Asepsis For Inhalational Therapy

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Infected human beings whether overtly ill or apparently healthy carriers are a source of infection to others. This is especially true in hospitals where man has organized a concentrated society of diseased individuals. The mode of transmission of disease from the infected person to another has been a controversial subject over the centuries and had to await the refinements of modern microbiology for definite scientific documentation. Thus, it required methods such as analysis of air, food, water, and techniques of bacterial, fungal, and viral propagation to take the epidemiology of infectious disease out of the realm of philosophy.

There are still, nevertheless, vast areas of ignorance, and until the etiologic agents of infectious hepatitis, infectious mononucleosis, and the malignant neoplasms can be cultured in the laboratory with ease, knowledge of their dissemination or agents for their control will not be available.

Increasing knowledge of the spread of infection has brought with it increased responsibilities for all hospital personnel. Everyone caring for the sick must continuously evaluate his activities to ensure that he does not contribute to cross infection.

This awareness has prompted changes in nursing techniques with hygienic care of the hands; disinfection of equipment and isolation of infected patients; changes in housekeeping practices with replacement of dry, dust-disseminating methods by hygienic cleaning with vacuum cleaners, germicidal detergents and steam jets; changes in laundering procedures with proper handling of contaminated linen and the use of germicidal textile lubricants. Wherever the spread of infection has been studied, changes have been instituted to perfect control and decrease the hazard of iatrogenic and nosocomial infection.

Are the techniques and equipment of the anesthesiologist now being used with recent developments in the epidemiology of infectious disease? Or is he so preoccupied with pharmacologic progress and advances in the mechanics and mechanisms of procedures that bacteriologic hazard is ignored?

Anesthesiologists and inhalation therapists are constantly dealing with the most highly colonized portion of a patient's body, the nasopharynx. Bowel surgery is categorized as "dirty" and "contaminated," yet nasopharyngeal probing and intubation of the respiratory tract violates the mucous membrane barrier, in an anatomic region that is highly contaminated, with little regard for the hazard to the subject, physician, or other patients. Even patients with healing tracheotomies are commonly cared for with neglect of asepsis.

The Respiratory Pathogens

Potential respiratory pathogens are present in the nose and throat of asymptomatic individuals. A recent study\(^1\) of throat cultures of military personnel during an outbreak of mild upper respiratory disease with Coxackie A-21 virus showed that 38 per cent of the asymptomatic recruits had the enterovirus in their throats. The investigators also isolated adenoviruses, parainfluenza virus, and 19 unidentified viral agents from the throats of these men. They found that the Coxackie virus persisted for 16-40 days after inoculation of volunteers.

In a study of 250 surgical patients at the Peter Bent Brigham Hospital, 35 per cent were found to be nasal carriers of Staphylococcus aureus. Another report\(^2\) revealed that 34 per cent of surgical patients carried S.
* aureus. Of these, 37 per cent had postoperative wound infections with *S. aureus*. In all but one instance, the infecting organisms had a phage pattern identical to that carried in the nasopharynx preoperatively. Other potential pathogens that may be unwittingly encountered include beta hemolytic streptococci, Necardia, Candida, and the gram-negative invaders *Aerobacter-Klebsiella* and *Pseudomonas aeruginosa*. In debilitated patients, lesser pathogens such as alpha hemolytic streptococci, pneumococci, diphtheroids and the myriads of micrococcii, characteristic of the normal respiratory tract present a hazard. Thus, articles which can be characterized as the most dangerously contaminated pieces of equipment in the hospital contact the patient’s nasopharynx. Casual handling of such equipment can hardly be condoned.

The logical approach, therefore, to the problem of the disinfection of anesthesia equipment, inhalation therapy equipment, and pulmonary function devices is to determine the type of contamination which may conceivably be encountered and to apply those methods of disinfection which have been proven adequate for destroying the microorganisms involved.

Bacteria and viruses in the moist, dark interior of the corrugated rubber tubing can persist for long periods. MacCallum and Noble reported that *S. aureus*, *Streptococcus pyogenes*, *Corynebacterium diphtheriae*, and *Escherichia coli* deposited on the surface of corrugated rubber tubing did not diminish appreciably in numbers in seven hours. Cossacke B-1 virus was not inactivated in three hours. A British investigator attributed the deaths of 20 infants to *P. aeruginosa* infection resulting from the use of a rubber catheter for removing mucus from the trachea. He also cited a number of infections proven to have originated from improperly disinfected bottles attached to electric suction machines.

