

1-6-2010

When are the hands of healthcare workers positive for methicillin-resistant *Staphylococcus aureus*?

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Citation

Creamer E, Dorrian S, Dolan A, Sherlock O, Fitzgerald-Hughes D, Thomas T, Walsh J, Shore A, Sullivan D, Kinnevey P, Rossney AS, Cunney R, Coleman D, Humphreys H. When are the hands of healthcare workers positive for methicillin-resistant *Staphylococcus aureus*? *Journal of Hospital Infection*. 2010;75(2):107-11.

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1 **When are the hands of healthcare workers positive for**
2 **methicillin-resistant *Staphylococcus aureus*?**

3
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21 **Keywords:** MRSA screening, staff hand sampling, hand hygiene agents, hand hygiene
22 occasions

23 **Running Title: Sampling HCWs hands for MRSA**

24

25 **Summary**

26 Hand hygiene is a key component in reducing infection. There are few reports on the
27 prevalence of methicillin-resistant *Staphylococcus aureus* (MRSA) on healthcare
28 workers' (HCWs) hands. The aim of this study was to establish if HCWs fingertips were
29 contaminated with MRSA in a clinical hospital setting. The study was conducted in an
30 acute tertiary referral hospital on four MRSA wards that were part of a larger research
31 study on MRSA epidemiology and four other wards not included. The fingertips from all
32 categories of 523 HCWs were sampled on 822 occasions by the imprinting of fingertips
33 on MRSA chromogenic agar plates. The type of hand hygiene agent used, if any, and the
34 immediate prior activity of the HCW were recorded. Overall, 38/822 (5%) fingertips
35 from 523 HCWs were MRSA-positive; 12/194 (6%) after clinical contact, 10/138 (10%)
36 after contact with the patient's environment and 15/346 (4%) after no specific contact.
37 MRSA was recovered on 2/61 (3%) occasions after use of alcohol hand rub, 2/35 (6%)
38 after 4% chlorhexidine detergent, 7/210 (3%) hand washing with soap and water, and
39 27/493 (5%) when no hand hygiene had been performed. MRSA was recovered from
40 HCWs on seven of the eight wards. MRSA was more frequently present on fingertips on
41 the four non-study wards *versus* the four MRSA-study wards, 18/250 (7%), 3/201 (1%),
42 respectively, $p < 0.004$). The isolation of MRSA from HCWs fingertips, including after
43 hand hygiene, indicates that more educational programmes are necessary to improve the
44 quality of hand hygiene to prevent transmission of MRSA.

45

46 **Introduction**

47 Hand hygiene is one of the most important elements in preventing infection and the
48 frequency and technique are important.^{1,2,3} Previous reports have largely concentrated on
49 hand hygiene compliance and the *in vitro* effectiveness of hand hygiene agents, but there
50 are few reports on the effectiveness of hand hygiene in eradicating nosocomial
51 pathogens in a clinical setting. While the carriage of MRSA on the hands of healthcare
52 workers (HCWs) has been reported as part of the wider investigation of MRSA,⁴⁻⁷ few
53 studies have investigated the prevalence of MRSA on hands in clinical practice.^{8,9}

54

55 Hand hygiene campaigns and education result in improved hand hygiene and a decrease
56 in cross contamination with MRSA,¹⁰ but sustained improvement is difficult to
57 achieve.^{11,12} The aim of this study was to investigate MRSA hand carriage on all
58 categories of HCWs associated with hand hygiene occasions and also with other non-
59 specific occasions in a hospital where MRSA is endemic. In addition, the hand hygiene
60 agent used was recorded.

61

62 **Materials and methods**

63 *Setting and participants:* The study was conducted in an adult 700-bed tertiary referral
64 hospital on four wards that were part of a wider programme of research on MRSA
65 (MRSA study wards) and four non-study wards. This research programme includes
66 assessing the value of near universal screening for MRSA, the level of MRSA
67 contamination, the use of PCR for rapid diagnosis and the contribution of enhanced

68 environmental decontamination to reduce MRSA. The eight wards included in this study
69 of MRSA hand carriage were four medical and four surgical wards that were considered
70 representative of the hospital. The study was conducted in two phases; phase one was
71 conducted on one ward (MRSA study ward) over a five-week period as an initial test
72 ward and phase two was conducted eight months later over a four-week period on eight
73 wards (seven other wards plus repeat sampling on the initial study ward).

