



### Also In This Issue:

- 2** Improving Environmental Hygiene in ICUs
- 3** Private Rooms Significantly Reduce Your Risk of Hospital-Associated Infections
- 3** MRSA Carriage in Healthcare Personnel in Contact With Farm Animals
- 4** International Federation of Infection Control
- 4** Book Review – Infections and Their Cause, A Historical Review
- 5** Book Review: Soap and Water & Common Sense
- 5** Green Team Updates
- 6** Spring 2010 Virox Updates
- 7** Norovirus Outbreaks in Dutch Nursing Homes

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## Microbicides in Healthcare: Usage, and Possible Problems

DR. JEAN-YVES MAILLARD, WELSH SCHOOL OF PHARMACY  
CARDIFF UNIVERSITY, WALES

Originally employed for food and water preservation, chemical microbicides have been used for centuries. There are accounts, as early as Lister's employment of carbolic acid in 1867, of their use for wound management. The advent of antisepsis and the use of chlorine water in the early 19th century issued in the era of microbicides in healthcare, and the 20th century witnessed a tremendous increase in the number of these agents. Microbicide (biocide) is now a term commonly used for a chemical compound showing antimicrobial activity and use as a disinfectant, antiseptic or preservative.

Microbicidal agents are used extensively in healthcare settings for different applications: disinfection of surfaces and water; "sterilization" of medical devices; skin antisepsis; and the preservation of various formulations. In addition, there are now numerous commercialized products containing low concentrations of microbicides, the (rapidly increasing) use of which is controversial. Indiscriminate use of disinfectants in the hospital environment is not a new problem as it was first raised in the 1960s, but it remains a current issue.

There needs to be a balance between efficacy (ie, destroying microorganisms) of a microbicide and toxicity. The increased usage of products containing low concentrations of commonly used microbicides, such as phenolics and cationic compounds such as quaternary ammonium compounds (QACs), has raised some concerns about their overall efficacy, but also about the possible emergence of microbial resistance. Indeed, there are now multiple laboratory reports about the emergence of bacterial resistance to microbicides, often as a result of exposure to a lower (sublethal) concentration. The possible development of bacterial resistance (not only to microbicides, but also to antibiotics), the benefit of microbicide usage, and their possible role in the emergence of multidrug-resistant bacteria, add further questions to the extensive use of microbicidal products. The benefits and disadvantages of microbicide usage in the healthcare environment need to be carefully considered.

### Alteration of activity

An understanding of the factors affecting antimicrobial activity is essential to ensure that a microbicidal product/formulation is used properly. A microbicide's concentration is probably the most important factor to affect antimicrobial activity. Poor understanding of the effect of dilution on microbicide antimicrobial efficacy can lead to microbial survival on surfaces, but also in products, and thus to infection or spoilage. Bacterial survival in microbicidal formulations, notably containing QACs, has been described since the 1950s and has been linked to inappropriate usage. Bacteria resistant to all known preservatives have also been reported.



# Improving Environmental Hygiene in ICUs to Decrease Multidrug-Resistant Bacterial Transmission

PHILIP C. CARLING, MD, CARITAS-CARNEY HOSPITAL, BOSTON UNIVERSITY SCHOOL OF MEDICINE

The risk of acquiring hospital-associated infections has been a recognized problem for intensive care units (ICUs) since their use became widely established 20 years ago. The medical and economic toll of these infections has created a new urgency to implement enhanced management and prevention strategies. Improving hand hygiene and isolation practices have been shown to have had limited impact, according to recent studies. Conversely, there is a growing body of evidence and documentation that pathogens, such as methicillin-sensitive and methicillin-resistant *S. aureus*, vancomycin-resistant enterococci (VRE), *Clostridium difficile*, and *Acinetobacter baumannii*, are readily transmitted from environmental surfaces to hands, and from hands to vulnerable people.

It is well evidenced that patients admitted to rooms previously occupied by individuals infected or colonized, particularly with MRSA, *A. baumannii*, and *C. difficile*, are at significant risk of acquiring these organisms from environmental sites contaminated by previous occupants. In a recently published study (Critical Care Medicine, 2010 Apr;38(4):1054-9) we attempted to determine the thoroughness of terminal disinfection and cleaning of patient rooms in hospital ICUs, and to assess the value of a structured intervention program to improve the quality of cleaning as a means of reducing environmental transmission of multidrug-resistant organisms.

