The role of mobile communication devices in the spread of infections within a clinical setting

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Abstract: Mobile communication devices (MCDs) are routinely used in clinical settings. Bacterial contamination of MCDs is a growing concern as they can serve as a potential reservoir for infectious diseases. Recent studies have found that between 9% and 15% of MCDs carry pathogenic bacteria. To reduce contamination, recommendations are to practice good hand hygiene, restrict MCDs in high-risk areas, and sanitize MCDs using 70% isopropyl alcohol.

Key words: infectious disease, public health, cell phone, hospital-acquired infection, mobile communication device

Introduction

Ubiquitous is a term readily applied to microbes and mobile communication devices (MCDs) alike. In a clinical setting however, this combination can become a hazard. MCDs include a wide range of electronics such as cell phones, tablets, personal digital assistants (PDAs), and pagers. Ascertaining the number and types of microbes found on MCDs, their origins and destinations, as well as determining effective reduction protocols are the best methods for mitigating this potential hazard. In this review, we examine the risk associated with MCDs as a reservoir for microbes, in particular, those that cause nosocomial or hospital-acquired infections (HAIs). Furthermore, we examine the bacterial load on MCDs including its prevalence, types of bacteria found (pathogenic and non-pathogenic), effects of sanitation, and recommendations going forward.

On dry surfaces, most gram-positive bacteria, including Methicillin-resistant *Staphylococcus aureus* (MRSA) and Vancomycin-resistant *enterococci* (VRE) have been shown to survive for months (Kramer et al., 2006). Some of the papers in this review included a questionnaire regarding phone sanitation. Rates were low, such as in Singh et al. (2002), where 88% of respondents stated they had never cleaned their phone. These two findings reflect the potential of MCDs as fomites and dangers to human health in a clinical setting.

Methods

Literature for this review was obtained from the following databases and search engines: Google Scholar, the University of Guelph Libraries (PRIMO), University of Ottawa Libraries (SCOPUS),

and the National Center for Biotechnology Information (NCBI). A few sources were also found as a result of being referenced by other papers that were examined. Search terms used to extract literature from the aforementioned websites were a combination of the following: “mobile phone bacteria”, “cell phone bacteria”, “infectious mobile”, “antibiotic resistance phone”, “MRSA phone”, “hospital staff cell phone”, and “fecal bacteria phones”. Developing countries such as Pakistan, India, and countries in the middle-East were excluded from this literature search as conditions of the physical and social environment may differ too greatly for results to be extrapolated to North American contexts. Prevalence and type of bacteria, clinical hygiene standards and practices, and mobile communication device usage patterns all may be distinct in developing countries.

Risk assessment

Mobile communication devices

MCDs have become instrumental in everyday life. According to a 2012 study, 75% of Canadians owned a mobile phone (Canadian Wireless Telecommunication Association, 2012). Smartphones made up 48% of those mobile phones (Canadian Wireless Telecommunication Association, 2012). It is estimated that by 2018, 93% of mobile phones in North America will be smartphones (Cisco Systems Inc, 2014).

In a clinical setting, healthcare workers (HCWs) use MCDs on a day-to-day basis for work and social purposes. Studies indicate that 87%–88% of HCWs use their MCD at the workplace (Koehler et al., 2013; Mark et al., 2014). These devices are used primarily to optimize patient care and client communications (Julian et al., 2012). Specifically, MCDs are used to access laboratory results, conduct Internet research, and seek consultation amongst colleagues (Mark et al., 2014).

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Reliance on mobile technology is increasing. As of 2013, there were approximately 20,000 medical apps available for download (Aungst, 2013). Some common apps include drug guides, medical calculators, coding and billing apps, and pregnancy wheels (Franco and Tirrell, 2011). Improvements to health such as better patient control of diabetes (Ferrer-Roca et al., 2004) and the increase in vaccination rates of travelers (Vilella et al., 2004) have been facilitated through the use of mobile innovations.

Patients and visitors also use their MCDs to communicate with relatives and manage their business from the hospital (Tekerekoglu et al., 2011). It has been demonstrated that inpatient experience can be enhanced through the use of MCDs (Brady et al., 2011). In addition, a study indicates that 92.6% of patients support the use of MCDs in hospitals (Brady et al., 2011).

