Acta Orthop. Belg., 2015, **81**, 620-628

ORIGINAL STUDY

Selective Methicillin-Resistant Staphylococcus Aureus (MRSA) screening of a high risk population does not adequately detect MRSA carriers within a country with low MRSA prevalence

Solange DE WOUTERS*, Jérémy DAXHELET*, Ludovic KAMINSKI, Emmanuel THIENPONT, Olivier CORNU, Jean Cyr YOMBI

From Department of Orthopedic and Trauma Surgery, Saint-Luc University Hospital, Université catholique de Louvain, Brussels, Belgium

Background : **Methicillin-Resistant *Staphylococcus Aureus* (MRSA) has been widely recognized as a serious problem in hospital settings. The purpose of this study is to evaluate the predictive value of MRSA colonization factors in the detection of MRSA carriers in an orthopedic ward.**

Materials and Methods : **A systematic MRSA detection strategy was set up to assess the predictive value of MRSA colonization factors among 554 patients undergoing elective knee arthroplasty.**

Results : **In total 116 patients were found positive for *Staphylococcus Aureus* ; among those 110/116 patients were found positive for Methicillin-Sensitive *Staphylococcus Aureus* (MSSA) and 6/116 for MRSA. Only one patient out of six presented two risk factors according to MRSA risk factors. In this study, no correlation was found between the remaining conventional risk factors, according to Belgian guidelines, defined to target high-risk populations and to identify MRSA carriers.**

Conclusions : **Established criteria for selective MRSA screening do not allow detecting MRSA carriers. The objective of detecting MRSA carriers is not correctly met by the actual applied criteria (Belgian consensus) for a selective screening policy. Future studies should aim at identifying the right risk factors, depending of the country's prevalence of MRSA, to improve the ability to predict the risk of MRSA carriage at hospital admission.**

Keywords : Methicillin-Resistant *Staphylococcus Aureus* ; infection ; systematic screening ; total knee arthroplasty.

INTRODUCTION

Methicillin-Resistant *Staphylococcus Aureus* (MRSA) has been widely recognized as a serious problem for the hospital environment for many

* Solange de Wouters and Jérémy Daxhelet are *equal contributors*.

- Solange de Wouters.
- Jérémy Daxhelet.
- Ludovic Kaminski.
- Emmanuel Thienpont.
- Olivier Cornu.
  Department of Orthopedic and Trauma Surgery, Saint-Luc University Hospital, Université catholique de Louvain, Brussels, Belgium.
- Jean Cyr Yombi.
  Department of Internal medicine and Infectious diseases, Saint-Luc University Hospital, Université catholique de Louvain, Brussels, Belgium.

Correspondence : Jean Cyr Yombi, *Department of Internal medicine and Infectious diseases, Saint-Luc University Hospital, Université catholique de Louvain, Brussels, Belgium*.
E-mail : jean.yombi@uclouvain.be

No benefits or funds were received in support of this study. The authors report no conflict of interests.

reasons. MRSA infections are associated with a higher mortality rate, longer length of stay and higher hospitalization costs (*12,13,16,23,33,37*). During the past decade the prevalence of MRSA has been increasing (*5*).

In a large series of *Staphylococcus* related periprosthetic joint infections (PJI), Methicillin-Sensitive *Staphylococcus Aureus* (MSSA) accounted for 88% and MRSA for 12% of the infections with a substantially high risk of treatment failure in the MRSA group (*34*). An analysis by Engemann *et al* of 479 patients with deep surgical-site infections (SSI) with *Staphylococcus Aureus* showed that MRSA patients had a longer hospital stay and a much higher hospitalization cost than those infected with MSSA (*16*). Methicillin resistance is also associated with increased mortality (*16*). Roche *et al* reported that the length of hospital stay was almost tripled in a series of 318 patients with MRSA undergoing orthopedic procedures (*52*).

The importance of MRSA screening programs is not yet clear because published studies have yielded conflicting results. Some studies found that MRSA screening on admission did not reduce the incidence of SSI (*2,3,25,57*), whereas other studies observed that MRSA screening significantly reduced SSI rates (*4,9,22,30-32,38,44,50,51,53*). A commonly used method to reduce hospital transmission of MRSA is universal screening on admission to identify MRSA carriers. Early identification of patients colonized with MRSA will lead to a faster implementation of enhanced control procedures with isolation measures (*24*) and the appropriate selection of antibiotic agents for preoperative prophylaxis (*60*), reducing hopefully the transmission of MRSA. Cost-benefit analyses have concluded that control policies are cost effective in situations where MRSA carriage rates vary on admission between 0.5 to 20%, efficacy of control measures score between 14 and 80% and finally the rate of infection among colonized patients is between 20 and 60% (*8,29,35,42*). Although the benefits of universal MRSA screening programs remain unclear, the absolute cost is not insignificant. Universal screening is advocated in countries with high MRSA prevalence rates at admission and in all clinical units with high risk of MRSA infections (Intensive Care Units (ICU), hematology- and oncology unit, burn unit, hemodialysis unit).

