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# Effect of gloved hand disinfection on hand hygiene before infection-prone procedures on a stem cell ward

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## SUMMARY

**Background:** Hand hygiene compliance even before infection-prone procedures (indication 2, 'before aseptic tasks', according to the World Health Organization (WHO)) remains disappointing.

**Aim:** To improve hand hygiene compliance by implementing gloved hand disinfection as a resource-neutral process optimization strategy.

**Methods:** We performed a three-phase intervention study on a stem cell transplant ward. After baseline evaluation of hand hygiene compliance (phase 1) gloved hand disinfection was allowed (phase 2) and restricted (phase 3) to evaluate and differentiate intervention derived from learning and time effects. The incidence of severe infections as well as of hospital-acquired multidrug-resistant bacteria was recorded by active surveillance.

**Findings:** Hand hygiene compliance improved significantly from 50% to 76% ( $P < 0.001$ ) when gloved hand disinfection was allowed. The biggest increase was for infection-prone procedures (WHO 2) from 31% to 65%;  $P < 0.001$ . Severe infections decreased by trend (from 6.0 to 2.5 per 1000 patient-days) whereas transmission of multidrug-resistant organisms was not affected.

**Conclusion:** Gloved hand disinfection significantly improved compliance with the hand hygiene, especially in activities relevant to infections and infection prevention. Thus, this process optimization may be an additional, easy implementable, resource-neutral tool for a highly vulnerable patient cohort.

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## Introduction

Hand hygiene is considered to be the major factor in preventing cross-transmissions as well as healthcare-associated infections (HCAIs) [1]. Overall hand hygiene compliance remains modest despite several interventions (~40%) [2]. Newer data from a national 'Clean hands campaign' reported a compliance rate of 73% [3]. Some patient groups seem to be associated with higher hand

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hygiene compliance rates, e.g. paediatric (53%) and neonatal (61%) patients [4]. Moreover, 85% hand hygiene compliance was reported in a haematology–oncology unit [5]. Although hand hygiene compliance seems to be higher than average among carers of severely immunocompromised haematology–oncology patients, there is still room for improvement. The lowest rates are generally seen in activities directly related to risk of transmission of infections. Such infection-prone procedures are predominantly represented by the indication 2 ('before aseptic tasks'). Others are indication 1 ('before patients contact'), indication 3 ('after contact with body fluid'), indication 4 ('after patients contact') and indication 5 ('after contact with the patients surrounding'). Hand hygiene is especially important in stem cell transplant patients, who comprise one of the most vulnerable patient populations. For example, healthcare-associated bloodstream infections (HABSI) in stem cell transplant patients is associated with a 30-day mortality of up to 27% [6]. The mortality rate in allogeneic stem cell recipients who had had at least one pneumonia episode was evaluated in a global, multi-centre study and amounted to 46% [7].

One reason for low hand hygiene compliance before infection-prone procedures is a high number of hand hygiene indications (according to the WHO protocol) occurring consecutively during very short time periods. In addition, for healthcare worker (HCW) safety reasons the use of medical examination gloves is recommended for virtually all of these procedures [8,9]. Consequently, to fulfil the WHO criteria gloves have to be changed before each hand rub additionally [10,11]. Allowing gloved hand disinfection would potentially overcome this problem. Thus, a new strategy focusing on increasing hand hygiene compliance before infection-prone procedures is needed.

The most common self-reported reason for non-compliance is generally a perceived lack of time [12,13]. The inverse correlation of workload and hand hygiene compliance was demonstrated recently in a '365/7/24' approach [14]. This is especially relevant, because the observation was made in a well-staffed stem cell transplant unit.

Usually, measures to improve hand hygiene compliance such as teaching and training of HCWs are effective only for short periods. By contrast, process-orientated strategies such as gloved hand disinfection may be more sustainable [15,16]. Gloved hand disinfection represents a simply implementable, resource-neutral, process-oriented tool focusing on infection-prone procedures. Gloved hand disinfection already has been analysed and reported to be successful *in vitro* [17].

