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ORIGINAL ARTICLE

Proactive infection control measures to prevent nosocomial transmission of vancomycin-resistant enterococci in Hong Kong

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proactive infection control;
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Background/Purpose: The study describes a proactive infection control approach to prevent nosocomial transmission of vancomycin-resistant enterococci (VRE) and tests if this approach is effective for controlling multiple-drug resistant organisms in a nonendemic setting.
Methods: In response to the increasing prevalence of VRE in Hong Kong since 2011, we adopted a multifaceted assertive approach in our health care network. This included active surveillance culture, extensive contact tracing, directly observed hand hygiene in conscious patients before they received meals and medications, stringent hand hygiene and environmental cleanliness, and an immediate feedback antimicrobial stewardship program. We report the occurrence of VRE outbreaks in our hospital after institution of these measures and compared with the concurrent occurrence in other public hospitals in Hong Kong.
Results: Between July 1, 2011 and November 13, 2013, VRE was identified in 0.32% (50/15,851) of admission episodes by active surveillance culture. The risk of VRE carriage was three times higher in patients with a history of hospitalization outside our hospital networks in the past 3 months (0.56% vs. 0.17%; $p = 0.001$) compared with those who were not. Extensive contact

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tracing involving 3277 patient episodes was performed in the investigation for the 25 VRE index patients upon whom implementation of contact precautions was delayed (more than 48 hours of hospitalization). One episode of VRE outbreak was identified in our hospital network, compared with the 77 VRE outbreaks reported in the other hospital networks (controls) without these proactive infection control measures.
Conclusion: Our multifaceted assertive proactive infection control approach can minimize the nosocomial transmission and outbreak of VRE in a nonendemic area.

Introduction

Vancomycin-resistant *Enterococcus* (VRE) has become a major nosocomial pathogen in many parts of the world since its first report in Europe in 1987.[1–6] In North America, there was a significant increase of VRE from 0.3% of all isolates in 1989 to over 28% in 2004.[7,8] VRE survives on the hands of health care workers (HCWs) and in hardy environments for up to 1 hour and 4 months, respectively,[9,10] which may have contributed to the global dissemination of VRE in the health care setting.[11]

In Hong Kong, we have been vigilant against emerging and re-emerging pathogens after the outbreak of SARS in 2003.[12,13] Hand hygiene practice, with an emphasis on directly observed hand hygiene, has demonstrated much success in the prevention and control of nosocomial outbreaks of viruses,[14–17] and multiple drug resistant organisms (MDROs) including methicillin-resistant *Staphylococcus aureus*,[18] carbapenemase-producing Enterobacteriaceae,[19] and VRE[20] in our health care network.

However, an increasing number of sporadic cases of VRE is observed in Hong Kong and has caused nosocomial outbreaks since the 4th quarter of 2010. To prevent nosocomial VRE transmission in our health care network, which includes transplantation and oncology service, proactive infection control measures using a combination of active surveillance culture, early single room isolation and strict contact precautions, directly observed hand hygiene practice in HCWs and conscious patients, environmental disinfection, and extensive contact tracing to identify secondary cases was introduced. These proactive infection control measures are particularly important in our hospital network because immunocompromised patients have the highest reported risk of VRE bacteremia and associated mortality after gastrointestinal colonization of VRE.[21,22] VRE outbreak has also led to temporary closure of intensive care units and oncology service.[23–25] We aim to minimize nosocomial transmission of VRE in our hospital network by implementation of the proactive infection control measures, while gauging our performance by comparing the occurrence of VRE outbreaks in other public hospitals in Hong Kong as control.

Materials and methods

Laboratory diagnosis of VRE

Rectal swabs with visible fecal components were collected and sent to microbiology laboratory on the same day for VRE screening. These specimens were inoculated onto chromogenic agar (chromID VRE, BioMérieux, Marcy-l'Étoile, France) and were incubated aerobically at 35°C for 48 hours. All enterococci were identified to species level by the commercial Vitek Gram-positive identification card (BioMérieux), motility and colonial pigment production. The Kirby–Bauer disk diffusion method and E-test (AB Biodisk, Solna, Sweden) were used to determine the antimicrobial susceptibility of the enterococci according to the Clinical and Laboratory Standards Institute or the manufacturer's instructions. Isolates with potential vancomycin resistance were confirmed by polymerase chain reaction as previously described.[26]

