

Norwalk-Like Viruses: Characterization of Four Outbreaks in Houston, Texas, 2002

Since the 1990's, mounting epidemiological and laboratory evidence suggests that Norwalk-like viruses (NLVs) are the most common cause of non-bacterial gastroenteritis world wide. Prior to the development of sensitive assays for detecting NLVs, clinical and epidemiological data alone were commonly used to suggest the viral etiology of outbreaks of gastroenteritis. The development of more readily applicable and sensitive technologies (enzyme immunoassays, nucleic acid hybridization assays, and RT-PCR) enables researchers to better define the burden of disease due to NLVs and the role of NLVs in outbreaks of gastroenteritis. The recent implementation of such technologies at HDHHS permitted the etiologic description of four NLV outbreaks which occurred in a variety of settings in Houston, Texas between January-March 2002.

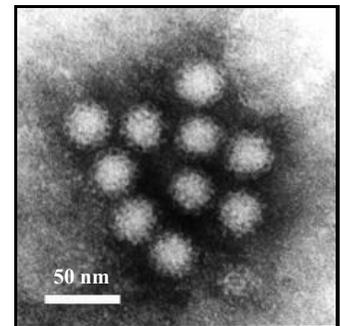
Introduction

Norwalk-like viruses (NLVs) are recognized as the most common cause of non-bacterial gastroenteritis in adults. Although the endemic level of disease is unknown due to the limited availability of simple diagnostic assays, recent studies provide evidence that this group of viruses is responsible for the majority of outbreaks of non-bacterial gastroenteritis globally.

Norwalk virus was first identified by electron microscopy in 1972 by researchers analyzing stool specimens previously stored from an outbreak of gastroenteritis that occurred in 1968. The outbreak took place in Norwalk, Ohio, where 50% of 232 elementary students and teachers became ill. More recently, researchers have identified Norwalk-like viruses as the etiologic agent in 96% (86/90) of non-bacterial gastroenteritis outbreaks reported to 33 state health departments in the United States between January 1996 and June 1997.¹ In the United Kingdom, Norwalk-like viruses were responsible for 68% (706/1039) of all outbreaks of non-bacterial gastroenteritis reported between 1992 and 1998.²

Norwalk virus and related Norwalk-like viruses belong to the *Caliciviridae* family and are small round RNA viruses with a surface structure that lacks distinctive geometric morphology (Figure 1). Strains pathogenic to humans belong to two distinct genogroups (GI and GII), which circulate widely throughout the world. The strains are named for the locations where they were first identified and bear such names as Norwalk, Southampton, Desert Shield, Snow Mountain, Mexico,

Figure 1. Negative-stain transmission electron microscopy of Norwalk virus identified in a stool sample from an individual with gastroenteritis. (Source: EPA).



Hawaii, and Bristol.

Illness due to NLV is characterized by sudden onset of nausea, vomiting, diarrhea, and abdominal cramps, with vomiting being more common in children, and diarrhea more common in adults. Vomiting is described as profuse, non-bloody, and non-bilious, while diarrhea is typically watery without blood, pus, or mucus. Other symptoms associated with illness include headache, fever, chills, and myalgia. Illness generally follows 12-48 hours after ingestion of infectious particles, and symptoms usually resolve within 12-60 hours after onset, with no long-term effects. Severe dehydration and death are rare outcomes, almost exclusively associated with immunocompromised individuals. Infection with one strain of NLV does not provide long-term immunity or cross-protection from infection with another strain, and as a result, individuals can become ill from NLVs repeatedly over their lifetimes.⁴

Outbreaks are frequently due to point source exposures to fecally-contaminated food or water. The set-

tings in which NLV outbreaks have occurred are diverse, including restaurants and catered events, nursing homes and hospitals, schools, cruise ships, hotels, recreational water sources, and municipal water supplies. Commonly implicated vehicles include water and ice, shellfish harvested from polluted seabeds, and fresh produce irrigated with sewage-contaminated water. Infected food handlers who prepare ready-to-eat items such as salads, sandwiches, and pastries have also been associated with large NLV outbreaks. NLVs account for 60% of all cases of foodborne illness in the US in which a pathogen has been identified.⁸

