



Endoscope disinfection using chlorine dioxide in an automated washer-disinfector

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Summary Although 2% glutaraldehyde is often the first-line agent for endoscopic disinfection, its adverse reactions are common among staff and it is less effective against certain mycobacteria and spore-bearing bacteria. Chlorine dioxide is a possible alternative and an automated washer-disinfector fitted with this agent is currently available. This study was conducted to evaluate the effectiveness of chlorine dioxide in endoscopic disinfection after upper gastrointestinal examination. In vitro microbicidal properties of chlorine dioxide solutions were examined at high (600 ppm) and low (30 ppm) concentrations against various microbes including *Pseudomonas aeruginosa*, *Helicobacter pylori*, *Mycobacterium avium-intracellulare* and *Bacillus subtilis* in the presence or absence of bovine serum albumin (BSA). Immediately following endoscopic procedures and after application to the automated reprocessor incorporating chlorine dioxide at 30 ppm for 5 min, endoscopic contamination with infectious agents, blood, *H. pylori ureA* gene DNA and HCV-RNA was assessed by cultivation, sensitive test tape, polymerase chain reaction (PCR) and reverse transcriptase-PCR analysis, respectively. Chlorine dioxide at 30 ppm has

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equivalent microbicidal activity against most microbes and faster antimicrobial effects on *M. avium-intracellulare* and *B. subtilis* compared with 2% glutaraldehyde, but contamination with BSA affected the microbicidal properties of chlorine dioxide. Endoscopic contamination with microbes, blood and bacterial DNA was eliminated after application of the automated reprocessor/chlorine dioxide system. Thus, chlorine dioxide is a potential alternative to glutaraldehyde. The use of automated reprocessors with compatibility to chlorine dioxide, coupled with thorough pre-cleaning, can offer effective, faster and less problematic endoscopic disinfection.

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Introduction

In the four decades since the introduction of flexible endoscopy into medical practice, nearly 300 cases of infectious complications involving bacteria, fungi and viruses have been linked to endoscopic procedures.^{1,2} In the majority of cases, inadequate cleaning and disinfection during the reprocessing of the instruments and/or their accessories have been likely contributing factors.^{1–4} Flexible endoscopes cannot withstand heat sterilization processes and hence are usually decontaminated by cleaning followed by disinfection with a sterilant or high-level disinfectant. Standard guidelines established by working parties have recommended exposure of the gastrointestinal endoscope to 2% glutaraldehyde for 10–20 min.^{1,3} Glutaraldehyde is effective against most viruses, fungi and vegetative bacteria,^{3,4} but it requires a longer contact time to kill atypical mycobacteria⁵ and *Bacillus* spp.⁶ Given the high volume of endoscope use in clinical settings, the reprocessing time of endoscopes should be as short as possible between procedures. Glutaraldehyde is also associated with health problems such as dermatitis, conjunctivitis and asthma among endoscopy personnel.^{3,4} Alternatives to glutaraldehyde must be non-toxic, non-irritant and rapid in action without reducing microbicidal effects. To date, no agent has completely satisfied these ideals.

Peracetic acid, superoxidized water, orthophthalaldehyde and chlorine dioxide are listed as possible alternatives to glutaraldehyde, whereas disinfectants such as chlorhexidine and iodophor solutions are not recommended.^{1,3,4} Chlorine dioxide is a powerful oxidizing agent and has been used for slime control and treatment of drinking water.^{3,7} Preparations at high concentrations of 700–1100 ppm are not only effective against most bacteria, fungi and viruses, but also rapidly

destroy resistant atypical mycobacteria and spore-bearing bacteria.^{3,4,8,9} Unfortunately, fumes given off during use may cause irritation, and it is desirable to investigate the effectiveness of lower concentrations of chlorine dioxide which are less problematic.^{3,4} An automated endoscope washer-disinfector can reduce staff contact with this disinfectant, providing a safer and preferable means of endoscopic reprocessing. The present study sought to evaluate the microbicidal properties of low-level chlorine dioxide solutions and the effectiveness of an automated washer-disinfector with special compatibility for chlorine dioxide in endoscopic disinfection after upper gastrointestinal examinations.

