Paper money and coins as potential vectors of transmissible disease

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ABSTRACT: Paper currency and coins may be a public health risk when associated with the simultaneous handling of food and could lead to the spread of nosocomial infections. Banknotes recovered from hospitals may be highly contaminated by Staphylococcus aureus. Salmonella species, Escherichia coli and S. aureus are commonly isolated from banknotes from food outlets. Laboratory simulations revealed that methicillin-resistant S. aureus can easily survive on coins, whereas E. coli, Salmonella species and viruses, including human influenza virus, Norovirus, Rhinovirus, hepatitis A virus and Rotavirus, can be transmitted through hand contact. Large-scale, 16S rRNA, metagenomic studies and culturomics have the capacity to dramatically expand the known diversity of bacteria and viruses on money and fomites. This review summarizes the latest research on the potential of paper currency and coins to serve as sources of pathogenic agents.

Background
Healthcare-associated infections are one of the most serious patient safety issues in healthcare today [1]. Most pathogens are able to survive on surfaces and these surfaces can act as sources of pathogen transmission if no disinfection is performed. In addition, the survival of nosocomial pathogens, including methicillin-resistant Staphylococcus aureus (MRSA), in the environment is of great interest to infection control professionals [2]. Moreover, food workers have been implicated in several outbreaks of food-borne diseases and human occupational activities could introduce the risk of food contamination [3]. Pathogens that can infect food workers have multiple sources and contaminated workers in turn become potential sources of contamination in food processing and preparation facilities [4].

Fomites are inanimate objects capable of absorbing, harboring and transmitting infectious microorganisms [5,6]. Banknotes and coins are handled by persons of varying health and hygienic standards, and are stored under varying environmental and personal hygienic conditions. Paper currency is widely exchanged for goods and services. Both paper banknotes and coins offer ample surface area to harbor bacteria and microorganisms, and the hygienic status of currency has been a scourge to some for over a century [5]. Several authors have raised the concern that banknotes and coins could serve as vectors for the transmission of disease-causing microorganisms [5,6]. Microbial contaminants may be transmitted directly, through hand-to-hand contact, or indirectly, via food or other inanimate objects. As a result, hand hygiene is considered critical for preventing food outbreaks and healthcare-associated infections [1]. However, only few data are available about the types of patient

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care activities that are able to transmit the patient flora to healthcare workers’ hands. In addition, it remains unclear how long bacteria can survive on paper or how many organisms may be transferred in a full hand-to-paper-to-hand transmission cycle [1]. Although little has been written concerning the potential of banknotes, coins and fomites to become reservoirs and vehicles for the transmission of pathogens, the data have been quietly accumulating. Here, we review the infectious potential of coins, currency notes and fomites.

Search strategy
We searched PubMed, Web of Science, Google and Google Scholar databases for peer-reviewed, English-language articles with no date restrictions. The search terms were combinations of ‘bacteria, virus, yeast, fungi, infection, transmission’ and ‘coins’, ‘currency notes’, ‘banknotes’, ‘fomites’, ‘dirty money’, ‘hands’ and ‘surfaces’. The literature was also searched for every pathogen identified by the previous search; for example, ‘S. aureus, hepatitis A virus (HAV) and so on’ and ‘coins’, ‘currency notes’, ‘banknotes’, ‘fomites’, ‘dirty money’, ‘hands’ and ‘surfaces’. We also examined the references cited in the identified articles and searched PubMed for other papers by the authors of the identified articles. When necessary, we contacted the corresponding authors for further clarification or additional information.

Persistence of pathogens on surfaces
Important factors for the survival of pathogenic agents on surfaces are the presence of organic matter, solar irradiation, temperature and humidity [7]. A recent review reported that many Gram-positive bacteria, such as Enterococcus spp., S. aureus and Streptococcus pyogenes, and Gram-negative bacteria, such as Acinetobacter spp., Escherichia coli, Klebsiella spp., Pseudomonas aeruginosa, Serratia marcescens and Shigella spp., can survive for months on surfaces [8]. In addition, mycobacteria and Clostridium difficile can survive for months, while other pathogens, such as Bordetella pertussis, Haemophilus influenzae, Proteus vulgaris or Vibrio cholera, persist only for days [8]. Candida albicans can survive for up to 4 months on surfaces, whereas respiratory tract viruses, such as Coronavirus, Coxsackievirus, Influenza virus, severe acute respiratory syndrome-associated virus or Rhinovirus, can persist on surfaces for a few days [8]. Noroviruses are environmentally stable, able to survive both freezing and heating (although not thorough cooking), and resistant to many common chemical disinfectants, and can persist on surfaces for up to 2 weeks [9]. Herpes viruses persist for only a few hours to 7 days, and viruses of the GI tract, such as Astrovirus, HAV, Poliovirus and Rotavirus, persist for approximately 2 months [8].

