An outbreak report of vancomycin-resistant *Enterococcus faecium* outbreak in a Dutch general hospital, 2014-2017: successful control with a low impact strategy

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Abstract

Background

We describe the control of a large VRE outbreak in a Dutch general hospital in 2014–2017.

Methods

After the outbreak was identified, a screening policy consisting of a single rectal swab culture (with enrichment broth) to identify VRE carriage in high risk patients, was implemented. In addition to screening, measures to improve compliance with standard infection control precautions and enhanced environmental cleaning were implemented to control the outbreak.

Results

Between September, 2014 and February, 2017, 140 patients were identified to be colonised by *vanA* mediated vancomycin-resistant *Enterococcus faecium* (VRE*fm*). Three of these patients developed bacteraemia. AFLP typing showed that the outbreak was caused by a single clone. Extensive environmental contamination was found in multiple wards. Within nine months after the detection of the outbreak no new VRE cases were detected.

Conclusion

We implemented a control strategy based on targeted screening and isolation in combination with implementation of general precautions and environmental cleaning. The strategy was less stringent than the Dutch national guideline for VRE control. This strategy successfully controlled the outbreak, while it was associated with a reduction in the number of isolation days and the number of cultures taken.

Background

In line with the increased global spread of multi-drug resistant microorganisms, the prevalence of vancomycin resistance among enterococci is rising. Whereas vancomycin-resistant enterococci (VRE) were detected only sporadically in the Netherlands before 2012, an increasing number of VRE outbreaks have required considerable resources to contain over the past eight years (1). At present, VRE outbreaks are among the largest and the most frequently reported in the Netherlands (period 2018 – June 2019: VRE 682 patients in 24 outbreaks versus MRSA 93 patients in 20 outbreaks) (2). Due to low virulence of VRE and its ability to survive on hospital environmental surfaces, VRE outbreaks have the potential to become substantial in size before they are detected by routine clinical cultures.

Strategies to prevent VRE transmission include screening of contact patients and isolation precautions of (suspected) VRE carriers (3, 4). The Netherlands has a national control strategy of highly resistant micro-organisms including VRE (5). During outbreaks, contact patients (those admitted to the same room or ward as the index patient) are pre-emptively isolated while awaiting test results to prevent further spread. In this context, there is ongoing discussion about the number of rectal swabs to be tested - with culture considered as gold standard - before a VRE suspected patient can be declared VRE negative. The negative predictive value of 1 negative rectal swab is considered insufficient, and the Dutch national guideline advocates taking 3–5 rectal cultures on separate days (5). The combination of late outbreak detection and multiple cultures per contact-patient before VRE carriage can be excluded can result in very large numbers of patients to be isolated and screened, hence it is a substantial burden for hospital infection control departments, lead to significant laboratory costs, and exhaust hospital isolation facilities.

We describe the successful control of a VRE*fm* outbreak in a general hospital in The Netherlands, while implementing a screening policy consisting of a single instead of multiple rectal swab culture (with enrichment broth) for excluding carriage in

VRE-suspected patients.

Methods

Design, setting and participants

We describe the interventions that were implemented to control an outbreak of VRE*fm* in a 364-bed general hospital with approximately 25,000 admissions per year in a setting which is non-endemic for VRE.

The Admiraal De Ruyter Hospital (ADRZ) is a general hospital with four separate locations in south-west of the Netherlands. The hospital has a catchment area of 248 000 inhabitants and supplies 85–90% of the requested hospital care in this area. For tertiary care patients are transferred to the surrounding academic centres. Most patients were admitted to an acute admission unit (AAU), consisting of six single rooms and eight multi-bed room with five beds each (total 46 beds), before being transferred to their specific wards (on average after 48 hours). The hospital has four locations but all VRE*fm* colonised patients were detected on the location Goes.

Participants were all patients admitted to the Admiraal De Ruyter Hospital (ADRZ) between September 1, 2014 and February 5, 2017. A case was defined as any patient infected or colonised with *vanA* mediated VRE*fm*, multilocus sequence type (MLST) ST117. Patients were categorised into three groups according to their VRE status and potential risk of VRE carriage: (1) **VRE carrier**: VRE-positive patients who met the case definition; (2) **VRE suspected patients**: all patients with prior hospitalisation in the ADRZ hospital location Goes from September 1, 2014. In the beginning of the outbreak it was unclear what the initial source of the outbreak was, therefore patients transferred from nursing homes or rehabilitation centres were also categorised as VRE suspected in the first phase of the outbreak. Patients with no prior hospitalisation in the ADRZ hospital in the outbreak period, nursing home or rehabilitation centre were categorised as (3) **low-risk patients.**

Interventions

The control measures could be divided into three phases based on the different screening and isolation policies. Table 1 summarizes the dates, isolation and screening policies per phase and risk group. In Table 2, an overview of the implemented control measures during the outbreak is shown.

