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Pathogens from fomites in clinical setting: A scoping review

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Abstract

Fomites can potentially transmit infectious or contagious pathogens thus contribute to the widespread of hospital-associated infections (HAIs). A scoping review was conducted to identify the types of fomites and pathogens as well as factors of pathogen distribution in clinical setting according to Arksey & O'Malley framework and PRISMA-ScR guidelines. Three online databases were used to collect the relevant data which revealed that there were 46 reported fomites in clinical setting that have been associated with bacteria, virus, and fungi. The most contaminated fomite with more than 10 species of pathogens was the mobile phone. This distribution might be due to the attitudes of healthcare workers and patients and their practice towards cleaning of mobile phones that prominent especially in Intensive Care Units (ICUs). Future study could investigate the effectiveness of proper hygiene to evaluate the contribution of this action towards the reduction of fomites contamination in the hospital.

Keywords: *clinical settings, fomite, mobile phone, hospital-associated infection (HAIs), Intensive Care Units (ICUs)*

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Introduction

Fomites are inanimate objects, including hair, particles of bedding and clothing, and skin cells, mobile phones, handrails, door knobs, bodily fluids and any equipment with the affinity of colonizing with microbes and transporting them between persons either directly or indirectly (Lopez *et al.,* 2013; Shaffer, 2013). Bacteria, viruses and fungi are microorganisms that are known as agents or pathogens that can cause fomite-transmitted infection. Long survival duration of pathogens on fomites had cause fomites to become a reservoir which increased the risk transmission of hospital-acquired infections (HAIs) (Olise & Simon, 2018; Massari, 2016; Otter *et al.,* 2013).

Around 2 million patients infected with HAIs had suffered in United State of America (USA) where the mortality was estimated to be 90,000 deaths, annually. This rank HAIs infection to be in top five death leading cause in USA (Klevens *et al.*, 2007; Centre for Disease Control, 1992). The increase risk transmission of HAIs would indirectly lead to economic pressure since the cost of treatment would escalate (Stone, 2009). It was estimated the annual hospital costs of HAIs in USA to be between US$28 billion to 45 billion per year (Douglas, 2009). A study conducted in Malaysia showed that in 100 patients, the prevalence of HAIs was 13.9%. Around half a million US$ worth of antibiotics were needed to cure HAIs infection, yearly (Hughes *et al.*, 2005).

Humidifier, nebulizer, urine-measuring device, thermometer and pressure transducer were among identified hospital fomites in a review in 1987 before computer keyboards, hand soap or sanitizer dispenser and ultrasound probe were added into the list 30 years later (Kanamori, Rutala & Weber, 2017). Stethoscope, white coats, neckties and digital devices were frequently contaminated by methicillin-resistant *Staphylococcus aureus* (MRSA) and Gram-negative rods (GNRs) (Haun, Hooper-Lane & Safdar, 2016). *Acinetobacter lwoffii*, MRSA and *Pseudomonas aeruginosa* were isolated from mobile phones samples which known as one of the threatening fomites in hospital (Aftab *et al.,* 2015).

Various aspects and factors contributed to colonization and the complexity of pathogens transmission in clinical setting (Monegro, Muppidi & Regunath, 2020). Contamination from the healthcare workers' hands and personal protective equipment (PPE) might associate with direct contact to fomites in the hospital (Jackson *et al.,* 2019; Huttenen & Syrjänen, 2014). Poor hygiene and incorrect disinfection procedure could also lead to more pathogen's contamination (Massari, 2016).

A few studies were conducted on pathogens from fomites in clinical or community settings. Most of them focused on the route of transmission of pathogens mediated by fomite and was published together with modelling of transmission pathway, observational epidemiological studies, microbiologic studies, intervention studies and outbreak reports (Otter *et al.* 2013). The published data regarding the transmission did not include various range of pathogens and the causal factors.

This scoping review would aid the research field by focusing on the literature regarding pathogens from fomites in order to synthesise the knowledge on their contamination by diverse range of pathogens and to determine the factors contributing to the distribution and species of pathogens in clinical setting.

Material and Method

Study design

This scoping review followed and referred the Arksey and O'Malley framework and guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco *et al.,* 2018). The study design of the framework was created by Arksey and O'Malley (2005) before it was advanced by Levac, Colquhoun and O'Brien (2010). The framework consisted of six stages which were identifying the research question, determining the relevant study, study selection, charting the data, collating, summarizing and reporting results and consultation.