Currency notes
Paper currency is commonly and routinely passed among individuals, and microbes can be spread on the surface of paper currency (Figure 1). Paper currency is made of a rugged mix of 75% cotton and 25% linen, and offers surface area for bacteria and microorganisms to reside on both sides [10]. Polymer-based banknotes presented lower bacterial counts than cotton-based banknotes [11]. It is possible that the fibrous surfaces of cotton-based banknotes provide a good surface for bacterial attachment [11]. As a result, fewer bacteria were isolated in Australia and New Zealand, where polymer-based banknotes were tested [11]. Moreover, in banknotes from Mexico, where both polymer and cotton-based notes are used, it was found that polymer-based banknotes were much less contaminated than cotton-based notes [11]. The longer the paper bill remains in circulation, the more opportunity there is for it to become contaminated, and lower-denomination notes receive the most handling because they are exchanged more often [10,11]. In addition, the economic status of a country was associated with the concentration of bacteria on the currency, and it was found that the average number of bacteria detected on banknotes is associated with the economic freedom of banknotes [11].

• Bacteria
The amount of bacterial contamination on currency varies widely between countries (Figure 2). As a result, 88% of the paper notes tested in Jeddah, Saudi Arabia were contaminated with a variety of microorganisms [12], and 94% of US$1 bills had bacterial contamination [13]. Approximately 80% of the paper notes tested in Bangladesh and 89% of the paper notes tested in Nigeria had bacterial contamination, whereas in Ghana, 100% of the currency notes tested were found to be contaminated with one or more bacterial species [14]. However, no difference was found in the bacterial presence among cotton-based notes from Nigeria, The Netherlands and Mexico [11]. In addition, more bacterial
contamination existed on older Egyptian [10] and Saudi Arabian paper notes than on new ones [12]. The number of bacteria per square cm on banknotes was also different between countries. As a result, polymer-based banknotes from Australia and New Zealand presented less than 10/cm² bacteria, whereas cotton-based notes from China presented more than 100/cm² bacteria [11]. Cotton-based notes from the USA contained about 10/cm² bacteria [11]. By contrast, on currency from Rangoon, Myanmar, total bacteria and fecal coliform counts were much higher, ranging from 0–2.9 × 10⁶/cm² [15]. The number of bacteria on currency also varies within a single country, as the number of bacteria isolated from US currency varied from 20 to 2.5 × 10⁴ CFU [11]. In Nigeria, currency notes had also a high level of contamination, reaching 4 × 10⁶ CFU [16]. Various bacteria have been isolated from money worldwide, including developed countries, and microbes, such as S. aureus, E. coli, Klebsiella spp. and Enterobacter spp., have been identified as common contaminants (Table 1). In the 1970s, Abrams and Waterman found that the 42% of paper currency collected from laboratory personnel was contaminated by potential pathogens, such as S. aureus, E. coli, Klebsiella sp., P. aeruginosa and Proteus mirabilis [6]. Similarly, US$1 bills and Egyptian paper money yielded pathogenic agents, such as S. aureus and Klebsiella pneumonia, or other bacterial contaminants, such as coagulase-negative staphylococci, α-hemolytic streptococci and Acinetobacter sp. [10,13]. In India, approximately 18–69 CFU of S. aureus were isolated per banknote [17]. Moreover, many bacterial agents have been isolated from banknotes in studies from India, Bangladesh, Saudi Arabia, Turkey,
Nigeria, Kenya, Pakistan, Myanmar, Egypt and Nepal (Table 1) [15,16,18–27]. In addition, *Vibrio cholera* were isolated from paper money samples obtained from Bangladesh [21]; *Vibrio* sp. have also been detected in Rangoon, Myanmar [15] and India [18]. In a recent study on banknotes from different countries, it was found that *E. coli* was most commonly isolated on banknotes from the USA and China, and a *Salmonella* sp. was isolated only from samples in the USA, China and Ireland, while the presence of *S. aureus* varied [11]. Moreover, bacterial isolates from currency exhibited a high incidence of antibiotic resistance [11]. In summary, several bacteria species have been isolated from banknotes from different countries.

- **Other agents**

  In a study performed in the 1970s, various yeast and fungi were isolated from paper currency collected from laboratory personnel [6]. In addition, 118 saprophytic fungal isolates were isolated from currency notes in India [19]. More recently, fungi were isolated from both old and new currency notes in Riyadh, Saudi Arabia [26]. The most commonly isolated fungal species was *Aspergillus niger*, followed by *Aspergillus flavus*, *Candida* spp., *Penicillium* spp. and *Rhizopus* spp. [26]. In another study in India, currency notes from different occupational groups were evaluated for the presence of microbial contaminants, and fungi such as *Aspergillus niger* and *Fusarium* spp. were
isolated from these currency notes, in addition to common pathogenic bacteria [30].

