Review

Factors influencing healthcare-associated infections

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Summary

Preventing healthcare-associated infections (HAIs) is a global goal of growing importance, promoting national and international discussions, and generating numerous awareness campaigns. Likewise, the number of scientific studies investigating a reduction of HAIs by introducing certain intervention measures is growing.
This review provides a comprehensive overview of important factors influencing HAIs with a focus on German guidelines and legislation. The aim is to illustrate the complexity and diversity of the individual factors and thus make clear that measures to reduce HAIs must be equally diverse. Toolboxes with useful aids for practice are intended to support this.

Keywords

- healthcare-associated infection
- HAI
- influencing factors

Healthcare-associated infections worldwide and in Germany

Healthcare-associated infections (HAIs) are a worldwide problem in health care facilities and occur equally in developed and less developed countries [1]. Exact data on a global scale do not exist, but the World Health Organisation (WHO) estimates that hundreds of millions of patients are affected every year and that the burden of disease is highest in low- and middle-income countries [1]. More precise estimates of the rate of HAIs have been published for Europe as well as Germany (see figure 1) [2, 3]. In a point prevalence survey carried out in 2016–2017, the prevalence of patients with at least one HAI in countries of the European Union (EU) or the European Economic Area (EEA) was 6.5% overall (country range: 2.9–10.0%) [2] decreasing from the last survey in 2011 [4]. Contrary to this trend, infection rates are currently on the rise again, which is also due to the change in patient clientele (predominantly older patients, some with pre-existing conditions) [5, 6].

Since complete prevention of all HAIs cannot be achieved, the fundamental question arises as to what proportion can realistically be reduced. This question was addressed by two systematic reviews, which suggest that 10–70% [7] and 35–55% [8] could be avoidable. However, it is also clear that there are countless influencing factors that can be changed by medical innovations and have varying degrees of reduction potentials [8].

Factors influencing healthcare-associated infections

In this review, the factors influencing HAIs are divided into three major subject areas: 1) processes and systems in the clinic, 2) staff and 3) patients. Current publications and reviews of the last ten years with an application-oriented and practice-related focus serve as background.

1. Processes and systems in the clinic – Infrastructure and logistics

Standard precautions

Elements of standard precautions in the clinic include hand hygiene, surface hygiene, personal protective equipment (PPE), reprocessing of medical devices, waste disposal, handling of linen and dishes, education of patients and visitors, and the type of accommodation [9]. The first four aspects of standard precautions are examined in more detail below.

Hand hygiene

Hand hygiene has been considered the most important element of infection prevention at least since 2000, when Pittet et al. published their study on low

initial hand hygiene compliance among health care workers in a Swiss teaching hospital [10].

Current guidelines of the WHO on hand hygiene in health care [11] and, at the national level in Germany, of the Commission on Hospital Hygiene and Infection Prevention (Kommission für Krankenhaushygiene und Infektionsprävention, KRINKO) [12], take into account the findings of the past decades and provide detailed recommendations.

The fact that the targeted improvement of hand hygiene compliance (HHC) can reduce the rate of HAIs has been demonstrated in different countries and for different wards, and is true even with initially high compliance (>80%) [13–15]. While Grayson et al. reported that 10% HHC improvement reduced HAIs by 15% [13], in Pessoa-Silva et al. a 13% HHC increase reduced HAIs by about a quarter [14]. Sickbert-Bennett et al. observed a 6% decrease in HAIs with a 10% HHC improvement [15].

Surface hygiene

Surface hygiene also plays an important role in infection prevention. After being underestimated for a long time, several publications in recent years have proven its importance and described surfaces as a possible reservoir for hospital pathogens [16–18]. For example, a meta-analysis with over 80,000 patients demonstrated that the possibility of infection not only exists with colonised/infected room neighbours, but can also occur indirectly through previous room occupancy [19]. The multicentre, randomised REACH study showed that the implementation of a multimodal intervention package for improved surface cleaning (consisting of optimised product use, cleaning technique, staff training, feedback and communication) significantly reduced the infection rate with vancomycin-resistant enterococci by one third when the proportion of cleaned high-touch surfaces increased by 20% [20]. The fact that the effects in this study were not significant for other pathogens examined could have been due to other transmission routes and a lower initial pathogen incidence.

A recently published review provides practical recommendations for routine cleaning and disinfection on general wards as well as for clinically relevant pathogens and outbreak situations [21]. Recommendations from the KRINKO on cleaning and disinfection in the healthcare sector are also available for Germany [22], as well as the DIN standard on hospital cleaning [23], which was published in September 2021 and contains a comprehensive catalogue of measures.

Personal protective equipment

PPE is a measure to protect employees from contamination with pathogens and depends on the type of pathogen and the route of transmission. Various studies imply that the risk of self-contamination can be significant, especially when doffing PPE, at 13–79% [24–26].

The data on self-contamination suggest that there is a great need for education on the correct use of PPE. Institutions such as the German Robert Koch Institute (RKI) or the German national clean hands campaign (Aktion Saubere Hände, ASH) provide instructions on how to put on and take off PPE safely.

Reprocessing of medical devices

In order to exclude medical devices as a source of contamination for HAIs, they must be properly reprocessed before being used on patients. The requirements are based, among other things, on their classification as non-critical (e.g. ECG electrodes), semi-critical (e.g. speculum) and critical medical devices (e.g. retractors) and are explained in the current KRINKO recommendations [27]. The legal basis in Germany is the Regulation on Medical Devices Operators (Medizinprodukte Betreiberverordnung), the Medical Device Regulation (Medizinprodukteverordnung) and the Medical Devices Law Implementation Act (Medizinprodukterecht-Durchführungsgesetz) [28–30]. While cleaning and disinfection for reprocessing is sufficient for non-critical medical devices, additional sterilisation may be necessary for semi-critical ones. Critical medical devices are always subjected to both procedures [27]. In 2014, the term central sterile supply department (Zentrale Sterilgutversorgungsabteilung, ZSVA) was replaced by the term reprocessing unit for medical devices (Aufbereitungseinheit für Medizinprodukte, AEMP) [31], as medical devices are not only reprocessed in hospitals and the term AEMP is more comprehensive.

Hand disinfectant dispenser

The provision of dispensers for hand disinfectant plays an essential role in compliance with HH. The minimum requirements for Germany are described in the KRINKO recommendations and the German Society for Hospital Hygiene (Deutsche Gesellschaft für Krankenhaushygiene, DGKH) also provides recommendations [12, 32]. According to these, those involved in patient care should not have to travel additional distances when following the indications for hand disinfection.