Person-to-person transmission via environmental contamination and aerosolized particles is known to extend outbreaks through secondary and tertiary transmission among close contacts of primary cases. The low infectious dose (<100 viral particles), high concentration of virus in stool and vomitus, and prolonged shedding of viral particles (≥ 14 days) may partially explain the high rate of secondary transmission in outbreaks caused by NLVs.^{5,7}

Norwalk-like Virus Outbreaks in Texas

Documentation of confirmed outbreaks of gastroenteritis in Texas due to NLVs is sparse. In January 1995, following reports of an NLV outbreak in Florida associated with oyster consumption, enhanced surveillance of diarrhea cases in Texas identified two clusters of NLV-related foodborne disease. Galveston Bay was temporarily closed to oyster harvesting in order to prevent an outbreak.⁹ In March 1998, an outbreak was reported at a local university when 125 students became ill after eating at the campus deli bar. The source of the outbreak was traced to a food handler whose infant had previously been ill with gastroenteritis. NLV was detected by reverse transcription polymerase chain reaction (RT-PCR) in stool specimens from ill students, the infant, and the deli ham—establishing the sources of the outbreak. The agent was classified as a genogroup II NLV.¹⁰ Again in August 1998, an estimated 205 illnesses among US Army trainees were reported at a Texas military base.¹¹ Illnesses were associated with soft drinks and with one specific dining facility on the base. The NLVs identified in this outbreak were also classified as genogroup II.

Norwalk-like Virus Outbreaks in Houston

One of the earliest laboratory-confirmed NLV outbreaks investigated by the Houston Department of Health and Human Services (HDHHS) occurred in January 1995 at a facility for the mentally-retarded. Illness was reported in 102 residents, staff, and day care clients. Snow Mountain virus, a genogroup II

Table 1. Summary of four laboratory-confirmed outbreaks due to Norwalk-like virus (NLV) in Houston, Texas, January-March, 2002.

SETTING	# ILL	ATTACK RATE	ONSET	OUTBREAK DURATION	POSITIVE SPECIMENS	GENOGROUP
Catered events	100	57%	01/07/02	4 days	12/29 (41%)	I
Assisted-living facility (A)	81	11%	02/26/02	8 days	5/8 (63%)	I
Elementary school	117	42%	03/01/02	18 days	2/5 (40%)	II
Assisted-living facility (B)	49	14%	03/20/02	12 days	2/4 (50%)	Not done

NLV, was detected by electron microscopy and RT-PCR in stool specimens from ill persons at the Centers for Disease Control and Prevention (CDC) laboratories in Atlanta, Georgia. Food contaminated by an infectious food handler and subsequent person-to-person transmission were determined by this investigation to have propagated the outbreak.

January 2002, marked the introduction of molecular technologies for the detection of NLVs by HDHHS. In fact, the HDHHS Bureau of Epidemiology, with support from the Bureaus of Consumer Health and Laboratory Services, identified four outbreaks of NLV within the city of Houston from January-March, 2002, affecting at least 350 individuals (Table 1). Prior to this time, gastroenteritis outbreaks in which no bacterial or parasitic agent was identified were presumed, given supportive clinical data, to have viral etiologies. However, confirmation required submission of clinical specimens to a reference laboratory, with a turn-around time that was not practical for outbreak investigations.

Outbreak 1: Catered Events

On January 10, and again on January 14, 2002, HDHHS was notified by four separate local businesses of outbreaks of gastrointestinal illness among their clients and employees at 6 unrelated social events between the dates of 1/7/02 and 1/9/02. All events were catered by a single company, which offered similar menus consisting of cold deli meat sandwiches and salads.

