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Universal risk assessment upon hospital admission for screening of carriage with multidrug-resistant micro-organisms in a Dutch tertiary care centre

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SUMMARY

Background: In Dutch hospitals a six-point questionnaire is currently mandatory for risk assessment to identify carriers of multidrug-resistant organisms (MDROs) at the time of hospitalization. Presence of one or more risk factors is followed by pre-emptive isolation and microbiological culturing.

Aim: To evaluate the yield of the universal risk assessment in identifying MDRO carriers upon hospitalization.

Methods: A cross-sectional study was performed using routine healthcare data in a Dutch tertiary hospital between January 1st, 2015 and August 1st, 2019. MDRO risk assessment upon hospitalization included assessment of: known MDRO carriage, previous hospitalization in another Dutch hospital during an outbreak or a foreign hospital, living in an asylum centre, exposure to livestock farming, and household membership of a meticillin-resistant *Staphylococcus aureus* carrier.

Findings: In total, 144,051 admissions of 84,485 unique patients were included; 4480 (3.1%) admissions had a positive MDRO risk assessment. In 1516 (34%) admissions microbiological screening was performed, of which 341 (23%) yielded MDRO. Eighty-one patients were categorized as new MDRO carriers, as identified through MDRO risk assessment, reflecting 0.06% (95% confidence interval: 0.04–0.07) of all admissions and 1.8% (1.4–2.2) of those with positive risk assessment. As a result, the number of 'MDRO risk assessments needed to perform' and individual 'MDRO questions needed to ask' to detect one new MDRO carrier upon hospitalization were 1778 and 10,420, respectively.

Conclusion: The yield of the current strategy of MDRO risk assessment upon hospitalization is limited and it needs thorough reconsideration.

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Introduction

Dissemination of multidrug-resistant micro-organisms (MDROs) in healthcare settings may lead to more infections caused by MDROs, which may reduce effectiveness of empirical antibiotic therapy [1—4]. The hospital setting facilitates patient-to-patient transmission of MDROs because of high antibiotic selective pressure, frequent contact between healthcare workers and patients, and vulnerability of patients to acquire carriage with MDROs. Optimizing control strategies is therefore important to prevent dissemination and associated risks of infections caused by MDROs. Hospital-based surveillance is recommended for timely detection of MDRO carriage and installation of transmission-based precautions. In the Netherlands, hospitals have adopted a risk-based screening for asymptomatic MDRO carriage upon admission. This originated in the mid-1980s to control the emergence of meticillin-resistant *S. aureus* (MRSA), as one of the elements of the Dutch 'search and destroy' strategy [5—10]. Over the years, this risk-based screening has been extended also to control other MDROs, such as multidrug-resistant Gram-negative bacteria (MDR-GNB) [11,12]. MDRO risk assessment is, for each patient, based on a six-point questionnaire that needs to be checked upon admission. These questions include risk factors for carriage of MRSA, MDR-GNB, and vancomycin-resistant enterococci (VRE). In patients at risk of MDRO carriage, according to this screening, pre-emptive transmission-based precautions should be installed and screening cultures should be obtained. Adherence to this strategy is monitored by the Dutch Healthcare Inspectorate and thereby standard practice in all Dutch hospitals. Yet, this approach requires time for questioning patients, pre-emptive isolation measures that may affect care of other patients, and resources for microbiological testing. The benefits of the strategy have not yet been quantified.

The aim of the current study was to evaluate the current risk assessment for screening of MDRO carriage upon hospital admission in a Dutch tertiary care hospital. We therefore determined the number of newly identified MDRO carriers and the number of questions needed to ask to identify one new MDRO carrier. The detected prevalence of MDRO carriage was also compared with the expected prevalence of MDRO carriage in the Dutch population upon hospital admission.

Methods

Study design

This observational study was performed in the University Medical Center Utrecht (UMCU) in the Netherlands. The UMCU is a tertiary care medical centre with 1042 beds for adults and children, all medical specialties represented, and around 180,000 inpatient days per year. A cross-sectional study using routinely collected healthcare data was performed of all hospital admissions between January 1st, 2015 and August 1st, 2019. For this study we extracted data from all hospital admissions with completion of the MDRO risk assessment in the electronic medical record (EMR) on the same day as hospitalization. A hospital admission was defined as any admission to any ward, including admissions for single-day treatments, and for all ages. Characteristics available per admission were age, sex, and length of stay (LOS). Results of this study were reported following the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) criteria [13].

