Original Article

Risk factors and Short-term Outcomes for Methicillin-resistant *Staphylococcus aureus* and Methicillin-sensitive *Staphylococcus aureus* Colonization among Hemodialysis Patients

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ABSTRACT. Patients with end-stage renal disease are susceptible to infection, particularly methicillin-resistant *Staphylococcus aureus* (MRSA). Although MRSA-related mortality and morbidity have been studied, methicillin-sensitive *Staphylococcus aureus* (MSSA) has not been investigated to the same degree. Five hundred and seventy-eight chronic hemodialysis patients were followed up retrospectively for 18 months. Routine screening for MRSA and MSSA was instigated. Two hundred and eighty-eight patients (49%) had at least one positive MSSA or MRSA swab. There was no statistical difference in age, Charlson index, diabetes, sex, ethnicity, deprivation index, or the duration of dialysis between the positive and negative groups. There were however, less fistulas and more lines in the positive patients (*P = 0.025*). Binary logistic regression revealed patients with a body mass index of greater than 30 had a significantly increased risk of *Staphylococcus aureus* colonization (*P = 0.044*, odds ratio (OR) 1.856 (95% confidence interval 1.016–3.397)). Those who entered the study using a temporary line for vascular access also conferred a greater risk of colonization (*P = 0.029*, OR 2.174 (95% CI 1.084–4.359)). Patients with positive swabs had significantly more admissions (*P = 0.025*) and in particular, more infection-related admissions (*P = 0.001*). They were less likely to survive the follow-up period (*P = 0.012*) and had substantially more bacteremia (*P <0.001*). Following multivariable analysis, swab positivity remained an independent risk factor for mortality. MRSA and MSSA colonization in patients is associated with significant mortality and morbidity in dialysis patients. Patients dialyzing with lines are also more likely to colonize compared to those with more permanent forms of vascular access.

Introduction

*Staphylococcus aureus* (*S. aureus*) is a difficult, pathogen, which provides many clinical chal-
End-stage renal disease patients are particularly vulnerable to infection due to their uremic immunocompromised state, frequent exposure to the hospital environment, and tunneled catheters, which allow the formation of bio-films. The pathogen’s extraordinary ability to cause long-lasting colonization makes it extremely problematic to eradicate and poses a persistent threat to patients on hemodialysis (HD). Once a patient has a *S. aureus* bacteremia the organism exhibits an almost metastatic ability leading to widespread complications, including endocarditis, meningitis, and osteomyelitis. Consequently, infection frequently leads to precious vascular access loss and the infection itself puts patients at a staggering nine-fold increased risk of death.

A major risk factor for *S. aureus* bacteremia is the mode of vascular access. Tunneled catheters confer the greatest risk and have been found to be a leading source of bacteremia. Screening for methicillin-resistant *Staphylococcus aureus* (MRSA) colonization has been frequently studied and widely adopted particularly in the surgical sector. The majority of UK Renal centers have also developed a screening policy for MRSA colonization. What remains unclear is the efficacy and cost-effectiveness for screening all HD patients. It is unclear whether resources are best targeted toward particular patient groups deemed at the highest risk and whether screening should be limited to MRSA or also include methicillin-sensitive *S. aureus* (MSSA). The success of decolonization regimes is conflicting and frequently dependent on patient motivation and compliance. This is compounded by a growing concern over the possibility of mupirocin and vancomycin resistance.

In an attempt to reduce the consequences of *S. aureus* infection our center implemented a local screening program for all HD patients. This involved screening for both MRSA and MSSA followed by a prompt decolonization protocol if a patient was screened positive for either organism. We aimed to identify the incidence of both MRSA and MSSA colonization in our patients and characterize clinical outcomes following colonization in an attempt to identify who is most at risk and whether screening for MSSA was useful for patients having HD.

### Materials and Methods

#### Design, setting, and participants

Our renal unit is set within East Birmingham. Around 650 patients undergo HD within our unit and include four satellite units in the community. Adult patients who had HD between June 1, 2009, and May 31, 2011 and were HD dependent for at least 4 weeks were selected (Table 1 for full exclusion and inclusion criteria).