Recent reports of multiple deaths and severe infections in neonates due to the “water bacteria,” *Flavobacterium meningosepticum* and *Achromobacter*, have jarred the astute clinical bacteriologist out of a smug complacency that these organisms, common to most hospital humidifiers, are nonpathogenic. These ubiquitous gram-negative bacilli, relatively inert biochemically, are usually not identified and are commonly regarded as nonsignificant environmental contaminants.

Sever cultured humidifiers in a nursery and reported 6,800 to 15,000 organisms per milliliter; stored distilled water had an average of 850 organisms per milliliter. All types of organisms were recovered with gram-negatives predominating.

Cultures of humidifiers in one hospital (PBBH) have shown all to be positive for gram-negative bacilli and fungi varying in numbers from several to 58,000 per milliliter. Only when sterilized humidifiers filled at the bedside with sterile distilled water were presented to each patient did the cultures become consistently negative. The humidifier must therefore be invariably regarded with suspicion unless such a program is enforced.

While outbreaks of infection attributable to anesthesia equipment have been suspected, they remain undocumented because cultures for the suspected organism are of necessity made long after an infection has been contracted, and the evidence is retrospective and circumstantial.

Cultures of anesthesia equipment, rebreathing tubes, masks, and bags in five hospitals in Georgia and Missouri showed extremely heavy contamination with pseudomonas, micrococcii, candida, and aerobic sporeformers.

Gross reported cultures taken immediately after use of endotracheal tubes, suction catheters, oropharyngeal Airways, face masks, “T” face mask adapters, inspiratory and expiratory tubing, and rebreathing bags, all to be heavily contaminated not only with typical nasopharyngeal flora but with fecal flora as well. Cultures for viruses and tubele bacilli were not done.

Because of the difficulty in cleaning intricate inner surfaces, random bacteriologic sampling of the interior of the corrugated tubing and reservoir bags in most hospitals will similarly reveal a repository for sepsis. Humidifiers and respiratory assistors are also heavily populated with microorganisms. Liquid reservoirs for spirometers usually harbor many thousand organisms per milliliter.

A respiratory pathogen that must be especially considered is the tubercle bacillus. One

* Hall, L. B.: Personal communication.
organism properly lodged in the alveoli of the lung initiates a tuberculous lesion and, according to recent observations, results in conversion to a positive tuberculin reaction. Methods of disinfection that do not consider the extraordinary resistance of this organism are not appropriate for anesthesia or inhalation equipment.

Agents Available for Disinfection

The problem is twofold. Both the containment and exclusion of infectious material must be considered. Fingers and objects that have been contaminated by contact with infected patients must be properly handled to prevent dissemination of microorganisms to the environment and personnel; and secondly, the susceptible patient must be protected from potential respiratory pathogens. Concurrent disinfection of the hands, terminal sterilization of all apparatus and hygienic methods accomplish this.

The use of detergents or soap containing bacteriostatic agents to suppress the bacterial flora of the hands is imperative to avoid becoming a carrier of pathogens picked up from the nasopharynx of successive patients. Concurrent disinfection of the skin with alcoholic solution of quaternary or hexachlorophene is quick and convenient. It is imperative after every patient contact. Suitable formulas are:

- Hexa-Cetf 50 ml.
- Isopropanol N. F. 665 ml.
- Water q.s. 1,000 ml.

or

- Benzalkonium chloride, 12.8 per cent 10 ml.
- Cetyl alcohol 5.0 Gm.
- Isopropyl or ethyl alcohol 665 ml.
- Water q.s. 1,000 ml.

The method of choice for sterilization of equipment is steam sterilization. This results in the destruction of all forms of life, whether viral, fungal, or bacterial. Most anesthesia equipment, because its fabrication includes rubber and plastic, cannot be sterilized by steam without excessive cost for replacement. Steam sterilization is most useful to the anesthetist for the sterilization of syringes and needles. Ethylene oxide is therefore the preferred method when properly used. This type of gas sterilization is effective in destroying all forms of microorganisms. However, the operation of an ethylene oxide sterilizer must be under constant surveillance and bacteriologically monitored because of its complex multiple-phase system. Since the temperature, 145°F, for practicable and successful performance, is considerably lower than that of the steam sterilizer, articles and equipment damaged by steam can be processed. Ethylene oxide is the method of choice for electrical equipment, suction apparatus, oxygenators, rubber, plastics, endoscopic instruments, books, and the like. One hospital has recently reported complete satisfaction after two years’ experience with ethylene oxide sterilization of all anesthesia equipment.

Chemical disinfection by germicides is resorted to only when neither of the above methods is applicable or feasible.

The ideal germicide should have a wide spectrum of activity. It should be bactericidal, tuberculocidal, viricidal, and fungicidal. One cannot expect it to be sporicidal, because no known cold chemical has this power under the conditions of use. It should not be destructive to equipment and any residual should be odorless, nonirritating, and nontoxic to tissue.

