Distribution of staphylococcal cassette chromosome mec types among methicillin-resistant coagulase negative staphylococci in central Iran

Ehsanollah Ghaznavi-Rad1,2*, Nasimeh Fard-Mousavi1, Ali Shahsavari1, Ali Japoni-Nejad1, Alex Van Belkum3,4

1Molecular and Medicine Research Center, Arak University of Medical Sciences, Arak, Iran
2Department of Microbiology and Immunology, School of Medicine, Arak University of Medical Sciences, Arak, Iran
3Scientific Office, BioMérieux, Route de Port Michaud, La Balme Les Grottes 38390, France
4Erasmus MC, Department of Medical Microbiology and Infectious Diseases, ’s Gravendijkwal 230, 3015 CE Rotterdam, The Netherlands

Received: December 2016, Accepted: August 2017

ABSTRACT

Background and Objectives: Methicillin-resistant coagulase-negative staphylococci (MR-CoNS) are important nosocomial pathogens. They may serve as a reservoir of SCCmec, the genomic island encoding amongst other methicillin resistance. This study was designed to determine the distribution of different SCCmec types from MR-CoNS isolated from clinical specimens in a tertiary hospital in central Iran, having high frequency of nosocomial methicillin-resistant staphylococcal infections.

Materials and Methods: We evaluated isolates from patients attending the Vali-Asr Hospital located in the center of Iran, from February to December 2012. Multiplex PCR was performed for SCCmec typing. For isolates in which SCCmec could not be typed directly, additional ccr and mec complex analyses were performed.

Results: Totally, 70 MR-CoNS isolates, comprising of 47 S. epidermidis strains (67%), 10 S. saprophyticus (14.3%), 9 S. hemolyticus (13%) and 4 S. lugdunensis (5.7%) were identified. Thirty-nine were characterized as type IVa 19 (27%), type III 11 (16%), type II 7 (10%) and type V 2 (3%). Only 20 isolates (28.6%) carried the ccr complex, while the current methods could not characterize the 11 remaining isolates.

Conclusion: A high level of SCCmec genetic diversity was found among MR-CoNS isolates. MR-CoNS may act as a reservoir of SCCmec IV for MRSA. This issue should be taken into consideration seriously.

Keywords: Coagulase negative staphylococci, Methicillin resistance, SCCmec typing

INTRODUCTION

Coagulase-negative staphylococci (CoNS) are part of the human normal flora and are considered human opportunistic pathogens, commonly associated with severe infections such as bacteremia and septicemia, particularly in patients with indwelling devices or immunocompromised patients (1). CoNS comprise
of a variety of Staphylococcus spp and are usually resistant to most β-lactams antibiotics including methicillin (2). Methicillin resistance is mainly due to the expression of the mecA gene, which specifies a penicillin binding protein 2a (PBP2a), a transpeptidase with a low affinity for β-lactams. mecA is part of SCCmec which often integrates at the 3’ end of a chromosomal open reading frame designated as orfX.

Generally, SCCmec contains two essential components, the mec gene complex and the ccr gene complex. The mec gene complex composed of mecA regulatory genes and it has been classified into six different classes: A, B, C1, C2, D and E. Cassette chromosome recombinase (ccr) genes (ccrC or the pair of ccrA1 and ccrB) encode recombinases-mediating integration and excision of SCCmec into and from the chromosome.

To date, 11 different types of SCCmec (I–XI) have been defined on the basis of the combination of ccr and mec complexes, but only type I–V are globally distributed, whilst others appear to exist as local strains in the country of origin (http://www.sccmec.org/Pages/SCC_TypesEN.html) (3).

The origin of SCCmec is still unknown. However, it is proposed that it was acquired by Staphylococcus aureus from S. sciuri or other mecA positive CoNS, especially S. epidermidis, which could be a potential reservoir for the SCCmec element, although the mechanism of inter-species transfer remains unknown.

Currently, in our hospital the incidence rate of methicillin-resistant S. aureus (MRSA) has increased to more than 80% in clinical isolates and the prevalence of methicillin resistant (MR) CoNS is also rising (4). The efficient management of MRSA infection in every hospital relies on a correct diagnosis, as well as understanding the antimicrobial resistance profile, epidemiology, transmission routes, appropriate therapeutics and appropriate infection control measurements. In Iran, the SCCmec types have been extensively studied in S. aureus, but little is known about MR-CoNS. Therefore, this study was designed to investigate the SCCmec element in CoNS isolated from clinical specimens of hospitalized patients in central Iran.