Search strategy

Literature searching process was done on PubMed, Scopus and Taylor & Francis Online to achieve diverse context of pathogens in clinical fomites. These four databases were selected due to accessibility and availability of wide range of literatures. Multiple combinations of search terms was used to obtained a diverse context of pathogens originated from clinical fomites. The search strategy was developed and improvised by the author and supervisor. Simple calibration was done to resolve inconsistencies of literatures obtained by trying various search terms. The terms that gave out relevant and highest amounts of articles were selected. The following search string was used by authors in all the data search: (Pathogens OR Germs OR Infectious Agents) AND Fomites AND ("Clinical Setting" OR "Medical Setting" OR Hospital) AND (Distribution OR "Reported pathogens" OR Factor OR Source OR Effect OR Impact OR Department OR Ward OR Unit).

Study selection

Studies obtained from the search string would be sorted alphabetically and screened for duplicates. After removing the duplicates, the studies would be screened for inclusion criteria. Studies were included if the research consists of information that could achieve one of the research objectives (type of fomite, pathogens isolated and pathogen distribution associated factors), quantities research, published in 2010-2021 and available full-text in English. Studies that did not explore pathogens from fomites in clinical settings or deviate from the main purposes of the study were excluded.

Another screening process was conducted to ensure the eligibility of the articles. This was done to ensure the articles had relevant discussion that aligned with the scoping review objectives. The quality of selected articles in the review was assessed by the author and supervisor. Both of them would wholly appraise the articles to ensure the validity and reliability of the evidence. The selected studies were then compiled in Microsoft Excel for further process. Figure 1 represented the research flow diagram based on PRISMA-ScR outlining the selected studies that passed the criteria for full review.

Data extraction and charting

The data compiled in Microsoft Excel consisted of: Titles, author/year, country, ward/department, type of fomite, pathogens isolated and pathogen distribution associated factors. The data that did not related to the scoping review objectives was not extracted from the articles. The findings would helped in answering the scoping review objectives where the data obtained would be represented in table format. The full text papers were stored in PDF format for references purposes.

Result

Study selection

An amount of 375 articles were retrieved with 232 articles from PubMed, four articles from Scopus and others from Taylor & Francis Online. The 371 articles remaining were screened based on the inclusion criteria after duplicates were removed. The 314 articles were excluded in the next step due to the articles did not meet the inclusion criteria and had no full-text documents. Next, 57 full-text articles were assessed for eligibility, of which 14 articles were excluded for having irrelevant discussion or study objectives. Finally, 43 articles were chosen for full review and were included in the final analysis. Table 1 illustrated the articles included in the scoping review.

Study overview

Out of 43 articles chosen, 37 studies had reported on contamination of fomites and its associated types of pathogens as shown in Table 2. Seven articles explored on the factors related to fomites contamination in clinical settings. Only two papers discussed on both aspects: fomites contamination and its associated types of pathogens and the related factors.

Identification of fomites

Among 37 papers reported about fomites, nine of them conducted investigation on the mobile phones of the medical students, healthcare workers and patients. Four studies recorded about faucet and bedside table contamination and three papers researched on stethoscope and bed rails. Two studies performed inquiry on contamination of scissors, keyboard, sink, trolley, pen and thermometer while only one study identified ball pits, floor, wall, medical charts and door handles as fomites.

Localization of fomites

All studies of the particular fomites were carried out in multiple department or wards of the hospital. However, the data showed that ICUs were likely to be chose for a for single research setting study based on a study conducted by Chen *et al.* (2014) regarding the relation of bacterial contaminations in different wards.

