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CURRENT KNOWLEDGE OF METHICILLIN-RESISTANT *STAPHYLOCOCCUS AUREUS* AND COMMUNITY-ASSOCIATED METHICILLIN-RESISTANT *STAPHYLOCOCCUS AUREUS*

Ivanka Matouskova, Vladimir Janout

Department of Preventive Medicine, Faculty of Medicine and Dentistry, Palacky University, Hnevotinska 3, 775 15 Olomouc, Czech Republic
e-mail: matouski@tunw.upol.cz

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Background: Bacterial strains that are oxacillin and methicillin-resistant, historically termed methicillin-resistant *Staphylococcus aureus* (MRSA) are resistant to all ß-lactam agents, including cephalosporins and carbapenems. MRSA are pathogenic and have a number of virulence factors that enable them to result in disease. They are transmissible and important causes of nosocomial infections worldwide. An MRSA outbreak can occur when one strain is transmitted to other patients or through close contacts of infected persons in the community. Hospital-associated MRSA (HA-MRSA) isolates are also frequent causes of healthcare-associated bloodstream and catheter-related infections. Community-associated MRSA (CA-MRSA) isolates are often only resistant to beta-lactam agents and erythromycin but they are an emerging cause of community-associated infections, ecpecially skin and soft tissue infections (SSTI) and necrotizing pneumonia.

Methods: Current possibilities for detecting MRSA strains in the laboratory are reviewed and discussed in the context of the recent literature.

Results and Conclusion: The active surveillance and prevention of MRSA occurence and spreading in hospitals are discussed in the context of recent literature.

Staphylococcus aureus

Staphylococci are very widespread bacteria. Their main representative, *Staphylococcus aureus* subsp. *aureus,* is one of the most important and successful human pathogens. According to current knowledge, the *Staphylococcus* genus has 50 taxons with 39 various types and several subtypes[1].

Staphylococcus aureus (*S. aureus*) is among the most ubiquitous of bacteria. It is highly resistant to adverse environmental conditions and it resists drying as well as high NaCl concentrations. This enables a probably temporary and even permanent colonization of skin and nasal mucosa.

S. aureus has been detected as a carrier strain in the nasal mucosa of the general population with a mean carriage rate of 37.2 %. However, the range of carriage rates is large. This may be due partly to differences in the quality of the sampling and of the culture techniques used in these studies[2]. Two billion individuals are estimated to be carrying *S. aureus,* worldwide. Persons colonized with *S. aureus* are at increased risk for subsequent infections[3]. Probably 1 % of these are MRSA colonised[4, 5]. *S. aureus* is also present in the skin and mucosae of various animals, and it is also found in the environment, especially around people, animals, and in food.

The *S. aureus* strains produce a number of extracellular enzymes (coagulase, hyaluronidase [spreading factor], penicillinase etc.) and toxins (haemolysins, staphylococcal super antigens and leukocidins), which function as virulence factors[6]. Among leukocidins, the Panton-Valentin leukocidin is currently the focus of considerable attention in connection with community-associated strains resistant to methicillin (CA-MRSA) which produce it. The Panton-Valentin leukocidin was described in 1932 and bears the name of its discoverers – Panton and Valentin[7]. In the literature the abbreviations PVL and Luk-PV are also used. In this case, a cytotoxin forms heptameric pores in the leukocyte membrane and this destroys the leukocyte. PVL consists of two components that are, depending on their relative speed during the chromatographic division, identified as fast (F) and slow (S)[8]. PVL increases the virulence of *S. aureus*. PVL-carrying strains can cause recurrent, chronic and particularly severe skin and soft-tissue infections as well as rapidly fatal pneumonia which occur notably in previously healthy, immunocompetent individuals[9]. However, its role as a virulence determinant has recently been disputed[10]. These MRSA strains are called community-associated MRSA (CA-MRSA). PVL production is a common trait among CA-MRSA, it is importatnt to recognise that PVL-negative strains can also occur[11]. Zhang with his colleagues state: ”the specific role that PVL plays in the epidemiological features and pathogenesis of CA-MRSA infections has remained undefined and controversial”[12].