This study aimed at increasing hand hygiene compliance only by gloved hand disinfection instead of glove change and hand disinfection as a resource-neutral and sustainable strategy.

## Methods

From February 2017 to April 2018, a tri-phase study was performed (Figure 1) with the intervention 'gloved hand disinfection' at the stem cell unit of the University Medical Center, Goettingen, a tertiary care centre.

The stem cell ward comprises 16 beds in 10 patient rooms. The staff consisted of eight physicians and 18 female/male nurses, of whom five physicians and nine nurses were present each day. The ward had already been sufficiently equipped with alcohol-based hand rub (ABHR) dispensers; only alcoholic disinfectants were used.

During phase I (February to August 2017) baseline observation was performed to determine baseline hand hygiene compliance. During phase II (September 2017 to January 2018) gloved hand disinfection was strongly advised for predefined situations, but not enforced. Because gloved hand disinfection makes work easier, HCWs were keen to try this tool. If the HCW preferred regloving with proper hand rub instead of disinfecting gloves, the infection control professional (ICP) documented correct behaviour. During phase III (February to May 2018) gloved hand disinfection was restricted to discriminate intervention effects from time trends and learning effects. The gloved hand disinfection was restricted to workflows including at least one infection-prone procedure only within one patient. Examples were (not restricted to):

- preparing and handling with intravenous medication and/or blood products;
- manipulations at central or peripheral lines including blood sampling procedure.

The primary endpoint, on which the power analysis was based, was full hand hygiene compliance determined by direct observation (reference standard) according to the WHO protocol [18]. Hand hygiene compliance was defined by the number of performed hand rubs divided by the number of observed hand hygiene opportunities. Observation was performed by three ICPs. Inter-observer agreement was  $\geq 90\%$  after a six-week training period. The secondary endpoints were: (i) WHO indication-specific hand hygiene compliance, notably compliance 'before aseptic tasks', defined by the number of hand rubs performed divided by the number of observed indications for specific opportunities [18,19]; (ii) incidence density of severe infection (defined by healthcare-associated primary bloodstream infection (HABSI; no. per 1000 patient days (PD)) and healthcare-associated pneumonia (HAP; no. per 1000 patient-days); (iii) incidence density (occurrence) of healthcare-acquired multidrug-resistant (micro-)organism (HAMDR0; no. per 1000 patient-days).

Severe infections (HABSI and HAP) were determined according national reference protocol designed for allogeneic stem cell transplant patients and adjusted at 1000 patient-days [20]. This protocol addressed patients undergoing allogeneic

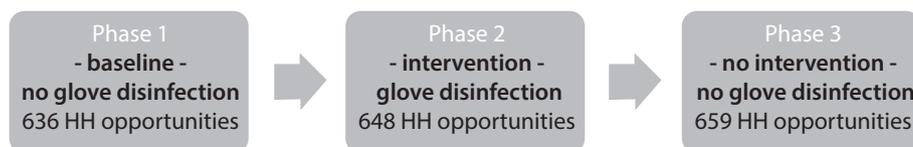


Figure 1. Study structure. HH, hand hygiene.

stem cell transplants and evaluated sepsis and pneumonia. HA MDROs were defined as meticillin-resistant *Staphylococcus aureus* (MRSA), extended spectrum  $\beta$ -lactamase (ESBL) or carbapenemase-producing Enterobacteriaceae and vancomycin-resistant enterococci. HA MDROs were defined according to the US Centers for Disease Control and Prevention guidelines for MDRO management [21,22]. Specimens from outpatients and inpatients of less than four days were excluded. Patient specimens included samples taken routinely for screening and for investigation of possible infection. All data, obtained from the laboratory information system, were analysed and assessed daily by ICPs. Length of stay (patient-days) was determined using the patient management system. Hand hygiene observations were made during day shifts; one observation period lasted 30–90 min and a range of five to 25 opportunities was observed in each. An additional secondary endpoint, HCWs acceptance of gloved hand disinfection, was assessed using a standardized questionnaire, using an ordinal scale, applied to 10 selected HCWs (Appendix A, including Supplementary Figure S1).