The four main types of broad spectrum chemical disinfectants are: (1) quaternaries, (2) synthetic phenolics, (3) iodophors, and (4) alcohols.

The quaternaries are excellent bactericides for gram-positive and gram-negative organisms. They are not tuberculocidal unless combined with alcohol. The combination is more effective than either quaternary or alcohol alone. The viricidal action of quaternaries is limited. Because these compounds are surface-active agents, they form coordination films with most materials and conjugate with organic matter. Hence, they are rapidly depleted from solution. They must be used with lavish excess and in sufficient concentration to leave a germicidal residual of 1:750. The quaternaries leave rubber tacky. They are often applied to plastic to make its surface electrostatically conductive. The great ad-
vantage of the quaternaries as clinical disinfectants is that they are nonirritating and nontoxic in the dilutions used.

The synthetic or substituted phenolics are effective against gram-positive and gram-negative bacteria and tubercle bacilli. They are moderately viricidal. When applied repeatedly to rubber the surface becomes irritating.

The iodophors, which are a complex of iodine with long-chain nonionic radicals such as detergents and polyvinyls, or cationics such as quaternaries, are effective against both gram-negative and gram-positive bacteria and tubercle bacilli. They are also viricidal. They do not stain surfaces as readily as aqueous iodine does, and yet they have the advantage of an intrinsic indicator of available iodine in the typical color of the solution. The iodine complexes are most useful as detergent germicides.

The alcohols, ethyl and isopropyl, are bactericidal and tuberculocidal. Their use is limited to skin and small-article disinfection as they are volatile, flammable, and expensive to use on large surfaces.

There is no ideal, all-purpose germicide. Disinfectants such as 70 per cent ethyl alcohol or 70 per cent isopropyl alcohol, while satisfactory for thermometers and skin, are not satisfactory for floors, walls, and furniture.

Formaldehyde, an excellent germicide, has not been considered here because of its tendency to polymerize on surfaces. This may result in irritation of tissue with consequent bronchospasm, pulmonary edema, and hypotension. Anesthesia equipment disinfected by formaldehyde must be adequately rinsed and aired.12

A hexachlorophene-containing detergent has been suggested for use in the care of endotracheal tubes and face masks.13 While this agent effectively suppresses the gram-positive flora of the skin, gram-negative organisms are not affected, and for this reason an agent with a broader microbial spectrum is preferable.

Methods of Disinfection

The bacteriological hazard created by modern anesthesia and inhalation methods can be eliminated by effective methods of disinfection. Each patient is entitled to hygienically safe equipment, and to ensure such safety, the assistance of the bacteriology laboratory should be enlisted. Cultures of the interior of reservoir bags and corrugated tubing can reveal the degree and nature of contamination. Porcelain plates can be made of water in humidifier and the reservoirs of spirometers. While there are no standards as to the numbers of organisms that are permissible in humidifier water, simple logic would lead one to conclude that no potential pathogens should be present. Moreover, since saprophytes are being implicated increasingly in human infections, their presence cannot be tolerated. Humidification water should therefore be sterile. All inhalation equipment, masks, tubing, reservoir bags, should be sterile. Reservoirs for spirometers can be maintained germfree if weekly cleaning is done with germicidal detergents and the water includes an odorless 2 per cent synthetic phenolic or 1:750 quaternary.

Berg and his co-workers14 studied the destruction of five enteroviruses by elemental iodine. They found the Coxsackie A-9 virus most resistant and one strain of type one polio virus to be almost equally resistant. Using an iodine concentration of 75 p.p.m., 25 minutes were required for 99 per cent destruction of Coxsackie virus at 5° C. (41° F.), 8 minutes at 15° C. (59° F.), and 1.5 minutes at 25° C. (77° F.). Extrapolation at 35° C. (95° F.), 0.32 minutes would be required.

Disinfection of anesthesia equipment therefore, when ethylene oxide is not available, consists of complete immersion in an iodophor solution containing 75 p.p.m. available iodine in water hot as the hands can tolerate (120° F.). All surfaces to be thoroughly brushed while submerged to remove secretions and a minimum contact time of 15 minutes allowed. The equipment is then to be thoroughly rinsed with flowing tap water, air dried, and stored to prevent recontamination.

Hygienic methods are an obvious factor in a program for the control of cross infection. So obvious that it seems crude to remind clinicians that suction catheters, airways, laryngoscopes, and other devices that are introduced into the nasopharynx must be handled in a sanitary manner. Yet it is still common to see catheters dangling to the floor, airways being retrieved from the floor, and
laryngoscopes being carried in the hip pocket along with the handkerchief.