Currency notes contaminated with parasites were found in a study performed in Nigeria [29]. Notes were found to be contaminated with *Ascaris lumbricoides* (8%), *Enterobius vermicularis* (7%), *Trichuris trichiura* (3%) and *Taenia* spp. (4%) [29]. Moreover, parasitic contamination was most prevalent on dirty/mutilated notes collected from butchers, farmers and beggars [29].

### Coins

Few studies have examined the contamination of coinage, and copper (Cu) seems to be a limiting factor for bacterial survival on coins [28]. As a result, coins have been found to carry opportunistic bacterial pathogens, but they exhibit a lower bacterial load than paper currency [28].

#### Bacteria

Coins have been shown to carry opportunistic pathogens, such as a variety of species of the genera *Staphylococcus*, *Bacillus*, and *Corynebacterium* (Table 1) [28,31]. Abrams and Waterman found that 13% of the coins collected from laboratory personnel were contaminated by potential pathogens, such as *S. aureus*, *Klebsiella* sp., *P. aeruginosa* and *P. mirabilis* [6]. Many different species were also isolated on coins from Kenya, and the average bacterial content on the coins ranged from 2.3 to 25 × 10^3 CFU (Table 1) [22]. Most commonly, Gram-positive staphylococci and micrococci were isolated from EU50 coins collected in Germany and Portugal (Table 1) [28]. The absence of streptococci isolates from coins probably suggests a high sensitivity of these bacteria to metallic Cu [28]. In a recent study on the bacterial flora collected from coins from 17 countries, all of the isolates from coins were Gram-positive strains, with the majority belonging to the genera *Bacillus* (40%) and *Staphylococcus* (28%) (Figure 3) [31]. Recently, *Pseudomonas psychrotolerans* and *Roesomonas pecuniae* were isolated from EU50 coins Cu-alloy coins [32,33]. Multiple genes that are potentially involved in Cu resistance were identified in these bacteria [32].

#### Other agents

Yeast and fungi were isolated from coins collected from laboratory personnel [6]. More recently, *Penicillium* spp, *Aspergillus niger*, *Fusarium*, *Rhizopus*, *Altenaria* spp, *Candida* spp. and *Cryptococcus* were isolated from Kenyan coins [22].

<table>
<thead>
<tr>
<th>Pathogens</th>
<th>Banknotes</th>
<th>Coins</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Escherichia coli</em></td>
<td>Yes</td>
<td>Yes</td>
<td>[6]</td>
</tr>
<tr>
<td><em>Bacillus</em> sp.</td>
<td>Yes</td>
<td>Yes</td>
<td>[18,22]</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>Yes</td>
<td>Yes</td>
<td>[6,17]</td>
</tr>
<tr>
<td>Coagulase-negative staphylococci</td>
<td>Yes</td>
<td>Yes</td>
<td>[10,13,28]</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>Yes</td>
<td>Yes</td>
<td>[6]</td>
</tr>
<tr>
<td><em>Salmonella</em> sp.</td>
<td>Yes</td>
<td>No</td>
<td>[18]</td>
</tr>
<tr>
<td><em>Enterococcus</em> sp.</td>
<td>Yes</td>
<td>Yes</td>
<td>[22]</td>
</tr>
<tr>
<td><em>Klebsiella</em> sp.</td>
<td>Yes</td>
<td>Yes</td>
<td>[6,18]</td>
</tr>
<tr>
<td><em>Proteus mirabilis</em></td>
<td>Yes</td>
<td>Yes</td>
<td>[6,18]</td>
</tr>
<tr>
<td><em>Acinetobacter</em> sp.</td>
<td>Yes</td>
<td>Yes</td>
<td>[10,13,22]</td>
</tr>
<tr>
<td><em>Yersinia</em> sp.</td>
<td>Yes</td>
<td>No</td>
<td>[26]</td>
</tr>
<tr>
<td><em>Enterobacter</em> sp.</td>
<td>Yes</td>
<td>Yes</td>
<td>[22,25]</td>
</tr>
<tr>
<td><em>Shigella</em> sp.</td>
<td>Yes</td>
<td>No</td>
<td>[25]</td>
</tr>
<tr>
<td><em>Vibrio</em> sp.</td>
<td>Yes</td>
<td>No</td>
<td>[18]</td>
</tr>
<tr>
<td><em>Aspergillus</em></td>
<td>Yes</td>
<td>Yes</td>
<td>[22,26]</td>
</tr>
<tr>
<td><em>Cryptococcus</em></td>
<td>No</td>
<td>Yes</td>
<td>[22,26]</td>
</tr>
<tr>
<td><em>Candida</em> spp.</td>
<td>Yes</td>
<td>Yes</td>
<td>[22,26]</td>
</tr>
<tr>
<td><em>Rhizopus</em> spp.</td>
<td>Yes</td>
<td>Yes</td>
<td>[22,26]</td>
</tr>
<tr>
<td><em>Penicillium</em> spp.</td>
<td>Yes</td>
<td>Yes</td>
<td>[22,26]</td>
</tr>
<tr>
<td><em>Ascaris lumbricoides</em></td>
<td>Yes</td>
<td>No</td>
<td>[29]</td>
</tr>
<tr>
<td><em>Enterobibius vermicularis</em></td>
<td>Yes</td>
<td>No</td>
<td>[29]</td>
</tr>
<tr>
<td><em>Trichuris trichiura</em></td>
<td>Yes</td>
<td>No</td>
<td>[29]</td>
</tr>
<tr>
<td><em>Taenia</em> spp.</td>
<td>Yes</td>
<td>No</td>
<td>[29]</td>
</tr>
</tbody>
</table>
Fomites & money in the spread of nosocomial infections

