Epidemiology of Methicillin-Resistant Staphylococcus Aureus in Arab Countries of the Middle East and North African (MENA) Region

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Abstract. Available data suggest a high burden of methicillin-resistant *Staphylococcus aureus* (MRSA) in Arab countries of the Middle East and North Africa (MENA). To review the MRSA rates and molecular epidemiology in this region, we used PubMed search engine to identify relative articles published from January 2005 to December 2019. Great heterogeneity in reported rates was expectedly seen. Nasal MRSA colonization ranged from 2%-16% in Gulf Cooperation Council (GCC), 1-9% in the Levant, and 0.2%-9% in North African Arab states. Infective MRSA rates ranged from 9%-38% in GCC, 28%-67% in the Levant, and 28%-57% in North African states. Studies demonstrated a wide clonal diversity in the MENA. The most common molecular types belonged to 5 clonal complexes (CC) known to spread worldwide: CC5, CC8, CC22, CC30, and CC80. The most prevalent strains had genotypes related to the European community-acquired MRSA (CA-MRSA), Brazilian/Hungarian hospital-acquired MRSA (HA-MRSA), UK-EMRSA-15 HA-MRSA, and USA300 CA-MRSA. Finally, significant antimicrobial resistance was seen in the region with variation in patterns depending on location and clonal type. For a more accurate assessment of MRSA epidemiology and burden, the Arab countries need to implement national surveillance systems.

Keywords: MRSA; Methicillin-Resistant *Staphylococcus aureus*; Arab countries; Middle East; North African.

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Introduction. The last few decades have witnessed an increasing interest in the molecular epidemiology of methicillin-resistant *Staphylococcus aureus* (MRSA). Various techniques have been utilized to decipher the MRSA genotype, which could provide insight into a strain's resistance capacity and virulence. It also provides insight into their origin of spread and helps implement proper infection control measures.1

To date, MRSA is the most frequently identified antibiotic-resistant microbe in many regions, including East Asia, the Middle East, North Africa, Europe, and the Americas.2 Available data suggest a high burden of MRSA in Arab countries of the Middle East and North Africa (MENA).3,4 However, the Arab world lacks both regional and national surveillance systems. Instead, the current literature is derived from fragmented single-centered research. Moreover, no review summarizing such findings is yet available. Therefore, the purpose of...
our paper is to examine the current literature on the epidemiology of MRSA in Arab countries of the MENA region.

Definitions.
The Middle East and North African Region: According to the World Bank, the MENA region comprises 21 member states. The Arab member states include the Kingdom of Saudi Arabia (KSA), United Arab Emirates (UAE), Kuwait, Qatar, Bahrain, Oman, Yemen, Syria, Lebanon, Jordan, and Palestine (west bank and Gaza strip). Iraq, Egypt, Tunisia, Algeria, Morocco, Yemen, and Libya.

MRSA molecular typing techniques: Currently, there are four molecular typing techniques, including pulsed-field gel electrophoresis (PFGE), Multilocus sequence typing (MLST), staphylococcal cassette chromosome mec (SCCmec) typing, and Staphylococcus aureus protein A gene (spa) typing.

Pulsed-field gel electrophoresis: It is considered the reference standard for MRSA typing. Uses restriction enzyme Smal to digest purified chromosomal DNA followed by agarose gel electrophoresis. A unique pattern is created and analyzed using the Dice coefficient and unweighted pair-group matching analysis (UPGMA). Thus, it is the most discriminative method and the best for investigating hospital outbreaks. Nonetheless, efforts to harmonize PFGE protocols have failed, which hinders inter-laboratory comparability. Therefore, it is not useful when comparing isolates from different centers.

Multilocus sequence: It is based on sequence analysis of 7 housekeeping genes (arcC, aroE, glpF, gmk, pta, tpi, yqiL). Each unique sequence within a gene is designated as an allele. When combined, the 7-allele pattern behaves as an allelic profile or sequence type (ST) that defines the MRSA isolate. For example, all isolates with the allelic profile 7-6-1-5-8-8-6 are clones and this sequence is referred to it as an allelic profile. When combined, the 7-allele pattern behaves as an allelic profile or sequence type (ST) that defines the MRSA isolate. For example, all isolates with the allelic profile 7-6-1-5-8-8-6 are clones and this sequence is known as ST228. It is laborious and time-consuming.

A database for MLST typed isolates identified and reported globally exists through the Staphylococcal Cassette Chromosome mec (SCCmec) typing, and Staphylococcus aureus protein A gene (spa) typing.

Staphylococcal Cassette Chromosome mec: SCCmec is a mobile genetic element that harbors mecA gene. Different typing methods exist, utilizing polymerase chain reaction (PCR) technology. There are five main types, SCCmec I to V, but overall, 13 types have been reported (type I-XIII), some of which have subvariants. Staphylococcus aureus Protein A Gene Typing: This is a single-locus DNA sequence typing of the polymorphic region X of spa gene. The typing reveals a specific pattern of repeats which is then used to deduce the spa type. It is simpler than the tedious MLST typing. It has good discriminatory power that lies between PFGE and MLST. Although individual laboratories use "in-house" sequencing platforms, a dedicated software (Ridom StaphType software) that analyzes sequencing patterns from different laboratories exists and is accessible to the public. This software helps ensure interlaboratory comparability. A laboratory's typing data can be uploaded and synchronized into the database via a central server available at http://www.spaserver.ridom.de. The database currently has 20,056 spa types reported, representing 444,798 total strains from 146 countries.

Clonal Complex: The primary method of determining clonal complex (CC) is based on MLST. Individual isolates with an identical sequence in at least 5 out of 7 housekeeping genes are grouped into a CC. The ancestor of a CC is the ST with the highest single-locus variants. Therefore, each ST will belong to a single CC, but each CC can have several STs with five identical housekeeping genes. For example, ST228 and ST5 both belong to CC5.

Due to a higher discriminatory power, several spa types can belong to the same ST. A unique spa-type can be shared among several STs but can belong to only 1 CC. Therefore, clustering analysis based on spa typing is also feasible (i.e., spa-CC). Supplementary Table 1 lists some of the major clones identified globally. Some clones can have more than 1 colloquial name.

For a more detailed description of MRSA molecular typing, we refer our readers to a publication by Deurenberg et al. Additionally, a comprehensive guide describing the different MRSA clones is available. Finally, Supplementary Figure 1 illustrates the interconnection of different typing methods.

Panton-valentine leucocidin (PVL) and toxic shock syndrome-toxin 1 (Tst1): The lukF/S-PV and TST genes encode PVL and Tst1, respectively, which are virulence factors found in MRSA. More specifically, [PVL+] strains can cause leukocyte destruction and tissue necrosis and are frequently associated with skin and soft tissue infections and necrotizing pneumonia.

Community-acquired MRSA (CA-MRSA) vs. Hospital-acquired MRSA (HA-MRSA): Distinguishing between CA-MRSA and HA-MRSA has traditionally been based on genetic makeup. CA-MRSA is typically associated with SCCmec types IV/V while HA-MRSA is associated with types I/II/III. However, HA-MRSA carrying SCCmec type I, II, and III and CA-MRSA carrying type IV have been identified questioning the distinction based on SCCmec alone.
Table 1. Major MRSA Clones Encountered Globally.

| Clone               | MLST       | ST   | CC | SCCmec | Spa | Geographic areas                                      |
|---------------------|------------|------|----|--------|-----|------------------------------------------------------|
| UK-EMRSA-3          | 1-4-1-4-12-1-10 | 5    | 5  | I      | 1003, 1002, 1001, 1010, 1045, 1053, 1062, 1105, 1178, 1179, 1187, 1214, t311, t319, t389, t443 | Af, Arg, Aus, Au, Bel, Bra, Can, Chi, China, Cro, Cyp, Cze, Den, Det, Es, Fin, Fr, Ga, Ger, Gr, HK, Hun, Ice, Iran, Irc, Isr, It, Jap, Ma, Mal, Mart, Min, Nets, NZ, Nor, Pol, Por, Ro, SA, Slo, Sp, Swe, Swit, Tai, UK, USA |
| New York/Japan      | 1-4-1-4-12-1-10 | 5    | 5  | II     | 1003, 1002, 1001, 1010, 1045, 1053, 1062, 1105, 1178, 1179, 1187, 1214, t311, t319, t389, t443 | Aus, Aus, Belg, Can, Cro, Den, Fin, Fra, Ger, HK, Hun, Ire, Jap, Kor, Mex, Por, Sin, Swe, Tai, Uru, UK, USA |
| Paediatric          | 1-4-1-4-12-1-10 | 5    | 5  | IV     | 1001, 1002, 1003, 1010, 1045, 1053, 1062, 1105, 1178, 1179, 1187, 1214, t311, t319, t389, t443 | Alg, Aus, Arg, Bra, Col, Den, Fr, Kor, Nor, Pol, Por, Sp, Swe, Uru, UK, USA |
| South German        | 1-4-1-4-12-24-29 | 228  | 5  | I      | 1041, 1023, 1201, t188, t001 | Aust, Aus, Cro, Ger, Hun, Isr, It, Malta, Par, Slo, Swit |
| Brazilian/Hungarian HA-MRSA | 2-3-1-1-4-4-3 | 239  | 8  | III    | t037, t030, t234, t387, t388 | Arg, Aus, Aus, Bel, Bul, Can, Chi, China, Cro, Cze, Den, Egy, Fr, Ger, Gr, Ice, Iran, Ire, Isr, It, Latvia, Ma, Mal, Min, Nets, NZ, Nor, Pol, Ro, SA, Sp, Swe, Swit, Tai, Tur, Ug, Uir, USA, China |
| Iberian             | 3-3-1-12-4-4-16 | 247  | 8  | I      | 1008, 1051, 1052, 1054, t200, t064 | Aust, Bel, Cro, Cze, Den, Fin, Fr, Ger, It, Nets, Pol, Por, Slo, Sp, Swe, Swit, UK, USA |
| USA 300 CA-MRSA     | 3-3-1-1-4-4-3-8 | 8    | 8  | IV     | 1008 | Aust, Ger, Irak, Ic, Sp, Swit, UK, USA, Jap, HK |
| UK-EMRSA-15 HA-MRSA | 7-6-1-5-8-8-6 | 22   | 22 | IV     | 1032, 1022, 1005, 1223, t309, t310, t417, t420 | Aus, Bel, Cro, Can, Den, Det, Ger, Ice, Ic, It, In, Mal, Malta, Min, Nets, NZ, Nor, Por, SA, Sp, Swe, Uk, |
| Southwest pacific CA-MRSA | 2-2-2-2-6-3-2 | 30   | 30 | IV     | 1012, 1021, 1019, 1018, t318, t338, t138, t276, t268, t391 | Aust, Ger, HK, Ire, Ku, La, NZ, Sca, Swit, Tai, UK, USA |
| European CA-MRSA    | 1-3-1-14-11-51-10 | 80   | 80 | IV     | 1044, t416 | Alg, Aus, Aus, Bel, Bul, Chi, Cro, Cyp, Cze, Den, Det, Egy, Fin, Fr, Ger, Gr, Hun, Ice, Iran, Ire, It, Isr, Ku, Malta, Neta, Nor, Ro, Sp, Swe, Swit, Tur, UK, Nats, Cam, Moz |

Data adopted from Deurenberg et al (5), Monecke et al (6), http://www.spaserver.ridom.de, and http://www.pubmlst.org Bolded spa types are the most commonly reported types globally (refer to supplementary table 1).

Arg: Argentina; Af: Afghan; Alg: Algeria; Aus: Australia; Au: Autre; Bel: Belgium; Bra: Brazil; Bul: Bulgaria; Cam: Cameroon; Can: Canada; CC: Clnal complex; Chi: Chile; Col: Colombia; Cro: Croatia; Cyp: Cyprus; Cze: Czech Republic; Den: Denmark; Det: Detmold; Egy: Egypt; Es: Estonia; Fin: Finland; Fr: Franc; Ga: Gabon; Ger: Germany; Gr: Greece; HK: Hong Kong; Hun: Hungary; Ice: Iceland; In: India; Ire: Ireland; Isr: Israel; It: Italy; Jap: Japan; Kor: Korea; Ku: Kuwait; La: Latvia; Ma: Macedonia; Mal: Malaysia; Mart: Martinique; Mex: Mexico; Min: Minden; MLST: Multilocus sequence; Moz: Mozambique; Net: Netherland; Nor: Norway; NZ: New Zealand; Par: Paraguay; Pol: Poland; Por: Portugal; Ro: Romania; Sa: South Africa; Sca: Scandinavia; Sin: Singapore; Slo: Slovenia; Spa: S. aureus protein A; Sp: Spain; ST: Sequence type; Swe: Sweden; Swit: Switzerland; Tai: Taiwan; Tur: Turkey; Ug: Uganda; Uk: United Kingdom; Uru: Uruguay; USA: United States of America

A Widely disseminated in Europe and Middle East, accounts for considerable percent of isolates in Greece. B When present, it tends to be abundant; accounts for 54% isolates in Por, 66% in Malta, 80% in Ire and Azores; This clone is also increasingly detected in UK; This clone is [PVL-], [Tst1+] but a [PVL+] variant and a [Tst1+] variant exist; the [Tst1+] variant occurs in some parts of the Middle East; the [PVL+] variant occurs in some European countries, Middle east, and Aust; spread extensively across USA.

Alternatively, MRSA can be classified by epidemiological criteria. The epidemiologic definition of CA-MRSA is any strain isolated in an outpatient setting or within 48 hours of admission in a patient with no prior history of MRSA infection or colonization, no permanent invasive medical devices, and none of the following risk factors within the past year: hemodialysis, surgery, hospitalization, residence in a long-term care facility. Strains not fitting this definition are considered HA-MRSA. Nonetheless, we now know that both genotypes can be acquired regardless of risk factors. Therefore, the better practice would be to use epidemiological criteria to label isolates as community-onset (CO-MRSA) versus hospital-onset (HO-MRSA).

For the sake of our review, we use the genetic makeup to identify CA-MRSA or HA-MRSA and, when provided, the epidemiological criteria to distinguish CO-MRSA from HO-MRSA.

Antimicrobial Susceptibilities: We reviewed reported susceptibility rates against rifampin, fusidic acid, clindamycin, trimethoprim-sulfamethoxazole (TMP-SMX), ciprofloxacin, tetracycline, erythromycin, vancomycin, linezolid, teicoplanin, daptomycin, mupirocin, and gentamicin.
Methodology. We used the PubMed search engine to identify articles published from January 2005 to June 2019. We selected 13 out of the 18 Arab countries listed in section the Middle East and North African Region, geographically spread across the MENA region. The area was subdivided into the Gulf Cooperation Council (GCC), which includes KSA, Kuwait, UAE, Qatar, Bahrain and Oman; the Levant region, which includes Lebanon, Palestine, Jordan, and Iraq; and the North African region, which includes Egypt, Algeria, and Tunisia. For our search we used the following terms: "Methicillin-Resistant Staphylococcus aureus", "Saudi Arabia", "Kuwait", "United Arab Emirates", "Oman", "Qatar", "Bahrain", "Iraq", "Lebanon", "Palestine", "Gaza strip", "West bank", "Jordan", "Syria", "Egypt", "Algeria," "Tunisia." Our search retrieved 134 articles. We excluded articles that lacked clear methodology and articles written in languages other than Arabic and English. We also disregarded articles that were not accessible unless all relevant information was clearly provided in the abstract. Finally, we included 20 articles from KSA, 8 from Kuwait, 5 from UAE, 2 from Qatar, 1 from Bahrain, 7 from Lebanon, 5 from Jordan, 3 from Gaza, 1 from West Bank, 10 from Algeria, 5 from Tunisia, and 7 from Egypt.