When the host is weakened, a spectrum of diseases can occur, from minor skin inflammations (furuncles, impetigo), alimentary poisoning, osteomyelitis, toxic shock syndrome (TSS), staphylococcal scalded skin syndrome (SSSS) and bacterial endocarditis to life-threatening sepsis and pneumonia[13]. *S. aureus* is one of the major causes of human infections which originate both in connection with staying in a hospital or outside of it. According to the authors Boyle-Vavra and Daum, *S. aureus* is the most virulent of the *Staphylococcus* genus, representing the most frequent pathogen in biological material isolated from in-patients, and in out-patients it is the second most frequent isolated pathogen[14].

Era of antibiotics

The high mortality rate connected to the *S. aureus* strain decreased only in the forties of the last century after the first antibiotic – penicillin – was introduced into staphylococcal infection treatment. Sir Alexander Fleming could not have foreseen that his discovery of penicillin would also trigger global problems: resistant and multidrug resistant bacterial strains emerged at this moment. Towards the end of 1940, hospitals in England and the USA reported that up to 50 % of *S. aureus* strains registered penicillin resistance[15]. Clinical trials have demonstrated the resistance which is caused by the penicillinase enzyme (ß-lactamase)[16, 17].

It was phage typing, a brand new method that enabled identification of the *S. aureus* strain that was infectious, penicillin-resistant, and extremely invasive. The strain was first described in Australia and subsequently it spread fast to America (epidemics in maternity units) and to hospitals in the UK. The strain was termed the 80/81 strain, according to its bacteriophage[18]. Decrease in the occurrence of this strain took place in the sixties when methicillin, the first semisynthetic penicillinase-fast penicillin was introduced. The staphylococci needed a mere six months to create methicillin-resistant strains. In 1960, a screening of 5000 clinical isolates identified 3 *S. aures* strains resistant to methicillin. All three of them had the same phenotype and came from the same hospital in the South of England[19]. In the medical literature there emerged an abbreviation – MRSA (methicillin-resistant *Staphylococcus aureus*) while in the English literature, the term HA-MRSA (healthcare-associated methicillin-resistant *Staphylococcus aureus*) is used.

From that time MRSA was considered to be the most important agent of hospital infections, both in adult and child patients[20].

In the second half of the sixties, MRSA strains developed that were resistant to other antibiotics and the occurrence of multidrug-resistant MRSA was reported from several Central European countries, England, Australia and India. In 1971 in Denmark, MRSA strains with a combined resistance to penicillin, streptomycin, tetracycline and occasionally to erythromycin represented 15 % of all isolated *S. aureus* strains. During the seventies and at the beginning of the eighties a decrease in these strains was registered (Denmark reported only 0.2 % of MRSA strains). The cause was not entirely clear but probably the change of prescribing streptomycin and tetracycline, and the introduction of strict preventive measures against spreading this infectious agent played a significant role[21].

In 1993 England and Wales registered only 47 deaths connected to the MRSA strains but in 1995 there were 377 deaths[22].

At the beginning of the eighties a gentamicin-resistant MRSA strain was reported. The findings were confirmed by two European countries (England and Ireland) and also by the USA. One health-care worker was believed to have imported the multidrug-resistant MRSA strain to England from Australia[23].

Vancomycin was first approved by the Food and Drug Administration in 1958, and resistance first emerged in coagulase-negative staphylococci in 1987 (ref.[24]). In 1996, the first clinical isolate of *S. aureus* with reduced susceptibility to vancomycin was identified in Japan (vancomycin-intermediate *S. aureus* = VISA)[25]. In July 1997 the Center for Disease Control and Prevention (CDC) issued an interim recommendation regarding prevention and control of these strains[26]. In June 2002, a strain of *S. aureus* fully resistant to vancomycin (vancomycin-resistance *S. aureus* = VRSA) was isolated from a patient in Michigan[27]. Conjugate transfer for the *vanA* gene from enterococci to *S. aureus* had previously been demonstrated in vitro[28]. Among enterococci, four phenotypes of glycopeptide resistance have been reported in the literature: *vanA* phenotype with high-level resistance to vancomycin and teicoplanin, *vanB* phenotype with resistance to vancomycin only, *vanC* phenotype and a "*vanC*-like" phenotype[29].