Table 1
Overview of dates, isolation and screening policies per phase and risk group during VREfm outbreak period

Risk group	Definition	Phase 1 Dec 14, 2015 – Mar 20, 2016		Phase 2 Mar 21, 2016 – Nov 13, 2016		Phase 3 Nov 14, 2016 – Feb 5, 2017	
		Identification strategy	Contact precautions	Identification strategy	Contact precautions	Identification strategy	Contact precautions
VRE carrier	Patient infected or colonised with VRE*fm*	N/A	Yes [a]	N/A	Yes [a]	N/A	Yes [a]
VRE-suspected	All patients with prior hospitalisation in the ADRZ hospital location Goes from September 1, 2014 until start of zero transmission period	Single rectal swab on admission	Yes, while awaiting result of single admission screening	Single rectal swab on admission	No	Single rectal swab on admission	No
	Patients transferred from nursing homes or rehabilitation centres	Single rectal swab on admission	Yes, while awaiting result of single admission screening	Single rectal swab on admission	No	No	No
	Roommate of unexpected VRE carrier	N/A	Yes[C]	3 separate rectal cultures (collection at day 3, 5 and 7 after the last exposure)	Yes [a]	3 separate rectal cultures (collection at day 3, 5 and 7 after the last exposure)	Yes [a]
All patients (incl. low risk)	Hospital wide surveillance	Weekly screening of all patients hospitalised > 2 days[b]	N/A	Weekly screening of all patients hospitalised > 2 days	N/A	Monthly screening of all patients hospitalised > 2 days	N/A

[a] Single room or cohorting with other VRE carriers if insufficient availability of single rooms, [b] In high risk departments (dialysis and ICU) all admitted patients are screened, regardless of the admission time. [C] After cleaning of the ward was completed, patients were separated int two cohorts: clean (new admissions not fulfilling the criteria of 'VRE suspected'), and VRE suspected, each with dedicated staff. **Contact precaution (CP) policy**: Single room or - if single room was not available - cohort CP of patients with same VRE status on multi occupancy room. Healthcare workers wear gown with long sleeves and gloves before each contact with the patient or the patient environment. Rooms were daily cleaned, medical devices were cleaning and disinfected (alcohol 70%) before leaving the room, and after patient discharge, the room is cleaned and disinfected (250 ppm chlorine)

Table 2 *Overview of the implemented control measures during VREfm outbreak period*

Table 2
Overview of infection control measures during outbreak:

2015	**December**	**Detection of the outbreak**
	(*Phase I*)	**Single hospital-wide screening limited to patients admitted for at least 48 h**
2016	January	Initiation of Outbreak Management Team (OMT)
		Reporting outbreak to the national Early warning and response meeting of Hospital-acquired Infections and AntiMicrobial Resistance (SO-ZI/AMR)
		Electronic labelling of VRE-positive patients (*confirmed label*) and patients with prior hospitalisation in het ADRZ hospital in from September 1, 2014, or prior hospitalisation in a nursing home or rehabilitation centre (*VRE suspected label*)
		Informing local hospital personnel and patients, and surrounding hospitals and nursing homes
		Introducing screening for VRE carriage on admission for all patients with electronic 'VRE suspected-label' and patients from nursing homes or rehabilitation centres
		Weekly hospital-wide VRE rectal screening limited to patients admitted for at least 48 h. In high risk departments (dialysis and ICU) all admitted patients are screened, regardless of the admission time
		Start of cleaning and disinfection (250 ppm chlorine) of the entire hospital: wards are cleaned one by one, whereby patients are temporarily transferred to other (not yet cleaned) parts of the same or other wards
		Introduction of disinfectant wipes for contact surfaces in patient rooms and general areas
		Start of mandatory plenary training sessions for all healthcare workers on general precautions and cleaning issues
		Clear division of cleaning tasks for healthcare workers and cleaning personnel
	February	After cleaning of the ward: release rooms previously occupied by VRE positive patients after cleaning and disinfection based on environmental cultures
	March	Audits of adherence to infection control and cleaning protocols by infection control department
	(Phase II)	Implementing screening protocol for ward mate of VRE carrier
		Reintroducing of cleaning and disinfection (250 ppm chlorine) of the entire hospital: departments are cleaned one by one, whereby patients are temporarily transferred to other (not yet cleaned) departments
		Intensifying communication to healthcare workers and managers
	November	Screening for VRE carriage on admission limited to only patients with prior hospitalisation in het ADRZ hospital in period December 1, 2015 – November 14, 2016
	(Phase III)	Monthly hospital-wide VRE rectal screening limited to patients admitted for at least 48 h. In high risk departments (dialysis and ICU) all admitted patients are screened, regardless of the admission time
2017	February	Removing all outbreak related 'VRE suspected labels' in the electronic patient system
	(End of the outbreak)	Start hospital-wide VRE rectal screening limited to patients admitted for at least 7 days