MATERIALS AND METHODS

A total of 102 CoNS clinical isolates (December 2013 to July 2014), recovered in Vali-Asr hospital (Arak University of Medical Sciences) were subjected to this cross-sectional study.

Isolated strains were identified using conventional methods (growth on mannitol salt agar, colony morphology), Gram stain, catalase-coagulase, DNase tests, acid production from mannose, xylose, maltose, sucrose, and urease test. All the samples were checked for methicillin susceptibility by cefoxitin disk.

All the confirmed isolates were subjected to a DNA genomic extraction procedure using a commercial DNA extraction kit (Bio flux bioer, Korea) according to the manufacturer’s instruction. The presence of the mecA gene was confirmed in all the cefoxitin-resistant isolates, using primers published elsewhere (5).

SCCmec typing was performed using a multiplex PCR assay that was published previously (6). The isolates, identified by this methodology were subjected to PCR amplification of the ccr and mec complex. ccrA1, ccrA2, ccrA3 and ccrC primers were used to determine the ccr class of SCCmec (6). The following mecA1, IS1272 and mecC primers were used to determine the class A, B or C of mec complex (6, 7).

Reference strains. The following strains were used as references: SCCmec type I (NCTC 10442); type II (N315); type III (85/2082); type IVa (JCSC 4744); type IVb (JCSC 2172); type IVc (JCSC 4788); type IVd (JCSC 4469); and type V (WIS).

RESULTS

Of the 102 isolates, 70 (68.6%) MR-CoNS belonging to four different species were identified, according to standard methods. The species distribution was as follows: S. epidermidis 47 (67%), S. saprophyticus 10 (14.3%), S. hemolyticus 9 (13%) and S. lugdunensis 4 (5.7%). These isolates were collected from different clinical specimens, including blood (n=36, 51.5%), wound (n=10, 14.3%), urine (n=17, 24%), catheter tips (n=2, 3%), drainage fluids (n=2, 3%) and sputum (n=3, 4.2%) (Table 1).

All of the 70 MR-CoNS isolates contained mecA gene, as detected by PCR. SCCmec types were assigned for 39 of 70 (56%) isolates by multiplex PCR. Among these 39 isolates, different SCCmec types were found containing type IVa (n=19, 27%), type III
(n=11, 16%), type II (n=7, 10%) and type V (n=2, 3%). The remaining 31 isolates, in which SCCmec types could not be determined by multiplex PCR, were subjected to single-plex PCR assays for determination of ccr and mec complex. Of the 31 isolates, 20 were positive for ccrA2B2 genetic element, while six of these isolates were carrying ccrA3B3, simultaneously. However, a further investigation through PCR assay for the determination of mec complex class was not successful in these isolates; therefore, despite repeated attempts mec complex genes could not be obtained from the remaining 11 isolates. The remaining 11 (15.7%) isolates were not typed by any of the mentioned methods (Table 2).

**DISCUSSION**

In this study, the distribution of SCCmec types in MR-CoNS isolated from clinical specimens in a central teaching hospital in the center of Iran was evaluated. Targeting ccr and the mec gene complex through the application of different typing methods determined the SCCmec types in 59 of 70 isolates (6, 8).

The frequency of methicillin resistance among coagulase negative staphylococci was found to be 68.6%. This frequency rate is increasing and has reached 70%-80% in central Europe and other geographical regions since the introduction of methicillin (9, 10). For instance, the overall frequency of methicillin resistance among coagulase negative staphylococci in our neighboring country, Turkey was 83.3% (11). Methicillin-resistant *S. epidermidis* is the predominant skin flora of hospitalized patients, and colonizing methicillin-resistant *S. epidermidis* can persist on the skin for months after discharge (12). Our result is consistent with the results of other studies in the literature. However, because we have not checked the patients upon admission, we are not sure whether these isolates are acquired in the hospital or from the community. Therefore, community diffusion and silent in-hospital influx of methicillin-resistant *S. epidermidis* -SCCmec IV may reflect a widely accessible reservoir of methicillin resistance for *S. aureus* in hospitals and the community (10).