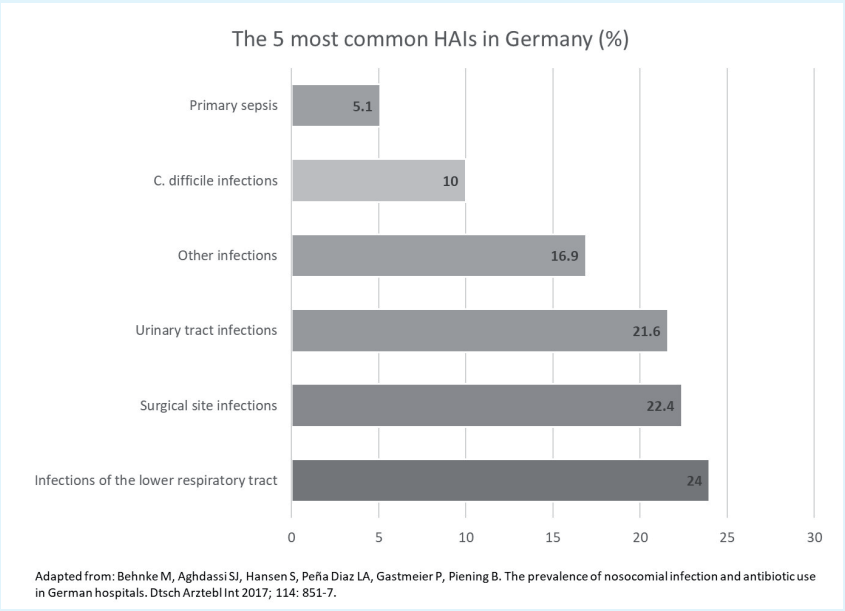

Figure 1: Overview of the most common HAIs in Germany.

As minimum equipment in patient rooms, the KRINKO currently recommends providing one dispenser per patient bed (intensive care and dialysis wards) or one dispenser for two patient beds plus one in the sanitary cell (normal wards) [12]. Basically, the spatial conditions determine whether fixed or mobile dispensers are used [12], whereby pocket bottles should be avoided as far as possible [32].

A recent survey-based study of 178 Swiss acute care hospitals showed a number of four times more dispensers per bed in the entire hospital than recommended in the current guidelines [33]. However, not only visibility and good accessibility of dispensers play a role in high HHC at the point-of-care [34, 35], but also details such as dispenser design (manual vs. touchless) [36].

Hygiene management

The heads of German hospitals are obliged by the Infection Protection Act to prevent transmissible diseases in humans, to detect infections at an early stage and to prevent their further spread [37]. The hygiene management of the hospitals is implemented by a hygiene commission (hospital hygienists, hygiene specialists, link nurses, etc.) [38], which can result in challenges in interface management, e.g., between administration and medical departments [39]. The hygiene commission draws up a binding hygiene plan, which, among other things, lays down rules for hospital cleaning. A study in German hospitals showed that there is still considerable potential for improvement in process standardisation and interdepartmental coordination and communication (e.g. with the cleaning service) [40]. Optimised standardised processes (SOPs) can create added value for treatment quality by mapping hygiene-relevant aspects from the hygiene plan. For better embedding, it is advisable to include the SOPs as applicable documents in the quality management system.

Recommendations on the personnel and organisational requirements as well as on the scope of capacity of hygiene management are provided by the KRINKO [38, 41]. Further requirements are regulated in the ordinances of the federal states. The importance of hygiene management is also reflected in the special hygiene programme created in 2011, which offers hospitals funding opportunities to implement the now binding requirements in terms of personnel and organisation [42].

Comprehensive hygiene management also includes surveillance of infectious diseases and pathogens, especially antibiotic-resistant ones. This includes programmes to prevent resistance (antimicrobial stewardship), which are usually more cost-effective than prolonged hospital stays due to resistant pathogens [43].

Data collection

In many countries, surveillance of HAIs is obligatory and can be carried out on a patient-related, ward-related or facility-related basis, as described by the KRINKO in Germany, for example [44]. Here, appropriately trained clinics can use the Hospital Infection Surveillance System (Krankenhaus-Infektions-Surveillance-System, KISS) of the National Reference Centre (Nationales Referenzzentrum, NRZ) (www.nrz-hygiene.de/surveillance/kiss/), which offers the advantage of being able to compare with national reference data [44]. Comparable surveillance also exists in other countries, for example in Switzerland through the Swiss National Center for Infection Control (Swissnoso) [45]. Surveillance requires precise identification of the pathogens. Molecular diagnostic methods enable prompt detection and efficient infection control and can be carried out internally or externally, depending on the requirements of the hospital [46–49]. It is important that the result is available quickly, is unambiguous and is forwarded directly to the relevant interfaces [50].

Even if not fully developed at the moment, automated surveillance systems may become established in the future – not only for HAI surveillance [51, 52], but also for monitoring and improving HHC [53–56].

Training

In principle, regular training events on hygiene and infection prevention are obligatory for hygiene staff, which are usually conducted and documented by state-certified hygiene specialists [38]. However, which other employees of various health care facilities must (mandatory) or can (voluntary) participate in regular hygiene-related training events is inconsistently regulated in the regulations of the federal states. Richter et al. showed that an early and continuous focus on hygiene already during medical studies helps to facilitate infection prevention in the daily clinical work of future medical staff and thus to increase patient safety [57]. Various training tools for improving HHC are provided by the WHO, for example [11]. This basis also proved useful in several countries for further development into a train-the-trainer course – consisting of lectures, simulation-based training and experiential activities – to extend the reach of hand hygiene training [58].

Premises

The premises of a clinic – especially the patient rooms and their wet rooms – also have an impact on the work of healthcare workers [59] and thus on infection prevention. Since wastewater-carrying systems such as washbasins, siphons, shower drains and toilets can be a reservoir of pathogens [60], the KRINKO also recommends taking infection prevention aspects into account in the future construction and renovation of patient rooms [61].

In addition, room climate and air exchange or air-conditioning systems have a significant influence on the spread of germs [62], as has also been shown with airborne pathogens such as SARS-CoV-2 [63]. To minimise this risk, regular maintenance should be carried out and the use of HEPA filters should be considered [64, 65].

Several reviews pointed out that outbreaks with pathogens such as *Pseudomonas aeruginosa*, *Legionella* and *Mycobacterium chimaera* were associated with water reservoirs and spread, for example, through electronic taps, heater-coolers [60] and water-carrying medical equipment (e.g. haemodialysis machines) [66].