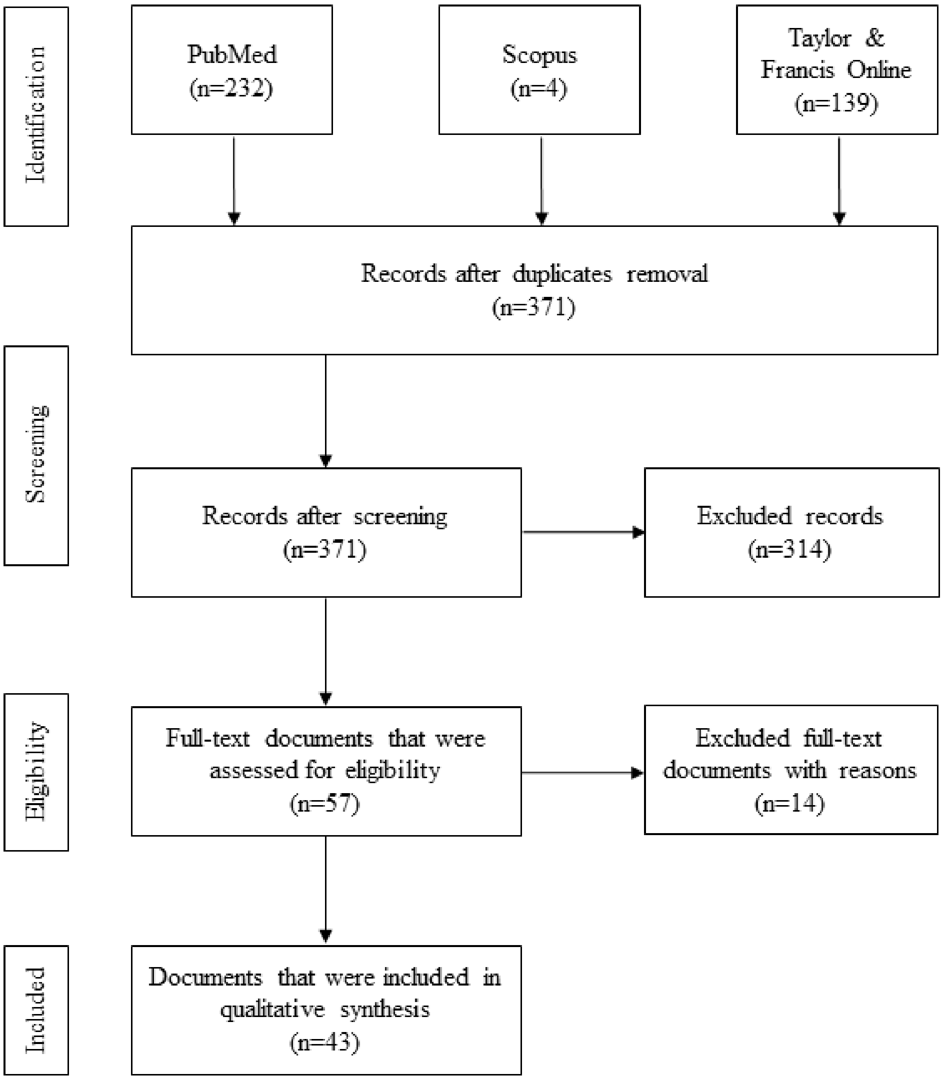

Figure 1. The flow diagram for data collection and extraction based on PRISMA-ScR guideline.

Table 1. List of articles accepted in the scoping review

No.	Title	Reference
1.	An outbreak of Legionnaires disease associated with a decorative water fall fountain in hospital	Haupt *et al.* (2012)
2.	Are balls pits located in physical therapy clinical settings a source of pathogenic microorganisms?	Oesterle *et al.* (2019)
3.	Are hospital floors an underappreciated reservoir for transmission of health care-associated pathogens?	Deshpande *et al.* (2017)
4.	Bacterial colonization on writing pens touched by healthcare professionals and hospitalized patients with and without cleaning the pen with alcohol-based hand sanitizing agent	Halton *et al.* (2011)
5.	Bacterial contamination and antimicrobial susceptibility patterns of intensive care units medical equipment and inanimate surfaces at Ayder Comprehensive Specialized Hospital, Mekelle,Northern Ethiopia	Darge *et al.* (2019)
6.	Bacterial contamination and stethoscope disinfectionpractices: A cross-sectional survey of healthcare workers in Karachi, Pakistan	Rao *et al.* (2017)
7.	Colonization of patients, healthcare workers, and the environment with healthcare-associated *Staphylococcus epidermidis* genotypes in an intensive care unit: A prospective observational cohort study	Widerström *et al.* (2016)
8.	Comparison of keyboard colonization before and afteruse in an inpatient setting and the effect of keyboard covers	Das *et al.* (2018)
9.	Contamination of medical charts: An important source of potential infection in hospitals	Chen *et al.* (2014)
10.	Contamination of X-ray cassettes with methicillin- resistant *Staphylococcus aureus* and methicillin- resistant *Staphylococcus haemolyticus* in a radiology department	Kim *et al.* (2012)
11.	Dissemination of human adenoviruses and rotavirus species A on fomites of hospital paediatric units	Ganime *et al.* (2016)
12.	Do mobile phones of patients, companions and visitors carry multidrug-resistant hospital pathogens?	Tekerekoğlu *et al.* (2011)
13.	Extended-spectrum β-lactamase-producing Enterobacteriaceae in cell phones of health careworkers from Peruvian pediatric	Loyola *et al.* (2016)

