

SARS-CoV-2 infection at the Huanan seafood market

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Abstract

The Huanan market harbored many of the early COVID-19 cases in 2019 and is a key element to understanding the origin of the pandemic. Whether the initial animal-to-human transmission did occur at this market is still debated. Here we do not examine how SARS-CoV-2 virus was introduced at the market, but focus on how early cases may have been infected at the market. Based on available evidence, we suggest that several early infections at the Huanan market may have occurred via human-to-human transmission in closed spaces such as canteens, Mahjong rooms or toilets. We advocate for further studies to investigate this hypothesis.



Figure 1. The Huanan seafood market. (A) Map of the West and East buildings of the Huanan market, Wuhan, China. The first cases were detected in the West building. (B) Aerial view of the West building on 15 January 2021. REUTERS/Thomas Peter.

Main Text

Introduction

To better understand the origin of the COVID-19 pandemic, it is necessary to examine carefully the earliest COVID-19 cases in Wuhan and to try to reconstruct the chains of transmission. The earliest confirmed COVID-19 patients declared symptoms in December 2019 (1). Among these December 2019 cases, about half were linked to Huanan Market (2, 3). This market was one of the largest seafood wholesale markets in central China, located in a busy part of Wuhan city, about 800 meters away from the Hankou railway station. About 10,000 people visited the market per day (1).

Despite claims in the March 2021 WHO-China joint report (1) that live wild mammals were not sold at the Huanan market, a survey (4) later showed that they were, including raccoon dogs (*Nyctereutes procyonoides*), which are potential transient hosts for severe acute respiratory syndrome-related coronaviruses (SARS-r-CoVs) (5). The exact role of the Huanan market in the early days of the COVID-19 pandemic remains unclear. Some scientists tend to think that an initial animal-to-human transmission occurred at this market (2, 6–9) whereas others believe that the Huanan market was the location of an early ‘superspreading’ event and that SARS-CoV-2 probably infected people elsewhere and earlier (10–12).

The Huanan seafood market underwent sanitary procedures and disinfection before closing permanently at 1am on 1 January 2020 (1, 13, 14). The closure, however, concerned only the first floor of the building, while the second floor, which housed eyeglass stores, remained open until 11 January 2020 (14). Future plans for the Huanan market have not yet been issued (15). In January-March 2020 researchers from China’s Center for Disease Control and Prevention collected environmental samples and animal swabs in the Huanan market and the exact details of these sampling efforts were recently provided in a preprint in February 2022 (12) (Table S1). All animal samples were negative and 64 environmental samples collected inside the market, mostly from stalls and sewage wells, showed the presence of SARS-CoV-2 RNA. The sequences of the virus present on surfaces were highly similar to the ones collected from patients from the market (11, 12). These positive samples may come from the patients themselves or from presumptive animals who contaminated them. In addition, a group of Beijing researchers were given a brief access to the Huanan market in February 2020 and they surveyed 80 environmental samples around animal-

selling stalls and 22 environmental samples from cold storage sites for animal products. They found no positive sample for SARS-CoV-2 (16) (Table S1).

Epidemiological studies have found that SARS-CoV-2 transmission is more likely to occur indoors than outdoors, and that closed, poorly ventilated environments are major sites of contamination (17–19). In particular, toilets are notable places for SARS and COVID-19 contamination, through inhalation of viral particles and possibly contact with contaminated surfaces. Indeed, bathrooms are usually narrow unventilated rooms. A thorough study of the 310 passengers on a Milan-South Korea flight clearly identified a 28-year-old person who was infected in the bathroom on the flight where she took her mask off (20). Furthermore, multiple studies have detected large amounts of SARS-CoV-2 particles in the toilets of hospitals and homes (21–24).

Here we review available epidemiological data about the Huanan market outbreak. Based on the spatial and temporal distribution of the initial positive cases at the market, we suggest that several early infections at the Huanan market may have occurred via human-to-human transmission, presumably in closed spaces. We discuss how further studies may investigate this hypothesis.

