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A preliminary analysis of hand disinfection use by travellers and their colonisation-risk with multi-resistant bacteria: A proof-of-concept study

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A B S T R A C T

Background: International travellers have the potential to transmit multidrug-resistant bacteria. However, the role of hygiene measures during travel has yet to be investigated.
Method: Travellers were asked about their use of disinfectants and hygiene behaviour. Stool samples were analysed for Gram-negative multi-resistant bacteria (MDRO). These data were analysed, and a new MDRO risk map was developed and compared with data from existing literature.
Result: Of 214 travellers, 6 (2.8 %) tested positive for an MDRO before and 16 (7.5 %) after the trip, with travel in known high-risk MDRO areas. Most travellers, 174 (81.3 %), regularly used disinfectants; only 36 (16.8 %) did not. There was no statistically significant correlation between the use of a disinfectant and colonisation with MDRO. In our and comparable studies, a high-risk region on the risk map was associated with an increased number of MDRO or extended-spectrum beta-lactamase (ESBL) positive returns.
Conclusion: Travellers showed a high willingness to use disinfectants. This preliminary study highlights the need for larger, randomized studies to better assess the true impact of hand disinfectants on MDRO acquisition.

1. Introduction

Multidrug-resistant Gram-negative bacteria (MDRO) are currently an increasing public health emergency worldwide [1]. Travel is a known risk factor for MDRO-colonisation with a clear geographical dependency and the possibility of global spreading [2]. During the SARS-CoV-2 pandemic, hygiene behaviour in the general population was changing worldwide, implementing hygienic measures in everyday situations [3]. This descriptive study examines travellers' use of disinfectants and their status regarding MDRO, contextualising this within the framework of a novel MDRO risk map.

2. Material and methods

Data were collected from July 2021 to September 2023 at the travel and tropical medicine outpatient clinic of the Saarland University Hospital in Homburg and the Centre Hospitalier de Luxembourg. The study included analysis of stool samples for MDRO and questionnaires before and 2–3 weeks after the trip. The questionnaires included risk factors for MDRO colonisation and hygiene behaviour. The pre-trip questionnaire included 15 open questions, 27 single-choice and six multiple-choice questions. The post-trip questionnaire contained 12 open questions, 39 single-choice questions, five multiple-choice questions, one multi-item question with 14 single-choice items and a table of 14 disease symptoms (see supplement S1 and S2). The disinfectants were analysed using the German Association for Applied Hygiene (VAH) standard.

This study is divided into two main parts.

2.1. Analysis of MDRO-colonisation

MDRO culture was performed on CHROMagar™ ESBL agar (Mast Diagnostica, Bootle, UK). The stool was applied directly to the agar and then each visible growth was isolated on a CHROMagar™ ESBL agar. Afterwards colony identification was performed by matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry (MALDI-TOF, Bruker, Germany). Resistance testing was conducted in the MicroScan WalkAway™ system (Brea (CA), USA). The results of the MicroScan WalkAway™ system were then subjected to a plausibility check. Not

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sufficiently valid results were subjected to an AmpC & ESBL Detection Test (Mast Diagnostics Bootle, UK). MDROs were classified as 3-MDRO and 4-MDRO based on the definition of the German Commission for Hospital Hygiene and Infection Prevention of the German Robert Koch Institute [4], the standardised classification of MDRO in Germany. The categorisation is based on resistance patterns to certain antibiotic groups. Each isolated bacterium is tested for resistance to a lead substance of the four antibiotic groups (piperacillin for the acylureidopenicillins, cefotaxime and/or ceftazidime for the third and fourth generation cephalosporins, imipenem and/or meropenem for the carbapenems and ciprofloxacin for the fluoroquinolones). If a pathogen is resistant to the lead substances in 3 groups, it is classified as a 3-MDRO. If there is resistance to all four antibiotic classes, the bacterium is categorised as a 4-MDRO.