Equipment

Finally, the general equipment of a clinic also influences the possibilities for infection prevention and thus the rate of HAIs. For example, a systematic review with a European focus identified key components for infection prevention that could be equally important – including the availability and easy accessibility of materials and equipment as well as their optimal ergonomics [67]. This is not self-evident in view

of the economisation of health care. In addition, quality assurance in Germany is largely externally controlled and has remained unchanged for years (e.g., focus on operations or minimally invasive procedures). This limits the dynamics of internal quality assurance and thus an expansion to new indicators (e.g., readmissions, quality of interfaces) [68]. In addition, factors such as hospital size, university status, urban connection and degree of specialisation favour the acquisition of additional financial resources, which make upmarket technical equipment possible in the first place [69].

The possibilities for infection prevention are also likely to be influenced by the (cost-related) decision for or against an own AEMP [27, 31].

2. Personnel

Qualification

In order to internalise the principle of infection prevention and apply it in everyday clinical practice, employees must be taught hygiene-relevant knowledge during their training. To this end, the DGKH already compiled a recommendation in 2017 on minimum requirements for imparting knowledge of infection prevention and hospital hygiene and calls for the mandatory integration of these topics in all theoretical and practical training [70]. Similar calls to improve infection prevention knowledge are also coming from the USA [71]. An increased focus on hygiene and infection prevention not only benefits nurses, but also medical students, who benefit from early and continuous training and can better apply the knowledge in practice later [57].

However, better hygiene and infection control in hospitals require sufficient and well-trained staff. This is countered by staff cuts in Germany [72]. If hygiene standards such as hand disinfection cannot always be met due to lack of time, the risk of HAIs increases [72]. Commercial and clinical risk management have a number of overlaps and should be considered holistically, as HAIs caused by poor hygiene also have a negative economic impact [40]. International observational studies confirm that staff reductions in the nursing sector and insufficient training have a negative impact on patient outcomes such as mortality [73, 74].

In order to avoid staff shortages in the future, the field of nursing should be made more attractive to young professionals through competitive salaries, in addition to a rethinking of policy [75]. Since January 2020, the new Nursing Professions Act has for the first-time defined activities specifically reserved for nursing professionals, such as the determination of nursing needs or the organisation and design of the nursing process. In this way, the nursing profession is to be given a higher status. In addition, the newly introduced nursing degree enables a closer link between science and practice and thus offers further career opportunities for nursing professionals [76, 77].

Outsourcing

Outsourcing is widespread in Germany's hospitals, especially in hospital cleaning. However, hospitals not only save costs and gain flexibility, but also partly give up control over this area. Thus, outsourced cleaning services are often understaffed and cleaners are more often overworked, receive less training and are less integrated in terms of communication and organisation [78]. Studies from England and the USA found strong evidence that outsourcing of the cleaning team is associated with an increased incidence of HAIs due to *Clostridioides difficile* and methicillin-resistant *Staphylococcus aureus* (MRSA) [78, 79]. A 2015 analysis of the German hospital landscape also found that cleaning had deteriorated in the past and – especially in high-risk areas – permanent staff should be deployed at lower area rates to improve the situation [80].

Communication and language barriers

In order to establish and maintain a functioning risk or hygiene management system, good interdisciplinary communication is essential, uniting different disciplines and hierarchies through open and respectful interaction [81–83]. This can only be achieved in an organisation where leaders drive such a culture and empower employees at all levels of the organisation. This includes bringing all employees up to the same level of knowledge on important

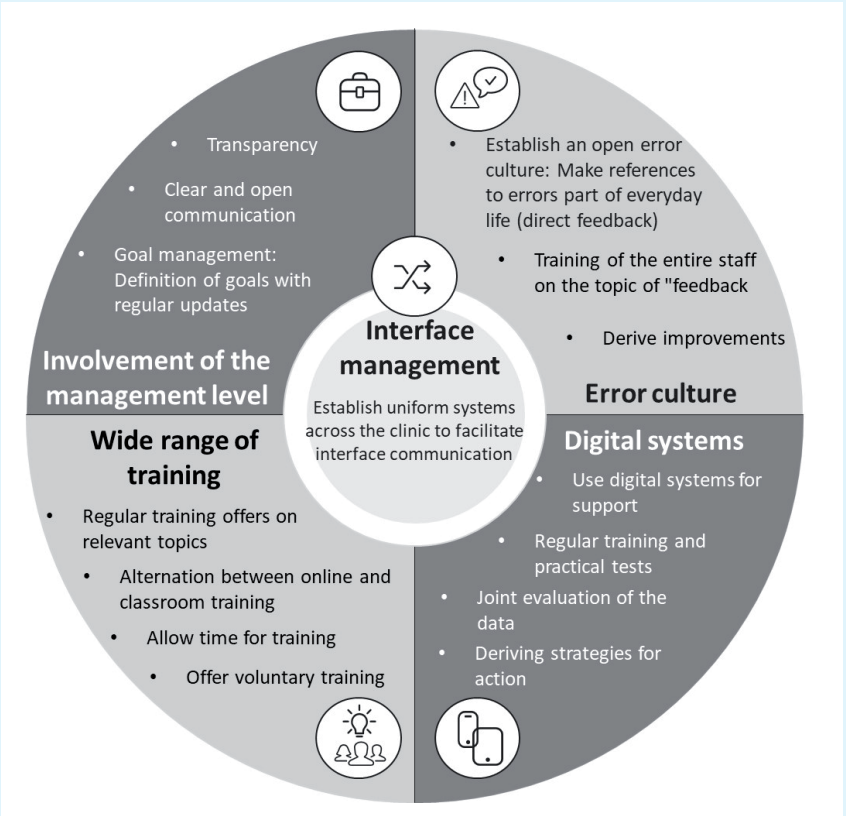

Figure 2: Toolbox 1. Practical recommendations for the area of „processes and systems in the clinic".

