Background: During the 2001-2002 respiratory season, Arkansas experienced one of its worst pertussis outbreaks. This crisis occurred shortly after the September 11, 2001, terrorist attacks.

Objective: To determine whether vulnerabilities in the public health infrastructure existed in the context of emerging infectious diseases or possible bioterrorist attacks.

Design: Key personnel involved in the Arkansas pertussis outbreak were interviewed, and health department epidemiologic data were reviewed.

Setting: Observations were made for the statewide private-public management of the epidemic.

Participants: Physicians, infectious disease specialists, epidemiologists, field nurses, health department staff, laboratory staff, and administrators.

Main Outcome Measures: Diagnosis capability; vaccine, prophylaxis, and treatment programs; and effectiveness of global outbreak management.

Results: Diagnosis of pertussis was a major barrier to management of the outbreak. The nonspecific clinical diagnosis, unreliability of testing methods, excessive number of samples, unavailability of reagents, and inadequate transport system, laboratory personnel, and equipment all impeded effective diagnosis. Vaccine shortage was not believed to contribute to the extent of the outbreak. Prophylaxis was problematic because of feared adverse effects of drugs and uncertainty about the efficacy of new drugs, but compliance was found to be good. From a public health perspective, isolation procedures, school absence policies, and health department referrals to private physicians all contributed to confusion. Problems with communications, staffing, and public cooperation were identified. Despite these barriers, the epidemic was well tolerated, with no known mortality and limited morbidity.

Conclusions: Despite many identified barriers to effective public health management, Arkansas tolerated its worst epidemic of pertussis in many years. However, were the state to experience an outbreak of a more pathogenic agent, introduced either naturally or of bioterrorist origin, these vulnerabilities could become critical. Natural outbreaks serve as excellent experiences on which to recognize and correct barriers to public health management.

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are described herein in a real-life outbreak setting. Although not as dramatic as a bioterrorist attack, the outbreak illustrates potential barriers to effective public health responses in this state.

METHODS

The investigation for the 2001-2002 pertussis season in Arkansas was carried out principally by interview method. Key participants included the medical director of the communicable diseases division of the ADH, the communicable disease nursing coordinator, the chief laboratory technician and laboratory medical director at the Arkansas Children’s Hospital (ACH) (Little Rock) laboratory, the epidemiology director for the ADH, the pediatric infectious disease director and clinical staff (single medical school and only pediatric infectious disease department in the state), and the infection control officer at the ACH. Interviews were open ended, with the goal of providing a complete case report of a public health event. Repeated interviews were conducted as needed. All potential interviewees agreed to be interviewed.

In addition, a full review of official ADH memos regarding pertussis was conducted, and a media search was performed to document media coverage and to validate the chronology of the events. The medical director and the department director of the ADH reviewed the summary report for accuracy and bias.

The case definition used by the ADH was the 1997 CDC and Council of State and Territorial Epidemiologists description: “a cough illness lasting at least 2 weeks with one of the following: paroxysms of coughing, inspiratory ‘whoop,’ or post-tussive vomiting, and without other apparent cause as reported by a health professional. A case is confirmed if any cough illness is associated with isolation of B. [Bordetella] pertussis, or if a clinical case is confirmed by PCR [polymerase chain reaction], or a case that meets the clinical definition is epidemiologically linked directly to a case confirmed by either culture or PCR.”

OUTBREAK DESCRIPTION

Each fall, the number of pertussis cases increases in Arkansas (ACH microbiology laboratory, unpublished data, 1994 to present; this laboratory has an agreement with the ADH to perform B pertussis testing). In August 2001, the first cases indicating the onset of the respiratory season were noted (Figure 1). On September 28, 2001, a physician in “county A” telephoned the ACH to report a few suspected cases of pertussis in his town. While attending a junior high school football game the night before, he noticed many of the players going to the sidelines after each play with coughing and subsequent emesis. The day of this report, the ACH called the local health unit of county A, ADH contacted the CDC, and local health nurses went to the school and began the investigation; 15 students were sent home. The next day, ADH communicable disease nurses began investigating the outbreak, and 50 to 100 students were sent home. The county health officer (a physician) was instructed to ensure that all physicians in his county were aware of the outbreak. Students identified as cases were excluded from school until 5 days of prophylaxis was completed. Contacts with no symptoms were not excluded but were given prophylaxis. The school closed for 3 days owing to lack of attendance.