One option to decrease the cost of MRSA control measures would be the use of selective MRSA screening, targeting only high-risk populations. Selective screening can be applied in countries were the prevalence at admission of MRSA is less than 5% (ie. all European countries). This strategy has been confirmed by the Belgian guidelines for Screening of MRSA (*11*). However the existing literature cannot be used to identify risk factors for MRSA colonization at the time of hospitalization (*18*). The prevalence of MRSA in our university hospital and at our orthopedic ward is 0.8% and 1.05% respectively. Given this very low prevalence, selective screening with targeting the high-risk population in our orthopedic ward was adopted as recommended by the Belgian guidelines (*11*).

The purpose of the present study is to evaluate the predictive value of MRSA colonization factors, according to Belgian guidelines (*11*), for the detection of MRSA carriers in an orthopedic ward for patients undergoing elective surgery.

MATERIALS AND METHODS

At our institution, a selective MRSA screening program targeting only the high-risk population is performed, according to Belgian guidelines (*11*) (Table I). For the purpose of this study, MRSA screening was carried out on all patients undergoing primary knee arthroplasty between August 2011 and August 2013, that were admitted to one of our orthopedic ward by systematic sampling of the anterior nares with use of a polymerase chain reaction-based diagnostic enabling a rapid diagnosis, within one day, of MRSA carriage (*19,26*).

MRSA control measures

Upon positive MRSA testing the MRSA control measures were in accordance with national and institutional guidelines (*10,45*). The identified MRSA carriers were isolated in single rooms and contact precautions were applied, including hand hygiene and the use of dedicated material (gowns, gloves, masks). MRSA carriers started topical decolonization treatment with 4% chlorexidine body washes once daily and 2% Mupirocin nasal ointment three times daily for a period of five days.

Table I. — Risk factors for MRSA carriage on admission according to Belgian guidelines

Age greater than eighty years
Inpatient in the previous 6 months
Previous colonization with MRSA
Living in a nursing or residential home
Exposure to invasive devices (tracheotomy, urinary catheter)
Chronic wounds or skin lesions
Healthcare personnel
Patients in contact with farm animals

Surgical Procedure

All patients had a shower with Iso-betadine soap the day before surgery and another on the day of surgery. All patients received antibiotic prophylaxis with cefazolin 2 g administered 30 minutes before skin incision. Alternatively, clindamycin was administered to patients with a history of IgE-mediated penicillin allergy. MRSA carriers did not receive antibiotic prophylaxis covering the MRSA spectrum because the nasal test results were only available after the surgery.

Data collection

Results of nasal screening were registered as either negative or positive for MSSA or for MRSA. Data collection for all patients included the risk factors for MRSA carriage on admission, type of preoperative antibiotic prophylaxis and its timing before the surgical incision. Baseline characteristics of the study population were also collected. The study protocol was approved by the ethical committee from the Saint-Luc University Hospital (Brussels, Belgium) and by the institutional review board as a continuous quality improvement project (2014/14AVR/178).

Statistical analysis

Continuous variables were compared using Student's *t* test. Categorical variables were studied with χ^2 analysis. Potential correlations were studied using Pearson's correlation. Analyses were performed with Statistical Package for the Social Sciences (SPSS) software version 20.0.

RESULTS

A total of 554 patients aged between 32 and 92 years old were enrolled in this study because they underwent systematic preoperative MRSA screening on admission before elective knee arthroplasty. Demographics and clinical characteristics of the patient group are summarized in Table II.

During the study period, systematic preoperative MRSA screening yielded in positive nasal cultures in 116 (21%) of 554 patients. One hundred and ten patients (20%) were identified as MSSA carriers, and six patients (1%) were identified as MRSA carriers. Only one patient out of six presented two risk factors (chronic wound and contact with farm animals). No correlation was found between the remaining conventional risk factors, according to Belgian guidelines (*11*), defined to target high-risk populations and the identification of MRSA carriers in this study (Table III).