Upon inspection of the catering facility by HDHHS on January 10, the caterer had already voluntarily shut down operation due to customer complaints and was in the process of sanitizing the premises. Consequently, normal food handling practices could not be observed. A review of the caterer's inspection record revealed no history of negative citations. No suspect food samples

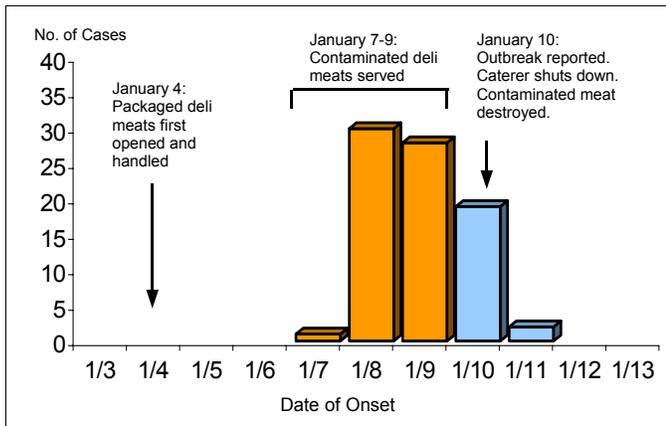


Figure 2. Epidemic curve of a common-source outbreak of NLV gastroenteritis related to a catering company in Houston, Texas, January 7-11, 2002.

were available for testing, as the company that distributed the meats had already reclaimed and destroyed them on the morning of January 10. Subsequent inspection of the meat distributor on January 18 by the Texas Department of Health revealed no major violations in food handling practices by that facility.

A survey of 54 events catered by the company a week prior to January 10 revealed that diners at 12 events (January 7-9, 2002) had experienced gastrointestinal illness. The menus served at these 12 events were similar, consisting of cold deli meat sandwiches (ham, chicken, or turkey) and salads containing deli meat (ham or chicken). Diners who were served primarily hot meals at 11 other events during the same time period reported no illness. No illnesses were reported by attendees of events catered prior to January 7 or after January 9 (Figure 2).

Standardized questionnaires were administered to 98 of 151 attendees from 10 events at which illness was reported, and a similar questionnaire was administered to all 24 employees of the catering company in order to collect food histories and information on activities and exposures between January 1-9. A case was defined as a person who was either employed by or who had eaten food catered by the company between January 7-9 and who developed vomiting and/or diarrhea within the next 72 hours.

A total of 122 out of 175 persons associated with the outbreak were interviewed—80 of whom met the case definition (72 attendees, 8 food handlers). The remaining 42 served as controls. The mean incubation period was 34.6 hours (range 5-62.5 hours) and the mean duration of symptoms was 39.5 hours (range 1-120 hours). Symptoms included nausea (85.9%), diarrhea (76.9%), vomiting (73.1%), fever (59%), headache (56.4%), chills (59%), dehydration (39.7%), and tenes-

mus (35.9%). One person was hospitalized briefly and nine others sought out-patient medical care. Half of those who visited a physician were prescribed antibiotics.

Eating a cold deli meat sandwich or salad with meat was associated with illness (OR=66.36; 95% CI [9.40-2777.36]).

Ten stool specimens were submitted by ill attendees from 2 catered events. All were negative for *Salmonella*, *Shigella*, *Campylobacter*, and shiga-toxin producing *E. coli*. Subsequent testing by RT-PCR detected NLV in 8 (80%) of the samples. Stool specimens from all 24 catering employees were screened for the same bacteria, and one was positive for *Shigella sonnei*. A randomized sample of the negative specimens (19/23) were screened for NLV, and four (4/19) tested positive for the virus. The finding of *Shigella* in one asymptomatic food handler was therefore considered incidental and unrelated to the outbreak given that *Shigella spp.* was not found in the stool of other food handlers or clients. Multiplex PCR was used to differentiate the genogroups of NLV found in two of the catering employees and three event attendees. All were classified as NLV genogroup I.

All 24 catering employees denied gastrointestinal illness in themselves and in close contacts during the two weeks prior to the outbreak, suggesting that NLVs were introduced among the company's staff and its clients at the same time. The potentially contaminated deli meats had been ordered in December 2001 and reportedly kept hermetically sealed in cold storage until removed for slicing on January 4. One NLV-positive food handler was normally responsible for assembling the deli meat sandwiches, but a review of the employee work log did not provide evidence that she had worked on January 7, the start of the outbreak. No work log was available (and recall was poor) to ascertain the work habits and food preparation activities of the employee on January 4. This employee further denied any personal history of illness at all—as well as illness in close contacts—and was the only infected employee who denied having eaten catered food items between January 7-9. This person was suspected, but could not be confirmed, as the index case and source of the outbreak.