It is believed that the main route of transmission of most pathogens is via the transiently contaminated hands of the healthcare worker [34]. A single contact of a hand with a contaminated surface can result in a variable degree of pathogen transfer [8]. In hospitals, surfaces, such as beds and keyboards, that come into contact with hands serve as reservoirs of nosocomial pathogens and vectors for cross-transmission [35,36]. Banknotes and coins can also serve as pathogen reservoirs [17]. Moreover, various inanimate objects in the operating room theatre that are directly or indirectly associated with surgical procedures were found to be variously contaminated with known bacterial and fungal pathogens (Box 1).

Banknotes can serve as a potential source of pathogens and, in a study from India, the greatest number of S. aureus isolates was found on paper currency that was recovered from hospitals [17]. In addition, it was found that epidemic nosocomial and community-acquired MRSA can easily survive on coins when soil (pus and blood) was also present [2]. Over half of the surface samples from hospitals in the USA and Ireland were found to be contaminated with MRSA, including those taken from beds and mattresses, and the strains were similar to those isolated from patients [37,38]. Cell phones could also be a source of pathogens, and in Saudi Arabia, coagulase-negative staphylococci and antibiotic-resistant Micrococcus spp. were isolated from cell phones [26]. Contamination of the faucet handles of the single sink used for hand washing by technologists in the work area was responsible for an outbreak of Shigella sonnei in the Rhode Island Hospital [39]. Moreover, hospital personnel may transmit C. difficile to susceptible patients by transient carriage on their hands. The same strain of C. difficile was isolated from the hands of children and teachers in a diarrheal outbreak in a day-care setting [40]. In summary, evidence from healthcare studies and outbreaks has revealed that fomites, including money and coins, can serve as reservoirs of nosocomial pathogens.

Fomites & money in the spread of food-borne outbreaks

Evidence for the transmission of pathogens through contact with fomites is provided by food-borne outbreaks [3]. Foods can become contaminated with pathogens at any point during their production, processing and preparation. In many food outlets, workers handle money and prepare food at the same time. In addition, pathogens of the nose, throat, feces or skin can be transmitted by hands, highlighting the need for hand hygiene. Moreover, other barriers to pathogen contamination can be used, such as no hand contact with ready-to-eat food [3].

The agents most likely to be transmitted by food workers are HAV, Norovirus, Shigella sp., Salmonella sp. and S. aureus [4]. In a recent study, the number of bacteria on banknotes obtained from food outlets varied widely within a single country and between individual countries [11]. Salmonella sp., E. coli and S. aureus were isolated from the banknotes of most countries [11]. In

Figure 3. Infectious agents isolated from coins from different countries.