Epidemiology of VRE in our hospital network

Our hospital network includes a 1600-bed tertiary referral university-affiliated acute hospital, Queen Mary Hospital (Hong Kong Special Administrative Region, China), and three other extended-care hospitals (hospitals M, P, and Q) with another 1600 beds. In response to the increasing prevalence of VRE in Hong Kong, an active surveillance culture program was initiated in our network. The active surveillance culture was described as the "whom TO screen model", as previously described,[19,26] taking the acronym of **T** as history of medical **t**ourism with hospitalization outside Hong Kong, and **O** as history of receiving surgical **o**peration outside Hong Kong, within the past 12 months prior to admission. Patients with a history of admissions to local hospitals other than Queen Mary Hospital in the past 3 months were also included in the active surveillance. Rectal swabs were collected from patients, who fulfilled the aforementioned criteria, to identify patients with asymptomatic gastrointestinal VRE carriage. This study was conducted between July 1, 2011 and November 13, 2013 with approval by the institutional review board. To understand the epidemiology of VRE among patients with and without risk factors in our hospital network and our community, universal admission screening of VRE was performed in all acute medical admissions for 50 days (from September 25, 2013 to November 13, 2013).

Proactive infection control measures for VRE

The hospital information system was screened during weekdays by the infection control team (ICT) to identify newly admitted patients fulfilling criteria for VRE screening. Telephone reminders to frontline staff were provided by ICT when rectal swab was not collected from

these patients within 24 hours of admission. As part of the proactive infection control measures, during infectious disease consultation service, clinical microbiologists would request additional VRE screening for patients transferred from other local hospitals with an ongoing VRE outbreak announced by the Centre for Health Protection, Department of Health, Hong Kong, especially those treated with broad spectrum antibiotics, such as vancomycin, extended-spectrum β-lactam−β-lactamase inhibitors, and carbapenem groups of antibiotics, regardless of any initial negative VRE admission screening by rectal swabs. ICT was notified when suspected VRE isolates were detected from CHROMagar screening of rectal swabs or other clinical specimens such as urine, sputum, wound swab, sterile body fluid, or blood culture.

ICT assessed all VRE-positive patients at bedside to recommend and monitor appropriate infection control measures. Extensive contact tracing for secondary cases was performed when a VRE index patient hospitalized for more than 48 hours was identified. Extensive contact tracing included the entire period of hospitalization of the index patient, covering all potentially exposed patients. Immediate VRE screening was conducted in all potentially exposed patients who were still hospitalized within our hospital network. Discharged exposed patients were labeled as "VRE contact patients" in the hospital computer system by ICT, which serves to alert VRE screening upon hospital readmission in these patients. For exposed patients discharged to residential care homes for elderly (RCHE), site visit and collection of rectal swabs were done by the community geriatric assessment teams within 1 week. These teams, comprised of geriatricians, nurses, and allied health professionals, provide regular on-site visits, comprehensive medical follow-up and recommendations on infection control measures at the RCHE within our health care region.[27] If a secondary VRE-positive case was confirmed in the RCHE, all residents in that RCHE would be screened for asymptomatic gastrointestinal carriage of VRE.

Nosocomial outbreak was defined as three or more laboratory confirmed cases of hospital-acquired VRE with an epidemiological link in the same ward. The source of VRE nosocomial transmission was investigated by ICT to identify areas for improvement.

Directly observed hand hygiene in patients was promoted as a new core infection control component. Alcohol-based handrub was delivered to all conscious patients immediately before meals and medications. Alcohol foam and handrub was also made available in patient's toilets. Patients were encouraged to disinfect toilet seats before use and to clean hands after toileting. When a bedpan was used, a wet tissue was provided to patients for wiping hands, followed by directly observed hand hygiene using alcohol-based handrub applied by health care assistants. "出入口管制", meaning "entry and exit control", was the slogan for this campaign to highlight the key measures in breaking the fecal−oral transmission of VRE during mouth cleansing or dispensing meals, nasogastric, or gastrostomy tube feeds and medications. Emphasis on hand hygiene using an alcohol-based handrub among HCWs in our hospital network, with ongoing regular audits, continued as previously described.[28] The consumption data of alcohol-based hand rub retrieved from the pharmacy was calculated in terms of L/1000 patient-days. Environmental cleaning of clinical areas was performed by supporting staff according to the hospital protocol, whereas ICT conducted teaching and regular audit of environment cleanliness.

Open staff forum and special education sessions were arranged by ICT. "Road shows" on the importance of infection control measures, especially on the practice of "entry and exit control", took place in all of the wards, providing an opportunity to meet the frontline HCWs at their handover meeting between morning and afternoon work shifts. Uninformed visits were also made to clinical areas by infection control nurses to detect any lapse in infection control practice.

An antibiotic stewardship program was conducted according to the established protocol,[29] and the consumption of broad spectrum antibiotics with potential for selecting MDROs including cefotaxime, ceftriaxone, ceftazidime, cefepime, piperacillin, cefoperazone/sulbactam, piperacillin−tazobactam, ticarcillin−clavulanate, meropenem, imipenem−cilastatin, vancomycin, linezolid (intravenous/*per os*), ciprofloxacin (intravenous/*per os*), levofloxacin (intravenous/*per os*), moxifloxacin (intravenous/*per os*), and ofloxacin (intravenous/*per os*) in the specialties of intensive care and high dependency units, medicine, oncology, orthopedic surgery, and surgery was described.