74

75 All wards, except one 29 bed ward, had up to 35 beds and consisted of a mixture of two,
76 four, and six-bedded bays and five single rooms for isolation or other segregation
77 purposes. None of the single rooms had negative-pressure ventilation or an ante room to
78 carry out hand hygiene and don personal protective equipment before entering. Wash
79 hand sinks were available at each of the two, four and six-bedded bays, and in four of the
80 five single rooms on each ward. Alcoholic hand rub dispensers were placed at each hand
81 wash sink and outside single rooms, and also inside and outside the entrance doors to
82 each ward. It is not hospital policy to issue individual alcohol hand gel to HCWs.

83

84 Ethical approval was obtained from the hospital's ethics committee on condition that
85 participation was voluntary, anonymous and that HCWs were given written and verbal
86 information about the study. All categories of staff, i.e. medical, nursing, care assistants,
87 support and allied health professionals were eligible to participate and HCWs could
88 participate more than once provided that the hand hygiene occasions were different. A
89 written report of each ward's results were provided to individual wards and also to the
90 hospital's infection prevention and control team (IPCT). MRSA is endemic in the

91 hospital, with 645 new MRSA cases per 21 883 (3%) hospital admissions during the
92 study period.

93

94 ***Sampling procedure:*** Hand sampling involved imprinting the tips of all fingers and
95 thumbs of both hands on one MRSA Select chromogenic agar plate (Bio-Rad Life
96 Science Group, France). Standard laboratory procedures were used for processing
97 samples and for the confirmation of MRSA (i.e. detection of coagulase and oxacillin
98 resistance). During phase two, 7/8 wards were sampled twice, once at 9.30 h and once at
99 14.00 h, on different days. Sampling was conducted by two researchers for approximately
100 1-2 hours per session, obtaining approximately 50 samples on each ward. The initial
101 phase 1 ward was re- sampled once. No neutralizing solution was used to negate the
102 antimicrobial effects of hand hygiene agents.

103

104 ***Hand hygiene occasions:*** The occasions for hand hygiene that were recorded were
105 derived from CDC and national guidelines on hand hygiene^{1,2,3} and were as follows:

- 106 • Before social hand contact with patients
- 107 • After social hand contact with patients
- 108 • Before clinical contact with patients
- 109 • After clinical contact with patients
- 110 • Before entering an isolation room
- 111 • After leaving an isolation room

112 • After contact with ward equipment or the environment

113 In addition, activities associated with hand hygiene and the hand hygiene agent used
114 (e.g. soap and water, alcohol hand rub, 4% chlorhexidine detergent), and if no hand
115 hygiene was performed, were recorded. Data were also recorded if there was contact
116 with a known MRSA patient or the patient's equipment or if contact with the
117 environment had occurred before hand sampling.

118

119 ***Hand hygiene educational intervention:*** Due to what was considered a high prevalence
120 of MRSA on HCWs hands during the first two weeks of phase one on one ward, an
121 educational intervention was deemed necessary. Screening ceased for one week when
122 this occurred, thereafter, sampling was completed in two weeks. This educational
123 intervention was conducted by the IPCT and involved six hand hygiene training sessions,
124 including demonstration of the steps of handwash technique,² advice on the occasions
125 for hand hygiene and the use of appropriate hand hygiene agents. HCWs on that ward
126 performed hand hygiene under observation and used both GloGerm™ cream (UV
127 Systems PLC, UK) and a fluorescent light box, that highlights the effectiveness of
128 removal of the hand hygiene agent.