	and neonatal intensive care units	
14.	Faucet aerators as a reservoir for carbapenem-resistant *Acinetobacter baumannii*: A healthcare-associated infection outbreak in a neurosurgical intensive care unit	Lv *et al.* (2019)
15.	Hand hygiene after touching a patient's surroundings: The opportunities most commonly missed	FitzGerald *et al.* (2013)
16.	Hand sanitizer dispensers and associated hospital-acquired infections: Friend or fomite?	Eiref *et al.* (2012)
17.	Health care workers' mobile phones: A potential cause of microbial cross-contamination between hospitals and community	Ustun *et al.* (2012)
18.	Identification of microorganisms on mobile phones of intensive care unit health care workers and medical students in the tertiary hospital	Kotris *et al.* (2017)
19.	Influence of biological fluids in bacterial viability on different hospital surfaces and fomites	Esteves *et al.* (2016)
20.	Isolation and characterization of *Stenotrophomonasmaltophilia* isolates from a Brazilian hospital	Gallo *et al.* (2016)
21.	Isolation of pathogenic bacteria from fomites in theoperating rooms of a specialist hospital in Kano, North-western Nigeria	Nwankwo *et al.* (2012)
22.	Methicillin resistant *Staphylococcus aureus* contamination of phlebotomy tourniquets and faucets	Abeywickrama *et al.* (2018)
23.	Knowledge, attitude, and practices of healthcare personnel regarding the transmission of pathogens via fomites at a tertiary care hospital in Karachi, Pakistan	Aftab *et al.* (2015)
24.	Microbial contaminants isolated from items and work surfaces in the post- operative ward at Kawolo General Hospital, Uganda.	Sserwadda *et al.* (2018)
25.	Microbial flora on cell-phones in an orthopaedic surgery room before and after decontamination	Murgier *et al.* (2016)
26.	Mobile phone technology and hospitalized patients: A cross-sectional surveillance study of bacterial colonization, and patient opinions and behaviours	Brady *et al.* (2011)
27.	Mobile phones as a potential vehicle of infection in a hospital setting	Foong *et al.* (2015)
28.	More than just teddy bears: Unconventional transmission agents	Hardy *et al.* (2018)

	in the operating room	
29.	Neonatal resuscitation equipment: A hidden risk for our babies?	Winckworth *et al.* (2016)
30.	Nosocomial infections in the ICU: Pens and spectacles as fomites	Murad *et al.* (2016)
31.	Nursing and physician attire as possible source ofnosocomial infections	Wiener-Well *et al.* (2011)
32.	Potential sources of transmission of hospital acquired infections in the volta regional hospital in Ghana	Tagoe *et al.* (2011)
33.	Prevalence of antibacterial resistant bacterial contaminants from mobile phones of hospital inpatients	Kumar *et al.* (2014)
34.	*Pseudomonas aeruginosa* infections due to electronic faucets in a neonatal intensive care unit	Yapicioglu *et al.* (2012)
35.	Quantitative assessment of interactions between hospitalized patients and portable medical equipment and other fomites	Suwantarat *et al.* (2017)
36.	Sphygmomanometer cuffs: A potential source of infection!	Zargaran *et al.* (2015)
37.	Sphygmomanometers and thermometers as potentialfomites of *Staphylococcus haemolyticus*: Biofilm formation in the presence of antibiotics	Sued *et al.* (2017)
38.	Stethoscopes as potential intrahospital carriers of pathogenic microorganisms	Campos-Murguía *et al.* (2014)
39.	Surface microbiology of the iPad tablet computer and the potential to serve as a fomite in both inpatient practice settings as well as outside of the hospital environment	Hirsch *et al.* (2014)
40.	Transfer of dry surface biofilm in the healthcare environment: The role of healthcare workers' hands asvehicles	Chowdhury *et al.* (2018)
41.	*Trichosporon asahii* among intensive care unit patients at a medical center in Jamaica	Fanfair *et al.* (2013)
42.	The occurrence of nosocomial pathogens on cell phones of healthcare workers in an Iranian tertiary care hospital	Khashei *et al.* (2019)
43.	Use of portable electronic devices in a hospital setting and their potential for bacterial colonization	Khan *et al.* (2015)

Table 2. The findings of studies on fomites.

Reference	Country	Ward/Department	Fomite	Types of Pathogens: Bacteria [a]: Gram-positive	Types of Pathogens: Bacteria [a]: Gram-negative	Types of Pathogens: Others [a]
(Brady *et al.*, 2011)	United Kingdom	Surgical/Urology	Mobile phone	CoNS, *S. aureus*, *Corynebacterium* spp., *Streptococcus* spp., *E. faecium*, *Enterobacter cloacae*, *Micrococcus* spp., *Dermacoccus nishinomiyaensis*, *Kocuria kristinae*, *Lactococcus garvieae*, *Gemella morbillorum*, *Bacillus* spp., Alpha-hemolytic *Streptococcus*	*Sphingomonas paucimobilis*, *Rhizobium radiobacter*, *A. ursingii*, *Moraxella* spp., *Burkholderia cepacia*	Fungi: *Candida albicans*
(Halton *et al.*, 2011)	United State of America	NA	Pen	*Micrococcus* spp., *Staphylococcus* spp., *Enterococcus* spp.	NA	NA
(Tagoe *et al.*, 2011)	Ghana		Door handle, lavatories, desk surfaces, faucet	*S. aureus*	*E. coli*, *P. aeruginosa*	NA
(Tekerekoğlu *et al.*, 2011)	Turkey	NA	Mobile phone	CoNS, *S. aureus*, *Streptococcus* spp., MRSA, *Bacillus* spp., *Enterococcus* spp. (ESBL and high-level	*Escherichia coli*, *Klebsiella* spp., *Proteus* spp., *P. aeruginosa*, *A. baumannii*	NA