DISCUSSION

MRSA infections are associated with considerably more morbidity and often with associated mortality (*12,13,16,23,33,37*). Reducing MRSA infection is therefore a major priority and the early detection of MRSA carriers seems a logical addition to current control measures. In the last decades the prevalence of MRSA is increasing over time (*5*), however, in the last years, there have been very marked declines in morbidity and mortality related to MRSA infection. In England, annual MRSA bacteraemia rates fell from 17.7 (April 2005-March 2006) to 3.2 cases per 100 000 bed days (April 2011-March 2012) (*46*). Significant declines have also been observed in SSI where MRSA was reported as the causative micro-organism (from 27% in 2004-2006 to only 4% in 2011-2012) (*47,48*). The number of death certificates in England and Wales mentioning MRSA infection has decreased each year since 2006, when the figure peaked at 1652 ; in 2012, MRSA accounted for 292 mentions of MRSA on death certificates (20% decrease on the previous year) (*39*). In England this decline of MRSA related morbidity and mortality, which was partially attributed to the introduction and implementation of

Table II. — Demographics and clinical characteristics

Characteristics	Total (N = 554)	Percentage (%)
Median age	67.5 y	
MSSA	110	19.5
MRSA	6	1.1
Risk factors :		
- Age > 80 at admission	87	15.5
- Hospitalization during last 6 months	69	12.5
- Previous colonization with MRSA positive	5	1
- Living in a nursing or residential home positive	7	1
- Exposure to invasive devices positive	0	0
- Chronic wounds or skin lesions positive	2	0.3
- Healthcare personnel positive	15	2.7
- In contact with farm animals positive	5	1
Antibioprophylaxis :		
- Cefazolin as prophylactic antibiotic	506	91.5
- Clindamycin as prophylactic antibiotic	20	3.5
- Others prophylactic antibiotic	4	0.7
- Unknown prophylactic antibiotic	24	4.5
Knee arthroplasty :		
- Left Knee	280	50.5
- Right Knee	272	49
- Bilateral Knee	2	0.5
Female	374	67.5
BMI	29.9	

mandatory surveillance of these infections and the promotion of alcohol-based hand rubs as part of multimodal and system change interventions, was observed before the implementation of the policy for screening all elective and emergency admissions between April 2009 and December 2010.

The most important finding of this study was that there is no correlation between conventional risk factors defined to target high-risk populations and MRSA positive testing. This study furthermore confirms a low rate of MRSA carriers as published for our country (Belgium) as well as a 20% positive MSSA rate.

The prevalence rate of 1% MRSA colonized patients admitted to an orthopedic ward for elective knee arthroplasty is equivalent to the earlier published Belgian rate (*46*) as well as for others centers in Europe (*28,38,57*). Barkatali *et al* reported in over 8868 patients in 2010 an MRSA prevalence of 0.47% in a Trauma and Orthopaedic surgery department (*2*). In 2004, Nixon *et al* screened 1795 of 1796 elective admissions and MRSA was found in 23 patients (1.3%) (*38*). They also screened 1122 of 1447 trauma admissions and 43 patients (3.8%) were carrying MRSA (*38*). In their study Nixon *et al* found that MRSA patients were older and more likely to come from a nursing home, but they did not observe a correlation with ASA-grading (*38*). In general, the most frequent trauma patients at the orthopaedic ward are predominantly hip fracture patients, which are older and live in nursing homes. This can partially explain why the prevalence of MRSA is higher for trauma than for elective surgery. In our hospital the prevalence of MRSA in 2014 was 0.8% and for the orthopedic ward 1.05%. Our MRSA prevalence is lower than other centers around the globe (North America), which have reported rates of MRSA colonization in elective patients between 3.5 and 27% (*14,58*).

The main purpose of this study was to determine whether risk factors used at our institution for selective MRSA screening (Table I) had the expected

Table III. — Analysis of impact of each risk factors

Risk Factor	χ^2	p-value
Age greater than eighty years	1.130	0.288
Inpatient in the previous 6 months	0.863	0.353
Previous colonization with MRSA	0.055	0.814
Living in a nursing or residential home	0.078	0.781
Exposure to invasive devices (tracheotomy, urinary catheter)	/	/
Chronic wounds or skin lesions	44.834	0.000
Healthcare personnel	0.169	0.681
Patients in contact with farm animals	16.854	0.000