129

130 ***Statistical analysis:*** Statistical analysis was performed using Epi Info 6 (version 6.04c;
131 Centers for Disease Control and Prevention, Atlanta, GA). Odds ratios were calculated.
132 The Mantel-Haenszel chi-square method was used to assess the significance of the
133 difference between proportions.¹³

134

135 **Results**

136 MRSA was recovered from 38/822 (5%) fingertips from 523 HCWs during both phases
137 of the study (Table 1). MRSA was isolated, 12/194 (6%) after clinical contact, 10/138
138 (10%) after contact with the patient's environment and 15/346 (4%) after no specific
139 contact. MRSA was isolated from 11/329 (3%) fingertips when hand hygiene was
140 performed, but 27/493 (5%) when no hand hygiene was used. MRSA was less frequently
141 recovered after use of alcohol hand rub, 1/59 (2%), than after 4% chlorhexidine
142 detergent, 2/35(6%), or after hand washing with soap and water, 7/210 (3%). MRSA was
143 recovered from fingertips following 10/138 (7%) environmental contacts. In nine of these
144 10 cases, hand hygiene had not been performed; on the other occasion, alcohol hand rub
145 and soap and water handwash combined, had been used. MRSA was not recovered after
146 contact with equipment or the environment of known MRSA-positive patients.

147

148 MRSA was not recovered on the 21 occasions when HCWs used gloves with or without
149 hand hygiene. The fingertips of 27/493 (5%) HCWs were positive for MRSA when no
150 hand hygiene had been performed before sampling *versus* 11/329 (3%) when hand
151 hygiene or gloves were worn. On four of 30 (13%) hand hygiene occasions, fingertips
152 were positive for MRSA following hand hygiene after contact with known MRSA
153 patients; 4% chlorhexidine detergent had been used on two occasions and soap and water
154 on the other two. Of the 26 occasions that were MRSA-negative after contact with known
155 MRSA patients, one HCW had used alcohol hand rub, one alcohol and soap and water,

156 ten soap and water, four gloves only, seven 4% chlorhexidine detergent and three had not
157 performed any hand hygiene.

158

159

160 ***Phase one study***

161 MRSA was recovered from HCWs fingertips 17/371 (5%) occasions on one medical
162 ward over a five-week period. After MRSA was recovered from HCWs at a higher than
163 anticipated frequency during the first two weeks, sampling ceased to facilitate an
164 educational intervention. MRSA was recovered from 11/182(6%) of HCWs fingertips
165 during the pre-education intervention and 6/189 (3%) after the intervention. Repeat
166 sampling on this ward during phase two, eight months later, did not reveal MRSA on
167 fingertips of any HCWs.

168

169 ***Phase two study***

170 Phase two took place eight months after phase one. MRSA was recovered on 21/451
171 (5%) hand hygiene occasions from HCWs fingertips on eight wards. MRSA was
172 recovered more frequently, 14/214 (7%) on medical than 7/235 (3%) on surgical wards,
173 OR 2.26 (95% CI 0.83-6.31), $p < 0.08$. MRSA was recovered more frequently from the
174 fingertips on the four wards not included in the larger MRSA research study, 18/250
175 (7%), *versus* the four MRSA study wards, 3/201 (1%), OR 5.12 (95% CI 1.40-20.18),
176 $p < 0.004$. MRSA was recovered less frequently, 7/231 (3%) when sampled at 09:30 h
177 than 14/220 (6%) at 14:00 h (OR 0.46 (95%CI 0.16-1.25), $p = 0.09$).

178 The number of occasions when MRSA was recovered from the fingertips of HCWs and
179 the number of MRSA-positive patients present on each of the eight wards are shown in
180 Figure 1. During the sampling phase, there were 42 MRSA-positive patients on the 8
181 wards; 23 on the MRSA study wards (17 in single rooms, 6 cohorted) and 19 on the non-
182 study wards (7 in single rooms, 12 cohorted). Two wards with long-stay patients, one
183 medical study ward (10) and the other a medical non-study ward (8), had MRSA-
184 positive patients both isolated and cohorted.