It was clear that a larger-than-usual outbreak was occurring statewide. On October 5, 2001, a press release was issued, a story appeared in the local media, and the ADH notified health care providers in the state via fax and e-mail. However, the day before the scheduled press release (October 4), anthrax reports appeared, and the CDC began focusing primarily on controlling anthrax. On October 10, the ACH microbiology laboratory contacted the CDC medical epidemiology unit.

The next day, the ADH began sending pertussis newsletters to hospital administrators and chiefs of staff with instructions to distribute the newsletter to all physicians on staff. No verification process existed to guarantee the delivery of these messages. At this point, there were 88 cases of pertussis in county A and confirmed cases in 5 other counties. The county health officer in each county with increased numbers of cases was notified.

On October 16, 2001, county A reported its last case. Cooperation was good among local physicians, school officials, the CDC, public health nurses, and families during the outbreak, which lasted a little more than 2 months. There were 116 cases in a population of 11,303.

At the end of October 2001, “county B” reported suspected cases of pertussis. It was reported by field nurses that suggestions for prophylaxis and isolation of cases by the local health unit were implemented less successfully in county B than in county A. It is unclear whether this was due to poor provider recognition, less effective communications, community attitudes, or other issues.

The infectious disease service of the Department of Pediatrics at the University of Arkansas for Medical Sciences provided telephone consultation for medical practices in Arkansas regarding children’s infectious diseases. During the peak October period, they received 5 to 15 questions per day from local health care providers concerning pertussis management.

Figure 1. A, Annual number of confirmed cases of pertussis in Arkansas (1991-2002). B, Cases by month (January 1, 2001, to March 31, 2002).
Between December 1, 2001, and February 28, 2002, the ACH (located in county C) admitted 50 patients with positive laboratory results (including direct fluorescent antibody [DFA]) suggesting pertussis infection. In previous years, the hospital averaged 2 to 3 admissions with positive laboratory results per month. Between July 1, 2001, and June 30, 2002, 113 hospital employee pertussis exposures required prophylaxis. For the similar period in 2000-2001, there were less than 20 exposures and only 4 employees with symptoms and a positive DFA test result.

By the middle of October 2001, the ACH laboratory was receiving 30 to 40 culture swabs per day from clinicians, exceeding the laboratory's capacity to process specimens. The ACH microbiology laboratory communicated with officials from the CDC respiratory disease branch several times to discuss pertussis culture, PCR, and methods for DNA collection and isolation. These communications were primarily via e-mail because telephone access to the CDC was difficult during the anthrax crisis. The laboratory requested media that was not available from distributors from the CDC, and it was provided within a week.

The ACH laboratory stopped culturing for pertussis on February 20, 2002, and PCR became the routine method for pertussis testing on May 28, 2002. Because of the heightened community anxiety present about pertussis, increased numbers of patients were requesting therapy. Many referring physicians relied on DFA test results for treatment decisions, whether the patient had symptoms or fit the case definition or not. This occurred even as the reliability of the DFA test was being challenged.

By November 21, 2001, more than 400 cases of pertussis were confirmed by culture or case definition in Arkansas, and cases of pertussis had been found in 34 of the state’s 75 counties.5

The number of cases peaked in October 2001, but the outbreak continued until June 2002. The ACH laboratory received 3442 samples between September 1, 2001, and April 30, 2002. The total number of cases was approximately 10-fold the number reported in any of the past 10 years (Figure 1). No deaths were caused by pertussis based on review of the ADH vital statistics.

**SPECIFIC PROBLEM AREAS**

The outbreak of pertussis in Arkansas ultimately subsided and resulted in no deaths and limited morbidity during the 2001-2002 season. These achievements were attributable to a highly vaccinated population, which likely led to attenuated disease, and vigorous responses by public and private health care providers. The experience raised several issues that deserve notice because of their generic quality; they offer state and federal officials examples of correctable barriers to a rapid and comprehensive response to terrorist or nonterrorist biological threats.

