**TITLE**

A Validated Risk Assessment Tool for the Carriage of Methicillin-Resistant Staphylococcus Aureus among Residents in Residential Care Homes for the Elderly in Hong Kong

**AUTHORS**

Valerie Wing Yu WONG#, 1, Wan In WEI#, 1, Liu Yu YANG2, Samuel Yeung Shan WONG 1, Margaret IP2, \*, Kin On KWOK2,3,4,\*,@

#Joint first author

\*Joint senior author

@ Correspondence

1 JC School of Public Health and Primary Care, The Chinese University of Hong Kong, Hong Kong Special Administrative Region, China

2 Department of Microbiology, The Chinese University of Hong Kong, Hong Kong Special Administrative Region, China

3 Stanley Ho Centre for Emerging Infectious Diseases, The Chinese University of Hong Kong, Hong Kong Special Administrative Region, China

4 Hong Kong Institute of Asia-Pacific Studies, The Chinese University of Hong Kong, Hong Kong Special Administrative Region, China

**INFORMATION FOR CORRESPONDENCE**

Name: Kin On KWOK

Email: [kkokwok@cuhk.edu.hk](mailto:kkokwok@cuhk.edu.hk)

Telephone: +852 22528405

Address: Room 421, School of Public Health Building, Prince of Wales Hospital, Shatin, Hong Kong

**KEYWORDS**

Methicillin-resistant Staphylococcus aureus, colonization, residential care homes for the elderly, risk factors, mixed-effects model, risk assessment tool

**ABSTRACT**

**Background**: Residential care homes for the elderly (RCHEs) are reservoirs of Methicillin-resistant Staphylococcus aureus (MRSA). Identification of RCHEs with a high prevalence of MRSA carriage is important for cost-effective infection prevention and control. This study aims to (i) determine the prevalence of MRSA colonisation in RCHEs in Hong Kong during the COVID-19 pandemic, (ii) identify factors associated with such MRSA colonisation, and (iii) develop a risk assessment tool to differentiate RCHEs with a high prevalence of MRSA colonisation.

**Methods**: From February 2021 to July 2022, a cross-sectional study was conducted in ten RCHEs in Hong Kong. Nasal specimens were collected from consenting residents. With a mixed-effects regression model, a risk assessment tool is developed for MRSA carriage. Both resident-level exposures (for example, recent use of antibiotics) and facility-level exposures (for example, and provision of portable alcohol-based hand rub [ABHR] to staff) were considered. Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) are presented.

**Results**: Of 502 residents, the prevalence of MRSA colonisation was 30.1%. Individual-level variables associated with a higher risk of MRSA colonisation included history of multidrug-resistant bacteria colonisation (aOR:2.55, 95% CI:1.21-5.36), history of stroke (aOR:1.93, 95% CI:1.21-3.08), two or more recent hospitalisation episodes (aOR:2.14, 95% CI:1.23-3.74), two or more recent antibiotic prescriptions (aOR:2.89, 95% CI:1.24-6.75), and increasing length of residence; while receipt of the seasonal influenza vaccine (aOR:0.58, 95% CI:0.36-0.92) was associated with a lower risk of MRSA colonisation. At the facility level, the provision of ABHR to staff (aOR:0.48, 95% CI:0.31-0.76) was significantly associated with a lower risk of MRSA colonisation. The risk assessment tool which accommodates the aforementioned factors was robust with good discrimination.

**Conclusions**: Clinicians and healthcare professionals involved in managing RCHE residents can use this assessment tool to optimize resource allocation of infection prevention and control among RCHEs.

Word count: 295

**BACKGROUND**

Residential care homes for the elderly (RCHEs) are reservoirs for Methicillin-resistant Staphylococcus aureus (MRSA). MRSA is one of the most opportunistic pathogens in healthcare facilities and community settings [**[1,2]**](https://paperpile.com/c/onTJdj/wpdl+6TJp). It is a leading cause of various infections, including endocarditis, bacteraemia, and skin and soft tissue infections. In 2017, the World Health Organisation classified MRSA as a high-priority pathogen which poses a threat to human health [**[3]**](https://paperpile.com/c/onTJdj/opBR). A recent systematic review reported that the global pooled prevalence of MRSA in elderly care centres was 14.69% [**[4]**](https://paperpile.com/c/onTJdj/lWFu). In Hong Kong, the prevalence of MRSA colonisation among RCHE residents was 48.7% in 2021 [**[5]**](https://paperpile.com/c/onTJdj/Afsd+lDC3), compared to 1.69-2.5% in the community in 2017-2019 **[6,7]**.