## Methods

As part of a larger hospital-wide analysis of terminal disinfection cleaning in a group of 27 acute care hospitals, ranging in size from 25 to 709 beds (mean, 206 beds), we specifically evaluated the efficacy of cleaning in the intensive care units. A transparent, easily removed, environmentally stable solution (DAZO Solution) was used to evaluate the thoroughness of cleaning of 14 high-risk objects in the near-patient environment. These objects included sinks, tray tables, toilet seats, flush handles, bedside tables, side rails, call boxes, chairs, telephones, bathroom hand holds, bathroom door knobs and light switches, patient room door knobs, and bedpan cleaners.

The target solution, which dries on surfaces rapidly and fluoresces when exposed to ultraviolet light, continues to be readily detected many months after placement if not removed by physical cleaning. The removal of the target indicated only that the surface was wiped, not that chemical disinfection took place. It is a measure of the efficacy of mechanical cleaning.

Patient rooms were selected randomly as they became available, marked with our target solution before terminal cleaning, and evaluated after terminal cleaning. Following initial analysis of the thoroughness of cleaning, identical, structured educational programs were developed for the environmental services staff of each hospital. Subsequently, the thoroughness of cleaning was re-evaluated and the results were used to direct further programmatic and educational interventions (feedback cycle).

## Baseline results

In total, 3532 high-risk objects were covertly marked, and the subsequent cleanliness evaluated as baseline performance data in 260 ICU rooms/bathrooms in the 27 study hospitals (median, 11 rooms per ICU). The overall thoroughness of baseline cleanliness was 49.5%, expressed as a portion of objects evaluated. Two thirds of hospitals were within 10% of the mean, overall thoroughness of cleaning ranged widely between 9% and 85%. This finding was particularly notable (and concerning) with respect to the cleaning of the three least-well-cleaned objects, bathroom light switches (26%), room doorknobs (25%), and bedpan cleaners (21%).

## Education & feedback

Structured and standardized educational interventions were subsequently undertaken with the environmental services staff at each hospital. As well, managers at each hospital used the results of between one and three performance feedback cycles to reinforce the education and further motivate the staff toward performance expectations. The overall thoroughness of cleaning improved to 82%. For some hospital ICUs in the study, this represented as much as an 8-fold improvement above baseline. In the three least-well-cleaned objects mentioned above, particular improvement was notable - averaging 73% after intervention compared to 24% before intervention.

The study also attempted to evaluate the sustainability of the results. In six of the participating hospitals the thoroughness of cleaning was evaluated for two subsequent years. Among these hospitals, without further targeted education or performance feedback, results deteriorated between 10% and 20% from the high point of the initial study.

## Potential limitations

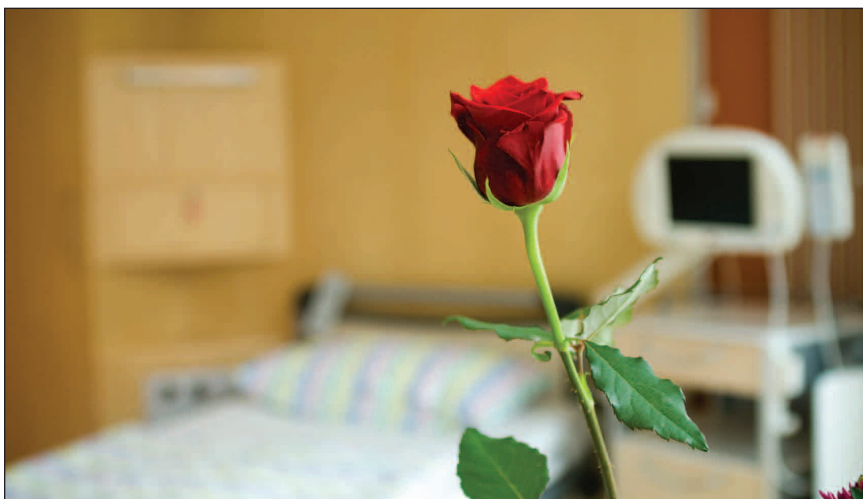
Our findings in this study should be viewed in the light of several potential limitations. The primary limitation of this study is that its design precluded an assessment of the actual impact of improved cleaning on environmental contamination with hospital-associated pathogens or their transmission. However, two environmental culture-based interventional studies – Hayden et al and Goodman et al - support the ability of programmatic enhancement of environmental cleaning to decrease environmental contamination, as well as to favorably affect transmission to patients. Haydon found that enforcement of routine environmental cleaning measures was the only intervention significantly associated with VRE cross-transmission. Goodman employed an approach similar to ours and was able to significantly reduced environmental contamination with MRSA and VRE in ten ICUs of a tertiary care referral hospital.

Despite the challenges in effecting behavioral change in healthcare settings, our large multi-centered study not only documented a widespread deficiency in a fundamental aspect of infection prevention in the ICU setting, but also demonstrated the means to achieve improvement in environmental hygiene through the use of an objective monitoring system, educational and administrative interventions, and ongoing performance feedback to environmental services personnel.