The ACH laboratory, located centrally in the state, was the only laboratory in the state culturing for pertussis. Testing samples from rural areas was difficult because transportation time in excess of 8 hours resulted in a loss of recovery of organisms for culture and slower turnaround times.

Owing to increased sample numbers, the regular staff of the ACH microbiology laboratory worked overtime (starting October 1, 2001), and the part-time staff worked full time. A new fluorescent microscope had to be purchased, and $14,550 in overtime wages was expended.

Diagnosis was impaired by the accuracy of the diagnostic tests. Culture is the standard and preferred method, but sensitivity decreases and can be as low as 15% when specimens are collected more than 3 weeks after the onset of illness.6,7 Culturing also takes approximately 10 days, delaying diagnosis.

Direct fluorescent antibody tests are more rapid than culture, and test results remain positive even if samples are exposed to extended transport time. The sensitivity and specificity of the DFA are reported to be 50% to 70% and 80% to 90%, respectively; however, the skill and experience of the technologist affects the result.8 Although the initial positive predictive value of the test at the ACH was 83%, it deteriorated under the increased workload and approached 0% toward the end of the outbreak. A positive DFA test result is not recognized by the CDC as a criterion for diagnosis of pertussis.

No PCR assay was available in Arkansas for pertussis diagnosis until the end of the outbreak, and it was developed at the ACH based on 2 previously reported methods8,9 using BP1 and BP2 primers. The PCR method may have higher sensitivity than DFA or culture, and, in our experience, it had higher specificity than DFA and was more rapid than culture. A recent review of PCR in pertussis outbreaks has raised concerns about the PCR diagnostic test.10 A positive PCR result alone does not define a case if the case definition is not also fulfilled.

**VACCINATION**

Because of a national shortage, Arkansas restricted use of the diphtheria and tetanus toxoids with acellular pertussis (DTaP) vaccine in children and delayed vaccinations. The ADH followed recommendations from the Advisory Committee on Immunization Practices and only gave the first 3 doses of the vaccine.11 Booster doses after the fourth birthday were given to those in 4 of the counties with the largest number of children aged 4 to 6 years.

The DTaP vaccine shortage began in 2000 when 2 of the 4 vaccine manufacturers stopped production of DTaP vaccine.12 It was not until July 1, 2002, that Arkansas had adequate supplies of DTaP vaccine to return to its regular vaccination schedule.

The relationship between vaccination and pertussis prevention was reviewed. Arkansan children aged 19 to 35 months had vaccination rates comparable to national rates. The 2000 vaccination rates for children aged 19 to 35 months for 3 or more doses of diphtheria and tetanus toxoids, absorbed, pediatric strength/diphtheria, tetanus, pertussis toxoids (anti-
gens unspecified)/DTaP vaccines were 94.3% for the United States and 90.6% for Arkansas.13 County A and county B had immunization rates greater than 90% for 3 or more doses of DTaP vaccine for patients with pertussis older than 4 years (the age range with the greatest number of cases). This was comparable to the rest of the state (Figure 2).

PROPHYLAXIS

The CDC3 and the Canadian4 guidelines both suggest a full 10- to 14-day regimen of the antibiotic erythromycin 4 times daily for contacts. Erythromycin is prescribed because it is inexpensive; however, gastrointestinal adverse effects are common and affect compliance. Azithromycin is a more expensive once-a-day drug. It causes fewer adverse effects than erythromycin and has been shown to be effective after a 5-day course.14,15 A review of MEDLINE revealed no specific data on compliance of erythromycin vs azithromycin in an outbreak situation.

In Arkansas, 46.9% of the drugs prescribed for pertussis were azithromycin or clarithromycin. In county A, the antibiotics of choice were azithromycin and clarithromycin (78.3% of cases where drug data were available). County B mainly used erythromycin (54.6%).

In county A, compliance determined by self-report at follow-up was 94% for azithromycin or clarithromycin and 37% for erythromycin. In county B, compliance was 96% for azithromycin and clarithromycin and 93% for erythromycin. These data suggest that drug compliance was not an explanation for the prolonged epidemic in Arkansas. In fact, they suggest that the local health units were very effective in implementing prophylaxis recommendations.

