〔教育講演〕

Contamination Control in Long-term Ventilation

A Clinical Study Using a Heat and Moisture-exchanging Filter

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We were prompted to perform our study because of the on going debate concerning the sterilisation policy of respiratory apparatus. We had previously surveyed the British Intensive Care Society and found that units around the country varied considerably in their sterilisation policies. Some units sterilise their ventilators everyday whereas others only in-between patients use. Moreover despite the fact that most units were using reliable inexpensive bacterial filters to protect their ventilators these were rarely used to obviate the need for sterilisation.

The need to avoid bacterial contamination of Intensive Care Equipment is of paramount importance. It has often been shown that the development of sepsis in the critically ill is likely to increase the length of stay on the Intensive Care Unit, increase the morbidity of the patients and in some cases directly contribute to their mortality.

Patients on Intensive Care Units are particularly prone to the development of nosocomial infection. Outside the Intensive Care Unit on general wards the nosocomial infection rate is approximately 5-10%, but two prospective studies have shown that this is very much increased in the Intensive Care Unit. In 1982 Daschner[1] looked at three units around the world one in Sweden, the other in his own unit at Freiburg and also unit in the United States. He found that the rate of infection overall was 12.5% but this could be as high as 27.6% in general surgical patients. Particularly common types of nosocomial infection are urinary tract infection followed by septicaemia and then skin or subcutaneous infection or pneumonia.

We further noted that nearly all cases in a nosocomial infection were related to some type of equipment being used to help the patient. For example it was rare to get a urinary tract infection in the absence of a transurethral bladder catheter and similarly it was unusual for pneumonia to develop in those patients who were not either intubated or intubated and artifically ventilated. And you see he quoted the risk of 3-11% of developing pneumonia in patients on ventilators.

He found that the length of stay was increased from an average of 4 to 21 days if nosocomial infection developed and that there is also quite of risk of secondary septicaemia. 36% of patients developing pneumonia develop secondary septicaemia and this is often the cause of increased mortality on Intensive Care.

The organisms most commonly seen are Staphylococcus aureus, Eascherichia coli, Pseudomonas aeruginosa and Pseudomonas sp. being the most common.

Dashner concluded that the Intentive Care patient is indeed particularly at risk of developing nosocomial infection and that this is often associated with various uses of Intensive Care equipment. The increase in the incidence of pneumonia which occurs in those patients

being artificially ventilated does suggest that contaminated respiratory equipment may play a part in clinically important infection.

There have been numerous recent reports that have confirmed that respiratory apparatus may harbour pathogens and thus, put patients at risk. In 1965 in the Lancet, Philips and Spencer[2] investigated and outbreak of Pseudomonas pneumonia on their respiratory unit and found the ventilators were harbouring and it was spreading directly to the patients. Im et al[3] also showed an outbreak of Pseudomonas which was traced back to a source in the ventilator tubing.

Humidifiers, water bath on nebulizer variety have also been reported as providing a very suitable environment for bacteria to grow and more recently some Heat and Moistures Exchanger with hygroscopic elements have also been found to become contaminated. Bygdeman[4] and others isolated bacteria from Siemens Humidifiers and recommended that these should not be used or regarded as bacterial filters and similarly letters have been written concerning the Engstrom Edith.

In 1981 Seal and Strangeways[5] looked at the epidemiology of Pseudomonas infection in their Intensive Care Units and they found that the epidemic variety was traced to ventilators and nebulisers. At this time they recommended that the use of bacterial filters be used at all times.

Recently inexpensive disposable filters have been available and one of these is the Pall Ultipor Filter BB50T. This combines uniquely the properties of a bacterial filter and a Heat and Moisture Exchanger. It consists of a pleated membrane composed of resin bonded ceramic fibres. The surface area is 10 square metres and has a mechanical dead space of 63 ml. A technical report by Latham[6] has shown.