2.2. Development of the risk score

A risk score (ranging from 1 to 5) reflecting the local MDRO prevalence was developed based on existing MDRO-prevalence data from the systematic analyses by Murray et al. [5]. From the publication mentioned, data on fluoroquinolone and third-generation cephalosporin-resistant *Escherichia coli*, carbapenem and third-generation cephalosporin-resistant *Klebsiella pneumoniae*, and carbapenem-resistant *Acinetobacter baumannii* were considered for the risk score. A score of 1 indicates "no-increased risk" relative to Central Europe (prevalence data from 0 to 20 %), and a score of 5 indicates "maximum increased risk",

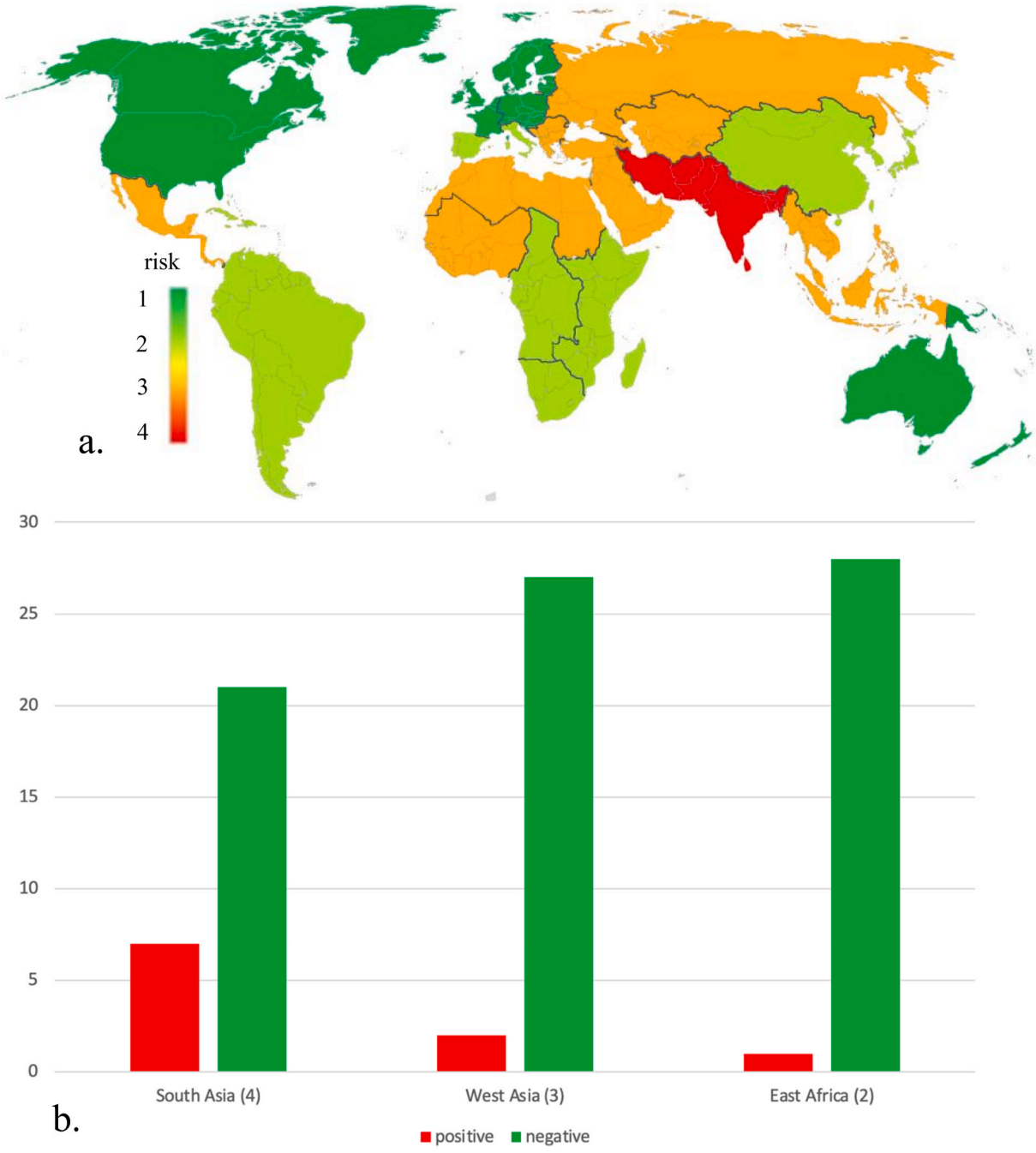

Fig. 1. a. Regions coloured according to MDRO risk score based on prevalence data from Murray, C. J. et al.; 1 = corresponds to no increased risk, 5 = to maximum increased risk. b. Travellers returning with multidrug-resistant bacteria in stool sample and MDRO negative travellers from same region (Central Asia was not listed due to the low number of travelers (n = 3)); in brackets the risk score of the region. MDRO: Multidrug-resistant Gram-negative bacteria.

which was not assigned since prevalence data of 80–100 % were not determined for any region. The gradations between 1 and 5 were defined as 20 % steps (e.g. risk score 2 corresponds to a 20–40 % prevalence). The score was used to create a colour-coded world map to visualise MDRO prevalence (Fig. 1).

The regional functionality of the developed map was tested using selective studies on travellers. These studies were selected using PubMed and Google Scholar and a focused keyword search with "travel", "multi-resistant", "Enterobacteriaceae", "stool sample", "diarrhoea", "MDRO", and "ESBL" in the study period from 2010 to 2020. Studies without a clear assignment of an MDRO or ESBL to a specific region were excluded. Studies with similar microbiology methodology (e.g. the use of a CHROMagar), more than 200 included participants and study participants in a European travel centre were preferred included. The studies finally included [6–11] were compared with the risk score of regions with positive returnees from our study (Table 1).

The Saarland Medical Association approved the main ethics approval under the number 205/21.

3. Result