result of adequately predicting MRSA colonization upon admission. In the current study, no correlation was found between these predetermined factors and the risk of carrying MRSA. Utilizing the applied national criteria, 5 of the 6 patients were missed (83%). Recently Dave *et al* found that approximately 50% of the MRSA-positive cases were missed using purely this selective screening policy (*14*). This is coherent with the findings of Thyagarajan *et al* who noted that more than 50% of the colonized patients came from their own home (*56*). These findings indicate that selective screening is inaccurate. One of the possible explanations for this inaccuracy is that the identification of all risk factors is very difficult and that the existing literature cannot be used to identify risk factors for MRSA carriage at the time of hospitalization (*18*). For example McKinnell *et al* found in their systematic review that a history of MRSA (infection or having been MRSA carrier), recent healthcare exposure (infection less than three months ago), past utilization of antibiotics, past admission (less than one year) and stay in a nursing home were the most predictive for MRSA colonization on hospital screening (*36*). Wounds (pressure ulcers or skin lesions) and certain comorbidities (heart failure, chronic obstructive pulmonary disease, renal failure) were also significantly associated with MRSA, while others were not (human immunodeficiency virus, liver cirrhosis and malignancy) (*36*). ICU admission was not associated with an increased risk for MRSA colonization (*36*). In contrary, recently HIV-infected patients and men who have sex with men have been identified as patients at risk for MRSA carriage by Peters *et al* (*43*). HIV is not cited as a risk factor in several guidelines (*11*). These criteria vary among guidelines, among countries or centers within the same country because data collection by medical and nursing teams can be suboptimal on admission. In our study only one patient presented with two risk factors (chronic wound and contact with farm animals). The low number of MRSA positive patients can allow a predictive value for theses two risk factors in our study.

Another explanation is that the actual applied criteria are not accurate for Community Acquired MRSA (CA-MRSA). CA-MRSA strains that have emerged worldwide over the past decade can affect healthy individuals of all ages in community settings (*41,61*). CA-MRSA has begun to transmit in hospitals, confounding epidemiological definitions and making a case for the definition and identification of CA-MRSA by their distinct genotypes (*40*). However CA-MRSA prevalence remains low in Belgium and Europe compare to United States (*6,55*).

Whatever the moment the elective MRSA screening program targeting high-risk populations is performed, it remains impossible to identify with certainty MRSA carriers and to organize a decontamination program. Such a program has proven its interest when MRSA SSI is highly prevalent (*59*). Universal screening has been advocated too. Universal screening of patients will increased the laboratory workload but will also simplify admission criteria for screening, with a substantial reduction of incorrect sampling (*14*). The Department of Health (DH) in England introduced mandatory screening of all elective and emergency admissions from April 2009 and December 2010, respectively. This decision was based on a DH impact assessment that modeled the cost-effectiveness of different screening and decolonization strategies in preventing MRSA bacteraemias, wound infections and deaths. They note that in other settings (e.g. Wales), where mandatory screening has not been implemented, MRSA infection rates have fallen markedly (*49*). The DH impact assessment committed to a review of this policy with additional data ; thus, the NOW study (*20*) was commissioned in 2011. The study showed that compliance with the current mandatory

screening policy was poor (e.g. only 61% were screened ; about half of new positives were isolated when their result became known ; and about a quarter did not receive decolonization therapy). The prevalence of MRSA in new admissions was low (1.5% overall), although this varied according to type of admission (2.1% in emergency admissions, 0.9% elective admissions and 0.7% in day cases admissions). These observations mean that the numbers of patients needed to be screened in order to identify one new positive were high in all admission types (emergency n = 102 ; elective n = 180 ; and day case n = 186) (*20*). Based on cost effectiveness analysis the study showed also that of the active screening strategies, screening high risk specialities and performing check list activated screening of others is optimal. They concluded that the screening for MRSA is recommended for those admitted to high-risk specialty units (defined in the guidance as vascular, renal, dialysis, neurosurgery, cardiothoracic surgery, haematology, bone marrow transplant, orthopaedics and trauma departments, as well as all intensive care units). Those previously identified as having been colonised or infected with MRSA (*20*).

Recently, Huang *et al* have shown that in routine ICU practice universal decolonization was more effective than targeted decolonization or screening followed by isolation, in reducing rates of MRSA clinical isolates and bloodstream infection from any pathogen (*27*). All theses data showed that prior to adopting any screening programme, accurate epidemiological data should be obtained from the target population to guide the decision-making process.

We can also wonder if the results of the MRSA screening should be made available before surgery, and if that would influence the choice of prophylactic antibiotics. In our study design, the result of MRSA screening was obtained after surgery and did not influence antibiotics prophylaxis policy.