# Private Rooms Reduce Risk of Hospital-Associated Infections

JIM GAUTHIER, MLT, CIC, PROVIDENCE CARE, KINGSTON, ONTARIO



A study recently published in the American Journal of Infection Control (Hamel M, Zoutman D, O'Callaghan C. *Exposure to hospital roommates as a risk factor for health care-associated infection*. Am J Infect Control 2010;38:173-81) evaluated the association between hospital roommate exposures and the risk of hospital-associated infections (HAI).

The premise of the research is that patients exposed to a higher number of roommates have an increased number of opportunities for transmission of microorganisms between themselves and these other patients. This could occur through direct (patient to patient) and indirect (healthcare worker hands, shared surfaces) transmission. This exposure variable was looked at in two ways: 1) the daily roommate exposure, measured as the number of roommates to which a patient was exposed to on a day-to-day basis and; 2) the number of unique roommate exposures on a day-to-day basis. This second variable looked only at the number of new roommates, meaning that sharing a room for multiple days with one other roommate will only count as one exposure.

The study supports the hypothesis that for Methicillin Resistant *Staphylococcus aureus* (MRSA), Vancomycin resistant enterococci (VRE) and *C. difficile* infection (CDI), the exposure to hospital roommates is associated with an increased risk of acquiring one of these pathogens.

The total number of roommates was associated with an 11% increase of risk of acquisition of CDI, a 10% increase in the risk of MRSA and an 11% increase in the risk of VRE. The unique roommate exposure had significant findings only for VRE, with a 15% increase in risk of acquiring VRE.

The authors questioned whether it is the exposure to the actual roommate that is increasing the risk, or whether it is the presence of another person in the room and what this represents (e.g. higher traffic levels from health care personnel, potential for more visitors, indirect exposures from contamination experienced in roommates' previous accommodations, shared washrooms).

The authors conclude that not only does the risk of MRSA, VRE and CDI increase with the total number of roommates exposed to on a daily basis, but that a private room is protective against infection/colonization. The authors suggest that new hospital construction should be mainly private rooms, or at most semi-private rooms.

## MRSA Carriage in Healthcare Personnel and Farm Animals

NICOLE KENNY, VIROX TECHNOLOGIES INC

Well here's something that I wouldn't have thought about studying. A group from the PAMM Laboratory for Medical Microbiology in The Netherlands observed that Dutch people in contact with pigs tend to have a higher risk of Methicillin-resistant *Staphylococcus aureus* (MRSA) than the general population. Their investigation sought to clarify whether contact with pigs, calves, or other livestock is a risk factor for MRSA carriage among Dutch healthcare workers. This research group included several notable researchers, including one of my favorites, Dr. Andreas Voss (Journ. Hosp. Inf 2008 Oct;70(2):186-90)

Healthcare Workers at four general hospitals and one university hospital filled in questionnaires that inquired about contact with animals. Subsequently MRSA cultures were taken of their throat and nares. Cultures of those workers in contact with livestock were processed, and samples from workers with no contact with livestock were controls.

Seventy-seven of the 1721 healthcare workers (4.4%) reported direct or indirect contact with pigs and/or veal calves, and 145 reported contact with other livestock animals. The MRSA carriage rate in the group in contact with pigs and veal calves was 1.7% and in the control group was 0.15%. No carriers were found among healthcare workers in contact with other livestock.

The researchers found that approximately 3% of hospital staff working in Dutch hospitals that serve rural populations belong to a high risk group for MRSA carriage. Further, they point out that although MRSA carriage in the healthcare workers in contact with livestock is as much as 10-fold higher than in other healthcare workers, the difference is not statistically significant.

Can we draw conclusions from this study that will have an impact on clinical practice? Probably not. The data gathered, results obtained, and conclusions drawn are unique to the Dutch population studied. But still, it gives one pause.



DR. MICHAEL BORG, IFIC CHAIRMAN, MALTA

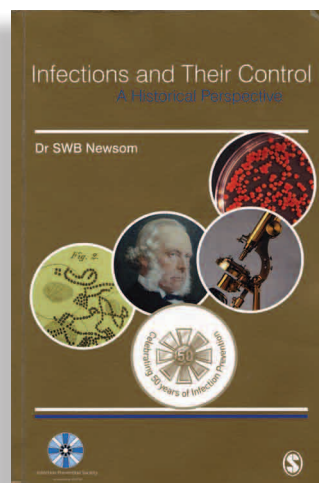
The International Federation of Infection Control (IFIC) provides global network for the prevention and control of healthcare associated infections. The Federation draws on the expertise of its member organizations to help each other and assist the development of infrastructure and output in countries still in early stages of infection control development. IFIC promotes high quality educational opportunities, including publications, teaching materials and training programs at no or low cost as well as conferences and workshops aimed to interest infection control professionals of the widest possible resource background and experience.