MDRO risk assessment

The screening strategy consisted of two consecutive steps. Step one was an individual 6-item risk assessment for MDRO carriage. The six questions referred to: (1) known MDRO carriage, (2) previous hospitalization in another Dutch hospital during the past two months with an ongoing outbreak during hospitalization, (3) previous hospitalization in a foreign hospital in the past two months, (4) living in an asylum shelter, (5) professional exposure to livestock farming (i.e. living pigs, veal calves, or broilers), and (6) living with a known MRSA carrier (the entire questionnaire is reproduced in Supplementary Table S1). The MDRO assessment was obligatory and embedded in the EMR, to be completed within 24 h for each patient admitted, visiting the emergency department or outpatient clinic for preoperative screening. This also included short-stay admissions, e.g. day treatment (i.e. for colonoscopy, labour) or short admissions to the coronary care unit. During the study period, adherence to the screening strategy was 90.3%, meaning that an MDRO risk assessment was performed on the day of admission in 90.3% of all hospital admissions. Answers of the assessment remained valid for 62 days after completion and answers were automatically completed if a new assessment was started within this time-window. In case of more than one MDRO assessment obtained on the day of admission, only the first one was used for the current study. A positive MDRO risk assessment was defined as at least one question answered with 'yes'. A positive assessment automatically generated an isolation label in the EMR with a responsive order for pre-emptive transmission-based precautions for that patient. The second step entailed obtaining targeted screening cultures from these patients, unless someone was a known carrier and/or there were culture results with MDROs that had been obtained in the past two months. Targeted screening cultures consisted of a throat, nose and perineal swab in case of risk factors for MRSA carriage, and a throat, nose, rectal and perineal swab in case of risk of MDR-GNB carriage (i.e. previous hospitalization in foreign hospital). Presence of other MDROs was only assessed upon indication (e.g. specific previous carriage, specific outbreak in previous hospital). If screening cultures yielded MDROs, transmission-based precautions were continued; if not, the EMR isolation label was removed and transmission-based precautions were discontinued. All steps were co-ordinated semi-automatically by the infection prevention (IP) specialists, who manually reviewed answers of positive MDRO assessments within 24 h and who modified infection control measures, where needed. IP specialists were also automatically notified in case of any (screening or clinical) culture yielding MDROs and manually assigned isolation labels in the EMR if transmission-based precautions were needed.

Microbiology

We collected microbiological results of screening cultures during the study period. Screening cultures were defined as nasal, throat, rectal, or perineal swabs obtained on the day of admission or on the day thereafter in patients with a positive MDRO assessment (Supplementary Table S2). MDROs included

MRSA, VRE, extended-spectrum β-lactamase (ESBL)-producing and/or multidrug-resistant Enterobacterales (ESBL/MDR-E), carbapenem-resistant Enterobacterales (CRE), multidrug-resistant *Acinetobacter* spp. (MDR-A), carbapenem-resistant *Acinetobacter* spp., multidrug-resistant *Pseudomonas aeruginosa*, cotrimoxazol-resistant *Stenotrophomonas maltophilia*, and penicillin-resistant *Streptococcus pneumoniae* (PSP) (Supplementary Table S3). The categories ESBL/MDR-E and CRE were mutually exclusive (i.e. strains categorized as ESBL/MDR-E were not carbapenem-resistant, because we categorized these separately). Definitions of MDRO were based on the Dutch Working Party Infection Prevention (WIP) guidelines and were adapted to local definitions of the UMCU if applicable [12].

Ethics approval

This study was performed in line with the Declaration of Helsinki, as revised in 2013 [14]. Because this study did not fall under the scope of the Medical Research Involving Human Subjects Act (in Dutch: 'WMO'), the Medical Research Ethics Committee of the UMCU waived the need for official approval by the UMCU Ethics Committee (IRB correspondence number 18—574C) and individual informed consent was not obtained. All data were analysed and stored pseudonymized.

Statistical analyses

'The number of MDRO risk assessments to perform' and 'the number of MDRO assessment questions needed to ask' to detect one new MDRO carrier upon hospital admission were determined by dividing the total number of admissions and the corresponding MDRO assessment questions by the total number of newly identified MDRO carriers, respectively. The positive predictive value (PPV) was determined for each of the individual questions of the MDRO assessment. The PPV was calculated as the number of admissions in which the question was answered positively and screening identified new MDRO carriage, divided by the total number of times the question was answered positively. Naturally, patients admitted might already have an isolation label in the EMR (usually based upon prior culture results), yet, in routine care, such patients are also part of the risk assessment. Therefore, in admissions with a positive MDRO assessment and with MDRO in screening cultures, the presence of prior isolation labels in the EMR was determined. The observed prevalence of detected MDRO carriage through risk assessment was compared to expected MDRO carriage of the Dutch population, based on recent studies (if available; of the last 10 years), to estimate the proportion of MDRO carriers that still remained undetected upon admission.

False-positive risk assessment leads to unnecessary (pre-emptive) isolation days until screening cultures turn out to be negative for MDROs. In the absence of our risk assessment strategy, true positives would remain undetected until clinical cultures yield MDROs or until patient discharge. Therefore, the length of stay until the first clinical culture yielding MDRO was determined for admissions with newly identified MDRO carriage identified through risk assessment. In absence of MDRO in clinical cultures, the total duration of hospital stay was used. This length of time was used as a proxy for the maximum duration of pre-emptive transmission-based precautions gained by the screening strategy. The total number of unjustified isolation days was calculated as the total number of isolation days until negative screening results were available. Data on the exact time-stamps of when culture results became available in the patient's EMR were not available. We therefore assumed 0.5 days until a negative MRSA culture (based upon rapid polymerase chain reaction testing of nasal swabs) and 1.5 days for other MDRO cultures (based upon conventional cultures).