Nosocomial outbreak of VRE in Hong Kong as a concurrent control

In Hong Kong, there are seven hospital networks comprising 42 public hospitals under the management of Hospital Authority serving over 90% of the local population of 7 million. Outbreaks with public health impact were reported to the Hospital Authority and a press release with relevant information would be uploaded to the Hospital Authority News Centre for public access as previously described.[16] Detailed descriptions of each VRE outbreak were retrieved from the Hospital Authority News Centre (http://www.ha.org.hk/visitor/ha_visitor/). The number of nosocomial outbreaks of VRE in all seven hospital networks between July 1, 2011 and November 13, 2013 was recorded as concurrent control.

Statistical analysis

Chi-square test, Fisher's exact test, or *t* test, was used where appropriate. A p-value ≤ 0.05 was considered to be statistically significant. Computation was performed using the SPSS version 18.0 for Windows, IBM Corporation, New York, USA.

Results

Epidemiology of VRE in our hospital network

A total of 68 patients were positive for *Enterococcus faecium*, of which 66 patients had fecal carriage and two patients had VRE first isolated from urine specimens during our study period. There were 41 male and 27 female patients with a median age of 72 years (range, 12−96 years). Prevalence of VRE among patient groups of active

surveillance culture in our hospital network is illustrated in Table 1. Overall, VRE was identified in 0.32% (50/15,851) of admission episodes under our active surveillance program. The risk of VRE carriage was two to three times higher in patients with a history of hospitalization outside Hong Kong in the past 12 months (0.46% vs. 0.17%, $p = 0.018$), and outside our hospital networks in the past 3 months (0.56% vs. 0.17%, $p = 0.001$). Extensive contact tracing were performed in 25 index patients with identification of VRE carriage or infection after 48 hours of hospitalization. Of 3277 patient episodes screened for VRE (average 131 patient episodes were traced per 1 index VRE patient), 18 (0.55%) were VRE positive, which included a cluster of 10 secondary cases, as previously described,[26] occurred in the early phase of our control program. The incidence of nosocomial acquisition of VRE had significantly decreased from 0.46 per 10,000 patient-days in the early phase (July–December 2011) of the control program, to 0.10 per 10,000 patient-days in the remaining phase (from January 2012 to November 13, 2013), ($p < 0.001$ under Poisson assumptions). Overall, 1300 (39.7%) of 3277 patient episodes were screened during the same hospitalization, 1710 (52.2%) were screened upon readmission, and 267 (8.1%) were screened at the RCHE. None of the elderly screened in residential care homes was VRE positive.

Nosocomial transmission of VRE occurred in nine (36%) of the 25 episodes of extensive contact tracing (Table 2). Delayed isolation of VRE-positive index cases was significantly associated with the occurrence of nosocomial transmission (Table 3). In one episode (episode 16 in Table 2), the rectal swab for VRE culture was "falsely" negative on admission screening, but VRE carriage status was subsequently revealed in a repeated rectal swab requested by clinical microbiologist during consultation service, resulting in a 14-day delay in the patient's isolation. Contact tracing was not performed in the other 25 VRE-positive patients who were identified and isolated with strict contact precautions within 48 hours of hospitalization.

Table 1 Prevalence of vancomycin-resistant enterococci (VRE) among different patient groups of active surveillance culture in our hospital network.

Active surveillance culture[a]	Prevalence of VRE
(1) Episodes of patient fulfilling "whom TO screen" criteria[b]	10/2175 (0.46%)
(2) Episodes of patient directly transfer-in from local hospitals outside our hospital network	6/1557 (0.39%)
(3) Episodes of patient with history of hospitalization from local hospitals outside our hospital networks in the past 3 months[c]	22/3907 (0.56%)
(4) Episodes of patient with history of hospitalization within our hospital networks in the past 3 months[d]	12/6891 (0.17%)
(5) Episodes of patient referred from residential care home for elderly and without history of hospitalization in the past 3 months[e]	0/240
(6) Episodes of patient referred from home and without history of hospitalization in the past 3 months[e]	0/1081

[a] Including those patients with delay collection of screening specimens after 48 hours of hospitalization.
[b] "Whom TO screen" model, taking the acronym of T as a history of medical tourism with hospitalization outside Hong Kong, and O as a history of receiving surgical operation outside Hong Kong, within the past 12 months prior to admission.
[c] 3907 episodes admitted from 29 local hospitals outside our hospital network. The median time between previous hospital discharge and present admission was 26 days (0–91 days).
[d] The median time between previous hospital discharge from our hospital network and present admission was 9 days (0–91 days).
[e] Data from universal VRE screening to all acute medical admission for 50 days (from September 25, 2013 to November 13, 2013).