The investigation was approved by the local ethics committee (Reference No. COMTRA-12/12/16).

For the study, nitrile-polymer gloves were used [17]. These were Purple-nitrile-xtra<sup>®</sup> (Halyard Health, Inc., Alpharetta, GA, USA; manufacturer's specifications: ISO 374-1/5 2016 Type C, ISO 10993-1/2/5/10/12; EN 16523-1, EN 455, 420, 374-2/4) and Nitrile LG PF<sup>®</sup> (Maimed GmbH, Neuenkirchen, Germany; manufacturer's specifications: EN420, 374, 455, ASTM 6319, CAT III) [17]. Hand rubs were performed using standard hand rub solutions used at each hospital: Desderman pure<sup>®</sup> (Schülke & Mayr GmbH, Nordstedt, Germany; pharmaceutical ingredients 78.2 g ethanol 96%, 0.1 g biphenyl-2-ol, povidone 30, isopropylmyristate, 2-ethylhexanoate, sorbitol, 2-propanol, purified water) and Softa-Man<sup>®</sup> (B. Braun Melsungen AG, Melsungen, Germany; pharmaceutical ingredients: 45% ethanol, 18% 1-propanol, purified water, diisopropyladipate, macrogol-6-glycerolcaprylocaprata, dexpathenol, bisabolol, lemon- and linalool-flavour, allantoin).

Gloved hand disinfection may have risks (e.g. skin damage, transmission of microbes), if HCWs perform gloving inappropriately, e.g. changing between patients with gloved hands, wearing gloves for too long, and inappropriate glove–ABHR combinations. However, disinfectability and stability of medical examination gloves has been recently demonstrated *in vitro* [17,23]. Moreover, gloved hand disinfection is in line with the national guidelines and recommendations of the Clean Hands campaign (ASH) which was founded initially by the German Coalition for Patient Safety (APS) and the German

National Reference Center for Surveillance of Nosocomial Infections (NRZ Surveillance).

To minimize the remaining risks, we defined the following rules before starting the study:

- All HCWs were informed individually and in detail about the design, timeline and aim of the study, and were given appropriate training on gloved hand disinfection.
- HCWs were warned about the risk of premature loss of integrity of gloves and were asked to report any event of suspicious alteration, e.g. stickiness, fragility, sacculation, or colour change of gloves when disinfected. Pretesting of several glove and ABHR combinations was used to determine the best combinations for the study.
- The number of consecutive gloved hand disinfections was restricted to a maximum of five.
- The duration of glove usage was shortened to 20 min (in contrast to the ASH statement).
- Gloves had to be changed immediately whenever dirty or damaged.
- The same gloves could only be worn for contact with an individual patient.
- The study was supported by the occupational health service.
- The trial was overseen by ICPs, who were empowered to interrupt the study if any rules were broken.

### Statistical analysis

Power calculation and expected increase in hand hygiene compliance of ~40% were applied according to previous intervention strategies supposing 80% power with a given two-sided  $\alpha$  error level of 5% [14,24]. Computation of odds ratio (OR); 95% confidence interval (CI); *P*-values and  $\chi^2$ -statistics were performed using PSP<sup>®</sup> 1.0.1 (GNU General Public License version 2), R 3.5.1 (GNU General Public License version 2) with Yates' correction and Medcalc<sup>®</sup> 18.6 (MedCalc Software bvba) [25–30]. To avoid errors by zero values of the odds ratios, values were slightly modified by adding 0.5 to all contingency cells [31,32]. Statistics were supported by the Department of Medical Statistics.

### Results

During the tri-phase study, 1943 opportunities for hand hygiene were analysed. The overall compliance increased significantly from 50% at baseline to 76% ( $P < 0.001$ ) after allowing

**Table 1**  
Effects of gloved hand disinfection on hand hygiene compliance

Indications	HH opportunities (n1)			Hand rubs (n2)			HH compliance (%)		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
1	103	109	116	68	95	102	66	87	88
2	300	322	299	93	209	117	31	65	39
3	114	86	102	64	66	75	56	77	74
4	94	103	108	76	96	101	81	93	94
5	25	28	34	15	28	27	60	100	79
$\Sigma$	636	648	659	316	494	422	x = 50	x = 76	x = 64

HH, hand hygiene.