Data were reported with means ± standard deviation (SD), medians with interquartile range (IQR) or percentages, where appropriate. Ninety-five percent confidence intervals (CIs) of proportions were calculated using the Exact method [15]. All statistical analyses were performed with Statistical Package for Social Sciences V.25.0.2 (SPSS, Chicago, IL, USA) and R Version 3.4.1.

Results

Study population

In all, 171,974 MDRO assessments of non-cancelled admissions were obtained. As two or more assessments were obtained in 27,923 (16.2%) admissions, exclusion of duplicate assessments led to 144,051 hospital admissions of 84,485 unique patients for analyses (Figure 1). The median age of admissions was 49 years (IQR: 19—67) and 48.0% ($N = 69,197$) were female. Median length of stay (LOS) was 1 day (IQR: 0—4) and 65.6% ($N = 92,992$) of all admissions included an overnight stay.

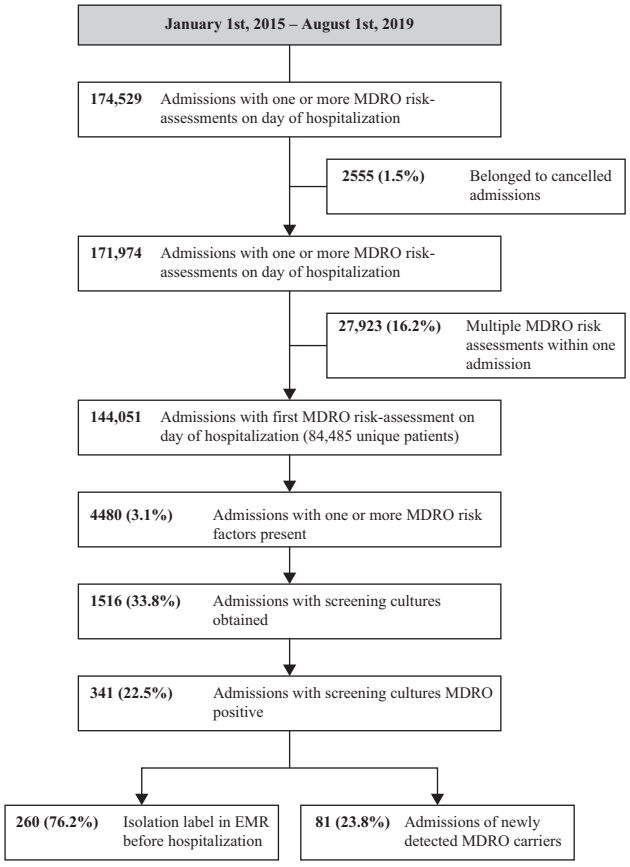

Figure 1. Study flowchart.

Identification of new MDRO carriers

In total, 4480 (3.1%) admissions had a positive MDRO assessment and pre-emptive transmission-based precautions installed, which was mainly based on the presence of known carriage with MDRO (N = 3206, 71.6%) (Table I). In 1516 (33.8%) of these admissions, screening cultures were obtained, of which 341 (22.5%) yielded MDROs (Figure 1). Predominant reasons for not obtaining screening cultures (N = 2964 admissions) were known MDRO carriage status (2307, 77.8%) or re-categorization to low risk by IP specialists (406, 13.7%). Of the remaining 253 (8.5%) episodes, discharge was on the same day as admission in 109 (3.7%) and reasons for not obtaining screening cultures were unknown in 144 (4.9%) admissions.

In all, 81 admissions (of 81 unique patients) were categorized as newly identified MDRO carriers due to the MDRO risk assessment screening strategy (Figure 1). This reflected 0.06% (81/144,051; 95% CI: 0.04–0.07) of all admissions and 1.8% (81/4480; 95% CI: 1.4–2.2) of all admissions with a positive risk assessment. In 260 (76.2%) admissions with MDRO growing in screening cultures, an isolation label was already present in the EMR at the time of hospitalization. Of these, seven (2.7%) were succeeding admissions of MDRO carriers identified through previous positive MDRO risk assessment (i.e. were second or third admissions of 'newly identified MDRO carriers').

Fifty-two (64.2%) and 26 (32.1%) of the 81 newly identified MDRO carriers carried MDR-E/ESBL-E and MRSA, respectively. MDR-E isolates (that were ESBL negative, N = 33) were defined as isolates that were resistant to fluoroquinolones and aminoglycosides, but susceptible to carbapenems. The MDRO risk assessment strategy identified CRE carriage (rectal carriage with OXA-48-like *Enterobacter cloacae* and OXA-48 *Klebsiella pneumoniae*, respectively) in two patients with recent hospitalization abroad, and one VRE carrier with known carriage due to screening in another hospital. The number of newly identified MDRO carriers through risk-based screening was stable over time (Supplementary Table S4) and the identified MDRO per risk factor is listed in Supplementary Table S5.