ISOLATION

Another important area in outbreak control is identification of cases and their contacts and appropriate isolation until prophylaxis is administered. In this outbreak, there were some reports by field nurses of health care providers who were reluctant to identify a case because of treatment and isolation issues. Because this issue was not systematically studied, it is unclear if this was a frequent occurrence. Underreporting by physicians to health officials was a primary issue. In some areas, schools were reluctant to release the names of the infected to officials; HIPAA (Health Insurance Portability and Accountability Act) regulations were cited by some physicians, although reporting of epidemiologic data is clearly protected under HIPAA regulations.

Many physicians complained about children sent to them with notes from the ADH requesting medications without specifics about the situation. A review of sample letters in fact did not reveal specifics but clearly stated that antibiotics were needed based on epidemiologic exposure. Administrators reported some tension between private physicians and the ADH, who work together on an irregular basis. Schools received similar guidelines about isolation, although physicians who were uninformed about the outbreak specifics occasionally provided contradictory recommendations about isolation. This was difficult for children whose reentry to school depended on completing prophylaxis.

PUBLIC HEALTH MANAGEMENT

General management of the epidemic fell to the ADH. Guidelines for management of an epidemic existed3 and were used, but strategic community involvement to accomplish the guidelines was hampered in some cases.

For the past 2 years, the ADH had been undergoing a structural reorganization and had experienced budget cuts. This combination contributed to the lack of trained staff during the outbreak, since many staff members had been reassigned to different areas or positions were simply not yet filled.

Still, the ADH tried to educate the state’s health care providers and citizens by using conventional communication methods. They distributed succinct newsletters and press releases to hospitals, which may or may not have been distributed to physicians. An e-mail newsletter was sent to the 10% to 20% of licensed physicians who had

![Figure 2. Age distribution and number of doses of vaccine received among pertussis cases in Arkansas (August 1, 2001, to March 31, 2002).](https://archpedi.jamanetwork.com/contentchein.html)
e-mail addresses registered with the ADH. Although more physicians are likely to have e-mail, there was no unified way to communicate with them through their professional societies.

The ADH made telephone calls and personal visits and hosted town meetings, which included local physicians, school officials, and town leaders. On October 4, 2001, the state's largest newspaper began running stories updating the outbreak.

Nurses in rural areas were overwhelmed with case identification, follow-up, and the associated paperwork. Detailed case reports and a contact sheet had to be filled out for each person. Two weeks later, a follow-up on the case had to be made. Follow-ups were not always complete owing to the workload. No electronic database was used at the time in the field.

A major burden was placed on local physicians. Local physicians were in charge of recognition, diagnosis, and treatment of people in their communities. Some physicians were uncomfortable managing pertussis. Others wanted to confirm the diagnosis before reporting it to the ADH, delaying outbreak containment. Some physicians declined to prescribe antibiotic prophylaxis because of concern for “saving the antibiotic” or because of lack of symptoms in a contact or “serious” symptoms in a patient.

The cooperation of a county’s citizens was considered a possible reason for the success or failure of containment in 2 counties. In county A, the duration of the outbreak was 77 days. In county B, the outbreak lasted 153 days. The presence of the CDC officials locally may have energized county A to be more aggressive compared with county B, where only state officials were present.

**COMMENT**

During the 2001-2002 respiratory season, Arkansas experienced its worst pertussis outbreak in more than 4 decades. Is it possible that increased reporting accounted for these observations? The attestations of physicians, school nurses, and public health workers suggest otherwise. How well did the health care system respond? Although there were many reasons to applaud, the outbreak made visible more weaknesses than were previously appreciated. For Arkansas, an outbreak of a common respiratory agent exposed these deficiencies and made us wonder how well the system would fare in a more accelerated time frame such as one might expect with an influenza pandemic or a biological terrorist attack. The problems experienced in this state are in fact generic and should be considered in preparing all states for future biological threats.