Analysis of available data

Early cases used to spend several hours in the market

Among the 53 early official COVID-19 cases with direct exposure to the Huanan market, 30 were vendors at fixed stalls in the market, 12 were important purchasers buying food materials at different stalls for hotels or restaurants, and 2 were deliverymen (Table 3 of WHO-China Joint Report Annexe, (1)). Passers-by and community residents who purchased food for their families in the market represented only 9 of these early COVID-19 cases (17%). One possibility is that the duration and frequency of exposure in the market correlate with infection and morbidity risks. Another is that the former group used shared closed rooms such as common activity rooms or toilets whereas the second group did not.

Initial cases were about 20-40 meters apart in the market

The earliest cases were located in the west side of the market, and they were not extremely clustered spatially (Fig. 1-2). Following the first detected case, the next five appeared a few days later, more than 20 meters away in other market stalls (Fig. 2), some of them isolated by walls reaching up to the ceiling (Table S2). If animals were the initial source of the infection, such animals would probably have been present at a particular stall on the market, and they would have led to early contamination of persons located closer than 20-40 meters. A 2020 study in a Chinese hospital revealed that the SARS-CoV-2 virus usually dispersed within a 4-meter radius around patients (25). Transmission at 6-7 meter distance was reported after a 1 hour and 40 minute bus ride in 2020 (26) but appeared to be very rare with the early SARS-CoV-2 variants (27). Experiments with ferrets showed that SARS-CoV-2 air transmission between animals occurs within a short distance (28). In large indoor spaces such as the Huanan market, transmission was expected to occur within 1-4 meters from the contagious individual.



Figure 2. Weekly spatial distribution of early COVID-19 cases in the Huanan market. The first two weeks (until 2019-12-13 and until 2019-12-20) are represented from left to right. Note the low resolution of the figure as in the WHO-China joint report. Patients who developed symptoms on week 2 are 20-40 meters away from the week 1 patient. Even if the detected week 1 patient is not located at the source of the contamination, patients from week 2 are too far apart to be consistent with one or two sources of SARS-CoV-2. From (1) (p. 181, Annexe).

Air dynamics within the market are unknown

The market ventilation system had been closed when live poultry trade was stopped following the outbreak of avian influenza (1), so that the market was overall poorly ventilated. However, a large alley between the West and the East building allowed the passage of small trucks, with a ceiling about 7 meters from the ground (Supplementary Information). Unfortunately, no analysis of the dynamics of air distribution within the West building is available. It would be useful to model air flows within the market to test whether they can explain the spatial distribution of early cases.

The early cases shared closed spaces at the market

The first Huanan market associated patient is a 57-year-old woman who fell sick on 10 December 2019 and who used to sell shrimp. Her interview by the Wall Street Journal reveals that she was using the toilets of the Huanan market: she "thinks she might have been infected via the toilet she shared with the wild meat sellers and others on the market's west side" (29). In addition, rumors circulated that some of the early patients were playing Mahjong in a small unventilated parlor located next to the public toilet (14) and several vendors appeared to eat in neighboring canteens (1). The so-called "chess and card rooms," are usually packed and poorly ventilated spaces where elderly people gather to play. Such locations were important sites of SARS-CoV-2 outbreaks in China in 2020-2021 and thousands of them were shut down in 2020-2021 to limit the spread of the virus (30). It is therefore possible that some of the early cases infected each other not at the market stalls but in smaller spaces.

Discussion

Given that the market had about 10,000 visitors per day, it is interesting to note that the majority of the early cases associated with the market were vendors. This suggests that infection required long or repeated exposure to the animal/human source in the early days of the outbreak, or that most early transmissions occurred from human to human between vendors at their work space, possibly as they shared facilities.

The SARS-CoV-2 sequences from the market patients are almost identical. Epidemiological data are consistent with a single point of introduction of the virus at the market, which is compatible with a zoonotic origin, but does not preclude other possibilities such as a vendor infected outside of the market. Despite extensive sampling (Table S1), no infected animal has been found at the market.