Results.

**MRSA colonization in the MENA region:**

**MRSA Nasal Carriage:** Subjects with MRSA isolated from nasal/pharyngeal swabs without symptoms attributed to MRSA infection are considered colonized. We report MRSA carriage rate as a percent of total nasal/pharyngeal swabs growing MRSA (i.e., total MRSA/total swabs). **Figure 1** provides the MRSA carriage rate of total subjects combined from all studies per country. **Table 2** lists rates stratified according to four cohorts (outpatients, inpatients, healthy volunteers, and HCWs).

When combining all subjects reported per country, the colonization rates ranged from 2%-16% in GCC,12-22 1-9% in Levant,23-30 and 0.2%-9% in North African Arab states.12,31-36 In the GCC, reported rates were overall higher in KSA and Oman compared to Kuwait. In the Levant and North Africa, Lebanon and Tunisia had very low rates.

Several factors may account for the difference in reported rates between studies. These include the difference in study cohorts (i.e., high risk vs. low risk for colonization), the difference in the study period, and the difference in local factors of the study site (i.e., resource-limited vs. resource-rich city or center). It is...
| Ref  | Total # subjects | % Subjects with risk factors for MRSA | # MRSA(%) | City (year) | Site |
|------|-----------------|--------------------------------------|-----------|-------------|------|
| [12] | 1,048 IP\(^a\)  | 31%                                  | 76 (7%)   | Buraydah (2011) | Multiple hospitals (n=NS) |
| [13] | 600             | 7 (1%)                               | 26 (25%)  | Al-Hofuf (2004) | King Fahad Hospital |
| [18] | 228B            | 21 (9%)                              | 21 (9%)   | Dammam (2011) | King Fahad Specialist Hospital |
| [14] | 220             | 48 (22%)                             | 1 (1%)    | Shaqra (2014-15) | Shaqra General Hospital |
|      | 152 CV          | 0%                                   | 1 (1%)    |             |      |
|      | 590 HCWs        | 100%                                 | 128 (22%) |             |      |
| [19] | 200             | 100%                                 | 36 (18%)  | Riyadh (2012-13) | King Khaled University Hospital |
| [15] | 100             | 73 (73%)                             | 73 (73%)  | Jeddah (NR) | Multiple hospitals (n=NS) |
| [16] | 68D             | 3 (4%)                               | 3 (4%)    | Al-Ahsa (NR) | Multiple hospitals (n=6) |
| [16] | 72              | 6 (8%)                               | 6 (8%)    | Al-Ahsa (NR) | Multiple hospitals (n=6) |
| [17] | 150D            | 10 (7%)                              | 1 (1%)    | Jeddah (2014-15) | King Abdulaziz University |
|      | 590 HCWs        | 100%                                 | 128 (22%) |             |      |
|      | Kuwait [20]     |                                      |           |             |      |
| [20] | 2,429 IP\(^e\)  | 100%                                 | 42 (2%)   | Kuwait City (2005-7) | Farwania Hospital |
|      | 312 CV          | 2%                                   | 48 (15%)  |             |      |
| [21] | 189             | 34 (18%)                             | 34 (18%)  | Muscat (NR) | Oman Medical College and Sultan Qaboos University Hospital |
| [22] | 123C            | 14 (11%)                             | 14 (11%)  | Muscat (NR) | Oman Medical College |
|      | 188 HCWs        | 100%                                 | 31 (17%)  |             |      |
| [21] | 116             | 16 (14%)                             | 16 (14%)  | Muscat (NR) | Oman Medical College and Sultan Qaboos University Hospital |
| [22] | 72D             | 15 (21%)                             | 15 (21%)  | Muscat (NR) | Oman Medical College |
|      | Gaza and West Bank [23-25] |                       |           |             |      |
| [24] | 843 IP\(^a\)    | 0%                                   | 17 (2%)   | West bank (2003) | Ramallah Government hospital |
| [23] | 758 CV          | 3%                                   | 94 (12%)  | Gaza (2009) | Multiple Gaza neighborhoods (n=12) |
|      | 272 HCWs        | 100%                                 | 61 (22%)  |             |      |
| [25] | 200             | 51 (26%)                             | 51 (26%)  | Gaza (2015) | Al Shifa Hospital |
| [24] | 72              | 10 (14%)                             | 10 (14%)  | West Bank (2003) | Ramallah Government hospital |
|      | Jordan [26, 27] |                                      |           |             |      |
| [26] | 227             | 17 (8%)                              | 17 (8%)   | Amman (2009) | University of Jordan |
| [27] | 419             | 26 (6%)                              | 26 (6%)   | Al-Karak (2011-12) | Al-Karak Hospital |
| [27] | 297 HCWs        | 100%                                 | 30 (10%)  | Al-Karak (2011-12) | Al-Karak Hospital |
|      | Lebanon [28, 29] |                                      |           |             |      |
| [28] | 1, 526 OP       | 17%                                  | 2 (0.1%)  | Beirut (2010-11) | Rizk Hospital, Beirut |
| [29] | 500 CV\(^c\)    | 12%                                  | 8 (2%)    | Beirut, Sidon (2006-7) | NS |
|      | Iraq [30]       |                                      |           |             |      |
| [30] | 198 CV          | 0%                                   | 8 (4%)    | Kurdistan (2015) | NS |

\(^a\) = Inpatient, \(^b\) = Inpatient, \(^c\) = Inpatient, \(^d\) = Inpatient, \(^e\) = Inpatient, \(^f\) = Inpatient.
difficult through our review to determine which factors explain the observed difference in rates. The cited studies from Lebanon were limited to outpatients and community volunteers only as opposed to Gaza, Jordan, and Iraq, where some studies included HCWs. Nonetheless, even when comparing similar groups, the rates in Lebanon remained lower. This is true for Beirut and Sidon, 2 heavily populated cities in Lebanon.\textsuperscript{28,29} It is also unclear why Kuwait in GCC and Tunisia in North Africa had lower rates than neighboring states. The study provides more details for each cited study.

Supplementary table 2

| Study | Country | Setting | Methicillin Resistance | MRSA Carriage Rate | Source |
|-------|---------|---------|------------------------|-------------------|--------|
| [36]  | Tunisia | OP      | 100%                   | 25 (14%)          | Université Tunis El Manar |
|       |         | OP      | 0%                     | 36 (28%)          |        |
| [31]  | Tunisia | CV      | NS                     | 29 (8%)           | Alexandria University |
| [32]  | Tunisia | CV      | NS                     | 32 (7%)           | Alexandria University |
| [33]  | Tunisia | CV      | NS                     | 30 (14%)          | Fayoum University Hospital |
| [34]  | Algeria | IP      | 33%                    | 9 (2%)            | Bejaia (2010-12) |
| [35]  | Algeria | CV      | NS                     | 23 (5%)           | Algiers (2009-11) |
| [36]  | Tunisia | CV      | 23%                    | 1 (0.2%)          | Tunis (2008-9) |

MRSA carriage rate reported as % of total nasal/pharyngeal swabs growing MRSA (i.e., total MRSA/total swabs). Bolded rows represent entire cohort. Risk factors for MRSA: isolate recovered > 48 hours of hospitalization, invasive medical devices, healthcare workers (including medical/pharmaceutical students with clinical exposure) and the following within the preceding year: hemodialysis, surgery, hospitalization, residence in a long-term care facility.

CV: community volunteer(s); HCWs: healthcare worker(s); IP: inpatient(s); NS: not specified; OP: outpatient(s).

MRSA Infections in the MENA Region:

MRSA Infection Rates: We report rates of MRSA infection as percent of clinical \textit{S. aureus} isolates showing methicillin resistance (total MRSA/total \textit{S. aureus} derived from clinical specimen). Figure 2 demonstrates percent methicillin resistance in total isolates derived from all studies per country. Supplementary table 2 provides more details for each cited study.

When examining all isolates recovered per country, methicillin-resistance ranged from 9%-38% in GCC,\textsuperscript{11,13,17,18} 28%-67% in the Levant,\textsuperscript{45-53} and 28%-57% in North African states.\textsuperscript{54,55} In the GCC, lower rates were recorded in UAE and Qatar compared to Oman and KSA. In UAE, the highest rate reached 29% in a study from Dubai examining 62 \textit{S. aureus} isolates derived from purulent skin and soft tissue infections (SSTI).\textsuperscript{41} In the Levant and North Africa, Lebanon and Tunisia again had the lowest rates in clinical isolates. Notably, one of the studies from Lebanon saw a rate of 72% resistance in 32 isolates.\textsuperscript{46} These isolates were randomly selected, not consecutive, and examined only wound and respiratory specimen. A subsequent study testing 4,890 isolates from 16 different hospitals across Lebanon showed a much lower rate of 28%.\textsuperscript{49} In Iraq, very high rates were seen in combat
Figure 2. Reported Rates of Methicillin-resistance among *S. aureus* from Clinical Specimen in the MENA Region. The figure demonstrates rates as percent of all clinical *S. aureus* isolates derived from all studies per country showing methicillin resistance (total MRSA/total *S. aureus* derived from clinical specimen).

| Country | All subjects | % MRSA | Cities (year) |
|---------|-------------|--------|---------------|
| KSA     | 960         | 367 (38%) | Dhahran, Taif, Makkah (2004-15) |
| UAE     | 763         | 70 (9%)  | Al Ain, Dubai (2003-12) |
| Oman    | 2,001       | 732 (37%) | Muscat, Sohar (2007-17) |
| Qatar   | 893         | 833 (21%) | Doha (2007-10) |

**Levant Region**

| Country | All subjects | % MRSA | Cities (year) |
|---------|-------------|--------|---------------|
| Gaza    | 215         | 121 (55%) | Gaza (2008-12) |
| Jordan  | 418         | 154 (37%) | Northern Jordan, Amman (2008-12) |
| Lebanon | 6,187       | 1725 (28%) | Beirut, Mount Lebanon, south Lebanon, north Lebanon (2006-13) |
| Iraq    | 1,333       | 894 (67%) | Baghdad, Salaymehiyah (2005-11) |

**North African Region**

| Country | All subjects | % MRSA | Cities (year) |
|---------|-------------|--------|---------------|
| Egypt   | 788         | 438 (56%) | Zagazig, Assiut, Izzuddin, Alexandria, Cairo (2010-13) |
| Algeria | 863         | 458 (52%) | Annaba, Algiers, Tlemcen (2006-12) |
| Tunisia | 602         | 170 (28%) | Tunis (1998-12) |

**Molecular Types of MRSA in MENA Region:** As expected, heterogeneity between studies in the typing techniques utilized and the reporting of results was evident. Some studies reported SCCmec types alone while others reported MLST and/or spa typing with or without CC assignment. Therefore, determining the relatedness of reported strains from different studies is challenging. For example, in the study from Bahrain, PFGE typing was used. While this is a good tool to investigate relatedness of strains in an institution, it does not allow for comparison with other centers.6

Studies demonstrated a wide clonal diversity across the region. This was evident by the large number of different *spa* and/or MLST types and their corresponding CCs. Furthermore, the epidemiology varied depending on center, city, study period, and subject cohort.

The bulk of studies recovered in our review did not classify their samples based on site of acquisition (CO-MRSA vs HO-MRSA). This would have been a valuable tool to distinguish the epidemiology between community and healthcare settings.

All studies examining colonizing MRSA were limited by a small sample size. Table 4 lists the relative frequencies of *PVL*, *Tst1*, SCCmes, MLST, *Spa*, and CCs in colonizing strains. Supplementary table 3 organizes

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support hospitals among U.S. military personnel, particularly when examining skin and soft tissue infections (SSTI), and in a burn center where the rate reached 88%. In North Africa, Algeria reached a high of 86% in Annaba when examining diabetic foot infections. A high rate of 75% in another study was also seen in surgical wound infections >48 hours postoperatively in Tlemcen. On the other hand, a study from Algiers showed a lower rate of 19% which again highlights the varying epidemiology depending on site within a country. When testing clinical isolates from neutropenic patients in Tunisia, a rate of 18% was detected, still lower than most studies in Egypt and Algeria.

Only few studies specified site of acquisition based on epidemiological criteria, i.e., CO-MRSA vs HO-MRSA, outlined in Table 3. Based on these few studies, isolates causing hospital-onset infections showed higher rates of methicillin resistance. *S. aureus* isolates causing community-onset infections had 51% methicillin resistance in KSA, 40% in Egypt, 47%-75% in Algeria, and 29% in Tunisia. In Egypt, the 40% rate was in community-onset SSTI. On the other hand, isolates causing hospital-onset infection had 66% resistance in KSA, 77% in Egypt, 47%-75% in Algeria, and 21% in Tunisia.
Table 3. Stratification of clinical isolates based on epidemiological criteria.

| Ref | S. aureus isolates | MRSA isolates | KSA | CO | HO |
|-----|------------------|---------------|-----|----|----|
| [5] |                  |               |     |    |    |
|      | Total # | CO | HO | Total # | CO | HO |
| [7] | 252A    | 136 | 116 | 146 | 70 | 76 |
| [23] | 62B    | NS | NS | 18 | 17 | 1 |
| [24] | 38C, D | 38 | 0 | 18 | 18 | 0 |
| [25] | 631A   | 183 | 448 | 364 | 21 | 343 |
| [28] | 148A   | 29 | 119 | 92 | 7 | 85 |
| [26] | 129A   | NS | NS | 35 | 10 | 15 |
| [29] | 220C, x | 0 | 220 | 165 | 0 | 165 |
| [30] | 72A    | 0 | 72 | 13 | 0 | 13 |
| [31] | 143A   | 77 | 66 | 58 | 22 | 36 |

CO: community-onset; HO: hospital-onset; NS: not specified. A Various clinical infections, B Purulent SSTI, C SSTI, D Study examined community-onset infections only, E Study examined hospital-onset infections only, F Neutropenic patients in bone marrow transplant center.