The above overview of the *S. aureus* strains' resistance to antibiotics, concerns so-called hospital-associated strains which have a major share in developing hospital infections.

Genetics and the development of antibiotic resistance

Resistance to methicillin and other ß-lactam antibiotics is caused by the *mecA* gene, which is situated on the Staphylococcal Cassette Chromosome *mec* (SCC*mec*)[30]. The *mecA* gene encodes the 78-kDa penicillin-binding protein (PBP) 2a or PBP2' (ref.[31]). To date, five SCC*mec* types (I–V) have been distinguished, and several variants of these SCC*mec* types have been described. All SCC*mec* elements carry genes for resistance to ß-lactam antibiotics, as well as genes for the regulation of the expression of *mecA*. Additionally, SCC*mec* types II and III carry non-ß-lactam antibiotic resistance genes on integrated plasmids and a transposon. The history of MRSA[32]. (Table 1)

The epidemiology of MRSA strains makes use of, for their description, pulsed-field gel electrophoresis (PFGE), multilocus sequence typing (MLST), SCC*mec* typing (four methods are currently available for the characterisation) and typing of the variable tandem repeat region of protein A (spa Tyliny)[33]. Using these methods the prevalence of MRSA has been found to range from 0.6 % in The Netherlands to 66.8 % in Japan[32].

Table 1. The history of MRSA

SCC*mec*	Date and state of an isolate
I	1961 UK
II	1982 Japan (New York/Japan clone)
III	1985 New Zealand
IV	spread round the world during the 1990s
V	at the beginning of the 21st century in Australia

"Two opposing theories have been suggested to describe the relationship between the first MRSA isolates and recent MRSA clones: The single-clone theory suggests that all MRSA clones have a common ancestor, and that SCC*mec* was introduced only once into *S. aureus*. The multi-clone theory hypothesis presumes that the SCC*mec* was introduced several times into different *S. aureus* genetic lineages. The latter theory has now been supported by several studies"[32].

Community-associated MRSA

The year 1993 marked the rise of a new clone of MRSA strains. These are called community-associated MRSA strains (CA-MRSA). They were isolated from indigenous Australian patients, original inhabitants of West Australia, who had no previous contact with a health-care system[34]. In the course of the last decade, information has emerged about the spread and isolation of these strains from different countries to almost all the continents of the world, in patients with no risk factor for nosocomial acquisition of MRSA. Community-associated MRSA (CA-MRSA) infections most commonly are skin and soft-tissue infections (SSTI); however, certain cases can progress to invasive tissue infections, bacteremia, and death[35-55].

In three Czech strains of *S. aureus*, the presence of *lukS-PV* a *lukF-PV* genes were determined by the National Reference Laboratory in the year 2004 and found to belong to CA-MRSA[56]. Antimicrobial resistance tests and selected methods of molecular biology demonstrated that their characteristics differ from the multi-drug resistant HA-MRSA strains described in hospital patients[14, 39, 57-70]. The main characteristics of HA-MRSA and CA-MRSA strains are specified. (Table 2)

Skin soft-tissue infections caused by the CA-MRSA strains have been described mainly in young people and children, athletes, prisoners, and army recruits[41, 71-73].

There have also been cases of infection caused by CA-MRSA strains acquired in connection with staying in hospital[52]. In 2007 a paper was published reporting that with the help of retrospective investigation of *S. aureus* strain isolates from 1991-2003, there were identified MRSA strains with a CA-MRSA pattern at a child clinic already in 1991[20].

Criteria for a probable infection caused by the community-associated MRSA (CA-MRSA)[74].