It is important to identify RCHEs with a high prevalence of MRSA carriage such that infection prevention strategies can be implemented cost-effectively at the facility level. In Hong Kong, the government introduces a decolonisation program of MRSA covering all RCHEs in 2023-2027 [**[8,9]**](https://paperpile.com/c/onTJdj/Afsd+76kc). Since such territory-wide universal screening and decolonisation is expensive, it is worth developing a validated risk assessment tool to prioritize RCHEs for interventions. There are validated prediction tools for MRSA colonisation and infection, but most focused on patients with specific conditions [**[10-14]**](https://paperpile.com/c/onTJdj/TzKv+sR2j+rMyK+mnzO+tF9W). There are also risk models which pinpoint a history of stay in nursing homes as a primary predictive factor for MRSA colonisation, but they are not specific to RCHEs [**[15-17]**](https://paperpile.com/c/onTJdj/lJHV+QPiY+49Li). Jackson and colleagues showed that RCHE residents likely transmitted MRSA to healthcare workers in order to prioritise infection control measures [**[18]**](https://paperpile.com/c/onTJdj/kOJe), but their prediction rule focused only on resident characteristics and was based on data collected the pandemic of coronavirus disease 2019 (COVID-19). To date, the epidemiology of MRSA in RCHEs is understudied during and after the COVID-19 pandemic, which disrupted the adherence of infection prevent and control programs in this setting **[19]** and has altered the prevalence of MRSA **[20]**. Besides, customising a risk assessment tool to the local context and facility-level characteristics is crucial because MRSA colonisation risk factors may vary by geography and demographics.

From the above rationale, this study aims to (i) determine the prevalence of MRSA colonisation in RCHEs in Hong Kong during the COVID-19 pandemic, (ii) identify factors associated with such colonisation, and (iii) develop a validated risk assessment tool which differentiates RCHEs with high prevalence of MRSA.

**METHOD**

*Study design*

From February 2021 to July 2022, a cross-sectional study was conducted in ten RCHEs in Hong Kong (Hong Kong Island: 4, Kowloon: 3, the New Territories: 3). Informed consent was obtained from RCHE residents (“residents”) or their guardians as referred by the RCHE staff in case of cognitive impairment or language barriers. In each study RCHE, nasal specimens were collected from consenting residents using a sterile swab applicator, which was inserted 1-2 cm into both nostrils and rotated for three seconds. Survey data was conducted by extracting relevant information from the medical health records in RCHEs.

There are two levels of survey data **(Table S1)**. At the facility level, facility managers provided information on the characteristics of the RCHEs, such as facility size, and the status of provision of portable alcohol-based hand rub (ABHR) bottles to staff. At the resident level, information of relevant exposures, as previously suggested [**[21–24]**](https://paperpile.com/c/onTJdj/XUzZh+skXXQ+H20hz+sevzz),were extracted from the medical records in RCHEs, for example history of multidrug-resistant bacteria colonisation, and recent antibiotic use.

*Laboratory method*

The nasal swabs were placed in nutrient broth containing 7% salt and incubated overnight before subculturing on selective agar (ChromID MRSA, BioMérieux, France). After incubating the subcultures at 37°C under ambient air overnight, the laboratory staff selected a colony for each morphotype and identified the bacteria using Matrix-assisted laser desorption/ionization-time of flight (MALDI-TOF).

*Statistical analysis*

The isolation of MRSA was the primary outcome. Bivariate associations were assessed by chi-square tests. A multilevel logistic regression model was fit to the individual-level data using backward elimination, followed by incorporating facility-level variables. Cross-level interaction terms were explored. The model with the smallest Akaike’s information criterion (AIC) was chosen as the final model. Results are presented with adjusted odds ratios (aORs) with 95% confidence intervals (CIs).

Validation of the final model was done using random oversampling with 400 repetitions. Its predictive performance was evaluated by the area under the curve (AUC) of the receiver operating characteristic (ROC) curve. To account for optimism bias resulting from overfitting, the difference in performance between the bootstrap samples and the original sample was calculated and the difference across all samples was averaged. The bias-corrected AUC was obtained by subtracting the estimated optimism bias from the ROC obtained from the original sample. The clinical utility of the final model was assessed with decision curve analysis.

Based on the final model, a risk assessment tool was developed using a regression coefficient-based scoring method [**[25-27]**](https://paperpile.com/c/onTJdj/iR9W+knYP+Sm82). Points were assigned to each predictor by dividing all coefficients of the final model by the smallest absolute value of the coefficients. These rescaled coefficients were then multiplied by a weighted constant and rounded to the nearest integer for easy application. The risk score was then calculated by summing up the points. Higher scores indicate a higher risk of MRSA colonisation. A cluster analysis was used to determine the optimal cut-off threshold of the risk scores [**[28]**](https://paperpile.com/c/onTJdj/6WUZ). To demonstrate the use of the assessment tool, the risk of MRSA colonisation in each study RCHE was visualized by displaying the proportion of residents in the "high-risk" category with respect to each factor.

