ZHAI YUJIA/CHINA NEWS SERVICE VIA GETTY

Workers spray disinfectant on a street in Shijiazhuang, China, in January 2020.

COVID-19 RARELY INFECTS THROUGH SURFACES. SO WHY ARE WE STILL DEEP CLEANING?

The coronavirus behind the pandemic can linger on doorknobs and other surfaces, but these aren't a major source of infection. **By Dyani Lewis**

When Emanuel Goldman went to his local New Jersey supermarket last March, he didn't take any chances. Reports of COVID-19 cases were popping up across the United States, so he donned gloves to avoid contaminated surfaces and wore a mask to prevent him inhaling tiny virus-laden droplets from fellow shoppers. Neither gloves nor masks were recommended at the time.

Then, at the end of March, a laboratory study showed that the coronavirus SARS-CoV-2 can persist on plastic and stainless steel for days[1]. That triggered startling headlines and a slew of advice on how to decontaminate everything from doorknobs to groceries. It also seemed to confirm guidance issued by the World Health Organization (WHO) in February that the virus that causes COVID-19 can spread through contaminated surfaces, known as fomites.

By May, the WHO and health agencies around the world were recommending that people in ordinary community settings — houses, buses, churches, schools and shops — should clean and disinfect surfaces, especially those that are frequently touched. Disinfectant factories worked around the clock to keep up with heavy demand.

But Goldman, a microbiologist at Rutgers New Jersey Medical School in Newark, decided to take a closer look at the evidence around fomites. What he found was that there was little to support the idea that SARS-CoV-2 passes from one person to another through contaminated surfaces. He wrote a pointed commentary for *The Lancet Infectious Diseases* in July, arguing that surfaces presented relatively little risk of transmitting the virus[2]. His conviction has only strengthened since then, and Goldman has long since abandoned the gloves.

Many others reached similar conclusions. In fact, the US Centers for Disease Control and Prevention (CDC) clarified its guidance about surface transmission in May, stating that this route is "not thought to be the main way the virus spreads". It now states that transmission through surfaces is "not thought to be a common way that COVID-19 spreads".

As evidence has accumulated over the course of the pandemic, scientific understanding about the virus has changed. Studies and

investigations of outbreaks all point to the majority of transmissions occurring as a result of infected people spewing out large droplets and small particles called aerosols when they cough, talk or breathe. These can be directly inhaled by people close by. Surface transmission, although possible, is not thought to be a significant risk.

But it's easier to clean surfaces than improve ventilation — especially in the winter — and consumers have come to expect disinfection protocols. That means that governments, companies and individuals continue to invest vast amounts of time and money in deep-cleaning efforts. By the end of 2020, global sales of surface disinfectant totalled US$4.5 billion, a jump of more than 30% over the previous year. The New York Metropolitan Transit Authority (MTA), which oversees subways and buses and lost billions of dollars in passenger revenue in 2020, spent $484 million last year in its response to COVID-19, including enhanced cleaning and sanitization, according to a spokesperson.

Part of the problem is that specialists can't rule out the possibility of fomite transmission, and the guidance from many health agencies about how to deal with surfaces has been unclear as the science has changed. In November, Chinese authorities introduced guidelines requiring disinfection of imported frozen-food packages. And the CDC directs people to a comprehensive list of agents that kill SARS-COV-2 and says: "Frequent disinfection of surfaces and objects touched by multiple people is important."

Experts say that it makes sense to recommend hand washing, but some researchers are pushing back against the focus on surfaces. In December, engineer Linsey Marr at Virginia Tech in Blacksburg co-wrote an opinion article for *The Washington Post* imploring people to ease up on cleaning efforts. "It's become clear that transmission by inhalation of aerosols — the microscopic droplets — is an important if not dominant mode of transmission," says Marr, who studies airborne disease transmission. Excessive attention on making surfaces pristine takes up limited time and resources that would be better spent on ventilation or the decontamination of the air that people breathe, she says.

Virus RNA can mislead

The focus on fomites — rather than aerosols — emerged at the very beginning of the coronavirus outbreak because of what people knew about other infectious diseases. In hospitals, pathogens such as methicillin-resistant *Staphylococcus aureus*, respiratory syncytial virus and norovirus can cling to bed rails or hitch a ride from one person to the next on a doctor's stethoscope. So as soon as people started falling ill from the coronavirus, researchers began swabbing hospital rooms and quarantine facilities for places the virus could be lurking. And it seemed to be everywhere.

In medical facilities, personal items such as reading glasses and water bottles tested positive for traces of viral RNA — the main way that researchers identify viral contamination. So, too, did bed rails and air vents. In quarantined households, wash basins and showers harboured the RNA, and in restaurants, wooden chopsticks were found to be contaminated. And early studies suggested that contamination could linger for weeks. Seventeen days after the *Diamond Princess* cruise ship was vacated, scientists found viral RNA on surfaces in cabins of the 712 passengers and crew members who tested positive for COVID-19 (ref. 3).