In the first phase (December 14, 2015 – March 20, 2016) a hospital-wide screening for VRE carriage was performed in all patients who were admitted for more than 48 hours.

All patients who were admitted to the hospital from September 1, 2014 (presumed start of the outbreak) until December 2016, were labelled 'VRE suspected' in the electronic patient system. Upon readmission, VRE suspected patients were isolated in single rooms. Isolation measures were discontinued and patients declared VRE negative based on a single negative rectal culture.

Furthermore, to detect unnoticed VRE transmission in the hospital, all patients hospitalised for more than two days, were screened weekly (point prevalence cultures). Patients of high-risk departments (dialysis and ICU) were screened weekly regardless of their admission time. Ward mates of unexpected VRE carriers (contact patients) were labelled 'VRE suspected' until the result of the next prevalence surveillance culture had become available.

From January 2016, patients on admission to the AAU or other nursing wards (elective admissions), were divided into three different VRE cohorts based on their VRE status: **VRE positive**, **VRE suspected** and **not suspected for VRE**. Mid-January 2016, two extra five-bed-rooms were opened (10 beds) on the AAU, to accommodate the different VRE cohorts with dedicated rooms, staff and (medical) equipment. On the other wards, VRE suspected or positive patients were placed in a single room or cohorted with other (suspected) VRE carriers if there was insufficient availability of single rooms.

In the second phase (March 21, 2016 – November 13, 2016) of the outbreak patients who had been admitted after September 2014 and labelled VRE suspected, were no longer pre-emptively isolated upon admission only screened for VRE carriage. For wardmates of unexpected VRE carriers now cultures were taken from on day 3, 5 and 7 after the last VRE exposure.

In the last and third phase (November 14, 2016 – February 5, 2017) the point prevalence survey was changed from a weekly to a monthly screening of all patients hospitalised for more than two days.

From February 5, 2017, only patients hospitalised for more than seven days were screened every week.

Audits, cleaning and education

Cleaning tasks had to be performed by nurses or by dedicated cleaning personnel depending on the objects. During audits it became clear that the tasks had not been defined clearly and consequently some items were not always cleaned. As an intervention the tasks were specified in writing and subsequently the cleaning responsibilities were clearly defined. Also, damaged hospital equipment and furniture were repaired or replaced, and the cleaning frequency of sanitary facilities was increased. Audits on implementation of infection control measures and cleaning practises were performed, including adenosine triphosphate (ATP) measurements (6) performed by the infection prevention department. The ATP measurements were performed in patient rooms and common areas and to control cleaning after discharge (data not shown). All healthcare workers and cleaning personnel received mandatory training on standard infection control and cleaning policies. The number of alcohol-based hand rub (ABHR) dispensers was increased so ABHR was available at 'point of care' in all wards.