The final data set included 214 (49.7 %/431) participants with a median age of 42 (range 16–75 years) and slightly more females (54.2 %/116). The participants had a high level of education (61.7 % baccalaureate), and 22 % worked in the healthcare sector.

In pre-travel stool samples, 6 (2.8 %) participants were MDRO positive (5x *Escherichia (E.) coli,* 1x *Klebsiella pneumonia)*. Two to three weeks after return, 16 (7.5 %) participants were MDRO positive, 12 (5.6 %) of whom were positive for the first time after the trip (*E. coli* 3-MDRO). All first-time colonised persons had travelled to areas with a higher risk score of 2–4, the majority (58.3 %/7) of them to South Asia with a risk score of 4 (Fig. 1). The application of the exclusion criteria resulted in the inclusion of six studies (27.3 %/22) for evaluation of the newly developed MDRO map. In the analysis of the MDRO map, the MDRO definition and ESBL definition were included. Correlations between the MDRO risk map and the literature data were observed irrespective of the resistance pattern definition (Table 1).

Pre-travel 179 (83.6 %) participants planned to use disinfectants. Of these 154 (86.0 %/179) subsequently confirmed afterwards that they had done so. After travelling, 174 (81.3 %/214) said they regularly disinfected their hands, of which 20 (11.5 %/174) had not originally planned to take disinfectant with them. Of all participants, 36 (16.8 %/214) did not use disinfectant. Furthermore, 184 (86 %/214) travellers answered "yes" to whether they regularly washed or disinfected their hands before eating. A total of 24 (11.2 %/214) travellers answered "no" and 57 (26.6 %/214) travellers did not know which disinfectant they had used. No significant correlation was observed between the use of a disinfectant and colonisation with MDRO.

A product with proven efficacy tested independently of the manufacturer by external laboratories (such as the German Association for Applied Hygiene (VAH)) was used by 39 (22.4 %/174) travellers. All others (44.8 %/78) used over-the-counter (OTC) products or products from the country they travelled to (Fig. 2). Some probands used disinfectants incorrectly (surface disinfectants as hand disinfectants) or used ineffective substances or even home-brew disinfectants with a high percentage of alcohol.