The IFIC web site ([www.thelific.org](http://www.thelific.org)) provides a source of information about IFIC goals and activities and is a location where infection control professionals can obtain information and resources as well as a forum for networking with organizations, agencies and IFIC corporate sponsors. The official publication of the Federation is the International Journal of Infection Control published electronically biannually at [www.ijic.info](http://www.ijic.info). It is freely accessible and no fee is requested to publish articles. It also offers help to authors from developing countries, whose first language is usually not English, with help in correcting or editing manuscripts. IFIC also publishes an e-newsletter that is also circulated to the membership on a quarterly basis.

IFIC's infection control manual, Basic Concepts in Infection Control, is authored by experts on infection control. The intent of the manual is to provide a scientific foundation for basic infection control principles, particularly for countries with limited resources. The book is available for download, free of charge, from the website and comes accompanied by a set of lecture slides. The Federation also organizes low-cost, high-quality annual congresses, often in conjunction with a local hosting member society. IFIC reviews, evaluates and supports initiatives consistent with its goals, and assists in their fruition wherever possible.

## Book Review – Infections and Their Cause, A Historical Review

PROF. GRAHAM AYLIFFE, EMERITUS PROFESSOR OF MEDICAL MICROBIOLOGY  
UNIVERSITY OF BIRMINGHAM, UK



In ancient times, infection was often considered to be due to malevolence of evil spirits, witchcraft, or the wrath of god, or later to the corruption of the air. More 'scientific' theories gradually emerged, the most important being the presence of miasmas, consisting of putrid air arising from decaying animal and vegetable matter or stagnant water and cesspools. Contagion (spread by emanation from an infected patient) was later recognized before the isolation and identification of living organisms in the late 19th century.

Dr. SWB (Bill) Newsom's series of articles begins mainly at this stage. His articles provide a wealth of information on the life and work of iconic workers in the field of infection. Particularly interesting is that so many of their colleagues did not initially accept their conclusions even when good evidence was provided.

Bill Newsom has always had a special interest in methods of sterilization. He was personally involved in the practical aspects of ensuring that the use of sterilizers in hospital was reliable and safe. He gives a fascinating account of their development over the years.

The evidence that infections were caused by living organisms and disproving the theory of spontaneous generation by Louis Pasteur in the late 19th century was one of the main advances in medicine. At about the same time Robert Koch and his colleagues identified the causative organisms of most bacterial diseases by laboratory methods, which are still in use today. Many bacteria were named after Koch's co-workers or assistants.

Sewage in the streets and rivers had long been recognized as a probable source of enteral infections, but John Snow showed that contaminated drinking water was the main hazard. His removal of the handle of the pump, which supplied well water in Broad Street, was followed by a reduction in cholera by users of the pump.

The discovery of penicillin by Alexander Fleming in 1929 and its development as a clinical agent by Florey, Chain and colleagues was followed by the discovery of a number of other antibiotics during the 1940s to the 1960s. It was suggested by some bacteriologists that penicillin provided the elimination of bacterial infections. The author's interest in staphylococci started as an adolescent when he developed recurrent boils at a time when penicillin-resistant strains were already spreading in hospitals.

Bill Newsom is an experienced medical microbiologist and research worker, with a long-standing interest in the history of bacteriology and infection. He has always stressed the importance of knowledge of the past in dealing with the problems of today. The articles in this book are eloquent, the diagrams and illustrations and his inclusion of descriptions of his personal experiences are of particular interest. The articles were originally published in the British Journal of Infection Control, and to great acclaim. A collection of them all, in one book, will be a welcome addition to the bookshelf of microbiologists, infection control professionals, and others interested in infection.



# Book Review: Soap and Water & Common Sense

NICOLE KENNY, VIROX TECHNOLOGIES INC

As far as I'm concerned, if a book doesn't make you say, "huh" at least a few times during its reading, it was not time well spent. One of the books that I read recently was peppered with such moments. If you didn't know that a group of dead flamingos in the Bronx Zoo heralded the North American landfall of West Nile Virus, or that an emergency dog-sled relay across Alaska to bring diphtheria antitoxin to the stricken community of Nome was the birth of the annual Iditarod race, then you've not read Dr. Bonnie Henry's book, "Soap and Water & Common Sense".