Regarding SCCmec type distribution, our MR-CoNS isolates were found to be diverse. Up to four different types were found and 20 (28.6%) isolates only carried

**Table 1. Frequency of the coagulase-negative Staphylococci isolated from different clinical specimens**

<table>
<thead>
<tr>
<th>Species</th>
<th>S. epidermidis</th>
<th>S. saprophyticus</th>
<th>S. hemolyticus</th>
<th>S. lugdunensis</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specimen</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood</td>
<td>30</td>
<td>-</td>
<td>4</td>
<td>2</td>
<td>36 (51.4%)</td>
</tr>
<tr>
<td>Wound</td>
<td>6</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>10 (14.3%)</td>
</tr>
<tr>
<td>Urine</td>
<td>7</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>17 (24.2%)</td>
</tr>
<tr>
<td>Catheter</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>2 (2.9%)</td>
</tr>
<tr>
<td>Body fluid</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2 (2.9%)</td>
</tr>
<tr>
<td>Sputum</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>3 (4.3%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>47 (67.2%)</td>
<td>10 (14.3%)</td>
<td>9 (12.9%)</td>
<td>4 (5.8%)</td>
<td>70 (100%)</td>
</tr>
</tbody>
</table>

**Table 2. Frequency of the different SCCmec types among different coagulase-negative Staphylococci**

<table>
<thead>
<tr>
<th>SCCmec</th>
<th>S. epidermidis</th>
<th>S. saprophyticus</th>
<th>S. hemolyticus</th>
<th>S. lugdunensis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iva</td>
<td>19</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>III</td>
<td>7</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>II</td>
<td>4</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>V</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>ccrA2B2</td>
<td>11</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ccrA2B2/ccrA3B3</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Non-typeable</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total number</strong></td>
<td>47 (67.2%)</td>
<td>10 (14.3%)</td>
<td>9 (12.9%)</td>
<td>4 (5.8%)</td>
</tr>
</tbody>
</table>
the ccr complex, while 11 isolates remained unclassified. Type IVA was the most abundant (27%), followed by types III, II and V.

Among the 47 isolates of S. epidermidis, 19 (40.4%), 7 (15%) and 4 (8.5%) harbor type IVA, III and II, respectively. These 11 (23.4%) only carry ccrA2B2, while 2 (4.3%) contain ccrA2B2/ccrA3B3 in their cassette (13).

Several studies have found that in MRSA clone ST-239, SCCmec type III has been identified; this clone was found to be circulating in Iranians hospitals and other Asian countries (14-16). Hence, as it is evident that MR-CoNS is the main ecological reservoir of the SCCmec gene, we expected that SCCmec III would be the main type of MR-CoNS in the investigated isolates. To clarify this controversy, a comprehensive SCCmec typing of the MRSA and MR-CoNS isolated from the infection site in the hospital is needed.

Meanwhile, SCCmec type IV was found as a minor clone emerged in the hospital setting in different parts of Iran (17, 18). In addition, SCCmec IV was the most frequent SCCmec type (90%) isolated from CA-MRSA (community acquired –methicillin resistant S. aureus) in healthy carriers at central Iran (19). Varied SCCmec types in MR-CoNS have been distributed and are dominant in different countries. For instance, SCCmec type III has been found to be the most prevalent in southern Brazil (52%) (20), whereas SCCmec type IV has been reported to be the most common in the United Kingdom (36%) (12). In Japan, MR-CoNS strains have been steadily disseminated within the community and have become more prevalent than CA-MRSA (21). These strains predominantly harbored type IV SCCmec elements, similar to CA-MRSA strains disseminated throughout the world (13, 22).

Currently, the emergence of a wide range of CA-MRSA clones carrying SCCmec IVA is one of the most alarming issues in terms of antibiotic resistance (19, 23, 24). The small size of the type IV plays an important role in its mobility and enables easier exposure among MRSA in the community, as in the hospital (24). Because high homology has been found between S. epidermidis and major clones of methicillin-resistant S. aureus (13), it could be suggested that CA-MRSA clones could have originated from coagulase negative staphylococci (25).

Interestingly, co-colonization by methicillin susceptible S. aureus and methicillin-resistant S. epidermidis-Iva upon hospital admission, further clarify this finding (13).