				aminoglycoside-resistant)	(carbapenem resistant)	
(Wiener-Well *et al.*, 2011)	Israel	Medical and Surgical	Uniform	MSSA, MRSA	*A. baumannii, A. lwoffii, E. cloacae, K. pneumoniae, K. oxytoca, Citrobacter freundii, E. coli, Pantoea agglomerans, P. stutzeri, P. putida, P. aeruginosa, P. fluorescens*	NA
(Eiref *et al.*, 2012)	United State of America	Surgical ICU	Hand sanitizer dispenser	CoNS, MSSA, *Micrococcus* spp., *Bacillus* spp., Diphtheroid, aerobic actinomycetes	Non-lactose fermenter non-enteric, lactose-fermenter enteric	NA
(Haupt *et al.*, 2012)	United State of America	NA	Water wall fountain	NA	*Legionella*	NA
(Kim *et al.*, 2012)	Korea	Radiology	X-ray cassette	MRSA, methicillin-resistant *S. haemolyticus*	NA	NA
(Nwankwo, 2012)	Nigeria	Operation Theatre	Floor	*B. circulans, Micrococcus*	*E. coli, Salmonella enterica*	Fungi: *Penicillium, Aspergillus* spp.
			Operating lamp	*Streptococcus* spp., CoNS, *B. circulans*	NA	NA
			Wall	*Streptococcus* spp., CoNS	NA	NA

			Sink	*NA*	*P. aeruginosa, P. mirabilis*	NA
			Suction tube	*Streptococcus* spp., *S. aureus, E. faecalis*	*P. aeruginosa, P. mirabilis, P. vulgaris*	Fungi: *Aspergillus* spp.
			Scissors	CoNS, *Micrococcus*	NA	NA
			Trolley	*B. circulans, Streptococcus* spp.	NA	Fungi: *Penicillium*
			Anaesthetic machine	*Micrococcus*	NA	NA
(Ustun & Cihangiroglu, 2012)	Turkey	Various	Mobile phones	MRSA, MSSA, ESBL positive, ESBL negative, MR-CoNS spp., MS-CoNS spp., *Enterococcus* spp.	*Klebsiella* spp.	NA
(Yapicioglu *et al.*, 2012)	Turkey	Neonatal ICU	Electronic faucet	NA	*P. aeruginosa*	NA
(Fanfair *et al.*, 2013)	Jamaica	ICU	Sink, bed rails, faucet, drawer, washbasin,	NA	NA	Fungi: *Trichosporon asahii*
(Campos-Murguia *et al.*, 2014)	Mexico	Various	Stethoscope	*E. faecalis, S. aureus*	*K. pneumoniae, A. baumannii, B. cepacia*	NA
(Chen *et al.*, 2014)	Taiwan	Various	Medical chart	CoNS, *S. aureus,* MRSA, *E. faecalis, S. viridans,*	*S. paucimobilis, P. aeruginosa, E. coli, K.*	NA

				Corynebacterium spp., *Bacillus* spp.	*pneumoniae, Pantoea* spp., *A. baumannii*	
(Hirsch *et al.,* 2014)	United State of America	Pharmacy	iPads	MRSA, vancomycin-resistant enterococci	*P. aeruginosa*	NA
(Kumar *et al.,* 2014)	Saudi Arabia	NA	Mobile phone	CoNS, *S. aureus, E. cloacae, E. faecalis*	*P. stutzeri, S. paucimobilis*	NA
(Foong *et al.,* 2015)	Australia	NA	Mobile phone	MRSA	Coliforms	NA
(Khan *et al.,* 2015)	United State of America	NA	Portable electronic devices	CoNS, MRSA, *Bacillus* spp., *Streptococcus* spp., *S. aureus, Enterococcus* spp.	*Acinetobacter* spp., *Pantoea* spp., *Pseudomonas* spp., *Enterobacter* spp., *Moraxella*	NA
(Zargaran *et al.,* 2015)	United Kingdom	Various	Sphygmomanometer cuff	*Bacillus* spp., CoNS, Diphtheroid, *Enterococcus* spp., *Micrococcus* spp., viridans streptococci, *S. aureus*	Coliform, *Proteus* spp.	NA
(Gallo *et al.,* 2016)	Brazil	NA	Bed rails, trolley, bedside table, ambubag, intravenous pump	NA	*Stenotrophomonas maltophilia*	NA
(Ganime *et al.,* 2016)	Brazil	Pediatric	Accompanying arm chair, bed rails, door knob, bedside table,	NA	NA	Virus:

			cardiac monitor keyboard, incubator door locks			Human adenovirus, Rotavirus A
(Loyola *et al.,* 2016)	Peru	Pediatric, neonatal ICU	Mobile phone	*Enterobacter* spp.	*E. coli,* *K. pneumoniae,* *K. oxytoca*	NA
(Murad & Inam Pal, 2016)	Pakistan	ICU	Pen	*Acinetobacter*	NA	Fungi: *Candida*
			Spectacles	Vancomycin-resistant *E. faecium*	NA	NA
(Murgier *et al.,* 2016)	France	Operation Theatre	Mobile phone	CoNS, *C. tuberculostearicum,* sporulating bacteria	*A. lwoffii, Radioresistens, Enterobacteria, Roseomonas mucosa,* *P. oryzihabitans*	Unidentified fungi
(Winckworth *et al.,* 2016)	United Kingdom	Neonatal ICU	Resuscitation equipment	CoNS,	*E. coli, E. cloacae*	NA
(Deshpande *et al.,* 2017)	United State of America	Patient room	Floor	MRSA, vancomycin-resistant enterococci, *Clostridium difficile*	NA	NA

(Kotris *et al.*, 2017)	Croatia	ICU	Mobile phone	CoNS, *S. aureus, Sarcina* spp., *Bacillus* spp., *Corynebacterium* spp.	*Neisseria* spp., non-fermenting bacteria	NA
(Rao *et al.*, 2017)	Pakistan	Various	Stethoscope	*S. aureus*	*E. coli*	NA
(Sued *et al.*, 2017)	Brazil	Various	Sphygmomanometers, thermometers	Oxacillin-resistant *S. haemolyticus*	NA	NA
(Abeywickrama *et al.*, 2018)	Sri Lanka	Various	Tourniquet, faucet	MRSA	NA	NA
(Das *et al.*, 2018)	United State of America	Medical	Keyboard	CoNS, *S. aureus,* α-haemolytic *Streptococcus,* γ-haemolytic *Streptococcus, Bacillus,* Diphtheroid, *Micrococcus*	Rod-shaped bacteria	NA
(Hardy *et al.*, 2018)	France	Operation Theatre	Stuff bear	*S. aureus*	*A. ursingii, A. baumannii, P. stutzeri*	NA
(Sserwadda *et al.*, 2018)	Uganda	Post-surgical	Scissors	*S. aureus*	*K. pneumoniae*	NA
			Infusion stands, light switch	*S. aureus*	*Enterobacter* spp., *K. pneumoniae, Serratia merscescans*	NA
			Patient beds	*S. aureus*	*P. vulgaris*	NA

			Tables, sink taps	*S. aureus*	*K. pneumoniae, P. vulgaris*	NA
(Darge *et al.*, 2019)	Ethiopia	ICU	Stethoscope	CoNS, *S. aureus*	*E. coli, P. vulgaris, S. typhi, E. aerogenes, C. freundii, K. pneumoniae*	NA
			Thermometer	CoNS	*E. coli, C. freundii*	NA
			Sphygmomanometer	CoNS, *S. aureus*	*K. pneumoniae*	NA
			Bedside table, mattress, computer	CoNS, *S. aureus*	NA	NA
(Khashei *et al.*, 2019)	Iran	Various	Mobile phone	*Staphylococci, Streptococci, Micrococci*	NA	NA
(Lv *et al.*, 2019)	China	ICU	Faucet aerator	NA	Carbapenem-resistant *A. baumannii*	NA
(Oesterle *et al.*, 2019)	United State of America	Pediatric	Ball pits	*B. fastidiosus, B. galactosidilyticus, B. mojavensis/subtilis, B. plakortidis, B. sporothermodurans, B. thuringiensis/cereus, B. lentus, B. horikoshii, Sporolactobacillus terrae, E. faecalis, Macrococcus brunesis, Paenibacillus xylanilyticus, S. hominis, S. oralis, S. sobrinus,*	*A. lwoffii, K. variicola, M. caprae, Pseudoxanthomonas yeogluenesis, P. agarici, P. fragi, P. pertucinogena, Psychrobacter immobilis, Raoultella terrigena, Stenotrophomonas rhizophila, Rhodotorula mucilaginosa*	NA

	Aerococcus viridans, Vagococcus salmoninarum, M. flavusx, Mycobacterium aichiense/novocastrense	

Note: [a]: Listed bacteria, fungi and virus did not cover the whole species listed in the reference articles.

Abbreviation: MRSA: methicillin-resistant *S. aureus;* MSSA: methicillin-sensitive *S. aureus;* CoNS: coagulase-negative *Staphylococci;* MR-CoNS: methicillin-resistant coagulase-negative *Staphylococci;* MS-CoNS: methicillin-sensitive coagulase-negative *Staphylococci;* ESBL: extended spectrum beta-lactamase; NA: not available.