Culturing and typing

Environmental sampling

To assess the extent of environmental contamination in general (surveillance) and after cleaning and disinfection of the patient rooms, a range of high touch surfaces and (medical) equipment's were sampled using 10 cm x 10 cm sterile gauzes moistened with sterile saline (7)

Microbiology

Rectal swabs or feces was collected by nursing staff using the eSwab medium (Copan, Murrieta, USA). In total, 100 μL eSwab transport medium was transferred to a brain heart infusion broth containing 4 mg/L amoxicillin. After an overnight incubation at 35–37 °C, 10 μL of the broth was transferred to a Columbia colistin nalidixic acid - agar with 5% Sheep Blood and vancomycin (6 μg/mL) and grown overnight at 35–37 °C. For all suspected colonies growing on the selective media, species identification and susceptibility testing was performed using automated systems (Vitek MS and Vitek 2) (bioMérieux, Marcy l'Etoile, France) and E-test (bioMérieux, Marcy l'Etoile, France).

Molecular methods

Resistance genes were detected using an in house *vanA*/ *vanB* duplex polymerase chain reaction (Elisabeth-TweeSteden Hospital, Tilburg, The Netherlands).

DNA was extracted using the QIAsymphony DSP virus/pathogen midi kit and pathogen complex 400 protocol of the QIAsymphony Sample Processing (SP) system (Qiagen, Hilden, Germany). Amplification reactions were performed in a volume of 25 µL with PCR mastermix (QuantiTect Multiplex PCR NoROX Kit, QIAgen) and 10 µL DNA sample. A multiplex PCR using *vanA*-, *vanB*-, and *E. faecium*-specific primers and probes (Table 3) was performed. For the amplification and detection of the internal control PCR primers and detection probe specific for PhHV-1 were used (8). The amplification reaction was performed using 200 nM of each *vanA*, *vanB* and *E. faecium*-specific primers, 100 nM of each PhHV-1-specific primer, and 100 nM of each *vanA*-, *vanB*-, *E. faecium*- PhHV-specific probe.

Amplification consisted of 15 minutes at 95 °C followed by 45 cycles of 15 seconds at 95 °C, 30 seconds at 60 °C, and 15 seconds at 72 °C. Amplification, detection, and analysis were performed with the Rotor-gene real-time detection system (QIAgen). Negative and positive control samples were included in each amplification run. PCR output from this system consists of a Ct-value, representing the amplification cycle in which the level of fluorescent signal exceeds the background fluorescence, and reflecting the target-specific DNA load in the sample tested.

Table 3
Primer and sequences for multiplex PCR of vancomycin resistance genotyping and enterococci species identification among vancomycin-resistant enterococci

Primer name	Primer sequence	Target gene
vanA-F1	GCCGGAAAAAGGCTCTGAA	*vanA gene*
vanA-R1	TCCTCGCTCCTCTGCTGAA	*vanA gene*
vanA-1-FAMBhq1	ACGCAGTTATAACCGTTCCCGCAGACC	*vanA gene*
vanB-F1	CGCAGCTTGCATGGACAA	*vanB gene*
vanB-R1	GGCGATGCCCGCATT	*vanB gene*
vanB-1-VIC (MGB)	TCACTGGCCTACATTC	*vanB gene*
Efa-F1	GGAATGGCGCAAAACTTAGA	*atpA gene*
Efa-R1	AGGCCTCTCCAACTGGAACT	*atpA gene*
Efa-1-TRBhq2	TGGCGATTTCGAGTCCATTCG	*atpA gene*

Further typing was performed for the isolates of first 15 VRE*fm* positive patients in the beginning of the outbreak period. VRE isolates were typed using multilocus sequence typing (MLST)(9) and Amplified fragment Length Polymorphism (AFLP) (10).

Results

Outbreak strain

From December, 2014 to February, 2017, 140 vancomycin-resistant *Enterococcus faecium* (VRE*fm*) cases were identified. All of the strains expressed a high level of resistance to vancomycin (MIC > 256 mg/L) and teicoplanin (MIC > 32 mg/L) and carried the *vanA* gene. VRE typing by MLST revealed ST117 and AFLP analysis of the first isolates of 15 patients in the early phase of the outbreak period revealed that all were clonally related.

Detection of the outbreak

During the last months of 2014 and in January 2015, VRE*fm* strains were isolated five times from clinical materials from patients that were admitted in the hospital (Fig. 1). These were initially considered to be incidental findings without a clear epidemiological link. Retrospectively, they were typed and it was shown that they were strongly related. On December 14, 2015, following an alert from a neighbouring academic hospital where VRE*fm* carriage was detected in four patients who had been transferred from location Goes, all patients admitted for more than 48 hours were screened for VRE carriage. Of the 158

patients screened, 13 patients (8%) were carriers of VRE*fm*. The VRE*fm* positive patients were admitted to various departments, including the intensive care, indicating that VRE*fm* had spread throughout the entire hospital (with the exception of the AAU, and the children's and maternity ward).