The one employee with *Shigella* infection was restricted from food handling duties until he had sought medical attention and until three successive stool specimens tested clear of the pathogen. All other symptomatic catering employees recovered from illness before the company resumed operations on January 11. No new cases were reported after that date.

Outbreak 2: Assisted-living facility "A"

On March 1, 2002, a Houston-area assisted-living facility reported an outbreak of gastrointestinal illness in its elderly residents. The facility provides housing and services to 440 senior citizens (mean age=87 years) and employs 270 staff, including nurses, nurse aids, and personal attendants (privately hired by residents, themselves). The outbreak was not reported by the facility until it had reached its peak, after as many as 57 persons had become ill (Figure 3). The facility was divided into independent-living and assisted-living residential quarters in two separate buildings. Building I was equipped primarily with private apartments for independent and ambulatory residents, but also housed the facility's sole clinic, its main kitchen, and a special care area for Alzheimer's and dementia patients. Building II was entirely dedicated to patients requiring assisted-living care, included a dedicated wing for Alzheimer's and dementia patients, and also had a small service kitchen where foods from the main kitchen were received and served exclusively to Building II residents. The great majority (94%) of cases occurred among residents and staff of Building II and the special care area of Building I. This high-risk population consisted of 143 residents, their 45 dedicated staff, and also 7 nurses who served both buildings.

Diarrhea was the most common complaint of ill persons (65.4%), followed by vomiting (34.5%). Inspection of the kitchen in Building I, where food services for the entire facility originated, revealed that the kitchen was operating without hot water and that the dish washing machine was not sanitizing at the optimal temperature (160 °F). The kitchen was briefly closed to correct these violations on March 1.

Epidemiological investigation was complicated by the delayed recognition and reporting of the outbreak (which effectively began February 26), by the lack of detailed documentation at the facility regarding the dietary habits of high-risk residents, and by the inability of a high proportion (44%) of those residents (i.e., dementia and Alzheimer's patients) to report their own histories. The case definition included any resident or employee of the facility who had experienced >1 bout of vomiting and/or diarrhea since February 26, with illness of at least a 24-hour duration. Prospective surveillance for disease among healthy residents was instituted from March 6-8 to obtain details of their daily exposures. Staff were instructed to observe strict enteric precautions during the three-day surveillance period.

Administrators denied unusual reports of gastroenteritis in any staff member or resident of the facility (other than persons with known chronic gastrointestinal and bowel disorders) during the two weeks prior to the

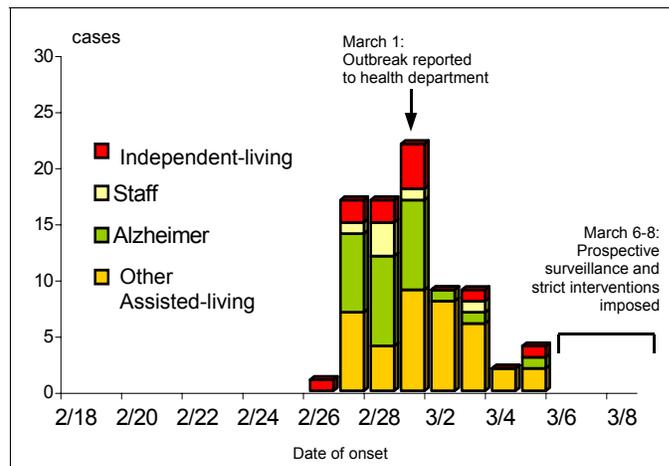


Figure 3. Epidemic curve of an outbreak of NLV-related gastroenteritis at Assisted-living Facility "A," Houston, Texas, February 26-March 5, 2002. Despite its resemblance to a common-source outbreak, epidemiological evidence acquired during investigation suggested that the outbreak was propagated by person-to-person transmission among highly susceptible groups within the facility. The outbreak appeared to have stopped by March 6.