The title of the book was unabashedly derived from a William Osler quote, "Soap and water and common sense are the best disinfectants". From viruses to bacteria to parasites and fungi, Dr. Henry dispels some of the all-too-common myths and misinformation about good bugs and bad bugs, and offers an eye-opening account of the history of disease as well as up-to-date and accurate information on everything from the bugs we breathe to the bugs we eat and drink to the bugs in our backyard and beyond.

*"Countless hours of misery are caused by bugs called viruses, bacteria, fungi and parasites, ... much of this suffering is preventable."*

Although much of the wisdom on display in this book will not come as a surprise to professionals in infection prevention and control, it is a delightful read. Her list of the "Top 10 ways to stay healthy" that predictably starts with hand hygiene, surprisingly ends with "Use condoms". That addition gave me pause likely because it is not a preventative measure that is commonly discussed in the manufacture of surface disinfectants (where I spend my life) and is not much addressed elsewhere in the book. Nevertheless, it is an absolutely necessary addition. In fact, there are little side stories, quips, and other surprises throughout the book that keep you moving forward.

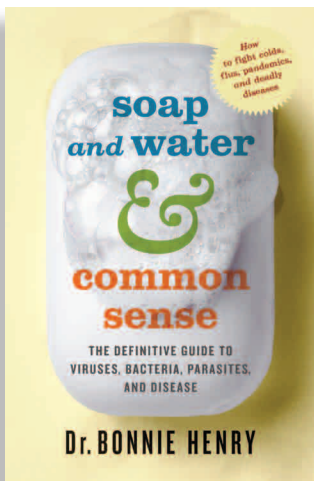
In her "Top 10 myths and truths about bugs", I found many ideas that all of us would be grateful to see disseminated in the wider community. For example:

*Myth: My immune system is healthy, so I don't need immunization. Besides, vaccines are dangerous.*

*Truth: Vaccines work with your immune system to help you fight infection. A report of a potential link between the MMR vaccine and autism has been debunked by scientific evidence. Vaccines are safe and effective, and our best protection against many infections.*

"Soap and Water & Common Sense - The Definitive Guide to Viruses, Bacteria, Parasites, and Disease" is an elegantly written book and well worth the time to read, but clearly the intended audience for this book is the larger community. Throughout you will find yourself nodding and thinking of all the people in your life to whom you want to gift a copy. Do. Pick up several and send them around. Invite your book club to discuss it. For someone who is not daily immersed in the prevention of infection, the "huh" moments will be plentiful indeed, and it may even be a life altering (or at least health-improving) experience.

Soap and Water & Common Sense: The Definitive Guide to Viruses, Bacteria, Parasites, and Disease, by Dr. Bonnie Henry, Anansi, 276 pages, (ISBN: 9781921401657) \$19.95



## GREEN TEAM UPDATES

Spring has arrived and with it came an opportunity for the Green Team to review our building maintenance and landscaping practices. Services and products were reviewed to ensure that our Landscape Service providers were conscious of their environmental impact by providing responsible solutions. We are excited to share that we are now using organic certified fertilizer manufactured by Acti-Sol ([www.acti-sol.ca](http://www.acti-sol.ca)) as part of our lawn care program and even more excited to be supporting another Canadian owned and operated company whose own desires to act responsibly and provide sustainable solutions marry when with Virox's core values.

The Green Team has also reviewed our purchasing practices for paper and printing practices for marketing literature. We are now purchasing 100% recycled content EcoLogo approved paper for our internal printing needs and all marketing materials – including the print version of this newsletter, are printed on FSC-certified paper. FSC-certified papers contain FSC-certified wood fibre from well-managed forests, postconsumer recycled content, or a combination of FSC-certified wood fibre, recycled content and other controlled forest friendly sources. FSC-certified forests protect wildlife habitat and endangered species, ensure clean water by respecting rivers and waterways, are not planted with genetically modified (GM) trees, or converted into plantations.

The last initiative we have started working on in the past several months is undergoing ISO 14001 Certification. ISO 14001 sets out requirements for an Environmental Management System (EMS) which can be employed by an organization to measure and document their environmental impact and requires the organization to take a hard look at all areas where its activities have an environmental impact. It can lead to benefits such as the following: reduced cost of waste management, savings in consumption of energy and materials, lower distribution costs, improved corporate image among regulators, customers and the public, and framework for continual improvement of environmental performance.

We look forward to keeping you updated on our initiatives!