All analyses were performed in R (version 4.02). More details of the model development were in the Supplementary Materials.

*Reporting guideline*

All domains of the study adhered to the guidelines presented in the transparent reporting of a multivariable prediction model for individual prognosis or diagnosis statement **(Table S2)** [**[29,30]**](https://paperpile.com/c/onTJdj/lFIG+XJY5).

*Ethics statement*

This study was approved by the Joint Chinese University of Hong Kong-New Territories East Cluster Clinical Research Ethics Committee (reference number: 2020.443).

**RESULTS**

*Characteristics of the study RCHEs and residents*

Of the ten study RCHEs (small-scale: 3, medium-scale: 4, large-scale: 3), the wash-basin-to-size ratio varied: six had a ratio of <1 per 1000 square feet, and four had a ratio of ≥1 per 1000 square feet. Half of the RCHEs provided portable ABHR bottles to their staff.

Overall, 502 residents were included in the analysis **(Table 1)**. Of them, 46% were aged ≥85 years, and 51.8% were male. About 70% of residents lived in the study RCHEs for one year or more, and half (52%) had a moderate-to-high level of self-care dependence (MDS-ADL scores ≥5). History of multidrug-resistant bacteria colonisation were present (8.4%). More than half of the residents received the seasonal influenza vaccine. Common comorbidities included hypertension (70.9%), diabetes mellitus (32.7%), dementia (32.5%), and stroke (27.3%). Hospital admission rates were 24.9% for one admission and 23.9% for two or more admissions.

*Associated factors of MRSA colonization*

The overall prevalence of MRSA colonisation was 30.1% (151/502). To reflect the between-facility variance, the resident-level model with the smallest AIC value **(model 8, Table S3)** was chosen to incorporate facility-level variables. Among the latter, the provision of ABHR bottles to staff significantly improved the model fit **(model 6, Table S4)**. The addition of random slopes or interaction between hospitalisation episodes and the provision of portable ABHR to staff did not further improve the model fit **(models 7-15, Table S4)**.

The final model included eight individual-level variables and one facility-level variable **(rightmost column of Table 1)**. Identified risk factors for MRSA colonization included: being hospitalised twice or more in a year (aOR: 2.14; 95% CI: 1.23-3.74), receiving oral or intravenous antibiotics twice or more in the past six months (aOR: 2.89; 95% CI: 1.24-6.75), a history of stroke (aOR: 1.93; 95% CI: 1.21-3.08), and a history of multidrug-resistant bacteria colonisation (aOR 2.55; 95% CI: 1.21-5.36). Besides, residents residing for 1-2 years, 3-6 years, and ≥7 years were respectively 1.83, 2.04, and 2.31 times more likely to have MRSA colonisation compared to their newly admitted counterparts. RCHEs that provided portable ABHR to staff had a 52% lower risk of MRSA colonisation among residents compared to those that did not.

*Model performance*

The optimism bias between the test model and the bootstrap model was 0.053. The AUC of the original model (averaged across all resamples) was 0.843, while the bias-corrected AUC was 0.790. The predictive performance of the final model was evaluated using a 10-fold cross-validation on both the original and oversampled data **(Table 2)**. The ability of the model to differentiate between MRSA carriers and non-MRSA carriers was assessed by the AUC with a median value of 0.74 (interquartile range [IQR]: 0.63 - 0.75) for the original data and 0.73 (IQR: 0.62-0.73) for the oversampled data, suggesting that the imbalance in the proportion of MRSA carriage did not have a significant effect on the model performance. The final model is more clinically beneficial than assuming that all residents are colonised with MRSA or that no residents are colonised with MRSA **(Figure S1)**.

*The risk assessment tool*

By assigning points to each variable in the final model **(Table 3)**, the scores of the risk assessment tool range from −15 to +35, which can be optimally divided into four risk levels of MRSA colonisation **(Figure S2, Table 4)**: <1 (low risk), 1-7, 8-13, and ≥14 (high risk). Residents in the highest-risk group were significantly more likely to carry MRSA than those in the lowest-risk group (65.8% *vs* 16.1%).

By adopting two score thresholds (≥8 and ≥14) to define a high-risk resident, the risk level of each study RCHE was determined based on the proportion of high-risk residents **(Table S5)**. Using either threshold and corresponding percentage of high-risk residents of ≥40% for a threshold of 8 and ≥10% for a threshold of 14, RCHEs with the highest proportion of MRSA carriers were identified **(Table S5)**. The risk tool was applied to the ten study RCHEs using a score of ≥8 to examine each component of the assessment **(Figure 1)**.