185

186 **Discussion**

187 The recovery rate of MRSA from HCWs fingertips after contact with patients and their
188 environment, and also when HCWs were not engaged in clinical contact, is of concern as
189 there is a risk of transmission of MRSA and other pathogens from HCWs to patients, if
190 hands are not adequately decontaminated. However, it is not clear if this rate of MRSA
191 carriage is above or below what might be expected in a clinical environment where
192 MRSA is endemic, as few if any similar studies have been undertaken.

193

194 MRSA was recovered after hand hygiene, including in two instances, after using 4%
195 chlorhexidine detergent, presumably due to poor hand hygiene technique. MRSA was
196 recovered on 3% of occasions after hand washing with soap and water. Previous reports
197 have highlighted the inadequacy of soap and water to remove MRSA,¹⁴ and also the
198 superiority of alcohol hand rub.¹⁵ Damp hands have been reported as associated with
199 higher contamination of hands.¹⁶ Hand sampling took place during the present study,

200 immediately after hand washing and drying when hands may not have been adequately
201 dried, and this may partly explain the higher recovery of MRSA after washing hands.
202 Despite the availability of alcohol hand rub throughout the wards, only 63 HCWs used
203 alcohol hand rub in contrast to 210 that used soap and water. Promotion of the use of
204 alcohol hand rub when appropriate could possibly result in reduced contamination with
205 MRSA.

206

207 Bacterial hand contamination has been reported as higher following clinical activities
208 compared with non-clinical activities (i.e. entering wards, reviewing patient notes,
209 administrative work, etc),¹⁷ and this is consistent with our findings of 6% after clinical
210 contact and 4% after no specific contact. The contamination of fingertips after reported
211 ‘no specific contact’, indicates possible contamination of the administrative areas, e.g.
212 desks, telephones, etc. or because HCWs may have incorrectly indicated that they had no
213 specific contact with a patient or the environment, as they did not remember their last
214 hand hygiene occasion.

215

216 The survival times of staphylococci on objects and the environment has been reported as
217 ranging from days to months^{18,19} and MRSA has been isolated from patient charts and
218 computer keyboards.²⁰⁻²² Even when HCWs are not in contact with patients or their
219 immediate environment, hand hygiene is necessary when entering and leaving wards or
220 other clinical areas to reduce transient carriage of MRSA on hands.

221 A number of studies have shown that the patient environment is frequently contaminated
222 and therefore a risk for transmission of MRSA.^{23,24} The recovery of 7% of MRSA from
223 HCWs fingertips after contact with the environment, not associated with MRSA isolation
224 rooms, may indicate un-identified MRSA patients in the ward or environmental
225 reservoirs and the need for enhanced environmental decontamination. It may also suggest
226 that MRSA is easier to recover from the fingertips following contact with the
227 environment, than from the actual environment itself.

228

229 MRSA was not recovered following the hand hygiene occasions when gloves had been
230 worn. Gloves have been found to confer protection against bacterial carriage,²⁵ although
231 there is report of a 3% MRSA carriage rate when hands were sampled after the removal
232 of gloves.²⁶

233

234 Our findings confirm other reports of hand contamination following clinical contact with
235 patients and their immediate environment,²⁵ but also highlights the additional risk of
236 HCW hand contamination when not directly involved in patient care. MRSA was not
237 recovered after social hand contact (i.e. non-clinical contact, but touching the patient such
238 as when shaking hands), possibly because HCWs attending patients had conducted hand
239 hygiene after their last clinical contact. While not statistically significant, less MRSA was
240 recovered from fingertips in the morning (3%), than in the afternoon (6%), suggestive
241 that repeated exposure to MRSA and inadequate hand hygiene throughout shifts may lead
242 to more hand contamination.