Hospital-acquired infections

HAIs fundamentally undermine the goal of any healthcare facility. Infections of this nature are acquired due to hospital admittance; a patient admitted for other reasons and not infected at the time of admittance then becomes ill because of an infection acquired during their hospital stay (Ducel et al., 2002). The yearly toll of HAIs in Canadian hospitals is close to a quarter million occurrences and over 8,000 deaths (Zoutman et al., 2003). Patients at-risk are those least able to bear the burden such as the elderly, the immunocompromised, and those already burdened with another disease or disability (Zoutman et al., 2003). The costs of HAIs include longer hospital stays, greater healthcare costs, additional bodily and mental stress on the patient, possible long-term disability, hospital re-admittance, imbalance of hospital resources through reallocation to potentially preventable illness, and for some death (Ducel et al., 2002; Canadian Institute for Health Information, 2008).

Converging in hospitals are multiple factors that allow for the development of HAIs. Patients are more susceptible to infection because of their physical condition (e.g., age, immune status, chronic disease, etc.) or due to medical procedures (e.g., immunosuppression, irradiation, catheterization, intubation, etc.) (Ducel et al., 2002). Among these patients are those admitted for an infection; these infected and susceptible groups are then mixed together through the shared hospital environment (Ducel et al., 2002). Further compounding the issue is antibiotic resistance in some of the microbes that cause HAIs (Ducel et al., 2002).

Three of the HAIs monitored by the Canadian Nosocomial Infection Surveillance Program are MRSA infections, VRE infections, and *Clostridium difficile* infections (Public Health Agency of Canada, 2013). These three are notable because they can be spread via skin-to-skin contact or contact with contaminated surfaces (Ducel et al., 2002). Given the level of interaction required to administer care in a hospital (Public Health Agency of Canada, 2013), these routes of transmission are of great importance. As an example of the continued and growing issue of HAIs note that MRSA infections in Canada have increased 1000-fold in less than 15 years (Public Health Agency of Canada, 2013).

Discussion

A summary of the findings can be found in Table 1. Although the majority of the studies we reviewed were conducted in a hospital or clinical setting, two studies tested MCDs for harmful bacteria outside of this environment. Blankinship et al. (2013) looked for antibiotic resistant bacteria on keyboards and cell phones of faculty, staff, and students at the University of Alabama, whereas Meadow et al. (2014) cultured bacteria off of touchscreen PDAs in a workshop. Blankinship et al. (2013) reported that antibiotic resistance was low and Meadow et al. (2014) reported that typical skin organisms are more likely found on PDAs than pathogenic organisms. MCDs are most likely not a source of infection for people outside of a clinical setting.

Studies that were conducted in a clinical setting found a range of bacteria on MCDs. The majority of MCDs were sampled from HCWs, such as physicians and nurses, with the exception of one study that sampled patient phones (Beckstrom et al., 2013). The most common types of bacteria found on MCDs were bacterial skin flora. These non-pathogenic bacteria include Coagulase-negative *Staphylococcus* spp., *Micrococcus* spp., *Diphtheroid* spp., and *Bacillus*. For most studies, the greatest concern was to report pathogens such as MRSA and Methicillin-sensitive *Staphylococcus aureus*. Other pathogenic bacteria that were found on MCDs were *Acinetobacter* spp., *Pseudomonas* spp., and VRE. These strains of bacteria can be a source of infection for both HCWs and their patients.

A study conducted by Braddy and Blair (2005) found zero traces of pathogenic bacteria. In contrast, many other studies found that approximately 9%–15% of MCDs were associated with bacteria that could cause infections (Brady et al., 2006, 2007, 2011; Karabay et al., 2007). MRSA levels varied from 0.1% to 12%, whereas one study in Turkey reported that MRSA was found on 52% of MCDs (Singh et al., 2002; Hassoun et al., 2004; Goldblatt et al., 2007; Ulger et al., 2009; Julian et al., 2012; Ustun and Cihangiroglu, 2012; Beckstrom et al., 2013; Pal et al., 2013).

Studies have reported that between 85% and 93% of HCWs never clean their MCDs (Singh et al., 2002; Hassoun et al., 2004; Brady et al., 2007). Furthermore, Mark et al. (2014) found that 45% of medical professionals never wash their hands after phone usage. Since a significant number of MCDs carry pathogenic bacteria, there is a need to determine the risk of transmission from MCDs to both HCWs and patients.