**DISCUSSION**

This study updates the estimate of MRSA prevalence in RCHEs in Hong Kong during the COVID-19 pandemic (30.1%), With updated epidemiology data, a risk assessment tool to identify RCHEs with high MRSA carriage is developed using a mixed-effects regression model that demonstrated good discrimination (a 10-fold cross-validated AUC value of 0.73). The risk assessment tool consists of eight individual-level factors (number of recent hospitalisation episodes, number of recent antibiotic prescription episodes, history of stroke, history of colonisation with multidrug-resistant bacteria, receipt of the seasonal influenza vaccine, length of residence, level of self-care dependence, and age) and one facility-level factor (provision of ABHR to staff).

Based on nasal specimens, the prevalence of MRSA during the COVID-19 pandemic in RCHEs in Hong Kong was 30.1% (151/502), which is higher than that before the pandemic **[31]** (22.1%, 227/1026) (p<0.01). Such increase is in line with overseas findings about rising rate of MRRA during the COVID-19 pandemic **[20]**, but is different from another local findings **[5]** (24.5%, 191/780) (p=0.03). More work should be done to unravel the reasons behind this inconsistent observation. The role of COVID-19 pandemic, during which there was reduced staff adherence to tightened infection control measures in RCHEs, in altering the epidemiology of MRSA remains unclear.

Risk factors for MRSA carriage among residents identified in this study were consistent with previous studies. While other studies identified additional risk factors such as male sex, chronic skin breakdown, dementia, and the use of medical devices [**[2]**](https://paperpile.com/c/onTJdj/6TJp), these variables were not significant in our study. While conflicting evidence exists on the association between length of residence and MRSA carriage [**[32,33]**](https://paperpile.com/c/onTJdj/aNbG+0iYN), this variable had a dose-response relationship in our study. The prevalence of MRSA carriage increased with increasing length of residence. Receiving the seasonal influenza vaccine was a protective factor for MRSA carriage. Complications from influenza infection are a strong driver of antibiotic prescription and hospitalisation, the two main risk factors for MRSA colonisation [**[34-36]**](https://paperpile.com/c/onTJdj/RARW+m5p7+FFhy). These findings support the growing number of recent studies suggesting seasonal influenza vaccination is essential to control the antimicrobial resistance crisis [**[37-39]**](https://paperpile.com/c/onTJdj/fTTo+fiBf+D62f). At the facility level, residents of facilities that provided bottles of ABHR to their staff had a lower prevalence of MRSA than those that did not. Previous studies have shown that provision of ABHR can improve hygiene compliance and reduce the prevalence of MRSA [**[40,41]**](https://paperpile.com/c/onTJdj/AyHO+Sp7E).

Our risk assessment tool has a higher net benefit than the current policy of no screening and screening all residents with a nasal culture **(Figure S1)**. By identifying RCHEs with high level of MRSA carriage without screening, resources of infection prevention and control, such as antimicrobial stewardship, can be effectively optimized, and interventions can be informed in a timely manner. It also dissects the risk profiles of each RCHE **(Figure 1)**, highlighting specific areas that require tailored improvement. Most importantly, the risk tool was developed using data collected during the COVID-19 pandemic. As we enter a period of COVID-19 endemicity, infection prevention and control remain a high priority, especially for vulnerable populations in RCHEs.

This study has two limitations. First, our estimate of MRSA prevalence was based only on nasal swabs rather than multiple body sites. While nasal swabs have traditionally been used to detect MRSA and have the highest positive carrier status prediction [**[42]**](https://paperpile.com/c/onTJdj/hFAY), MRSA can be detected in other body parts [**[43-46]**](https://paperpile.com/c/onTJdj/q2D1+5d05+l5bG+nPJ3). Relying only on nasal swabs potentially underestimates the prevalence of MRSA carriage and should be considered when interpreting our results. Second, caution should be exercised when extrapolating our risk assessment tool to different types of RCHEs as external validation of our results was not possible.

**CONCLUSION**

This study updates the epidemiology of MRSA in RCHEs during the COVID19 pandemic. A validated risk-assessment tool was developed to identify RCHEs with a high MRSA carriage. It enhances the ability of healthcare providers to pinpoint RCHE residents at risk of MRSA carriage for patient-centred care, and streamlines the resource allocation of infection prevention and control on the facility level.

Word count = 2299

**ACKNOWLEDGEMENT**

We would like to acknowledge support from the Health and Medical Research Fund (reference number: CID-CUHK-A). This work formed part of the doctoral thesis requirements for Valerie Wong Wing Yu.