Methods

Chlorine dioxide and other antimicrobial agents

A chlorine dioxide formulation at a concentration of 600 ppm was obtained from Seiken (Nagoya, Japan) to evaluate microbicidal properties in vitro and in practical use. Glutaraldehyde (Johnson and Johnson, Tokyo, Japan) was used as a comparison. Chlorhexidine (ICI-Pharma, Osaka, Japan) was also used in this study. As chlorhexidine does not meet criteria for high-level disinfection or chemical sterilization, this agent was used for settings of endoscopic cleaning.^{1,3,4}

Test micro-organisms

Meticillin-resistant *Staphylococcus aureus* (MRSA), meticillin-resistant *Staphylococcus epidermidis* (MRSE), (α)-haemolytic streptococcus, *Enterococcus faecalis*, *Klebsiella pneumoniae*, *Enterobacter cloacae*, *Mycobacterium avium-intracellulare* and *Candida albicans* were obtained from clinical

specimens at Nagasaki University Hospital. *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853, *Bacillus subtilis* ATCC 6633, *Serratia marcescens* ATCC 8100 and *Helicobacter pylori* ATCC 49503 were used as additional controls.

In vitro microbicidal activity

The microbicidal properties of chlorine dioxide were assessed as described previously.¹⁰ In brief, 1 mL of each microbial suspension in saline at a density of 10^8 colony-forming units (CFU)/mL was added to 5 mL of diluted (30 ppm, with distilled water) or undiluted (600 ppm) chlorine dioxide solution, followed by incubation for 10, 60 or 300 s at room temperature for MRSA, MRSE, (α)-haemolytic streptococcus, *E. coli*, *K. pneumoniae*, *E. cloacae*, *P. aeruginosa*, *S. marcescens*, *H. pylori* and *C. albicans*, and for 60, 300 or 600 s for *B. subtilis* and *M. avium-intracellulare*. In addition, bovine serum albumin (BSA, Sigma-Aldrich, St. Louis, MO, USA) at a final concentration of 0.3 g/L was added to the disinfectants as an organic material, placed in contact with MRSA, *P. aeruginosa* and *H. pylori*, and subjected to the microbiological tests in the same way.⁸ The sample mixture (0.1 mL) was immediately transferred into tubes containing 0.9 mL of neutralizer, which was 0.5% sodium thiosulphate in normal saline (0.85% NaCl) with 0.5% Tween 80, transferred on appropriate media and cultivated under specific conditions as follows: MRSA, MRSE, (α)-haemolytic streptococcus, *E. coli*, *K. pneumoniae*, *E. cloacae*, *S. marcescens*, *P. aeruginosa* and *B. subtilis* on sheep blood agar (Japan Becton-Dickinson, Tokyo, Japan) at 37 °C for two days; *H. pylori* on Helicobacter-selective agar (Nissui Pharmaceutical, Tokyo, Japan) at 37 °C in 5% O₂ and 15% CO₂ for seven days; *C. albicans* on Sabouraud agar (Nissui Pharmaceutical) at 30 °C for two days; and *M. avium-intracellulare* on egg-based Ogawa agar (Nissui Pharmaceutical) at 37 °C for up to six weeks. The microbicidal activity was expressed as mean CFU/0.1 mL of recovered micro-organisms in accordance with Haley *et al.*¹¹ The microbicidal properties for other disinfectants were evaluated in the same way. For each microbiological test, at least three independent experiments were performed.