243

244 There was less MRSA following the education intervention on one ward during phase
245 one but this did not completely eliminate MRSA hand carriage. However, eight months
246 later, no MRSA was found on HCWs fingertips on that same ward, suggesting sustained
247 improved hand hygiene practice. It may also indicate that the sampling of HCW hands
248 may be an alternative method of creating awareness and improving compliance, as well
249 as conventional approaches such as observation of practice, education and posters on
250 hand hygiene. MRSA was more frequently recovered from HCWs fingertips on medical
251 wards, 7%, compared to 3% on surgical wards, as has been reported elsewhere,¹⁵ but this
252 difference was not statistically significant. This may have been related to greater
253 exposure of HCWs to MRSA patients on medical wards, with more long-stay patients
254 than surgical wards. Significantly more MRSA was recovered from the fingertips on non-
255 study wards, indicating, perhaps, that the research created a heightened awareness on the
256 study wards and may have led to improved professional practice. In addition, the number
257 of MRSA patients on wards was not a predictor for increased MRSA from fingertips, as
258 less MRSA was recovered on the study wards where more MRSA patients were
259 isolated/cohorted than on the non-study wards.

260

261 There are a number of limitations to this study. In laboratory processing, no neutralizing
262 solution was used to inactivate residual antimicrobial compounds from the hand hygiene
263 agents. These compounds could have been carried over on to the agar plate and may have
264 potentially led to some false-negative results, particularly in relation to the
265 chlorohexidine scrub. As such, the figures relating to MRSA recovery after hand hygiene

266 agents were used, may have been an underestimation. The sampling of hands is often
267 conducted by the ‘glove juice’ method, with volunteers immersing hands in sterile gloves
268 containing sterile liquid media.⁸ This method samples the whole hand surface, not just the
269 fingertips, and also allows for quantitation of the bacteria isolated. The imprinting of
270 fingertips on to agar plates has been reported elsewhere,¹⁵ and is convenient when taking
271 relatively large numbers of samples over a short period of time on each ward, as was the
272 case in this study. While, only fingertips were cultured in our study, the 5% MRSA
273 recovery rate may be an underestimation of MRSA hand carriage rate. However, this rate
274 is similar to other reports when the ‘glove juice’ method was used, with a rate of 3%,⁸
275 and also when individual fingertips were sampled.²⁶ The presence of researchers on the
276 ward had the potential to alter hand hygiene behaviour and therefore as suggested these
277 results may well be conservative.^{15,27} Also, as the study was both voluntary and
278 confidential, we were unable to identify the categories of HCWs with a higher carriage.
279 Some HCWs probably provided multiple samples but we were unable to derive a HCW
280 carriage rate rather than a sample positivity rate due to the conditions required for
281 institutional ethical approval. The study was conducted exclusively during day time and
282 not during the evening or at night when levels of hand hygiene and rates of MRSA
283 carriage may be different. In addition, it was not possible to establish if transmission of
284 MRSA from HCW hands to patients occurred.

285

286 HCWs in our institution receive training for their roles and responsibilities and one of the
287 most important components of this is hand hygiene. It is mandatory that as part of all
288 medical and healthcare training programmes, hand hygiene skills are part of the formal

289 assessment to practice.^{1,2,3} If a decrease in MRSA hand carriage is to be achieved, hand
290 hygiene technique must be adequate, and all patient, environmental and administrative
291 contacts should be considered potentially hazardous.

292 **Acknowledgements:** We wish to acknowledge the enthusiasm and support of all staff on
293 the wards where we sampled. We are grateful to the RCSI Summer Student Programme
294 for support and to the Health Research Board, (TRA/2006/4), Ireland, for the funding of
295 our research programme.

296

297 **Conflict of interest:** None declared

298

299 **References**

300 1. World Health Organisation (WHO), *WHO Guidelines on Hand Hygiene in Health Care: First*
301 *Global Patient Safety Challenge, Clean Care is Safer Care*. World Health Organisation 2009,
302 Geneva, Switzerland. http://whqlibdoc.who.int/publications/2009/9789241597906_eng.pdf
303 (accessed Oct. 26, 2009).

304

305 2. Boyce JM, Pittet D. Guideline for Hand Hygiene in Health-Care Settings: recommendations of
306 the Healthcare Infection Control Practices Advisory Committee and the
307 HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *MMWR* 2002;51:RR-16.

