Evaluation of *Staphylococcus aureus* eradication therapy in orthopaedic surgery

S. T. J. Tsang,¹,²,* M. P. McHugh,³ D. Guerendaiin,³ P. Gwynne,² J. Boyd,⁴ I. F. Laurenson,³ K. E. Templeton,³ S. Lewis,⁵ A. H. R. W. Simpson¹ and T. S. Walsh⁴

**Abstract**

**Purpose.** Despite WHO recommendations, there is currently no national screening and eradication policy for the detection of methicillin-sensitive *Staphylococcus aureus* (MSSA) in the UK prior to elective orthopaedic surgery. This study aimed to evaluate the effectiveness of current standard methicillin-resistant *S. aureus* (MRSA) eradication therapies in the context of *S. aureus* (both MRSA and MSSA) decolonization in an elective orthopaedic population.

**Methodology.** A total of 100 patients awaiting joint replacement surgery who were positive for *S. aureus* on PCR nasal screening underwent the current standard MRSA pre-operative decolonization regimen for 5 days. Prior to commencement of the eradication therapy, swabs of the anterior nares, throat and perineum were taken for culture. Further culture swabs were taken at 48–96 h following treatment, at hospital admission for surgery and at hospital discharge. Following the completion of treatment, patients were asked to provide feedback on their experience using Likert rating scales. The primary outcome of this study was *S. aureus* clearance 48–96 h following eradication treatment.

**Results/Key Findings.** Clearance of *S. aureus* 48–96 h following treatment was 94 % anterior nares, 66 % throat and 88 % groin. Mean completion with nasal mupirocin was 98 %. There was no statistically significant recolonization effect between the end of the eradication treatment period and the day of surgery (P>0.05) at a median time of 10 days.

**Conclusion.** Current MRSA decolonisation regimens are well tolerated and effective for MSSA decolonization for the anterior nares and groin. The decolonization effect is preserved for at least 10 days following treatment.

**INTRODUCTION**

Healthcare-associated infection (HAI) is a significant clinical issue. This is particularly the case for surgical site infection (SSI). SSI is widely tracked as a quality indicator in healthcare systems and reporting is mandatory in many settings. Orthopaedic surgery is a primary focus of SSI surveillance, given the very high rates of implant use. The development of SSI has been shown to have major implications for patient-reported quality of life and function, healthcare costs and medicolegal costs [1]. A national audit of orthopaedic practice in the UK highlighted the wide variation in the prevalence of periprosthetic joint infection (PJI), ranging from 0.2–5 % [2]. It was estimated that between £200–300 million could be saved annually through the standardization of practice in the prevention of PJI across the UK. Amongst mono-microbial SSIs following hip and knee replacements (around 75 % of all cases), 30–38 % were methicillin-sensitive *Staphylococcus aureus* (MSSA), 4–5 % were methicillin-resistant *S. aureus* (MRSA) and 25–28 % were coagulase-negative staphylococci. In poly-microbial infections Gram-positive organisms were implicated in 70–80 % of cases [3]. High-level nasal carriers of MSSA have a risk of healthcare-associated MSSA infection that is three to six times the risk among non-carriers and low-level carriers. It is known that more than 80 % of healthcare-associated *S. aureus* infections are endogenous,
implying acquisition from sites on the patient’s own body [4, 5]. The association between nasal carriage of *S. aureus* and SSI has been demonstrated in cohort studies [6, 7] and a systematic review [8]. A pan-European study reported that 21.6% of healthy residents carry *S. aureus* in their nose, with wide variation between countries [9]. Amongst orthopaedic patients the prevalence has been estimated to range from 20–36% [10, 11]. In contrast to MSSA, MRSA prevalence in healthy community individuals is estimated to be <2% [12]. A recent retrospective cohort study in the UK reported a threefold reduction in MSSA-associated SSI with peri-operative systemic antibiotic treatment, known colonisation by mupirocin- or chlorhexidine-resistant MRSA. All isolates were mupirocin-sensitive. The study aimed to evaluate the effectiveness of current MRSA decolonization therapies in the context of *S. aureus* decolonization prior to joint replacement surgery.