- Escherichia coli
- Bacillus sp.
- Staphylococcus aureus
- Coagulase-negative staphylococci
- Pseudomonas sp.
- Pseudomonas aeruginosa
- Roseomonas pecuniae
- Micrococcus spp.
- Kocuria palustris
- Brachybacterium conglomeratum
- Salmonella sp.
- Enterococcus sp.
- Proteus mirabilis
- Klebsiella sp.
- Serratia sp.
- Moraxella spp.
- Acinetobacter sp.
- Enterobacter spp.
- Stenotrophomonas maltophilia
- Penicillium spp.
- Aspergillus niger
- Rhizopus spp.
- Fusarium spp.
- Altenaria spp.
- Candida spp.
- Cryptococcus spp.
Bangladesh, banknotes collected from fish sellers, meat sellers, vegetable sellers, food vendors and shopkeepers were contaminated with *E. coli*, *Klebsiella* sp., *Salmonella* sp., *S. aureus*, *Bacillus* sp., *Pseudomonas* sp. and *V. cholera*; the highest numbers of isolates were recovered from currencies obtained from the fish and meat sellers [21]. In Nepal, 62% of the currency notes obtained from food sellers were found to be contaminated [20], while in Kenya, banknotes collected from greengrocers, butchers, food kiosk/restaurant attendants and roast maize vendors were also highly contaminated [22]. In addition, yeast fungi, including *A. niger*, *Penicillium* spp., *Candida* spp. and *Cryptococcus* spp., were isolated from coins collected from butchers, maize roasters and food kiosk attendants in Kenya [22]. In summary, money collected from food sellers is highly contaminated, and the presence of infectious agents on banknotes or coins is indicative of poor hygiene in the person who recently handled the banknotes or coins. Moreover, the manner in which the banknotes or coins were kept in food outlets can influence the presence of these infectious agents on the currency.

### Experimental evidence of pathogen transfer by banknotes and coins

Laboratory simulations have shown that pathogens can survive on banknotes and coins. Moreover, indirect evidence of hand-to-hand and fomite-to-hand contact has shown that banknotes and coins are viable modes of transmission. In addition, it seems that wet hands can transfer larger numbers of infectious agents [41,42] and that the transfer of pathogens can easily occur when fingers are moist [43].

#### Bacteria

Due to the differences between the textures of paper notes and the metal alloys used for coins, paper notes can accommodate a variety of contaminants, and these contaminants can persist for longer periods (Table 2) [20]. The inoculation of *S. aureus* onto paper currency revealed that all of the isolates were able to survive for 8 days at room temperature [17]. On paper surfaces, *E. coli* was reduced by almost $10^5$ in 24 h, whereas *P. aeruginosa* and *Enterococcus hirae* were more resistant to room conditions, and were reduced by only $10^3$ after 7 days [44]. In addition, *E. coli* was able to be transmitted from one person’s hands to paper and back to another person’s hands [44], and *C. albicans* was able to survive in hands and on inanimate surfaces, and could be transmitted with hand contact (Table 3) [45]. Sufficient bacteria numbers to represent a potential hazard if in contact with food occurred when surfaces contaminated with *E. coli*, *Salmonella* spp. or *S. aureus* came into contact with fingers, a steel bowl or laminate surfaces [46]. In a recent study, nonporous surfaces had a greater transfer efficiency for *E. coli*, *S. aureus* and *Bacillus thuringiensis* than porous surfaces [47]. Moreover, the transfer efficiencies were higher under high relative humidity for both porous and nonporous surfaces [47]. However, the occurrence of pathogens on money does not mean that it is effectively transferred to the hands as the transfer efficiency was least with paper currency under both low and high relative humidity conditions for *E. coli*, *S. aureus* and *B. thuringiensis* [47].

In coins, $10^5$ CFU/ml of MRSA *S. aureus* did not survive 4 h after inoculation [2]. By contrast, when coins were treated with pus or blood, bacteria survived for at least 2 weeks when stored in the dark at ambient temperature, during which time the quantitative counts were reduced by approximately 10 and 100 for blood and pus, respectively [2]. When $5 \times 10^4$ CFU of *E. coli* O157:H7 and *Salmonella enteritidis* were applied to the surfaces of sterile US coins, it was found that these coins could serve as potential vehicles for the transmission of pathogens even a few days after contamination [49]. Moreover, it was found that *E. coli* can survive for up to 7 days on coins [49], whereas bacteria isolated from coins were able to survive on Cu surfaces for 48 h or more [28].

In conclusion, laboratory experiments revealed that bacteria are able to survive on banknotes and coins, and that the potential for their transmission via money is possible.

<table>
<thead>
<tr>
<th>Box 1. Commonly used objects by healthcare workers serving as reservoirs of nosocomial pathogens.</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Cell phone</td>
</tr>
<tr>
<td>- Toilet paper</td>
</tr>
<tr>
<td>- Pen</td>
</tr>
<tr>
<td>- Stethoscope</td>
</tr>
<tr>
<td>- Paper money</td>
</tr>
<tr>
<td>- Coins</td>
</tr>
<tr>
<td>- Uniform</td>
</tr>
<tr>
<td>- Computer keyboard</td>
</tr>
<tr>
<td>- Books</td>
</tr>
<tr>
<td>- Paper files</td>
</tr>
<tr>
<td>- Patient equipment, such as beds and bedding</td>
</tr>
</tbody>
</table>