MDRO risk assessment

Positive predictive values of the individual questions for identifying new MDRO carriage ranged from 1.0% (95% CI: 0.7–1.3) for 'Are you a known carrier of an MDRO?' to 7.0% (95% CI: 4.3–11.1) for 'Did you live in an asylum shelter during the past 2 months?' (Table I). Yet, the number needed to ask of the individual questions to detect one new MDRO carrier ranged from 4647 for 'Are you a known carrier of an MDRO?' to 71,563 for 'Are you a household member of an MRSA carrier?' The numbers of 'MDRO risk assessments needed to perform' and individual 'MDRO-questions needed to ask' to detect one new MDRO carrier upon hospital admission were 1778 (144,041/81) and 10,420 (844,031/81), respectively.

When comparing the observed prevalence of newly identified carriers based on the screening strategy to the perceived prevalence of MDRO carriage upon hospital admission based on recent epidemiological studies in the Netherlands, we estimated that the current MDRO risk assessment screening strategy detected only <1%, <1%, <2%, and 18.2% of all admissions of ESBL-E, VRE, CRE, and MRSA carriers, respectively (Table II).

MDRO in clinical cultures during hospital stay

In 1279 (0.9%) of all hospital admissions, clinical cultures yielded MDRO during hospital stay, of which 59.8% (N = 765)

Table I
Admissions with positive multidrug-resistant organism (MDRO) risk assessment, positive MDRO screening cultures and positive predictive value for new identified MDRO carriage per question

Question	No. of times asked	Answered positively	Screening cultures obtained	New identified MDRO carriage[a]	PPV (%) (95% CI)	NNA[b]
1. Are you a known carrier of an MDRO (e.g. MRSA, VRE, MDR-GNR)?	144,051	3206 (2.3%)	901 (28.1%)	31 (3.4%)	1.0 (0.7–1.3)	4647
2. During the past 2 months, were you hospitalized in another Dutch hospital during a known MDRO outbreak?	143,394	200 (0.1%)	46 (23.0%)	3 (6.5%)	1.5 (0.5–4.4)	47,798
3. During the past 2 months, were you hospitalized in a foreign hospital?	143,747	673 (0.5%)	372 (55.3%)	34 (9.1%)	5.0 (3.9–6.5)	4228
4. In the past 2 months, did you live in an asylum shelter?	115,376[c]	187 (0.2%)	106 (56.7%)	13 (12.3%)	7.0 (4.3–11.1)	8875
5. Do you work with living pigs, veal calves or broilers?	143,351	340 (0.2%)	141 (41.5%)	8 (5.7%)	2.4 (1.2–4.5)	17,919
6. Are you a household member of an MRSA carrier?	143,126	116 (0.1%)	54 (46.6%)	2 (3.7%)	1.7 (0.4–6.5)	71,563
One or more of six questions answered positively	144,051	4480 (3.1%)	1516 (33.8%)	81 (5.3%)	1.8 (1.5–2.2)	1778

PPV, positive predictive value; NNA, number needed to ask; CI, confidence interval; MRSA, meticillin-resistant *S. aureus*; VRE, vancomycin-resistant enterococcus; MDR-GNR, multidrug-resistant Gram-negative rod.

[a] Individual columns count up to >81 because risk assessment could contain a positive reply to multiple questions.

[b] 'Number of questions needed to ask'; calculated as the total number of times the question was asked divided by the number of newly identified MDRO carriers with a positive reply to this question.

[c] This question was added to the risk assessment on October 21st, 2015.

Table II
Estimated proportion of multidrug-resistant organism (MDRO) carriers detected upon hospital admission by the current MDRO screening strategy

	Prevalence of newly identified carriage upon admission by risk-based screening (95% CI): current study (%)	Estimated prevalence of carriage upon admission: inferred from other Dutch studies[a] (%)	Estimated proportion detected by risk-based screening (%)
ESBL-positive Enterobacterales	0.03 (0.02–0.04)	6.4 to 7.0 [16]	0.4 to 0.5
MRSA	0.02 (0.01–0.03)	0.11 [17] to 0.13 [18]	15.4 to 18.2
Carbapenem-resistant Enterobacterales	0.001 (0.0002–0.005)	<0.06 [19] to 0.25 [20–22] [b]	0.4 to 1.7
VRE	0.0007 (0.00002–0.004)	1.3 [22] to 1.5 [23,24][c]	0.05

CI, confidence interval; ESBL, extended-spectrum β-lactamase; MRSA, meticillin-resistant *S. aureus*; VRE, vancomycin-resistant enterococcus.
[a] The aim was to estimate the prevalence of carriage upon hospital admission in the Netherlands for the different types of MDRO. In case there was no information from Dutch studies that measured actual prevalence upon hospital admission, best available evidence was used from other settings (see below).
[b] Estimates for carbapenem-resistant Enterobacterales carriage upon admission derived from point-prevalence surveys in patients during admission and population-based studies on community intestinal carriage.
[c] Estimates for VRE carriage upon admission derived from point-prevalence surveys in patients during admission and a population-based study on community intestinal carriage.