MSSA was much more prevalent in our series than MRSA. Denis *et al* reported in 2011 in Belgium that the majority of patients with MRSA infection or colonization were elderly with a median age of 79 years old and the median age of patients with MSSA infection or colonization was 69 years old (*15*). In our series the overall median age was 67.5 years old. The median age for patients with MSSA was 62.5 years old and for MRSA was 64.5 years old with no significant difference. The high prevalence of MSSA and the low prevalence of MRSA justified our actual policy of antibiotics prophylaxis using cephalosporin (cefazolin). The American Academy of Orthopaedic Surgeons recommendations for the use of intravenous antibiotic prophylaxis in primary joint arthroplasty states that "vancomycin may be used in patients with known colonization with MRSA or in facilities with recent MRSA outbreaks" (*27*). Several studies provide convincing data on the clinical effectiveness of vancomycin in preventing SSIs when MRSA prevalence is high (*1,29,51*). Nevertheless, there is ample evidence that vancomycin is inferior against methicillin-sensitive strains of Staphylococcal species when compared to cephalosporin and penicillinase-resistant penicillin (*54*). In a low MRSA prevalence situation, prevention of MSSA infection must be insured and cephalosporin shall be preferred. Some authors argue that cephalosporin can be combined with vancomycin but this association is harmful in terms of renal toxicity (*7*).

The limitation of this study is of course that not all consecutive patients undergoing arthroplasty during the study period underwent MRSA screening. Patients entering the day of surgery were not included. Another limitation is that only primary arthritis patients scheduled for primary knee arthroplasty were included. Potentially patients planned for revision knee arthroplasty might present other risk factors than the primary arthroplasty group. A final limitation would be that patients were only screened for MRSA by nasal swapping and that no perineal or other anatomic site cultures were taken. Nasal screening gives the highest yield for detection of MRSA carriage but screening only the nares may fail to identify those patients who are colonised at body sites outside of the nares and who can still transmit the organism to others (*17*). In a survey of MRSA carriage using culture-based methods, 1250 patients were screened at multiple body sites on admission to hospital (*17*). The proportion of patients identified by nasal screening alone was 73%, whereas an additional 27% of the MRSA-colonized patients were detected when three anatomical sites

(nares, skin and rectum) were combined. These data suggest that screening of multiple body sites may provide better diagnostic accuracy data and improve rates of detection (*3,17*).

CONCLUSION

In conclusion, the actual recommended selective MRSA screening policy does not allow detecting MRSA carriers in an elective arthroplasty population. Larger studies are needed to draw definitive conclusions due to the low number of MRSA positives in our study. A systematic MRSA screening appears questionable, as screening policy did not influence the standard of care. Local epidemiology plays a critical role. Surgical wards should carefully assess local MRSA prevalence before introducing a universal screening policy. Future studies should aim to develop standardized risk factors to improve the ability to predict the risk of MRSA carriage at hospital admission.