**METHODS**

This study was conducted at a university teaching hospital from October 2015 to September 2016. The study protocol was reviewed and approved by the regional ethics committee. Patients presenting for assessment prior to orthopaedic implant surgery were prospectively enrolled and consented into the study. Pre-operative screening via a swab of the anterior nares was undertaken using the Xpert *S. aureus* Nasal Complete Assay (Cepheid). Those positive for *S. aureus* (either MSSA or MRSA) on nasal PCR screening were invited to participate in the study. Once enrolled, further swabs of the anterior nares, throat and perineum were taken for culture assays. To ensure the detection of both MRSA and MSSA, swabs were subcultured onto Brilliance MRSA 2 Agar and mannitol salt agar (Oxoid, Basingstoke, UK). Antibiotic sensitivity testing was performed on the VITEK 2 system (bioMérieux, Marcy-l’Étoile, France).

All enrolled patients received a 5-day decolonization regimen comprising nasal mupirocin 2% ointment applied to the inner surface of each anterior nares (three times daily), chlorhexidine gluconate 0.2% mouthwash solution to be gargled and used to rinse the oropharynx (twice daily), and chlorhexidine gluconate 4% (Hibiscrub) solution to be used as a soap/shampoo substitute (once daily). Patients were required to keep a daily record documenting their ability to administer the above decolonization regimen, including concordance with personal hygiene habits as recommended by the study institute’s MRSA decolonization policy. Patients were excluded on grounds of known chlorhexidine allergy, peri-operative systemic antibiotic treatment, known colonization by mupirocin- or chlorhexidine-resistant *S. aureus*, pregnancy or breast-feeding, or age <16 years.

In addition to *S. aureus* colonization status, the following baseline information was also collected: age, gender, ethnicity, body mass index (BMI), aetiology of joint disease, planned surgical procedure, concurrent medication, functional comorbidity index, documented MSSA or MRSA infection during the previous 12 months (plus site), hospital admissions within the past 12 months, date of last hospital admission, admission to a long-term care facility or a rehabilitation facility within the past 12 months, usual residence, any surgical interventions within the past 12 months, presence of indwelling urinary catheter or other implant device, antibiotic use within the past 3 months, signs or symptoms of current respiratory infection and presence of skin lesions.

Further culture swabs were taken at 48–96 h after completion of the 5-day eradication regimen. Additional swabs were taken at hospital admission for surgery (or day 21–28 for participants with postponed or cancelled surgery) and at either hospital discharge or 14 days post-surgery (whichever occurred first). Patients were followed up for 6 weeks post-surgery. Following the 5-day treatment period patients were asked to provide feedback on their experience using Likert rating scales.

The primary outcome of this study was the proportion of *S. aureus* clearance at 48–96 h following the eradication treatment period. The secondary outcomes were the proportion of *S. aureus* clearance at hospital admission and hospital discharge, the development of a hospital-acquired infection, the length of stay in acute hospital care, the discharge destination, the development of a surgical site infection and the history of infections requiring antibiotics following hospital discharge.

**Statistical analysis**

Data were analysed using Minitab v17 (Minitab Ltd, UK). Fisher’s exact testing or Chi-squared analysis were used to compare categorical data, Student’s *t*-test was used in the analysis of univariate continuous data and a multivariate analysis of variance (MANOVA) was used for multivariate continuous data. A *P*-value <0.05 was deemed to be statistically significant.

**RESULTS**

A total of 273 patients gave consent, were enrolled and underwent nasal PCR screening in this study. A total of 100 patients were found to be positive for nasal *S. aureus*. Fourteen patients were withdrawn from the study prior to commencement of the eradication therapy (Fig. 1). Of the 86 full participants, 81 were found to be colonized with MSSA, while 5 were colonized with MRSA. All isolates were mupirocin-sensitive. The baseline characteristics of the enrolled patients are shown in Table 1. A further two patients were withdrawn, as they could not complete the 5-day course of eradication therapy because the date of their surgery was brought forward. Surgery was cancelled for 10 patients, who were followed up for a second and final time 21–28 days following the eradication therapy. The remaining 74 patients went on to have their joint
replacement surgery, with all patients being assessed on hospital admission and discharge. All patients received prophylactic antibiotics (cefuroxime 1500 mg 30 min prior to skin incision and two further doses of cefuroxime 750 mg eight hourly) and surgical skin preparation (chlorhexidine gluconate 0.5% (Hydrex Ecolab, Leeds, UK)/povidone-iodine 10% (Videne Ecolab, Leeds, UK) in the perioperative period. Following this, eight patients were lost to final follow-up (6 weeks post-surgery), as they could not be contacted for confirmation of the visit (Fig. 1).