The substance class most frequently used was that of alcohol-based disinfectants, which accounted for 54 (69.2 %, with an alcohol range of 40–74 %). Those classified on the VAH list contained alcohol in 21 (53.9 %/39) cases. No relevant differences were found in the disinfectants used between the groups of MDRO positive and negative returnees (Table 2).

4. Discussion

To the best of our knowledge, this is the first analysis to address the relationship between disinfectant use, hygiene behaviour among travellers and the risk of MDRO colonisation by region of travel. Despite the availability of detailed data on MDRO prevalence and their transmission to travellers in several countries or regions [12], this information has not yet been uniformly incorporated into travel advice. Utilising the novel MDRO risk map and analysing it using study data, this study demonstrates that the map accurately reflects pertinent risk areas irrespective of whether ESBL resistance or alternative resistance definitions were employed [6–11]. This indicates that the map can be implemented in a manner analogous to the malaria maps that are routinely used in travel clinics [13], for the purpose of visualising the MDRO risk in the context of international medical travel advice. Overall, the rate of MDRO colonisation was low during the study period. Also, among travellers returning from known high-risk areas, a low colonisation rate was measured, compared to results of comparable studies, especially from the time before the SARS-CoV-2 pandemic [14]. However, colonisations were more frequent when returning from regions with the highest risk scores, which is consistent with other studies before the COVID-19 pandemic [15]. This shows that, independent of hygiene measures during the pandemic, the risk map can be an adequate aid in informing travellers about their individual risk of infection or colonisation with MDRO or ESBL (Fig. 1 and Table 1).

The discrepancy in colonisation rates between this study and the comparative studies for the risk score, can be attributed to various

Table 1
Comparison of the new risk score to colonisation rates among returning travellers per region in travel related studies and MDRO colonisation status (similarities regarding same sample material, inclusion numbers and risk of home country of participants; Central Asia was not listed due to the low number of travelers (n = 3)). [positive returnees/all returnees].

MDRO pattern	Lübbert et al. (2015) [7]	Lääveri et al. (2018) [10]	Kantele et al. (2015) [8]	Ruppé et al. (2015) [6]	Arcilla et al. (2016) [11]	Östholm-Balkhed et al. (2013) [9]
	ESBL-PE	ESBL-PE	ESBL-PE	ESBL-PE	ESBL-PE	ESBL-PE
South Asia (4)[a]	India[b] 11/15 (73.3 %)		28/61 (45.9 %)	India[b] 48/53 (90.6 %)	136/181 (75.1 %)	India[b] 10/15 (66,7 %)
South East Asia (3)[a]	22/46 (47.8 %)		33/101 (32.7 %)	Asia[b] 142/196 (72.4 %)		Asia (except India)[b] 26/58 (44,8 %)
West Asia (3)[a]			North Africa and West Asia[b] 4/12 (33.3 %)			
East Africa (2)[a]		30/185 (16.2 %)	Sub-sahara Africa[b] 23/193 (11.9 %)	Sub-sahara Africa[b] 93/195 (47.7 %)		Africa (south of equator)[b] 15/71 (21,1 %)

ESBL-PE: Extended-spectrum beta-lactamase-producing Enterobacteriaceae.
MDRO: Multidrug-resistant Gram-negative bacteria.
[a] New developed risk score based on prevalence data from Murray, C. J. et al. (1 = corresponds to no increased risk, 5 = to maximum increased risk).
[b] Travel region specified in the study.