[255]
Although viruses have not been found on money, the potential for their transmission via money is possible. Laboratory simulations have demonstrated that the efficiency of viral transmissions varies according to viral strain, the nature of the host cells and surfaces, and atmospheric conditions [53]. Human influenza viruses were able to survive and remain infectious for days when they were deposited on banknotes [48]. Moreover, the virus concentration and presence of a beneficial microenvironment are critical for the duration of viral infectiousness [48]. The concentration of H1N1 deposited on hands by coughing or sneezing was <2.15 × 10 to 2.94 × 10 tissue culture infectious dose (TCID) /ml [53], and a 10⁸ to 10⁶ reduction of H1N1 after 2 min of artificial inoculation onto human hands has been reported (Table 3) [52]. Influenza virus deposited at a concentration of 8.9 × 10⁵ TCID /ml was able to survive for up to 17 days, but the concentration of virus diluted in mucus and deposited on banknotes was rapidly decreased (10⁰-fold after 2 h and 10⁵-fold after 2 weeks) [48]. Influenza-contaminated hands can transfer the viruses to other surfaces or subjects [58, 59], and hands could become contaminated with influenza by coming into contact with surfaces inoculated with viral secretions containing between 10⁵

### Table 2. Laboratory simulations demonstrating the survival of pathogens on money.

<table>
<thead>
<tr>
<th>Type of money</th>
<th>Agent</th>
<th>Concentration</th>
<th>Survival</th>
<th>Transfer</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banknotes</td>
<td>Influenza A (H3N2)</td>
<td>8.9 × 10⁴ TCID /ml</td>
<td>2 h</td>
<td>NT</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td>Influenza A (H3N2) and mucus</td>
<td>8.9 × 10⁴ TCID /ml</td>
<td>8 days</td>
<td>NT</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td>Influenza B</td>
<td>3.2 × 10⁵ TCID /ml</td>
<td>1 day</td>
<td>NT</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td>Influenza B and mucus</td>
<td>3.2 × 10⁵ TCID /ml</td>
<td>2 h</td>
<td>NT</td>
<td>[48]</td>
</tr>
<tr>
<td>Coins</td>
<td><em>Staphylococcus aureus</em> (MRSA)</td>
<td>10⁶ CFU/ml</td>
<td>4 h</td>
<td>NT</td>
<td>[2]</td>
</tr>
<tr>
<td></td>
<td><em>S. aureus</em> (MRSA) and organic soil component</td>
<td>10⁶ CFU/ml</td>
<td>13 days</td>
<td>NT</td>
<td>[2]</td>
</tr>
<tr>
<td></td>
<td><em>Escherichia coli</em> O157:H7</td>
<td>5 × 10⁴ CFU</td>
<td>7 days</td>
<td>Yes</td>
<td>[49]</td>
</tr>
<tr>
<td></td>
<td><em>Salmonella enteritidis</em></td>
<td>5 × 10⁴ CFU</td>
<td>1 day</td>
<td>NT</td>
<td>[49]</td>
</tr>
<tr>
<td></td>
<td>HSV-1</td>
<td>Decrease of 2–3 log in 1 h</td>
<td>NT</td>
<td>[50]</td>
<td></td>
</tr>
</tbody>
</table>

NT: Not tested; TCID: Tissue culture infectious dose.

### Table 3. Laboratory simulations of the potential transmission of pathogens by fomites.

<table>
<thead>
<tr>
<th>Infectious agents</th>
<th>Concentration</th>
<th>Material</th>
<th>Survival</th>
<th>Hand-to-hand or fomite-to-hand transfer</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>10⁶ CFU/ml</td>
<td>Fabric</td>
<td>NT</td>
<td>Yes</td>
<td>[43,46]</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>2.75 × 10⁷ CFU/ml</td>
<td>Paper</td>
<td>10⁵ in 24 h</td>
<td>Yes</td>
<td>[44]</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>2.75 × 10⁷ CFU/ml</td>
<td>Paper</td>
<td>10⁵ in 7 days</td>
<td>Yes</td>
<td>[44]</td>
</tr>
<tr>
<td><strong>Fungi</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Candida albicans</em></td>
<td>10⁵ CFU/ml</td>
<td>Hands</td>
<td>24 h</td>
<td>Yes</td>
<td>[45]</td>
</tr>
<tr>
<td><strong>Virus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influenza</td>
<td>10⁷ TCID /ml</td>
<td>Tissue</td>
<td>15 min</td>
<td>Yes</td>
<td>[51]</td>
</tr>
<tr>
<td></td>
<td>10⁷ TCID /0.1 ml</td>
<td>Hands</td>
<td>10⁴ reduction after 2 min</td>
<td>Yes</td>
<td>[52]</td>
</tr>
<tr>
<td></td>
<td>&lt;2.15 × 10 to 2.94 × 10 TCID /ml</td>
<td>Hands</td>
<td>~5 min NT</td>
<td>[53]</td>
<td></td>
</tr>
<tr>
<td>Rhinovirus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[54]</td>
</tr>
<tr>
<td>Hepatitis A virus</td>
<td>10⁵ PFU or 6 × 10⁴ PFU</td>
<td>Hands</td>
<td>NT</td>
<td>Yes</td>
<td>[55,56]</td>
</tr>
<tr>
<td>Rotavirus</td>
<td>4 × 10⁴ PFU</td>
<td>Hands</td>
<td>7% alive after 240 min</td>
<td>Yes</td>
<td>[57]</td>
</tr>
</tbody>
</table>