An outbreak management team was initiated to control the outbreak, consisting of a clinical microbiologist, an infection control specialist, representatives of the hospital management and of the medical staff, the manager of housekeeping and logistics, and a member of the communication department.

Outbreak overview

The start of the outbreak was retrospectively set at September 1, 2014, as on this date the first VRE*fm was* detected in a clinical specimen of a patient admitted to the surgical ward. From January until March, 2016 (phase I), patients who had been hospitalised in the epidemic period were screened upon admission. Only 2 of 647 patients (0.31%) were positive for VRE*fm*. Given this low VRE prevalence in admission cultures, the large cohort of patients who had been admitted after September 2014 and labelled VRE suspected, were no longer pre-emptively isolated upon admission from March 21, 2016 (phase II). Screening was only performed in patients who had been in contact with a VRE*fm*-positive patient (Table 1).

Figure 1 shows the epidemic curve of detection of new VRE*fm*-positive patients per week, with a total of 140 VRE*fm* positive patients. After an initial decline in the number of new VRE*fm* findings in February and March, 2016 – there was a second peak in the number of VRE*fm* positive patients in May – June, 2016. On-site audits performed during phase II showed shortcomings in infection control preconditions on several wards in the hospital: wards were cluttered, the separation of dirty and clean areas was not clear, and the replacement of damaged hospital equipment and furniture had not been implemented. The division of labour with regards to cleaning responsibilities between cleaning personnel and healthcare workers was further emphasized in this phase, and environmental sampling increased in frequency (see below).

As per November 2016, there were no new VRE*fm* findings in the preceding three months and therefore screening for VRE carriage on admission was limited to only patients with prior hospitalisation in het ADRZ hospital in the period December, 2015 – November, 2016 (phase III). Furthermore, the frequency of hospital-wide screening of patients with > 48 hours length of stay was from then on performed monthly instead of weekly.

Control of the outbreak

No further cases occurred over a three months period and control measures were terminated in February, 2017. Admission and prevalence surveillance cultures were discontinued and all outbreak related 'VRE suspected' labels in the electronic patient system were removed. Furthermore, a hospital-wide VRE rectal screening limited to patients admitted for at least 7 days, was implemented as a standard surveillance form that moment on.

Environmental cultures

In January 2016, environmental cultures were obtained throughout the hospital to assess the extent of environmental contamination. The cultures showed extensive VRE contamination on the surgical, internal, pulmonary and neurology wards (43/80 samples VRE positive; 53.7%). Environmental samples of the AUU, ICU and dialysis department were VRE negative (0/60 samples). (Fig. 2a)

In June 2016, environmental screening was repeated on multiple wards (n = 130 samples), and again extensive VRE contamination was found in the surgical ward (19/20 samples, 95,0%) and to a lesser extent on the cardiology ward (4/20 samples; 20.0%). Consequently, stepwise cleaning and disinfection (250 ppm chlorine) of these wards was performed. After cleaning these wards were closed pending VRE negative environmental results. Following a peak in VRE transmission, environmental surveillance was continued and intensified: from June 2016, rooms previously occupied by VRE-positive patients were only released after cleaning and negative environmental cultures. Ten percent (74/713 culture) of the room surfaces remained VRE*fm* positive after terminal disinfection. (Fig. 2b) In some cases, VRE*fm* was still detected after two rounds of terminal disinfection on e.g. patient bed, infusion pole and pull-up bar.

Infections during the outbreak period

Eight (5.7%) patients developed a *VREfm* infection, of whom three (2.1%) had bacteraemia. Two of these patients, with extensive co-morbidities, died shortly after detection. One patient, also with extensive co-morbidities (including renal failure, haemodialysis and vascular disease) developed a severe osteomyelitis following a surgical procedure, which eventually led to amputation of her left hand.

Discussion

Here we describe the successful control of a VRE*fm* outbreak in a hospital using a mitigated screening and isolation policy, as compared with the national guidelines. With this approach, within nine months after the detection of the outbreak no new VRE*fm* cases were detected and after twelve months the outbreak was considered fully controlled. Besides the targeted screening and isolation there was an intensive focus on optimisation of environmental cleaning procedures.