A single patient (1.2%) had an MRSA-positive respiratory infection within 12 months prior to enrolment onto this study. There were 12 patients (14.0%) who had been admitted to a hospital in the previous 12 months, 11 (12.8%) of whom were admitted for the purpose of surgical intervention. Surgical interventions occurred at a median time of 5 months (IQR 3–9) prior to inclusion in this study. There was no longstanding indwelling medical device or catheter-use amongst the enrolled patients. There were 11 (12.8%) participants who had undergone and completed antibiotic
therapy within the previous 3 months, at a median time of 1 month (IQR 1–2 months). Almost all participants lived in their own home, with only two patients (2.3%) residing in long-term care facilities.

Patient completion of the eradication regimen is presented in Table 2. Completion was defined as the number of treatments reported to have been administered by each participant divided by the total number of prescribed treatments. Mean completion of nasal mupirocin was 98.2% (±5.2). All other aspects of the eradication regimen, except for daily changes of bed sheets (61.2% (±31.5)), also had >90% completion. Full compliance was defined as no deviation from the eradication regimen (Table 3), i.e. all the prescribed treatments for a particular element were completed by the participant. Only 19/85 (22.3%) reported full compliance with the entire regimen. There was full compliance with the nasal mupirocin regimen in 69/85 (81.2%) cases. Unsurprisingly, full compliance was lowest with respect to daily changes of bed sheets [26/85 (30.6%)].

Following the treatment period, 78% patients strongly agreed that the regimen did not cause discomfort, 96% patients were in strong agreement that the treatment was painless and 79% patients in strong agreement that the treatment was acceptable (Fig. 2).

The clearance of S. aureus 48–96 h following treatment was 93.8% [95% confidence interval (CI): 79.2–99.2%]

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**Table 1.** Baseline characteristics of participants undergoing S. aureus eradication therapy

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-category</th>
<th>Total n=86</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Median (Q1–Q3)</td>
<td>65 years (57–72)</td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>56 (65.1%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>White</td>
<td>85 (98.8%)</td>
</tr>
<tr>
<td>BMI</td>
<td>Median (Q1–Q3)</td>
<td>31 kg m⁻² (27–36)</td>
</tr>
<tr>
<td>Planned orthopaedic procedure</td>
<td>Primary total hip replacement</td>
<td>30 (34.8%)</td>
</tr>
<tr>
<td></td>
<td>Primary knee replacement</td>
<td>48 (55.8%)</td>
</tr>
<tr>
<td></td>
<td>Primary bilateral knee replacements</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td></td>
<td>Primary unipartamental knee replacement</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td></td>
<td>Primary total shoulder replacement</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td></td>
<td>Primary total ankle replacement</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td></td>
<td>Revision total hip replacement</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td></td>
<td>Revision total knee replacement</td>
<td>3 (3.5%)</td>
</tr>
<tr>
<td>Days to planned procedure</td>
<td>Median (Q1–Q3)</td>
<td>15 (12–19)</td>
</tr>
<tr>
<td>Aetiology of joint disease</td>
<td>Osteoarthritis</td>
<td>83 (96.5%)</td>
</tr>
<tr>
<td></td>
<td>Rheumatoid arthritis</td>
<td>2 (2.3%)</td>
</tr>
<tr>
<td></td>
<td>Seronegative inflammatory arthropathy</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td>Co-morbidities</td>
<td>Asthma or COPD*</td>
<td>18 (20.9%)</td>
</tr>
<tr>
<td></td>
<td>Ischaemic heart disease</td>
<td>11 (12.8%)</td>
</tr>
<tr>
<td></td>
<td>Congestive cardiac failure</td>
<td>2 (2.3%)</td>
</tr>
<tr>
<td></td>
<td>Cerebrovascular disease</td>
<td>2 (2.3%)</td>
</tr>
<tr>
<td></td>
<td>Peripheral vascular disease</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td></td>
<td>Diabetes (types I and type II)</td>
<td>8 (9.3%)</td>
</tr>
</tbody>
</table>

*Chronic obstructive pulmonary disease.