Indications 1–5 according to World Health Organization protocol.

gloved hand disinfection. Withdrawal of gloved hand disinfection led to a significant decrease in compliance to 64% ( $P < 0.001$ ) (Table 1). Compliance before infection-prone procedures showed the highest increase from 31% at baseline to 65% when gloved hand disinfection was allowed ( $P < 0.001$ ) as well as the highest decrease after withdrawal of gloved hand disinfection to 39% in phase 3 ( $P < 0.001$ ), respectively (Figure 2). Thus, compliance before infection-prone procedures is driven by gloved hand disinfection. Hand hygiene compliance rates with indications 1, 3, and 4 increased continuously from baseline to phases 2 and 3 (Figure 2). For effective strength, see odds ratios (Tables IIa, IIb, IIc). The incidence density of severe infections in allogeneic stem cell patients was 6.0 per 1000 patient-days (95% CI: 3.36–8.62) when gloved hand disinfection was not permitted, and it decreased to 2.5 per 1000 patient-days (95% CI: 0.03–4.85;  $P = 0.1$ ) when gloved hand disinfection was allowed (Figure 3). The occurrence of HA MDROs did not depend on gloved hand disinfection (Figure 3).

The main result of the questionnaire was the perception that gloved hand disinfection is a relief for HCWs. HCWs did not perceive gloved hand disinfection as a marked or unacceptable impairment (Appendix A).

## Discussion

Our hypothesis of an improvement in hand hygiene compliance by introducing gloved hand disinfection was confirmed, with a significant increase from 31% (baseline) to 65% (post-interventional) before infection-prone procedures. This is especially impressive because we offered no training on general infection control or hand hygiene either before or during the study. Thus, gloved hand disinfection may be an effective single strategy for improving hand hygiene compliance before infection-prone procedures.

According to WHO's requirements a hand rub must be performed before gloving and after removing gloves, e.g. when moving from dirty to clean tasks or when aseptic activities are interrupted and continued afterwards. This scenario is

complex, time-consuming, and in a real-life setting not always realized [23,33].

Achieved compliance of 31% (indication 2; phase 1) in our study seems to be low compared to hand hygiene compliance with other indications, e.g. 81% (indication 4), 56% (indication 3). Compared to other studies aiming at hand hygiene compliance, the improvement in our study represents a major improvement without increasing the workforce or costs. This is of great importance, since the most often self-reported and currently proven reason for HCWs' non-compliance is lack of time and a forced workload, and this is in line with previous results for another strategy, namely process optimization [12–16]. Indication 2 is regarded as the most important for patients, is associated with the lowest compliance rates in most studies, and is least improved by most hand hygiene improvement strategies. Thus, gloved hand disinfection could help to improve patient safety in a resource-neutral, easy implementable way.

During the study the incidence density of severe infections decreased (6.0 per 1000 vs 2.5 per 1000 patient-days) by trend. This is in line with the improvement for hand hygiene especially before infection-prone procedures. However, this is no definite proof of reduction of infections. Notably, power calculation did not primarily address this secondary endpoint. Investigation of severe infections during gloved hand disinfection in a roll-out setting is warranted.

Hand hygiene compliance with indications 3 and 4 (after contact with body fluid or patient) were not expected to improve by gloved hand disinfection in this setting. This hypothesis was proven by our study, since hand hygiene compliance improvement in this case was not driven by the intervention itself. Interestingly, our study showed an increase in hand hygiene compliance after contact with patients' surroundings. HA MDRO remained constant during all study phases independently from outpatients' incidence. Thus, we infer that gloved hand disinfection did not represent a patient risk when safety rules were followed. On the contrary, gloved hand disinfection improved hygiene in those situations most relevant for patients.