Table 4. Molecular Typing of Colonizing MRSA Isolates in the MENA Region.

| Ref | # MRSA | PVL | Tstl | SCCmec (%) | Spa (%) | MLST | Clonal Complexes/PFGE/singletons (%) | Study location (year) |
|-----|--------|-----|------|------------|--------|------|-------------------------------------|----------------------|
| [12] |       | 26 OP | 12% | ND | V (42), NT (35), IVa (23) | t084 (14), t085 (13), t088 (13), t349 (7), t660 (7), t002 (7), t223 (7), t376 (7), t189 (7), t442 (7), t6836 (7), t11841 (7) | ND | CC15 (27), CC8 (13), CC25 (13), CC5 (7), CC22 (7), CC80 (7), CC188 (7), CC-NA (20) | KSA Buraydah (2011) |
| [16] |       | 20 CV | ND | ND | IV (90), IVa (10) | t131 (20), t1328 (20), t688 (20), t304 (20), t126 (10), t1339 (10) | ND | CC80 (20), CC22 (20), CC5 (20), PFGE F (20), CC1 (10), PFGE K CC88 (10) | Al-Ahsa (NR) |
| [20] |       | 18 IP | ND | ND | III (72), IV (28) | t421 (33), t495 (28), t4410 (6), t388 (6), t226 (6), t3010 (6), t6665 (6), t1234 (6), t044 (6) | ST239 (72), ST22 (11), ST97 (11), ST80 (6) | ND | Kuwait City (2005-7) |
| [23] |       | 94 CV | 9% | ND | IV (1), IVa (81), V (11), ND (5), IVc (2) | t223 (76) | ST22 (74), ST78 (7), ST80 (5), ST-ND (5), ST1784 (2), ST1785 (2), ST5 (1), ST30 (1), ST1734 (1), ST913 (10) | CC22 (76), CC88 (7), CC80 (5), CC5 (3), CC30 (2), CC913 (1), CC-ND (5) | Gaza (2009) |
| [26] |       | 37 HCW | 5% | 100% | IVc (81), IV (14), IVc (5) | t0519 (73), t223 (14), t044 (5), NT (8) | ND | ND | Amman (2009) |
| [27] |       | 26 CV | 8% | 58% | IVa (69), IVc (19), NT (8), IVg (4) | t223 (39), t214 (12), t615 (8), t386 (8), t6397 (4), t790 (4), t012 (4), t253 (4), t044 (4), t1234 (4), t03 (4) | ND | CC22 (46), CC30 (23), CC5 (12), CC1 (8), CC80 (4), CC97 (4), CC15 (4) | Al-karak (2011-12) |
| [30] |       | 30 HCW | 3% | 57% | IVa (80), IVc (17), V (3) | t223 (40), t386 (20), t309 (7), t018 (7), t10683 (7), t021 (6), t693 (3), t012 (3), t044 (3), t703 (3) | ND | CC22 (47), CC1 (23), CC30 (17), CC5 (7), CC80 (4), CC45 (3) | Tunisia (2011) |
Table 5 lists the PVL, Tst1, SCCmec, MLST, Spa, and CCs in infective strains. Supplementary table 4 organizes the genotypes into clones. In GCC, PVL carriage ranged from 0%-77%, while Tst1 carriage ranged from 4%-24% in the Levant, PVL gene was detected in 37%-96% of infective MRSA. Most cited studies did not determine Tst1 carriage except one from Algeria where none of the isolates carried the toxin gene.

Both HA-MRSA and CA-MRSA genotypes were frequently detected among colonizing and infective strains in the MENA region. Most of the globally prevalent spa types were detected in the Arab countries, as illustrated in supplementary table 1. Spa types belonging to European CA-MRSA, Brazilian/Hungarian HA-MRSA, and EMRSA-15 HA-MRSA were most widely distributed across the region. The most frequently detected CCs were CC5, CC8, CC22, CC30, and CC80, which are globally spread complexes briefly reviewed in table 1. In this section we review the epidemiology of these CCs in the MENA Arab world.

Clonal Complex 5: Members of CC5 are widespread geographically. Established clones from this group can carry SCCmec-I, II, III, IV, and V and can be HA-MRSA and CA-MRSA. It consists of several clones including the South German Epidemic HA-MRSA (ST228-SCCmec-I), Geraldine CA-MRSA (ST5-SCCmec-I), West Australian (W.A.) MRSA-18, and -21 (both ST5-SCCmec-I) and -48 (ST835-SCCmec-I), New York/Japan (ST5-SCCmec-II), and Paediatric (ST5-SCCmec-IV) clones, among others. The last 2 clones are described as pandemic. Another clone previously described is ST5-SCCmec-V which is colloquially known as WA MRSA-11, -14, -34, and -35. This isolate was detected in Australia, Ireland, and Germany.

Colonizing isolates of this group were detected in KSA, Gaza, Jordan, and Egypt. These included the CC5-V and CC5-IV which are likely related to WA MRSA and Paediatric clones, respectively. All these strains were [PVL-]. In Egypt, CC5-V made up 30% of colonizing strains from outpatients.

In infective strains from the MENA, the CC5 and its clones were among the less commonly detected strains. Detected SCCmec types were II, IV, and V. Therefore, observed clones included the Paediatric, New York/Japan, and WA MRSA-(11, -14, -34, and-35).

Clonal Complex 8: Several clones belong to this complex, including both CA-MRSA and HA-MRSA. Its strains can carry SCCmec-I, IV, V, and VIII. MLST types include ST8, ST72, and ST239/ST240/ST241. It houses the first known MRSA clone (ST250-SCCmec-I), known as Ancestral MRSA. This clone is disappearing with time. It also houses the famous Iberian (ST8-SCCmec-I), USA300 CA-MRSA ([PVL+] ST8-SCCmec-IV+ACME) and Brazilian/Hungarian HA-MRSA ([PVL-] ST239-SCCmec-III). USA300 has disseminated throughout the United States of America (U.S.) in few years. Sporadic cases have been identified in some European countries. The Brazilian/Hungarian HA-MRSA is considered the oldest pandemic strain. It is described from countries in every continent. This clone is always [PVL-]. It is prevalent in Europe, Australia, Middle East, and Asia and can be divided into 3 clades [European, Asian, and south American]. ST240 and 241 are closely related to ST239, each differ in mutations within 1 housekeeping gene only.

In MENA region, the Brazilian/Hungarian HA-MRSA was very prevalent in some centers in Kuwait and KSA, but had a decreasing presence in a center from UAE, and was completely absent in 1 hospital in Qatar. It had a modest presence in the Levant. It was notably nonexistent in combat support hospitals in Iraq. In Algeria, It was very common in Annaba but not in Algiers, and in Tunisia, it was frequently encountered in HO-MRSA isolates but not CO-MRSA. All ST239 isolates in the MENA region were [PVL-] and
Table 5. Molecular Typing of Infective MRSA Isolates in the MENA Region.

| Ref | #MRSA | PVL | TstI | SCCmec (%) | Spa (%) | MLST (%) | Clonal Complexes/PFGE/singletons (%) | Study location | Study (year) |
|-----|-------|-----|------|------------|---------|----------|------------------------------------|---------------|-------------|
| [66] | 120Â | 0%  | 8%   | III (100)  |  t037 (35), t044 (19), t030 (5), t363 (5), t304 (4), t002 (4), t661 (3), t690 (3), t019 (2), t388 (2), t032 (2), t223 (2), t305 (2), t138 (1), t459 (1), t748 (1), t932 (1), t1070 (1), t790 (1), t4573 (1), t7604 (1), t8506 (1), t855 (1), t737 (1), t729 (1), t8507 (1), t701 (1), t664 (1), t2235 (1) | ND | Spa-CC037 (55), spa-CC790 (8), spa-CC376 (21), cluster 4 spa CC690 (4), Spa-no founder (5), S-t002 (4), S-t305 (2), S-t664 (1), S-t2235 (1) | Riyadh (210) |
| [67] | 107B  | 54% | 8%   | III (21), IV (75), V (4) | ND | ST239 (21), ST772 (1), ST834 (1) | ND | ND | Riyadh (NR) |
| [68] | 117   | 49% | 9%   | III (8), IV (80), V (10) | ND | ST239 (8), ST8 (1), ST72 (1), ST913C | ND | ND | Riyadh (2009-15) |
| [72] | 101   | 38% | ND   | I (3), II (9), III (47), IV (29), NT (12) | ND | ND | ND | ND | Jeddah (2009-11) |
| [87] | 100   | 19% | ND   | I (3), II (9), III (47), IV (29), NT (12) | ND | ND | ND | ND | Makkah (2012) |
| [37] | 71    | 28% | ND   | I (34), II (10), III (20), IV (20), V (16), NT (1) | ND | ND | ND | ND | Taif city (2013-15) |
| [69] | 400Â  | 16% | ND   | II (5), III (55), IV (32), V (8), VI (0.2) | t030, t037, t421, t495, t860, t064, t008, t1902, t138, t459, t032, t790, t223, t5708, t309, t3935, t2251, t852, t3107, t5983, t002, t003, t242, t105, t045, t306, t2164, t688, t5258, t1154, t376, t8154, t1154, t018, t042, t044, t019, t345, t318, t1130, t605, t6811, t127, t321, t345, t10795, t657, t12211, t304, t1234, t13204, t690, t4067, t5041, t5562, t314, t991, t370, t050, t315, t1427, t4000, t605 | ST239 (46), ST22 (9), ST80 (7), ST5 (7), ST30 (4), ST241 (3), ST6 (2), ST36 (2), ST772 (2), ST8 (2), ST97 (2), ST113 (1), ST225 (1), ST105 (1), ST149 (1), ST361 (1), ST1 (0.3), ST88 (0.3), ST121 (0.3), ST913 (0.3), ST46 (0.3), ST72 (0.3), ST508 (0.3), ST1289 (0.3), ST1465 (0.3), ST1637 (0.3), ST2816 (0.3) | CC8 (58), CC22 (9), CC5 (9), CC80 (7), CC30 (6), CC1 (3), CC6 (2), CC97 (2), CC88 (1), CC121 (1), CC913 (1), CC45 (1), CC61 (1) | Multiple sites (1992-2010) |
| [84] | 6922  | ND  | ND   | I (0.3), II (1), III (29), IV (54), V (15), NT (1) | ND | ND | ND | ND | Multiple sites (2011-15) |
| [70] | 26    | 77% | ND   | IV (89), IVa (8), IVc (4) | ND | ST80 (46), ST30 (31), ST5 (8), ST6 (4), ST8 (8), ST361 (4) | CC80 (46), CC30 (31), CC5 (12), CC8 (8), CC-ND (4) | Multiple sites (2001-3) |
| Location | Year | Multiple Sites | Urease | IV (22), IVa (70), IVh (8) | t223 (51), t032 (8), t853 (14), t790 (8), t3107 (5), t009 (3), t2251 (3), t3915 (3), t7008 (3), t5983 (3) | ST22 (100) | ND | Multiple Sites (2005-10) |
|---|---|---|---|---|---|---|---|---|
| [78] | 37 ST22 Urease (+) | 22% | 62% | IV (22), IVa (70), IVh (8) | t223 (51), t032 (8), t853 (14), t790 (8), t3107 (5), t009 (3), t2251 (3), t3915 (3), t7008 (3), t5983 (3) | ST22 (100) | ND | Multiple Sites (2005-10) |
| [7] | 209 E. F | 31% | 5% | IV (40), III (34), V (26), VI (4) | t860 (24), t945 (9), t127 (7), t688 (7), t304 (6), t044 (6), spu-NT (1), t003, t002, t005, t008, t018, t019, t021, t032, t037, t042, t045, t148, t105, t1120, t1836, t14700, t1247, t12398, t16185, t1839, t16202, t414, t306, t314, t355, t359, t362, t363, t376, t3841, t1425, t535, t5414, t657, t6845, t690, t701, t713, t7583, t790, t8154, t8168, t852, t084 | ST239 (27), ST2867 (1) | ND | Farwaniya h (2016) |
| [73] | 1,327 G | 45% | 24% | IV (50), V (27), III (9), VI (8), I (0.1), II (1) | 261 identified; t688, t304, t860, t127, t044, t311, t002, t223, t267, t019, t3841, t005, t084, t852, and t657 (collectively made 51%) | ND | ND | Multiple sites (2016) |
| [71] | 26 (2003) h | 27% | 4% | II (19), III (12), IIIa (12), IV (54), IVa (4) | t002 (23), t032 (19), t037 (16), t044 (12), t421 (8), t690 (8), t019 (4), t359 (4), t064 (4), t878 (4) | ST239 (23), ST5 (23), ST22 (19), ST80 (12), ST88 (8), ST30 (4), ST97 (4), ST113 (4), ST779 (4) | ND | Al-Ain (2003-8) |
| [88] | 57 CO | 100% | ND | IV (100) | ND | ND | ND | Sharjah (2011-12) |
| [11] | 61 | 66% | ND | IV (90), V (10) | t019 (28), t002 (21), t044 (13), t852 (13), spu-NT (8), t008 (3), t121 (3), t690 (3), t267 (2), t657 (2), t7358 (2), t314 (2) | ST30 (28), ST5 (21), ST80 (13), ST22 (13), ST8 (12), ST15 (5), ST88 (3), ST-NT (3), Based on PFGE: Southwest pacific (28), Pediatric (21), UK-EMRSA-15 (13), European (13), USA300 (7), USA900 (5), USA400 (5), USA1200 (2), Unknown (7) | Doha (2009-10) |
| [6] | 53 | ND | ND | III (87), IV (13) | ND | ND | PFGE: A (83), C (6), D (6), B (2), E (2) | Manama (2005) |
| [45] | 121 | 42% | 40% | I (3), III (7), IV (2), IVa (49), IVc (29), V (7), VI (3) | t044 (30), t223 (28), t7063 (9), t318 (8), t037 (8), t008 (6), t309 (2), t541 (2), t5485 (2), t2229 (2), t001 (2), t698 (2), t144880 (2), t7793 (2), t003 (1), t458 (1), t4229 (1) | ST22 (41), ST80 (31), ST8 (8), ST30 (8), ST239 (7), ST228 (2), ST5 (1), ST6 (1), ST121 (1), ST1153 (1) | CC22 (41), CC80 (31), CC8 (8), CC30 (8), CC239 (7), CC55 (3), CC6 (1), CC121 (1%), CC1153 (1) | Gaza (2008-12) |
| [47] | 41 | 37% | ND | ND | t044 (38), t037 (11), t318 (5), t386 (5), t1149 (5), t701(3), t5849 (3), t318 (3), t6438 (3), t091 (3), t6432 (3), t012 (3), t743 (3), t6439 (3), t6503 (3), t363 (3), t159 (3), t5802 (3) | ND | ND | Amman (2009-10) |
| [81] | 31 Spa-CC044 | 48% | 58% | ND | t044 (83), t5849 (6), t131 (3), t5802 (3), t6438 (3) | ST80 (97), ST997(3) | CC80 (100%) | Amman (2000-11) |
**Lebanon**

| Ref | Study | Country | % Spa | WT | ST | CC | Type | Study Period |
|-----|-------|---------|------|----|----|----|------|--------------|
| [48] | 93 | Lebanon | 62% | ND | II (1), III (10), IVb (1), IVc (87), V (1) | t044 (53), t037 (6), t030 (4), t008 (4), t267 (4), t304 (3), t032 (3), t131 (2), t311 (1), t318 (1) | ST80 (55), ST239 (11), ST8 (4), ST97 (4), ST6 (3), ST22 (3), ST5 (1), ST30 (1) | Beirut (2006-7) |
| [81] | 63 spa-CC044 | Lebanon | 92% | 0% | IV (100) | t044 (85), t131 (8), t4222 (2), t6438 (2), t021 (2), t9135 (2) | ST80 (100) | Beirut (2000-11) |

**Iraq**

| Ref | Study | Country | % Spa | WT | ST | CC | Type | Study Period |
|-----|-------|---------|------|----|----|----|------|--------------|
| [74] | 182 | Iraq | 96% | ND | IV (90), III (3), I (1), NT (4) | ND | ND | Multiple sites (2007-9) |