had negative MDRO risk assessment at the time of admission. Of the 765 admissions with a negative risk assessment upon admission and a clinical culture positive for MDRO, the most common identified MDRO were ESBL/MDR Enterobacterales (73.6%) (Supplementary Tables S6 and S7). In 297 (39%), 127 (17%), 43 (6%) and 298 (39%) of these admissions the clinical culture was obtained the day of admission, on day 1, day 2, and from day 3 onwards, respectively, resulting in a proportion of 61% and 39% admissions classified as admissions with community-acquired and hospital-acquired MDRO infection (Supplementary Figure S1).

In 12 (14.8%) of the 81 admissions with newly identified MDRO carriage, the same type of MDRO was also identified in ($N = 17$) clinical cultures during hospital stay. For these 12 admissions, the median LOS until MDRO detection in clinical cultures was 4 days (IQR: 2–6), and the total number of hospitalization days was 53. Most clinical cultures were from urine ($N = 5/17$, 29.4%) (Supplementary Table S8). The total LOS of the 69 MDRO carriers that would not have been detected without risk-based screening was 513, making 566 days of unprotected ward stay that was prevented by the screening strategy. The total number of unjustified isolation days due to false-positive risk assessment was calculated as 1436 days.

Discussion

In this analysis of 144,051 hospital admissions, a strategy of risk-based screening for MDRO carriage upon hospital admission identified previously unknown MDRO carriage in 0.06% (95% CI: 0.04–0.07) of all admissions and in 1.8% (95% CI: 1.4–2.2) of all admissions of patients considered to be at high risk of MDRO carriage. The numbers of 'MDRO risk assessments needed to perform' and individual 'MDRO risk assessment questions needed to ask' to detect one new MDRO carrier upon hospital admission were 1778 and 10,420, respectively.

The calculated numbers needed to ask are underestimated, as 16% of admissions had more than one MDRO risk assessment completed on the same day, and these copy-assessments were excluded from the analysis. If included, the numbers of 'MDRO risk assessments actually performed' and 'MDRO risk assessment questions actually asked' to detect one new MDRO carrier upon admission would have been 2123 (171,974/81) and 12,440 (1,007,640/81), respectively. If at a conservative estimate, 1 min of labour time was spent per MDRO risk assessment and 1 min for administration, then at least 160 working weeks of 36 h were spent on performing assessments during these four-and-a-half years. This reflects at least two working weeks spent per newly identified MDRO carrier (160 weeks divided by 81 new carriers).

Newly identified carriers were most often colonized with ESBL-producing and/or Enterobacterales strains resistant to both an aminoglycoside and ciprofloxacin (70%); however, the value of screening for these MDROs upon admission for the prevention of transmission and hospital-acquired infections is not well established [25–27]. In our study, the prevalence of newly detected ESBL carriage upon admission was 0.03% (95% CI: 0.02–0.04) – considerably lower than the prevalence of faecal ESBL carriage in the Dutch community, which was 5% in randomly selected subjects and 6.4–7.0% upon admission to our hospital [16,19]. Thus, in our hospital, we estimated that the proportion of ESBL carriers who remained undetected upon admission despite risk-based screening was probably >99%. For CRE and VRE the proportion of undetected carriers was equally high, being >98% and >99%, respectively.

The second most common MDRO in new carriers was MRSA (26%), which was identified in 0.02% (95% CI: 0.01–0.03%) of all admissions. Screening and pre-emptive isolation of high-risk patients for MRSA has been an important part of the Dutch 'search and destroy' policy for the prevention of MRSA transmission [6–8,17,28–31]. In our study, positive predictive values to detect – among others – MRSA carriage ranged from 2.4% (95% CI: 1.2–4.5%) (working with living pigs, veal calves, or broilers) to 5.0% (95% CI: 3.9–6.5%) (previous hospitalization in a foreign hospital). Still, the presence of these risk factors was rare and even lowest for the question about being a household member of an MRSA carrier (0.1%), which needed to be asked 71,563 times in order to identify one new MRSA carrier upon hospital admission. In a recent analysis of routine universal preoperative screening for nasal *S. aureus* carriage during a 7-year period in another Dutch hospital, the prevalence of MRSA carriage was 0.13%, comparable to the reported

prevalence of 0.11% upon admission in a study performed eight years earlier [17,18]. Assuming a similar prevalence in patients admitted to our hospital would imply that the current screening strategy identified only 15% of all MRSA carriers upon admission, suggesting that 85% remained undetected. This is in line with other studies reporting that currently a large proportion of MRSA carriers do not have the classical risk factors (i.e. as inquired with our risk assessment) for MRSA carriage [7,32—34].