NT: Not tested; TCID: Tissue culture infectious dose.
and 10^7 TCID_{50}/ml [51]. In addition, coins contaminated with HSV-1 exhibited a decrease of 100–1000 in the viral concentration within 1 h of contamination [50].

Although they have not been tested, many other viruses are stable in the environment and exhibit high infectivity and, thus, could possibly be transferred by money and coins. The transmission of Rhinovirus was very efficient by hand-to-hand contact [60–62], and 50% of subjects developed an infection after handling a coffee cup contaminated with Rhinovirus [54]. However, other studies contradict the efficiency of rhinovirus spread by direct and indirect hand-to-hand contact with self-inoculation [61]. In addition, the spread of HAV, Rotavirus and Astrovirus from hands to fomites and vice versa has been well documented in several experimental models. Astroviruses exhibited a notable persistence when dried on porous and nonporous materials, particularly at low temperature [64]. A longer survival period was found for Rotavirus on nonporous surfaces at low temperature and humidity [65]. Moreover, Rotavirus can survive for extended periods when dried in fecal matter [66], and contact between a contaminated and clean hand 20 and 60 min after rotavirus inoculation resulted in the transfer of 6.6 and 2.8%, respectively, of the original infectious virus [57]. Considerable amounts of HAV remained infectious on the finger pads 4 h after infection [55], and contaminated finger pads transferred 9% of deposited HAV to lettuce [56].

In summary, laboratory simulations have revealed that the transmission of virus via banknotes and coins is possible.

**Prevention**

Money can provide an indirect route for hand-to-hand contamination, and hand washing is critical after handling money if a clinical or food preparation procedure is to be performed. Many pathogenic or antibiotic-resistant bacteria have been isolated from various coins and paper money collected from medical staff and food handlers [2]. Moreover, the possibility that terrorists could contaminate banknotes with pathogens and then put those notes back into circulation has been proposed [67]. As a result, microbial testing of banknotes and replacement of contaminated notes, and the regular withdrawal of damaged notes by federal authorities is recommended. Antimicrobial polymer materials can also be used in the manufacture of banknotes and banknote paper can be treated with antimicrobial-active compounds, which prevent the growth of microorganisms on banknotes and consequently limit risks of contamination during handling [68]. In addition, the banknote paper can be treated with metallic ions, which are known to have a wide range of antibacterial properties.

Hands are the most important fomites for the spread of nosocomial infection. Alcohol-based hand rubs can improve compliance with hand hygiene and reduce the transmission of pathogenic agents [69]. In addition, routine surface disinfection is crucial to control the spread of nosocomial pathogens. However, the disinfection and hygiene intervention studies conducted so far could not determine a definitive causal relationship due to the lack of statistical significance, presence of confounding factors or absence of randomization [1,70].

An essential measure for preventing foodborne outbreak is hygiene training for food handlers. Many food outlets heavily rely on the exchange of money for food. The possibility that the handling of money might result in food contamination should bring about changes regarding how foods are handled and traded. Appropriate and regular hand hygiene, particularly after toilet visits and handling money, is critical. In addition, food-handling tools can help prevent cross-contamination occurring between money and food through contact with the hands if workers cannot or will not wash hands between tasks. Routine vaccination of food handlers for HAV infection can reduce the foodborne transmission of HAV.

**Conclusion**

In this review, we show that contaminated money and coins are a public health risk when associated with the simultaneous handling of food, and currency may spread nosocomial infections. We have highlighted the potential for banknotes and coins to carry bacteria and fungi, as well as their potential capacity to spread infectious agents. In addition, banknotes and monetary coinage can act as potential reservoirs for antibiotic-resistant bacteria, such as MRSA [2]. Many food handlers do not give much attention to hygienic practices, and money recovered from food handlers was highly contaminated. As a result, the presence of pathogens, such as *E. coli* and *Salmonella* spp., in currency can be potentially detrimental. *E. coli* and *Salmonella* spp. are indicators of poor hygiene
and sanitation standards, and typically associated with fecal contamination. Studies highlight the importance of humidity in the organism fomite-to-finger transfer efficiency rates but there are no standard methods for quantifying transfer rates in the organism fomite-to-finger transfer, and it is difficult to compare the results from various studies [47]. Unwashed hands resulted in greater fomite-to-finger microbial transfer efficiencies. It is possible that the changes in moisture level and pH on skin from hand washing or other residual effects from soap may contribute to this effect [71]. Therefore, important bacterial transfer efficiency can possibly result after handling money under unwashed-hand conditions. As a result, we reinforced the need for good hand hygiene after handling money, especially when simultaneously handling food and money.