## Conference Schedule

Virox representatives will be participating in the following functions during the upcoming months:

### May

**May 13 to 15, 2010** - Ontario Dental Association Conference

**May 17 to 19, 2010** - AIPI Annual Conference

**May 29 to June 3, 2010** - CHICA Canada National Conference

**May 31, 2010** - CHICA Canada National Conference Booth #100, 102, 104, 106

VIROX SPONSORED PRE - CONFERENCE DAY ON CLEANING, DISINFECTION AND STERILIZATION

### June

**June 10, 2010** - SickKids Partners in Pediatric Patient Safety Symposium

**June 16 to 17, 2010** - 4th National Community Health Nurses Conference

**June 17, 2010** - CHICA HANDIC & RICN Education Day

**June 18, 2010** - CHICA Manitoba Education Day

**June 20 to 23, 2010** - CIPHI Ontario Education Conference

**June 22, 2010** - TPIC's Annual BBQ and Education Meeting

### July

**July 7 to 10, 2010** - OANHSS Conference

**July 11 to 15, 2010** - APIC National Conference

We are very excited about participating in each of these conferences & education days. We wish the best to all of the various organizers and would like to thank them for their dedication and effort in organizing these very important educational opportunities. We look forward to attending and talking to all of the participants.

## Spring 2010 Virox Update

### Congratulations 2010 CHICA Scholarship Winners!!

Virox and the Patron Members (Diversey, Deb Canada, STERIS and Webber Training) would like to congratulate the 2010 CHICA Scholarship winners. Eighteen Infection Control Practitioners from across Canada were chosen by the CHICA-Canada Board of Directors. This year's winners are: Alexis Silverman, Amber-Leah Wolfe, Angela Thomas, Beverly Morgan, Cassandra Brubacher, Danielle Henri, Debbie Demizio, Debra Foster, Janice Briggs, Kathie Pender, Lola Gushue, Lyndsay O'Hara, Mary Vachon, Patsy Rawding, Sally Martin, Shelly Rempel, Sue Cooper and Sylvia Eaton.

### Partnerships in Pediatric Patient Safety Corporate Sponsor

In our continued support of facilities dedicated to patient safety, Virox is the corporate sponsor for the SickKids Foundation 6th Annual Partnerships in Pediatric Patient Safety Symposium - "Partnering in Patient Safety for a Better SickKids" - that will be taking place on June 10th at SickKids Hospital (Hollywood Theatre). The symposium will focus on enhancing awareness of the required organizational practices (ROPs) that organizations must have in place to enhance patient safety and to minimize risk. For more information on this event please contact the Patient Safety Symposium organizers at 416-813-7654, ext. 28022.

### Second Annual Virox Future Forum – Sheridan School of Business

The Virox Future Forum is an opportunity for Sheridan School of Business student leaders and successful business leaders to discuss the future needs of employment, and to help Sheridan graduates launch their successful careers in business. The forum featured top speakers including Lee-Anne McAlear, Ian Portsmouth, and Sean Wise.

*"It's great to see the business stars of tomorrow learning from the business stars of today," said Scott Stratten, professor, Sheridan College and master of ceremonies of The Virox Future Forum 2010.*



In February 2010, Sheridan's SCAET theatre was also re-named the Virox Technologies Inc Theatre in recognition of Virox's contributions to Sheridan College and the Sheridan School of Business.

*Sheridan School of Business students Sonya Jenkins, Renee Harty and Sara Laurencic join Randy Pilon, right, and Dr. Jeff Zabudsky left, for the dedication of the Virox Technologies Inc Theatre.*

### 2010 CHICA Cleaning, Disinfection and Sterilization Symposium

In line with our mandate to provide educational opportunities to the Infection Control Community, Virox has partnered with CHICA-Canada to sponsor a pre-conference day on Monday May 31st on cleaning, disinfection and sterilization at the Vancouver 2010 CHICA National conference. The day promises to provide the most current information on disinfection of the environment, medical device reprocessing, patient safety, audit tools and occupational health and safety. The breadth of subject matter is sure to lead to debate of best practices, reflection on misconceptions and lead us to search for responses in face of the challenges we face in our daily practice and research. It is in this sense that we hope to explore information, practical skills and common ground for everyone who is actively in and interested in cleaning, disinfection and sterilization. For more information on the day please check out the CHICA-Canada website at [www.chica.org](http://www.chica.org). Please visit our booth at the CHICA – Canada Conference (Booth No. 100, 102, 104, 106) for more information.