The spatial scattering of early cases in the market (Fig. 2) is not indicative of direct aerosol transmission from a unique source. We suggest investigating further the possibility that the early contaminations at the market were due to the use of common areas such as toilets or canteens. How many restrooms were there in the market? Were they ventilated? Could they be a place for COVID-19 transmission? Were the toilets public or accessible to vendors only? What were the other activity rooms where market people gathered? Questionnaires to Huanan vendors and purchasers would help for elaborating possible scenarios of transmission, by asking which persons were regular users of the washrooms, which restrooms they used, on which days, etc. Other possible epidemiological links between the early market cases should also be scrutinized: did they share other activities (dinner, board games, card games, etc.) either at the Huanan market or at other locations?

In addition, the exact details of the animal and environmental samples that were examined for the presence of SARS-CoV-2, both positive and negative, should be made available and an analysis of air flows within the market would help to infer possible routes of air contamination from localized sources.

In the early days of the pandemic in 2020, exemplary, meticulous COVID-19 case and contact identifications were performed by epidemiologists in China and several landmark papers were published [see for example (25, 31–34)]. These helped the world to better understand the characteristics of SARS-CoV-2 virus transmission. An analytical epidemiological study among vendors and shoppers, with detailed mapping of exposure and contamination factors at the market, and type of products and animals sold, would help to shed light on the possible paths of contamination for the early market cases.

Even if several early market outbreak cases may turn out to be explained by human-to-human transmission, we note that it remains unclear how the first person at the Huanan market was contaminated and whether the market was a site of animal-to-human contamination. However, taking into account the exact location of the early patients in the market can help to refine scenarios about the origin of the pandemic. The earliest detected case is located in a stall that is a few dozens of meters north compared to the presumed animal source hotspot highlighted in the recent Worobey et al. preprint (8). If this patient was infected at the market by an animal, then either the place highlighted by Worobey et al. for animal-to-human contamination is incorrect and should be close to this first patient or this early case somehow contracted the virus around the distant stall highlighted by Worobey et al. Alternatively, this earliest case at the market was infected by humans and the initial introduction of the virus into the human population occurred earlier.

If a cluster of patients located a few meters away from each other had been detected at the market in the early days of the pandemic, it would be natural to suggest an animal source hotspot and animal-to-human contamination at the market. However, the first detected patients are relatively far from each other. We suggest here that they infected each other in common rooms such as toilets. Our analysis therefore decreases the possibility of substantial animal-to-human contamination at the market.

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Supporting Information
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Table S1. Various summary reports of the sampling efforts done at the Huanan market early 2020. The exact details of all the collected samples, dates of collection and associated results have not been published in scientific journals so far. The total number of environmental samples that were collected is indicated in bold.

Information	References
<p>"Thirty-three of the 585 environmental samples collected from the Wuhan's Huanan Seafood Wholesale Market were found to contain the nucleic acid of the novel coronavirus, according to the National Institute for Viral Disease Control and Prevention under the China CDC."</p> <p>"Experts of the institute took the samples on Jan. 1 and Jan. 12 on instruction of the Chinese CDC. Thirty-one of the 33 positive samples were collected from the western zone of the market, where booths of wildlife trading concentrated."</p>	<p>Xinhua Net, 27 Jan 2020 (35)</p>
<p>"585 environmental samples were collected at the Wuhan's Huanan Seafood Wholesale Market"</p> <p>"33 were positive."</p> <p>"Among them, 93.9% (31/33 of the positive specimens were distributed in the western area of the South China Seafood Market."</p> <p>The CDC report includes a detailed table of the environmental samples and associated rRT-PCR results.</p>	<p>Epoch Times; 1 Jun 2020 (36); CDC Report Number 53, issued by Wu Guizhen.</p>
<p>"Of the 336 samples collected from animals, none were PCR positive for SARS-CoV-2, whereas 69 out of 842 environmental samples were positive by PCR for SARS-CoV-2. Sixty-one of those (88%) were from the western wing of the market. Of these, 22 samples were from 8 different drains and sewage, and 3 viruses were isolated, sequenced and shared on GISAID."</p>	<p>WHO-convened Global Study, Terms of references, 31 July 2020</p>
<p>"Huanan market was officially closed on 1 January 2020 and on early morning of that same day China CDC began collecting environmental and animal samples. Staff from China CDC entered the market about 30 times before the market's final clean-up on 2 March 2020." (p. 98)</p> <p>"Among the positive samples, 69 were environmental samples from or related to the Huanan market, of which 61 were collected from or related to the west area of the market. The other four samples were collected from other markets or community sewerage wells in Wuhan. The PCR cycle threshold (Ct) values of most samples ranged from 23.9 to 41.7, and SARS-CoV-2 strains were successfully isolated from three samples with Ct values below 30 (Table 1)." (p. 98)</p> <p>"Huanan market: 718 samples, 40 RT-PCR-positive, virus successfully isolated from 3 samples.</p> <p>Drainage system in the Huanan market: 110 samples, 24 RT-PCR-positive.</p> <p>Warehouses related to the Huanan market: 14 samples, 5 RT-PCR-positive." (p. 98)</p> <p>"A total of 457 animal-related samples from 188 individuals of 18 species were collected and tested between 1st January and 2nd March. [...] All samples were</p>	<p>WHO-China joint report, 30 Mar 2021 (1)</p>