308

309 3. SARI Infection Control Sub-committee. *Guidelines for Hand Hygiene in Irish Health Care*
310 *Settings*. Health Protection Surveillance Centre 2005, Dublin.

311

312 4. Wilson AP, Hayman S, Whitehouse T. *et al*. Importance of the environment for patient
313 acquisition of methicillin-resistant *Staphylococcus aureus* in the intensive care unit: a baseline
314 study. *Crit Care Med* 2007; **35**: 2275-2279.

315

316 5. Bhalla A, Pultz NJ, Gries DM, *et al*. Acquisition of nosocomial pathogens on hands after
317 contact with environmental surfaces near hospitalized patients. *Infect Control Hosp Epidemiol*
318 2004;**25**:164-167.

319

320 6. Cespedes C, Miller M, Quagliarello V, Vavagiakis P, Klein RS, Lowy FD. Differences
321 between *Staphylococcus aureus* isolates from medical and nonmedical personnel. *J Clin*
322 *Microbiol* 2002;**7**: 2594-2597.

323

- 324 7. Cookson B, Peters B, Webster M, Phillips I, Rahman M, Noble W. Staff carriage of epidemic
325 methicillin-resistant *Staphylococcus aureus*. *J Clin Microbiol* 1989; **27**:1471-1476.
326
- 327 8. McBryde ES, Bradley LC, Whitby M, McElwain DL. An investigation of contact transmission
328 of methicillin –resistant *Staphylococcus aureus*. *J Hosp Infect* 2004; **58**: 104-108.
329
- 330 9. Cimiotti JP, Wu F, Della- Latta P, Nesin M, Larson E. Emergence of resistant staphylococci
331 on the hands of new graduate nurses. *Infect Control Hosp Epidemio* 2004;**25**: 431-435.
332
- 333 10. Pittet D. Compliance with hand disinfection and it's impact on hospital – acquired infections.
334 *Journal of Hospital Infection* 2001;**48**: Suppl A S40-46.
335
- 336 11. Macdonald DJ, McKillop EC, Trooter S, Gray A. Improving hand-washing performance – a
337 crossover study of hand-washing in the orthopaedic department. *Ann R Coll Surg Engl* 2006; **88**:
338 289-291.
339
- 340 12. Creedon, SA . Healthcare workers' hand decontamination practices : compliance with
341 recommended guidelines. *J Adv Nurs*; 2005;51: 208-216.
342
- 343 13. Daly LE, Bourke GJ, McGilvray JW. *Interpretation and uses of medical statistics*: Blackwell
344 Scientific, Oxford. 1991.
345
- 346 14. Tvedt C, Bukholm G. Alcohol-based hand disinfection: a more robust hand-hygiene method
347 in an intensive care unit. *J Hosp Infect* 2005; **5**: 229-234.
348

- 349 15. Kac G, Podglajen I, Gueneret M, Vaupré S, Bissery A, Meyer G. Microbiological evaluation
350 of two hand hygiene procedures achieved by healthcare workers during routine patient care: a
351 randomized study, *J Hosp Infect* 2005; **60**: 32–39.
- 352
- 353 16. Patrick DR, Findon G, Miller TE. Residual moisture determines the level of touch-contact-
354 associated bacterial transfer following hand washing. *Epidemiol Infect* 1997; **119**:319-325.
- 355
- 356 17. Pittet D, Mourouga P, Perneger TV. Compliance with hand washing in a teaching hospital.
357 *Ann Int Med* 1999;**130**: 126-130.
- 358
- 359 18. Huang R, Mehta S, Weed D, Price CS. Methicillin–resistant *Staphylococcus aureus* survival
360 on hospital fomites. *Infect Control Hosp Epidemiol* 2006;**27**:1267-1269.
- 361
- 362 19. Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate
363 surfaces? A systemic review. *BMC Infect Dis* 2006; **6**:130-133.
- 364
- 365 20. Neely AN, Maley MP. Survival of enterococci and staphylococci on hospital fabrics and
366 plastic. *J Clin Microbiol* 2000; **38**:724-726.
- 367
- 368 21. Oomaki M, Yorioka K, Oie S, Kamiya A. *Staphylococcus aureus* contamination on the
369 surface of working tables in the ward staff centers and it’s preventative methods. *Biol Pharm Bull*
370 2006; **29**:1508-1510.
- 371
- 372 22. Panhotra BR, Saxena AK, Al-Mulhim AS. Contamination of patients’ files in intensive care
373 units : an indication of strict hand washing after entering case notes. *A J Infect Control* 2005;**33**:
374 398-401.