- Diagnosis of MRSA was made in the outpatient setting or by a culture positive for MRSA within 48 hours after admission to the hospital
- No medical history of MRSA after admission to the hospital

Table 2. The main characteristics HA-MRSA and CA-MRSA strains

Characteristic	HA-MRSA	CA-MRSA
Clinical	surgical site infections, invasive	skin infections, "bug bites", rarely invasive, multiple, recurrent
Epidemiology	old, healthcare	young, athletes, drug users, correctional facilities and military
Antibiotic resistance	multi-drug resistant	β-lactam resistant
Molecular markers	PVL – SCC*mec* I-III	PVL + SCC*mec* IV, V

Table 3. Definitions used for epidemiologic classification of invasive methicillin-resistant *Staphylococcus aureus* (MRSA) infections

Classification	Definition
Health care-associated	
Community-onset	Cases with at least 1 of the following health care risk factors: 1) presence of an invasive device at time of admission, 2) history of MRSA infection or colonization, 3) history of surgery, hospitalization, dialysis, or residence in a long-term care facility in previous 12 months preceding culture date.
Hospital-onset	Cases with positive culture result from a normally sterile site obtained > 48 h after hospital admission. These cases might also have ≥ 1 of the community-onset risk factors.
Community-associated	Cases with no documented community-onset health care risk factor.

- No medical history of MRSA infection or colonization
- No medical history in the past year of:
  - Hospitalization
  - Admission to a nursing home, skilled nursing facility, or hospice
  - Dialysis
  - Surgery
- No permanent indwelling catheters or medical devices that pass through the skin into the body

In the majority of the published studies, there is missing a clinical and epidemiological classification of invasive infections induced by MRSA strains (HA-MRSA and CA-MRSA). The recent characteristics are shown in table 3[75].

"Health care-associated infections, in turn, have been classified as either community-onset (cases with a health care risk factor but with a culture obtained ≤ 48 hours after hospital admission) and hospital-onset (cases with a culture obtained > 48 hours after admission, regardless whether they also had other health care risk factors)" [75].

Laboratory diagnostics of Methicillin-Resistant *Staphylococcus aureus* (MRSA)

The National Committee for Clinical Laboratory Standards (NCCLS), now called the Clinical and Laboratory Standards Institute (CLSI), recommends the cefoxitin disk screen test, the latex agglutination test for PBP2a, or a plate containing 6 ug/ml of oxacillin in Müeller-Hinton agar supplemented with NaCl (4 % w/v; 0.68 mol/l) as alternative methods of testing for MRSA[76].

Accurate detection of oxacillin/methicillin resistance can be difficult, due to the presence of two subpopulations (one susceptible and the other resistant) that may coexist within a culture of staphylococci. All the cells in a culture may carry the genetic information for resistance, but only a small number may express the resistance in vitro. This phenomenon is termed heteroresistance. Cells expressing heteroresistance grow more slowly than the oxacillin-susceptible populations and may be missed at temperatures above 35 °C. For this reason, CLSI recommends incubating isolates being tested against oxacillin, methicillin, or nafcillin at 33-35 °C (maximum of 35 °C) for a full 24 hours before reading[76].

Nucleic acid amplification tests, such as the polymerase chain reaction (PCR), can be used to detect the *mecA* gene, which mediates oxacillin resistance in staphylococci. Staphylococcal resistance to oxacillin/methicillin occurs when an isolate carries an altered penicillin-binding protein, PBP2a, which is encoded by the *mecA* gene[31, 32].

The classic microbiological methods (microscopy, cultivation, biochemical identification) are procedures that enable identification of bacteria strains within 24-96 hours. They are not suitable for active surveillance of the MRSA strains spreading in hospitals or for rapid identification of serious bacteremia. Microbiologists strive to prepare kits for rapid and reliable identification of the MRSA strains in carriers, and for detecting the presence of these strains in infections. Not all laboratories however are equipped with recent molecular biological instruments and methods. For direct identification of MRSA strains, it is recommended that these clinical microbiology laboratories use chromogenic selective media and subsequent confirmation tests of the MRSA strains (agglutination tests for testing for PBP2a), or a plate containing 6 ug/ml of oxacillin[77]. The following are the most frequent and laboratory verified chromogenic media.