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**Table 2.** Patient reported completion with eradication therapy

<table>
<thead>
<tr>
<th>Component of regimen</th>
<th>Mean (standard deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>90.4 (±10.1)</td>
</tr>
<tr>
<td>Nasal mupirocin (three times per day)</td>
<td>98.2 (±5.2)</td>
</tr>
<tr>
<td>Chlorhexidine mouthwash (twice per day)</td>
<td>98.8 (±6.1)</td>
</tr>
<tr>
<td>Daily change of bedding</td>
<td>61.2 (±31.5)</td>
</tr>
<tr>
<td>Daily change of towels</td>
<td>93.6 (±18.6)</td>
</tr>
<tr>
<td>Daily change of clothing</td>
<td>96.0 (±12.6)</td>
</tr>
<tr>
<td>Daily chlorhexidine body wash</td>
<td>94.8 (±16.9)</td>
</tr>
</tbody>
</table>

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**Table 3.** Patient reported full compliance with eradication therapy, i.e. no deviation from regimen

<table>
<thead>
<tr>
<th>Component of regimen</th>
<th>Full compliance</th>
<th>Total (n=85)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire regimen</td>
<td>Yes</td>
<td>19 (22.3%)</td>
</tr>
<tr>
<td>Nasal mupirocin (three times per day)</td>
<td>Yes</td>
<td>69 (81.2%)</td>
</tr>
<tr>
<td>Chlorhexidine mouthwash (twice per day)</td>
<td>Yes</td>
<td>80 (94.1%)</td>
</tr>
<tr>
<td>Daily change of bedding</td>
<td>Yes</td>
<td>26 (30.6%)</td>
</tr>
<tr>
<td>Daily change of towels</td>
<td>Yes</td>
<td>72 (84.7%)</td>
</tr>
<tr>
<td>Daily change of clothing</td>
<td>Yes</td>
<td>75 (88.2%)</td>
</tr>
<tr>
<td>Daily chlorhexidine body wash</td>
<td>Yes</td>
<td>75 (88.2%)</td>
</tr>
</tbody>
</table>
from the anterior nares, 65.6 % (95 % CI: 46.8–81.4 %) from the throat and 87.5 % (95 % CI: 71.0–96.5 %) from the groin (Fig. 3). There were no statistically significant differences in colonization between the first follow-up (48–96 h following the eradication treatment period) and the day of surgery ($P > 0.05$) (Fig. 3). Surgery was performed at a median time of 9.5 days (IQR 6–13 days) following the eradication treatment period. No statistically significant associations between treatment completion and decolonization at time of surgery were demonstrated in the comparative analysis ($P > 0.05$). Final swabs were taken on discharge at a median time of 4 days (IQR 3–5 days) from the date of surgery and showed evidence of further decolonization [pre-op 43.8 % (95 % CI: 26.4–62.3 %) vs post-op 84.0 % (95 % CI: 63.9–95.5 %), $P = 0.003$]. However, only the improvements in $S. aureus$ decolonization from the throat [pre-op 66.7 % (95 % CI: 47.2–82.7 % vs post-op 92.0 % (95 % CI: 74.0–99.0 %), $P = 0.046$] and groin [pre-op 76.7 % (95 % CI: 57.7–90.1 %) vs post-op 96.0 % (95 % CI: 79.6–99.9 %), $P = 0.026$] were found to be statistically significant.

All patients were discharged back to their home accommodation. There was a single episode of a HAI, in the form a urinary tract infection, during the admissions. Of the 66 patients available for follow-up at 6 weeks, three patients reported surgical/anaesthetic site infections. Two of these were at the operative site and one was at the site of the spinal anaesthetic. All were treated with oral antibiotics. A further three patients required antibiotic therapy for urinary tract infections. There were no reported deep infections or requirement for revision surgery.

Fig. 2. Summary of patient feedback, using Likert rating scales, following the treatment period. Each questionnaire was scaled 0–10, where 0 means strongly agree, 5 means uncertain and 10 means strongly disagree.

Fig. 3. $S. aureus$ clearance following eradication therapy according to site and sampling time point. Statistically significant differences within site groupings are denoted by *. 

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DISCUSSION

The prevention of PJI is currently a hot topic in the field of orthopaedics. The publication of a national audit highlighted the wide variation in the prevalence of PJI across the UK (0.2–5%) [2]. It was estimated that between £200–300 million could be saved annually through standardization of practice across the UK in the prevention of PJI. The most recent joint registry data recorded ~182,000 primary joint replacements being performed in the UK in 2015 [15, 16]. From previous studies it is estimated that 45,000–66,000 of these patients were colonized with MSSA [10, 13] prior to joint replacement surgery. Nasal MSSA colonization has previously been reported to confer a 7.7% (95% CI: 5.4–10.8%) absolute risk of S. aureus PJI in elective orthopaedic patients [17]. Screening and eradication programmes prior to elective orthopaedic surgery are reported to confer a 66.4% (95% CI: 45.8–87.0%) relative risk reduction for the prevention of S. aureus PJI [13, 17–21]. Therefore, 1000–6200 cases of S. aureus PJI per annum could potentially be prevented in the UK with the creation of a national I screening and eradication programme, in line with the latest WHO recommendations [14]. It has previously been estimated that the total hospital costs of PJI treatment are between £20,000–100,000 per case [2, 22], and so a national S. aureus decolonization programme could result in £20–620 million worth of savings in avoided treatment costs.