Recommendations

There are currently no recommendations regarding safe MCD-use in clinical settings in the countries in which the studies were conducted (Canada, the United States, Austria, Turkey, and the United Kingdom). However, the studies reviewed did have recommendations on how to control HAIs infections as a result of MCDs. The strategy that was recommended by almost all authors and that was also deemed as most effective in reducing the potential of MCD-contamination was strict adherence with hand hygiene (Singh et al., 2002; Braddy and Blair, 2005; Goldblatt et al., 2007; Ulger et al., 2009; Brady et al., 2011;

Table 1. Summary of papers

Authors	Sample size and trial type	Main findings
Basol et al., 2014	Chicago, USA <ul style="list-style-type: none"> $n = 66$ shared mobile phones routinely used by clinical Registered Nurses (in 11 acute care units and critical care units) Randomized control trial 	<ul style="list-style-type: none"> No pathogenic bacteria detected on mobile phones before or after using wipes Normal skin flora (<i>Coagulase-negative Staphylococcus spp.</i>, <i>Micrococcus spp.</i>, <i>Diphtheroid spp.</i>, and <i>Bacillus spp.</i>) was reduced from 64% to 12% with isopropyl alcohol wipes and 64% to 15% with ethyl alcohol wipes, as a result mobile phones weren't a source of healthcare-associated infections Cleaning of mobile phones using alcohol wipes effectively eliminates bacteria
Blankinship et al., 2013	Alabama, USA <ul style="list-style-type: none"> $n = 20$ mobile phones Cross-sectional study 	<ul style="list-style-type: none"> 38 bacterial isolates identified, Some isolates were pathogenic, whereas other isolates were multidrug resistant, which could lead to HAI Antibiotic resistance predicted to increase with the continued overuse/misuse of antibiotics
Beckstrom et al., 2013	Washington, USA <ul style="list-style-type: none"> $n = 50$ mobile phones and hands Questionnaire Cross-sectional study 	<ul style="list-style-type: none"> Before applying antimicrobial gel, 96% of hands had bacteria (2 had <i>Acinetobacter spp.</i> and 1 had MRSA) before applying antimicrobial gel and only 26% of hands had no bacterial growth after using antimicrobial gel Antimicrobial gel is not an appropriate way to eliminate bacteria transmitted from cell phone to hand
Braddy and Blair, 2005	Arizona, USA <ul style="list-style-type: none"> $n = 82$ PDAs Healthcare workers in hospital and clinics Questionnaire Randomized trial 	<ul style="list-style-type: none"> 40% of the PDAs showed organism growth of which coagulase-negative <i>Staphylococcus</i> was the most common organism found The specific type of healthcare job, hand-washing technique and presence/type of PDA cover had no correlation with the presence of bacterial/fungal growth PDAs often contain organisms found on skin, and less often are colonized by organisms that cause disease
Brady et al., 2011	Edinburgh, UK <ul style="list-style-type: none"> $n = 102$ mobile phones, males and females 16 years of age or older Inpatients on surgical/urological wards of hospital Questionnaire Cross-sectional surveillance study 	<ul style="list-style-type: none"> 84.3% of mobile phones tested were contaminated with bacteria, of which 11.8% contained nosocomial infection-causing bacteria Of those with pathogenic bacteria species, no association was found between gender or age There is an association between MRSA contamination in the nasal cavity and finding MRSA colonies on mobile phones
Brady et al., 2006	Northern Ireland, UK <ul style="list-style-type: none"> $n = 105$ doctors, nursing staff Questionnaire Cross-sectional study 	<ul style="list-style-type: none"> 96.2% of phones showed evidence of bacterial contamination <i>Coagulase-negative staphylococcus</i> was isolated most often (93%) 15% of phones had bacteria known to cause nosocomial infections No statistically significant association between finding bacterial growth and doctor/nurse, medical speciality, type of phone (e.g., flip-top, clam shell, or sliding), daily presence of phone

Table 1 (continued).