#### Screening and treatment protocol

The screening program at our center involved swabs taken from the nose and vascular access site at the time of commencing HD and then at four-monthly intervals. If a positive result (MRSA or MSSA) was obtained a decolo-

| Exclusion criteria                                      | Inclusion criteria                                      |
|----------------------------------------------------------|---------------------------------------------------------|
| <18 years of age                                         | >18 years of age (no upper age limit)                   |
| Patients who transferred to PD during follow-up          | At least one session of HD between June 2009 and May 2011|
| Patients who were transplanted during the follow-up period| HD dependent for > 4 weeks                              |
| Those who commenced hemofiltration temporarily due to acute kidney injury | HD dependent for the duration of follow-up |
| Those who were screened for MRSA only (rather than MSSA and MRSA) |                                                |

PD: Peritoneal dialysis, HD: Hemodialysis, MRSA: Methicillin-resistant *Staphylococcus aureus*, MSSA: Methicillin-sensitive *Staphylococcus aureus*.
Decolonization involved daily 4% Chlorhexidine Gluconate body wash and a 2% Mupirocin nasal ointment applied three times a day to both nostrils for five days. If the positive swab was from a vascular access site the ointment was also applied to the exit site for the next three dialysis sessions. Patients were subsequently screened again in two days following completion of decolonization. A further decolonization course was recommenced if the swab is positive.

Microbiology laboratory techniques
For analysis, swabs were plated onto blood agar at 37°C in air for 18–24 hours. If S. aureus was present, antimicrobial resistance testing was performed by Vitek® 2 Systems (bioMérieux, Marcy l’Etoile, France).

Follow up period
The start of the study for each patient was defined by the date of the patient’s first positive swab in the study period (June 1, 2009 to May 31, 2011). If the patient only had negative swabs in the study period, the date of the first negative swab was defined as the start of the study for that patient.

Patients were followed up for 18 months following the date of their first swab in the defined study period or death if death occurred first. A small minority of patients were transferred to local satellite dialysis units managed by a neighboring hospital trust and were consequently followed up to the point at which they transferred.

Definitions
1. Negative- patients who had persistently negative swabs throughout the follow-up period
2. Positive- patients who had a least one positive swab throughout the follow-up period. Their “positive” status remained even if all subsequent swabs were negative
3. Incident cases- patients who entered the study having been dependent on HD for <1 year
4. Prevalent cases- patients who entered the study having been dependent on HD for over one year
5. Dialysis days- dialysis days are calculated based on the median follow-up period of 18 months with the assumption that a chronic HD patient has three sessions of HD “dialysis days” per week. Events have been displayed as per 1000 dialysis days
6. Duration of dialysis- calculated from the date the patient commenced dialysis to the date of entry into the study (therefore first swab in the study period).

Outcome measurements
Electronic patient records (iCARE©) and (PROTON©) were used to record demographics, including age, sex, ethnicity, postcode, dialysis duration, type of vascular access, and body mass index (BMI). These were determined at the point the patient entered the study. Mortality and frequency of admissions were calculated from clinical letters and discharge summaries. Positive blood cultures were determined from microbiology records. Comorbidity was calculated using the Charlson index and deprivation index was calculated from postcodes using the 2011 census data from the Office of National statistics both of which were determined at the point the patient entered the study.

The UK deprivation index is based on nationally collated statistics where areas of the country are scored according to domains of deprivation (a score of 1 is most deprived). Duration of dialysis was calculated from the patient’s first dialysis session until the date they entered the study, therefore the date of their first swab regardless of the result.

Data availability
The datasets generated during the current study are available from the corresponding author on reasonable request.

Statistical Analysis
Statistical analysis was performed using the IBM SPSS© version 19 (Armonk, New York,
USA). Statistical significance was defined as a $P < 0.05$. Unpaired t-tests were used to analyze age and BMI. A Mann–Whitney U-test was used to analyze the Charlson index, duration of dialysis and deprivation scores. Kendall tau b test was used for admissions data and frequency of positive blood cultures. Remaining data was analyzed using a Fisher’s exact test for two by two tables or a Chi-squared test for larger tables. Survival was analyzed using survival plots, Kaplan Meier curves and log-rank (mantel cox) analysis for significance.