In addition to concern for his equipment, the anesthesiologist whose hands and clothing of necessity become equally contaminated must eliminate himself as a vector in the transport of organisms by the use of germicidal lubricants on his hands, and a change of clothing between patients. The universal gown described by Adams makes this feasible and economical. The anesthesiologist can do no less as his share of the responsibility in diminishing the bacterial jeopardy to which the hospitalized patient is exposed.

Recommendations

(1) All anesthesia and inhalational therapy equipment is submerged, immediately after use, in an iodophor solution containing 73 p.p.m. available iodine at 120° F. Both inside and outside of all articles are vigorously scrubbed with a bristle brush while submerged to prevent splattering of clothing and environment allowing a minimal contact time of 15 minutes with the germicide. The equipment is thoroughly rinsed in running tap water and allowed to dry.

(2) Synthetic phenolics in 2 per cent solution can be similarly used for terminal disinfection provided prolonged immersion is avoided and all surfaces thoroughly rinsed to avoid skin irritation due to a residual.

(3) Under no circumstances should plain soap or detergent and water be used in washing contaminated equipment as bacteria and viruses are not destroyed and the equipment may come out of the wash water with alkali earth films (soap curd) to trap the bacteria. Moreover, this practice constitutes a potential hazard to personnel responsible for the cleaning through splashing of the bacteria-laden water.

(4) After cleaning (as indicated in 1 and 2) the equipment is sterilized by either of two methods, autoclaving or ethylene oxide sterilization.

(5) All equipment which can withstand the required heat 121° C. (250° F.) characteristic of steam under 15 pounds pressure for 30 minutes is to be steam sterilized. Because moisture is essential for sterilization, humidifiers must have some residual moisture in the interior to be autoclaved upright. The interior of plastic and rubber tubing should be wetted prior to sterilization. Dry containers must be inverted or placed on their side to permit escape of air. Flasks containing liquid up to 2 liters require 30 minutes, 9 liters, 55 minutes at 121° C. They must be autoclaved separately as the steam is vented slowly at the end of the sterilizing cycle to prevent boiling over of liquid.

(6) Ethylene oxide can be used for the sterilization of all rubber tubing, face masks, reservoir bags and is the only method of sterilization for oxygen tents and respiratory assistors (IPPB). Articles to be maintained and stored sterile can be placed in the sterilizer encased in paper, polyethylene, or glassine bags. Since the cycle takes six hours, an increased inventory of equipment is necessary for an adequate supply.

(7) Humidifiers are presented sterile to each patient. Sterile distilled water is added at the bedside. They are refilled with sterile distilled water as needed after the residual is emptied. One humidifier should never be used for a patient for longer than one week.

(8) Random bacteriological cultures should be taken weekly to check sterility of the equipment and humidification water. The presence or absence of coliforms and S. aureus, reliable indicators of human contamination, will attest to the success of the sanitation program.

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uary, 1957.

**EMPHYSEMA** Minute volume of ventilation was determined in patients with pulmonary emphysema, as they inhaled air or oxygen during studies of rest and exercise. The hazards of administering oxygen in the presence of carbon dioxide retention have been overemphasized, since carbon dioxide induces adverse reactions only with a concomitant fall in arterial blood pH, indicating uncompensated respiratory acidosis. Those few patients receiving oxygen therapy in the presence of uncompensated respiratory acidosis who showed temporary alterations in behavior (irritation, disorientation, or lethargy), improved on lowering the oxygen flow and administering stimulants to the central nervous system such as caffeine, sodium benzoate, oramphetamine. Recently ethamivan has been shown to be effective in the treatment of uncompensated respiratory acidosis. (Beck, G. J., and others: Effect of Oxygen on Patients with Pulmonary Emphysema, J.A.M.A. 179: 404 (Feb. 10) 1962.)

**HUMIDIFICATION IN TRACHEOSTOMY** A simple method for achieving satisfactory humidification in a tracheostomized patient is to drip isotonic saline solution continuously into the trachea. Sterile physiological saline solution is run into a tracheal oxygen catheter inserted about 2 cm. into the cannula through a 25-gauge needle at the rate of four drops per minute. The bottle of solution is hung at the level of the bed to avoid a rapid flow rate. If thick, profuse secretions develop, the flow rate may be increased, and the excess fluid suctioned out. Flugs already present may be removed by the installation of trypsin or detergent solutions. (Editorial: Tracheotomy: Complications and their Management, Canad. Med. Ass. J. 85: 1354 (Dec. 16) 1961.)