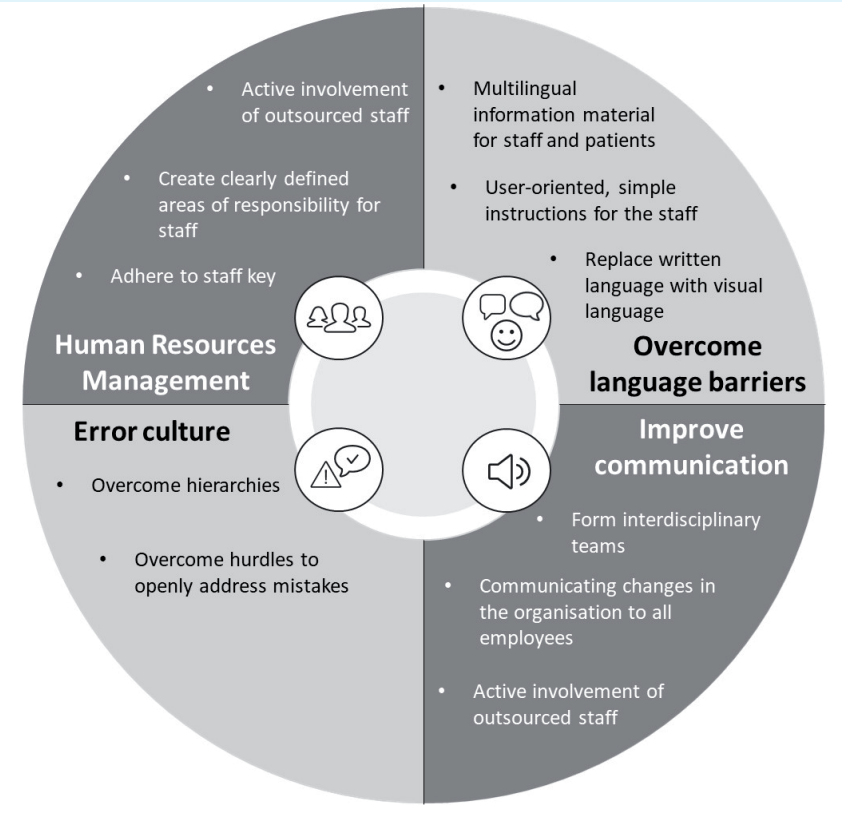

Figure 3: Toolbox 2. Practical recommendations for the area of „staff".

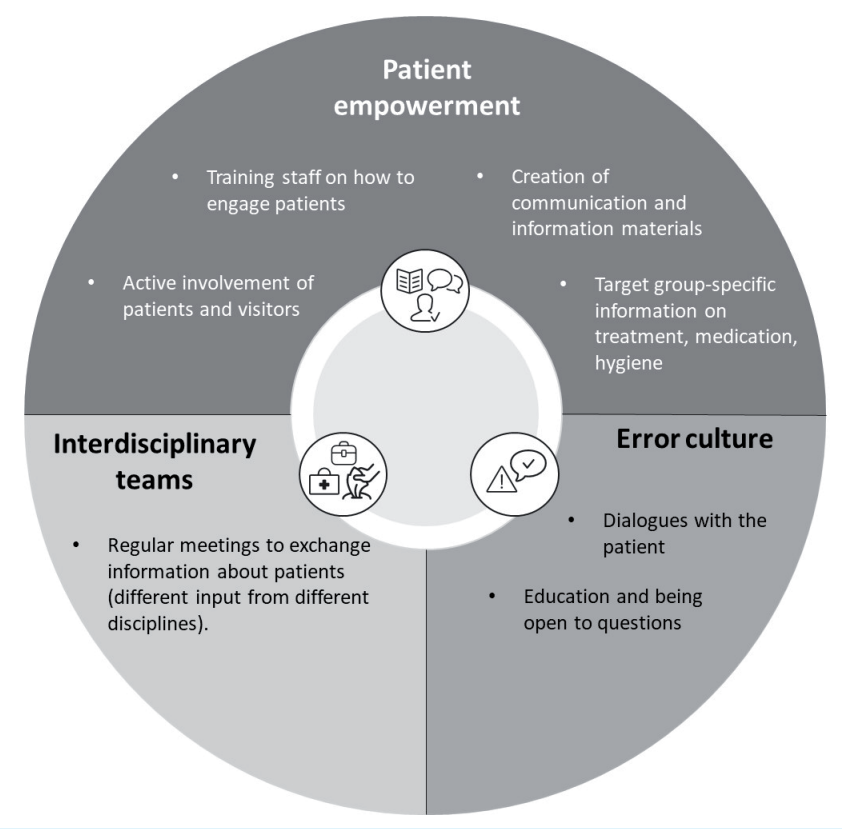

Figure 4: Toolbox 3. Practical recommendations for the area of „patients".

organisational topics – e.g. by means of information and communication technology [84]. Especially with regard to HAIs, interdisciplinary communication plays an essential role [85]. Information on infection status, treatment and special hygiene measures should be communicated clearly and comprehensibly to all interfaces involved. This includes physicians, nursing staff, physiotherapists, service staff and cleaning management. Language barriers make communication difficult not only with less qualified staff such as cleaners, but also with medical staff and patients [83, 86, 87], so multilingual information should be considered.

Special attention should be paid to communication with patients. An open and continuous exchange of information based on patient-centred forms of communication, encouraging the participation of patients and their families and involving patients as partners is beneficial [88].

3. Patients

Pre-existing conditions

HAIs can be acquired by both exogenous (pathogens from the environment) and endogenous pathogens (flora of the patient). In contrast to the past, endogenous infections now account for 2/3 of total HAIs [89]. In principle, patients have different baseline risks for HAIs due to individual factors such as pre-existing conditions, premedication, and age. Nevertheless, even endogenous HAIs are often caused by poor hygiene, e.g., by spreading germs from a contaminated to a clean body site [90]. It must be emphasised that immunosuppression or the use of certain medications favour colonisation, but are not a prerequisite for it, and colonisation can also occur independently [90].

Complete avoidance of all HAIs will not be achieved simply because of the multitude of factors affecting the patient, so the goal should be a reduction [7, 8].

Type and duration of the treatment

In general, invasive treatments are associated with a significantly higher risk than non-invasive treatments [7, 8]. Catheter-associated HAIs have been well described and can be reduced particularly effectively through optimised processes, daily indication reviews and stricter hygiene rules [7, 8]. In addition,

the length of stay also has an impact on the risk of HAIs. Studies show that this increases with the length of the hospital stay [91–93]. This also applies to COVID-19 patients, who often stay in hospital for a long time and are dependent on invasive measures [91].

Patient Empowerment

Last but not least, patients themselves influence the risk of HAIs through their behaviour. While staff in Germany are naturally bound by hygiene regulations and guidelines, patients could be more actively involved [40]. According to the patient empowerment propagated by the WHO, they should be supported by target group-oriented information to understand their own role and the importance of their actions, e.g., regarding compliance with hygiene or taking medication [11]. An important concept in this context is health literacy, the ability to find, evaluate and finally use health information for decision-making. A study by the Robert Koch Institute (RKI) showed that the general level of information on health aspects of patients was better compared to 2009, but that there is still room for improvement [94]. An important factor for this is also the empowerment of staff to actively involve patients and strengthen their role [95, 96].