- 375 23. Sexton T, Clarke P, O'Neill E, Dillane T, Humphreys H. Environmental reservoirs of
376 methicillin-resistant *Staphylococcus aureus* in isolation rooms: correlation with patient isolates
377 and implications for hospital hygiene. *J Hosp Infect* 2006; **62**: 187-194.
378
- 379 24. Boyce JM, Potter-Bynoe G, Chenevert C, King T. Environmental contamination due to
380 methicillin-resistant *Staphylococcus aureus*: possible infection control implications. *Infect*
381 *Control Hosp Epidemiol* 1997; **18**:622-627.
382
- 383 25. Hayden MK, Blom DW, Lyle EA, Moore CG, Weinstein RA. Risk of hand or glove
384 contamination after contact with patients colonized with vancomycin-resistant *Enterococcus* or
385 the colonized patients' environment. *Infect Control Hosp Epidemiol* 2008; **29**:149-154.
386
- 387 26. Snyder GM, Thom KA, Furuno JP. *et al.* Detection of methicillin-resistant *Staphlococcus*
388 *aureus* and vancomycin-resistant *Enterococci* by healthcare workers on infection control gown
389 and gloves. *Infect Control Hosp Epidemiol* 2008; **29**: 583-589.
390
- 391 27. Larson E, Kretzer EK. Compliance with hand washing and barrier precautions.
392 *Journal of Hospital Infection* 1995; **30**: Suppl: 88-106.
393