Effects of chlorine dioxide and glutaraldehyde on microbial contamination acquired during upper gastrointestinal endoscopy

A video endoscope (GIF-XQ200, Olympus, Hachioji, Japan), which had been in use for some time, was

used in the endoscopy unit at Nagasaki University Hospital for upper gastrointestinal screening of 60 patients, who were the first cases on each endoscopic day to avoid exogenous infections (mostly between patients) transmitting during endoscopy. Twenty-four of the 60 patients were diagnosed as having *H. pylori* infection using serology (HEL-p TEST, AMRAD Co., Melbourne, Australia) and urea breath test (UBiT, Otsuka Pharmaceutical, Tokushima, Japan).¹² None of the patients were infected with hepatitis B virus (HBV), whereas hepatitis C virus (HCV) infection was identified in six patients based on serological examination. Endoscopic contamination by micro-organisms was assessed in accordance with Tsuji *et al.*¹³ with slight modifications. After endoscopic procedures, the endoscope was wiped with sterile gauze, and forceps and aspiration channels were rinsed with 20 mL of saline. The gauze and saline were collected into a sterile container, and an aliquot was subjected to the assessment of microbial contamination using appropriate culture media, as described above. A well-trained staff member (KK) performed manual cleaning that consisted of washing the instrument surface and accessible channels with an enzymatic detergent (Endozime AW Plus, Ruhof, Mineola, NY, USA) in accordance with established guidelines.^{1,3} Thereafter, the endoscope was randomly soaked either with 2% glutaraldehyde for 10 min or with chlorine dioxide solution (30 ppm) for 5 min, and subjected to microbiological assessment.

Next, the antimicrobial effects of the automated washer-disinfector specially fitted with chlorine dioxide (ESPAL; Seiken) were evaluated. The concentration of and exposure time to chlorine dioxide were set at 30 ppm for 5 min, respectively, based on the antimicrobial results. The XQ200 endoscope, which had been in use for some time, was used for upper gastrointestinal examinations of 30 patients, among whom 12 and 5 were infected with *H. pylori* and HCV, respectively, in the endoscopy unit at Shunkaikai Inoue Hospital. Before and after cleaning/disinfection employing the equipment, microbial contamination was assessed as described above. Contamination of the endoscope with blood was also examined using Haemastix (Bayer-Sankyo, Tokyo, Japan) immediately after endoscopic procedures and after the application of ESPAL. Furthermore, using sample aliquots from the endoscope used for *H. pylori*- or HCV-infected patients, contamination with the *H. pylori ureA* gene and HCV ribonucleic acid was analysed by seminested polymerase chain reaction (PCR)¹³ and reverse transcriptase PCR,¹⁴ respectively. The PCR-based analyses were

performed immediately after endoscopic procedures and again after ESPAL.

The concentration of chlorine dioxide was monitored daily before use in this study and the solution was discarded after each procedure.

Results

In vitro microbicidal properties of chlorine dioxide and other disinfectants

Chlorine dioxide solution at either 30 ppm or 600 ppm, as well as 2% glutaraldehyde, killed MRSA, MRSE, α streptococcus, *E. coli*, *E. faecalis*, *K. pneumoniae*, *E. cloacae*, *P. aeruginosa*, *S. marcescens*, *H. pylori* and *C. albicans* within 10 s of contact (Table I). However, 0.05% chlorhexidine was less effective for MRSE, *E. cloacae* and *C. albicans* and did not kill MRSA or MRSE, even after 300 s of contact (Table I). Chlorine dioxide solutions at either 600 or 30 ppm killed *M. avium-intracellulare* within 60 s of contact, whereas 2% glutaraldehyde exerted bactericidal effects 300 s after exposure (Table II). Thus, glutaraldehyde 2% showed slower bactericidal activity against *M. avium-intracellulare* than chlorine dioxide. Chlorhexidine 0.05% did not kill *M. avium-intracellulare* or *B. subtilis*, even after 600 s of contact.

There was no significant impact of BSA on the antimicrobial effects of glutaraldehyde and chlorhexidine, whereas contamination by organic material affected the microbicidal properties of chlorine dioxide; neither the 30 ppm nor the 600 ppm solution killed any bacteria examined, even after 300 s of contact (Table III).