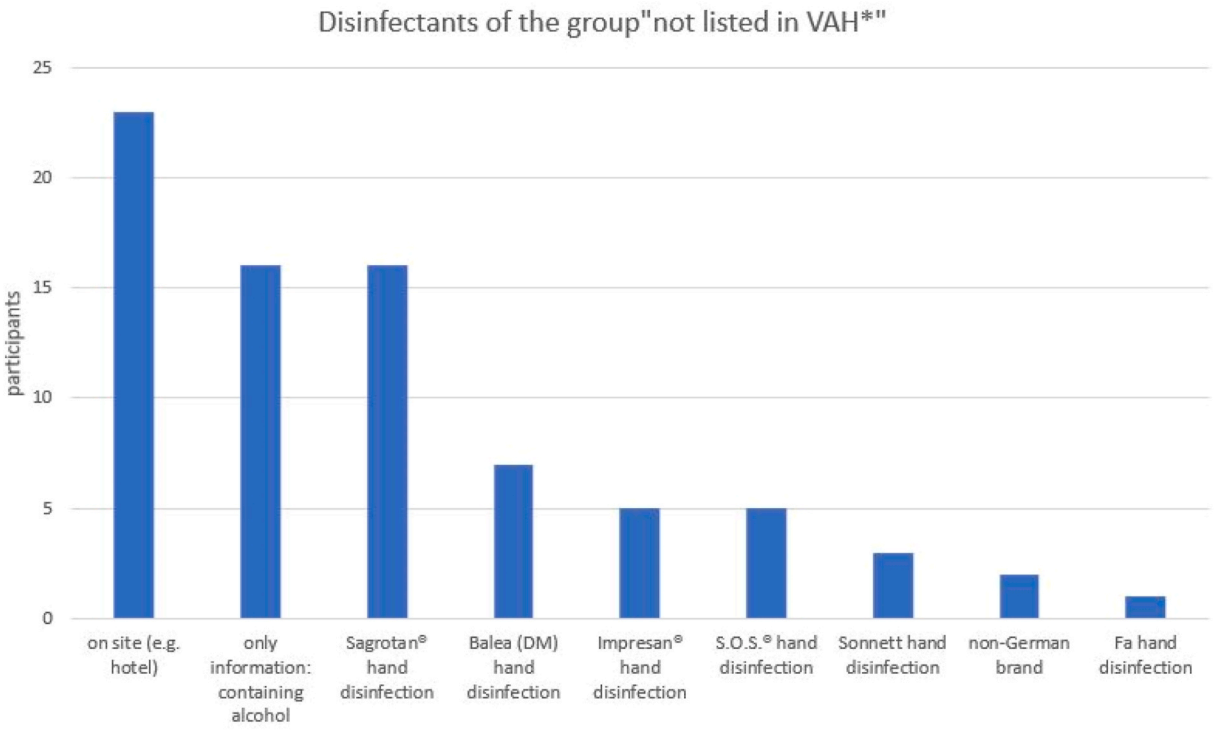

Fig. 2. Information for used disinfections not listed on VAH list. VAH: Verbund für angewandte Hygiene e.V. (German Association for Applied Hygiene).

Table 2
Comparison of the use of disinfectants by MDRO positive and negative travel-returnees.

Travel returnees tested	negative n = 194	positive n = 12
Planned carrying of disinfectant	163 (84 %)	11 (91.7 %)
Disinfectant used	158 (81.4 %)	11 (91.7 %)
Disinfectant not listed in VAH[a]	71 (36.6 %)	5 (41.7 %)
Substance not known	51 (26.3 %)	4 (33.3 %)
Disinfectant listed in VAH[a]	36 (18.6 %)	2 (16.7 %)
Content according to VAH[a]:	20 (10.3 %)	1 (8.3 %)
Alcohol		
Alcohols and quaternary ammonium compounds	14 (7.2 %)	1 (8.3 %)
Alcohols and pyridine derivatives	2 (1 %)	–

[a] VAH: Verbund für angewandte Hygiene e.V. (German Association for Applied Hygiene), MDRO: Multidrug-resistant Gram negative bacteria.

causes and must be reflected. A direct comparison of the absolute figures is not permissible due to the different definitions of resistance between the use of ESBL or MDRO definitions [6]. However, independently of the used definition the risk map reflects these risks. Furthermore, it should be noted that there is always the possibility that some participants lost their colonisation in the tested period or the cultural methods had not detected all colonizations with MDRO.