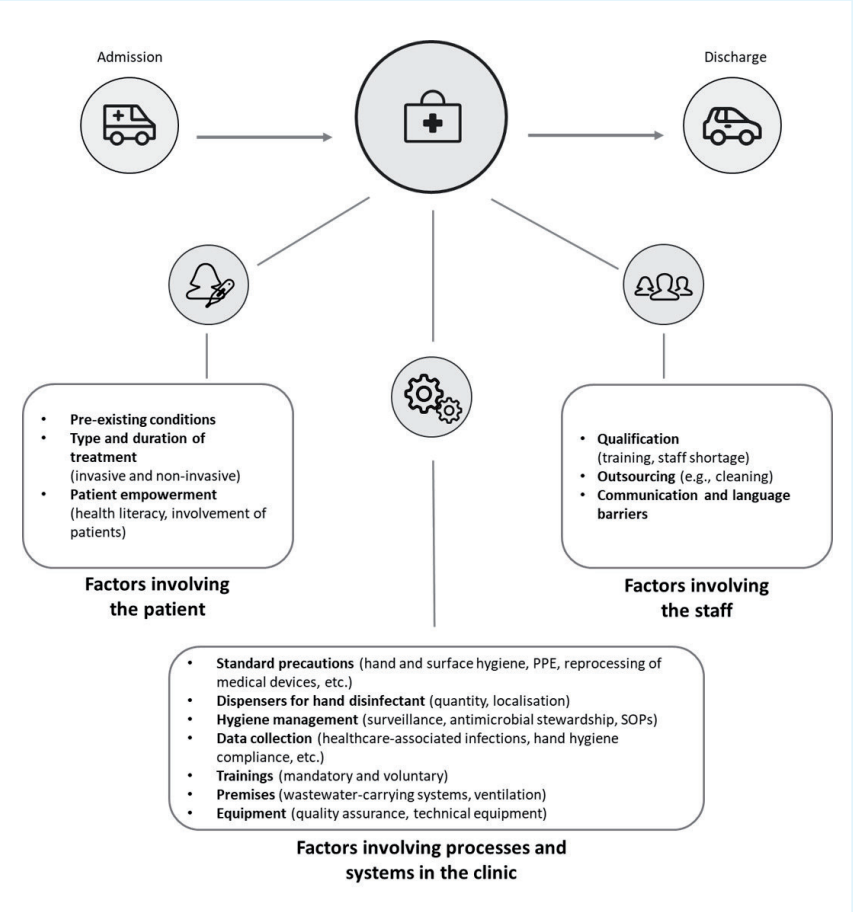

Figure 5: Overview of direct and indirect factors influencing healthcare-associated infections. PPE, personal protective equipment; SOP, standard operating procedure.

Conclusions

This review article sheds light on the complex field of HAIs and illustrates the numerous influencing variables that can have a direct or indirect impact on the rate of HAIs (Figure 5). The challenge for clinics is now to orient themselves in this multi-layered field and to derive concrete practical measures from it. Especially in the areas of "processes and systems in the clinic" as well as "personnel", there is much scope for change. On the other hand, it is also clear that improvements in the area of "patients" are essentially limited to empowerment, since other patient factors such as age and previous illnesses are given and the type and duration of the treatment depend on the illness. Due to the large number of influencing factors, each of which is only briefly explained here, it becomes clear that the reduction of HAIs cannot be achieved by individual measures, but that a complex interaction of several, multimodal measures is necessary to prevent infections. It is important that the individual components are considered holistically and that interfaces are formed.

There will always be new challenges for hospitals in the future. The "green hospital" with a view to more sustainable care is one of the topics that is already occupying many and that will also have a major influence on hygiene. Furthermore, we are developing more and more into a knowledge society due to new technologies and the data available. But also, demographic developments as well as changes in legislation (e.g., financial drivers) will play a decisive role.

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References

1. World Health Organization. Report on the Burden of Endemic Health Care-Associated Infection Worldwide Clean Care is Safer Care; 2011. https://apps.who.int/iris/bitstream/handle/10665/80135/9789241501507_eng.pdf (zuletzt abgerufen am 23.03.2022).
2. Suetens C, Latour K, Kärki T, Ricchizzi E, Kinross P, Moro ML, et al. Prevalence of healthcare-associated infections, estimated incidence and composite antimicrobial resistance index in acute care hospitals and long-term care facilities: Results from two european point prevalence surveys, 2016 to 2017. Eurosurveillance. 2018; 23(46):1–16.