The Pall Ultipor BB50 is an effective bacterial filter with an efficiency of 99.999% or more. In addition, because of their large surface area of hydrophobic material, the filter also functions as Heat and Moisture Exchanger. Two reports, one from the United Kingdom and the other from America have reported in vitro studies demonstrating its efficiency and Chalon[7], in New York, went on to use them clinically during anaesthesia. Bethune and Shelly[8] also demonstrated their bacterial efficiency in their in vitro model. So our study was devised to examine the efficiency of the filters in protecting our respiratory equipment from contamination and by placing them close to the patient to use them as a Heat and Moisture Exchanger Humidifier.

We hope to abandon our use of using water bath humidifiers. Our aims were to rationalise our policy concerning the decontamination of our respiratory equipment and also to observe the long term use of Heat and Moisture Exchangers as sole humidifiers. A report was published in Anaesthesia before we started our trial which described an increase in resistance which had been encountered when the filters were used[9]. The filters in this study were used in conjunction with a water bath humidifier and what almost certainly happened in the study. The filters were allowed to drop down and become full of water. Nevertheless we plan need to measure the resistance of all our filters after every use in our study.

I'd like to explain in more detail our study now. In 1985 for a five month period between January and June all patients who entered our intensive care unit and required artifical ventilation for more than 12 hours were studied. All ventilators were used to help with the study and, prior to the study, they were decontaminated in the usual way which is with a combination of autoclaving and ethylene oxide sterilisation. They were then not further de-

contaminated during the study unless (contamination was found or) servicing of the unit took place.

The patients were connected to the ventilators using clean disposable ventilator tubing. A Pall Ultipor BB50 Filter was placed at the Y piece. The filters were changed daily at set time unless there was a build up of secretions before then. The change was done with gloved hands and the new filter was placed on the catheter mount prior to the removal of the old filter in order to minimise the risk of contamination. The ventilator tubing was not changed throughout the whole period of ventilation. Following removal of the filter the resistance was immediately measured. This was performed by passing a fixed flow of 50 litres of air through the filters and measuring the change in pressure using a simple manometer. Any filter which had to be changed or was removed earlier than 24 hours also had its resistance measured.

Microbiological investigations were performed with the help of the Olympic Aero Test Sampler. The Olympic Aero Test Sampler consists of a plastic tube on to one end which is placed a trypton soya agar plate and, at the other end, there is a conical inlet into which a tubing supplying gas flow can be attached, there are vents at the side to allow the gas to subsequently escape.

Prior to the study these samplers were attached to the catheter mount and the ventilators run were at high level volume for 2 hours. These plates were then incubated for 5 days at 37°C and checked daily for growth, any bacteria grown were identified. During the study gases were sampled in a similar way from the expiratory port of the ventilators and this was performed for approximately 2 hours daily on patients undergoing ventilation. This plate was then examined in the same way. When the patients period of ventilation stopped the disposable tubing was divided into inspiratory and expiratory limbs and clamped and sent immediately to the Microbiology Department. Here each limb was rinsed with 50 ml of 40% Ringers Lactate Solution, 4 aliquots of this were withdrawn and filtered through 4×0.45 μm filter discs. The filter discs were then placed on two cysteine lactose electrolyte deficient agar plates and two chocolate blood agar plates before incubation for 5 days again at 37°C. Thus, controls we also sent consisting of lengths of unused tubing and these were processed in the same way in order to test the efficiency of our sampling known amounts of a bacteria infact the Oxford Staphylococcus aureus was deliberately used to contaminate some unused tubing and this was also sent to microbiology for assessment. At the end of the study the ventilators were checked, as they were at the beginning, by cycling the ventilators for a couple of hours and by attaching an Aero Test Sampler to a catheter mount at the inspiratory port.

Throughout the study the nursing procedure was not change in any way on the Intensive Care Unit although both nurses and physiotherapists were asked to install saline, as they felt was appropriate, when suctioning the patients.

We looked at 28 patients in all, 4 of whom had to be ventilated on more than one occasion. The patients varied in age from approximately in their early 20's to their late 70's and they suffered from varied problems. Some were only ventilated for post-operative ventilation and others had previously suffered a cardiac arrest and had been resuscitated.