The assessment question on known MDRO carriage had the highest yield, as it was answered positively in 2.8%. Indeed, 76% ($N = 260$) of all patients with an MDRO positive screening culture were already labelled in our EMR as a known MDRO carrier, of which 2.7% ($N = 7$) were readmissions of patients who had received this label due to previous risk-based screening. This implied that if the risk assessment would have been replaced by the use of existing MDRO labelling in the EMR, then 74% (253/341) of admissions of MDRO carriers — that were now identified by risk-based screening — would still be captured.

Typically, the unexpected identification of an MDRO carrier during admission (i.e. through a positive clinical culture) is associated with extra workload, for screening of exposed roommates or healthcare workers of the index patient. This is not needed if the carrier has already been identified upon admission (and thus transmission-based precautions have already been installed). In our study, only 15% ($N = 12$) of detected carriers had a clinical culture positive for MDRO during admission, for which contact tracing would have been implemented if screening upon admission had not been applied. We estimated that abandoning risk-assessment-based screening would have led to 566 patient-days without protective measures for MDRO carriers in the 4.5 years of the observation period. The number of prevented episodes of cross-transmission due to the identification of new MDRO carriers upon admission is difficult to determine. Yet, as the vast majority of MDRO carriers remained undetected, we consider that these 566 days add little to the total number of patient-days without protective measures for — unknown — MDRO carriers.

A strength of the current analysis was the combination of routine care data and medical microbiology information of 90% of all admissions during the predefined study period. There are also important limitations of this study that should be acknowledged. First, retrograde manual changes to the MDRO risk assessment during hospital admission could not be retrieved. It is therefore not excluded that the MDRO risk assessment (e.g. the first question) was manually changed to 'positive' in case of MDRO-positive cultures during admission. If so, the value of MDRO risk assessment would have been overestimated. Second, this was a real-life evaluation of clinical practice, without confirmation whether the individual questions of the MDRO risk assessment were answered correctly. Third, for the calculation of unjustified isolation days there was no formal check on whether a patient with an isolation label in the EMR has been in isolation. Yet, from regular audits on adherence to isolation procedures in our hospital we consider it highly likely that patients were treated in isolation if an isolation label was present. Also, we were conservative in our estimation of time until negative screening results and lifting of transmission-based precautions (i.e. resulting in possible underestimation of the total number of unjustified isolation days). Fourth, this was a single-centre analysis in an academic medical centre in the Netherlands, with a well-developed system of identification, labelling and isolation of MDRO carriers as well as good adherence to standard precautions in routine care. Extrapolation of findings to other settings or countries should always occur in light of local epidemiology and established routine infection and prevention practices within a hospital.

The current low levels of AMR in hospitals in the Netherlands are partly explained by a restrictive use of antibiotics combined with the well-established 'search and destroy' policy over the last decades. Still, critical appraisal as well as continuous improvement is a fundamental part of infection prevention and control, considering that local epidemiology and target populations may change over time. Results of this study imply that the majority of MDRO carriers in the community remains undetected upon admission despite current risk-based screening. Combined with the low prevalence of risk factors and the types of MDRO that are most often identified, the question arises whether the number of newly identified MDRO carriers justifies the invested workload across all hospital wards in risk assessment upon admission. We propose a system for Dutch hospitals in which risk-based screening is abandoned and, instead, transmission-based precautions are installed upon hospitalization of patients that are known (previous) carriers of MDROs. This captures the majority of MDRO carriers that would otherwise be identified through risk assessment. We recommend that this process be continuously monitored and we emphasize the importance of having well-established MDRO surveillance systems in place. Surveillance should contain hospital-wide longitudinal data on microbiological culture results, occurrence of MDRO and labelling of MDRO carriers.

In conclusion, in an academic Dutch hospital with a well-established MDRO surveillance system, individual risk assessment and screening for MDRO carriage upon hospital admission resulted in a low yield of newly identified MDRO carriers in comparison to overall invested workload, while the majority of carriers most likely remained undetected. Our findings justify a reconsideration of the current individual risk assessment for MDRO carriage upon admission.

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Conflict of interest statement
None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2020.12.007.

References

[1] Mehl A, Asvold BO, Kummel A, Lydersen S, Paulsen J, Haugan I, et al. Trends in antimicrobial resistance and empiric antibiotic therapy of bloodstream infections at a general hospital in Mid-Norway: a prospective observational study. BMC Infect Dis 2017;17:116. https://doi.org/10.1186/s12879-017-2210-6.

[2] de Kraker MEA, Jarlier V, Monen JCM, Heuer OE, van de Sande N, Grundmann H. The changing epidemiology of bacteraemias in Europe: trends from the European Antimicrobial Resistance Surveillance System. Clin Microbiol Infect 2013;19:860—8. https://doi.org/10.1111/1469-0691.12028.

[3] Van Der Steen M, Leenstra T, Kluytmans JAJW, Van Der Bij AK. Trends in expanded-spectrum cephalosporin-resistant *Escherichia coli* and *Klebsiella pneumoniae* among Dutch clinical isolates, from 2008 to 2012. PLoS One 2015;10:e0138088. https://doi.org/10.1371/journal.pone.0138088.