Multivariable analysis was conducted using binary logistic regression to determine the influence of independent variables on colonization. Mortality was analyzed using cox regression (proportional hazard analysis) including forward and backward stepwise regression to determine the influence of comorbidity, diabetes, vascular access, age and dialysis vintage on mortality.

Results

Microbiology results and carriage states

A total of 578 chronic HD patients meeting the study criteria were identified. Of these patients 288 (49%) had at least one positive MSSA or MRSA swab during the follow-up period. Of those positive swabs 90% ($n = 258$) were MSSA.

Patient demographics

There was no statistical difference in baseline patient demographics when comparing patients who had positive swabs ($n = 288$) and those with negative swabs ($n = 290$) (Table 2). Following binary logistic regression, the odds ratio of colonization increased for those with a BMI of greater than 30 and patients entering the study with a temporary line (Table 3).

Vascular access and duration of dialysis

The duration of dialysis was a median of 804 days in the group with positive swabs. The duration of dialysis was comparable in the group with negative swabs with a median of 617 days. There was no statistical significance in the duration of dialysis between the two group’s $P = 0.245$ (Table 2). Of the 288 patients with positive swabs 200 patients (69%) had fistulas, 7 (3%) had grafts, 56 (19%) had permcaths, and 25 (9%) had temporary lines at the time of their first positive MSSA/MRSA swab. In comparison patients who had negative swabs had a greater proportion of fistulas with 231 patients (79.5%), less grafts at three patients (15%), less permcaths at 43 patients (15%), and less temporary lines at 13 patients (4.5%) ($P = 0.025$) (Figure 1). A similar pattern of vascular access was also seen when looking back to the very first method of vascular access patients had when commencing HD $P = 0.039$ (Figure 2).

Short-term outcomes

During the 18 months follow-up period, there were a total of 1154 admissions for 578 patients. Those with positive swabs had significantly more total admissions to the hospital at 2670/1000 dialysis days ($P = 0.033$) and more infection-related admissions to hospital at 707/1000 dialysis days ($P = 0.001$) (Figure 3). In comparison those with negative swabs who had less total hospital admissions and infection-related hospital admissions at 2247/1000 dialysis days and 524/1000 dialysis days, respectively. Infection-related admissions were determined from the discharge letter. The chest was the most frequent source of infection in both groups; however, there was a greater percentage of infected access, pyrexia of unknown origin, and joint infections in those with positive swabs (Table 4). Urinary and gastrointestinal infections were more frequent in the negative group.

There were 78 cases of bacteremia recorded within the 18 months follow-up period (a rate of 332/1000 dialysis days) from a total of 56 patients. Twenty-eight of the positive blood cultures were $S. aureus$ (a rate of 119/1000 dialysis days) (26× MSSA, 2× MRSA). All $S. aureus$ positive blood cultures were cultured from patients with positive skin colonization on the swabs (either nasal or access). This was statistically significant at $P < 0.001$.

Patients with negative swabs were more likely to survive the follow-up period 80%
versus 71% (Table 4). Of those patients with positive swabs who died we were able to determine known causes of death for 53 patients, 27 of these deaths were attributed to infection. On the death certificate 13 patients had pneumonia mentioned, 12 mentioned sepsis (one of which was S. aureus bacteremia) and two patients had endocarditis. Of those patients with negative swabs 14 out of 40 known causes of death were related to infection (8 patients had pneumonia on the death certificate, 5 sepsis, and 1 endocarditis) (Table 4). Survival analysis was carried out for all-cause mortality (Figure 4). The log-rank (mantel cox) was P = 0.08 indicating a significant difference in mortality rate between the two groups. Survival analysis was also carried out for infection-related mortality (Figure 5). Despite an observed trend this did not demonstrate a significant difference between the positive and negative groups (log-rank P = 0.140).