Effects of chlorine dioxide and glutaraldehyde on microbial contamination acquired during upper gastrointestinal endoscopy

Eleven bacterial species and *C. albicans* were recovered from the endoscopes used for 42 of 60 patients (Table IV) just after procedures. *Streptococcus* spp., followed by *Neisseria* spp., which are the normal oral flora, were most commonly isolated from the upper gastrointestinal endoscopes after use. *H. pylori* grew on selective media from the pre-reprocessing endoscopes in three of 24 positive cases. Less frequently, *P. aeruginosa* and *S. marcescens*, whose growth is favoured by moist environments, and endogenous intestinal flora such as *Klebsiella* spp., *E. faecalis*,

Table I In vitro microbicidal activity of disinfectants against various infectious agents

Infectious agent	Recovery after each contact time with each disinfectant (CFU/0.1 mL)												
	Chlorine dioxide (600 ppm)			Chlorine dioxide (30 ppm)			2% Glutaraldehyde			0.05% Chlorhexidine			Control
	10 s	60 s	300 s	10 s	60 s	300 s	10 s	60 s	300 s	10 s	60 s	300 s	
MRSA	0	0	0	0	0	0	0	0	0	>500	>500	>500	>500
MRSE	0	0	0	0	0	0	0	0	0	>500	484	15	>500
α Streptococcus	0	0	0	0	0	0	0	0	0	>500	0	0	>500
<i>Enterococcus faecalis</i>	0	0	0	0	0	0	0	0	0	>500	0	0	>500
<i>Escherichia coli</i>	0	0	0	0	0	0	0	0	0	0	0	0	>500
<i>Klebsiella pneumoniae</i>	0	0	0	0	0	0	0	0	0	1	0	0	>500
<i>Enterobacter cloacae</i>	0	0	0	0	0	0	0	0	0	5	5	3	>500
<i>Pseudomonas aeruginosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	>500
<i>Serratia marcescens</i>	0	0	0	0	0	0	0	0	0	0	0	0	>500
<i>Helicobacter pylori</i>	0	0	0	0	0	0	0	0	0	0	0	0	>500
<i>Candida albicans</i>	0	0	0	0	0	0	0	0	0	>500	>500	0	>500

MRSA, methicillin-resistant *Staphylococcus aureus*; MRSE, methicillin-resistant *Staphylococcus epidermidis*, CFU, colony-forming units; s, seconds. For control, distilled water was used.

Table II In vitro bactericidal effects of disinfectants on *Mycobacterium avium-intracellulare* and *Bacillus subtilis*

Infectious agent	Recovery after each contact time with each disinfectant (CFU/0.1 mL)												Control
	Chlorine dioxide (600 ppm)			Chlorine dioxide (30 ppm)			2% Glutaraldehyde			0.05% Chlorhexidine			
	60 s	300 s	600 s	60 s	300 s	600 s	60 s	300 s	600 s	60 s	300 s	600 s	
<i>Mycobacterium avium-intracellulare</i>	0	0	0	0	0	0	>500	0	0	>500	>500	>500	>500
<i>Bacillus subtilis</i>	>500	0	0	>500	0	0	>500	>500	0	>500	81	52	>500

CFU, colony-forming units; s, seconds.

E. cloacae and *E. coli* were recovered. None of the microbes were detected from the endoscope after exposure to either chlorine dioxide (30 ppm) or 2% glutaraldehyde (Table IV).

Although seven microbial species grew from the endoscope immediately after endoscopic examination in 19 of 30 patients, none were recovered from the endoscopes after reprocessing with ESPAL. Contamination with blood was found in 13 of 30 cases tested just after endoscopic procedures, whereas the sensitive test tapes did not detect occult blood from the endoscopes after ESPAL. PCR identified *H. pylori* genomic DNA in 10 of 12 *H. pylori*-positive cases, whereas ESPAL completely eliminated the *ureA* gene from the endoscopes (Figure 1). HCV-RNA was not detected before or after ESPAL.