It is reasonable to assume that following the outbreak of the global pandemic caused by the SARS-CoV-2 virus, the provision of disinfectants and other hygiene measures by the authorities and, among others, accommodation providers will no longer be provided in the same way as during the pandemic. Furthermore, the use of disinfectants and the colonisation with MDRO or ESBL (which can affect not only the travellers themselves but also their domestic animate and inanimate environment [16]) are currently not standard topics in travel medicine counselling. As shown, maps with simple risk scores would be a potential additional resource. Travellers should, therefore, be advised during travel counselling to focus on hygiene measures and the reduction of other risk factors (e.g. food safety) to reduce the risk of MDRO acquisition.

Furthermore, the demonstrated frequent use of disinfectants purchased in the country of residence or abroad reflects the willingness of travellers to incorporate disinfectant use into their daily travel practices. However, the largely unspecific information about the disinfectants in this study shows that travellers have limited awareness of the substances and the associated effects of disinfectants, despite a high level of education and almost one quarter working in the health care system. Skin diseases are one of the three most common health problems in travellers [17]. The misuse of non-replenishing, alcohol-based or surface disinfectants could potentially represent an additional skin stressor [18], along with other factors such as sun exposure [19], increased and prolonged contact with salt and fresh water, the risk of travel-associated dermatological diseases and the use of repellents. The adequate use of the disinfectants depending on the individual risk at the destination covering the application of disinfectants (for hands, skin, surface) and the identification of products with proven effectiveness could be important advice not only to counter risk factors for MDRO colonisation but also to prevent the most common travel-associated gastrointestinal and respiratory infections [20] and avoid unnecessary adverse reactions. However, it should be acknowledged that MDROs are primarily transmitted via food, which limits the effectiveness of hand disinfection in preventing MDROs.

Depending on the destination, advice on repellents, sunscreens or exposure prophylaxis for vector-transmitted infections is a cornerstone in travel medicine. This should be one of the reasons to address and classify the non-selective use of disinfectants in travel medicine, along with the use of sunscreen products and repellents. In some cases, the analysis of the disinfectants used was limited by missing or inaccurate information on the disinfectants used. Furthermore, this study cannot establish a significant correlation between the use of a disinfectant and colonisation with MROD during travel due to limited MDRO positive participants. It should be mentioned that the low rates are limited in their significance by a further factor: The samples were examined 2–3 weeks after the trip. Other studies have shown a decline in colonisation rates as a function of the interval between travel returns [6]. The number of isolates obtained per sample (1–3) may have further

increased the discrepancy to the actual colonisation rate. More detailed surveys could provide more thorough assessments of disinfectant usage behaviour in the future.

5. Conclusion

The rates of MDRO colonisations detected in this study were typical for high-risk regions. The use of hand disinfectants showed that travellers are willing to use hand disinfectants during trips. It was demonstrated that knowledge about the right use of disinfectants and risks for a wrong use is low. Therefore further advice in travel medicine counselling is needed. The newly developed MDRO risk score showed correlations with MDRO risk regions described in previous studies. The risk score integrated in a risk map could be used in travel medicine consultations to indicate the individual risk concerning increased compliance with hygiene measures. Further detailed studies with travellers on the use and impact of disinfectants in the post-COVID-19 era and critical review of the benefits of such a risk map are certainly needed to analyse these points further.

CRediT authorship contribution statement

Tobias Kaspers: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Cosima Berdin:** Writing – review & editing, Data curation. **Thérèse Staub:** Writing – review & editing, Data curation. **Barbara Gärtner:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Fabian Berger:** Writing – review & editing, Conceptualization. **Alexander Halfmann:** Writing – review & editing, Validation. **Sören L. Becker:** Writing – review & editing, Resources. **Sophie Schneitler:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Sophie Schneitler reports financial support was provided by Saarland federal state. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Glossary

MDRO	Multidrug-resistant Gram-negative bacteria
KRINKO	German Commission for Hospital Hygiene and Infection Prevention of the German Robert Koch Institute
ESBL	Extended-spectrum beta-lactamases
VAH	German Association for Applied Hygiene
OTC	Over-the-Counter

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tmaid.2025.102837.

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