> **"What we really, really value is epidemiological investigations of transmission patterns."**

But contamination with viral RNA is not necessarily cause for alarm, says Goldman. "The viral RNA is the equivalent of the corpse of the virus," he says. "It's not infectious."

To address that part of the equation, researchers began testing whether coronavirus samples left for days on various surfaces could infect lab-grown cells. One study in April found that the virus remained infectious on hard surfaces such as plastic and stainless steel for 6 days; on bank notes, it lasted for 3 days; and on surgical masks, at least 7 days[4]. A later study announced that viable virus was present on skin for up to 4 days, but on clothes it survived for less than 8 hours[5]. And others found infectious virus on library books bound in natural and synthetic leather after 8 days[6].

Unrealistic conditions

Although these types of experiment demonstrate that the coronavirus can survive on surfaces, this doesn't mean that people are catching it from surfaces such as doorknobs. Goldman and others caution against reading too much into virus-survival studies, because most don't test conditions that exist outside the lab. "They were experiments that started out with humongous amounts of virus, nothing that you would encounter in the real world," he says. Other tests have used mock saliva and controlled conditions such as humidity and temperature, all of which widen the gulf between experimental and real-world conditions, says Goldman.

Only a handful of studies have looked for viable virus outside the lab. Tal Brosh-Nissimov, who heads the infectious-diseases unit at the Assuta Ashdod University Hospital in Israel, and his colleagues swabbed personal items and furniture in hospital isolation units and rooms at a quarantine hotel. Half of the samples from two hospitals and more than one-third of samples from the quarantine hotel were positive for viral RNA. But none of the viral material was actually able to infect cells, the researchers reported[7].

Indeed, researchers have struggled to isolate viable virus from any environmental samples, not just fomites. In the only study that has succeeded, researchers grew virus particles from hospital air samples collected at least 2 metres from a person with COVID-19 (ref. 8).

Nevertheless, scientists warn against drawing absolute conclusions. "Just because viability can't be shown, it doesn't mean that there wasn't contagious virus there at some point," says epidemiologist Ben Cowling at the University of Hong Kong.

Human exposure studies of other pathogens provide additional clues about fomite transmission of respiratory viruses. In 1987, researchers at the University of Wisconsin–Madison put healthy volunteers in a room to play cards with people infected with a common-cold rhinovirus[9]. When the healthy volunteers had their arms restrained to stop them touching their faces and prevent them transferring the virus from contaminated surfaces, half became infected. A similar number of volunteers who were unrestrained also became infected. In a separate experiment, cards and poker chips that had been handled and coughed on by sick volunteers were taken to a separate room, where healthy volunteers were instructed to play poker while rubbing their eyes and noses. The only possible mode of transmission was through the contaminated cards and chips; none became infected. The combination of experiments provided strong evidence that rhinoviruses spread through the air. But such studies are considered unethical for SARS-CoV-2, because it can kill.

Although it's probably rare, says Cowling, transmission through surfaces can't be ruled out. "It just doesn't seem to happen that much, as far as we can tell."

Estimates of transmission based on levels of viral RNA persisting in the environment seem to bear this out. From April to June, environmental engineer Amy Pickering then at Tufts University in Medford, Massachusetts, and her colleagues took weekly swabs of indoor and outdoor surfaces around a town in Massachusetts. On the basis of the levels of RNA contamination and how often people touched surfaces such as doorknobs and buttons at pedestrian crossings, the team estimated[10] that the risk of infection from touching a contaminated surface is less than 5 in 10,000 — lower than estimates for SARS-CoV-2 infection through aerosols, and lower than surface-transmission risk for influenza or norovirus.

NOAM GALAI/GETTY

Sanitization of public transport in New York City cost hundreds of millions of dollars in 2020.

"Fomite transmission is possible, but it just seems to be rare," says Pickering, who is now at the University of California, Berkeley. "A lot of things have to fall into place for that transmission to happen."

That might explain why a global comparison of government interventions to control the pandemic in its early months found that cleaning and disinfection of shared surfaces ranked one of the least effective at reducing transmission[11]. Social distancing and travel restrictions, including lockdowns, worked the best.

Messy data

That leaves researchers sorting through messy epidemiological data about how the virus spreads. Hundreds of studies of COVID-19 transmission have been published since the pandemic began, yet there is thought to be only one that reports transmission through a contaminated surface, by what it termed the snot–oral route. According to the report, a person with COVID-19 in China blew his nose with his hand and then pressed a button in his apartment building elevator. A second resident in the building then touched the same button and flossed with a toothpick immediately after, thereby transferring the virus from button to mouth[12]. But without genome sequences of the viruses infecting each person, transmission through another unknown person couldn't be ruled out.