**COMPETING INTEREST**

None

**AUTHORS’ CONTRIBUTIONS**

Conceptualized: Kin On KWOK (KOK)

Funding: KOK

Data curation: Valerie Wing Yu WONG (VWYW), Liu Yu YANG (LYY)

Data analysis: VWYW, KOK

First draft of the manuscript: VWYW, Wan In WEI (WIW)

Data interpretation: VWYW, WIW, KOK

Manuscript editing: LYY, Samuel Yeung Shan WONG (SYSW), Margaret IP (MI), KOK

Supervision: MI, KOK

Provision of critical comments: LYY, SYSW, MI, KOK

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**Table 1.** Characteristics of the study cohort and the final prediction model for MRSA colonisation in RCHEs

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Total** | | **MRSA status** | | | | ***p*-value *a*** | **Crude OR**  **(95% CI)** | **Adjusted OR  (95% CI)** |
|  | **Positive** | | **Negative** | |
| **Potential exposure variables** | **N** | **%** | **n** | **%** | **n** | **%** |
| **502** | **100** | **151** | **30.1** | **351** | **69.9** |
| **Individual level variables** |  |  |  |  |  |  |  |  |  |
| **Demographic characteristics and health** | |  |  |  |  |  |  |  |  |
| **Age, years** |  |  |  |  |  |  | *0.326* |  |  |
| < 70 | 84 | 16.7 | 26 | 17.2 | 58 | 16.5 |  | 1 | 1 |
| 70 - 84 | 187 | 37.3 | 49 | 32.5 | 138 | 39.3 |  | 0.79 (0.45, 1.39) | 0.72 (0.39, 1.34) |
| ≥ 85 | 231 | 46.0 | 76 | 50.3 | 155 | 44.2 |  | 1.09 (0.64, 1.87) | 1.16 (0.63, 2.14) |
| **Sex** | | | | | | | *0.955* |  |  |
| Male | 260 | 51.8 | 79 | 52.3 | 181 | 51.6 |  | 1 | - |
| Female | 242 | 48.2 | 72 | 47.7 | 170 | 48.4 |  | 0.97 (0.66, 1.42) | - |
| **Education** **level b** | | | | | | | *0.953* |  |  |
| Low | 366 | 72.9 | 111 | 73.5 | 255 | 72.6 |  | 1 | - |
| Intermediate | 114 | 22.7 | 34 | 22.5 | 80 | 22.8 |  | 0.98 (0.62, 1.55) | - |
| High | 22 | 4.4 | 6 | 4.0 | 16 | 4.6 |  | 0.86 (0.33, 2.26) | - |
| **Length of residence, years** | | | | | | | *0.681* |  |  |
| < 1 | 152 | 30.3 | 41 | 27.1 | 111 | 31.6 |  | 1 | 1 |
| 1 - 2 | 145 | 28.9 | 43 | 28.5 | 102 | 29.1 |  | 1.14 (0.69, 1.89) | 1.83 (1.02, 3.28) |
| 3 - 6 | 126 | 25.1 | 40 | 26.5 | 86 | 24.5 |  | 1.26 (0.75, 2.12) | 2.04 (1.12, 3.73) |
| ≥ 7 | 79 | 15.7 | 27 | 17.9 | 52 | 14.8 |  | 1.41 (0.78, 2.53) | 2.31 (1.17, 4.55) |
| **Self-care dependence score c** | | | | | | | *0.006* |  |  |
| 0 | 184 | 36.7 | 43 | 28.5 | 141 | 40.2 |  | 1 | 1 |
| 1 - 4 | 57 | 11.4 | 13 | 8.6 | 44 | 12.5 |  | 0.97 (0.48, 1.96) | 0.82 (0.38 – 1.74) |
| 5 - 28 | 261 | 52.0 | 95 | 62.9 | 166 | 47.3 |  | 1.88 (1.23, 2.87) | 1.37 (0.86 – 2.19) |
| **Any enteral feeding tubes** | 43 | 8.6 | 17 | 11.3 | 26 | 7.4 | *0.215* | 1.59 (0.83, 3.02) | - |
| **Any urethral catheters** | 40 | 8.0 | 15 | 9.9 | 25 | 7.1 | *0.375* | 1.44 (0.74, 2.81) | - |
| **Any peritoneal dialysis catheters** | 9 | 1.8 | 4 | 2.6 | 5 | 1.4 | *0.463* | 1.88 (0.50, 7.11) | - |