3. Zacher B, Haller S, Willrich N, Walter J, Sin MA, Cassini A, et al. Application of a new methodology and R package reveals a high burden of healthcare-associated infections (HAI) in Germany compared to the average in the European Union/European Economic Area, 2011 to 2012. Eurosurveillance. 2019; 24(46):1900135.
4. Zarb P, Coignard B, Griskeviciene J, Muller A, Vankerckhoven V, Weist K, et al. The European Centre for Disease Prevention and Control (ECDC) pilot point prevalence survey of healthcare-associated infections and antimicrobial use. Euro Surveill. 2012; 17(46):20316.
5. Weiner-Lastinger LM, Pattabiraman V, Konnor RY, Patel PR, Wong E, Xu SY, et al. The impact of coronavirus disease 2019 (COVID-19) on healthcare-associated infections in 2020: A summary of data reported to the National Healthcare Safety Network. Infect Control Hosp Epidemiol. 2021;1–14.
6. BARMER Krankenhausreport 2021. https://www.bifg.de/publikationen/reporte/krankenhausreport-2021 (zuletzt abgerufen am 23.03.2022).
7. Harbarth S, Sax H, Gastmeier P. The preventable proportion of nosocomial infections: An overview of published reports. J Hosp Infect. 2003; 54(4):258–266.
8. Schreiber PW, Sax H, Wolfensberger A, Clack L, Kuster SP. The preventable proportion of healthcare-associated infections 2005-2016: Systematic review and meta-analysis. Infect Control Hosp Epidemiol. 2018; 39(11):1277–1295.
9. Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) beim Robert Koch-Institut (RKI). Infektionsprävention im Rahmen der Pflege und Behandlung von Patienten mit übertragbaren Krankheiten. Bundesgesundheitsbl. 2015; 58:1151–1170.
10. Pittet D, Hugonnet S, Harbarth S, Mourouga P, Sauvan V, Touveneau S, et al. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. Infection Control Programme. Lancet (London, England). 2000;356(9238):1307–1312.
11. World Health Organization. WHO guidelines on hand hygiene in health care; 2009. https://www.who.int/publications/i/item/9789241597906 (zuletzt abgerufen am 23.03.2022).
12. Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) beim Robert Koch-Institut. Händehygiene in Einrichtungen des Gesundheitswesens. Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz. 2016; 9:1189–1220.
13. Grayson ML, Stewardson AJ, Russo PL, Ryan KE, Olsen KL, Havers SM, et al. Effects of the Australian National Hand Hygiene Initiative after 8 years on infection control practices, healthcare worker education, and clinical outcomes: a longitudinal study. Lancet Infect Dis. 2018; 18(11):1269–1277.
14. Pessoa-Silva CL, Hugonnet S, Pfister R, Touveneau S, Dharan S, Posfay-Barbe K, et al. Reduction of health care associated infection risk in neonates by successful hand hygiene promotion. Pediatrics. 2007; 120(2):e382-390.
15. Sickbert-Bennett EE, Dibiase LM, Schade Willis TM, Wolak ES, Weber DJ, Rutala WA. Reduction of healthcare-associated infections by exceeding high compliance with hand hygiene practices. Emerg Infect Dis. 2016; 22(9):1628–1630.
16. Stiefel U, Cadnum JL, Eckstein BC, Guerrero DM, Tima MA, Donskey CJ. Contamination of hands with methicillin-resistant *Staphylococcus aureus* after contact with environmental surfaces and after contact with the skin of colonized patients. Infect Control Hosp Epidemiol. 2011; 32(2):185–187.
17. Otter JA, Yezli S, French GL. The role played by contaminated surfaces in the transmission of nosocomial pathogens. Infect Control Hosp Epidemiol [Internet]. 2011; 32(7):687–699.
18. Rutala WA, Kanamori H, Gergen MF, Knelson LP, Sickbert-Bennett EE, Chen LF, et al. Enhanced disinfection leads to reduction of microbial contamination and a decrease in patient colonization and infection. Infect Control Hosp Epidemiol [Internet]. 2018; 39(9):1118–1121.
19. Wu Y-L, Yang X-Y, Ding X-X, Li R-J, Pan M-S, Zhao X, et al. Exposure to infected/colonized roommates and prior room occupants increases the risks of healthcare-associated infections with the same organism. J Hosp Infect. 2019; 101(2):231–239.
20. Mitchell BG, Hall L, White N, Barnett AG, Halton K, Paterson DL, et al. An environmental cleaning bundle and health-care-associated infections in hospitals (REACH): a multicentre, randomised trial. Lancet Infect Dis. 2019; 19(4):410–418.
21. Assadian O, Harbarth S, Vos M, Knobloch JK, Asensio A, Widmer AF. Practical recommendations for routine cleaning and disinfection procedures in healthcare institutions: a narrative review. J Hosp Infect [Internet]. 2021; 113:104–114.
22. Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) beim Robert Koch-Institut. Anforderungen an die Hygiene bei der Reinigung und Desinfektion von Flächen. Bundesgesundheitsbl Gesundheitsforsch Gesundheitsschutz. 2004; 47:51–61.
23. DIN 13063:2021-09. Krankenhausreinigung – Anforderungen an die Reinigung und desinfizierende Reinigung in Krankenhäusern und anderen medizinischen Einrichtungen.
24. Chughtai AA, Chen X, Macintyre CR. Risk of self-contamination during doffing of personal protective equipment. Am J Infect Control [Internet]. 2018; 46(12):1329–1334.
25. Kang JH, O'Donnell JM, Colaianne B, Bircher N, Ren D, Smith KJ. Use of personal protective equipment among health care personnel: Results of clinical observations and simulations. Am J Infect Control [Internet]. 2017; 45(1):17–23.
26. Tomas ME, Kundrapu S, Thota P, Sunkesula VCK, Cadnum JL, Mana TSC, et al. Contamination of Health Care Personnel During Removal of Personal Protective Equipment. JAMA Intern Med. 2015; 175(12):1904–1910.
27. Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) beim Robert Koch-Institut (RKI) und Bundesinstitut für Arzneimittel und Medizinprodukte (BfArM). Anforderungen an die Hygiene bei der Aufbereitung von Medizinprodukten. Bundesgesundheitsbl. 2012; 55:1244–1310.
28. Medizinprodukte-Betreiberverordnung in der Fassung der Bekanntmachung vom 21. August 2002 (BGBl. I S. 3396), die zuletzt durch Artikel 7 der Verordnung vom 21. April 2021 (BGBl. I S. 833) geändert worden ist.
29. Verordnung EU 2017/745 des Europäischen Parlaments und des Rates vom 5. April 2017 über Medizinprodukte.
30. Medizinprodukterecht-Durchführungsgesetz vom 28. April 2020 (BGBl. I S. 960), das zuletzt durch Artikel 2 des Gesetzes vom 12. Mai 2021 (BGBl. I S. 1087) geändert worden ist.
31. Fachausschuss Hygiene Bau und Technik. Anforderungen für den Bau oder Umbau einer Aufbereitungseinheit für Medizinprodukte (AEMP): Teil 1 – Grundlagen. Zentralsterilisation. 2014; 4:259–262.
32. Assadian O, Kramer A, Christiansen B, Exner M, Martiny H, Sorger A, et al. Empfehlung zu Anforderungen an Seifen-und Händedesinfektionsmittelspender in Einrichtungen des Gesundheitswesens. Hyg und Medizin. 2011; 36(10):407.
33. Kuster S, Roth JA, Frei R, Meier CA, Dangel M, Widmer AF. Handrub dispensers