Authors	Sample size and trial type	Main findings
Brady et al., 2007	Edinburgh, Scotland <ul style="list-style-type: none"> $n = 78$ MCDs (mobile phones, pagers, PDAs) surgeons, anaesthetists, and medical students Questionnaire Cross-sectional study 	<ul style="list-style-type: none"> 84.8% of phones, 96.3% of pagers, 80% of PDAs were never cleaned prior to study 89.7% MCDs were found with bacteria, 11.5% of which had bacteria that could cause nosocomial infection (3 MCDs with MSSA) No attention placed on mobile phones in clinical practice to reduce HAI
Goldblatt et al., 2007	New York, NY Haifa, Israel <ul style="list-style-type: none"> $n = 400$ mobile phones HCWs, and others not employed in the hospital Questionnaire Cohort study 	<ul style="list-style-type: none"> 50% of physicians and nurses carried MCDs and used them while attending to patients, regardless of signs banning cell phone use in hospitals 20% mobile phones harboured potentially pathogenic microorganisms MRSA (10.3%) was most common microbial in New York Mobile phones that did not enter the hospital had no bacterial growth
Hassoun et al., 2004	New York, USA <ul style="list-style-type: none"> $n = 75$ PDAs of HCWs prospective Cross-sectional study 	<ul style="list-style-type: none"> 93% of HCWs never cleaned their PDAs 96% of samples were culture positive before cleaning with alcohol swab 85% had coagulase-negative <i>Staphylococcus</i> prior to cleaning, 11% of PDAs had <i>S. aureus</i>, 75% of which were MRSA prior to cleaning 75% became culture negative after cleaning with an alcohol swab, thus it helped significantly reduce microbial contamination on PDAs No direct evidence that bacteria on PDA will infect patients
Jeske et al., 2007	Austria <ul style="list-style-type: none"> $n = 40$ anaesthetists Pilot study 	<ul style="list-style-type: none"> After use of in-hospital mobile phones, bacterial contamination was found on 95% of anaesthetists' hands and 10% of anaesthetists' hands showed pathogenic bacteria Compared with fixed phones in the hospital, 83% of anaesthetists showed bacterial contamination (10% of which showed pathogenic bacteria) Use of mobile phones may have more serious hygiene issues and carry greater risk of unperceived contamination and infection compared with fixed phones
Julian et al., 2012	Ontario, Canada <ul style="list-style-type: none"> $n = 123$ Mobile phones, personal mobile phones, hospital-issued Cross-sectional study 	<ul style="list-style-type: none"> Methicillin-resistant staphylococci was isolated from 2.4% of mobile phones 21.9% of personnel had cleaned their device within the past month No difference in prevalence of contamination overall between personal and hospital-issued mobile phones

Table 1 (continued).

Authors	Sample size and trial type	Main findings
Karabay et al., 2007	Bolu, Turkey <ul style="list-style-type: none"> $n = 122$ mobile phones Cross-sectional study 	<ul style="list-style-type: none"> 91% of mobile phones tested positive for bacteria Bacteria associated with hospital infections was found on 9% of mobile phones (4 phones with <i>Escherichia coli</i>, 2 phones showing <i>Enterococcus faecalis</i>, 2 <i>Pseudomonas aeruginosa</i> samples, 1 <i>Pseudomonas fluorescens</i>, 1 phone with <i>Klebsiella pneumoniae</i>) No MRSA or VRE
Meadow et al., 2014	New Jersey, USA <ul style="list-style-type: none"> $n = 17$ MCDs Males and females Cross-sectional study 	<ul style="list-style-type: none"> 22% of the bacteria found on a PDA is found on the owners hand, compared with 17% shared with another person's phone As a group, the bacterial community on men's phones were significantly different from their fingers, whereas women's were not 82% of OTUs were shared between index fingers and phone, whereas 96% of OTUs were shared between index fingers and thumbs
Mark et al., 2014	Belfast, UK <ul style="list-style-type: none"> $n = 50$ mobile phone $n = 150$ HCWs Males and females Medical practitioners, nursing staff, auxiliary medical professionals, secretarial staff, and students Questionnaire Cross-sectional study 	<ul style="list-style-type: none"> 60% of phones had a contaminant isolated (the majority of positive isolates was staphylococcus) No drug-resistant strains of pathogenic bacteria were identified 88% of HCWs use their mobile phone within the workplace, 55% use it for clinical use (on-call) With proper hand hygiene it is safe to use touchscreen mobile phones in a clinical environment
Namias et al., 2000	Florida, USA <ul style="list-style-type: none"> $n = 36$ pagers Physicians, residents, and respiratory therapists Cross-sectional study 	<ul style="list-style-type: none"> Study excluded microorganisms found on skin or in the environment 47% of pagers were contaminated with microbial pathogens HCW occupation and level of exposure in the intensive care unit have no correlation to the likelihood of contamination of the pager
Pal et al., 2013	London, UK <ul style="list-style-type: none"> $n = 71$ mobile phones (keypad, touchscreen, unsuitable for analysis) Mobile phones were exclusively on-call hospital phones Phones came from medicine, surgery, and anaesthetics departments Random sampling 	<ul style="list-style-type: none"> 13% cell phones contained either MRSA or VRE 24% keypad phones grew either MRSA or VRE compared with one touch screen phone (3%) of the total 9 phones contaminated Keypad phones are more likely to host pathogenic bacteria and are more likely to harbour drug-resistant bacteria Only criteria associated with a higher number of bacteria recovered was whether the phone had a keypad or a touchscreen (job or department of owner had no bearing)
Tekerekoğlu et al., 2011	Malatya, Turkey <ul style="list-style-type: none"> $n = 200$ mobile phones Patients, patients' companions, visitors, HCWs Cross-sectional study 	<ul style="list-style-type: none"> Bacterial growth was found more often on patients' mobile phones (90.1%) in comparison with HCW's mobile phones (85.6%) Multidrug-resistant pathogens were found on the mobile phones of patients but not on the mobile phones of HCWs

