROBERTSON, D. S. and WILLIAMS, S. R. (1964). The use of ethylene oxide for sterilization of mechanical ventilators. *Br. J. Anaesth., 36,* 53

4 PETERSON, N. O. A. and ROSDAHL, K. G. (1966). Ultraljudsnebuliserad etylalkohol för desinfektion av andningsapparatur. *Opusc. Med. (Stockh.), 11,* 278

5 JUDD, P. A., TOMLIN, P. J., WHITBY, J. L., INGLIS, T. C. M. and ROBINSON, J. S. (1968). Disinfection of ventilators by ultrasonic nebulisation. *Lancet, 2,* 1019

6 MEADOWS, G. A., RICHARDSON, J. C., FISH, E. and WILLIAMS, A. (1968). A method of sterilization for the East–Radcliffe ventilator. *Br. J. Anaesth., 40,* 71

7 HOLMAN, R. A. and PEXTON, J. M. (1968). The value of a new disinfectant in the control of hospital cross infection. *Br. Hosp. soc. Serv., J. 77,* 490