In general, there is no consensus on the optimal VRE screening, isolation and surveillance protocol, reflected by the variation in infection control approaches within and between countries (11–13). Especially, the number of rectal cultures required to consider a patient (known carrier or contact patient) VRE-negative is unclear. Studies show that the sensitivity of a single rectal swab is low, ranging from 42,5–79% (14–17), and this increases when taking multiple swabs: Pearman *et al.* showed that on average four rectal swabs, collected on separate days, were needed to detect 95% of carriers compared to 56% with one rectal swab (13). Explanations for the increase in sensitivity when taking multiple rectal swabs include a fluctuation in faecal excretion of VRE, and/or the presence of an intestinal transit time after VRE is transmitted (time between transmission event and detectable VRE levels in the faeces). It should be noted that in most of these studies the rectal swabs were inoculated directly on selective media. Addition of a broth enrichment step (as done in our study) increases the yield of a rectal swab culture substantially (18). Lastly, sensitivity may depend on the load of VRE in faeces (17); a high VRE load in faeces also results in a higher sensitivity of a rectal swab, whereby patients with lower faecal loads probably contribute less to transmission.

In 2015, a Dutch guideline was published which recommends taking 3–5 rectal cultures on separate days to reliably exclude carriage in a suspected VRE carrier (5). This guideline makes no specific recommendation about the timing of the 3–5 separate rectal culture collection, apart from recommending that the last culture is ideally performed at least seven days after the last exposure. During our outbreak, the screening policy consisting of a single rectal swab culture (with enrichment broth) upon re-admission for excluding VRE carriage in VRE suspected patients. In this outbreak, there was a long period of time between the first clinical VRE finding (September 2014) and the detection of the outbreak (December 2015), resulting in a large cohort of approximately 25,000 discharged and potentially exposed patients, hence classified as a ‘VRE suspected’. Readmission of these patients occurred frequently and it was estimated, based on historical data, that approximately 4,700 admissions / year would be categorised as ‘VRE suspected’. According to the guideline this would result in 75,000–125.000 cultures to detect all carriers (by screening all discharged patients). This would have required considerable administrative effort and laboratory costs. In case of limiting the screening to those who were re-admitted (appr. 4,700/year), isolating all ‘VRE suspected’ patients in a single room upon admission pending at least 3 rectal screening cultures on separate days would place a large burden on hospital room capacity, and still require a very large number of cultures.

With the assumption that the sensitivity of a single swab is substantially higher when performed > 7 days after the last exposure, and because a substantial proportion of exposed patients was expected to have lost VRE carriage within 6 months (19), we decided to perform screening for VRE by taking a single swab, and limit screening to patients who were re-admitted to the hospital. By ending pre-emptive contact precautions after a single VRE-negative rectal swab, most patients were isolated only the first two days of admission. With this strategy, that was less stringent than the Dutch national recommendations for VRE control, a total of 19.677 rectal swabs (of 9,279 patients) were collected during the entire outbreak (admission-, prevalence- and contact surveillance cultures together), thereby significantly cutting administrative effort, time of isolation and laboratory costs.

Though it can be argued that we have not detected all VRE*fm* carriers (and underestimated the size of the outbreak) due to suboptimal sensitivity of our screening policy, our experience shows that VRE transmission from undetected carriers was, even if present, insufficient to caused sustained transmission. Whether this strategy would have been effective in settings with higher complexity of care (where patients probably have longer duration of carriage, longer admissions, and a higher transmission potential and infection risk) is unclear. In such settings, even a small loss in sensitivity may lead to ongoing transmission. In a recent paper, Frakking *et al.* describe a successful control of a large VRE outbreak (n = 242 patients) in a Dutch teaching hospital and tertiary referral centre. The outbreak lasted 18 months and was eventually controlled after major efforts, including twice-weekly screening of all admitted patients, environmental decontamination with hydrogen peroxide vapour, strict isolation precautions (in isolation rooms with anteroom), a VRE quarantine ward and abandoning the use of ciprofloxacin prophylaxis during neutropenic fever. The authors advocate a screening policy with at least 4–5 rectal swabs before excluding VRE carriage.

It should be noted that in our study, for the majority of the cohort of suspected VRE patients the last exposure was > 7 days ago (for many patients even several months), which (in combination with intensive focus on general precautions and environmental cleaning) may have been an important reason for the success of this strategy. In addition, the prevalence among re-admitted patients was < 1%, indicating a low background risk of undetected introductions of VRE in the hospital.