[4] Vihta K-D, Stoesser N, Llewelyn MJ, Quan TP, Davies T, Fawcett NJ, et al. Trends over time in *Escherichia coli* bloodstream infections, urinary tract infections, and antibiotic susceptibilities in Oxfordshire, UK, 1998—2016: a study of electronic health records. Lancet Infect Dis 2018;18:1138—49. https://doi.org/10.1016/S1473-3099(18)30353-0.

[5] Werkgroep Infectiepreventie. WIP Richtlijn Meticilline-resistente Staphylococcus aureus (MRSA). 2012. https://www.rivm.nl/sites/default/files/2018-11/121205%20MRSA%20v1a%20def.pdf.

[6] Vos MC, Ott A, Verbrugh HA. Successful search-and-destroy policy for methicillin-resistant *Staphylococcus aureus* in The Netherlands. J Clin Microbiol 2005;43:2034—5. https://doi.org/10.1128/JCM.43.4.2034-2035.2005. Author reply 2034—5.

[7] Vos MC, Behrendt MD, Melles DC, Mollema FPN, de Groot W, Parlevliet G, et al. 5 years of experience implementing a methicillin-resistant *Staphylococcus aureus* search and destroy policy at the largest university medical center in the Netherlands. Infect Control Hosp Epidemiol 2009;30:977—84. https://doi.org/10.1086/605921.

[8] van Rijen MML, Bosch T, Heck MEOC, Kluytmans JAJW. Meticillin-resistant *Staphylococcus aureus* epidemiology and transmission in a Dutch hospital. J Hosp Infect 2009;72:299—306. https://doi.org/10.1016/j.jhin.2009.05.006.

[9] Vandenbroucke-Grauls CM. Methicillin-resistant *Staphylococcus aureus* control in hospitals: the Dutch experience. Infect Control Hosp Epidemiol 1996;17:512—13. https://doi.org/10.1086/647355.

[10] Werkgroep Infectiepreventie. Beleid Bij Meticilline-resistente *Staphylococcus aureus*. 1988. Leiden.

[11] Werkgroep Infectiepreventie. WIP Richtlijn Maatregelen tegen overdracht van bijzonder resistente micro-organismen (BRMO). 2017. Leiden.

[12] Werkgroep Infectiepreventie. WIP Richtlijn Bijzonder resistente Micro-organismen (BRMO). 2017. Leiden, https://www.rivm.nl/sites/default/files/2018-11/130424%20BRMO.pdf (in Dutch).

[13] von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. PLoS Med 2007;4:e296. https://doi.org/10.1371/journal.pmed.0040296.

[14] World Medical Association. Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA 2013;310:2191—4. https://doi.org/10.1001/jama.2013.281053.

[15] Tobi H, van den Berg PB, de Jong-van den Berg LTW. Small proportions: what to report for confidence intervals? Pharmacoepidemiol Drug Saf 2005;14:239—47. https://doi.org/10.1002/pds.1081.

[16] Kluytmans-van den Bergh MFQ, van Mens SP, Haverkate MR, Bootsma MCJ, Kluytmans JAJW, Bonten MJM, et al. Quantifying hospital-acquired carriage of extended-spectrum beta-lactamase-producing Enterobacteriaceae among patients in Dutch hospitals. Infect Control Hosp Epidemiol 2018;39:32—9. https://doi.org/10.1017/ice.2017.241.

[17] Bode LGM, Wertheim HFL, Kluytmans JAJW, Bogaers-Hofman D, Vandenbroucke-Grauls CMJE, Roosendaal R, et al. Sustained low prevalence of meticillin-resistant *Staphylococcus aureus* upon admission to hospital in The Netherlands. J Hosp Infect 2011;79:198—201. https://doi.org/10.1016/j.jhin.2011.05.009.

[18] Weterings V, Veenemans J, van Rijen M, Kluytmans J. Prevalence of nasal carriage of methicillin-resistant *Staphylococcus aureus* in patients at hospital admission in The Netherlands, 2010—2017: an observational study. Clin Microbiol Infect 2019;25:1428.e1—5. https://doi.org/10.1016/j.cmi.2019.03.012.

[19] van den Bunt G, van Pelt W, Hidalgo L, Scharringa J, de Greeff SC, Schurch AC, et al. Prevalence, risk factors and genetic characterisation of extended-spectrum beta-lactamase and carbapenemase-producing Enterobacteriaceae (ESBL-E and CPE): a community-based cross-sectional study, the Netherlands, 2014 to 2016. Eur Commun Dis Bull 2019;24. https://doi.org/10.2807/1560-7917.ES.2019.24.41.1800594.

[20] Dautzenberg MJ, Ossewaarde JM, de Kraker ME, van der Zee A, van Burgh S, de Greeff SC, et al. Successful control of a hospital-wide outbreak of OXA-48 producing Enterobacteriaceae in the Netherlands, 2009 to 2011. Eurosurveillance 2014;19:20723. https://doi.org/10.2807/1560-7917.es2014.19.9.20723.