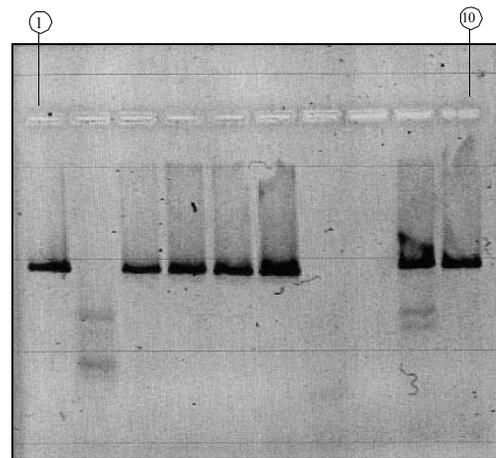


Figure 4. Molecular analysis of NLV outbreak in Assisted Living facility "A," Houston, Texas, February 2002. Gel electrophoresis of genomic RNA isolated in stool and amplified by RT-PCR. Lanes 1 and 10 represent positive controls; lanes 2-9 are from specimens of residents. Only 3-6, and 9 are positive for NLV.

outbreak. Illness was reported by 52% (75/143) of high-risk residents, compared to 3.4% (10/297) of all other residents, 43% (3/7) of nurses, and 8.6% (3/35) of nursing assistants who attended high-risk residents.

The attack rate among all residents outside the high-risk cohort (3.4%) remained significantly lower than would have been expected had the facility's kitchen been the common source of the outbreak ($\chi^2=149.18$, $p<.01$). The disease risk associated with foods distributed from the service kitchen in Building II could not be determined due to the lack of adequate records on the specific dietary habits of employees and residents in the high-risk cohort. Within the high-risk group, no

significant difference was observed in the attack rate among Alzheimer's patients when compared to other assisted-living residents at risk [RR=1.14, Yates corrected $X^2 = 0.14$, $p > .70$]. Thirty-five stool samples collected from asymptomatic food handlers, ill staff, and residents between February 27-March 4 were submitted for routine bacterial screens. All were negative for *Salmonella*, *Shigella*, and pathogenic *E.coli*. A randomized sample of eight (8/35) stool specimens yielded five (all from residents) that were positive for NLV by RT-PCR, and were classified as genogroup I.

The absence of evidence implicating food as a vehicle in this outbreak suggested that person-to-person transmission played a more important role than previously recognized. This was potentially corroborated by reports of investigators who observed staff members providing various personal services to residents and subsequently hugging and touching other residents without benefit of gloves or hand washing between contacts. No hand sanitation stations were observed in the affected areas of Building II, despite the intimacy and frequency of staff-resident contact, and staff were discouraged by management from using hygienic facilities in the private rooms of residents. Anecdotal reports from nursing staff further suggested that the "index case," an independent-living resident of Building I, had presented to the clinic on February 26 with vomiting and diarrhea, and following an over-night stay for observation, "several" other patient-residents at the clinic also developed symptoms.

The prospective surveillance proved moot: disease incidence had already begun to decline by March 2, and no new cases were reported after March 5. The source of the outbreak could not be determined.

Outbreak 3: Elementary school

On March 8, 2002, the parent of a student at an elementary school reported an apparent outbreak of gastroenteritis in students who attended the school. An on-site investigation was conducted on March 8 by epidemiologists and food-service inspectors who reviewed attendance records, interviewed students and staff, and collected stool samples. Sporadic complaints of illness had been reported since March 1, primarily among Kindergarten and 1st grade students, but complaints increased dramatically on March 7, when at least 20 students from 3rd and 4th grades were sent home for vomiting and stomach pain. Ten staff members, including 6 teachers and one food handler, also reported illness. No major violations were noted in the food handling practices of kitchen staff.