As described we are careful to generalize our findings to other settings. Our results suggest, however, that the current general Dutch recommendations to take 3–5 cultures to exclude VRE carriage in all exposed patients may be reconsidered for centres with lower complexity of care, especially when the last exposure was > 7 days ago. This lowers the costs and limits the duration of pre-emptive isolation.

Conclusion

To conclude, we describe a large VRE outbreak in a general hospital in The Netherlands, that was successfully controlled, while substantially reducing the number of cultures to be taken and the number of isolation days, and thereby cutting laboratory costs.

Abbreviations

AAU acute admission unit

ADRZ Admiraal De Ruyter Hospital (ADRZ)

AFLP amplified fragment length polymorphism

ICU intensive care unit

MLST multilocus sequence typing

MRSA methicillin-resistant *Staphylococcus aureus*

VRE vancomycin-resistant enterococci

VRE*fm* vancomycin-resistant *Enterococcus facium*

Declarations

Ethics approval and consent to participate

The data of patients used in this study were part of routine clinical practices in the ADRZ hospital and their anonymous use is beyond the scope of the Medical Research Involving Human Subjects Act.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

AvO, EN, JN, BW, JvL, JK and JV performed the investigation and management of the outbreak. VW and JV did the data analysis. VW wrote the first draft of the manuscript. AvO, EN, AV, JN, BW, JvL, JK and JV reviewed, provided critical feedback and contributed to subsequent draft. All authors approved the final version for publication.