Factors of pathogens contamination

Various factors or reasons of pathogens distribution in clinical setting were shown in Table 3. Seven studies had revealed a total of 11 factors related to pathogens distribution. Nevertheless, three factors identified might lead to similar cause which contributed by health workers. The other identified factors were contributed from environment, patients, biological fluids, hands, mobile phones and medical equipment.

Table 3. Factors of pathogens distribution on fomites in clinical setting.

Factor	Reference
Lack of education and knowledge of the patient and surrounding people	(Brady *et al.*, 2011)
Healthcare workers' attitude	(FitzGerald *et al.*, 2013)
Knowledge and practice gap of healthcare workers	(Aftab *et al.*, 2015)
Biological fluids Poor hygiene Portability of mobile phone	(Esteves *et al.*, 2016)
Hospital environment Healthcare workers Patients transferred from other hospital	(Widerström *et al.*, 2016)
Shared portable medical equipment	(Suwantarat *et al.*, 2017)
Contaminated hands	(Chowdhury *et al.*, 2018)

Discussion

Types of pathogens from fomites in clinical setting

Two types of pathogens were identified on mobile phones where majority of them were bacteria. The mobile phones of the patients contained a much bigger proportion of infection than the device used by the healthcare workers. Multi-drug resistant bacteria were not detected on the mobile phones of the workers, contrary to predictions by Tekerekoğlu *et al.* (2011). A research conducted by Brady *et al.* in 2011 showed that there was a relationship between *S. aureus* nasal colonization and the presence of this pathogen on the patient's mobile phone. Another research involving the same fomite on healthcare workers was conducted on the following year. The researchers managed to demonstrate the contamination of pathogens which was believed to be contributed by improper touching of the phone unconsciously while treating the patients (Ustun & Cihangiroglu, 2012). This contaminated device had a potential to serve as a vector of nosocomial pathogens in a hospital setting which indirectly could also lead to transmission in the healthcare workers' homes.

Foong *et al.* (2015) revealed that MRSA and coliforms had contaminated the mobile phones of the people in the hospital. Another group of researchers had conducted a study in 2016 to investigate the trend of the mobile phone's contamination in the ICU ward. More than 70% of the workers did not practice disinfection as standard of operation and nearly half of them frequently touched the mobile phones during working (Loyola *et al.*, 2016). However, Kotris *et al.* (2017) who studied on fomite contaminations in the same department, stated that the isolated pathogens on the mobile phones obtained from the research were non-pathogenic.

Another group of researchers had studied the same device but in different department. The researchers demonstrated the contamination of CoNS, *C. tuberculostearicum, A. lwoffii, Radioresistens, Enterobacteria, R. mucosa, P. oryzihabitans,* fungi and sporulating bacilli on the mobile phones of the healthcare workers (Murgier *et al.,* 2016). The most recent study on mobile phones depicted that Gram-positive *Staphylococci* as the most prevalent microorganism that contaminated this device in the hospital (Khashei *et al.*, 2019). The healthcare workers' uniforms especially physicians and nurses were contaminated with various pathogens of Gram-negative bacteria and some of Gram-positive bacteria (Wiener-Well *et al.,* 2011). The ball pits of the paediatric physical therapy department had found contamination of bacteria where nine of the pathogens were identified as opportunistic pathogens (Oesterle *et al.,* 2019). Three studies on the stethoscopes had reported different number of isolated bacteria (Darge *et al.,* 2019; Rao *et al.,* 2017; Campos-Murguía *et al.,* 2014).

Sphygmomanometers and thermometers were also among the common bacteria-contaminated fomites that had direct contact with patients (Sued *et al.,* 2017). Interestingly, sphygmomanometers cuff was reported to be contaminated with different species of bacteria than of sphygmomanometer which could contribute to a number of infections such as nosocomial meningitis, bacteraemia, diphtheria, infective endocarditis and urinary tract infections (Zargaran *et al.,* 2015).
Another study showed that patient beds and infusion stand had greater bacterial contamination levels compared to swabbed surfaces and equipment (Sserwadda *et al.,* 2018). This was likely due to medical practitioners' hands as a means of transmission point during patient care in the hospital.

A study conducted by Eiref *et al.* in 2012 showed that bacteria had contaminated the 100% waterless alcohol-based hand sanitizer dispensers from surgical ICU, including commensal skin flora and Gram-negative enteric. Although the reported bacteria were not usually associated with HAIs, they could still potentially become opportunistic pathogens in immunocompromised patients or those with indwelling medical devices.