Proactive infection control measures for VRE

VRE-positive patients were isolated in single rooms for strict contact precautions. Cohort nursing in open ward area was not allowed. Dedicated medical equipment was provided for VRE-positive patients. HCWs were required to wear gloves and gowns, and to comply with hand hygiene practice using alcohol-based handrub during patient care.

The overall compliance of hand hygiene was maintained at 73.9–78.6% with the consumption of alcohol-based handrub at a volume of 42.4 L/1000 patient-days (2011) to 49.6 L/1000 patient-days (2013, 1st–3rd quarter).

Two open staff forums were conducted with 216 attendances, and two special education sessions were arranged for senior nursing staff and infection control linked nurses. A total of 60 road shows were organized to 60 wards to ensure that infection control measures, especially the slogan of "entry and exit control" were delivered to our frontline HCWs. More than 350 posters were displayed in the clinical areas and patients' toilet facilities, and 283 toilet seat disinfectors were installed distributed over 46 wards' toilets. Information sheets were given to all patients upon admission to empower patients on performing hand hygiene and personal hygiene during hospitalization.

Environmental cleaning of clinical areas, especially toilet facilities and frequently touched areas, such as bed rails and bed tables, were disinfected with 1000 ppm sodium hypochlorite at least once daily in the general wards, and twice daily in the isolation rooms where VRE-positive patients were nursed. Four teaching sessions were held for the supporting staff, with audited compliance of environmental cleaning being over 80%.

The consumption of broad spectrum antibiotics with a potential for selecting MDROs, expressed by divided daily dose per 1000 acute patient-bed-days, increased gradually from 150 (2011 3rd quarter) to 205 (2013 3rd quarter).

Nosocomial outbreak of VRE in Hong Kong as a concurrent control

Between July 1, 2011 and November 13, 2013, 78 VRE outbreaks were reported in the public hospitals in Hong Kong. VRE outbreaks predominantly occurred in medical

Table 2 Epidemiological characteristics of nine episodes of extensive contact tracing with identification of secondary cases with vancomycin-resistant enterococci (VRE) isolated in our hospital network.

Episode of secondary case identified in extensive contact tracing[a]	Sex/ age, y	Clinical specimen (colonization vs. infection)	Specialty ward/hospital (date of investigation)/underlying diseases	Possible source of VRE acquisition	Duration between admission and patient isolation in single room with strict contact precautions	*N* (%) of secondary cases positive for VRE/number of contact tracing
1[b]	M/74	Rectal swab (colonization)	Surgical ward / hospital M (December 2011)/ hepatocellular carcinoma	From Hospital B outside our hospital network 3 days before admission	21 days[c]	10 (2.6)/381
5	M/80	Rectal swab (colonization)	Respiratory ward/hospital P (July 2012) / COPD	Within our hospital network	20 days	1 (5.6)/18
8	M/80	Rectal swab (colonization)	Orthopedic ward/QMH (January 2013)/HT, CVA, fracture right NOF	Within our hospital network	15 days	1 (0.6)/180
10	M/76	Rectal swab (colonization)	Medical ward/QMH (May 2013)/ AF, COPD, CVA	From Hospital B outside our hospital network 13 days before admission	4 days	1 (1.4)/71
11	F/79	Midstream urine (colonization)	Medical ward/QMH (May 2013)/ CRF, HT, colonic tumor, lymphoma	Within our hospital network	5 days	1 (1)/102
12	F/93	Rectal swab (colonization)	Geriatric ward/hospital Q (May 2013)/AF, CVA, HT	From Hospital H outside our hospital network 7 days before admission	7 days	1 (1.6)/61
16	M/48	Rectal swab (colonization)	Medical ward/QMH (August 2013)/HCV related cirrhosis	Directly transferred from Hospital I outside our hospital network	14 days[d]	1 (0.6)/174
18	F/81	Midstream urine (colonization)	Medical ward/QMH (August 2013)/glaucoma, HT	Within our hospital network	10 days	1 (1)/96
21	F/74	Rectal swab (colonization)	Geriatric ward/hospital Q (September 2013)/AF, DM, HT, dementia, parkinsonism	Within our hospital network	22 days	1 (1)/100

AF = atrial fibrillation; COPD = chronic obstructive pulmonary disease; CRF = chronic renal failure; CVA = cardiovascular accident; DM = diabetic mellitus; HCV = hepatitis C virus; HT = hypertension; NOF = neck of femur; QMH = Queen Mary Hospital.