# Norovirus Outbreaks in Dutch Nursing Homes: Evaluating Infection Control Measures

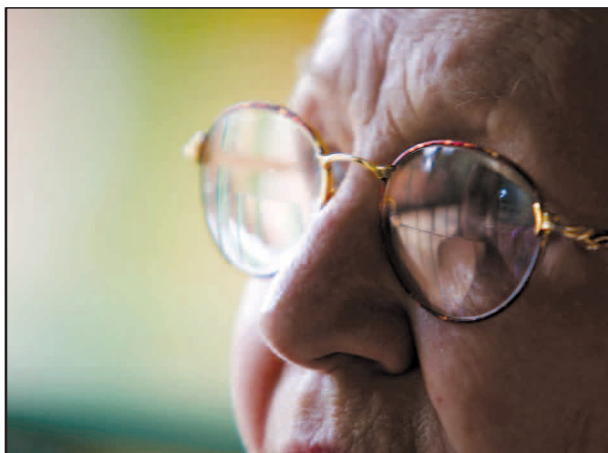
DR. INGRID FRIESEMA, CENTRE FOR INFECTIOUS DISEASE CONTROL  
NATIONAL INSTITUTE FOR PUBLIC HEALTH AND THE ENVIRONMENT (RIVM), THE NETHERLANDS

Noroviruses cause approximately 500,000 episodes of gastroenteritis per year in the Dutch population. Outbreaks seriously disrupt the daily routine in nursing homes, due to relatively high attack rates in residents requiring more care, while some of the staff are absent because of sick leave. Moreover, extra costs incurred through the implementation of infection control measures and those related to staff can turn such an event into a serious incident that should be prevented or eased wherever possible.

The onset of the disease is acute and is characterized by abdominal cramps, diarrhea, nausea, and vomiting. In rare cases, severe dehydration can occur. Most patients recover within 12–60 h, but for some people, like the elderly, the duration of illness can be prolonged. Long time shedding and recurring episodes have been described for immunocompromised patients. Norovirus is highly contagious. Infections occur mostly by person-to-person transmission through fecal–oral contact, but they can also occur indirectly via contaminated surfaces or food. A second pathway is that of droplet transmission, especially when vomit is involved. In places where vulnerable individuals gather (e.g. nursing homes) noroviruses are easily spread and can cause outbreaks. The control measures that are currently advised are mainly based upon experience from previous outbreaks and laboratory experiments on cleaning and disinfection. Field testing of different infection control protocols in nursing homes has not yet been done. In our study (Norovirus outbreaks in nursing homes: the evaluation of infection control measures, *Epidemiol. Infect.* Cambridge University Press 2009, 137(12):1722–33), a more systematic approach was chosen to investigate the effectiveness of a number of infection control measures in daily practice.

Easy-to-implement measures that were found to be widely applied in nursing homes were stringent hand washing with water and soap, and use of gloves and plastic aprons when taking care of residents. Cohorting was often mentioned as being problematic, as in most nursing homes all beds are occupied. Moreover, moving residents from their own room to another room is considered undesirable from the perspective of the residents' welfare. An alternative could be closure of the entire ward. This should incorporate no exchange of staff between wards and extra precautions for staff working throughout the entire nursing home, e.g. physicians. In that way, spread of the infection to other wards can be prevented.

Use of separate toilets for symptomatic residents/staff up to 7 days following recovery was effective for the odds of staff members becoming ill. Stringent contact precautions also appeared to be an effective way of decreasing the number of ill staff.



Norovirus can also be transmitted by aerosols. Three infection control measures dealt with this kind of transmission, and were found to reduce attack rates in staff in the univariate analyses - use of face masks when dealing with vomit, removal of exposed food, and careful closing of rubbish bags and laundry bags. Multivariately, only use of face masks remained significant. A possible explanation could be that this transmission route is less effective than the more efficient person-to-person spread and spread through contaminated surfaces. In an outbreak investigation, an inverse relationship between distance from the person vomiting and the

risk of becoming ill was found, suggesting a short-term and location-restricted transmission in case of aerosols.

Immediate cleaning of a room when contaminated with vomit or stool prevents embedding of the virus and further spread. Although the effectiveness of disinfection with 1000ppm chlorine could not be supported by a significant association in multivariate models, in univariate analyses it decreased attack rates. Use of 1000ppm chlorine may be incompatible with some surfaces, and requires correct safety measures to be taken by the cleaning staff, which can be impractical. No differences were found between disinfection with 250ppm chlorine and the use of no chlorine.

A significant decrease in the number of secondary cases per patient after implementation of new cleaning materials for every room compared to no implementation of the measure. However, this measure was not found to be related to duration of the outbreak in our analyses. The prolongation could also be caused by occasional omission of measures - when a measure is not applied, new cases emerge, but with a longer interval between successive cases than when the measure had not been implemented at all.

In conclusion, the implementation of infection control measures reduced attack rates, but had little effect on the length of the outbreak. Overall, there are staff benefits from the implementation of infection control measures, as fewer staff members will become ill. Consequently, continuous care for residents is better guaranteed as well as fewer costs for sick leave and the substitution of staff. Measures reducing transmission between persons and via contaminated surfaces appear to be the most effective. Therefore, contact precautions, and immediate cleaning of contaminated surfaces are the most effective measures for the control of an outbreak.