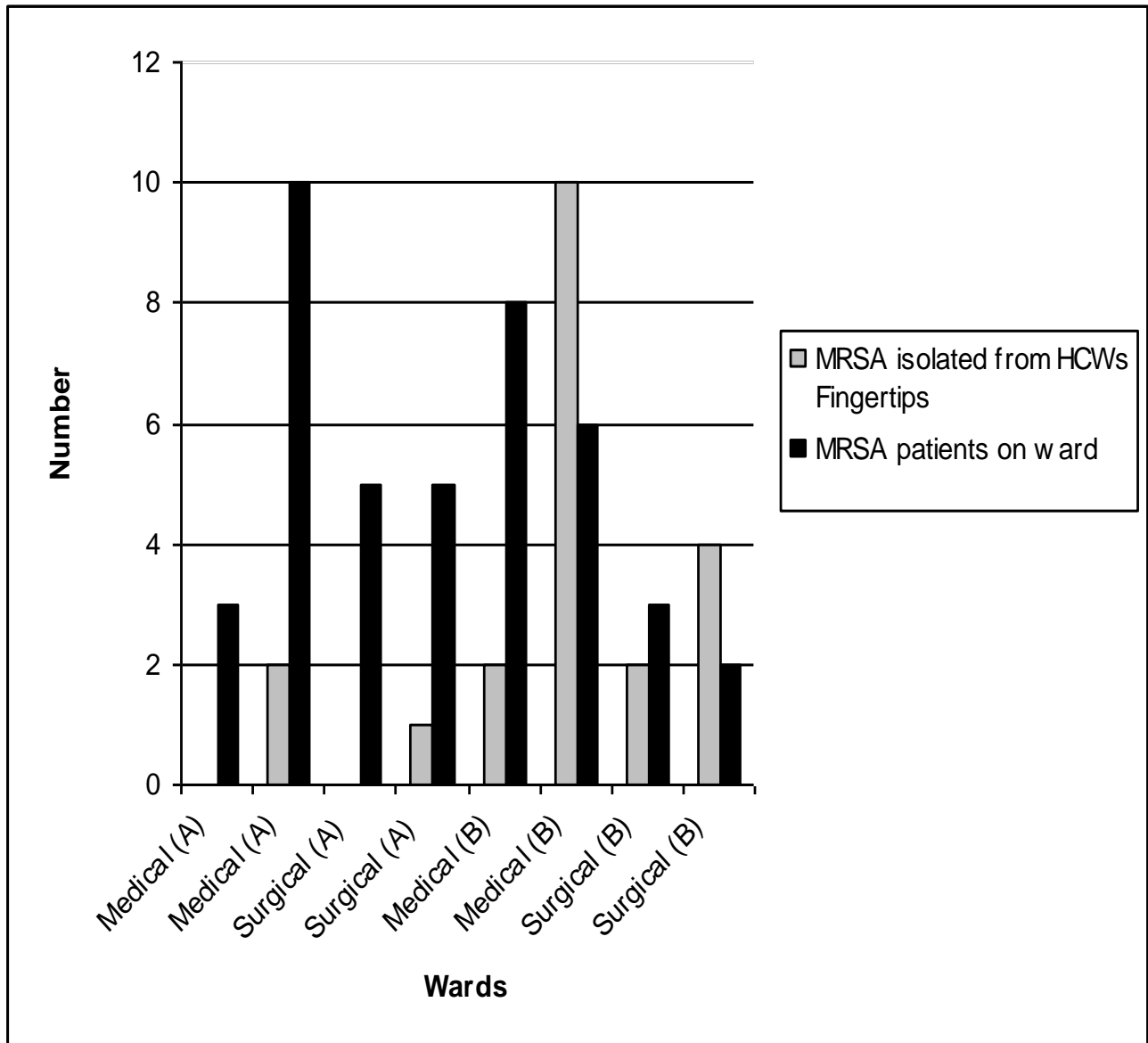
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395

Table 1. Hand hygiene occasions and hand hygiene agents associated with the recovery of the number and percentage () of MRSA from the fingertips of healthcare workers.

Hand hygiene occasions	Gloves only	Gloves and Alcohol hand rub	Gloves and Handwash	Gloves & 4% chlorhexidine detergent	Alcohol hand rub	Alcohol and handwash	Handwash	4% chlorhexidine detergent	No hand hygiene	Total
Before clinical contact	0/1(0)	-	-	-	0/2(0)	0/1(0)	0/6(0)	0/1(0)	1/25(4)	1/36(3)
Before isolation room	-	-	-	-	-	-	0/1(0)	-	0/1(0)	0/2(0)
Before social hand contact	-	-	-	-	-	-	0/1(0)	-	0/2(0)	0/3(0)
After clinical contact	0/8(0)	0/1(0)	0/2(0)	0/2(0)	0/28(0)	0/2(0)	5/87(6)	2/18(11)	5/46(11)	12/194(10)
After environmental contact	0/4(0)	-	-	-	0/6(0)	1/1(100)	0/24(0)	0/1(0)	9/102(9)	10/138(7)
After isolation room	-	-	-	-	-	-	0/2(0)	0/4(0)	0/2(0)	0/8(0)
After social hand contact	-	0/1(0)	-	0/1(0)	0/6(0)	-	0/29(0)	0/7(0)	0/51(0)	0/95(0)
No specific contact	0/1(0)	-	-	-	1/17(6)	-	2/60(3)	0/4(0)	12/264(5)	15/346(4)
Total	0/14(0)	0/2(0)	0/2(0)	0/3(0)	1/59(2)	1/4(25)	7/210(3)	2/35(6)	27/493(5)	38/822(5)

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Figure 1. The number of occasions (38) when MRSA was recovered from HCWs fingertips (822) and the number (42) of MRSA patients present on eight wards.



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A, wards included in larger MRSA study; B, wards not included in study

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