**Egypt**

| Ref | Study | Country | % Spa | WT | ST | CC | Type | Study Period |
|-----|-------|---------|------|----|----|----|------|--------------|
| [55] | 12 | Egypt | 25% | ND | ND | ND | ND | Ismailia (2013) |
| [56] | 18 CO | Egypt | 33% | ND | V (50), NT (33), IV (11), IVc (6) | ND | ND | Alexandria (NR) |
| [54] | 18 | Egypt | 83% | ND | II (33), V (17), IVd (17), III (11), IVa (6), IVc (6), NT (11) | ND | ND | Zagazig and Assuit (2010-12) |

**Algeria**

| Ref | Study | Country | % Spa | WT | ST | CC | Type | Study Period |
|-----|-------|---------|------|----|----|----|------|--------------|
| [58] | 92 | Algeria | 21% | ND | III (78), IVc (22) | t037 (43), t932 (35), t044 (21), t005 (1) | ST239 (78), ST80 (21), ST22 (1) | CC8 (78), CC80 (21), CC22 (1) | Annaba (2010) |
| [59] | 15 HO | Algeria | 100% | ND | IVc (100) | ND | ND | Algiers (2010-11) |
| | 10 CO | Algeria | 70% | ND | II (10), IVc (90) | ND | ST80 (90), ST39 (10) | ND |
| [61] | 84 CO | Algeria | 88% | 0% | IV (97), V (6), III (3) | t044 (85), t4143 (3) | ST80 (91), ST8 (6), ST241 (3) | ND | Algiers (2006-7) |
| | 137 HO | Algeria | 75% | 0% | IV (88), III (12) | t044 (96) | ST80 (89), ST5 (11) | ND | Algiers (2006-11) |
| [75] | 84 | Algeria | 86% | ND | IV (88), III (8), II (1), ND (2) | ND | ST80 (86), ST239 (8), others (6) | ND | Constantine (2005-7) |
| [76] | 64 | Algeria | 30% | 0% | IV (50), V (44) | ND | ND | ND | Annaba (2011-12) |
| [60] | 73M | Algeria | 15% | 0% | ND | ND | ST239 (82), ST80 (14), ST-NT (4) | ND |

**Tunisia**

| Ref | Study | Country | % Spa | WT | ST | CC | Type | Study Period |
|-----|-------|---------|------|----|----|----|------|--------------|
| [75] | 84 | Tunisia | 86% | ND | IV (88), III (8), II (1), ND (2) | ND | ST80 (86), ST239 (8), others (6) | ND | Constantine (2006-11) |
| [76] | 64 | Tunisia | 30% | 0% | IV (50), V (44) | ND | ND | ND | Annaba (2011-12) |
| [60] | 73M | Tunisia | 15% | 0% | ND | ND | ST239 (82), ST80 (14), ST-NT (4) | ND | Annaba (2011-12) |
| [64] | 58 | 36% | ND | ND | ND | ND | ND | ND | ND | Tunis (2005-7) |
|------|----|-----|----|----|----|----|----|----|----|----------------|
| [65] | 24 tetracycline resistant | 4% | 0% | ND | ND | ND | t052 (5), t037 (21), t14712 (4), t129 (4), t044 (8), t311 (4), t7144 (4), t899 (4) | ST247 (50), ST239 (25), ST728 (8), ST241 (4), ST641 (4), ST7144 (4), ST398 (4) | CC8 (80), CC80 (8), CC5 (8), CC398 (4) | Tunisia (2011-12) |
| [77] | 28 CO<sup>N</sup> | 79% | ND | IVc (79), NT (18), I (4) | ND | ST80 (74), ST5 (8), ST153 (8), ST2563 (4), ST1 (4), ST45 (4) | CC80 (86), CC5 (7), CC1 (4), CC45 (4) | Tunisia (2004-8) |
| 41 HO<sup>N</sup> | 51% | ND | I (15), III (17), IVc (56), NT (12) | ND | ST80 (49), ST239 (10), ST241 (7), ST247 (7) ST1819 (7), ST5 (7), ST97 (5), ST1440 (2), ST1 (2), ST22 (2) | CC80 (51), CC8 (32), CC5 (7), CC15 (5), CC1 (2), CC22 (2) | |

CO: CO-MRSA; HO: HO-MRSA; NR: not reported; NT: not typeable; S-: singleton; Spa-CC: spa cluster. When a sample is not designated “CO” or “HO” it indicates that the study does not distinguish site of acquisition. Values were rounded to the nearest whole number.  
<sup>A</sup> 60 cancer and 60 non-cancer patients,  
<sup>B</sup> MLST types in this study were only reported for CC8, CC1, and CC9,  
<sup>C</sup> MLST types in this study were reported only for CC8, and CC913,  
<sup>D</sup> Percentages for each spa type was not provided in the study,  
<sup>E</sup> Spa types with no percentages were described as sporadic in this study,  
<sup>F</sup> In this study only 120 from the 209 isolates underwent DNA microarray analysis; these isolates represented the 56 spa types found. The MLST types were only reported for CC8 and S-ST2867,  
<sup>G</sup> Only 102 novel variants from the 1,327 were further typed into CCs.  
<sup>H</sup> PVL and Tst1 rates were provided only for the 102 novel variants. SCCmec and spa types were provided for the entire 1,327 sample,  
<sup>I</sup> Study distinguished between 2003 and 2008 isolates,  
<sup>J</sup> Isolates from USA service members deployed to Iraq. Sixteen strains displayed 11 unique pulsotypes not previously described and were labeled CSH1-CSH11,  
<sup>K</sup> subjects were neonates. In this study, outpatients and inpatients <48 hrs from admission were considered CO-MRSA while inpatients >48 hrs. post admission were HO-MRSA. Other epidemiological risk factors for HO-MRSA were not specified,  
<sup>L</sup> This study distinguished between CO-MRSA and HO-MRSA by the epidemiological criteria specified in text,  
<sup>M</sup> spa typing was done for 46 [PVL +] isolates only and revealed only 2 spa types: t044 and t14143,  
<sup>N</sup> Diabetic foot infections,  
<sup>O</sup> Criteria used to distinguish between HO-MRSA and CO-MRSA is not specified.
had SCCmec-III. Spa types t037, t030, and t008 were most commonly seen.  

The USA300 CA-MRSA was overall less commonly encountered than the Brazilian/Hungarian clone. It was isolated infrequently in KSA,67,68 Kuwait,69,70 Qatar,11 Gaza,45 and Lebanon.48 In Kuwait, it accounted for 8% of 26 SCCmec-IV MRSA isolates only, as opposed to the European CA-MRSA, which made up 46%. Nonetheless, USA300 was very common in Iraq, where it accounted for 80% of infective isolates from deployed U.S. soldiers.74 The clinical specimen was 95% from wound infections. Most non-wound isolates were not USA300. Almost all USA300 isolates were [PVL+]. Despite being in separate geographical locations, similar pulsotypes were identified in the 3 combat support hospitals (CSH), which indicated the same origin of MRSA.74 It is possible that soldiers were colonized before deployment as USA300 is a prevailing clone in the U.S.8

Finally, a [PVL-] CC8-V-t008 clone was detected in few isolates from KSA,12 Egypt,12 and Kuwait.73 This clone was previously described in Saxon and Australia.  

Clonal complex 22: This complex contains multiple MRSA lineages.8 The best example is the ST22-SCCmec-IV pandemic clone, also known as UK-EMRSA-15 HA-MRSA. When present, it tends to become abundant. It is considered HA-MRSA but can also disseminate in the community. In previous reports, it accounted for 50%-80% of isolates from countries in Europe. It is typically [PVL-] and [Tst1-], but variants carrying either or both toxins exist. For example, [PVL+] ST22-SCCmec-IV was previously described in a large hospital outbreak in Germany.8 This variant was also detected in other parts of Europe. A [PVL+, Tst1+] variant was previously identified in India.8 Investigators hypothesize that these variants could have a polyphyletic origin since they can exist in epidemiologically unrelated settings. A [PVL-] SCCmec-V clone was also infrequently detected in Saxon and western Australia. CC22-SCCmec-I, II, or III are not described in the literature.8

[PVL-] ST22-SCCmec-IV or its related spa types were commonly reported in colonizing strains from the MENA region,12,16,20,23,26,27,31,34 particularly common in Gaza, Jordan, Egypt, and Algeria.12,23,27,31,34 This clone was also prevalent in infective strains from the GCC and Gaza. It was reported in 10%-28% of isolates from KSA,67,68 13% in Qatar,11 and 9% in Kuwait,7,69,73 In UAE, it accounted for 19% of isolates in 1 center in 2003 but then dropped to 4% in 2008, showing a decreasing presence with time while other clones dominated.71 The ST22-SCCmec-IV clone was exceptionally common in Gaza, where it made up 41% of isolates in 1 study. On the other hand, this clone was infrequently encountered in the other Levant and North African countries.47,48,58,61,65,74,75,77

All the CC22 isolates from the MENA carried either SCCmec-IV or V. The most common spa types were t223 and t032. The majority were [PVL-] as expected. Nonetheless, the [PVL+] variant was detected in KSA, Kuwait, and Qatar, where, in some centers, this variant exceeded the [PVL-] ST22 strains.11,68,69 Furthermore, many isolates from KSA and Kuwait were [Tst1+], also known as the "Middle Eastern" variant. In Kuwait, 62% of a subset of urease (+) EMRSA-15 isolates belonged to the Middle Eastern variant.78 This variant mostly carried SCCmec-Iva and was [PVL-], except for some isolates from Kuwait, [PVL+] indicating the potential to acquire both toxins. Notably, the bulk (91%) of infective isolates in Gaza were [Tst1+].45 Nonetheless, these were collectively referred to as the "Gaza" strain.45 The Gaza strain also exists in Jordan where it was dominant in colonizing strains in 1 study.27 On the other hand, it was not detected in studies from Lebanon.48,79 The Gaza strain was associated with the SCCmec-Iva-t223 genotype. Like the Middle Eastern variant, the Gaza strain was mostly [PVL-].

While the PFGE analysis of the Gaza strain in Gaza showed 76% pattern similarity with UK-EMRSA-15, some distinguishing features exist. The UK-EMRSA-15 is associated with SCCmec-Ivh-t032 and t022 instead of SCCmec-Iva-t223.23,27 Furthermore, Unlike UK-EMRSA-15, the Gaza strain is susceptible to ciprofloxacin and resistant to tetracycline.21,27 Some of the ST22-SCCmec-IV strains in GCC and North African Arab regions also carried SCCmec-Iva-t223 distinguishing them from UK-EMRSA-15 clone.12,23,27,34,45,78 One study examined 47 CC22-SCCmec-IV isolates from patients from KSA, Abu Dhabi, Kuwait, and Germany.80 Six distinct albeit related strains were detected. Only 9 isolates showed complete resemblance to the UK-EMRSA-15.80 The study concluded that none of the isolates from Riyadh were true UK-EMRSA-15. True UK-EMRSA-15, however, was identified in Abu Dhabi and Kuwait.80

Lastly, [PVL-] CC22-SCCmec-V was detected in few strains from KSA and Gaza.12,23,45 This clone carried t223 and t7063 spa types and was [Tst1+] in Gaza. 

Clonal complex 30: Important clones include UK-EMRSA-16 HA-MRSA (ST36/39-SCCmec-II) and Southwest Pacific CA-MRSA ([PVL+] ST30-SCCmec-IV).8 The former was an important clone in Europe but is becoming rare. The latter is widespread globally. A [PVL-, Tst1+] ST30-SCCmec-IV is sporadically isolated from Ireland and Australia.8

Overall, CC30 was only occasionally encountered in most of the countries in the region. It was detected in few colonizing isolates from Gaza,27 Jordan,27 and Egypt.12 Most colonizing isolates were [PVL-], and in Jordan, several of them were [Tst1+] It was also rarely seen in infective isolates from KSA,68 Kuwait,69 and UAE,71
Gaza,45 Lebanon,48 and Jordan.47 None of the studies from Algeria and Tunisia isolated CC30.55,77 However, this was the most common clone in infective isolates from 1 center in Qatar.11 Also, it made up 31% of a sample of 26 SCCmec-IV isolates in Kuwait.79 Almost all isolates from the region carried SCCmec-IV, resembling Southwestern pacific CA-MRSA.27 Associated spa types were t019 and t018 in the GCC,68,69,71 and t318 in the Levant.45,47,48 Unlike colonizing strains, all infective isolates from this region were [PVL+] except for 1 in Jordan.

The UK-EMRSA-16 HA-MRSA was also rarely reported in the region; only 8 isolates from Kuwait.59 Finally, when isolates carrying novel genotypes in Kuwait were tested, 15% carried CC30-SCCmec-VI.73 Clonal complex 80: This complex houses the European CA-MRSA clone (ST80-SCCmec-IV), which gains its name due to its significant presence throughout Europe. However, this clone is encountered worldwide; most isolates belonging to CC80 carry [PVL+] ST80-SCCmec-IV and IV variants. [PVL-] strains are infrequently detected.

ST80-SCCmec-IV or the associated spa types were detected in colonizing strains from all recovered studies.12,16,20,23,27,31,34 Among infective strains, it was detected in 20-30% of isolates from KSA,67,68 79% in Kuwait,7,69 and 13% in Qatar.11 In UAE, one center experienced a rise in rates from 12% in 2003 to 27% in 2008.71 When examining a sample of SCCmec-IV isolates in Kuwait, 46% were ST80-SCCmec-IV.70 This clone was even more prevalent in infective isolates from the Levant and North Africa. It made up 31% of isolates in Gaza,35 and 55% in Lebanon.48 In Jordan, [PVL+] t044 and [PVL-] t044 were detected in 27% and 11% of isolates, respectively.47 This clone was completely absent in an Iraqi study examining clinical isolates from U.S. soldiers.74 In Algeria, this was the most frequently encountered clone in Algiers, 77%-100% of isolates.59,61,75 This was true even for HO-MRSA isolates,59,61,75 indicating the infiltration of this CA-MRSA clone into the hospital setting. However, its presence was less frequent in studies from a different city, Annaba.58,60 In Tunisia, it accounted for 51% of HO-MRSA and 86% of CO-MRSA.77

There is evidence that isolates belonging to European CA-MRSA in the region could have different evolutionary lineages. For example, PFGE typing revealed 21 different clonal groups among spa-clonal-cluster-044 isolates from Lebanon and Jordan.41 Moreover, the PVL gene was detected more frequently in the Lebanese subset, while the Tst1 gene was detected only in the Jordanian subset.81

The [PVL-] variant was infrequently encountered in KSA,67 Kuwait,69,82 Jordan,47,81 Lebanon41, Algeria,59,61 and Tunisia.55,77 A [Tst1+] variant was detected in Kuwait,42 Gaza,45 and Jordan.41 On the other hand, all strains in UAE,71 Qatar,11 Gaza45 were [PVL+]. The most encountered spa type was t044,55,48,58,61,65,81 Other Clonal Complexes: CC15 was detected in a small number of colonizing isolates from KSA,12 Jordan,27 and Egypt.31 These were carrying t083, t084, and t085. It was also seen in some infective strains from KSA,68 Kuwait,7 and Tunisia.77 This CC is rarely described.8 It was detected in a collection of strains from Italy in 1980, 4 SCCmec-I isolates.8 More recently, it was reported in Europe, Iran, Gabon, and the Gulf of Guinea.12 In Europe, it accounted for 17% of MRSA and methicillin-susceptible (MSSA) isolates combined and carried ST1, ST15, ST188, ST772, and ST1835. In KSA, isolates of CC15 carried both SCCmec-IVA and V.12

In Jordan, a novel genotype, [PVL-,Tst1+]-IVe-t9519, made up the bulk of colonizing isolates from Amman.26 There are still other CCs and clones identified in the region but seem to be of lower prevalence compared to the 5 main CCs we chose to discuss.