MRSA*SELECT* – a selective chromogenic medium designed for isolation and direct identification of the methicillin-resistant *Staphylococcus aureus* strain (MRSA). Pink colonies grow within 18-24 hours and all the other microorganisms are inhibited. The test specificity is 99.8 % and its sensitivity is 98.9 % (ref.[77]). Studies in which researchers compared the sensitivity and specificity of a number of types of chromogenic cultivation media for isolating the MRSA strains have confirmed the data by the producer of the above mentioned media[78-81]. A Dutch author van Loo and his colleagues stress the fact that in connection with a prolonged incubation (from 20 to 48 hours) there is an increase in false-positive (pink) colonies[79]. Also the work by Swiss authors considers the **MRSA*SELECT*** medium more sensitive than the media containing oxacillin designed for screening. I believe their comment is important and therefore I am citing them: „However, their respective performances under real conditions of utilization are heterogeneous, underlining the absence of gold standard medium for MRSA screening"[80].

Oxacillin Resistance Screening Agar Base (ORSAB) is intended as a medium for the screening for methicillin resistant *Staphylococcus aureus* (MRSA) directly from routine swab samples. The screening of patients and staff for the early detection of MRSA colonisation is essential if epidemics are to be prevented. ORSAB is a novel medium which uses aniline blue to detect mannitol fermentation creating intense blue colonies of presumptive MRSA[82, 83]. Using this cultivation medium, after 24 hrs (48 hrs) Apfalter et al found a sensitivity of 51 % (68 %) and a specificity of 96 % (95 %). Within the context of the detected values they draw attention to the existence of mannitol-negative *S. aureus* strains and mannitol-positive methicillin-resistant coagulase-negative staphylococci[84].

ChromID MRSA is a new chromogenic medium for the rapid and reliable screening of methicillin-resistant *Staphylococcus aureus* (MRSA). Direct identification of MRSA strains is based on spontaneous green coloration of alpha-glycosidase-producing colonies (patent pending) and the presence of an antibiotic, cefoxitin. Immediate identification of MRSA = green colonies is possible after 18-24 hours of incubation[85]. This chromogenic medium was also assessed as the best by both English and Belgian authors compared to the others in use (including even the ORSAB medium)[86, 87]. Compernolle and his colleagues recommend using the Gram–stain and direct Pastorex Staph as well plus the latex agglutination test for positive colonies[87].

Microbes, especially MRSA strains are now a global problem linked to high mortality, morbidity and high hospital costs. Methods for rapid identification of MRSA

strains are needed for targeted control of admitted patients, staff and environment so that these strains are not transmitted from patient to patient, especially through indirect transmission caused by the unwashed hands of health-care workers.

At present, a number of methods are described that use molecular biology findings for rapid detection of the MRSA strains. Most of these are based on the PCR multiplex for detecting genes that identify the *S. aureus* strains (*nuc* gene and *mecA* gene). The *nuc* gene that encodes the thermostable nuclease of *S. aureus*. Thermostable nuclease is a protein with a molecular mass of 17, 000 Da (ref.[88]). MRSA originates from the introduction of a large mobile genetic element – Staphylococcal Cassette Chromosome *mec* (SCC*mec*) into a methicillin-susceptible *S. aureus* strain. These methods can be used only with clear staphylococci colonies but not for direct examination of e.g. nose swabs. Here false-positive results can be obtained because there are coagulase-negative staphylococci strains that carry the *mecA* gen. For maximum shortening of the time needed for examining the MRSA strains it is necessary to have kits available that will enable an analysis: 1/ directly from the executed swabs. This predominantly concerns detecting the MRSA strain carriers when admitted to high-risk departments (cardio surgery, vascular surgery, burn centres etc.) and 2/ of positive blood cultures in the Bactec system from patients suffering from bacteremia. Recently published studies deal with comparing the "IDI-MRSA real-time PCR assay" (Infectio Diagnostic, Sainte-Foy, Canada) kit with other procedures already in use. The studies' results show it to be the most sensitive kit for locating the MRSA strains in nose swabs (sensitivity of 92 %) when compared to other methods. The processing time is 2-4 hours in comparison to 3 days needed for chromogenic cultivation methods[89-93]. The StaphSR assay (BD GeneOhm, San Diego, CA) is a multiplex real-time PCR assay, for the identification and differentiation of methicillin-susceptible *S. aureus* (MSSA) and methicillin-resistant *S. aureus* (MRSA) from positive blood cultures[94]. MRSA bacteremia is associated with significantly higher mortality than MSSA bacteremia[95, 96].