Cox regression modeling for confounders indicates that positive colonization is independently associated with mortality after taking into account age, diabetes, comorbidity, dialysis vintage, and vascular access at the start of the study (Table 5). Using forward stepwise regression, the hazard ratio for swab positivity was 1.449 [95% Confidence interval (CI) 1.029–2.042] P = 0.034. For backward stepwise regression, the hazard ratio for swab positivity was 1.464 (CI 1.037–2.067) P = 0.030.

### Table 2. Patient demographics by swab positivity.

| Demographics | Positive swabs | Negative swabs | P    |
|--------------|----------------|----------------|------|
|              | Number         | Statistic      | Number | Statistic |            |
| Age (years)  | 288            | 62.51 (16.92)  | 290    | 64.56 (14.95) | 0.120 |
| Charlson index | 287            | 5 (2–12)      | 290    | 5 (2–12)    | 0.742 |
| Diabetes     | 288            | Non diabetic=180 (62.5%) | 290 | Non diabetic=190 (65.5%) | 0.545 |
|              |                | Diabetic=108 (37.5%) |       | Diabetic=100 (34.5%) |        |
| Case type    | 288            | Incident=108 (37.5%) | 290    | 117 (40.3%) | 0.496 |
|              | 180            | Prevalent=180 (62.5%) | 173    | Prevalent=173 (59.7%) |      |
| Sex          | 288            | Female=118 (41%) | 290    | 106 (36.5%) | 0.306 |
|              | 170            | Male=170 (59%) | 184    | Male=184 (63.5%) |        |
| BMI          | 266            | 26.58 (6.06)  | 283    | 25.75 (5.66) | 0.390 |
| Ethnicity    | 281            | Caucasian=172 (61%) | 289 | Caucasian=172 (59.5%) | 0.105 |
|              | 91             | Asian=91 (32%) | 89     | Asian=89 (31%) |        |
|              | 15             | Afro-Caribbean=15 (6%) | 26     | Afro-Caribbean=26 (9%) |        |
|              | 3              | Other=3 (1%)   | 2      | Other=2 (0.5%) |    |
| Deprivation score | 265 | 5225 (46–32264) | 277    | 7127 (46–32301) | 0.089 |
| Duration of dialysis (days) | 288 | 804 (0–9646) | 290    | 617.50 (0–9055) | 0.245 |
|              | 288            | Less than a year n =108 (37.5%) | 240 | Less than a year n=117 (40.3%) | 0.121 |
| Dialysis vintage |                | 1–3 years n =63 (21.9%) | 1–3 years n=28 (26.9%) |        |
|              |                | Over 3 years n =117 (40.6%) | Over 3 years n=95 (32.8) |    |

Data are reported as mean ± standard deviation, with P-values from independent samples t-tests; median (range), with P-values from Mann–Whitney U-tests; or as n (%) with P-values from Fisher’s exact test or Chi-squared test, as applicable. P <0.05 are in bold.
Table 3. Risk factors for *Staphylococcus aureus* colonization.