Investigation was impeded by the fact that the school was preparing to close for Spring Break on

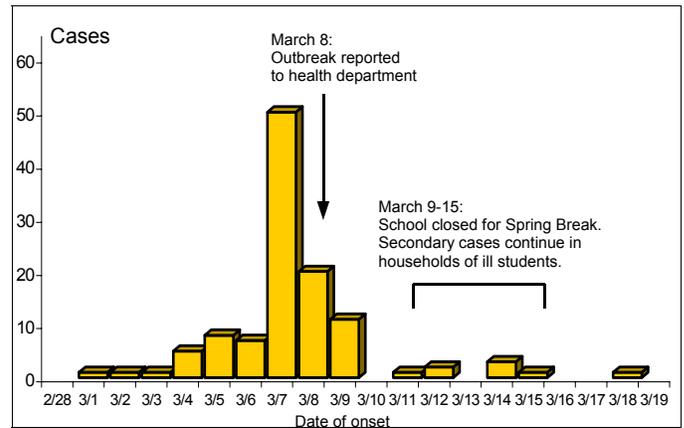


Figure 5. Epidemic curve of an outbreak of gastroenteritis due to NLV in an elementary school in Houston, Texas, March 1-18, 2002. Spring Break vacation interrupted transmission in the school, but secondary transmission in the households of ill students continued more than one week, thereafter.

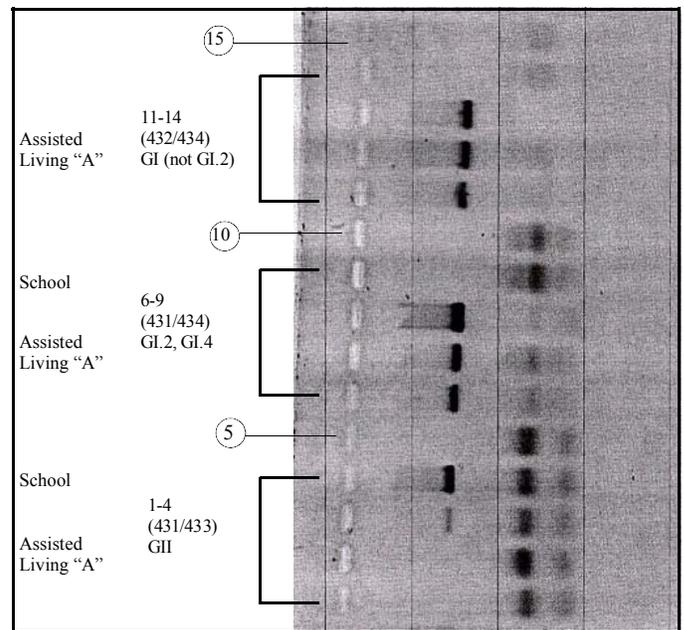


Figure 6. Genotypic classification of two NLV outbreaks, Houston, Texas, 2002. This image represents specimens from both the Assisted Living "A" (AL) and the school outbreaks. Lanes 1-3, 6-8, and 11-13 represent the AL specimens; lanes 4, 9, and 14 represent the school specimens. The numbers in parentheses indicate primer pairs used during RT-PCR to differentiate the corresponding genotypes. Lanes 5, 10, and 15 represent negative controls.

March 8, and therefore the bulk of the investigation had to be conducted by telephone and through visits to the homes of available cases and controls. A total of 138 individuals were interviewed from March 9-18, and 99 cases were identified in this way—73 (74%) students, 10 (10%) staff members, and 16 (16%) household contacts. An additional 39 available persons from the student body, along with their households, served as un-

matched controls. Attack rates were lowest among students and teachers of the very youngest and eldest age groups (Pre-Kindergarten: 6.67%; 4th grade: 6.02%; 5th grade: 7.8%) and highest for those in the middle (Kindergarten: 16%, 1st grade: 14.44%, 2nd grade: 25.68%, 3rd grade: 11.58%). Vomiting was the primary complaint (90%), followed by diarrhea (45%). The incubation period for the illnesses ranged from 24 – 72 hours, and had a duration of 12 – 96 hours. A case was defined as being either a student, or a household contact of a student, who reported ≥ 1 episode of vomiting and/or diarrhea since March 1.