per acute care hospital bed: a study to develop a new minimum standard. Antimicrob Resist Infect Control [Internet]. 2021; 10(1):1–6.
34. Cure L, Van Enk R. Effect of hand sanitizer location on hand hygiene compliance. Am J Infect Control [Internet]. 2015; 43(9):917–921.
35. Kirk J, Kendall A, Marx JF, Pincock T, Young E, Hughes JM, et al. Point of care hand hygiene – where's the rub? A survey of US and Canadian health care workers' knowledge, attitudes, and practices. Am J Infect Control [Internet]. 2016; 44(10):1095–1101.
36. Kendall A, Landers T, Kirk J, Young E. Point-of-care hand hygiene: Preventing infection behind the curtain. Am J Infect Control [Internet]. 2012; 40(4 SUPPL.):S3–10.
37. Gesetz zur Neuordnung seuchenrechtlicher Vorschriften (SeuchenrechtsneuordnungsgesetzSeuchRNeuG, Art. 1 – IfSG). Bundesgesetzblatt Tl I33, vom 25 Juli 2000.
38. Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) beim Robert Koch-Institut. Personelle und organisatorische Voraussetzungen zur Prävention nosokomialer Infektionen. Bundesgesundheitsbl. 2009; 52:951–962.
39. Conrad CB. 2.3 Organisation Krankenhaus–Balanceakt zwischen Spezialisierung und Koordination. In: Unternehmen Krankenhaus. Georg Thieme Verlag; 2013. p. 107.
40. Hygienemanagement im Krankenhaus. KU Konkret; 03/2020. https://ku-gesundheitsmanagement.de/wp-content/uploads/sites/2/2020/04/KUKO_Hygienemanagement_167x240.pdf (zuletzt abgerufen am 23.03.2022).
41. Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) beim Robert Koch-Institut. Empfehlung zum Kapazitätsumfang für die Betreuung von Krankenhäusern und anderen medizinischen Einrichtungen durch Krankenhaushygieniker/innen. Bundesgesundheitsbl. 2016; 59:1183–1188.
42. Bericht des GKV-Spitzenverbandes zum Hygienesonderprogramm in den Förderjahren 2013 bis 2019 an das Bundesministerium für Gesundheit.
43. Giraldi G, Montesano M, Napoli C, Frati P, La Russa R, Santurro A, et al. Healthcare-Associated Infections Due to Multidrug-Resistant Organisms: a Surveillance Study on Extra Hospital Stay and Direct Costs. Curr Pharm Biotechnol. 2019; 20(8):643–652.
44. Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) beim Robert Koch-Institut. Surveillance von nosokomialen Infektionen. Bundesgesundheitsbl. 2020; 63:228–241.
45. Metsini A, Widmer A, Zingg W, Gardiol C, Vuichard-Gysin D, Eder M, et al. Evaluation of existing and desired measures to monitor, prevent and control healthcare-associated infections in Swiss hospitals. Swiss Med Wkly. 2021; 151:w20516.
46. Boccia S, Pasquarella C, Colotto M, Barchitta M, Quattrocchi A, Agodi A. Molecular epidemiology tools in the management of healthcare-associated infections: Towards the definition of recommendations. Epidemiol Prev. 2015; 39(4):21–26.
47. Lax S, Gilbert JA. Hospital-associated microbiota and implications for nosocomial infections. Trends Mol Med. 2015; 21(7):427–432.
48. Mintzer V, Moran-Gilad J, Simon-Tuval T. Operational models and criteria for incorporating microbial whole genome sequencing in hospital microbiology – A systematic literature review. Clin Microbiol Infect [Internet]. 2019; 25(9):1086–1095.
49. Vincent JL, Brealey D, Libert N, Abidi NE, O'Dwyer M, Zacharowski K, et al. Rapid diagnosis of infection in the critically ill, a multicenter study of molecular detection in bloodstream infections, pneumonia, and sterile site infections. Crit Care Med. 2015; 43(11):2283–2291.
50. Löffert S, Damerau M. Die Bedeutung der Labordiagnostik für die Krankenhausversorgung. Eine Studie im Auftrag der Deutschen Vereinten Gesellschaft für Klinische Chemie und Laboratoriumsmedizin (DGKL) und des Verbands der Diagnostica-Industrie (VDGH). Dtsch Krankenhausinstitut e.V. 2014; https://www.dki.de/sites/default/files/2019-05/bed.
51. Streefkerk HRA, Verkooijen RP, Bramer WM, Verbrugh HA. Electronically assisted surveillance systems of healthcare-associated infections: a systematic review. Euro Surveill. 2020; 25(2):1900321.
52. Van Mourik MSM, Perencevich EN, Gastmeier P, Bonten MJM. Designing Surveillance of Healthcare-Associated Infections in the Era of Automation and Reporting Mandates. Clin Infect Dis. 2018; 66(6):970–976.
53. Boyce JM. Electronic monitoring in combination with direct observation as a means to significantly improve hand hygiene compliance. Am J Infect Control [Internet]. 2017; 45(5):528–535.
54. Hagel S, Reischke J, Kesselmeier M, Winning J, Gastmeier P, Brunkhorst FM, et al. Quantifying the Hawthorne Effect in Hand Hygiene Compliance Through Comparing Direct Observation with Automated Hand Hygiene Monitoring. Infect Control Hosp Epidemiol. 2015; 36(8):957–962.
55. Meng M, Sorber M, Herzog A, Igel C, Kugler C. Technological innovations in infection control: A rapid review of the acceptance of behavior monitoring systems and their contribution to the improvement of hand hygiene. Am J Infect Control [Internet]. 2019; 47(4):439–447.
56. Scheithauer S, Bickenbach J, Heisel H, Fehling P, Marx G, Lemmen S. Do WiFi-based hand hygiene dispenser systems increase hand hygiene compliance? Am J Infect Control [Internet]. 2018; 46(10):1192–1194.
57. Richter A, Chaberny IF, Surikow A, Schock B. Hygiene in medical education - Increasing patient safety through the implementation of practical training in infection prevention. GMS J Med Educ. 2019; 36(2):Doc15.
58. Tartari E, Fankhauser C, Masson-Roy S, Márquez-Villarreal H, Moreno IF, Navas MLR, et al. Erratum: Train-the-Trainers in hand hygiene: A standardized approach to guide education in infection prevention and control. Antimicrob Resist Infect Control. 2020; 9(1):1–11.
59. Fay L, Santiago JE, Real K, Isaacs K. Patient Room Design: A Qualitative Evaluation of Attributes Impacting Health Care Professionals. Crit Care Nurs Q. 2021; 44(3):334–356.
60. Kanamori H, Weber DJ, Rutala WA. Healthcare outbreaks associated with a water reservoir and infection prevention strategies. Clin Infect Dis. 2016; 62(11):1423–1435.
61. Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO) beim Robert Koch-Institut. Anforderungen der Hygiene an abwasserführende Systeme in medizinischen Einrichtungen. Bundesgesundheitsbl. 2020; 63:484–501.
62. Shajahan A, Culp CH, Williamson B. Effects of indoor environmental parameters related to building heating, ventilation, and air conditioning systems on patients' medical outcomes: A review of scientific research on hospital buildings. Indoor Air. 2019; 29(2):161–176.
63. Anghel L, Popovici C-G, Stătescu C, Sascău R, Verdeș M, Ciocan V, et al. Impact of HVAC-Systems on the Dispersion of Infectious Aerosols in a Cardiac Intensive Care Unit. Int J Environ Res Public Health. 2020; 17(18):6582.
64. Saran S, Gurjar M, Baronia A, Sivapurapu V, Ghosh PS, Raju GM, et al. Heating, ventilation and air conditioning