After disinfection using chlorine dioxide, problems such as interference with endoscopic function, channel blockage, corrosion and cosmetic surface changes were checked every day. No functional or cosmetic damage was noted in the instruments or accessories during repeated applications of chlorine dioxide to endoscopes. Glutaraldehyde 2% also had no effect on endoscopes during the study.

Discussion

The present study demonstrated that chlorine dioxide solution at lower concentrations than

applied previously was as effective as 2% glutaraldehyde against non-spore-bearing bacteria and fungus. The chlorine dioxide solutions had faster microbicidal effects on *B. subtilis* and *M. avium-intracellulare* compared with glutaraldehyde. Indeed, endoscopes contaminated after upper gastrointestinal examination were successfully disinfected by low-level chlorine dioxide solution either manually or by using the automated reprocessor. These findings indicate that chlorine dioxide can be listed as a potential alternative to 2% glutaraldehyde, offering the prospect of rapid high-level disinfection in endoscopy units.

When choosing an agent/method for disinfection of endoscopes, the first consideration is microbicidal performance. For this purpose, in vitro microbicidal properties of chlorine dioxide were tested against a variety of pathogens, most of which were detected from the upper gastrointestinal endoscopes before reprocessing.¹⁵ It was not possible to reaffirm the antiviral activity of chlorine dioxide as HCV-RNA was not detected from the endoscopes used for HCV-infected patients even before disinfection, but chlorine dioxide can destroy HBV (with easy probability of transmission in nature) within 2–5 min and human immunodeficiency virus within 2 min.^{1,4} The vegetative bacterium *P. aeruginosa* is most commonly reported in infections related to endoscopic procedures.^{1,2} It is of note that endoscopic transmission of *P. aeruginosa* resulted in mediastinitis or fatal septicaemia in leukaemic patients.¹⁶ Since

Table III In vitro bactericidal activity of disinfectants in the presence of bovine serum albumin (0.3 g/L)

Infectious agent	Recovery after each contact time with each disinfectant (CFU/0.1 mL)												Control
	Chlorine dioxide (600 ppm)			Chlorine dioxide (30 ppm)			2% Glutaraldehyde			0.05% Chlorhexidine			
	10 s	60 s	300 s	10 s	60 s	300 s	10 s	60 s	300 s	10 s	60 s	300 s	
MRSA	>500	>500	>500	>500	>500	>500	0	0	0	>500	>500	>500	>500
<i>Pseudomonas aeruginosa</i>	>500	>500	>500	>500	>500	>500	0	0	0	0	0	0	>500
<i>Helicobacter pylori</i>	>500	>500	>500	>500	>500	>500	0	0	0	0	0	0	>500

MRSA, methicillin-resistant *Staphylococcus aureus*; CFU, colony-forming units; s, seconds.

Table IV Impact of disinfection processes using chlorine dioxide or glutaraldehyde preparations on microbial contamination of endoscopes during upper gastrointestinal examinations

Infectious agent	Chlorine dioxide (30 ppm)		After disinfection	2% Glutaraldehyde		After disinfection
	After endoscopic procedures	Microbial titres (CFU/mL)		After endoscopic procedures	Microbial titres (CFU/mL)	
<i>α</i> Streptococcus	18/30 ^a	10 ⁴ –2 × 10 ⁶	0/30	24/30	10 ⁴ –4 × 10 ⁶	0/30
<i>γ</i> Streptococcus	16/30	10 ⁵ –2 × 10 ⁶	0/30	14/30	10 ⁵ –2 × 10 ⁶	0/30
<i>Neisseria</i> spp.	7/30	10 ³ –4 × 10 ⁶	0/30	13/30	10 ⁴ –5 × 10 ⁶	0/30
<i>Serratia marcescens</i>	3/30	10 ⁴ –10 ⁵	0/30	1/30	10 ⁵	0/30
<i>Helicobacter pylori</i>	1/30	5 × 10 ³	0/30	2/30	2 × 10 ³ –2 × 10 ⁴	0/30
<i>Klebsiella pneumoniae</i>	2/30	5 × 10 ³ –10 ⁴	0/30	1/30	10 ⁵	0/30
<i>Pseudomonas aeruginosa</i>	1/30	10 ⁴	0/30	1/30	2 × 10 ⁴	0/30
MRSA	ND			2/30	10 ⁵ –2 × 10 ⁶	0/30
<i>Enterobacter cloacae</i>	ND			2/30	10 ³ –2 × 10 ⁵	0/30
<i>Escherichia coli</i>	1/30	10 ⁴	0/30	ND		
<i>Candida albicans</i>	ND			1/30	10 ³	0/30