Prevention of the MRSA occurrence and its spreading

Patient screening

According to Girou et al., colonized and infectious patients are the most important reservoir of MRSA in hospitals[97]. Šrámová draws attention to the fact that the border between colonization and infection is often unclear and must be determined by the attending physician[98]. When MRSA is detected in patients' palms, the possibility of MRSA contamination of their surrounding environmental surfaces is high[99]. Occurrence of MRSA colonized patients depends on the type of the department. In long-term care the colonization is much higher[100, 101]. In a spinal unit it reaches 40-50 % (ref.[102]). The literature reports that 35-84 % of MRSA colonized patients fail to be identified by swabs that are ordered by doctors for clinical reasons[97, 100, 101]. It is recommended that swabs mainly of the anterior nares are taken – this screening should detect up to 80 % of the MRSA carriers, and other swabs from additional body sites will increase the sensitivity to over 92 % (ref.[2, 97, 102]). MRSA carriers without any obvious infection are considered a serious reservoir of MRSA and it is assumed this infectious agent could be transmitted to other patients or health-care workers[103]. Studies that have found the prevalence of MRSA colonizing nasal mucosae report that this usually concerns people over 60 with no prior contact with a health centre. Nasal carriage of *S. aureus* and MRSA has been identified as a risk factor for the development of infections in various settings. This has been studied extensively in surgical patients, and in patients undergoing hemodialysis[2, 104-107]. Human innate immune factors are crucial in nasal colonization by *S. aureus*[108]. Cookson draws attention to different and often contradictory data on the carrying duration, risk factors connected to it, and even carrying associated with HLA[36]. It is recommended that selected hospital departments do a screening (a nasal swab) to detect MRSA prior to admitting a patient. This concerns mainly intensive care units, patients who are being prepared for vascular and cardio surgical operations, hemodialysis patients, and elderly patients[104-107]. However, the effectiveness of the "screening" cultivations for reducing the risk of transferring MRSA has not been proven in a randomized trial[109]. It is assumed that screening of admitted patients and of the exposed health-care workers contributes to the very low long-term prevalence of MRSA (1-3 %) occurrence in Dutch and Scandinavian hospitals[110-113]. Microbiologists from the South East England (long-term high prevalence of MRSA strains occurrence in hospitals) in their cohort study confirmed the need of a rapid detection of MRSA in patients in order to be able to significantly reduce the occurence and prevent its spread. The PCR method was launched into routine practice as an obligatory screening in adult patients that are being admitted to a surgical intensive care unit[93, 114-116]. It is probably a question of time before the screening for the MRSA strains presence will become mandatory – given that transfer of a plasmid coding for resistance to antiseptics has been recorded[117, 118].

Screening of health-care workers

As published in the literature, nasal MRSA carriers among the health-care workers can be MRSA sources (transfer and spreading) but they are not considered as important a reservoir as the colonized or infectious patients. The nasal carrying in the health-care workers can be temporary. However, there is a risk of MRSA transfer to a patient, especially in hospitals where endemic strains of MRSA occur[2, 102, 105]. Different countries follow different recommendations: e.g. a short-term local application of antibiotics or strict observation of using personal protective equipment (mask, gloves, hand washing and hand disinfection). The health-care worker who comes into contact with colonized or infectious patients should regularly undergo screening for the MRSA strain presence[119-121].

Decolonization therapy

Because *S. aureus* colonization is thought to lead to subsequent infection, decolonization is a potential

strategy used for prevention. However, the effectiveness of CA-MRSA decolonization is unclear[122].