| **Any chronic skin breakdown** | 34 | 6.8 | 10 | 6.6 | 24 | 6.8 | *1.000* | 0.97 (0.45, 2.07) | - |
| **History of MDR bacteria colonisation** | 42 | 8.4 | 23 | 15.2 | 19 | 5.4 | *<0.001* | 3.14 (1.65, 5.96) | 2.55 (1.21, 5.36) |
| **Receipt of seasonal influenza vaccine** | 255 | 50.8 | 66 | 43.7 | 189 | 53.8 | *0.047* | 0.67 (0.45, 0.98) | 0.58 (0.36, 0.92) |
| **Comorbidities** |  |  |  |  |  |  |  |  |  |
| Cancer | 43 | 8.6 | 14 | 9.3 | 29 | 8.3 | *0.844* | 1.13 (0.58, 2.21) | - |
| Chronic heart failure | 66 | 13.1 | 21 | 13.9 | 45 | 12.8 | *0.852* | 1.10 (0.63, 1.92) | - |
| Chronic respiratory condition | 46 | 9.2 | 15 | 9.9 | 31 | 8.8 | *0.823* | 1.14 (0.60, 2.18) | - |
| Dementia | 163 | 32.5 | 53 | 35.1 | 110 | 31.3 | *0.471* | 1.18 (0.79, 1.77) | - |
| Diabetes mellitus | 164 | 32.7 | 59 | 39.1 | 105 | 29.2 | *0.057* | 1.50 (1.01, 2.24) | - |
| Hepatitis B | 14 | 2.8 | 6 | 4.0 | 8 | 2.3 | *0.374* | 1.77 (0.60, 5.20) | - |
| Hypertension | 356 | 70.9 | 109 | 72.2 | 247 | 70.4 | *0.762* | 1.09 (0.72, 1.67) | - |
| Stroke | 137 | 27.3 | 53 | 35.1 | 84 | 23.9 | *0.01* | 1.72 (1.14, 2.60) | 1.93 (1.21, 3.08) |
| **Number of antibiotic prescription episodes** | | | | | | | *<0.001* |  |  |
| 0 | 395 | 78.7 | 104 | 68.9 | 291 | 82.9 |  | 1 | 1 |
| 1 | 75 | 14.9 | 27 | 17.9 | 48 | 13.7 |  | 1.57 (0.93, 2.65) | 1.50 (0.83, 2.72) |
| ≥ 2 | 32 | 6.4 | 20 | 13.2 | 12 | 3.4 |  | 4.66 (2.20, 9.87) | 2.89 (1.24, 6.75) |
| **Number of hospitalisation episodes** | | | | | | | *<0.001* |  |  |
| 0 | 257 | 51.2 | 60 | 39.7 | 197 | 56.1 |  | 1 | 1 |
| 1 | 125 | 24.9 | 38 | 25.2 | 87 | 24.8 |  | 1.43 (0.89, 2.31) | 1.34 (0.79, 2.26) |
| ≥ 2 | 120 | 23.9 | 53 | 35.1 | 67 | 19.1 |  | 2.60 (1.64, 4.12) | 2.14 (1.23, 3.74) |
| **Any surgical procedures** | 15 | 3.0 | 5 | 3.3 | 10 | 2.8 |  | 1.17 (0.39, 3.48) |  |
| **Facility level variables** | | | | | | |  |  |  |
| **District** |  |  |  |  |  |  | 0.625 |  |  |
| Hong Kong Island | 148 | 29.5 | 41 | 27.2 | 107 | 30.5 |  | 1 | - |
| Kowloon | 227 | 45.2 | 68 | 45.0 | 159 | 45.3 |  | 1.12 (0.71, 1.77) | - |
| New Territories | 127 | 25.3 | 42 | 27.8 | 85 | 24.2 |  | 1.29 (0.77, 2.16) | - |
| **Facility size** |  |  |  |  |  |  | 0.090 |  |  |
| Small (n=3) | 67 | 13.3 | 18 | 11.9 | 49 | 14.0 |  | 1 | - |
| Medium (n=4) | 242 | 48.2 | 84 | 55.6 | 158 | 45.0 |  | 1.45 (0.79, 2.64) | - |
| Large (n=3) | 193 | 38.4 | 49 | 32.5 | 144 | 41.0 |  | 0.93 (0.49, 1.74) | - |
| **Basin-to-size ratio** (per 1000 feet2**)** |  |  |  |  |  |  | 0.364 |  |  |
| < 1 (n=6) | 283 | 56.4 | 80 | 53.0 | 203 | 57.8 |  | 1 | - |
| ≥1 (n=4) | 219 | 43.6 | 71 | 47.0 | 148 | 42.2 |  | 1.22 (0.83, 1.79) | - |
| **Provision of portable ABHR to staff** |  |  |  |  |  |  | 0.016 |  |  |
| No (n=5) | 204 | 40.6 | 74 | 49.0 | 130 | 37.0 |  | 1 | 1 |
| Yes (n=5) | 298 | 59.4 | 77 | 51.0 | 221 | 63.0 |  | 0.61 (0.42, 0.9) | 0.48 (0.31, 0.76) |