REFERENCES

1. **American Academy of Orthopaedic Surgeons.** Advisory statement. Recommendations for the use of intravenous antibiotic prophylaxis in primary total joint arthroplasty. http://www.aaos.org/about/papers/advistmt/1027.asp. 2013.
2. **Barkatali BM, Heywood N, White R *et al*.** MRSA screening in orthopaedic surgery : clinically valuable and cost effective ? A prospective analysis of 8 867 patients. *Acta Orthop Belg* 2013 ; 79 : 463-469.
3. **Berthelot P, Grattard F, Cazorla C *et al*.** Is nasal carriage of *Staphylococcus aureus* the main acquisition pathway for surgical-site infection in orthopaedic surgery ? *Eur J Clin Microbiol Infect Dis* 2010 ; 29 : 373-382.
4. **Bode LGM, Kluytmans JAJW, Wertheim HFL *et al*.** Preventing surgical-site infections in nasal carriers of *Staphylococcus aureus*. *N Engl J Med* 2010 ; 362 : 9-17.
5. **Boucher HW, Corey GR.** Epidemiology of methicillin-resistant *Staphylococcus aureus*. *Clin Infect Dis* 2008 ; 46 : 344-349.
6. **Brauner J, Hallin M, Deplano A *et al*.** Community-acquired methicillin-resistant Staphylococcus aureus clones circulating in Belgium from 2005 to 2009 : changing epidemiology. *Eur J Clin Microbiol Infect Dis* 2013 ; 32 : 613-620.
7. **Cantoni L, Glauser MP, Bille J.** Comparative efficacy of daptomycin, vancomycin, and cloxacillin for the treatment of *Staphylococcus aureus* endocarditis in rats and role of test conditions in this determination. *Antimicrob Agents Chemother* 1990 ; 34 : 2348-2353.
8. **Chaix C, Durand-Zaleski I, Alberti C, Brun-Buisson C.** Control of endemic methicillin-resistant *Staphylococcus aureus* : a cost-benefit analysis in an intensive care unit. *JAMA* 1999 ; 282 : 1745-1751.
9. **Chen AF, Wessel CB, Rao N.** *Staphylococcus aureus* screening and decolonization in orthopaedic surgery and reduction of surgical site infections. *Clin Orthop Relat Res* 2013 ; 471 : 2383-2399.
10. **Coia JE, Duckworth GJ, Edwards DI *et al*.** Guidelines for the control and prevention of meticillin-resistant *Staphylococcus aureus* (MRSA) in healthcare facilities. *J Hosp Infect* 2006 ; 63 : 1-44.
11. **Conseil Supérieur d'Hygiène - Hoge Gezondheidsraad.** Recommandations pour le contrôle et la prévention de la transmission de *Staphylococcus aureus* résistant à la méthicilline dans les hôpitaux belges. Groupement pour le dépistage, l'étude et la prévention des infections hospitalières (GDEPIH) - Groep ter opsoring, studie en preventie van de infecties in de ziekenhuizen (GOSPIZ). http://health.belgium.be/internet2Prd/groups/public/@public/@shc/documents/ie2divers/4448393_fr.pdf
12. **Cosgrove SE, Qi Y, Kaye KS *et al*.** The impact of methicillin resistance in *Staphylococcus aureus* bacteremia on patient outcomes : mortality, length of stay, and hospital charges. *Infect Control Hosp Epidemiol* 2005 ; 26 : 166-174.
13. **Cosgrove SE, Sakoulas G, Perencevich EN *et al*.** Comparison of mortality associated with methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* bacteremia : a meta-analysis. *Clin Infect Dis* 2003 ; 36 : 53-59.
14. **Dave JL, Jenkins PJ, Hardie A *et al*.** A selected screening programme was less effective in the detection of methicillin-resistant *Staphylococcus aureus* colonisation in an orthopaedic unit. *Int Orthop* 2014 ; 38 : 163-167.
15. **Denis O.** Microbiological Surveillance of *Staphylococcus aureus* in Belgian Hospitals in 2011. www.erasme.ulb.ac.be/files/files/…/nrc_saureus_report_surv_2011.pdf
16. **Engeman JJ, Carmeli Y, Cosgrove SE *et al*.** Adverse clinical and economic outcomes attributable to methicillin resistance among patients with *Staphylococcus aureus* surgical site infection. *Clin Infect Dis* 2003 ; 36 : 592-598.
17. **Eveillard M, de Lassence A, Lancien E *et al*.** Evaluation of a strategy of screening multiple anatomical sites for methicillin resistant Staphylococcus aureus at admission to a teaching hospital. *Infect Control Hosp Epidemiol* 2006 ; 27 : 181-184.
18. **Forster AJ, Oake N, Roth V *et al*.** Patient-level factors associated with methicillin-resistant *Staphylococcus aureus* carriage at hospital admission : a systematic review. *Am J Infect Control* 2013 ; 41 : 214-220.
19. **Francois P, Pittet D, Bento M *et al*.** Rapid detection of methicillin-resistant *Staphylococcus aureus* directly from sterile or nonsterile clinical samples by a new molecular assay. *J Clin Microbiol* 2003 ; 41 : 254-260.