Antimicrobial Resistance Patterns of MRSA in the MENA Region: An in-depth description of the antimicrobial susceptibility of MRSA in the MENA region is not the primary objective of our review. Therefore, we do not discuss this topic in detail. Table 6 lists cumulative susceptibilities for 462 colonizing and 11, 373 infective MRSA isolates per country. Supplementary Table 5 provides the susceptibilities from individual studies. The susceptibility ranges are wide for some antimicrobials, indicating a significant difference in resistance patterns between different centers within a country.

Antimicrobial Resistant patterns of Colonizing MRSA: Studies from GCC and North African Arab countries showed high resistance to TMP-SMX.12,14,19,20,23,34 Nonetheless, studies from GCC and North African Arab countries showed high resistance to tetracycline, clindamycin, and erythromycin.12,14,19,20,23,27,29,34 Isolates also remained highly susceptible to rifampin in most centers. Surprisingly, significant vancomycin resistance was detected in KSA, Oman, Egypt, and Gaza.12,14,21,22,25 The majority of these studies used Kirby Bauer's disk diffusion method using Mueller-Hinton agar12,14,22,25 except for 1 study, which used E-test for minimum inhibitory concentration (MIC).21 The remaining studies showed 100% susceptibility to vancomycin.19,20,23,27,29,34 Isolates were almost universally susceptible to linezolid except in 1 study from KSA.14

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Table 6. Percent susceptibility of total MRSA isolates. Susceptibility presented as total # isolates susceptible/total isolates tested (% susceptible).

| Country | Ref (date) | # MRSA | Rif | FA | Cl | TS | Cip | Tet | Dox | EM | Vanc | Lin | Teic | Dap | Mup | Gen |
|---------|------------|--------|-----|----|----|----|-----|-----|-----|----|------|-----|------|-----|-----|-----|
| OmanA   | [21, 22]   | 83     | 81/83 (98) | -   | 58/83 (70) | -   | -   | -   | 75/83 (90) | 42/83 (51) | 73/83 (88)³ | 83/83 (100) | 69/83 (83) | -   | -   | -   |
| KSA³    | [12, 14, 19] (2011-15) | 110 | 53/74 (72) | - | 40/110 (36) | 60/110 (55) | 62/110 (56) | 39/110 (35) | - | 29/110 (26) | 108/110 (98)³ | 68/84 (81) | 26/48 (54) | -   | -   | 63/74 (85) |
| Lebanon³ | [29] (2006-7) | 8 | - | - | - | 8/8 (100) | 8/8 (100) | - | - | - | 8/8 (100) | - | - | - | 8/8 (100) | - |
| Gaza²   | [23] -2009 | 145 | 45/51 (88) | 89/94 (95) | 104/145 (72) | 94/94 (100) | 138/145 (95) | 44/51 (86) | - | 91/145 (63) | 137/145 (94)³ | - | - | - | 138/145 (95) |
| Jordan² | [27] (2011-12) | 56 | 56/56 (100) | 52/56 (93) | 53/56 (95) | - | 54/56 (96) | - | - | 24/56 (43) | 56/56 (100) | 56/56 (100) | 56/56 (100) | 56/56 (100) | 56/56 (100) |
| Egypt²  | [12] -2011 | 33 | 30/33 (91) | - | 22/33 (67) | 17/33 (52) | 33/33 (100) | - | - | 15/33 (45) | 30/33 (91)³ | - | - | - | 22/33 (67) |
| Algeria² | [34] (2010-12) | 9 | 9/9 (100) | - | 9/9 (100) | 7/9 (78) | 9/9 (100) | 6/9 (67) | - | 8/9 (89) | 9/9 (100) | 9/9 (100) | - | - | 6/9 (67) |
| Kuwait² | [20] (2005-7) | 18 | 18/18 (100) | 6/18 (33) | 6/18 (33) | 13/18 (72) | 5/18 (28) | 5/18 (28) | - | 6/18 (33) | 18/18 (100) | 18/18 (100) | 18/18 (100) | - | 17/18 (95) | 5/18 (28) |

Colonizing MRSA strains- Susceptibility presented as total # of susceptible isolates /total # of tested isolates tested (%)

| Country | Ref (date) | # MRSA | Rif | FA | Cl | TS | Cip | Tet | Dox | EM | Vanc | Lin | Teic | Dap | Mup | Gen |
|---------|------------|--------|-----|----|----|----|-----|-----|-----|----|------|-----|------|-----|-----|-----|
| KSA³    | [66, 72, 85] (2004-11) | 733 | 170/221 (77) | 148/733 (20) | 136/221 (62) | 175/632 (28) | 63/101 (62) | 58/101 (57) | - | 103/221 (47) | 733/733 (100)³ | 575/613 (94) | 89/101 (88) | - | 565/733 (77) | 275/613 (45) |
| Kuwait³ | [7, 73, 84] (2011-16) | 8,458 | 8389/8458 (99) | 4911/8458 (58) | 4911/8458 (58) | 5480/8458 (65) | 4859/8458 (57) | 5218/8458 (62) | - | 4911/8458 (58) | 8389/8458 (99)³ | 8458/8458 (100) | 8250/8458 (98) | - | 8054/8458 (95) | 4316/7131 (61) |
| Oman³   | [43] (2016-17) | 733 | - | - | 571/733 (78) | 689/733 (94) | 506/733 (69) | - | - | 520/733 (71) | 733/733 (100) | 733/733 (100) | - | - | 623/733 (85) |
| Bahrain³ | [6] -2005 | 53 | 53/53 (100) | 4/53 (8) | 7/53 (13) | 6/53 (11) | 4/53 (8) | 6/53 (11) | - | 5/53 (9) | 53/53 (100) | 53/53 (100) | 53/53 (100) | - | 47/53 (89) | 14/53 (26) |
| Lebanon³ | [79] -2011 | 39 | 39/39 (100) | - | 34/39 (87) | 38/39 (97) | 34/39 (87) | 27/39 (69) | - | 31/39 (80) | 39/39 (100) | - | 39/39 (100) | - | - | - |

Infective MRSA Strains- Susceptibility presented as total # of susceptible isolates /total # of tested isolates tested (%)

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| Country | Year(s) | MRSA Isolates | Cip | Cl | CO-MRSA | Dapt | EM | FA | Gen | HCWs | HO-MRSA | Lin | Mup | NR | Rif | Tet | Teic | TS | Vanc |
|---------|---------|---------------|-----|----|---------|------|----|----|-----|------|---------|-----|-----|----|-----|-----|------|----|------|
| Gaza    | 2008-12 | 121           | -   |    | -       | -    | -  | 82/121 (68) | 86/121 (71) | 121/121 (100) | 121/121 (100) | 121/121 (100) | 121/121 (100) | 97/121 (80) |
| Jordan  | 2008-12 | 113           | -   | 93/121 (77) | 97/121 (80) | - | 66/113 (58) | 26/113 (23) | 113/113 (100) | 110/113 (97) | 110/113 (97) | - | - | 53/113 (47) |
| Iraq    | 2005-9  | 500           | -   | 379/500 (76) | 454/500 (91) | - | 401/485(83) | 66/500 (13) | 485/485 (100) | 174/182 (96) | - | - | 423/485 (87) |
| Egypt   | 2005-13 | 364           | -   | 171/364 (47) | 302/364 (83) | - | 140/364 (39) | 364/364 (100) | - | - | - | - | 84/364 (23) |
| Algeria | 2007-11 | 190           | -   | 167/190 (88) | 24/25 (100) | - | 6/25 (24) | 91/165 (55) | 187/190 (98) | - | - | 141/190 (74) |
| Tunisia | 2004-8  | 69            | -   | 84 | 91 | 59 | 17 | - | 48 | 100 | - | 100 | - | - | 74 |

Cip: ciprofloxacin; Cl: clindamycin; CO-MRSA: community-onset MRSA [isolates from healthy individuals, outpatients or inpatients within 48-72 hours of admission]; Dapt: daptomycin; EM: erythromycin; FA: fusidic acid; Gen: gentamicin; HCWs: health-care workers; HO-MRSA: hospital-onset MRSA [isolates from HCWs or inpatients > 72 hours after admission]; Lin: linezolid; Mup: Mupirocin; NR: not reported; Rif: Rifampicin; Tet: tetracycline; Teic: teicoplanin; TS: trimethoprim-sulfamethoxazole; Vanc: vancomycin. A Antibiotic susceptibility testing (AST) by standard agar disk diffusion methodology according to clinical and laboratory standards institute guidelines. B Non-susceptible strains (whether intermediate or resistant) detected by disk diffusion method. C 94 MRSA isolates were tested by VITEK-2 system; 51 were tested by disk diffusion method. D AST for 613 MRSA isolates was performed via disc diffusion method; AST methodology for 120 MRSA isolates can’t be confirmed (access to abstract only). E AST performed via E-test methodology. F AST for 2003 isolates performed via VITEK2 system; AST for 2012 isolates done via MicroScan WalkAway Plus System (Siemens Healthcare, Erlangen, Germany). G AST for 485 MRSA isolates was performed via disc diffusion method; AST methodology for 15 isolates not specified. H These were specifically identified as vancomycin resistant and not vancomycin intermediate.
Antimicrobial Resistant patterns of Infective MRSA: Infective MRSA in the MENA region were highly resistant against most antimicrobials. Susceptibility to TMP-SMX varied widely depending on the center. It reached acceptable to high levels in UAE and Oman in some studies. Strains from Lebanon and Iraq were highly susceptible to TMP-SMX as opposed to Gaza and Jordan. Nonetheless, the Gaza strain commonly encountered in Gaza was susceptible to TMP-SMX. Reported sensitivities to vancomycin, linezolid, and teicoplanin remained high among infective isolates in the region. In Egypt, this strain was often susceptible to TMP-SMX but differed due to high resistance to ciprofloxacin and high sensitivity to tetracycline. When compared to ST22-IV isolates from GCC, similar susceptibility rates were seen with few exceptions. The Middle Eastern variant was similarly sensitive to ciprofloxacin but, unlike the Gaza strain, was resistant to TMP-SMX. In contrast, [Tsr1+] Middle Eastern variant had 100% sensitive to ciprofloxacin but only 70% to tetracycline. The "Gaza strain" was susceptible to most tested antimicrobials, including ciprofloxacin and TMP-SMX. It was often resistant to tetracycline. When compared to ST22-IV isolates from GCC, similar susceptibility rates were seen with few exceptions. The Middle Eastern variant was similarly sensitive to ciprofloxacin but, unlike the Gaza strain, was resistant to TMP-SMX. On the other hand, the [PVL+] and [PVL-] variants in GCC were similarly sensitive to TMP-SMX but differed due to high resistance to ciprofloxacin and high sensitivity to tetracycline.

ST239 isolates from UAE were sensitive to vancomycin, linezolid, teicoplanin but resistant to other tested agents. In Egypt, they were highly resistant to tested antibiotics such as TMP-SMX, tetracycline, and gentamicin. ST80-IV CA-MRSA strains in GCC had high susceptibility rates to rifampin, TMP-SMX, vancomycin, linezolid, teicoplanin, and gentamicin. Furthermore, the majority of Spa-clonal cluster-044 isolates from the Levant were susceptible to rifampin and gentamicin, which was consistent with GCC reports. The Lebanese isolates were often resistant to tetracycline, while the Jordanian isolates showed significantly higher resistance to erythromycin. In Egypt, this strain was often susceptible to TMP-SMX but resistant to tetracycline. Discussion. This review highlights a significant threat imposed by MRSA on both the community and healthcare settings within the Arab world. The rates of MRSA varied depending on the country and center. A significant spread of MRSA in some Arab communities was evident by the high nasal MRSA carriage rate among healthy outpatients, hospital visitors, or university students seen in certain cities. As expected, HCWs had higher nasal MRSA rates.

In the clinical setting, methicillin resistance was highly prevalent among clinical isolates of S. aureus in the region. Thus, while some countries like UAE, Lebanon, Qatar, and Tunisia showed lower cumulative rates compared to others, there is still evidence of a high burden in some centers within these countries. Regional variability in MRSA rates has been detected in other areas of the world, such as Europe. In the Arab world, this variance in rates could be due to differences in antibiotic prescribing practices and infection control efforts across the region and within each country. Additionally, Arab countries of the Levant and North Africa have suffered decades of economic and political instability, which negatively impacted medical resources and healthcare infrastructure instead of the prospering Arab countries in the GCC region. This could explain the lower rates seen in UAE and Qatar. Nonetheless, such a theory is challenged by the high MRSA rates seen in KSA. Perhaps these factors are offset by other determinants in KSA.

Certain genotypes were particularly prevalent in the Arab world, many of which belonged to 5 CCs known to spread worldwide. These were previously discussed in table 1. This is not surprising given that the Arab World is a center for multinational ex-pats seeking jobs abroad. Furthermore, KSA is the home of al-Ka’bah al-Musharrafah, the destination of Muslim pilgrimage, where masses of Muslims from across the globe crowd up every year to perform religious rituals. These crowded conditions are likely to facilitate the spread of various MRSA strains.

Three clones were particularly important: European CA-MRSA, UK-EMRSA-15 HA-MRSA, and Brazilian/Hungarian HA-MRSA. Genotypes linked to these clones were distributed across the region. Notably, HA-MRSA clones might be decreasing in prevalence in some centers while CA-MRSA takes over. With time, a shift in clonal distribution was noted in Kuwait and UAE, where CA-MRSA genotypes became more prevalent. In Kuwait, this was clearly seen in 3 studies examining large samples from several hospitals across the country from 1992 to 2016. This is particularly true of the European CA-MRSA, which was detected in almost all cited studies and often accounted for a significant proportion of the study sample. Hence, this clone or its related strains seem to be infiltrating into the Arab World. Nonetheless, the presence of HA-MRSA clones remained strong in many studies, including both the Brazilian/Hungarian clone and the UK-EMRSA-15 clone.

USA300 CA-MRSA is another important clone that made up the bulk of isolates in Iraq's CSHs. However, the subjects here were U.S. military personnel and might
have been colonized prior to being deployed. Hence this might not be reflective of the Iraqi population.

It is important to acknowledge distinguishing features when comparing local strains with these epidemic/pandemic clones. Strains from the Arab world have distinguishing antimicrobial resistance, SCCmec subtypes, and virulence factors. This was highlighted briefly during our discussion of CC22 in section Clonal complex 22. Another distinction was previously made between ST80-SCCmec-IV strains from the Arab world and the European CA-MRSA clone.

The European CA-MRSA is known to be [PVL+] and resistant to tetracycline, streptomycin, kanamycin, and fusidic acid (TSKF profile). Overall, only 16% of the ST80 isolates were resistant to streptomycin, kanamycin, and fusidic acid (SKF pattern). Phenotypical variation between the Kuwaiti ST80 isolates and the European CA-MRSA clone was highlighted.