[a] A total of 25 episodes of extensive contact tracing were performed and the remaining 16 episodes traced without secondary VRE cases were not listed.

[b] Detail of this nosocomial outbreak was published previously (26).

[c] Patient died on the date of VRE identification.

[d] Rectal swab for VRE culture was falsely negative upon admission screening, and the VRE carriage was subsequently identified by a repeat rectal swab (after combination therapy with cefotaxime for 8 days, oral levofloxacin for 7 days, and piperacilin–tazobactam for 4 days) requested by clinical microbiologist upon infectious disease consultation service.

units (36 outbreaks, 46.2%), rehabilitation units (15 outbreaks, 19.2%), surgical units (11 outbreaks, 14.1%), and orthopedic units (6 outbreaks, 7.7%). A total of 720 patients were involved in the 78 VRE outbreaks. The median number of affected patients in the VRE outbreaks was seven (range, 3–39 patients). There was an increasing trend of VRE outbreak during the study period where the number of reported VRE outbreaks increased from three (2011 3rd quarter) to eight (2013 1st quarter) to 18 (2013 2nd quarter), peaking at 20 (2013 3rd quarter). Our hospital network had

Table 3 Epidemiological characteristics of index patients with or without nosocomial transmission of vancomycin-resistant enterococci (VRE) in the hospitals.

	Index VRE patients resulted in nosocomial transmission ($n = 9$)	Index VRE patients without nosocomial transmission ($n = 16$)	p
Age, y	76 ± 12.3	66 ± 15.7	0.126
Male sex	5 (56)	9 (56)	0.973
Presence of indwelling device			
Nasogastric tube	1 (11.1)	1 (6.3)	0.667
Tracheostomy tube	0	2 (12.5)	0.269
Chronic wound or ulcer	3 (33.3)	2 (12.5)	0.211
Urinary catheter	5 (55.6)	3 (18.8)	0.058
Drain	1 (11.1)	2 (12.5)	0.918
Underlying diseases			
Chronic cerebral conditions	4 (44.4)	2 (12.5)	0.073
Chronic cardiac conditions	5 (55.6)	6 (37.5)	0.383
Chronic pulmonary conditions	2 (22.2)	1 (6.3)	0.238
Chronic renal failure	0	3 (18.8)	0.166
Liver cirrhosis	1 (11.1)	3 (18.8)	0.617
Diabetes mellitus	1 (11.1)	3 (18.8)	0.617
Malignancy	2 (22.2)	3 (18.8)	0.835
Use of antibiotic 90 d before admission			
β-lactam–β-lactamase inhibitors	8 (88.9)	12 (75)	0.405
Cephalosporin	3 (33.3)	6 (37.5)	0.835
Carbapenem	0	1 (6.3)	0.444
Fluoroquinolones	3 (33.3)	5 (31.1)	0.915
Time to implementation of single room isolation with strict contact precautions, mean ± SD, d	13.1 ± 7.0	5.4 ± 3.6	0.001

Data are presented as n (%) or mean ± SD.
SD = standard deviation.

one (1.3%) outbreak among the 78 VRE outbreaks, which occurred in an extended care hospital (Hospital M) in the 4th quarter of 2011. With the enforcement of proactive infection control measures, no further VRE outbreaks were reported in our hospital network despite the increasing VRE outbreaks reported in other public hospitals.

Discussion

Our results illustrate that our proactive infection control approach is effective in minimizing nosocomial transmission and outbreaks of VRE as only one (1.3%) out of the 78 reported VRE nosocomial outbreaks, occurred in our health care network within 28 months in Hong Kong. Because our hospital network served as a tertiary referral center, almost 50% of patient admission episodes subjected to VRE screening had either a recent history of hospitalization outside Hong Kong or outside our hospital network. Patients with recent exposure to health care settings outside our hospital network had a significantly higher chance of gastrointestinal VRE carriage upon admission screening, suggesting that "search and confine" of VRE carriers is a key measure to limit importation of VRE in our hospitals. Our findings suggest that delayed recognition of VRE carriers and delayed implementation of single room isolation and strict contact precautions are significantly associated with the nosocomial transmission, as room sharing with patient colonized or infected with VRE was found to be a risk factor associated with VRE acquisition.[30] In addition, the unique feature of directly observed hand hygiene, "entry and exit control", and extensive contact tracing for potential secondary VRE cases in our control program contributed to minimizing the incidence of nosocomial acquisition of VRE to 0.1/10,000 patient-days, which was much lower than that in the acute care settings of three other teaching hospitals employing strict infection control measures based on the guidelines of the Centers for Disease Control and Prevention.[31]