Disease incidence at the school peaked on March 7 but was interrupted by Spring Break on March 8. Secondary rates in households also peaked on March 7 and began to decline sharply with the close of school.

Though comprehensive menus served at the school during the outbreak were available, detailed food histories could not be collected from cases and controls because of their very young age and poor recall. However, children who did not normally eat food prepared in the school kitchen were four times more likely to report illness than those who regularly did (OR = 4.27, 95% CI [1.79 - 10.57])—suggesting that the school’s kitchen was an unlikely source of contamination. Investigators were unable to identify any other common social or school activities associated with disease. These findings, and the general epidemic picture of this outbreak, suggested propagation of the virus by person-to-person contact.

One staff person, three school children, and one secondary case in a household submitted stool specimens for analysis. Two (2/5) of the stool samples (both from students) tested positive for NLV by RT-PCR and were characterized as belonging to genogroup II.

Outbreak 4: Assisted-living facility “B”

On March 25, 2002, a relative of a resident of a Houston-area assisted-living facility reported an outbreak of gastroenteritis at the site in 8 elderly residents. A field investigation conducted the same day revealed that at least 25 (7%) of the facility’s population had experienced illness since March 20. Symptoms were described as diarrhea (75%) vomiting (68%), nausea (64%), and abdominal cramps (25%). Fever was not documented in any case, and all illnesses resolved after 24-48 hours. The case definition therefore included any resident or staff person of the assisted-living facility with a history of ≥ 2 of the above-mentioned symptoms since March 20, and with a duration of illness ≥ 24 hours.

The facility housed 186 residents (median age=87 years), and employed 174 staff, including 33 nurses and

71 certified nursing assistants. The facility was divided into four sectors (I-IV), each of which had its own nursing station. Sectors I, II, and IV were accessible to one another; their residents shared a common dining area and freely moved between sectors. Sector III, dedicated to Alzheimer patients, was secured against unauthorized entry/exit and had its own dining facility. A single kitchen served residents and staff of all sectors. Residents occupied either 2-bed or 4-bed rooms. Rooms with 2 beds were most common (59/79 or 75%), and 72 of the 79 rooms were fully occupied at the time of the outbreak. The facility had a single kitchen that served all residents and staff. Inspection of the kitchen, and subsequent interviews with kitchen staff, revealed no history of illness or serious violations in food handling practices.

The 25 cases identified on the first day of the investigation consisted of 18 residents and 7 staff. The majority (76%) of these illnesses occurred in sector IV (13 residents and 6 staff). Sector II reported three cases (all residents), Sector I reported two cases (one resident and one staff), and Sector III, a single case in a resident. An inspection of the kitchen and interviews with food handlers revealed minor violations which were corrected during the site visit. As disease was most strongly associated with Sector IV, the epidemiological investigation focused there for recognition of potential modes of transmission. A nursing staff member assigned to Sector IV made the earliest known complaint of NLV-like illness on March 20. This potential index case had worked in the sector from March 18-19 but had suddenly called in sick on March 20 (Figure 7). Within 48 hours of their last exposure to this staff person, a resident of Sector IV and a resident of Sector II became ill on March 21. Over the next 24 hours, on March 22, two more residents of Sector IV became ill. By March 24 gastrointestinal illness was being reported in all sectors.

To reduce potential person-to-person transmission, epidemiologists recommended implementation of strict infection control measures. Investigation of the source of the outbreak was complicated by a lack of detailed documentation on the food histories, activities, and interactions of residents with staff. Beginning on March 25, an attempt to implement prospective surveillance in the facility was unsuccessful, as exposure histories were not documented by staff in a consistent manner from day to day.