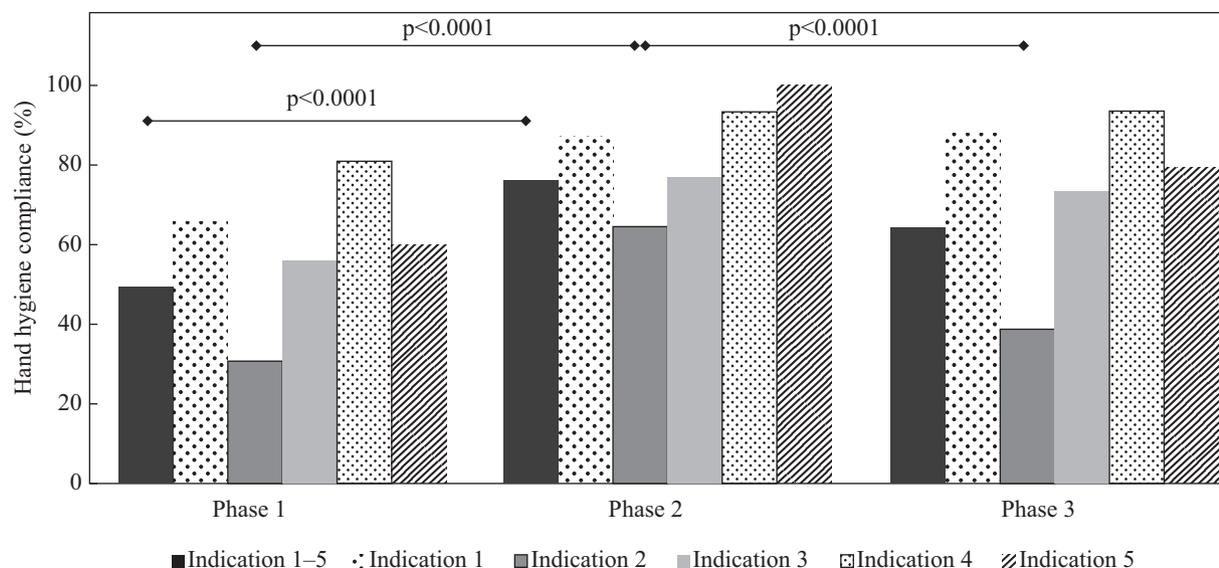
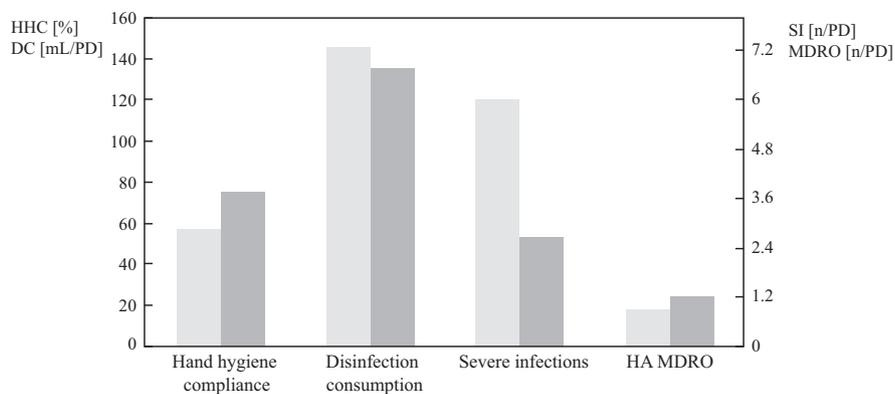


Figure 2. Impact of gloved hand disinfection on hand hygiene compliance stratified by World Health Organization indications 1–5.