| Demographics          | Odds Ratio          | P     |
|-----------------------|---------------------|-------|
| Age (years)           | NA                  | 0.637 |
| <55                   | *                   | *     |
| 56–64                 | 0.828 (0.504–1.358) | 0.454 |
| 65–74                 | 0.709 (0.455–1.105) | 0.129 |
| 75+                   | 0.767 (0.493–1.193) | 0.239 |
| Charlson index        | NA                  | 0.389 |
| 2–3                   | *                   | *     |
| 4–5                   | 0.752 (0.470–1.202) | 0.234 |
| 6–7                   | 0.805 (0.509–1.221) | 0.352 |
| 8+                    | 1.113 (0.630–1.965) | 0.712 |
| Diabetes              | 1.140 (0.811–1.602) | 0.450 |
| Incident case         | 0.887 (0.635–1.240) | 0.887 |
| BMI (kg/m²)           | NA                  | 0.049 |
| <20                   | *                   | *     |
| 20–22                 | 0.948 (0.510–1.761) | 0.866 |
| 23–25                 | 1.518 (0.842–2.738) | 0.165 |
| 26–30                 | 1.042 (0.574–1.890) | 0.893 |
| 30+                   | 1.856 (1.016–3.397) | 0.044 |
| Ethnicity             | NA                  | 0.856 |
| Caucasian             | *                   | *     |
| Asian                 | 1.022 (0.713–1.466) | 0.904 |
| Afro-Caribbean and other | 0.613 0.862 (0.485–1.532) | 0.613 |
| Deprivation score     | NA                  | 0.790 |
| (Most deprived)       |                     |       |
| <1000                 | *                   | *     |
| 1000–4999             | 1.106 (0.636–1.922) | 0.721 |
| 5000–9999             | 0.851 (0.430–1.598) | 0.616 |
| 10000–19999           | 0.865 (0.468–1.601) | 0.645 |
| (Most affluent)       |                     |       |
| 20,000+               | 0.879 (0.482–1.604) | 0.675 |
| Dialysis vintage (years) | NA                  | 0.121 |
| <1                    | 0.750 (0.514–1.092) | 0.133 |
| 1–3                   | 0.656 (0.422–1.007) | 0.540 |
| 3+                    | *                   | *     |
| Access at the start of the study | NA                  | 0.030 |
| Fistula and graft     | *                   | *     |
| Permcathe             | 1.472 (0.949–2.284) | 0.840 |
| Temporary lines       | 2.174 (1.084–4.359) | 0.029 |

Factors were analyzed using binary logistic regression. The odds ratio is shown for each variable with 95% CI P <0.05 are in bold. NA represents variables not used in the analysis. *indicates reference variables, BMI: Body mass index, CI: Confidence interval, NA: Non-applicable.
Figure 1. Method of vascular access at the start of the study for both carriage states.
Vascular access methods are determined as percentages for comparison. There are more fistulas and less lines in the negative group compared to the positive group. The numbers indicate the raw number of patients in each group.

Figure 2. First method of vascular access in both carriage states.
The very first method of vascular access used for HD can be seen in each group. Again there is a greater use of fistulas in the negative group. The numbers indicate the raw number of patients in each group.

Figure 3. Rate of hospital admissions in each carriage state.
Illustrates the rate of hospital admissions for both groups in terms of total admissions, infection-related admissions and access related admissions. Event rate is given per 1000 dialysis days to enable comparison.
Table 4. Survival, death attributable to infection and details of infection-related admissions.

| Outcomes                                      | Positive swabs (n=total analyzed) | Negative swabs (n=total analyzed) | P   |
|-----------------------------------------------|-----------------------------------|-----------------------------------|-----|
| Survival in 18 month follow-up period         |                                    |                                   |     |
| Survival at 18 months                         | 71%                               | 80%                               |     |
| Death rate: 354 in 1000 dialysis days         | 354 in 1000 dialysis days         |                                   |     |
| Died of infection-related disease             | 27 out of 53 (51%) died of infection | 14 out of 40 (35%) died of infection | 0.140 |
| Infection-related admissions*                 |                                    |                                   |     |
| Chest=74 (45%)                                | Chest=59 (48%)                    |                                   |     |
| Urinary=5 (3%)                                | Urinary=20 (16%)                  |                                   |     |
| Gastro=17 (10%)                               | Gastro=15 (12%)                   |                                   |     |
| Infected access=24 (14%)                     | Infected access=4 (3%)            |                                   |     |
| Skin/ulcers=18 (11%)                          | Skin/ulcers=16 (13%)              |                                   |     |
| Pyrexia of unknown origin=22 (13%)            | Pyrexia of unknown origin=9 (8%)  |                                   |     |
| Joint=5 (3%)                                  | Joint=2 (2%)                      |                                   |     |
| ENT=1 (1%)                                    | ENT=1 (1%)                        |                                   |     |

Data are reported as median (range), with P-values from Mann–Whitney U–tests; or as n (%) with P-values from Log-rank (Mantel cox) survival analysis. *Infection-related admissions are categorized broadly according to the source documented on the discharge letter.