However, our extensive active surveillance culture and contact tracing approach has some constraints. The identification of gastrointestinal carriage of VRE is affected by the intrinsic limitations of rectal swab culture, where a poor sensitivity is noted when the density of VRE is lower than 4 log colony forming units/g of stool.[32] This may result in a false negative VRE carriage status, especially in patients who are not receiving broad spectrum antibiotic treatment. Previous studies demonstrated that the use of broad spectrum antibiotics increases the microbial load of MDROs and unmasked the carriage status.[33–35] Moreover, a biological false negative VRE screening result may be related to the gastrointestinal transit time, where 48–72 hours is required for the passage of VRE from oral acquisition to the rectum.[36] If an index patient acquired VRE just prior to interhospital transfer, VRE would not be detected by rectal swab upon admission to the receiving hospital on the same day. In fact, the rectal swab in one of our VRE index patients (extensive contact tracing episode 16) did not detect VRE on admission. Therefore additional VRE control protocols must be introduced.

Our experience showed that the memorable slogan of "entry and exit control" to highlight the key measures to staff and patients in order to break the fecal–oral transmission of VRE is helpful. Extensive environmental contamination was reported in patients with gastrointestinal VRE, which may lead to nosocomial transmission of VRE with a median of 5 days.[37] Although the implementation of bleach-based cleaning–disinfection program was associated with marked reductions in nosocomial acquisition of VRE,[38] frequently touched surfaces, such as hospital curtains between bed space, are difficult to disinfect and are rapidly re-contaminated.[39] Therefore, directly observed hand hygiene using alcohol-based handrub in patients just before meals and medications remains a simple and practical measure to reduce oral acquisition of VRE in hospital. Similarly, promotion of personal hygiene in toilet facilities can help to reduce VRE acquisition from occult VRE carriers who use shared toilet facilities.

Unlike the USA, where there is a large community reservoir of VRE,[40] the burden of VRE is still limited in Hong

Kong. In a 50-day universal surveillance of VRE among patients in acute medical wards by means of admission screening, patients without a recent history of hospitalization were all VRE-negative. Universal surveillance culture in acute medical wards was conducted because almost 50% of nosocomial VRE outbreaks were reported in medical departments. More importantly, VRE was rarely detected in livestock animals in China and avoparcin is not used in food animals in this region.[41] Therefore, person-to-person transmission is the main source of nosocomial dissemination of VRE, and infection control measures within hospitals are of utmost importance. Our proactive infection control measures overcame the selective pressure of increasing antibiotic usage as a result of the increasing number of MDROs.[42,43]

There are several limitations in this study. Firstly, although the epidemiological characteristics of index patients with and without nosocomial transmission of VRE were sought, we did not address the risk factors for nosocomial acquisition of VRE among contact patients in this particular study. Nonetheless, risk factors for nosocomial VRE acquisition among contact patients were reported in our previous studies.[20,26] Secondly, the sequential introduction of additional control measures over 2 years complicates data analysis. However, we demonstrated a decreasing incidence of nosocomial acquisition of VRE during the study period. All public hospitals in Hong Kong adopted our proactive infection control approach from November 13, 2013, especially the active surveillance culture, in view of our success in the control of nosocomial VRE transmission in our hospital network. Further investigation is warranted to evaluate the outcome of VRE control after the implementation of proactive infection control measures in all public hospitals in Hong Kong.