SARS-CoV-2 NAT negative (Tables 3 and 4)." (p. 102)	
<p>"30 Dec 2019: Wuhan CDC and Jiangnan CDC went to Huanan market for environment sample collection." (p. 125)</p> <p>"Environment samples collected from the Huanan market: The positive samples were mostly at stalls where the positive cases had worked – on the floor, walls, chopping boards, and cleaning tools." (p. 126)</p> <p>"Testing of various samples from Huanan market, wildlife markets, urban stray cats, domestic cats etc., revealed positive results in cats (not from Huanan market)." (p. 131)</p> <p>"Environmental samples were collected from 134 stalls in the Huanan Market for SARS-CoV-2 nucleic acid test (Table 7). It was found that 21 business environments tested positive in the SARS-CoV-2 nucleic acid test, and 7 of them appeared cases. Among the 113 stalls with negative environmental NATs results, 9 of them have confirmed cases." (p. 184)</p>	WHO-China joint report annexes, 30 Mar 2021 (1)
"Chinese researchers collected nearly 1,000 samples from the Huanan market in early 2020, swabbing doors, rubbish bins, toilets, stalls that sold vegetables and animals, stray cats and mice. The majority that tested positive were from stalls that sold seafood, livestock and poultry. The researchers also took samples from 188 animals from 18 species at the market, all of which tested negative."	Maxmen A., Nature, 30 March 2021 (37)
<p>"None of the animal products sampled in the market tested positive."</p> <p>"Environmental samples taken after the seafood market was closed revealed widespread environmental contamination by the virus, particularly in the aquatic products stalls."</p>	Xinhua Net, 31 Mar 2021 (38)
<p>"We collected 22 environmental samples from cold storages for animal products and 80 samples from environment around animal-selling stalls of Wuhan Huanan Market, once we had brief access to WHM in February, 2020."</p> <p>"None of any sequence of SARS-CoV-2 or SC2r-CoVs was found in any samples."</p>	Wu Z. et al., Nature Portfolio preprint, 20 September 2021 (16)
<p>1380 environmental samples in and around the Huanan market were collected from a wide diversity of surfaces, animals and products.</p> <p>The current manuscript presents a list of the positive environmental samples (with no detail about their location within the market) (Table 1), a list of the animals collected in the market (Table 2) and an overview of the positive environmental samples (Extended Data Figure S1). The exact list, location and description of all the samples, whether positive or negative is not provided.</p>	Gao G. et al., Nature Portfolio preprint, 25 February 2022 (12)

Table 2. Hyperlinks to videos of the Huanan market. These videos give an idea of the general layout of the stalls and the spaces within the market.

<https://www.ixigua.com/6545296264865513997?logTag=f193fecfe9f581a5df96>

Duration: 5:45, video published on 2018-04-17.

Walking into the West part, entering into the central alley by the South-West corner and walking North to the glass hall, then on Xinhua road up to the South. One can observe that the market stalls are often isolated by walls reaching up to the ceiling.

<https://www.youtube.com/watch?v=-c0iOjGjwsk>

Duration 14:23, pre-pandemic video published on YouTube on 2020-02-01. Walking into the West part, from the glass hall to the central alley, the seventh street and south of Xinhua road.

More pictures and videos can be found here:

<http://babarlephant.free-hoster.net/visiting-the-wuhan-seafood-market/?i=1>