Nonetheless, our work is not without limitations. Most studies in our review were single-centered reports, limiting our ability to uncover the full burden of MRSA. Furthermore, there was significant heterogeneity in molecular typing methods and reporting of results, which hinders our ability to compare between different centers or countries in the region. Furthermore, the bulk of studies did not distinguish between CO-MRSA and HO-MRSA based on epidemiological criteria, and so we are unable to accurately distinguish the epidemiology of MRSA in the community vs. healthcare setting.

**Conclusion.** This manuscript provides a review of the current literature on MRSA epidemiology in Arab countries. There is enough evidence to suggest that the Arab region struggles from a heavy MRSA burden. Genotypes associated with European CA-MRSA play the biggest role, but Brazilian/Hungarian HA-MRSA and UK-EMRSA-15 HA-MRSA are also prevalent. Therefore, the Arab countries need to implement a nationwide surveillance system to understand better the true epidemiology and burden of MRSA in this part of the world.

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Supplementary Files

**Supplementary Table 1.** The table presents the relative global frequencies of *spa* types. Only those \( \geq 0.5\% \) are reported here. Data is adopted from [http://www.spaserver.ridom.de](http://www.spaserver.ridom.de). It also lists the Arab countries that reported these *spa* types based on our review of literature.

| *spa* Type | Relative Global Frequency | Arab Countries Reporting This *spa* Type |
|------------|---------------------------|------------------------------------------|
| t032       | 9.98%                     | KSA, Ku, Leb, UAE                        |
| t003       | 8.57%                     | Ku                                       |
| t002       | 6.56%                     | KSA, Ku, Qa, UAE                        |
| t008       | 5.81%                     | Egy, Gaz, KSA, Ku, Leb, Qa               |
| t011       | 3.30%                     |                                          |
| t127       | 2.64%                     | Ku, UAE                                  |
| t034       | 2.18%                     |                                          |
| t084       | 1.75%                     | Egy, Ku, KSA                             |
| t012       | 1.53%                     | Jor                                      |
| t037       | 1.12%                     | Alg, Gaz, Jor, KSA, Ku, Leb, Tun, UAE    |
| t021       | 1.07%                     | Egy, Jor, Ku, Leb                       |
| t015       | 1.02%                     |                                          |
| t091       | 0.99%                     | Jor                                      |
| t044       | 0.85%                     | Alg, Egy, Gaz, Jor, KSA, Ku, Leb, Qa, Tun, UAE |
| t022       | 0.79%                     |                                          |
| t437       | 0.78%                     |                                          |
| t005       | 0.70%                     | Alg, Ku, UAE                             |
| t045       | 0.69%                     | Ku                                       |
| t067       | 0.66%                     |                                          |
| t024       | 0.64%                     |                                          |
| t223       | 0.62%                     | Alg, Egy, Gaz, Jor, KSA, Ku              |
| t189       | 0.59%                     | KSA                                      |
| t304       | 0.58%                     | KSA, Ku, Leb, UAE                       |
| t018       | 0.56%                     | Jor, Ku, UAE                             |
| t004       | 0.51%                     |                                          |
| t026       | 0.51%                     |                                          |

Alg: Algeria; Egy: Egypt; Gaz: Gaza; Jor: Jordan; KSA: kingdom of Saudi Arabia; Ku: Kuwait; Leb: Lebanon; Qa: Qatar; Tun: Tunisia; UAE: United Arab Emirates
Supplementary Table 2. Reported Rates of Methicillin-Resistance among Staphylococcus aureus from clinical specimen in MENA Region. MRSA rates presented as total MRSA/total *S. aureus* isolates. All isolates were from various clinical samples unless otherwise specified. Numerical values are rounded to the nearest whole digit.

| Ref | # S. aureus isolate | # MRSA (%) | Study site (year) |
|-----|----------------------|------------|------------------|
|     |                      |            |                  |
|     |                      |            |                  |
| [37] | 445                  | 71 (16%)  | Multiple hospitals (n=NS), Taif city (2013-15) |
| [38] | 206                  | 114 (55%) | Multiple hospitals (n=5), Makkah city (2012)   |
| [39] | 57                   | 36 (63%)  | Multiple hospitals (n=2), Makkah city (2015)   |
| [40] | 252                  | 146 (58%) | Al-Hada Armed Forces Hospital, Taif city (2004) |
| [71] | 701                  | 52 (7%)   | Tawam Hospital, Al Ain (2003-8)                |
| [41] | 62                   | 18 (29%)  | Rashid Hospital and Trauma Center, Dubai (2011-12) |
| [42] | 29                   | 4 (14%)   | Royal Hospital, Muscat (2007)                 |
| [43] | 1972                 | 733 (37%) | Sohar Hospital, Sohar (2016-17)               |
| [44] | 53                   | 7 (13%)   | Hamad General Hospital, Doha (2007-8)         |
| [11] | 840                  | 176 (21%) | Al-Ahli Hospital, Doha (2009-10)              |
| [45] | 215                  | 121 (56%) | Al-Shifa Hospital (2008-12)                   |
| [46] | 358                  | 113 (32%) | Multiple hospitals (n=NS), Northern Jordan. (2008-12) |
| [47] | 60                   | 41 (68%)  | Jordan University Hospital, Amman (2009-10)   |
| [48] | 130                  | 93 (72%)  | American University of Beirut Medical Center, Beirut (2006-7) |
| [49] | 4890                 | 1350 (28%)| Multiple hospitals (n=16), Beirut, Mount Lebanon, North Lebanon, and South Lebanon |
| [50] | 1167                 | 282 (24%) | American University of Beirut Medical Center, Beirut (2000-11) |
| [51] | 505                  | 251 (50%) | Ibn Sina Hospital, Baghdad (2005-9)           |
| [51] | 152                  | 52 (34%)  | Ibn Sina Hospital, Baghdad (2005-9)           |
| [52] | 22                   | 15 (68%)  | Witmer Troop Medical Clinic, Camp Liberty, Baghdad (2008) |
| [53] | 654                  | 576 (88%) | Sulaymamiany Burns and Plastic Hospital, Sulaymamiany, Kurdistan region (2008-11) |
| [54] | 55                   | 18 (33%)  | University Hospital and Diagnostic Laboratories, Zagazig, and Assuit (2010-12) |
| [55] | 64                   | 38 (59%)  | Suez Canal University, Ismailia (2013)        |
| [56] | 38                   | 18 (47%)  | Alexandria University, Alexandria (NR)       |
| [57] | 631                  | 364 (58%) | Multiple hospitals (n=12)                     |
| [58] | 148                  | 92 (62%)  | Multiple hospitals (n=4), Annaba (2010)       |
| [59] | 129                  | 25 (19%)  | Beni Messous University Hospital, Algiers (2010-11) |
| [60] | 85                   | 73 (86%)  | University Hospital Ibn Rochd, Annaba (2011-12) |
| [61] | 221                  | 99 (44%)  | Mustapha Bacha University Hospital, Algiers (2006-7) |
| [62] | 220                  | 165 (75%) | Tlemcen teaching hospital, Tlemcen (2007-9)   |
| [63] | 72                   | 13 (18%)  | Centre National de Greffe de Moelle Osseeuse, Laboratory Service, Tunis (1998-2007) |
| [64] | 143                  | 58 (40%)  | Charles Nicolle Hospital of Tunis, Tunis (2005-7) |
| [65] | 387                  | 99 (26%)  | Military Hospital of Tunis, Tunis (2011-12)   |
A Purulent skin and soft tissue infection, B Bacteremia, C Random wound and respiratory infections, D Study sites represent 40.7% of all hospital, eds in Lebanon at time of study, E US military personnel in combat support hospital, F 70% of the patients were active-duty service members; the rest were a mix of U.S. Department of Defense civilians and contractors and third country nationals (including India, Pakistan, and Turkey), G Burn patients, H Skin and soft tissue infection (does not specify if purulent vs non-purulent), I Diabetic foot infection, J Surgical wound infection > 48 hours postoperatively, K Neutropenic patients at bone marrow transplant center.
| Ref | Description | Molecular typing (CC, Spa, MLST, PFGE) | Study location (year) |
|-----|-------------|----------------------------------------|-----------------------|
| [12] | 26 MRSA from nasal swabs of outpatients | **CC15** (27%):  
[PVL-] CC15-t084 (7%)  
[PVL-] CC15-V-t084 (7%)  
[PVL-] CC15-t085 (13%)  
**CC8** (13%):  
[PVL-] CC8-V-t008 (13%)  
[PVL-] CC25-t349 (7%)  
[PVL-] CC25-t660 (7%)  
**CC5** (7%):  
[PVL-] CC5-V-t002 (7%)  
[PVL+] CC5-ST80-IVa-t002 (6.7%)  
[PVL+] CC5-ST80-IV (6.7%)  
[PVL+] CC5-IVa-t11841 (6.7%)  | Outpatient clinics, Buraydah city (2011) |
| [16] | 20 MRSA from nasal swabs of healthy volunteers, clinical students, HCWs | **CC80** (20%):  
CC80-ST80-IV-t131 (20%)  
**CC22** (20%):  
CC22-IV-t1328 (20%)  
**CC5** (20%):  
CC5-IV-t688 (20%)  
PFGE F (20%):  
PFGE F-ST6-II-t304 (20%)  
**CC1** (10%):  
CC1-IVa-t128 (10%)  
PFGE K CC88 (10%):  
PFGE K-CC88-IV-t1339 (10%)  | Al-Ahsa (NR) |
| [20] | 18 Nasal, axillary, and groin swabs from ICU inpatients | **ST239** (72%):  
ST239-II-t421 (33%)  
ST239-III-t945 (28%)  
ST239-III-t4410 (6%)  
**ST22** (11%):  
ST22-IV-t223 (6%)  
ST22-IV-t3010 (6%)  
ST97 (11%):  
ST97-IV-t6665 (6%)  
ST97-IV-t1234 (6%)  
**ST80** (6%):  
ST80-IV-t044 (6%)  | Farwania Hospital, Kuwait City (2005-7) |
| [23] | 94 MRSA from nasal swabs of healthy children and parents | **CC22** (76%):  
[PVL-] ST22-IVa-t223 (64%)  
[PVL+] ST22-IVa-t223 (2%)  
[PVL-] ST22-V-t223 (7%)  
**CC78** (7%):  
[PVL-] ST78-V-t223 (7%)  
**CC80** (5%):  
[PVL+] ST80-IVa (4%)  
[PVL+] ST80-IV (1%)  | 12 Gaza neighborhoods and villages, northern and central Gaza (2009) |
| [26] | 37 MRSA from nasal and hand swabs of healthy volunteers | **T9519** (73%):  
[PVL-, Tst1+] IV-t9519 (73%)  
**T233** (14%):  
[PVL-, Tst1+] IV-t233 (14%)  | University of Jordan, Amman, (2009) |
| [27] | 26 MRSA from nasal swabs of healthy volunteers | **CC22** (46%):  
[PVL-, Tst1+] CC22-IV-t223 (39%)  
[PVL-, Tst1+] CC22-IVa-t6397 (4%)  
[PVL-, Tst1+] CC22-IVa-t790 (4%)  
**CC30** (23%):  
[PVL-, Tst1+] CC30-IV-t012 (4%)  
[PVL-, Tst1+] CC30-IVa-t021 (4%)  
[PVL-, Tst1+] CC30-IVa-t253 (4%)  
[PVL-, Tst1+] CC30-IV-t1651 (8%)  | Al-Karak Hospital, Alkarak province (2011-12) |
| Country          | MRSA Isolates | spa Typing | CC Assortment | Predicted MLST | MLST Assortment |
|------------------|---------------|------------|---------------|----------------|-----------------|
| **Egypt**        | 30 MRSA from nasal swabs of HCWs | -           | CC22 (47%): [PVL-, TstI+] CC22-IVa-t223 (40%) [PVL-, TstI+] CC22-IVa-t309 (6.7%) | CC5 (7%): [PVL-, TstI-] CC5-IVa-t10683 (6.7%) | - |
|                  |               |            | CC1 (23%): [PVL-, TstI-] CC1-IVa-t386 (20%) [PVL-, TstI-] CC1-IVa-t693 (3.3%) | CC80 (3%): [PVL+, TstI-] CC80-IVc-t044 (3.3%) | - |
|                  |               |            | CC30 (17%): [PVL-, TstI+] CC30-IVc-t018 (6.7%) [PVL-, TstI+] CC30-IVc-t012 (3.3%) [PVL-, TstI-] CC30-IVa-t021 (3.3%) [PVL-, TstI-] CC30-V-t021 (3.3%) | CC45 (3%): [PVL-, TstI-] CC45-IVc-t370 (3.3%) | - |
| **Egypt**        | 30 MRSA from nasal swabs of HCWs | -           | -             | Singleton t267 (24%): Predicted MLST CC 80 (24%) | - |
|                  |               |            |               | [PVL-, TstI-] t267-IV (10%) [PVL-, TstI-] t267-I (5%) [PVL-, TstI-] t267-IV (5%) [PVL-, TstI-] t14339-I (5%) [PVL-, TstI-] t14339-II (5%) [PVL-, TstI-] t14339-V (5%) [PVL-, TstI+ t14339-V (5%) [PVL-, TstI-] t3689-IV (5%) [PVL-, TstI+ t3689-IV (5%) | - |
| **Egypt**        | 21 MRSA from hands and nasal swabs of HCWs | -           | Spa-CC23 (52%): Predicted MSLT-CC22 (52%): | Singleton t1339 (5%): Predicted MLST-CC80 (5%): | - |
|                  |               |            | [PVL-, TstI-] t223-I (10%) [PVL-, TstI-] t223-NT (5%) [PVL-, TstI+] t223-I (5%) [PVL-, TstI+] t14339-I (5%) [PVL-, TstI+] t14339-II (5%) [PVL-, TstI-] t14339-IV (5%) [PVL-, TstI+] t14339-V (5%) [PVL- TstI-] t3689-I (5%) [PVL-, TstI+] t3689-IV (5%) | [PVL-, TstI-] t1339-IV (5%) [PVL-, TstI-] t1339-V (5%) [PVL-, TstI-] t1339-I (5%) [PVL-, TstI-] t1339-II (5%) [PVL-, TstI-] t1339-IV (5%) [PVL-, TstI-] t1339-V (5%) [PVL-, TstI-] t1339-I (5%) [PVL-, TstI-] t1339-II (5%) |
| **Egypt**        | 33 MRSA from nasal swabs of outpatients | -           | CC5 (30%): [PVL-] CC5-V-t688 (30%) | CC48 (15%): [PVL-] CC48-IVa-t786 (15%) | - |
|                  |               |            | CC30 (20%): [PVL-] CC30-IVa-t021 (10%) [PVL-] CC30-IVa-t318 (10%) | CC22 (10%): [PVL-] CC22-V-t223 (5%) [PVL-] CC22-IVa-t223 (5%) | - |
|                  |               |            | CC80 (15%): [PVL+] CC80-IVa-t044 (5%) [PVL+] CC80-V-t044 (10%) | CC8 (5%): [PVL+] CC8-V-4008 (5%) | - |
| **Egypt**        | 33 MRSA from nasal swabs of outpatients | -           | -             | - | - |
| **Algeria**      | 9 MRSA from nasal swabs of inpatients < 48 hours of admission | -           | ST80 (44%): [PVL+, TstI-] ST80-IVc (33%) [PVL-, TstI-] ST80-IVa (11%) | ST5 (22%): [PVL-, TstI-] ST5-IVc (11%) [PVL-, TstI-] ST5-IVa (11%) | - |
|                  |               |            | ST22 (22%): [PVL-, TstI+] ST22-IVa-t223 (22%) | ST35 (11%): [PVL-, TstI-] ST35-IVh (11%) | - |

**Supplementary table 3.** Molecular Typing of Colonizing MRSA Strains in the MENA Region. Numerical values are rounded to the nearest whole digit.