**Table II**  
Comparing hand hygiene compliance depending on intervention

Indications	Phase 1		Phase 1 vs phase 2		
	HH compliance (%)	No HH compliance (%)	OR (95% CI)	$\chi^2$	P
1	66	34	0.29 (0.14–0.57)	12.15	<0.001
2	31	69	0.24 (0.17–0.34)	70.13	<0.001
3	56	44	0.39 (0.21–0.72)	8.26	0.004
4	81	19	0.31 (0.12–0.76)	5.70	0.170
5	60	40	0.03 (0.00–0.47)	11.31	<0.001
$\Sigma$	50	50	0.31 (0.24–0.39)	96.01	<0.001
Indications	Phase 2		Phase 2 vs phase 3		
	HH compliance (%)	No HH compliance (%)	OR (95% CI)	$\chi^2$	P
1	87	13	0.93 (0.42–2.06)	0.00	1.000
2	65	35	2.88 (2.08–3.99)	40.28	<0.001
3	77	23	1.18 (0.61–2.31)	0.11	0.735
4	93	7	0.95 (0.32–2.81)	0.00	1.000
5	100	0	15.55 (0.85–285.45)	4.61	0.032
$\Sigma$	76	24	1.80 (1.42–2.29)	22.61	<0.001
Indications	Phase 3		Phase 1 vs phase 3		
	HH compliance (%)	No HH compliance (%)	OR (95% CI)	$\chi^2$	P
1	88	12	0.27 (0.13–0.53)	13.85	<0.001
2	39	61	0.70 (0.50–0.98)	4.00	0.056
3	74	26	0.46 (0.26–0.82)	6.36	0.012
4	94	6	0.29 (0.12–0.74)	6.31	0.012
5	79	21	0.36 (0.11–1.16)	1.79	0.182
$\Sigma$	64	36	0.56 (0.44–0.69)	26.89	<0.001

HH, hand hygiene; OR, odds ratio; CI, confidence interval.



**Figure 3.** Secondary endpoints stratified according permission of gloved hand disinfection. HHC, hand hygiene compliance; DC, hand disinfections consumption (left axis); SI, severe infections; HA MDRO, hospital-associated multidrug-resistant organism (right axis); PD, patient-days; light grey, no glove disinfection; dark grey, with glove disinfection.

Different strategies may influence hand hygiene compliance. System-related (e.g. ABHR dispenser availability and localization, implementation of standardized procedures, process simplification and optimizing or automated monitoring) and individual patient-related (individual training, feedback audits) strategies differ in implementation workforce and probability of sustained effectiveness [2,15,34–38]. Thus, as a system-related strategy, disinfection of gloves is probably a sustainable component of a multi-faceted infection control strategy.

Support by the staff is a basic requirement of implementation. HCWs rated the release of the gloved hand disinfection as

an improvement or alleviation of personal working conditions. In fact, gloved hand disinfection was not perceived as a burden, but as a tool that made work easier.

There were limitations to this study. It was a single-centre study only on one stem cell ward. The data shown cannot easily be extrapolated to other settings. However, the study was initiated as a proof-of-principle study. At baseline, hand hygiene compliance was only at a moderate level, thus the effect could be overestimated with regard to settings starting at higher baseline levels. The study was designed to correct potential time and training effects from the 'glove effect'. However, the significant 'glove effect' shown in phase 2 is no

definite proof. The direct observation was intended to be performed in a completely anonymous manner without HCW anonymization. ICPs were asked to rotate HCW sequence when observing. Thus, observation bias cannot be excluded completely. Although direct observation is widely accepted as a reference standard to calculate hand hygiene compliance, there is no method to ensure compliance with gloved hand disinfection beyond the observation period.

Every entity of infection belongs to different transmission events and those that are related to hand hygiene compliance according to the WHO indications have not been investigated in detail. However, according to the national surveillance programmes we used the combined infection parameter as secondary endpoint. It may be useful to distinguish different entities in further studies to compare their responses to the hand hygiene compliance.

In conclusion, this study is the first to investigate gloved hand disinfection in real-work scenarios, demonstrating an improvement in hand hygiene compliance. Hand hygiene compliance was even improved before infection-prone procedures, the situations with the highest impact on infections, and thus infection control. Notably, severe infections decreased by trend.

Taken together, gloved hand disinfection could be an easy implementable, resource-neutral tool as a new component within the infection control bundles. Settings with a high number of aseptic procedures and unsatisfactory baseline levels would benefit most, especially in times of HCW shortage.

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### Conflict of interest statement

None declared.

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None.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jhin.2019.06.004>.

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