Figure 4. Kaplan-Meir curve for all cause-mortality.

The dashed line indicates those with negative swabs, total survival at 18 months was 80%. The solid line indicates patients with positive swabs, the total survival at 18 months was 71%. Censored patients represent patients who transferred to satellite dialysis units outside of our hospital trust.
Table 5. Multivariable models of survival using Cox (Proportional Hazard) regression.

| Factors influencing mortality | Hazards ratio (95% CI) | P     |
|------------------------------|------------------------|-------|
| Swab (positive)              | 1.470 (1.041–2.077)    | 0.029 |
| Age (years)                  | N/A                    | 0.248 |
| <55                          | *                      | *     |
| 55–64                        | 1.099 (0.507–2.384)    | 0.811 |
| 65–74                        | 1.257 (0.588–2.686)    | 0.555 |
| 75+                          | 1.842 (0.824–4.120)    | 0.137 |
| Diabetes                     | 0.912 (0.603–1.382)    | 0.665 |
| Charlson                     | N/A                    | 0.030 |
| 2–3                          | *                      | *     |
| 4–5                          | 1.423 (0.612–3.313)    | 0.413 |
| 6–7                          | 2.699 (1.045–6.971)    | 0.040 |
| 8+                           | 3.582 (1.246–10.303)   | 0.018 |
| Access                       | N/A                    | 0.007 |
| Fistulas/grafts              | *                      | *     |
| Permcaths                    | 1.836 (1.220–2.763)    | 0.004 |
| Temporary lines              | 1.838 (0.983–3.435)    | 0.057 |
| Dialysis vintage (years)     | N/A                    | 0.020 |
| <1                           | *                      | *     |
| 1–3                          | 0.836 (0.509–1.373)    | 0.479 |
| 3+                           | 1.529 (1.015–2.304)    | 0.042 |

Several variables were used to account for confounders in mortality. Increasing comorbidity (Charlson index), dialysis vintage over 3 years and permcath use were associated with increased mortality. Swab positivity, however, remained an independent predictor of mortality. \( P < 0.05 \) are in bold. NA represents variables not used in the model. *indicates reference variable HR: Hazards ratio, NA: Non-applicable, CI: Confidence interval.

![Kaplan Meir curve for infection related deaths](image)

Figure 5. Kaplan Meir curve for infection-related mortality only.

The dashed line indicates those with negative swabs, 65% died of causes other than infections. The solid line indicates those with positive swabs, 49% died of causes other than infection. Although there appears to be more infection-related death in those with positive swabs this did not reach statistical significance.
Discussion

In the UK screening programs vary between centers.\textsuperscript{17} In the USA, periodic testing for MRSA in HD units has been implemented in some units and not others.\textsuperscript{7} Within Europe screening has also not been taken up universally.\textsuperscript{18} We believe that screening and treating for MSSA is unique to our unit.\textsuperscript{13}

Almost half of our patients swabbed positive for either sensitive or resistant \textit{S. aureus}. The vast majority, >90%, swabbed positive for MSSA rather than MRSA. Interestingly, we found no demographic susceptibility for patients swabbing positively for MRSA or MSSA other than an elevated BMI. This is in keeping with previous published work by Duran et al which found no increased risk of colonization with diabetes, age or sex.\textsuperscript{19}

Previous studies have, however, found a correlation between social deprivation and increased risk of colonization, but this is in contrast to our cohort.\textsuperscript{20} Following multi-variable analysis the hazard ratio for those with a BMI >30 indicated an increased risk of \textit{S. aureus} colonization. This is perhaps not unsurprising as obesity is thought to effect the immune response and those with an elevated BMI are at greater risk of both community and nosocomial infections.\textsuperscript{21,22} Olsen et al found that in the general population obesity was an independent predictor of nasal colonization.\textsuperscript{21} Befus et al also found an association with elevated BMI and colonization in female prisoners.\textsuperscript{22}