NR: Not reported. A spa typing, and CC assortment was done for 15 randomly selected isolates out of 26 total MRSA isolates. B spa typing, and CC assortment was done for 15 randomly selected isolates out of 33 total MRSA isolates.
| Ref  | # MRSA | Molecular typing (CC, Spa, MLST, PFGE) | Study location (study date) |
|------|--------|---------------------------------------|----------------------------|
| [66] | 120^A  | **Spa-CC037 (55%):**<br>t037 (35%)<br>t030, t663 (5% each)<br>t631 (3%)<br>t019, t388 (2% each)<br>t138, t459, t748, t932, t1070 (1% each) **Spa-CC790 (8%):**<br>t032, t223 (2% each)<br>t790, t4573, t7604, t8506, t8855 (1% each) **Spa-CC376 (21%):**<br>t044 (19%)<br>t376, t8731 (1% each) **Spa-CC690 (4%):**<br>t690 (2.5%)<br>t729, t8507 (0.8%) | Armed Forces Hospital, Riyadh (2010) |
| [67] | 107    | **CC22 (28%):**<br>[PVL+, Tst-] CC22-IV (19%)<br>[PVL-, Tst+] CC22-IV (6%) **CC8 (21%):**<br>[PVL-, Tst+] CC8-IV (18%)<br>[PVL-, Tst+] CC8-IV (2%) **CC30 (12%):**<br>[PVL+, Tst+] CC30-IV (12%) **CC5 (8%):**<br>[PVL-, Tst+] CC5-IV (3%)<br>[PVL-, Tst+] CC5-IV/SCCfus (2%)<br>[PVL-, Tst+] CC5-IV/SCCfus (1%) **Spa-CC6 (3%):**<br>[PVL+] CC6-IV (3%) **CC88 (3%):**<br>[PVL+, Tst-] CC88-IV (3%) **CC97 (2%):**<br>[PVL-, Tst-] CC97-V (2%) **CC1 (2%):**<br>[PVL-, Tst+] CC1-IV/SCCfus (1%) **CC9 (1%):**<br>[PVL-, Tst+] CC9-ST834-IV (0.9%) **CC45 (1%):**<br>[PVL-, Tst-] CC45-IV (1%) | King Fahad Medical City, Riyadh (NR) |
| [72] | 101    | **CC80 (30%):**<br>[PVL-, Tst+] CC80-IV (30%) **CC6 (13%):**<br>[PVL-, Tst+] CC6-IV (13%) **CC5 (11%):**<br>[PVL-, Tst+] CC5-IV/SCCfus (6%)<br>[PVL-, Tst+] CC5-IV/SCCfus (3%)<br>[PVL-, Tst+] CC5-IV (2%) **CC30 (12%):**<br>[PVL-, Tst+] CC30-IV (12%) **CC22 (10%):**<br>[PVL-, Tst+] CC22-IV (6%)<br>[PVL-, Tst+] CC22-IV (3%)<br>[PVL-, Tst+] CC22-IV (1%) **CC8 (9%):**<br>[PVL-, Tst+] CC8-IV (9%)<br>[PVL-, Tst+] CC8-IV (8%) | Multiple hospitals (n=NS), Jeddah (2009-2011) |
| [38] | 100    | [PVL-] I (3%)<br>[PVL-] II (9%)<br>[PVL-] III (39%)<br>[PVL+] III (8%) | Multiple hospitals (n=5), Makkah city (2012) |
| [68] | 117    | **CC80 (30%):**<br>[PVL-, Tst+] CC80-IV (30%) **CC6 (13%):**<br>[PVL-, Tst+] CC6-IV (13%) **CC5 (11%):**<br>[PVL-, Tst+] CC5-IV/SCCfus (6%)<br>[PVL-, Tst+] CC5-IV/SCCfus (3%)<br>[PVL-, Tst+] CC5-IV (2%) **CC22 (10%):**<br>[PVL-, Tst+] CC22-IV (6%)<br>[PVL-, Tst+] CC22-IV (3%)<br>[PVL-, Tst+] CC22-IV (1%) **CC8 (9%):**<br>[PVL-, Tst+] CC8-IV (9%)<br>[PVL-, Tst+] CC8-IV (8%) | King Khalid University Hospital, Riyadh (2009-15) |
| [37] | 71     | **SCCmec I, II, and III (63%):**<br>[PVL-] I (34%)<br>[PVL-] II (20%)<br>[PVL-] III (10%) **SCCmec IV, V, and NT (37%):**<br>[PVL-] IV (17%)<br>[PVL-] V (10%)<br>[PVL-] V (6%)<br>[PVL-] IV (3%)<br>[PVL-] NT (1%) | Multiple hospitals, Taif city (2013-15) |
Multiple hospitals (n=13), Kuwait (1992-2010)

Multiple hospitals (=7), Kuwait (2001-3)

Multiple hospitals (n=8), Kuwait (2005-6)

Multiple hospitals (n=14), Kuwait (2011-15)

Multiple hospitals (n=10), Kuwait (2005-10)
| CC361 (32%) | CC102 (6%) |
|-------------|-----------|
| PVL-, Tst- | PVL+, Tst+ |
| CC361-V-t3841 (28%) | CC152-V-t355 (3%) |
| CC361-V-t1309 (1%) | CC152-V-t4019 (1%) |
| CC361-V-t15778 (1%) | CC152-V-t11206 (1%) |
| CC361-V-t3175 (1%) | CC152-V-t4019 (1%) |
| CC361-V-t16901 (1%) |
| CC30 (15%) | |
| PVL+, Tst- | CC30-V-t018 (6%) |
| PVL+, Tst- | CC30-V-t012 (1%) |
| PVL-, Tst- | CC30-V-t021 (4%) |
| PVL+, Tst- | CC30-V-t318 (1%) |
| PVL+, Tst- | CC30-V-t018 (1%) |
| PVL-, Tst- | CC30-V-t021 (1%) |
| PVL-, Tst- | CC30-V-t253 (1%) |

| CC22 (13%) | |
|-------------|-----------|
| PVL+, Tst- | CC22-IV-t005 (7%) |
| PVL+, Tst- | CC22-IV-t309 (3%) |
| PVL+, Tst- | CC22-IV-t223 (1%) |
| PVL+, Tst- | CC22-IV-t10659 (1%) |
| PVL-, Tst- | CC22-VI-t16578 (1%) |

| CC1 (11%) | |
|-------------|----------------|
| PVL+, Tst- | CC1-V-t127 (4%) |
| PVL+, Tst- | CC1-V-t2207 (6%) |
| PVL-, Tst- | CC1-pseudoSCCmec-t127 (class B mec) (1%) |

| CC8 (6%) | |
|-------------|----------------|
| PVL- | CC8-V-t008 (5%) |
| PVL- | CC8-V-t211 (1%) |

| CC3 (27%) | |
|-------------|----------------|
| PVL- | ST239-III-t860 (13%) |
| PVL- | ST239-III-t945 (8%) |
| PVL+ | ST239-III-t037 (1%) |
| PVL- | ST239-III-t713 (1%) |
| PVL- | ST239-III-t425 (1%) |
| PVL- | ST239-III-t1247 (1%) |

| CC5 (18%) | |
|-------------|----------------|
| CC5-V+SCCfus (5%) |
| CC5-V+SCCfus (WA-MRSA-14/109) (4%) |
| CC1 (9%) |
| PVL+|CC1-V+SCCfus (4%) |
| CC6 (9%) |
| CC6-V (WA-MRSA-51) (8%) |

| CC22 (9%) | |
|-------------|----------------|
| PVL+, tst+ | CC22-IV (3%) |
| PVL+, tst- | CC22-IV (2%) |

| CC80 (7%) | |
|-------------|----------------|
| PVL- | CC80-IV (7%) |

| CC30 (6%) | |
|-------------|----------------|
| PVL- | CC30-IV (4%) |

| CC97 (3%) | |
|-------------|----------------|
| CC15 (3%) |
| CC152 (2%) |
| CC88 (2%) |
| CC361 (2%) |
| CC2250/2277 (1%) |

| CC45 (1%) | |
|-------------|----------------|
| CC121 (1%) |
| CC59 (1%) |
| Singleton ST2867 (1%) |

| 209C | |
|-------------|----------------|
| PVL- | ST239-III-t860 (13%) |
| PVL- | ST239-III-t945 (8%) |
| PVL+ | ST239-III-t037 (1%) |
| PVL- | ST239-III-t713 (1%) |
| PVL- | ST239-III-t425 (1%) |
| PVL- | ST239-III-t1247 (1%) |

| CC97 (2%) | |
|-------------|----------------|
| PVL-, Tst- | CC97-V-t2297 (1%) |
| PVL-, Tst- | CC97-V-t1359 (1%) |

| CC1153 (1%) | |
|-------------|----------------|
| PVL-, Tst- | CC1153-ND-t504 (1%) |

| CC5 (1%) | |
|-------------|----------------|
| PVL-, Tst- | CC5-V-t1588 (1%) |
| CC6 (1%) | |
| PVL- | CC6-V-t14700 (1%) |
| Singleton (1%) |
| PVL-, Tst- | ST2867-V-t148 (1%) |

| UAE | |
|-------------|----------------|
| Tawam Hospital, Al Ain (2003-8) | |

| Multiple hospitals (n=13), Kuwait (2016) | |
|-------------|----------------|

| 26 (year 2003) | |
|-------------|----------------|
| ST239 (23%) | |
| PVL-, Tst- | ST239-IIIa-t037 (8%) |
| PVL-, Tst- | ST239-III-t037 (8%) |
| PVL-, Tst- | ST239-III-t421 (4%) |
| PVL-, Tst- | ST399a-t421 (4%) |
| ST15 (23%) | |
| PVL-, Tst- | ST5-II-t002 (19%) |
| PVL+, Tst+ | ST5-II-t002 (4%) |

| ST22 (19%) | |
|-------------|----------------|
| PVL-, Tst- | ST22-IV-t032 (19%) |

| ST80 (12%) | |
|-------------|----------------|
| PVL+, Tst- | ST80-IV-t044 (12%) |
| PVL-, Tst- | ST80-IV-t044 (12%) |

| ST88 (8%) | |
|-------------|----------------|
| PVL-, Tst- | ST88-IV-t690 (8%) |
| ST30 (4%) | |
| PVL-, Tst- | ST30-IV-t019 (4%) |

| ST113 (4%) | |
|-------------|----------------|
| PVL-, Tst- | ST113-IVa-t064 (4%) |

| ST779 (4%) | |
|-------------|----------------|
| PVL-, Tst- | ST779-IV-t878 (4%) |
| Country | ST88 (3%): | ST88 (13%): |
|---------|------------|------------|
| Qatar   | ST88 (3%): | ST88 (13%): |
| CO      | ST88 (3%): | ST88 (13%): |

| Country | ST88 (3%): | ST88 (13%): |
|---------|------------|------------|
| Bahrain | ST88 (3%): | ST88 (13%): |
| CO      | ST88 (3%): | ST88 (13%): |

| Country | ST88 (3%): | ST88 (13%): |
|---------|------------|------------|
| Gaza    | ST88 (3%): | ST88 (13%): |
| CO      | ST88 (3%): | ST88 (13%): |

| Country | ST88 (3%): | ST88 (13%): |
|---------|------------|------------|
| Jordan  | ST88 (3%): | ST88 (13%): |
| CO      | ST88 (3%): | ST88 (13%): |
| [47] | 41 | [PVL+] t044 (27%) | [PVL+] t044 (11%) | [PVL+] t037 (11%) | [PVL+] t318 (5%) | [PVL+] t386 (5%) | [PVL+] t1149 (5%) | [PVL+] t701 (3%) | [PVL+] t5849 (3%) | [PVL+] t318 (3%) | [PVL+] t6438 (3%) | [PVL+] t091 (3%) | [PVL+] t6432 (3%) | [PVL+] t012 (3%) | [PVL+] t743 (3%) | [PVL+] t6439 (3%) | [PVL+] t1573 (3%) | [PVL+] t6303 (3%) | [PVL+] t363 (3%) | [PVL+] t159 (3%) | [PVL+] t5802 (3%) | Jordan University Hospital, Amman (2009-10) |
| [81] | 31 | Spa-CC044 MRSA | CC80 (100%): [PVL+, Tst1+] CC80-ST80-IV-t044 (19%) | [PVL+, Tst1+] CC80-ST80-IV-t044 (29%) | [PVL+, Tst1+] CC80-ST80-IV-t044 (19%) | [PVL-, Tst1-] CC80-ST80-IV-t044 (13%) | [PVL+, Tst1+] CC80-ST997-IV-t044 (3%) | [PVL-, Tst1-] CC80-ST080-IV-t131 (3%) | [PVL-, Tst1-] CC80-ST80-IV-t5849 (3%) | [PVL+, Tst1+] CC80-ST80-IV-t6438 (3%) | [PVL-, Tst1-] CC80-ST80-IV-t6432 (3%) | [PVL-, Tst1-] CC80-ST80-IV-t091 (3%) | [PVL-, Tst1-] CC80-ST80-IV-t6432 (3%) | [PVL-, Tst1-] CC80-ST80-IV-t012 (3%) | [PVL-, Tst1-] CC80-ST80-IV-t743 (3%) | [PVL-, Tst1-] CC80-ST80-IV-t6439 (3%) | [PVL-, Tst1-] CC80-ST80-IV-t159 (3%) | [PVL-, Tst1-] CC80-ST80-IV-t5802 (3%) | | Jordan University Hospital, Amman (2000-11) |
| [48] | 93 | CC80 (55%): [PVL+] ST80-IV-t044 (53%) | [PVL+] ST80-IV-t131 (2%) | CC8 (15%): [PVL+] ST239-III-t037/t030 (11%) | [PVL+] ST3-IVc-t008 (4%) | CC97 (4%): [PVL+] ST-IVc-t267 (4%) | [PVL+] ST6-IVc-t304 (3%) | [PVL+] ST4-IVc-t222 (2%) | [PVL+] ST-IVc-t318 (1%) | American University of Beirut Medical Center, Beirut, Lebanon. (2006-7) |
| [81] | 63 | Spa-CC044 | CC80 (100%): [PVL+, Tst1+] ST80-IV-t044 (79%) | [PVL+, Tst1+] ST80-IV-t044 (6%) | [PVL+, Tst1+] ST80-IV-t131 (8%) | [PVL+, Tst1+] ST80-IV-t4222 (2%) | [PVL+, Tst1+] ST80-IV-t6438 (2%) | [PVL+, Tst1+] ST80-IV-t643 (2%) | [PVL+, Tst1+] ST80-IV-t021 (2%) | [PVL+, Tst1+] ST80-IV-t9135 (2%) | American University of Beirut Medical Center, Beirut, Lebanon. (2000-11) |
| [74] | 182 | USA300 (80%): [PVL+] IV (78%) | [PVL+] MB (2%) | [PVL+] IV (1%) | [PVL+] NT (3%) | [PVL+] IV (1%) | [PVL+] IV (3%) | USA1100 (4%): [PVL+] IV (3%) | USA400 (2%): [PVL+] IV (2%) | USA800 (1.6%): [PVL+] IV (2%) | USA1000 (1%): [PVL+] IV (1%) | CSH1, CSH2, CSH3, CSH6, CSH9, CSH10, and CSH11 (1% each): [PVL+] IV (4%) | CSH4 (0.5%), CSH5 (2%), CSH7 (1%) | [PVL+] III (3%) | [PVL+] III (1%) | CSH8 (1%): [PVL+] I (1%) | CSH5 (1%): [PVL+] NT (1%) | Multiple combat support hospitals (n=3), Baghdad and Al Anbar province (2007-9) |
| [55] | 12 | - | - | - | - | - | - | - | - | - | Suez Canal University, Ismailia (2013) |
| [56] | 18 | CO | - | - | - | - | - | - | - | - | Alexandria University, Alexandria (NR) |
| [54] | 18 | [PVL+] II (33%) | [PVL+] IVd (11%) | [PVL+] III (11%) | [PVL+] IV (11%) | [PVL+] NT (11%) | [PVL+] IVa (6%) | [PVL+] IVd (6%) | [PVL+] IV (6%) | [PVL+] IVc (6%) | University Hospital and Diagnostic Laboratories, Zagazig and Assuit (2010-12) |
### Algeria