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Figures

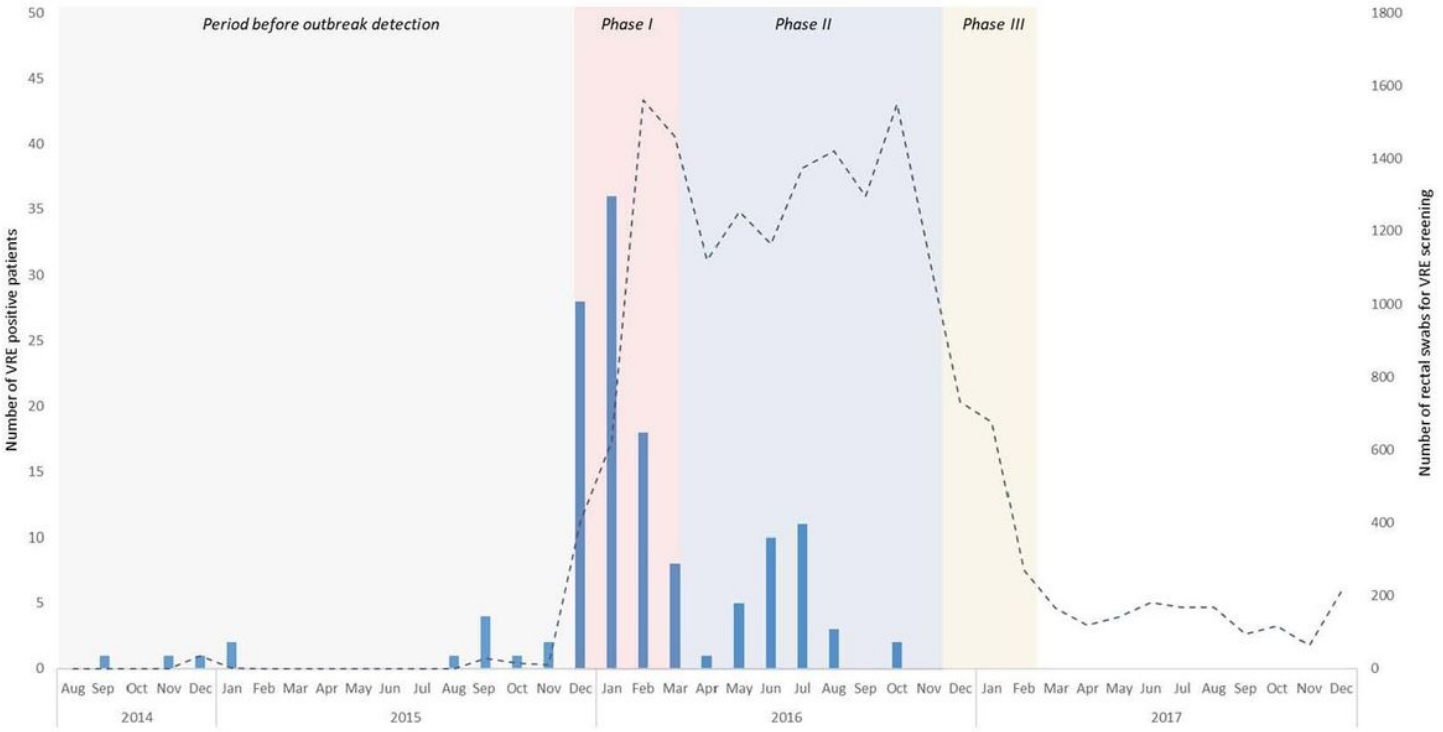

Figure 1

Epidemiological curve of new VRE-positive patients (blue bar, n = 135) and number of rectal screening cultures on admission, prevalence and contact tracing (dotted line) in ADRZ. Patients who were transferred to other healthcare settings when found to be VRE positive (n = 5) are not shown in this graph.

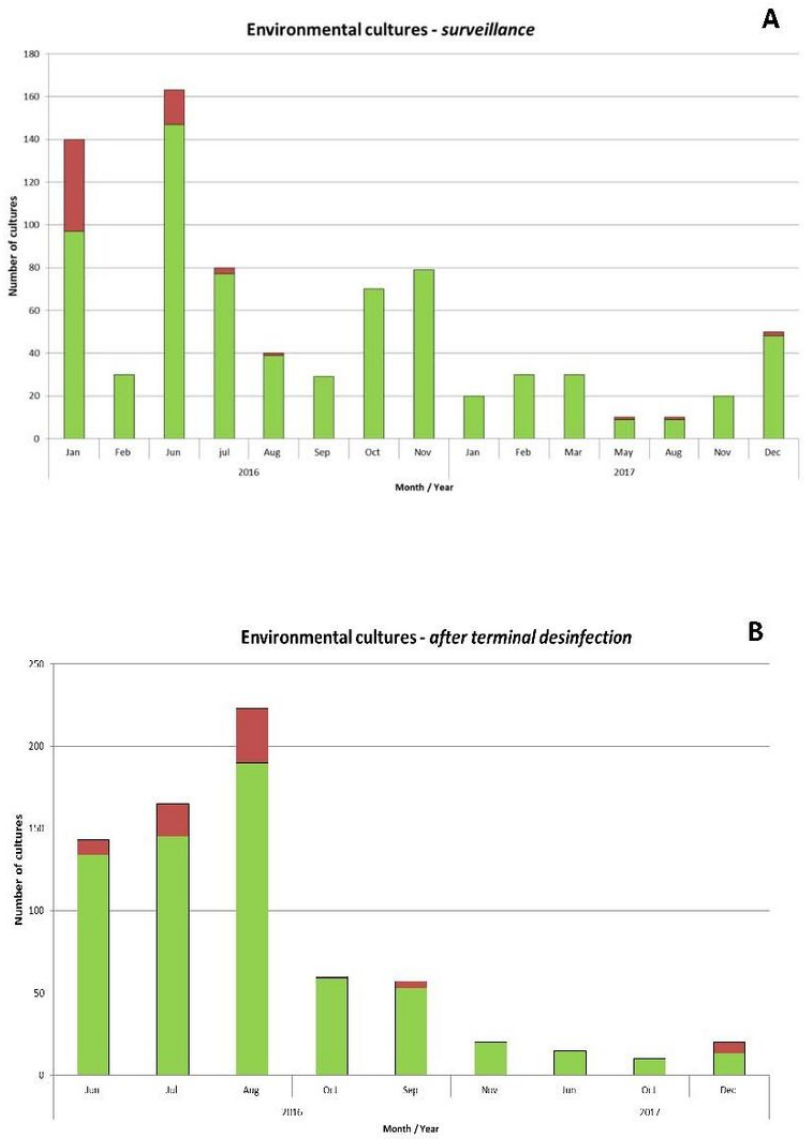

Figure 2

Environmental cultures of the patient rooms, a range of high touch surfaces and (medical) equipment's at random times (surveillance) (a) and after disinfection (b). Red bar: VREfm positive cultures; green bar: VRE negative cultures.