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Exposure time is also essential. Decreasing exposure time is often associated with a decrease in activity. Other important factors relate to the conditions in which a product is employed, mainly the presence of organic materials (which will inactivate certain microbicides), or the concurrent use of a quenching agent (eg, combining a cationic agent with an anionic surfactant), or the combined use of a microfibre cloth with a cationic agent (eg, QAC). In addition, the effect of temperature on microbicidal activity is important to understand in specific situations, for example, where microbicidal efficacy relies upon a combination of chemical inactivation and elevated temperature (eg, certain sterilization process; automated washer-disinfector). Finally, pH might not be as important here, but should not be allowed to change drastically during use. Understanding these factors is essential and the appropriate training of end users, ie, nursing and housekeeping staff, is important to ensure that the efficacy of a biocidal product/formulation is maintained.

### Bacterial resistance to microbicides

As mentioned earlier, some microorganisms are better at surviving a biocidal treatment than others, primarily through their intrinsic properties. "Impermeability barriers", encountered in spores but also in vegetative bacteria such as mycobacteria and to some extent in gram-negative bacteria, limits the amount of a microbicide that penetrates within the cell. The role of specific cell structure, such as lipopolysaccharides in gram-negative bacteria, have been demonstrated to be important in preventing the penetration (and subsequent activity) of certain microbicides in the microbial cell. The insusceptibility of gram-negative bacteria to biocidal agents can be decreased further by a change in overall hydrophobicity, outer membrane ultrastructure, protein content, and fatty acid composition.

Bacteria are also able to decrease the intracellular concentration of toxic compounds by using a range of efflux pumps. The involvement of multidrug efflux pumps in bacterial resistance to various compounds including QACs, phenolics, and intercalating agents has been widely reported, particularly in *Staphylococcus aureus*, and in gram-negative such as *Pseudomonas aeruginosa*, *Salmonella* spp. and *Escherichia coli*.

The acquisition of resistance is of notable concern since a previously sensitive microorganism can become insusceptible to a microbicide or a group of antimicrobials through, for example, the acquisition of multidrug resistant determinants. Acquired resistance can arise through several processes - mutations, the amplification of an endogenous chromosomal gene, and the acquisition of genetic determinants. Phenotypic variations resulting from microbicide exposure also might lead to bacterial resistance and this is now well supported by documented laboratory evidence. Phenotypic variation and antimicrobial resistance also concern bacterial biofilms, which are increasingly associated with bacterial contamination and infection.

### Emergence of bacterial resistance to microbicides and antibiotics

While there is ample evidence from laboratory studies of bacterial adaptation to microbicides, linkage to antibiotic resistance is not always clear-cut. Several

laboratory investigations have explored a possible linkage between bacterial resistance to antibiotics and different microbicides such as chlorhexidine and QACs. Although similar mechanisms of resistance have been identified such as impermeability, the induction of multidrug efflux pumps, over expression of multi-gene components or operons, and the alteration of a target site, the evidence in situ is lacking overall. Nevertheless, there have been a number of cases linking microbicide usage and emerging antibiotic resistance. For example, the use of chlorhexidine scrub-based preoperative showers might be associated with the emergence of methicillin-resistant *S. aureus* (MRSA), and the heavy use of QACs has been blamed for the dissemination of qac genes and the spread of efflux pumps.

### Other considerations

Microbicides are chemical agents that are usually toxic at relatively high concentration, not only for the end user, but also for the environment. The toxicity of some microbicides has been particularly well described. The use of glutaraldehyde has been associated with dermatitis and occupational asthma. Toxicity and irritation have also been reported with other microbicides such as chlorhexidine, povidone iodine, QACs, and other disinfectants and antiseptics. A recent study found that hospital staff using disinfectants might not appreciate the health risks associated with a product.

### The future of microbicides in the healthcare environment

The increased usage of microbicide in formulations needs to be balanced between the clear benefit of controlling infection and the potential risk associated with usage, not only in terms of emerging microbial resistance, but also their toxicity and environmental pollution. For a microbicidal formulation/policy to be effective, three essential components must include: knowledge of the chemical microbicide (ie, activity and limitation), training of end users, and verifiable compliance.

### Conclusion

Microbicides are essential in preventing and controlling infections in the healthcare environment and the benefits from their prudent usage currently outweigh possible disadvantages. Disinfection of noncritical surfaces and items, and the usage of microbicide-containing products, need to be reviewed, although the incorporation of microbicides into medical devices to prevent bacterial infection is promising, if controlled and assessed appropriately.