| [58] | 92 | **CC8 (78%):**  
|      |    | [PVL+] ST239-III-t037 (43%)  
|      |    | [PVL+] ST239-III-t032 (35%)  
|      |    | **CC80 (21%):**  
|      |    | [PVL+] ST80-IVc-t044 (21%)  
|      |    | **CC22 (1%):**  
|      |    | [PVL+] ST22-IVc-t005 (1%)  
|      |    | Annaba Hospitals, Annaba (2010)  
| [59] | 15 HOF | **ST80 (100%):**  
|      |    | [PVL+] ST80-IVc (100%)  
|      |    | Beni Moussous University Hospital, Algiers (2010-11)  
|      | 10 COF | **ST80 (90%):**  
|      |    | [PVL+] ST80-IVc (70%)  
|      |    | [PVL+] ST80-IVc (20%)  
|      |    | **ST39 (10%):**  
|      |    | [PVL+] ST39-IVc (10%)  
|      |    | Mustapha Ba’ha University Hospital, Algiers (2006-7)  
| [61] | 84 COFG | **ST80 (97%):**  
|      |    | [PVL+] ST80-IV-t044 (85%)  
|      |    | [PVL+] ST80-IV-t4143 (3%)  
|      |    | [PVL-] ST80-IV (3%)  
|      |    | **ST241 (3%):**  
|      |    | [PVL-] ST241-III (3%)  
|      |    | Didouche Mourad Hospital, Constantine Province (2005-7)  
| 137 HOFG | **ST80 (77%):**  
|      |    | [PVL+] ST80-IV-t044 (75%)  
|      |    | [PVL-] ST80-IV (2%)  
|      |    | **ST39 (10%):**  
|      |    | [PVL+] ST39-II (10%)  
|      |    | **ST5 (11%):**  
|      |    | [PVL+] ST5-IV (11%)  
|      |    | University Hospital Ibn Rochd, Annaba (2011-12)  
| [76] | 64 | -  
|      |    | -  
|      |    | Didouche Mourad Hospital, Constantine Province (2005-7)  
| [75] | 84 | **ST80 (86%):**  
|      |    | [PVL+] ST80-IV (59%)  
|      |    | [PVL+] ST80-IVc (2%)  
|      |    | **ST239 (8%):**  
|      |    | [PVL+] ST239-III (8%)  
|      |    | Bolghine Ibn Ziri University Hospital, Algiers (2006-11)  
| [60] | 73H | **ST239 (82%):**  
|      |    | [PVL+] ST239 (82%)  
|      |    | University Hospital Ibn Rochd, Annaba (2011-12)  

### Tunisia

| [64] | 58 | -  
|      |    | -  
|      |    | Charles Nicolle Hospital, Tunis (2005-7)  
| [65] | 24 | **tetracycline-resistant**  
|      |    | **CC8 (79%):**  
|      |    | [PVL-, Tst1-] ST247-t052 (50%)  
|      |    | [PVL-, Tst1-] ST239-t037 (21%)  
|      |    | [PVL-, Tst1-] ST239-t14712 (4%)  
|      |    | [PVL-, Tst1-] ST241-t129 (4%)  
|      |    | **CC80 (8%):**  
|      |    | [PVL+, Tst1+] ST728-t044 (4%)  
|      |    | [PVL+, Tst1+] ST728-t044 (4%)  
|      |    | Military Hospital of Tunis, Tunis (2011-12)  
| [77] | 28 COF | **CC80 (86%):**  
|      |    | [PVL+] ST80-IVc (60%)  
|      |    | [PVL+] ST80-IVc (4%)  
|      |    | [PVL+] ST80-NT (7%)  
|      |    | [PVL+] ST153-IVc (4%)  
|      |    | [PVL+] ST153-NT (4%)  
|      |    | [PVL+] ST2563-IVc (4%)  
|      |    | [PVL+] ST80-IVc (7%)  
|      |    | Habib Bourguiba Hospital and Charles Nicolle Hospital, Tunis (2004-8)  
| 41 HOF | **CC80 (51%):**  
|      |    | [PVL+] ST80-IVc (49%)  
|      |    | [PVL+] ST80-IVc (2%)  
|      |    | **CC8 (32%):**  
|      |    | [PVL+] ST239-III (10%)  
|      |    | [PVL+] ST241-III (7%)  
|      |    | [PVL+] ST247-I (7%)  
|      |    | [PVL+] ST1819-I (7%)  
|      |    | [PVL+] ST2563-IVc (4%)  
|      |    | [PVL+] ST2563-IVc (4%)  

### Supplementary Table 4.

Molecular Typing of Infective MRSA Isolates in the MENA Region.

CO: CO-MRSA; HO: HO-MRSA; NR: not reported; NT: not typeable; S-: singleton; Spa-CC: spa cluster. When a sample is not designated “CO” or “HO” it indicates that the study does not distinguish site of acquisition. Values were rounded to the nearest whole number.

A 60 cancer and 60 noncancer patients, B Percentages for each spa type was not provided in the study, C In this study only 120 from the 209 isolates underwent DNA microarray analysis; these isolates represented the 56 spa types found. The MLST types were only reported for CC8 and S-ST2867. D Isolates from USA service members deployed to Iraq. Sixteen strains displayed 11 unique pulsotypes not previously described and were labeled CSH1-CSH11. E subjects were neonates. In this study, outpatients and inpatients <48 hrs from admission were considered CO-MRSA while inpatients >48 hrs. post admission were HO-MRSA. Other epidemiological risk factors for HO-MRSA were not specified.
This study distinguished between CO-MRSA and HO-MRSA by the epidemiological criteria specified in text, spa typing was done for 46 PVL [-+] isolates only and revealed only 2 spa types: t044 and t4143. Diabetic foot infections, Criteria used to distinguish between HO-MRSA and CO-MRSA is not specified.
| Country       | Ref (date) | MRSA | Rif | FA | Cl | TS | Cip | Tet | Dox | EM | Vanc | Lin | Teic | Dap | Mup | Gen |
|--------------|------------|------|-----|----|----|----|-----|-----|-----|----|------|-----|------|-----|-----|-----|
| Oman         | [21, 22] (NR) | 34 CV | 100 | -  | 76 | -  | -   | -   | 88  | 50 | 88   | 100 | 82   | -   | -   | -   |
| Oman         | [21, 22] (NR) | 49 HCW | 96  | -  | 65 | -  | -   | -   | 92  | 51 | 88   | 100 | 84   | -   | -   | -   |
| KSA          | [12] (2011) | 26 OP CO² | 96  | -  | 89 | 54 | 100 | -   | -   | 42 | 96   | -   | -    | -   | -   | 73  |
| KSA          | [14] (2014-15) | 48 IP | 58  | -  | 13 | 33 | 12  | 29  | -   | 15 | 98² | 67  | 54   | -   | -   | 92  |
| KSA          | [19] (2012-14) | 36 HCWs | -   | -  | 3  | 83 | 83  | 69  | -   | 3  | 100³ | 100 | -    | -   | -   | -   |
| Oman         | [21, 22] (NR) | 8 CV  | -   | -  | -  | 100 | 100 | -   | -   | 100| -   | -    | -    | -   | 100 | 100 |
| KSA          | [19] (2012-14) | 51 HCW | 88% | -  | 86%| -   | 88% | 86.3%| -  | 65%| 84% | -    | -    | -   | 92% | -   |
| Jordan       | [27] (2011-12) | 26 CV | 100 | 96 | 100 | -   | 100 | -   | -   | 42 | 100 | 100  | 100  | 100 | 100 | 100 |
| Jordan       | [27] (2011-12) | 30 HCW | 100 | 90 | 90  | -   | 93  | -   | -   | 42 | 100 | 100  | 100  | 100 | 100 | 100 |
| KSA          | [85] (2004-5) | 397 NS | -   | 4  | -  | 21  | -   | -   | -   | -  | 100³ | 97  | -    | 74  | 30  |
| KSA          | [85] (2004-5) | 115 NS | -   | 6  | -  | 77  | -   | -   | -   | -  | 100³ | 91  | -    | 89  | 74  |
| KSA          | [66] (2010) | 120 NS | 68  | 45 | 57  | 2   | -   | -   | -   | 38 | 100 | -    | -    | -   | 68  | -   |
| KSA          | [72] (2009-11) | 101 NS | 87  | 71 | 67  | -   | 62  | 57  | -   | 56 | 100 | 83   | 88   | -   | 88  | 71  |
| Kuwait       | [84] (2011-13) | 6,922 NS | 99  | 59 | 58  | 66  | 57  | 61  | -   | 58 | 99³ | 100  | 97   | -   | 95  | 61  |
| Kuwait       | [71] (2016) | 1,327 NS | 100 | 53 | 60  | 60  | 61  | 68  | -   | 60 | 100³ | 100  | 100  | -   | 96  | -   |
| Kuwait       | [7] (2016) | 209 NS | 100 | 36 | 48  | 55  | 50  | 45  | -   | 48 | 100³ | 100  | 100  | -   | 98  | 45  |
| Oman         | [43] (2016-17) | 733 NS | -   | 78 | 94  | 69  | -   | -   | 71  | 100| -    | -    | -    | 85  | -   | -   |
| Bahrain      | [6] (2005) | 53 NS | 100 | 8  | 13  | 11  | 8   | 11  | -   | 9  | 100³ | 100  | 100  | -   | 89  | 26  |
| Lebanon      | [79] (2011) | 39 NS | 100 | 87 | 97  | 87  | 69  | -   | 80 | 100 | -    | 100  | -    | -   | -   | -   |
| Gaza         | [45] (2008-12) | 121 NS | 92  | -  | 77 | 80  | -   | 68  | -   | 71 | 100 | 100  | 100  | 100 | 100 | 80  |

**Colonizing MRSA strains**

**Infective MRSA Strains**
Jordan\textsuperscript{A} (2008-12) | 113 NS | 86 - 55 58 - 58 - 23 100 97 97 - - 47

Iraq\textsuperscript{NS} (2007-9) | 182 NS\textsuperscript{H} | 95 - 77 91 - 91 - 10 100 96 - - - 87

Iraq\textsuperscript{NS} (2005-9) | 303 NS\textsuperscript{H} | 91 - 75 91 49 80 - 15 100 - - - 89

Iraq\textsuperscript{A} (2008) | 15 NS\textsuperscript{H} | 100 - 87 100 73 - - 13 - - - -

Egypt\textsuperscript{A} (2005-13) | 21 CO\textsuperscript{I} | 86 - 100 81 91 14 81 100 - - - - 91

Egypt\textsuperscript{A} (2005-13) | 343 HO\textsuperscript{I} | 80 - 44 83 30 16 36 100 - - - - 19

Algeria\textsuperscript{A} (2006-11) | 84 NS | 100 46 91 76 - 85 42 - 100 - 100 - -

Algeria\textsuperscript{A} (2010-11) | 10 CO\textsuperscript{I} | 100 - 80 100 70 40 - 70 100 100 100 - - 100

Algeria\textsuperscript{A} (2010-11) | 15 HO\textsuperscript{I} | 100 - 93 100 87 13 - 73 100 100 100 - - 100

Algeria\textsuperscript{A} (2007-9) | 165 HO\textsuperscript{I} | - - 88 - - - - 44 98\textsuperscript{D} - - - - 70

Tunisia\textsuperscript{A} (2004-8) | 69 NS | 80 - 84 91 59 17 - 48 100 100 - 100 - - 74

**Supplementary table 5.** Antimicrobial Susceptibility Profile of MRSA Isolates in the Arab World. Presented values are percentages of tested isolates. Infective isolates are labeled as CO-MRSA or HO-MRSA when specified by the cited study, otherwise they are labeled as Not specified. Cip: ciprofloxacin; Cl: clindamycin; CO: community-onset MRSA; CV: community volunteers; Dapt: daptomycin; EM: erythromycin; FA: fusidic acid; Gen: gentamicin; HCWs: health-care workers; HO: hospital-onset MRSA; IP: inpatient; Lin: linezolid; Mup: Mupirocin; NR: not reported; NS: not specified; OP: outpatients; Rif: Rifampicin; Tet: tetracycline; Teic: teicoplanin; TS: trimethoprim-sulfamethoxazole; Vanc: vancomycin.

\textsuperscript{A} Antibiotic susceptibility testing (AST) by standard agar disk diffusion methodology according to clinical and laboratory standards institute guidelines. \textsuperscript{B} CO-MRSA by epidemiological criteria described in text. \textsuperscript{C} Non-susceptible strain identified as Vancomycin intermediate \textit{S. aureus} (VISA). \textsuperscript{D} AST determined using the VITEK-2 system. \textsuperscript{E} AST to this antibiotic was tested via E-test method. \textsuperscript{F} AST by standard agar disk diffusion and interpretation according to British society for antimicrobial chemotherapy method. \textsuperscript{G} AST for 2003 done with VITEK2 system, AST for 2012 done with MicroScan WalkAway Plus System (Siemens Healthcare, Erlangen, Germany). \textsuperscript{H} Combat support hospitals. \textsuperscript{I} CO-MRSA was defined as infection diagnosed < 2-3 days from admission, and HO-MRSA >2-3 days from admission. \textsuperscript{J} Non-susceptible isolates identified as vancomycin resistant \textit{S. aureus} (VRSA) as opposed to VISA.
**Supplementary Figure 1.** Illustrates how different typing techniques can be grouped together into a clonal complex.

**Interconnection Between the Various Molecular Typing Techniques.**

- One *spa* type can have multiple SCCmecs. One *spa* type can belong to multiple STs and multiple clones but only 1 clonal complex (CC).
- One ST can have multiple *spa* types and SCCmecs. One ST can belong to multiple clones but only 1 CC.
- Clone nomenclature depends on ST + SCCmec combination. Therefore, one clone can have only 1 ST and SCCmec combination. One clone can belong to only 1 CC.
- The highest level of classification is the CC. One CC can have multiple clones, STs, *spa* types and SCCmecs.