MRSA, methicillin-resistant *Staphylococcus aureus*; CFU, colony-forming units; ND, not detected.

^a Data represent the number(s) of positive cases per 30 cases.

Langenberg *et al.*¹⁷ documented compelling evidence of endoscopic transmission of *H. pylori* by restriction endonuclease DNA analysis, several lines of direct evidence have revealed severe gastritis caused by cross-infection with *H. pylori* via gastrofibrescope.¹⁸ As a consequence of gastritis,

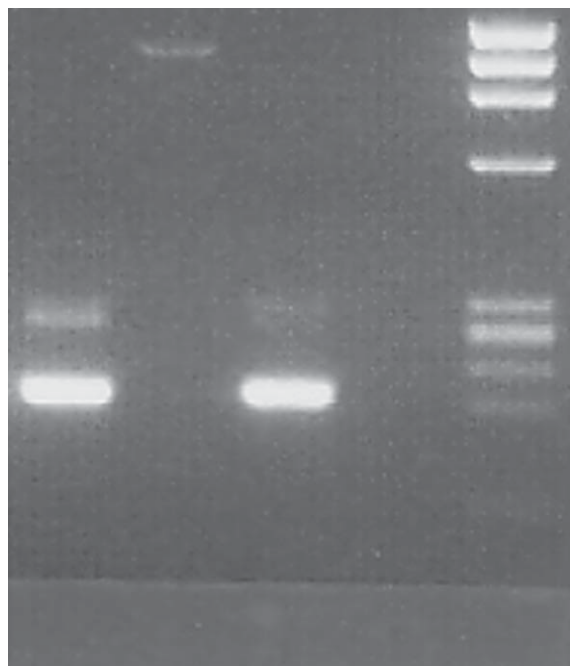


Figure 1 Semi-nested polymerase chain reaction amplification of the *Helicobacter pylori* *ureA* gene. Samples 1 and 2 were taken just after endoscopic procedures and after the use of an automated washer-disinfector, respectively. P, positive control; N, negative control; M, molecular size markers.

persistent *H. pylori* infection is implicated in the pathogenesis of serious upper gastrointestinal diseases including peptic ulcer, gastric cancer and lymphoma.¹⁹ Hence, preventing endoscopic transmission of this organism by adequate reprocessing is of clinical importance. Indeed, chlorine dioxide solutions were highly effective against these pathogens, as well as the other aetiological agents responsible for opportunistic or nosocomial infections,¹⁵ with equivalent microbicidal properties to 2% glutaraldehyde.

However, when contaminated with BSA as an organic material,⁸ chlorine dioxide at ≤600 ppm, but not glutaraldehyde or chlorhexidine, exhibited lower antimicrobial effects compared with those in non-contaminated conditions. The same was true for the other oxidizing disinfectant, superoxidized water; its microbicidal activity was almost lost in the presence of BSA.²⁰ Contamination with the *ureA* gene, in cases of *H. pylori* infection and occult blood, was often detected from endoscopes before the manual cleaning process. It has also been reported that pre-cleaning can achieve a 10³- to 10⁴-fold reduction in microbial contamination load.²¹ These data highlight the indispensability of thorough cleaning to remove blood, mucus and other organic material from endoscopic instruments and components prior to subsequent disinfection steps.