20. **Fuller C, Robotham J, Savage J *et al*.** The National One Week Prevalence Audit of Universal Methicillin-Resistant Staphylococcus aureus (MRSA). Admission screening. *PLoS ONE* 2012 ; 8 : e74219.
21. **Garey KW, Lai D, Dao-Tran TK, Gentry LO, Hwang LY, Davis BR.** Interrupted time series analysis of vancomycin compared to cefuroxime for surgical prophylaxis in patients undergoing cardiac surgery. *Antimicrob Agents Chemother* 2008 ; 52 : 446-451.
22. **Hacek DM, Robb WJ, Paule SM *et al*.** *Staphylococcus aureus* nasal decolonization in joint replacement surgery reduces infection. *Clin Orthop Relat Res* 2008 ; 466 : 1349-1355.
23. **Haessler S, Mackenzie T, Kirkland KB.** Long-term outcomes following infection with meticillin-resistant or meticillin-susceptible *Staphylococcus aureus*. *J Hosp Infect* 2008 ; 69 : 39-45.
24. **Harbarth S.** Control of endemic methicillin-resistant *Staphylococcus aureus* – recent advances and future challenges. *Clin Microbiol Infect* 2006 ; 12 : 1154-1162.
25. **Harbarth S, Fankhauser C, Schrenzel J *et al*.** Universal screening for methicillin-resistant *Staphylococcus aureus* at hospital admission and nosocomial infection in surgical patients. *JAMA* 2008 ; 299 : 1149-1157.
26. **Harbarth S, Masuet-Aumatell C, Schrenzel J *et al*.** Evaluation of rapid screening and pre-emptive contact isolation for detecting and controlling methicillin-resistant *Staphylococcus aureus* in critical care : an interventional cohort study. *Crit Care* 2006 ; 10 : 25.
27. **Huang SS, Septimus E, Kleinman K *et al*.** Targeted versus universal decolonization to prevent ICU infection. *N Engl J Med* 2013 ; 368 : 2255-2265.
28. **Jans B, Glupczynski Y, Denis O.** Institut scientifique de santé publique. Surveillance des bactéries résistantes aux antibiotiques dans les hôpitaux belges : rapport annuel. Epidémiologie 2013. http://www.nsih.be/download/MREA/AMR_2012/RAPPORT_ COMPLET_Y2012_FRV1.pdf
29. **Jernigan JA, Clemence MA, Stott GA *et al*.** Control of methicillin-resistant *Staphylococcus aureus* at a university hospital : one decade later. *Infect Control Hosp Epidemiol* 1995 ; 16 : 686-696.
30. **Jog S, Cunningham R, Cooper S *et al*.** Impact of preoperative screening for meticillin-resistant *Staphylococcus aureus* by real-time polymerase chain reaction in patients undergoing cardiac surgery. *J Hosp Infect* 2008 ; 69 : 124-130.
31. **Kalmeijer MD, van Nieuwland-Bollen E, Bogaers-Hofman D *et al*.** Nasal carriage of *Staphylococcus aureus* is a major risk factor for surgical-site infections in orthopedic surgery. *Infect Control Hosp Epidemiol*. 2000 ; 21 : 319-323.
32. **Kim DH, Spencer M, Davidson SM *et al*.** Institutional prescreening for detection and eradication of methicillin-resistant *Staphylococcus aureus* in patients undergoing elective orthopaedic surgery. *J Bone Joint Surg Am* 2010 ; 92 : 1820-1826.
33. **Lodise TP, McKinnon PS.** Clinical and economic impact of methicillin resistance in patients with *Staphylococcus aureus* bacteremia. *Diagn Microbiol Infect Dis* 2005 ; 52 : 113-122.
34. **Lora-Tamayo J, Murillo O, Iribarren JA *et al*.** A large multicenter study of methicillin-susceptible and methicillin-resistant *Staphylococcus aureus* prosthetic joint infections managed with implant retention. *Clin Infect Dis* 2013 ; 56 : 182-194.
35. **Lucet JC, Chevret S, Durand-Zaleski I, Chastang C, Regnier B.** Prevalence and risk factors for carriage of methicillin-resistant *Staphylococcus aureus* at admission to the intensive care unit : results of a multicenter study. *Arch Intern Med* 2003 ; 163 : 181-188.
36. **McKinnell JA, Miller LG, Eells SJ, Cui E, Huang SS.** A systematic literature review and meta-analysis of factors associated with methicillin-resistant *Staphylococcus aureus* colonization at time of hospital or intensive care unit admission. *Infect Control Hosp Epidemiol* 2013 ; 34 : 1077-1086.
37. **Melzer M, Eykyn SJ, Gransden WR *et al*.** Is methicillin-resistant *Staphylococcus aureus* more virulent than methicillin-susceptible *S. aureus* ? A comparative cohort study of British patients with nosocomial infection and bacteremia. *Clin Infect Dis* 2003 ; 37 : 1453-1460.
38. **Nixon M, Jackson B, Varghese P, Jenkins D, Taylor G.** Methicillin-resistant *Staphylococcus aureus* on orthopaedic wards : incidence, spread, mortality, cost and control. *J Bone Joint Surg Br* 2006 ; 88 : 812-817.
39. **ONS.** Deaths Involving MRSA, 2008/2012. England.
40. **Otter JA, French GL.** Community-associated methicillin-resistant Staphylococcus aureus : the cas for a genotypic definition. *J Hosp Infect* 2012 ; 81 : 143-148.
41. **Otter JA, French GL.** Molecular epidemiology of community associated methicillin-resistant Staphylococcus aureus in Europe. *Lancet Infect Dis* 2010 ; 10 : 227-239.
42. **Papia G, Louie M, Tralla A, Johnson C, Collins V, Simor AE.** Screening high-risk patients for methicillin-resistant *Staphylococcus aureus* on admission to the hospital : is it cost effective ? *Infect Control Hosp Epidemiol* 1999 ; 20 : 473-477.
43. **Peters PJ, Brooks JT, McAllister SK *et al*.** Methicillin-resistant *Staphylococcus aureus* colonization of the groin and risk for clinical infection among HIV-infected adults. *Emerg Infect Dis* 2013 ; 19 : 623-629.
44. **Pofahl WE, Goettler CE, Ramsey KM *et al*.** Active surveillance screening of MRSA and eradication of the carrier state decreases surgical-site infections caused by MRSA. *J Am Coll Surg* 2009 ; 208 : 981-986.
45. **Pratt RJ, Pellowe CM, Wilson JA *et al*.** National evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. *J Hosp Infect* 2007 ; 65 : 1-64.
46. **Public Health England.** MRSA bacteraemia : annual data. www.hpa.org.uk