Forty-nine persons (41 residents and 8 staff) became ill by the end of March, with illness principally characterized by nausea and vomiting (22%) or vomiting with diarrhea (78%). Room occupancy rates were related to disease, as a case was five times more likely to be

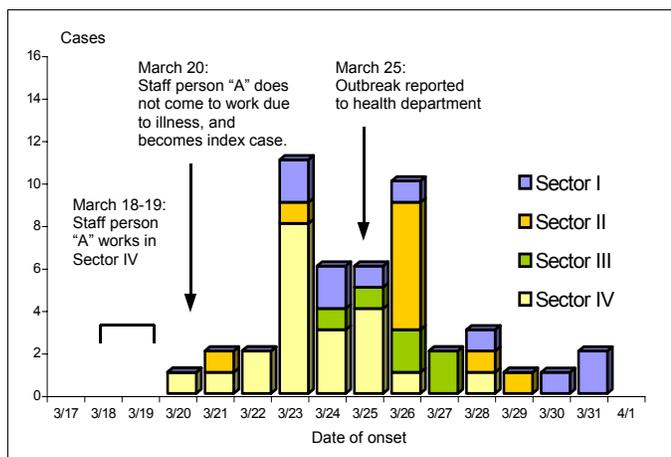


Figure 7. Epidemic curve of a propagated outbreak of NLV in assisted-living facility “B,” Houston, Texas, March 20-31, 2002. Transmission appeared to be entirely person-to-person, possibly having begun with an infected staff person who worked in one sector of the facility.

found in a fully-occupied room with 4 beds than in a fully-occupied room with 2 beds (OR = 5.14, 95% CI [2.23 – 16.05]). Attack rates remained highest in Sector IV (29%) throughout the outbreak, followed by Sector III (27%), Sector II (20%), and Sector I (12%). Sector III, with restricted access to the rest of the facility, was the last to be affected by disease, but its residents developed the second highest attack rate—possibly through exposure to infected staff who provided them intimate personal care. These data again suggest that disease was likely due to person-to-person transmission.

Twelve stool specimens, all from residents, were submitted for analysis, and all were found negative on routine bacterial screens. A randomized selection of 4 specimens was screened for NLV by RT-PCR, and two (50%) were positive for the virus. Genotypic identification of the virus was not performed in this instance.

Conclusion

The four investigations described in this article represent the first successful efforts on the part of HDHHS to routinely identify the etiologies of Houston area viral gastroenteritis outbreaks. This has been facilitated by the recent application of sensitive diagnostic methods, such as RT-PCR, in support of public health investigations. Nonetheless, RT-PCR remains a complex and time-consuming process, and the foregoing investigations therefore followed a CDC recommendation to randomly select samples from among outbreak specimens for NLV screening. The finding of a common pathogen in $\geq 50\%$ of the specimens in such a sample was sufficient to determine the etiology of an outbreak.¹² The positive RT-PCR findings in these

four investigations are therefore adequate to suggest, if not always confirm, NLV as the cause of each of the outbreaks.

Person-to-person transmission was suggested in all three institutional outbreaks, with food-borne transmission apparent only in the non-institutional setting. Containment of environmental contamination and person-to-person transmission in institutional settings is difficult and requires stringent hygienic measures. The virus is fairly resistant to adverse environmental conditions, including relatively high concentrations of chlorine and extremes of temperature (32°F, 140°F).^{5,6} Frequent and thorough hand-washing, disinfection of environmental surfaces, exclusion of affected staff from work, and isolation of infected individuals within inpatient settings are effective means of decreasing transmission. Current public health guidelines recommend the exclusion of food handlers with NLV infection from food preparation until 48-72 hours after resolution of symptoms.⁴

Daily prospective surveillance was attempted in residential facilities for the elderly to capture more detailed exposure histories than would be recorded normally by their nursing staff. The success of this surveillance strategy varied because it was labor-intensive and depended heavily upon the commitment of facility staff. Less laborious strategies may be needed in the future to obtain consistent and meaningful data. Recognition and reporting of an outbreak was delayed in all four events until 4-6 days following the onset of the index case and until after peak incidence had already been reached. Remarkably, in three of the four outbreaks, the initial report of a public health problem came from concerned members of the public, rather than from the organizations directly affected by the outbreaks themselves. Reporting delays such as these were accompanied in all instances by considerable morbidity—an observation that underscores the importance of timely disease reporting by not only medical personnel, but by the general public as well, to ensure early public health intervention.

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