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References

1. Lu JJ, Ben RJ, Perng CL, Chi WM, Chu ML, Lee WH. Characterization of the first clinical isolate of vancomycin-resistant *Enterococcus faecalis*, AH803, in Taiwan. *J Formos Med Assoc* 2000;**99**:178—81.
2. Zheng B, Tomita H, Xiao YH, Wang S, Li Y, Ike Y. Molecular characterization of vancomycin-resistant *Enterococcus faecium* isolates from mainland China. *J Clin Microbiol* 2007;**45**:2813—8.
3. Cai Y, Chan JP, Fisher DA, Hsu LY, Koh TH, Krishnan P, et al. Vancomycin-resistant Enterococci in Singaporean hospitals: 5-year results of a multi-centre surveillance programme. *Ann Acad Med Singapore* 2012;**41**:77—81.
4. Oh HS, Kim EC, Oh MD, Choe KW. Outbreak of vancomycin resistant enterococcus in a hematology/oncology unit in a Korean University Hospital, and risk factors related to patients, staff, hospital care and facilities. *Scand J Infect Dis* 2004;**36**:790—4.
5. Leclercq R, Derlot E, Duval J, Courvalin P. Plasmid-mediated resistance to vancomycin and teicoplanin in *Enterococcus faecium*. *N Engl J Med* 1988;**319**:157—61.
6. Uttley AH, Collins CH, Naidoo J, George RC. Vancomycin-resistant enterococci. *Lancet* 1988;**1**:57—8.
7. National Nosocomial Infections Surveillance (NNIS) System Report. Data summary from January 1992—April 2000, issued June 2000. *Am J Infect Control* 2000;**28**:429—48.
8. National Nosocomial Infections Surveillance (NNIS) System Report. Data summary from January 1992 through June 2004, issued October 2004. *Am J Infect Control* 2004;**32**:470—85.
9. Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. *BMC Infect Dis* 2006;**6**:130.
10. Kampf G, Kramer A. Epidemiologic background of hand hygiene and evaluation of the most important agents for scrubs and rubs. *Clin Microbiol Rev* 2004;**17**:863—93.
11. Willems RJ, Top J, van Santen M, Robinson DA, Coque TM, Baquero F, et al. Global spread of vancomycin-resistant *Enterococcus faecium* from distinct nosocomial genetic complex. *Emerg Infect Dis* 2005;**11**:821—8.
12. Cheng VC, Lau SK, Woo PC, Yuen KY. Severe acute respiratory syndrome coronavirus as an agent of emerging and reemerging infection. *Clin Microbiol Rev* 2007;**20**:660—94.
13. Cheng VC, Chan JF, To KK, Yuen KY. Clinical management and infection control of SARS: lessons learned. *Antiviral Res* 2013;**100**:407—19.
14. Cheng VC, Wu AK, Cheung CH, Lau SK, Woo PC, Chan KH, et al. Outbreak of human metapneumovirus infection in psychiatric inpatients: implications for directly observed use of alcohol handrub in prevention of nosocomial outbreaks. *J Hosp Infect* 2007;**67**:336—43.
15. Cheng VC, Tai JW, Ho YY, Chan JF. Successful control of norovirus outbreak in an infirmary with the use of alcohol-based hand rub. *J Hosp Infect* 2009;**72**:370—1.
16. Cheng VC, Wong LM, Tai JW, Chan JF, To KK, Li IW, et al. Prevention of nosocomial transmission of norovirus by strategic infection control measures. *Infect Control Hosp Epidemiol* 2011;**32**:229—37.
17. Cheng VC, Tai JW, Wong LM, Chan JF, Li IW, To KK, et al. Prevention of nosocomial transmission of swine-origin pandemic influenza virus A/H1N1 by infection control bundle. *J Hosp Infect* 2010;**74**:271—7.
18. Cheng VC, Tai JW, Chan WM, Lau EH, Chan JF, To KK, et al. Sequential introduction of single room isolation and hand hygiene campaign in the control of methicillin-resistant *Staphylococcus aureus* in intensive care unit. *BMC Infect Dis* 2010;**10**:263.
19. Cheng VC, Chan JF, Wong SC, Chen JH, Tai JW, Yan MK, et al. Proactive infection control measures to prevent nosocomial transmission of carbapenem-resistant Enterobacteriaceae in a non-endemic area. *Chin Med J (Engl)* 2013;**126**:4504—9.
20. Cheng VC, Chan JF, Tai JW, Ho YY, Li I, To KK, et al. Successful control of vancomycin-resistant *Enterococcus faecium* outbreak in a neurosurgical unit at non-endemic region. *Emerg Health Threats J* 2009;**2**:e9.
21. Salgado CD. The risk of developing a vancomycin-resistant *Enterococcus* bloodstream infection for colonized patients. *Am J Infect Control* 2008;**36**:S175. e5—8.
22. Olivier CN, Blake RK, Steed LL, Salgado CD. Risk of vancomycin-resistant *Enterococcus* (VRE) bloodstream infection among patients colonized with VRE. *Infect Control Hosp Epidemiol* 2008;**29**:404—9.