M. avium-intracellulare is known to be resistant to glutaraldehyde, and a much longer contact time is required to destroy *B. subtilis* spores,^{1,3,5,6} as confirmed in the present study, providing stringent tests for the new disinfectant. Chlorine dioxide solutions displayed more rapid microbicidal activity

against these resistant bacteria.^{3,8} In support of this, disinfection with chlorine dioxide successfully eradicated glutaraldehyde-resistant *M. chelonae* isolated from rinse water within the endoscope reprocessor.²² Although described by manufacturers as 'user-safe', an unpleasant irritating odour is given off during preparation and use, and health surveillance of staff is still needed. As the quantity of fumes increases with the concentration of chlorine dioxide,⁸ the authors sought to successively evaluate microbicidal properties of low-level solutions. At a concentration of 30 ppm, but not at lower levels (data not shown), chlorine dioxide killed intractable spore-bearing organisms and atypical mycobacterium within 5 min of contact.

Thus, the exposure time to and concentration in solution of chlorine dioxide were set at 30 ppm for 5 min, respectively. Once it had been confirmed that microbial contamination after endoscopic procedures was completely removed by manual disinfection with chlorine dioxide at these settings, the automated washer-disinfector ESPAL incorporating this disinfectant was applied to practical reprocessing of upper gastrointestinal endoscopes. After use of the ESPAL/chlorine dioxide system, no isolates were recovered from the endoscopes after procedures. Furthermore, microbial nucleic acids and blood were successfully decontaminated with this reprocessing system. Although functional and cosmetic damage to flexible endoscopes, including corrosion and discoloration with protein stains, are possible concerns when contemplating a switch from glutaraldehyde to such oxidizing disinfectants as chlorine dioxide, paracetic acid and superoxidized water,^{3,4,8} there were no functional or cosmetic changes in endoscopes reprocessed with chlorine dioxide during this study. In addition to minimizing contact time and the concentration of the solution, the ESPAL system involves several ways to reduce the risk of damage; i.e. incorporating corrosive inhibitors into the chlorine dioxide solution and thorough and repeated rinsing with water. Addition of an anti-oxidizing agent in the final rinse water and a protective coating on to the outer surface of the endoscope may further reduce the risk. It is, however, apparent that long-term monitoring is warranted, especially where there is heavy use of a limited number of endoscopes. In this respect, a superoxidized water, Sterilox, which has a pH of 5.0–6.5 and an oxidation-reduction potential (redox) of >950 mV, is claimed to be non-corrosive and non-damaging to endoscopes and processing equipment.²³ Since it is also effective in killing spores, mycobacteria and a wide range of other potentially pathogenic micro-organisms

associated with endoscopic procedures,²³ this new superoxidized water would be a possible alternative to chlorine dioxide.

The chlorine dioxide formulation supplied at 600 ppm costs more per gallon than the retail glutaraldehyde preparation (\$18.90 vs \$13.20). The automatic reprocessor requires about six gallons of either chemical for every 14-day use period, totalling \$113.4 vs \$79.2, respectively. Although concentrations of 150–250 ppm of chlorine dioxide are commonly used for endoscope disinfection,⁸ the chlorine dioxide solution at 30 ppm had acceptable microbicidal properties both in vitro and in practical use, and thus would still represent a cost saving and further reduce the likelihood of corrosion.

Clostridium difficile is an increasingly common nosocomial pathogen. The authors did not study the potential of chlorine dioxide to inactivate *C. difficile* spores. More recently, Perez *et al.* showed that chlorine dioxide needed approximately 30 min for not less than 6 log₁₀ reduction in the viability titre of the spores.²⁴ In their study, such oxidative microbicides as acidified bleach and Virox STF containing 7% hydrogen peroxide could inactivate the spores within 10 min of contact.²⁴

In conclusion, minimizing the concentration of and exposure time to chlorine dioxide solution while maintaining its high and rapid microbicidal activity encouraged the authors to incorporate this agent into the automated washer-disinfector. This can result in less problematic and faster reprocessing of flexible endoscopes, contributing to a cost-effective increase in endoscope throughput and eventually to improved patient satisfaction in medical services.

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