[21] Reuland EA, Overdevest ITMA, Al Naiemi N, Kalpoe JS, Rijnsburger MC, Raadsen SA, et al. High prevalence of ESBL-producing Enterobacteriaceae carriage in Dutch community patients with gastrointestinal complaints. Clin Microbiol Infect 2013;19:542—9. https://doi.org/10.1111/j.1469-0691.2012.03947.x.

[22] Zhou X, Garcia-Cobos S, Ruijs GJHM, Kampinga GA, Arends JP, Borst DM, et al. Epidemiology of extended-spectrum beta-lactamase-producing *E. coli* and vancomycin-resistant enterococci in the northern Dutch—German cross-border region. Front Microbiol 2017;8:1914. https://doi.org/10.3389/fmicb.2017.01914.

[23] van den Braak N, Ott A, van Belkum A, Kluytmans JA, Koeleman JG, Spanjaard L, et al. Prevalence and determinants of fecal colonization with vancomycin-resistant Enterococcus in hospitalized patients in The Netherlands. Infect Control Hosp Epidemiol 2000;21:520—4. https://doi.org/10.1086/501797.

[24] van den Bunt G, Top J, Hordijk J, de Greeff SC, Mughini-Gras L, Corander J, et al. Intestinal carriage of ampicillin- and vancomycin-resistant *Enterococcus faecium* in humans, dogs and cats in the Netherlands. J Antimicrob Chemother 2017:607—714. https://doi.org/10.1093/jac/dkx455.

[25] Otter JA, Mutters NT, Tacconelli E, Gikas A, Holmes AH. Controversies in guidelines for the control of multidrug-resistant Gram-negative bacteria in EU countries. Clin Microbiol Infect 2015;21:1057—66. https://doi.org/10.1016/j.cmi.2015.09.021.

[26] Tacconelli E, Cataldo MA, Dancer SJ, De Angelis G, Falcone M, Frank U, et al. ESCMID guidelines for the management of the infection control measures to reduce transmission of multidrug-resistant Gram-negative bacteria in hospitalized patients. Clin Microbiol Infect 2014;20(Suppl 1):1—55. https://doi.org/10.1111/1469-0691.12427.

[27] Gardam MA, Burrows LL, Kus JV, Brunton J, Low DE, Conly JM, et al. Is surveillance for multidrug-resistant Enterobacteriaceae an effective infection control strategy in the absence of an outbreak? J Infect Dis 2002;186:1754—60. https://doi.org/10.1086/345921.

[28] Bootsma MCJ, Diekmann O, Bonten MJM. Controlling methicillin-resistant *Staphylococcus aureus*: quantifying the effects of interventions and rapid diagnostic testing. Proc Natl Acad Sci USA 2006;103:5620—5. https://doi.org/10.1073/pnas.0510077103.

[29] Wertheim HFL, Vos MC, Boelens HAM, Voss A, Vandenbroucke-Grauls CMJE, Meester MHM, et al. Low prevalence of methicillin-resistant *Staphylococcus aureus* (MRSA) at hospital admission in the Netherlands: the value of search and destroy and restrictive

antibiotic use. J Hosp Infect 2004;56:321—5. https://doi.org/10.1016/j.jhin.2004.01.026.

[30] Souverein D, Houtman P, Euser SM, Herpers BL, Kluytmans J, Den Boer JW. Costs and benefits associated with the MRSA search and destroy policy in a hospital in the region Kennemerland, the Netherlands. PLoS One 2016;11:e0148175. https://doi.org/10.1371/journal.pone.0148175.

[31] Clancy M, Graepler A, Wilson M, Douglas I, Johnson J, Price CS. Active screening in high-risk units is an effective and cost-avoidant method to reduce the rate of methicillin-resistant *Staphylococcus aureus* infection in the hospital. Infect Control Hosp Epidemiol 2006;27:1009—17. https://doi.org/10.1086/507915.

[32] Lekkerkerk WS, van de Sande-Bruinsma N, van der Sande MAB, Tjon-A-Tsien A, Groenheide A, Haenen A, et al. Emergence of MRSA of unknown origin in the Netherlands. Clin Microbiol Infect 2012;18:656—61. https://doi.org/10.1111/J.1469-0691.2011.03662.X.

[33] De Greeff SC, Mouton JW, Schoffelen AF, Verduin CM. NethMap 2019: Consumption of antimicrobial agents and antimicrobial resistance among medically important bacteria in the Netherlands / MARAN 2019: Monitoring of antimicrobial resistance and antibiotic usage in animals in the Netherlands in 2018. Rijksinstituut voor Volksgezondheid en Milieu (RIVM) 2019. https://doi.org/10.21945/RIVM-2019-0038.

[34] Donker T, Bosch T, Ypma RJF, Haenen APJ, van Ballegooijen WM, Heck MEOC, et al. Monitoring the spread of meticillin-resistant *Staphylococcus aureus* in The Netherlands from a reference laboratory perspective. J Hosp Infect 2016;93:366—74. https://doi.org/10.1016/j.jhin.2016.02.022.