In one other case, eight people in China are thought to have been infected after stepping in sewage containing the virus on the street and then walking the contamination into their homes[13].

Despite the rarity of published examples of fomite transmission, Chinese authorities require that imported frozen food be disinfected. The change in guidelines followed a report, which has not been released in detail, that a worker at a frozen-food business in the northern port city of Tianjin became infected after handling contaminated packaging of frozen pork imported from Germany. But the WHO and other experts have disputed claims that people can be infected through the food chain in this manner.

Cowling says that more detailed investigations are needed, carefully tracking who infects whom, and what surfaces and spaces they shared around the time of infection. "What we really, really value is epidemiological investigations of transmission patterns, whether it's in households or workplaces or elsewhere," he says. "I don't think we've been doing enough of that."

The greatest threat

Armed with a year's worth of data about coronavirus cases, researchers say one fact is clear. It's people, not surfaces, that should be the main cause for concern. Evidence from superspreading events, where numerous people are infected at once, usually in a crowded indoor space, clearly point to airborne transmission, says Marr. "You have to make up some really convoluted scenarios in order to explain superspreading events with contaminated surfaces," she says.

Hand washing is crucial, says Marr, because surface transmission can't be ruled out. But it's more important to improve ventilation systems or to install air purifiers than to sterilize surfaces, she says. "If we've already paid attention to the air and we have some extra time and resources, then yes, wiping down those high-touch surfaces could be helpful," she says.

Households can also ease up, says Pickering. Quarantining groceries or disinfecting every surface is going too far. "That's a lot of work and it also is probably not reducing your exposure that much," she says. Instead, reasonable hand hygiene, as well as wearing a mask and social distancing to reduce exposure from close contacts is a better place to focus efforts.

The WHO updated its guidance on 20 October, saying that the virus can spread "after infected people sneeze, cough on, or touch surfaces, or objects, such as tables, doorknobs and handrails". A WHO spokesperson told *Nature* that "there is limited evidence of transmission through fomites. Nonetheless, fomite transmission is considered a possible mode of transmission, given consistent finding of environmental contamination, with positive identification of SARS-CoV-2 RNA in the vicinity of people infected with SARS-CoV-2." The WHO adds that "disinfection practices are important to reduce the potential for COVID-19 virus contamination".

The CDC did not respond to *Nature*'s queries about inconsistencies in its statements about the risks posed by fomites.

The conundrum facing health authorities, says Marr, is that definitively ruling out surface transmission is hard. Authorities can be reluctant to tell people not to be cautious. "You never want to say, 'Oh, don't do that,' because it can happen. And you know, we should follow the precautionary principle," she says.

Despite the evolving evidence, the public might have grown to expect extra levels of sanitization after the early months of the pandemic. When the New York MTA surveyed passengers in late September and early October, three-quarters said that cleaning and disinfecting made them feel safe when using transport.

Goldman continues to wear a cloth mask when he leaves home, but when it comes to the possibility of catching the coronavirus from a contaminated surface, he doesn't take any special precautions. "One of the ways we protect ourselves is by washing our hands," he says, "and that applies pandemic or no pandemic."

Dyani Lewis is a science journalist in Melbourne, Australia.

1. van Doramalen, N. *et al. N. Engl. J. Med.* **382**, 1564–1567 (2020).
2. Goldman, E. *Lancet Infect. Dis.* **20**, 892–893 (2020).
3. Moriarty, L. F. *et al. Morb. Mortal. Wkly Rep.* **69**, 347–352 (2020).
4. Chin, A. W. H. *et al. Lancet Microbe* **1**, E10 (2020).
5. Harbourt, D. E. *et al. PLoS Negl. Trop. Dis.* **14**, e0008831 (2020).
6. The REALM Project. *Test 5: Natural attenuation as a decontamination approach for SARS-CoV-2 on textile materials* (REALM, 2020); available at go.nature.com/3t1eycg
7. Ben-Shmuel, A. *et al. Clin. Microbiol. Infect.* **26**, 1658–1662 (2020).
8. Lednicky, J. A. *et al. Int. J. Infect. Dis.* **100**, 476–482 (2020).
9. Dick, E. C. *et al. J. Infect. Dis.* **156**, 442–448 (1987).
10. Harvey, A. P. *et al. Environ. Sci. Technol. Lett.* https://doi.org/10.1021/acs.estlett.0c00875 (2020).
11. Haug, N. *et al. Nature Human Behav.* **4**, 1303–1312 (2020).
12. Xie, C. *et al. BMC Public Health* **20**, 1202 (2020).
13. Yuan, J. *et al. Clin. Infect. Dis.* https://doi.org/10.1093/cid/ciaa1494 (2020).