A major limitation of this study is its retrospective design, which means causation cannot be inferred. Disentangling the complex direction of events in this data is challenging. While \textit{S. aureus} colonization is associated with an increase in admissions it may be an indirect marker of morbidity burden, thus leading to more admissions and \textit{S. aureus} colonization. Lu et al demonstrated that contact with the health-care setting allows repeated colonization between patients and health-care workers.\textsuperscript{23} Surprisingly, there was no observed difference in the duration of dialysis between those patients who swabbed positive and those who swabbed negative. It might be expected that patients with a longer dialysis duration have more contact with the hospital environment. We did not, however, have clear data on hospitalization rates before swab analysis which has previously been shown to be an important factor in colonization.\textsuperscript{24} Frequent contact with the hospital environment can increase risk of colonization.\textsuperscript{25} Sexton et al found that over half of swabs of surface areas within hospitals were contaminated with MRSA, half of which were swabs from beds and mattresses.\textsuperscript{26} Health-care workers are also more likely to colonize with MRSA and are vectors for transmission to patients.\textsuperscript{25}

There were significant differences between the type of vascular access in those patients who swabbed positive for MRSA and MSSA and those who had negative swabs. Nearly 80% of patients in the negative group had fistulas at the start of the study compared to 69% in the positive group. Patients with temporary lines were also more likely to colonize with MRSA or MSSA. It is well recognised that temporary lines and tunneled catheters are associated with increased risk of infection.\textsuperscript{27-29} HD catheters have been shown to become colonized with bacteria which produce mucopolysaccharide matrix, otherwise known as a biofilm.\textsuperscript{29} This biofilm confers some protection against both the immune system and antibiotics.\textsuperscript{3}

Once again however, the direction of this association cannot be ascertained. Catheter use is also independently associated with mortality and is more likely to be used in patients with an increased comorbidity burden or present to nephrology services late.\textsuperscript{30} It is known that colonization precedes infection and frequent manipulations in these patients, especially with lines increases the risk.\textsuperscript{31} It is unclear whether it is the greater frequency of intervention, greater exposure to the hospital environment or the presence of a prosthetic line itself which confers the greatest risk.

We can hypothesize that those patients who have fistulas are likely to have less intervention due to less complex vascular access. In keeping with this a meta-analysis of 10
studies found that both hospitalization within the last year and the use of temporary vascular access was associated with colonization of MRSA. In this study, we were unable to ascertain the complexity of vascular access within our cohort; thus, it is not known whether patients who swabbed positive had a greater frequency of line exchanges or a greater incidence of groin lines. Of note, other researchers have found that the method of line insertion itself does affect the rate of catheter-associated infections.

The majority of units in the UK consistently decolonize for MRSA only. Our unit is unique in actively screening and decolonizing for MSSA. There is concern that consistent over use of mupirocin will lead to antimicrobial resistance leading to our most vulnerable patients developing resistance. While there are some studies into mupirocin and vancomycin resistance, many of these concerns appear unfounded. We did not see an increase in mupirocin resistance in our patients.

This study indicates that nearly half of our cohort have colonized MSSA and positive colonization is associated with a greater volume of hospital admissions and higher rates of bacteremia. In contrast to our study Coucke et al studied 154 patients and found that nasal MSSA prevalence was similar to the general population at approximately 30%. The authors subsequently concluded that screening just three times a year is sufficient. There are limited data investigating the risk of MSSA colonization in HD patients, however given this population is already at high risk of infection as a result of uremia, further research is warranted to reduce risk.

In conclusion, we have shown that in our HD cohort the method of vascular access and elevated BMI significantly increase the risk of colonization with MSSA/MRSA, which is in return associated with a higher prevalence of infection-related mortality. Importantly both of these risk factors are modifiable. There is a well-known association between BMI and mortality in HD patients in which mortality risk is significantly lower in those with a BMI of greater than 28 kg/m². These data suggest that maintaining a healthy weight and avoiding temporary lines provides the best chance of staying MSSA or MRSA free, thereby reducing the risks associated with colonization. New techniques for avoiding tunneled catheters and temporary lines such as the accuseal grafts which can be needled early also remain interesting alternatives to this dilemma.

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