There is no unambiguous opinion on bathing patients with disinfection preparations or local application of antibiotics (2% mupirocin) in case of nasal carriage of MRSA[123, 124]. An additional concern with routine use of mupirocin for nasal decolonization is the level of mupirocin resistance that has been observed with usage in MRSA endemic areas[125]. The plasmid-encoding mupirocin resistance has been found in the genome of the CA-MRSA strain, USA 300 (ref.[126]). We conclude that selective use of intranasal mupirocin and daily chlorhexidine bathing for patients with MRSA reduced the incidence of MRSA colonization and infection and contributed to reduction identified by active-surveillance cultures[127]. Wendt and his colleagues performed a double-blind, placebo-controlled clinical trial to compare the efficacy of whole-body washing with chlorhexidine combined with treatment with oral chlorhexidine rinse and nasal mupirocin with the efficacy of nasal mupirocin and oral chlorhexidine rinse alone. And conclusion: whole-body washing can reduce skin colonization, but it appears necessary to extend eradication measures to the gastrointestinal tract, wounds, and/or other colonized body sites if complete eradication is the goal[128].

Isolation rooms and a barrier procedure

If the hospital does not have special isolation rooms with a three-level air filtration system and prescribed pressure parameters[129] then a single room is recommended, or it is possible to place several MRSA infected or colonized patients to one room – called a cohort[117, 130]. The abovementioned ways of hospitalizing risky patients should be accompanied with so called hygienic sluice (the designated staff changes into apparel earmarked only for treating MRSA patients. The health-care workers should always use disposable gloves when dealing with a risk patient. No agreement has been reached in the literature as to whether health-care workers should use masks or not[117, 131, 132].

The arrangement and technical equipment of isolation rooms and hygienic sluices are described in the literature[133]. The Czech Republic handles the prevention and origin of hospital infections under Regulation 195/2005 Coll. currently in force[134].

Hand Washing and Hand Disinfection

The risk of transferring MRSA strains is connected to temporary (transient) microflora. The amount and level of microbial types in the transient microflora of contaminated hands reflects the microbial load of the environment and the character of the executed work[97]. Contaminated hands are considered the most frequent way of transferring MRSA strains from health-care workers to patients. All prevention of transfer and spread the MRSA strains closely depends on using disposable gloves when treating MRSA infected patients. Hands are to be washed and disinfected prior to using the gloves and also after the attendance is over. The disposable gloves are to be disposed of. After washing, disinfecting liquid soap is recommended. For hand disinfection the most suitable preparations are the alcohol-based ones[135-139]. Christiaens et al. state that the level of transferring MRSA strains when using disinfection alcohol-based preparations decreased from 11.04 to 7.07 cases for every 1000 admitted patients[136]. Gordin and his colleagues report similar findings – they found an HA-MRSA strain decrease by 21 % after a three-year usage of alcohol-based preparations for hand disinfection[139, 140].

Resistance to quaternary ammonium compounds (QAC) in staphylococci is common in hospital environments and has been described in the food industry, too. Resistance to quaternary ammonium–type antiseptic compounds, mediated by the *S. aureus* plasmid Psk1 is specified by an energy-dependent export mechanism encoded by the *qacA* gene. The *qacB* gene characteristically differs from *qacA* by conferring lower or no resistance to divalent organic cations[141, 142]. The transfer of a plasmid coding for resistance to antiseptics has been confirmed. The *qacA* and *qacB* genes situated on the MRSA strain plasmid are responsible for antiseptics- resistance, and they are spread worldwide[143, 144]. Attention is also drawn to the fact that the sensitivity of the MRSA strains to selected used biocides (e.g. chlorhexidine digluconate) has decreased. MRSA strains survive under lower concentrations than the stated minimum bactericidal concentration (MBC). Some authors stress the necessity to revise the used concentrations of some biocides owing to the fact that tests in vitro had been performed with clinical isolates of the MRSA strains[144]. An increase tolerance of the MRSA strains to chlorhexidine gluconate has been demonstrated as well[145]. In 2005 Australian researchers published the results of a time-restricted study (12 months) when in a university hospital with 840 beds and a high level of hospital infections induced by MRSA strains hand disinfection was introduced. It was a mix made according to the recipe of the authors Pitter et al. (70% of isopropyl alcohol, 0.5% of chlorhexidine, skin emollient)[146]. A 40% reduction of isolated MRSA strains from the clinical material and a 57% reduction of bacteraemia – when the HA-MRSA strain was the agent – were detected[102].

The hand washing and disinfection methods currently used in the Czech Republic are described[147]. Test method and requirements for chemical disinfection preparations and antiseptics are specified in the ČSN EN[148, 149].