Systematic reviews of the efficacy and cost-effectiveness of MRSA screening and eradication programmes concluded that treatment with mupirocin nasal ointment (three times daily for 5 days) combined with antiseptic wash (once daily for 5 days) is the optimum intervention [23]. Although the proportion of MRSA clearance 2 days after completion of the regimen has been reported to be as low as 53% [24], it remains the most widely used approach, especially when combined with changing of bed sheets [23]. Using the same regimen in this study for patients colonized with S. aureus (MSSA or MRSA), there was 94% clearance from the anterior nares, 66% from the throat and 88% from the groin. There was evidence of further decolonization of the throat and groin during the patient’s admission to hospital. This was likely due to the use of perioperative prophylactic antibiotics and surgical skin preparation, which was received by all the participants enrolled in this study. Chen et al. [25] reported an 83% (20/24) clearance of nasal MSSA in elective orthopaedic patients, using a 5-day course of nasal mupirocin and chlorhexidine body wash. A similar level of MSSA elimination from the nose in elective orthopaedic patients was also reported by Kalmeijer et al. [84%, 80/95] using a 5-day course of nasal mupirocin only. In an analysis of six clinical trials, Doebbeling et al. [26] reported a pooled proportion of elimination of 91% (range 68–100%) for healthy volunteers who received a 5-day course of mupirocin twice per day. The effectiveness of mupirocin in the decolonisation of S. aureus (both MSSA and MRSA) nasal carriers was reported in a meta-analysis to be up to 90% at 1 week, but only 65% after 2 weeks. In a further meta-analysis of topical nasal mupirocin effectiveness, using it in MRSA-colonized cohorts [relative risk (RR) of treatment failure, 0.71; 95% CI: 0.55–0.90] was reported to be less effective than using it in MSSA-colonized (RR, 0.52; 95% CI: 0.43–0.64) or mixed (MRSA and MSSA) cohorts (RR, 0.30; 95% CI: 0.24–0.38) [8]. This should be considered when interpreting the results presented in our study, given the proportion of MSSA in our mixed S. aureus cohort. Treatment failure was reported to be associated with bacterial resistance to mupirocin, extra-nasal colonization and longer hospital stays [8]. A further reason for treatment failure may be the intensity of the decolonization protocols (especially when carried out at the patient’s home) resulting in low patient compliance. A further explanation that has been postulated for low treatment completion is poor patient tolerance of nasal mupirocin. A recent survey found that 39% of orthopaedic patients undergoing preoperative decolonization described ‘unpleasant or very unpleasant symptoms’ associated with treatment [27].

One study of nasal decolonization in non-orthopaedic patients found that there was a 75% failure rate for nasal MRSA eradication due to mupirocin resistance, including both low- and high-level resistant organisms [28]. Low-level resistance is defined as a minimum inhibitory concentration of 8 to 256 mg l−1 and is mediated by a point mutation in the gene coding for isoleucyl-tRNA synthetase. High-level resistance is defined as a minimum inhibitory concentration of ≥512 mg l−1 and is mediated by the acquisition of a plasmid containing the mupA gene, which encodes for an alternative isoleucyl-tRNA synthetase [29]. The prevalence of high-level mupirocin resistance in the USA has previously been estimated to be 3.3% [30]. The absence of mupirocin-resistant organisms in our cohort undoubtedly contributed to the high levels of treatment success seen in this study and our data should be interpreted within this context.

Topical agents such as chlorhexidine or triclosan body wash are recommended for patient-administered preoperative skin preparation, as they have been shown to decrease bacterial counts on the skin [31]. They are often used as adjuncts to topical nasal mupirocin ointment in decolonization protocols to reduce bacterial density at extra-nasal sites. Recently, 2% chlorhexidine wipes have been introduced to improve ease of administration and have been shown to be as effective as 4% chlorhexidine solution in reducing bacterial skin counts [32]. Several studies have also examined whether chlorhexidine wipes used as empirical preoperative monotherapy can reduce PJI risk after total hip or knee arthroplasty. These studies, which did not screen for S. aureus carrier status [33–35], have reported mixed results. The application protocols in these studies varied greatly. Those that instructed patients to apply the 2% chlorhexidine wipes preoperatively to six anatomical sites (head and neck, both arms, both legs, and the surgical site [33, 34]) were found to be effective in reducing the risk of PJI. Other studies that only instructed patients to apply wipes to the surgical site [35] were not effective in reducing the risk of PJI. In this study chlorhexidine body wash alongside daily...
changes of clothes, towels and bed sheets was found to be effective in decolonization of the groin. However, the effectiveness of chlorhexidine mouthwash (66%) was limited, despite high levels of patient-reported treatment completion.