The microbiological results are shown. To look at the ventilators first. Before the study (there were 7 ventilators used in the study) 6 plates were fond to yield no growth and one yielded some skin flora. At the end of the

study 3 plates now showed no growth, 4 had some environmental flora of less than 5 colonies and no skin flora at all. The samples of expired gases which were sampled during the study demonstrated that 16 out of 35 plates were found to show no growth, 10 showed a smaller number of environmental organisms and a similar number small numbers of skin flora. At no time were any pathogens found.

The two sets of tubing sent to microbiology because of, as I explained four patients had two periods of ventilation each. The control showed that half of the unused tubing yielded environmental or skin organisms and, looking at our sampling efficiency, this was found to be in excess of 95%. The tubing which came from the study ventilators showed little difference between the inspiratory and expiratory limbs. 10 sets of tubing had both limbs completely sterile. In 9 further sets 1 limb was sterile and in all the others only mixtures of environmental flora with the occasional skin flora was found. The increase of duration of ventilation is not associated with an increased contamination.

So we found that our conclusions were that here were no respiratory pathogens isolated from our ventilators during any time. It didn't become contaminated even with increased periods of ventilation. There was no increased number of organisms found and because there was no significant difference between the types of organisms isolated from the inspiratory, as compared with expiratory limbs, we felt this was further evidence that the filters were completely efficient.

As a more general investigation we also looked at the nosocomial infection contamination rate on the Intensive Care for the period of the study and also for the year previously when the water bath humidifiers have been used. A similar number of patients were admitted to the Intensive Care Unit although slightly more of these received artificial ventilation during 1985.

In 1984, 35 patients, which represented 53% of ventilated patients became, colonised or frankly infected with Pseudomonas aeruginosa. This compares with 1985 when the Heat and Moisture Exchanging Filters were in use. There were only 16 patients (which represents 20% of the patients) that became affected with Pseudomonas. So this can be seen to be quite a large fall. (Approx 60%)

The flow resistance in a total 128 filters were tested and out of these 125 were shown to have a resistance of less than 1.2 cm of water per litre per second. The other three filters and higher resistance readings 2 of which were in the range of 1.2 to 1.8 cm of water per litre per second and 1 was greater, bt this was found to be frankly full of secretions.

Clinically we found no problems with the humidification and the nurses and had no problems at all with their routine respiratory care. The nurses, in particular, very much preferred the system to the more difficult to manage and generally more complicated system of using water bath humidifiers.

Our study demonstrates therefore that these filters do provide an efficient barrier to bacteria in vivo and prevent contamination of respiiratory apparatus with human pathogens. There was no build up of organisms in the ventilators during the study and no pathogens were obtained from them following the study or from the expiratory ports during their use. Some environmental organisms and human skin flora were found both in the ventilators and from the tubing. These may have been contamination by nurses or other health workers. In the case of the tubing may have been present before the tubing was used. We therefore concluded that routine disinfection and sterilisation of our

ventilators was no longer necessary. The isolation of the patient from the ventilator by a Heat and Moisture Exchanging Filter protects the patient from any pathogens which may be in the ventilator or the tubing and, of course, protect the circuit contamination by the patient. The further benefit is the abolition or pathogens from being expelled from ventilator expiratory ports into the general atmosphere of the Intensive Care Units. We feel that it is important in decreasing the risk of nosocomial infection and that this was particulary borne out by the fact that our nosocomial infection rate fell compared to the previous year.

Prior to the start of this study we had been using water bath humidifiers as our routine method of humidification. However this method of humidification is expensive and as it electrical it is prone to technical problems. There is also increased nursing work with constant vigilance being reguired and frequent topping up with water. Other risks often reported have been the actual risk of thermal injury to patients and even water logging and, perhaps, the problem of getting actual droplets of water into the lungs themselves. They have often been found as, I said before, to be reservoirs of infection and because respiratory tubing invariably becomes wet water traps are require and these also provide a suitable environment for bacteria to flourish.