**Future perspective**
The capacity of banknotes, coins and fomites to serve as sources of pathogenic agents represents a major challenge in the 21st century. It is possible that the replacement of cotton-based banknotes by substrate material can play an important role in the reduction of bacterial concentration [11]. As often occurs during scientific progress, technological advances in microbiology can allow scientists to revisit the knowledge base. Large-scale 16S rRNA or metagenomic studies could allow scientists to dramatically expand the known diversity of contaminants on money and fomites [72]. In addition, ‘microbial culturomics’ studies, using different atmospheres, temperatures, pH, nutrients, minerals, antibiotics or phages can provide comprehensive culture conditions and significantly increase the number of different bacteria isolates from banknotes, coins and fomites [72,73]. Our knowledge of the potential role of currency in virus transmission is limited. In some studies, the enumeration of bacterial agents was difficult because their existence was below that of a typical detection limit.

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**EXECUTIVE SUMMARY**

**Persistence of pathogens on surfaces**
- Many bacteria and viruses can survive on surfaces.

**Currency notes**
- Cotton-based banknotes provide a fibrous surface, which provides ample opportunity for bacterial attachment, and the longer a paper bill stays in circulation, the more opportunity there is for it to become contaminated.
- Various bacteria, yeasts, fungi, cysts and ova of intestinal parasites have been isolated from money worldwide.

**Coins**
- The presence of an appreciable amount of copper in coined metal alloys seems to be the limiting factor for bacterial survival on coins in general.
- Various bacteria, yeasts and fungi have been isolated from coins worldwide.

**Fomites & money in the spread of nosocomial infections**
- In hospitals, surfaces such as beds and keyboards, which have direct contact with hands, serve as reservoirs of nosocomial pathogens and vectors for cross-transmission.
- Banknotes can serve as a potential source of pathogens, and paper currency recovered from hospitals was highly contaminated by *Staphylococcus aureus* isolates.

**Fomites & money in the spread of food-borne outbreaks**
- *Salmonella* species, *Escherichia coli* and *S. aureus* are commonly isolated from banknotes from food outlets.
- Prepared foods, such as salads, sandwiches and bakery items, are frequently associated with outbreaks of viral food-borne disease.

**Experimental evidence of pathogen transfer by banknotes & coins**
- In laboratory simulations, methicillin-resistant *S. aureus* can easily survive on coins.
- In experimental models, human influenza virus, Norovirus, Rhinovirus, hepatitis A virus and Rotavirus were able to be transmitted through hand-to-hand contact.

**Prevention**
- Hygiene training, including training in the techniques of hand washing and disinfection, is an essential measure for preventing nosocomial and food-borne outbreaks.
for enumeration [11]. Concerning the presence of virus in currency, classical methods, including isolation and culture of the virus, can improve our knowledge, although frequently, the virus cannot be cultivated under laboratory conditions or the virus does not exhibit its characteristic cytopathic effects in culture [74]. Viral metagenomics are particularly suitable for providing a global overview of the diversity of the viral community and possess functional potential [74].

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Papers of special note have been highlighted as:
● of interest
●● of considerable interest
●● Proposes a dynamic model for hand hygiene research and education strategies, together with corresponding indications for hand hygiene during patient care.
➤ Todd EC, Greig JD, Bartlesea CA, Michaela BS. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 6. Transmission and survival of pathogens in the food processing and preparation environment. J. Food Prot. 72(1), 202–219 (2009).
➤ Todd EC, Greig JD, Bartlesea CA, Michaela BS. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 4. Infective doses and pathogen carriage. J. Food Prot. 71(11), 2339–2373 (2008).
● First study of the bacterial contamination of bank notes.
●● Systematic review of the literature on the survival of nosocomial pathogens on inanimate surfaces.
●● Tested a very large number of banknotes obtained from food outlets in ten different countries.
➤ Espiritio Santo C, Morais PV, Grass G. Isolation and characterization of bacterial


48 Very recent study in which the effect of low and high relative humidity on bank note to finger transfer efficiency was tested.


50 In this study, it was found that influenza virus can survive on banknotes.


66 Abad FX, Villena C, Guix S, Caballero S, Pinto RM, Bosch A. Potential role of fomites


In this study, different culture conditions for the isolation of different bacteria species were proposed.