A combination of earlier detection of MRSA, isolation with selective patient decolonization, compliance with best professional practice, such as with hand hygiene and antibiotic stewardship, will reduce MRSA colonization and infection in the ICU, and given the severity of illness in such a group of patients. However, all these measures must be combined with adequate numbers of staff and suitable space and facilities[150]. Basic principles are essential for all hospitals.

Cleaning and decontamination of the environment and the equipment

The method and intensity of cleaning and decontamination of the environment predominantly depends on the

type of department and on observing all the recommended procedures and on using personal protective equipment. The percentage of contaminated surfaces is reported to be between 64-74 %. The most frequently contaminated objects used by the patients include hospital beds and mattresses, bedding (bed sheets), grab bars along the walls, door handles, and taps[136-143]. When changing the bed sheets not only objects of a certain size but also infectious agent (MRSA) are released into the inner environment. The highest number was detected 15 minutes after this activity was executed. This shows that the MRSA strains circulate even in the inner environment[151-154]. As to various devices, keyboards are always stated as first[157], as to the medical equipment it is mainly the sleeves on the blood pressure gauges and tourniquets used for taking blood[140]. Contamination of stethoscope membranes by MRSA strains, and possibilities of subsequent patient-to-patient transmission are also treated. The percentages of positive findings vary. We believe that the results depend on the type of department (a cardio surgery intensive care unit, general practitioners, paediatric outpatient department) where the research was conducted. The information that the stethoscope membrane could be contaminated with MRSA must clearly lead to realizing that its regular disinfection is vital[155-160]. There is also a close link to the infection type. In case of respiratory infections the inner air becomes MRSA contaminated and subsequently also the surfaces[148, 149]. For decontamination and a significant decrease of the MRSA strains occurrence on the working surfaces in nurses' rooms the authors recommend using rags impregnated with 80% ethyl alcohol[161].

Each country follows its own recommendations[121, 162, 163], which in most cases ensue from the amended recommendations of CDC in Atlanta[119]. In the Czech Republic, in connection with the increase in MRSA strain prevalence in hospitals a recommendation has been drafted by a group of prominent experts. This contains a method for decontaminating the environment as well[121].

Apart from antibiotics resistance, there can also be resistance to disinfection preparations[143, 144]. Even in 2000 Jana Kneiflová et al described a *S. aureus* strain highly resistant to chlorine. The strain was found in the water of a swimming pool[164].

In connection with a complete sequence of the MRSA strain genome (Mu50) a genus *qacA* was identified on the genome of the strain's plasmid. This causes resistance to biocides based on quarternary ammonium compounds[165]. In the literature, attention has been drawn to the increased tolerance and resistance of the MRSA strains to biocides containing this effective component[145].

The current situation in the Czech Republic

The European Antimicrobial Resistance Surveillance System (EARSS), funded by the European Centre for Disease Prevention and Control of the European Commision is an international network of national surveillance systems. In the Czech Republic, antimicrobial resistance surveillance in invasive *Staphylococcus aureus* isolates within EARSS was started in July 2000. Analysis of blood isolates strains *S. aureus* collected in 2000-2005 showed increase in oxacillin resistance. Over the period , the MRSA incidence tripled from 3.8 % to 12.5 %. These organisms spread rapidly in hospitals[166, 167].

In conclusion

"Methicillin-resistant *Staphylococcus aureus* (MRSA) is an important cause of nosocomial infection worldwide. Interpretation of community MRSA trends is problematical, in that the term is ill-defined, and related data are difficult to put into context. There are four relevant battlefronts, all of interest to risk assessment and prevention. These are: an increasing pool of patients with MRSA discharged from hospitals into the community; MRSA spreading to patients in nursing and residential homes; and MRSA spreading from patients and health-care workers to others in community. There are often difficulties in determing whether the fourth issue, MRSA arising apparently de novo in the community, is in fact due to one of these other fronts. All these battlefronts are important and not yet lost. However, we must agree on definitions and design-appropriate surveillance strategies, so that we can best plan prevention and control activities to contain these emerged or emerging problems"[36].

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