Table 1 (continued).

Authors	Sample size and trial type	Main findings
Singh et al., 2002	Ohio, USA <ul style="list-style-type: none"> $n = 100$ pagers HCWs (house staff, attending physicians, registered nurses, respiratory therapists, and medical students) Questionnaire Prospective cross-sectional study 	<ul style="list-style-type: none"> 88% of respondents reported never cleaning their pager Microorganisms were isolated from all pagers: 21% of which contained <i>S. aureus</i>, 14% of which were MRSA Emergency, intensive care, and respiratory units had significantly higher microbial rates Cleaning with 70% isopropyl alcohol reduced the total colony count by an average of 94% Hand hygiene policy and increased adherence is vital Role of pagers as vectors of HAIs inconclusive
Ulger et al., 2009	Samsun, Turkey <ul style="list-style-type: none"> $n = 200$ mobile phones and hands Cross-sectional study 	<ul style="list-style-type: none"> 94% of mobile phones were contaminated with bacteria 52% of mobile phones and 37.7% of hands were contaminated with MRSA There was cross-contamination of bacteria between dominant hands and 33.33% of mobile phones
Ustun and Cihangiroglu, 2012	Elazig, Turkey <ul style="list-style-type: none"> $n = 183$ mobile phones Nurses, laboratory workers, healthcare staff Cross-sectional study, secondary referral hospital Second division was by ICU/non-ICU 	<ul style="list-style-type: none"> 97.8% of culture-positive specimens isolated from mobile phones 9.5% of phones had MRSA, 11.2% had ESBL-producing <i>Escherichia coli</i>, which can cause nosocomial infections Recovery of MRSA and ESBL-producing <i>E. coli</i> was not statistically linked to a HCW group 24.6% of specimens were isolated from mobile phones of ICU workers Isolation of ESBL-producing <i>E. coli</i> was statistically higher in ICU workers compared to non-ICU workers
White et al., 2012	West Yorkshire, UK <ul style="list-style-type: none"> $n = 16$ smartphones Males and females Longitudinal sampling of mobile devices Operating department practitioner students 	<ul style="list-style-type: none"> All devices had microbial contamination and 86% had polymicrobial contamination <i>Staphylococcus</i> was the most common organism found Mobile phones are contaminated with a lot of transient and potentially transferrable bacteria

Note: HAI, hospital-acquired infections; MRSA, Methicillin-resistant *Staphylococcus aureus*; PDA, personal digital assistant; MCD, mobile communication device; MSSA, Methicillin-sensitive *Staphylococcus aureus*; HCW, healthcare worker; VRE, Vancomycin-resistant enterococci; OTU, operational taxonomic units; ICU, intensive care unit; ESBL, extended-spectrum beta-lactamase, enzymes that confer resistance to penicillin.