ABHR: alcohol-based hand rub; MDR: multidrug-resistant. Dashes indicate variables not included in the final model.

a Chi-square test.

b Education level was classified as high for bachelor’s degree holders or above, intermediate for secondary level; and low for primary level or below.

c Self-care dependence was measured with the Minimum Data Set - Activities of Daily Living (MDS-ADL) scale. The total score is the sum of the responses to seven items, each of which ranges from 0 (total independence) to 4 (total dependence). The sum of scores ranges from 0 to 28, with higher scores indicating greater dependence.

**Table 2.**  Predictive performance of the final model using 10-fold cross-validation

|  |  |  |
| --- | --- | --- |
| **Performance metric** | **Original data** | **Oversampled data** |
| AUCROC | 0.736 (0.626 – 0.751) | 0.725 (0.623 – 0.734) |
| AUCPR | 0.445 (0.401 – 0.510) | 0.478 (0.360 – 0.575) |
| Accuracy | 0.694 (0.652 – 0.728) | 0.663 (0.582 – 0.712) |
| Sensitivity | 0.445 (0.420 – 0.559) | 0.500 (0.409 – 0.544) |
| Specificity | 0.778 (0.688 – 0.829) | 0.750 (0.634 – 0.840) |
| PPV | 0.500 (0.431 – 0.523) | 0.544 (0.339 – 0.576) |
| NPV | 0.802 (0.738 – 0.826) | 0.761 (0.720 – 0.814) |
| Brier score | 0.122 (0.098 – 0.136) | 0.249 (0.231 – 0.273) |

Numbers in table are median (interquartile range).   
AUCROC: area under the receiver operating characteristic curve. AUCPR: area under the precision-recall curve. PPV: positive predictive value. NPV: negative predictive value.

**Table 3.** Final weighted risk scores

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variable** | **p-value** | **β coefficient** | **Rescaled coefficient†** | **Weighted score** |
| **Individual level variables** | | | | |
| **Number of antibiotic prescription episodes** | | | | |
| 0 | **-** | 0 | 0 | 0 |
| 1 | 0.177 | 0.408 | 2.740 | 3 |
| ≥ 2 | 0.014 | 1.061 | 7.131 | 8 |
| **History of MDR bacteria colonisation** |  |  |  |  |
| No | - | 0 | 0 | 0 |
| Yes | 0.014 | 0.936 | 6.293 | 7 |
| **Length of residence, years** | | | | |
| < 1 | **-** | 0 | 0 | 0 |
| 1 – 2 | 0.044 | 0.602 | 4.046 | 5 |
| 3 – 6 | 0.020 | 0.714 | 4.803 | 6 |
| ≥ 7 | 0.016 | 0.835 | 5.615 | 6 |
| **Number of hospitalisation episodes** | | | | |
| 0 | - | 0 | 0 | 0 |
| 1 | 0.279 | 0.290 | 1.948 | 2 |
| ≥ 2 | 0.007 | 0.762 | 5.119 | 6 |
| **History of stroke** | | | | |
| No | **-** | 0 | 0 | 0 |
| Yes | 0.006 | 0.656 | 4.413 | 5 |
| **Receipt of seasonal influenza vaccine** | | | | |
| No | **-** | 0 | 0 | 0 |
| Yes | 0.020 | -0.553 | -3.717 | -4 |
| **Self-care dependence score** |  |  |  |  |
| 0 | - | 0 | 0 | 0 |
| 1 – 4 | 0.600 | -0.203 | -1.363 | -2 |
| 5 – 28 | 0.190 | 0.315 | 2.115 | 2 |
| **Age, years** | | | | |
| < 70 | - | 0 | 0 | 0 |
| 70 – 84 | 0.304 | -0.325 | -2.186 | -3 |
| ≥ 85 | 0.635 | 0.149 | 1.000 | 1 |
| **Facility level variables** | | | | |
| **Provision of portable ABHR to staff** | | | | |
| No | - | 0 | 0 | 0 |
| Yes | 0.001 | -0.733 | -4.929 | -6 |