(HVAC) in intensive care unit. Crit Care. 2020; 24(1):194.
65. Weaver L, Michels HT, Keevil CW. Potential for preventing spread of fungi in air-conditioning systems constructed using copper instead of aluminium. Lett Appl Microbiol. 2010; 50(1):18–23.
66. Yiek W-K, Coenen O, Nillesen M, van Ingen J, Bowles E, Tostmann A. Outbreaks of healthcare-associated infections linked to water-containing hospital equipment: a literature review. Antimicrob Resist Infect Control. 2021; 10(1):77.
67. Zingg W, Holmes A, Dettenkofer M, Goetting T, Secci F, Clack L, et al. Hospital organisation, management, and structure for prevention of health-care-associated infection: A systematic review and expert consensus. Lancet Infect Dis [Internet]. 2015; 15(2):212–224.
68. Klakow-Franck R. Qualitätsentwicklung im Gesundheitswesen–Defizite und Lösungsvorschläge. Gesundheitswes aktuell. 2020; (2020):60–77.
69. Ex P, Vogt V, Busse R, Henschke C. The reimbursement of new medical technologies in German inpatient care: What factors explain which hospitals receive innovation payments? Health Econ Policy Law. 2020; 15(3):355–369.
70. Deutsche Gesellschaft für Krankenhaushygiene e.V. Mindestanforderungen zur Unterrichtsempfehlung zur Infektionsprävention und Krankenhaushygiene für Gesundheits- und Krankenpflege- und Kinder- und Altenpflegeschulen. Hyg und Medizin. 2017; 42(3):31–37.
71. Jack D, Wheeler L, Pogorzelska-Maziarz M, Manning M Lou. Evaluation of Infection Concept and Content Integration in a Baccalaureate Nursing Program Curriculum. Am J Infect Control. 2021; S0196-6553(21)00401-6.
72. Deutscher Berufsverband für Pflegeberufe. Position des DBfK zur Sicherung der Hygienestandards in Krankenhäusern. 2015. https://www.dbfk.de/media/docs/download/DBfK-Positionen/Positionspapier-Hygienestandards-2015-09-11.pdf (zuletzt abgerufen am 23.03.2022).
73. Aiken LH, Sloane D, Bruyneel L, Heede K Van den. Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study. Lancet. 2015; 383(9931):1824–1830.
74. Cho E, Sloane DM, Kim EY, Kim S, Choi M, Yoo IY, et al. Effects of nurse staffing, work environments, and education on patient mortality: An observational study. Int J Nurs Stud. 2015; 52(2):535–542.
75. Deutscher Berufsverband für Pflegeberufe. Konkurrenzfähige Pflegelöhne – Welches Lohnniveau macht die Pflegebranche wettbewerbsfähig ? 2020. https://www.dbfk.de/media/docs/download/DBfK-Positionen/Positionspapier-DBfK_konkurrenzfaehige-Pflegeloehne_2020-06-16.pdf (zuletzt abgerufen am 23.03.2023).
76. Pflegeberufegesetz vom 17. Juli 2017 (BGBl. I S. 2581), das zuletzt durch Artikel 9a des Gesetzes vom 11. Juli 2021 (BGBl. I S. 2754) geändert worden ist.
77. Bundesministerium für Gesundheit. Pflegeberufegesetz. 2022 https://www.bundesgesundheitsministerium.de/pflegeberufegesetz.html. (zuletzt abgerufen am 23.03.2022).
78. Litwin AS, Avgar AC, Becker ER. Superbugs versus outsourced cleaners: Employment arrangements and the spread of health care-associated infections. Ind Labor Relations Rev. 2017; 70(3):610–641.
79. Toffolutti V, Reeves A, McKee M, Stuckler D. Outsourcing cleaning services increases MRSA incidence: Evidence from 126 english acute trusts. Soc Sci Med [Internet]. 2017;174:64–69.
80. Repschläger U, Schulte C, Osterkamp N. Gesundheitswesen aktuell 2015. Gesundheitswesen. 2015;48–79.
81. Müller M. Risiko- und Fehlermanagement in der Luftfahrt. Bundesgesundheitsblatt - Gesundheitsforsch - Gesundheitsschutz [Internet]. 2015;58(1):95–99.
82. Ojanperä H, Korhonen A, Meriläinen M, Syrjälä H, Kanste O. The role of managers in promoting good hand hygiene in a Finnish tertiary care hospital. Am J Infect Control. 2021;49(6):753–758.
83. Peters A, Otter J, Moldovan A, Parneix P, Voss A, Pittet D. Keeping hospitals clean and safe without breaking the bank; summary of the Healthcare Cleaning Forum 2018. Antimicrob Resist Infect Control. 2018;7(1):132.
84. Burkhart S, Grabmeier S. Der Einfluss von Digital Leadership auf Organisationen im Gesundheitswesen. In: Die Digitale Transformation im Gesundheitswesen. 2017. p. 255–261.
85. Rosen MA, DiazGranados D, Dietz AS, Benishek LE, Thompson D, Pronovost PJ, et al. Teamwork in healthcare: Key discoveries enabling safer, high-quality care. Am Psychol. 2018;73(4):433–450.
86. Arndt J. Sprachbarrieren im Krankenhaus: Wenn dem Arzt die Worte fehlen. Dtsch Med Wochenschr. 2016;141(14):1044–1046.
87. Bowen S. The impact of language barriers on patient safety and quality of care. Société Santé en français. 2015;603–623.
88. Newell S, Jordan Z. The patient experience of patient-centered communication with nurses in the hospital setting: a qualitative systematic review protocol. JBI database Syst Rev Implement reports. 2015;13(1):76–87.
89. Gastmeier P. From hygiene to infection prevention – Past, present and future of infection prevention and control (IPC) in Germany. Abstract presented at the ICPIC scientific conference 2019. Geneva, Switzerland.
90. Pittet D, Allegranzi B, Sax H, Dharan S, Pessoa-Silva CL, Donaldson L, et al. Evidence-based model for hand transmission during patient care and the role of improved practices. Lancet Infect Dis. 2006;6(10):641–652.
91. Baccolini V, Migliara G, Isonne C, Dorelli B, Barone LC, Giannini D, et al. The impact of the COVID-19 pandemic on healthcare-associated infections in intensive care unit patients: a retrospective cohort study. Antimicrob Resist Infect Control [Internet]. 2021;10(1):87.
92. Hassan R, El-Gilany A-H, Abd elaal AM, El-Mashad N, Azim DA. An overview of healthcare-associated infections in a tertiary care hospital in Egypt. Infect Prev Pract [Internet]. 2020;2(3):100059.
93. Moore M. The ICEL Healthcare-Associated Infection Probability Equation. Infect Control Hosp Epidemiol [Internet]. 2020;41(S1):s405–406.
94. Horch K. Informationsbedarf der Bevölkerung Deutschlands zu gesundheitsrelevanten Themen–Ergebnisse der KomPaS-Studie. J Heal Monit. 2021;6:62–70.
95. Davis R, Parand A, Pinto A, Buetow S. Systematic review of the effectiveness of strategies to encourage patients to remind healthcare professionals about their hand hygiene. J Hosp Infect. 2015;89(3):141–162.
96. McGuckin M, Govednik J. Patient empowerment and hand hygiene, 1997-2012. J Hosp Infect. 2013;84(3):191–199.