23. Ergaz Z, Arad I, Bar-Oz B, Peleg O, Benenson S, Minster N, et al. Elimination of vancomycin-resistant enterococci from a neonatal intensive care unit following an outbreak. *J Hosp Infect* 2010;**74**:370—6.
24. Sample ML, Gravel D, Oxley C, Toye B, Garber G, Ramotar K. An outbreak of vancomycin-resistant enterococci in a hematology-oncology unit: control by patient cohorting and terminal cleaning of the environment. *Infect Control Hosp Epidemiol* 2002;**23**:468—70.
25. Iosifidis E, Karakoula K, Protonotariou E, Kaperoni M, Matapa E, Pournaras S, et al. Polyclonal outbreak of vancomycin-resistant *Enterococcus faecium* in a pediatric oncology department. *J Pediatr Hematol Oncol* 2012;**34**:511—6.
26. Cheng VC, Tai JW, Ng ML, Chan JF, Wong SC, Li IW, et al. Extensive contact tracing and screening to control the spread of vancomycin-resistant *Enterococcus faecium* ST414 in Hong Kong. *Chin Med J (Engl)* 2012;**125**:3450—7.
27. Cheng VC, Tai JW, Wong ZS, Chen JH, Pan KB, Hai Y, et al. Transmission of methicillin-resistant *Staphylococcus aureus* in the long term care facilities in Hong Kong. *BMC Infect Dis* 2013; **13**:205.
28. Cheng VC, Tai JW, Ho SK, Chan JF, Hung KN, Ho PL, et al. Introduction of an electronic monitoring system for monitoring compliance with Moments 1 and 4 of the WHO "My 5 Moments for Hand Hygiene" methodology. *BMC Infect Dis* 2011;**11**:151.
29. Cheng VC, To KK, Li IW, Tang BS, Chan JF, Kwan S, et al. Antimicrobial stewardship program directed at broad-spectrum intravenous antibiotics prescription in a tertiary hospital. *Eur J Clin Microbiol Infect Dis* 2009;**28**:1447—56.
30. Zhou Q, Moore C, Eden S, Tong A, McGeer A. Mount Sinai Hospital Infection Control Team. Factors associated with acquisition of vancomycin-resistant enterococci (VRE) in roommate contacts of patients colonized or infected with VRE in a tertiary care hospital. *Infect Control Hosp Epidemiol* 2008; **29**:398—403.
31. Padiglione AA, Wolfe R, Grabsch EA, Olden D, Pearson S, Franklin C, et al. Risk factors for new detection of vancomycin-resistant enterococci in acute-care hospitals that employ strict infection control procedures. *Antimicrob Agents Chemother* 2003;**47**:2492—8.
32. D'Agata EM, Gautam S, Green WK, Tang YW. High rate of false-negative results of the rectal swab culture method in detection of gastrointestinal colonization with vancomycin-resistant enterococci. *Clin Infect Dis* 2002;**34**:167—72.
33. Donskey CJ, Chowdhry TK, Hecker MT, Hoyen CK, Hanrahan JA, Hujer AM, et al. Effect of antibiotic therapy on the density of vancomycin-resistant enterococci in the stool of colonized patients. *N Engl J Med* 2000;**343**:1925—32.
34. Cheng VC, Li IW, Wu AK, Tang BS, Ng KH, To KK, et al. Effect of antibiotics on the bacterial load of meticillin-resistant *Staphylococcus aureus* colonisation in anterior nares. *J Hosp Infect* 2008;**70**:27—34.
35. Cheng VC, Chan JF, To KK, Tai JW, Ho PL. Detection of community-associated MRSA as a result of the unmasking effect of antibiotic treatment. *J Hosp Infect* 2009;**72**:273—4.
36. Meir R, Beglinger C, Dederding JP, Meyer-Wyss B, Fumagalli M, Rowedder A, et al. Age- and sex-specific standard values of colonic transit time in healthy subjects. *Schweiz Med Wochenschr* 1992;**122**:940—3.
37. Bonten MJ, Hayden MK, Nathan C, van Voorhis J, Matushek M, Slaughter S, et al. Epidemiology of colonisation of patients and environment with vancomycin-resistant enterococci. *Lancet* 1996;**348**:1615—9.
38. Grabsch EA, Mahony AA, Cameron DR, Martin RD, Heland M, Davey P, et al. Significant reduction in vancomycin-resistant enterococcus colonization and bacteraemia after introduction of a bleach-based cleaning-disinfection programme. *J Hosp Infect* 2012;**82**:234—42.
39. Ohl M, Schweizer M, Graham M, Heilmann K, Boyken L, Diekema D. Hospital privacy curtains are frequently and rapidly contaminated with potentially pathogenic bacteria. *Am J Infect Control* 2012;**40**:904—6.
40. Omotola AM, Li Y, Martin ET, Alshabani K, Yadav D, Sarkar M, et al. Risk factors for and epidemiology of community-onset vancomycin-resistant *Enterococcus faecalis* in southeast Michigan. *Am J Infect Control* 2013;**41**:1244—8.
41. Ho PL, Lai E, Chan PY, Lo WU, Chow KH. Rare occurrence of vancomycin-resistant *Enterococcus faecium* among livestock animals in China. *J Antimicrob Chemother* 2013;**68**:2948—9.
42. Ho PL, Ho AY, Chow KH, Cheng VC. Surveillance for multidrug-resistant *Acinetobacter baumannii*: a lesson on definitions. *Int J Antimicrob Agents* 2010;**36**:469—71.
43. Ho PL, Chow KH, Lai EL, Lau EH, Cheng VC. Extended-spectrum-beta-lactamase-positive *Escherichia coli* mainly adds to, rather than replaces, extended-spectrum-beta-lactamase-negative *E. coli* in causing bacteraemia in Hong Kong, 2000—10. *J Antimicrob Chemother* 2012;**67**:778—80.