The SCCmec structure was found to be more polymorphic in MR-CoNS, with different ccr-mec combinations not described in MRSA and untypable ccr allotypes.

In MR-CoNS strains, the presence of multiple ccr-carrying strains was reported; for instance, type III SCCmec was found to contain an SCC mercury element driven by the ccrC3 allotype (26, 27) or type V strains, which contain ccrAB2 and ccrC in community-acquired MRSA (28). This finding could be due to the addition of non-mecSCC elements in the SCCmec structure. In addition, while focusing on the composite structure of SCCmec, this indicates that ccr gene expression has an important role in the SCCmec exchange between species.

In addition, 20 out of 31 of the non-typable isolates (64.5%) were found to harbor the ccrA2B2 complex that belongs to type II or IV SCCmec. These non-typable isolates could be similar to a few variants of SCCmec type II, but with lack of lpd operon in the J-region. Therefore, current multiplex PCR methods are not able to identify them as SCCmec type II (29). However, mec complex typing was also not able to categorize these isolates. All of these factors emphasize on a frequent loss and acquisition of mobile genetic elements in S. epidermidis (30).

Most of the studies have reported that methicillin-resistant S. saprophyticus harbor untypable SCCmec types (31, 32). This difficulty could be due to a combination of DCS and mecA amplification products that were not consistent with those known types of SCCmec elements (32), or could be due to difficulties in ccr complex of methicillin-resistant S. saprophyticus, which has been previously reported (31). This is the first report to show that methicillin-resistant S. saprophyticus isolates from Iran carry ccrA2B2 or ccrA3B3 elements. While the study of Soderquist et al. (31) found that all three non-typable S. saprophyticus isolates were negative for all the investigated ccr elements, two carried the class A mec gene complex. The investigation on eight mecA-positive S. saprophyticus isolates from Japan revealed that they were positive for the class A mec gene, but were negative for the ccr complex (32). It can be concluded that the recipient chromosomes of various MR-CoNS are different because of the variety in the SCCmec types. In addition, this finding suggests that SCCmec in methicillin-resistant S. saprophyticus should be further investigated, while a further analysis of S. saprophyticus prototypes.
is necessary.

Out of nine methicillin-resistant S. hemolyticus isolates, four (44.4%) were identified as type III, two (22.2%) as type II and two isolates were non-typable. S. hemolyticus isolates have been found to be diverse and harbor SCCmec II, III and IV in different countries (27, 33). Therefore, in our region, S. hemolyticus could be a considerable reservoir of type III and II SCCmec, respectively.

Interestingly, we found that two S. lugdonensis isolates carrying SCCmec V. S. hemolyticus isolates with type V SCCmec had been reported in the literature from Brazil and Taiwan and could be misidentified as MRSA (34, 35). The clinical and epidemiological significance of this resistance phenotype must be taken into consideration seriously, because of the potential danger of type V SCCmec in the community and in hospitals.

In conclusion, this is the first report of SCCmec typing among MR-CoNS isolates from Iran. A high frequency of MR-CoNS isolated from the infection site is an important finding of this study that could be correlated with a high frequency of MRSA in this hospital setting. The predominance of type IV and III SCCmec, which are the genetic determinants of CA and HA-MRSA, emphasize that MR-CoNS can serve as the possible sources of SCCmec for MRSA. The application of different typing methods was not able to determine the SCCmec construction of 16 (23%) isolates, indicating the need for developing or modifying a classification system for SCCmec types in MR-CoNS.

ACKNOWLEDGEMENTS

This study has been funded by the Arak University of Medical Sciences. The authors would like to thank the Microbiology Department of Vali-Asr Hospital, particularly Mrs Marzieh Ranjbaran and Mr Masoud Sarafian for the technical assistance in the samples collection.

REFERENCES


11. Mert Gr, KiliÅ‘ A, Bedir O, BaÅŸustaoÅŸlu AC. Clinical significance and staphylococcal cassette chromosome mec (SCCmec) characterization of coagulase-negative staphylococci isolated from blood cul-


32. Higashide M, Kuroda M, Omura CT, Kumano M, Ohkawa S, Ichimura S, et al. Meticillin-resistant Staphylococcus saprophyticus isolates carrying staphylococcal cassette chromosome mec have emerged in