Pens and spectacles were also in the list of contaminated fomites in the hospital setting. Only one study was conducted on them where four species of bacteria and a species of fungi were found on pens while spectacles were reported contaminated with vancomycin-resistant *E. faecium* (Murad & Inam Pal, 2016). The researchers also reported the relationship between the vancomycin-resistant *E. faecium* and the outbreaks in many hospitals where the bacteria usually affect the urinary tract and bloodstream of the victim or patient.

Electronic faucet was another vector for pathogens transmission where the most contaminated faucets' components were the output, magnetic valve and mixing device (Yapicioglu *et al.,* 2012). The researchers acknowledged that the magnetic valve was made of *P. aeruginosa* biofilm-friendly rubber, plastic and polyvinylchloride membranes.

An outbreak of legionellosis in hospital had led to a study on the contaminated water wall fountain. The study found that the usage of floodlights and an electric fireplace on the back side of the wall which might warmed the fountain water to temperature favourable for *Legionella* growth (Haupt *et al.,* 2012).

X-ray cassettes in the radiology department were contaminated by two species of bacteria which were MRSA and methicillin-resistant *S. haemolyticus*. Both of the species were believed to be transferred from contaminated workers' hands or patients' skin and clothing (Kim *et al.,* 2012).

Stuff toys that were brought by the paediatric patients into the operating rooms also included as one of the fomites in hospital setting. The toys were discovered to be contaminated with a species of Gram-positive bacteria and three species of Gram-negative bacteria (Hardy *et al.,* 2018). The findings suggested that bringing these unusual transmission agents into the operating room could contribute a considerable, potentially pathogenic contribution to the bacteria load, thus increasing the risk of surgical site infection.

Factors of various distribution of pathogens from fomites in clinical setting

There was only one study that discussed on the comparison of the wards and departments in relation to pathogen contamination from fomites in clinical setting. Based on the study, most of the medical charts examined had bacteria contamination with nearly 70% in general wards and more than 80% in ICUs (Chen, Chen & Wang, 2014). The researchers emphasised that the contamination of ICUs that similar to general wards could lead to increase in nosocomial infection.

The factors associated with contaminated fomites distributions in hospital setting were discussed in a few studies. A study in 2016 demonstrated the widespread of hospital-acquired methicillin-resistant *S. epidermidis* due to healthcare workers, patients referred from other hospitals and the hospital environment. Almost all workers, more than half of the referred patients and 50% of the hospital environment were reported to be contaminated (Widerström *et al.,* 2016).

In contrast, Aftab *et al.* (2015) depicted that the huge gap between the knowledge and practices of the healthcare workers contributed to the large distribution of pathogen. Majority of the workers recognised and knowledgeable on the potential fomites in hospital. Yet, only a small number of them practised the appropriate hygiene and sanitisation. Similarly, previous study also reported the same root cause had high potential in leading to the pathogen's transmission in the hospital (Brady *et al.,* 2015).

The attitude of the healthcare workers that did not comply with the hand hygiene routine might increase the contamination of clinical fomites (Chowdhury *et al.,* 2018; FitzGerald *et al.,* 2013). The poor hygiene and portability of mobile phones of patients or healthcare workers might contribute to the ESBL producing and multidrug resistant bacteria across the wards and department in hospital (Loyola *et al.,* 2016).

Biological fluids could also facilitate the pathogens transmission through sharing between hosts (Esteves *et al.,* 2016). Shared portable medical equipment were usually contaminated with the pathogens found in the clinical setting (Suwantarat *et al.,* 2017). The contaminated portable medical equipment was often touched or used by the hospitalized patients which could contribute to a rise in nosocomial infections.

Limitation of study

The study conducted was restricted by the imbalance of obtained data in achieving the study objectives. Most of the studies obtained from the database were investigating and discussing on the types of reported pathogens on fomites in clinical settings. The studies did not include factors behind the emergence of pathogens as a part of their research purposes. This review also did not focus on the effects of the hygiene or actions that reduced the pathogen contamination on the hospital fomites. There was also a problem of getting access to full-text documents which effect the scope of the review.

Conclusion

In conclusion, there were 46 reported group of fomites in clinical setting that were associated with various pathogen contamination which were bacteria, fungi and virus. The most reported contaminated fomite was mobile phone with more than 10 identified species of pathogens, including MRSA, MR-CoNS and ESBL pathogens. The various distribution of contamination might be due to several factors, including the healthcare workers and the patients' attitude and practice towards cleaning of the mobile phones. ICUs had a higher potential to be contaminated with pathogens compared to other departments in the hospital.

The scoping review study was just a preliminary stage to more studies of this in the future. It is suggested for future study to address the exact mechanism of pathogen distribution throughout the clinical setting. More studies should be conducted in discovering the effectiveness of proper hygiene to evaluate the effect of this action towards fomite contamination in the hospital. Future study should lean more on investigation and construction of appropriate and effective plan that could tackle the problem of fomites contamination in clinical setting.

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