There is of course no doubt that gases which bypass the upper areas do need to be humidified. In normal breathing the upper airways functions as a Heat and Moisture Exchanger. In temperate climate the inspired air contains 10-25 miligrams per litre of water vapour and this reaches the alveoli at 37°C with a water content of 43.4 miligrams per litre. Nasal breathing delivers at the larynx at a temperature of 30-32°C and a water content of 33 mg per litre whilst mask breathing delivers 26 mg per litre at 31°C. The additional humidification was provided by the lower tracheal and bronchi. It is known that ciliary activity and tracheal mucus flow is dependent on the moisture content of tracheal air and the mucociliary escalator functions within a temperature range of 21-37°C at absolute humidity range of 22-44 mg per litre of water, below 22 mg per litre it appears to cease.

Recently several cheap disposable Heat and Moisture exchangers have become available.

The first type was described by Mapleston in 1956 and this was the Garthur Wire Gauze type of humidifier. Since then there have been several conventional ones and more recently there has been the introduction of the hydroscopic element into Heat and Moisture Exchangers, the Edith in particular only works because of its hygroscopic element although some humidifiers such as the Siemens combine a traditional condenser element with a hygroscopic element. The Pall Filter is the only example of a combined heat and moisture exchanger and bacterial filter and it also is unusual in that it has a hydrophobic membrane.

The efficiency of the Pall Filter is enhanced over those which have hygroscopic elements because of the fall in temperature which occurs it the filter itself. This is because it loses the latent heat to vapourisation.

Now there has been debate for sometime whether the Heat and Moisture Exchangers were sufficient or effective as humidifiers and Macintyre[10] did some studies although he only looked at patients for a 24 hour period. He started by looking at the lung mechanics and sputum volume and at the actual oxygen exchanged and parameters of the lungs which had been ventilated for 24 hour periods, both using Cascade water bath humidifier and a Heat and Moisture Exchanging Humidifier. I want go in detail through the figures but there is no

significant difference between any of the figures when comparing the different types of humidifiers. In addition in five patients the clearance of diethylene triamine penta acetic from the lung and this has been shown to be a good indicator of mucociliary function. The conventional cascade system and the Heat and Moisture Exchanger show the difference in the clearance rates. He therefore concluded that they were definitely effective for up to 24 hours of use although he did not feel able to recommend them for longer periods at that time.

The difference in moisture and temperature in patients who have a Heat and Moisture Exchanger and these patients have a Heat and Moisture Exchanger which adds water and increases the temperature to between 30° and 35°C and the water content between 26 and 30 mg. So there is no doubt as to the efficiency of Heat and Moisture Exchangers.

Mebius[11] in Scandinavia stated that an optimal content of around 25-30 mg water per litre at 37°C and a temperature around 32°C at the upper part of the trachea should be more than adequate to preserve mucociliary function and lung function in the vast majority of cases.

However, these and similar recommendations have been put up by British Standards and also from America[12]. The Pall BB50T produces 24 mg of water at 31°C and is therefore suitable.

These five Heat and Moisture Exchangers have been compared by Bethune and Shelley[8] in an in vitro study model and they have also found that the Pall BB50T was suitable to be used as a Heat and Moisture Exchanging Filter. This also worked both when dry gases and atmospheric gases which were already partly humidified were employed. In addition of the five they studied it was the only bacterial filter that was found to be efficient.

So perhaps the ideal characteristics for a device for humidification and filtering of ventilator gases are that they obviously provide optimal humidification and heating and that they do isolate the patient from the ventilator. That there is minimal interference with the patients and ventilator performance. They should be simple, safe and cheap and I think you will agree from my talk today that the Pall Ultipor BB50 does in fact qualify in all regards.

In conclusion therefore, from our work and that of others we have concluded that Pall Ultipor Filters are effective bacterial filters and when used correctly can reliably protect the ventilators from contamination. Our use of these filters as humidifiers was found to be clinically satisfactory in patients who are ventilated longterm and have now been used for a further 2 years in the Intensive Care at St James. In particular the hydrophobic nature of those filters and placed at the Y piece in the ventilation circuit they ensure that the respiratory tubing remains dry and thus a hostile environment to bacteria and viruses is present which we feel further decreases the risk of contamination and nosocomial infection.

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