Overall treatment completion in this study was high (>90%), with the exception of daily changes of bed sheets (31%). On the whole, patients thought the decolonization was acceptable (79%) and did not cause pain (96%). Despite this, only 19/85 (22%) reported full compliance with the nasal mupirocin regimen. However, this is higher than in previous studies that assessed patient compliance with pre-operative S. aureus eradication bundles. Schweizer et al. reported that only 39% of patients undergoing elective cardiothoracic surgery were fully compliant with a regimen that involved the use of topical mupirocin and chlorhexidine body wash.

Clearance was preserved at all sites up to the day of surgery at a median time of 10 days from the end of the treatment period. Recolonization is highly relevant but poorly understood and studied. Studies have indicated that there are broadly two groups of patients, those who are transiently colonized and quickly lose S. aureus, and those who are persistent carriers for whom S. aureus becomes established as part of their 'normal' flora [36]. These populations may respond differently to eradication regimens, and have different recolonization profiles. This is particularly relevant to managing the risk of cross-colonization/infection between patients and healthcare workers. Long-term studies have suggested that 30% of successfully treated patients remain decolonized after 12 months [37]. Repeated eradication treatment is not recommended, because it may promote the development of mupirocin resistance. The effect of widespread decolonization, in particular mupirocin treatment, on infections caused by organisms other than S. aureus is also of concern. A Cochrane systematic review concluded that although mupirocin treatment of S. aureus carriers is effective at reducing infections caused by S. aureus, it may increase the incidence of infections with other organisms [38].

A potential argument against the inclusion of mupirocin in decolonization regimens is the development of resistance [39], with prior therapeutic use having been shown to increase the risk of resistance in MRSA carriers by ninefold [40]. A systematic review reported that there was a 1% risk of resistance with short-term prophylaxis [8]. Other studies have noted evidence for increasing low-level mupirocin resistance being associated with increased mupirocin consumption [41]. The relevance of mupirocin resistance to the development of healthcare-associated infection is uncertain, but it remains the chief concern limiting its widespread use in this context, leading to the exploration of alternative decolonization strategies [29]. Other methods of decolonization include phototherapy-based disinfection, total-body chlorhexidine gluconate wipes preoperatively and iodine-based solutions applied hours before surgery [37]. Chlorhexidine gluconate wipes (2%) eliminate the need to bathe just before surgery and have started to gain popularity and prominence in the orthopaedic literature [42].

This study presented a comprehensive evaluation of the effectiveness of current MRSA eradication therapy in the context of S. aureus eradication. Its effectiveness has been described across a number of clinically relevant time points and anatomical sites. The study also quantified patient compliance for each aspect of the treatment and overall patient perceptions regarding the regimen. However, these results should be taken in the context of possible selection bias. The patients recruited to this study would have been likely to be highly motivated, thus leading to high patient compliance, positive feedback and high efficacy of the treatment. The patient diary and regular follow-up encounters would have also created an additional Hawthorne effect [43, 44], further improving patient-reported compliance. A further limitation of this study was that strain typing was not performed. It is therefore possible that the study isolates belong to a single clonal lineage. However, the patients included in our study were identified as carriers over a period of 12 months and none were involved in known transmission clusters, so the clonal relationships between isolates are less likely. In addition, unpublished strain typing of S. aureus from our health board showed that the population was diverse, containing multiple strain types (Andrew Robb, personal communication). Future recommended studies include analysis of S. aureus clearance dynamics to optimize the treatment regimen. A shorter treatment period would allow it to be applied to emergency surgery patients, improve patient compliance and reduce the development of antimicrobial resistance [45].

In conclusion, this study found that current MRSA decolonization regimens were well tolerated and effective in pre-operative MSSA decolonization of the anterior nares and groin. This effect was preserved for at least 10 days following treatment.

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Conflicts of interest
The authors declare that there are no conflicts of interest.

Ethical statement
This study was approved by the South-east Scotland Research Ethics Committee (reference 15/SS/0091) and witnessed consent was obtained from all enrolled patients.

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