47. Public Health England. Sixth report of the mandatory surveillance of surgical site infection in orthopaedic surgery, 2004/2010. London. December 2010. www.hpa.org.uk

48. Public Health England. Surveillance of surgical site infections in NHS hospitals in England, 2011/2012. London. December 2012. www.hpa.org.uk

49. Public Health Wales. Clostridium difficile and Staphylococcus aureus. Bacteraemia monthly update. www.wales.nhs.uk/sites3/page.cfm?orgid=379&pid=67899

50. Rao N, Cannella B, Crossett LS *et al*. A preoperative decolonization protocol for *Staphylococcus aureus* prevents orthopaedic infections. *Clin Orthop Relat Res* 2008 ; 466 : 1343-1348.

51. Richer SL, Wenig BL. The efficacy of preoperative screening and the treatment of methicillin-resistant *Staphylococcus aureus* in an otolaryngology surgical practice. *Otolaryngol Head Neck Surg* 2009 ; 140 : 29-32.

52. Roche SJ, Fitzgerald D, O'Rourke A, McCabe JP. Methicillin-resistant *Staphylococcus aureus* in an Irish orthopaedic centre : a five-year analysis. *J Bone Joint Surg Br* 2006 ; 88 : 807-811.

53. Sankar B, Hopgood P, Bell KM. The role of MRSA screening in joint-replacement surgery. *Int Orthop* 2005 ; 29 : 160-163.

54. Spelman D, Harrington G, Russo P, Wesselingh S. Clinical, microbiological, and economic benefit of a change in antibiotic prophylaxis for cardiac surgery. *Infect Control Hosp Epidemiol* 2002 ; 23 : 402-404.

55. Stegger M, Wirth T, Andersen PS *et al*. Origin and evolution of European community-acquired methicillin-resistant Staphylococcus aureus. *MBio* 2014 ; 5 : 1044.

56. Thyagarajan D, Sunderamoorthy D, Haridas S, Beck S, Praveen P, Johansen A. MRSA colonisation in patients admitted with hip fracture : implications for prevention of surgical site infection. *Acta Orthop Belg* 2009 ; 75 : 252-257.

57. Uçkay I, Teterycz D, Ferry T *et al*. Poor utility of MRSA screening to predict staphylococcal species in orthopaedic implant infections. *J Hosp Infect* 2009 ; 73 : 89-91.

58. Walley G, Orendi J, Bridgman S, Davis B, el Ahmed N, Maffulli N. Methicillin resistant *Staphylococcus aureus* (MRSA) is not always caught on the orthopaedic ward. *Acta Orthop Belg* 2009 ; 75 : 245-251.

59. Walsh EE, Greene L, Kirshner R. Sustained reduction in methicillin-resistant *Staphylococcus aureus* wound infections after cardiothoracic surgery. *Arch Intern Med* 2011 ; 171 : 68-73.

60. Zanetti G, Goldie SJ, Platt R. Clinical consequences and cost of limiting use of vancomycin for perioperative prophylaxis : example of coronary artery bypass surgery. *Emerging Infect Dis* 2001 ; 7 : 820-827.

61. Zetola N, Francis JS, Nuermberger EL *et al*. Community acquired meticillin-resistant Staphylococcus aureus : an emerging threat. *Lancet Infect Dis* 2005 ; 5 : 275-286.