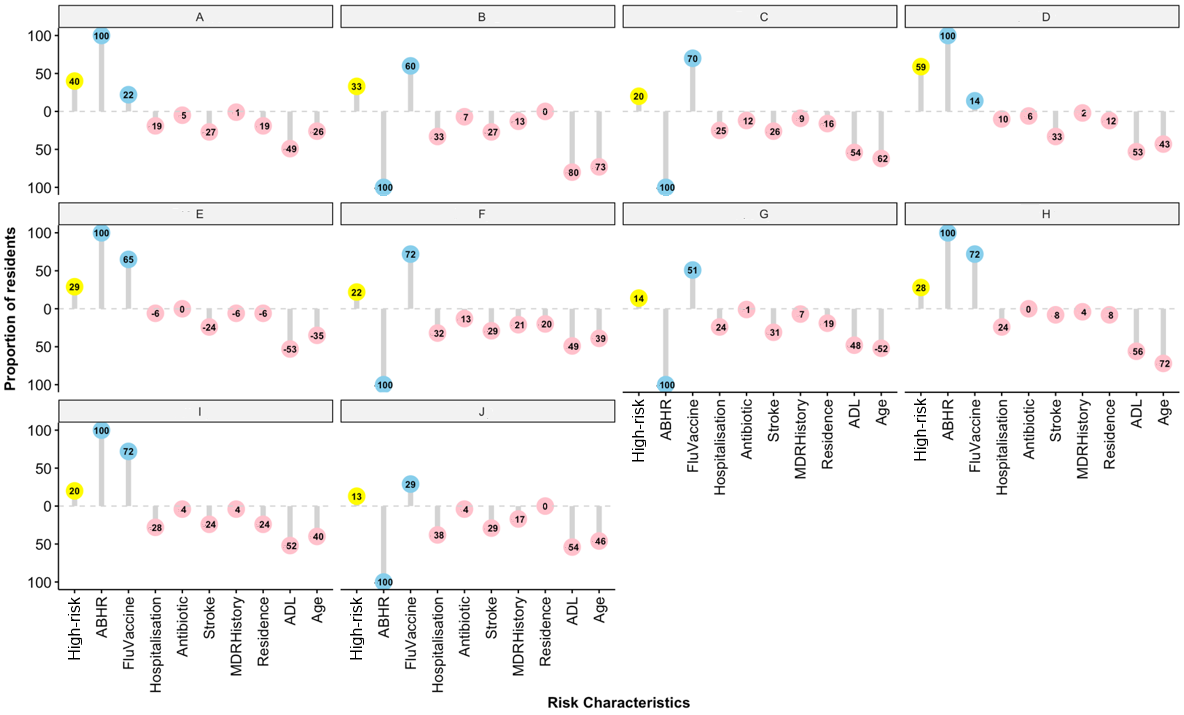
MDR: multidrug resistant. ABHR: alcohol-based hand rub.

**†**Points were assigned to each risk factor category by dividing the β coefficient for each category of individual variable in the final model by the β coefficient with the smallest magnitude, then multiplying by 1.15 and rounding to the nearest integer.

**Table 4.** Risk stratification of MRSA colonisation for residents by risk score category (N=502).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Risk score category** | | | | |
|  | **< 1  (Lowest risk)** | **1 – 7** | **8 – 13** | **≥ 14 (Highest risk)** |
| Number of residents (%) | 161 (32.1) | 204 (40.6) | 99 (19.7) | 38 (7.6) |
| Colonised with MRSA, n (%) | 26 (5.2) | 63 (12.5) | 37 (7.4) | 25 (5.0) |
| Proportion of residents colonised with MRSA in each risk score category | 16.1% | 30.9% | 37.4% | 65.8% |

MRSA: methicillin-resistant Staphylococcus aureus.



**Figure 1**. Lollipop chart showing the application of the MRSA risk tool to each RCHE (A - J).

The chart displays a dashed horizontal line at a value of zero with vertical lines extending upward or downward representing the proportion of residents in different categories. Lines that extend below or above the horizontal line indicate whether the categories are contributing (below the line) or reducing (above the line) the risk of MRSA colonisation. The yellow dot represents the proportion of residents at high risk of MRSA colonisation based on their risk scores (threshold ≥ 8) [**High-risk**]. Blue dots denote the proportion of residents with protective factors, such as receipt of the influenza vaccine [**FluVaccine**] and provision of alcohol-based hand rub to staff [**ABHR**]. Red dots denote the proportion of residents with risk factors, such as number of recent hospitalisation episodes (≥2) [**Hospitalisation**], number of antibiotic prescription episodes (≥2) [**Antibiotic**], history of multidrug-resistant bacteria colonisation [**MDRHistory**], history of stroke [**Stroke**], self-care dependence score ≥5 [**ADL**], length of residence ≥7 years [**Residence**], and age ≥ 85 years [**Age**].