Julian et al., 2012; Ustun and Cihangiroglu, 2012; White et al., 2012; Beckstrom et al., 2013; Pal et al., 2013; Basol et al., 2014; Mark et al., 2014). Other recommendations included: specific infection control measures, training of HCWs and patients and their families regarding strict control procedures, and methods to disinfect MCDs.

Beckstrom et al. (2013) noted that bacteria transmitted from a cell phone to hands may not be eliminated by anti-microbial gel, and therefore they recommended prevention through hand hygiene and cell phone cleaning guidelines. They also noted that the safest approach to minimize the risk of bacterial transmission

from cell phones is to generate a “no tolerance” policy, which would prohibit their use at the bedside. However, Mark et al. (2014) found 75% of HCWs sampled felt banning mobile phones would “not be a practical or realistic solution to reduce infection.” Therefore, a more realistic and enforceable approach would be to reduce the bacterial load on hands by educating HCWs and the families of patients on regular cleaning of MCDs and hand hygiene as well as limiting sharing and usage of MCDs around patients.

Ulger et al. (2009) recommended limiting mobile phone usage in the settings that are in close proximity with patients such as

operating rooms and intensive care units because of the high risk for spreading infections. Another recommendation was routine decontamination of mobile phones with alcohol wipes or regular cleaning agents to reduce cross-infection. White et al. (2012) noted that sharing phones could directly facilitate the spread of pathogenic bacteria both in and out of the hospital. In concordance with Ulger et al. (2009), they recommend that strict regulations should be in place to limit mobile phone usage in hospital settings to reduce the spread to both internal and external environments. Basol et al. (2014) recommended using either 70% isopropyl alcohol wipes or ethyl alcohol wipes; both were deemed effective in eliminating bacteria on MCDs. Two studies found that due to the uneven surface of a keypad, such devices were able to harbour more bacteria than the smooth surface of touchscreen phones (Pal et al., 2013; Mark et al., 2014); as a result, they recommended investing in touchscreen phones for clinical use as cost-effective in reducing infection risk.

Despite the weight of evidence regarding bacterial transmission and MCDs in clinical settings, there has yet to be a knowledge translation of this evidence into guidelines that can be used by all stakeholders. After reviewing the literature regarding MCD use in clinical settings and HAIs, the studies overwhelmingly show that MCDs are a potential source for bacterial transmission, and therefore regulations that specifically mandate good hand hygiene and limit the use of MCDs must be in place to control pathogenic and infectious spread in clinical settings.

Limitations

There are limitations to the application of the findings in this review in a Canadian setting. Firstly, Julian et al. (2012) published the only paper that using Canadian data. An overwhelming number of studies were conducted in the Middle East and South Asia; however, to maximize generalizability to Canada only articles published in the United States, United Kingdom, Austria, and Turkey were used. As a result a small number of studies were reviewed, which limits the characterization of potential risk factors of MCDs with respect to HAIs. Lastly, this review looked at primary research articles that had relatively small sample sizes and no controls. This could be why causal relationships were not identified between MCD use and HAIs.

Conclusion

MCDs have provided an accurate and efficient means of communication in health care and as a result have improved patient quality-of-care (Pal et al., 2013). There is evidence of bacterial presence, including pathogenic bacteria, on MCDs used in clinical settings and this presents a risk of HAIs. Hand hygiene was concluded to be the most effective infection control method in reducing phone contamination potential and risk of HAIs. Other recommendations include disinfection using 70% isopropyl alcohol or ethyl alcohol wipes, mandating strict disinfection control guidelines, the use of touch-screen devices over keypad devices, limiting MCD use, and educating HCWs and patients and their families regarding MCD disinfection methods and hand hygiene. Further research should be conducted on MCDs in the clinical setting and the evaluation of disinfection

methods to determine the efficacy of sampling techniques and cleaning methods (White et al., 2012). A key area for further investigation is determining the true risk of HAIs as a result of MCD use in clinical settings (White et al., 2012). It is only in carrying out such work that policy makers can develop a “robust evidence-based infection control policy” (White et al., 2012) regarding MCDs in clinical settings.

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