**DIAGNOSIS**

One of the first problems encountered was difficulty in diagnosis. Although pertussis is well described and case definitions have existed for years, determination of a case is anything but precise. Since pertussis disease is based on a clinical definition, diagnosis is based on perceptions and observations of the parent or patient who reports the symptoms and on the physician who determines the diagnosis. Failure to consider the diagnosis of pertussis in children was described in Canada, where only one fourth of the children who met the case definition were considered to have pertussis. Pertussis-like disease is clearly mimicked by other pathogens and processes that produce respiratory symptoms and repetitive coughing. Only 33% of submitted samples from suspected cases were positive by any method. In a bioterrorist attack, individuals with similar symptoms as the case definition would imagine that their symptoms resemble those of the case definition, as occurred at ACH among personnel and among communities seeking a diagnosis of and therapy for pertussis. Similar behaviors were noted in Arkansas during the reporting of cases of anthrax nationally, although no cases were diagnosed in this state.

Ideally, some definitive testing procedures would be available. In this outbreak, tests (DFA) previously considered effective by local authorities ultimately failed. For years, the DFA test under rigid conditions and trained eyes had reasonable specificity and sensitivity. Under the stress of large numbers of samples, however, its sensitivity and specificity waned as tired or less trained eyes were called on to review these subjective test results. During a bioterrorist attack, technicians would be taxed with large numbers of clinical samples. It seems reasonable to have trained non–public health technicians in reserve, much like the armed forces are backed up by reserves. Equipment would also need to be updated to provide adequate support for the technical reserves as well. In Arkansas, a private children’s hospital (ACH) fulfilled this reserve support, but as the only laboratory in the state providing pertussis diagnosis, its effectiveness ultimately lessened.

Another issue was the problem of implementing new diagnostic testing (PCR). The AHD was in transition and had funding issues that marginalized their microbiology laboratory and epidemiology services, and the ACH ultimately chose to set up PCR diagnostics. Providing adequate molecular laboratories in all state health departments with common technical support through the CDC or other central laboratory would avoid this obstacle. Material support needs to be coordinated as well, since media was in short supply for bacterial cultures in this outbreak and one could well imagine shortages of other reagents for any testing method. Another issue, not a factor in this outbreak, is the determination of antimicrobial sensitivity. Bioterrorist-released microbes may be engineered to be drug resistant. If so, central laboratories for testing must be available. To make such a system work, efficient transportation of samples would be required as well. Currently in Arkansas, an informal courier system exists that randomly delivers samples for diagnosis. Some samples in our outbreak arrived by mail, a process forbidden by federal law. Systematic specimen transport is required and should be planned. We believe that the lack of rapid and precise diagnosis played a major role in early recognition and containment of this epidemic.

**VACCINATION**

The classic approach to disease prevention is vaccination. Among the most important lessons is the vulnerable
ability of our vaccine supply. In some cases, vaccines are prepared by only 1 or 2 manufacturers. Although the pertussis vaccine was made by 4 manufacturers at the beginning of the outbreak, the cessation of production by 2 manufacturers for business reasons led to a shortfall in production that reduced vaccine availability at the worst possible time during this outbreak. Health care providers provided the minimal amount of protection with available resources, and they did so with maximal effort and considerable disturbance in the office routine. Patients were recalled later for catch-up vaccinations when the vaccine supply was reestablished, and much explanation to confused parents was required. Clearly, protection of the vaccine supply is critical in future protection against preventable diseases.

Questions were considered regarding the efficacy of the new DTaP vaccine. However, most of the affected children in this outbreak were older and were vaccinated with the whole-cell diphtheria, tetanus, pertussis toxoid (DTP) vaccine. The observation of a shift in disease rates to older children and adults has been well described. Therefore, we do not believe that vaccination status was a factor in this outbreak.

**PROPHYLAXIS**

Postexposure prevention of disease is a hallmark defense against infectious diseases in general and pertussis in particular. Several barriers were noted in this outbreak. First, there were concerns about the adverse effects of erythromycin therapy by lay and hospital personnel that limited willingness to take antibiotics; second, alternative antibiotics were costly, and “definitive” recommendations were not available.

Compliance was not reported to be an issue during this outbreak. Public health care nurses who followed up known cases documented good compliance. It remains unclear whether success in county A in eradicating the local pertussis outbreak can be attributed to the choice of antimicrobial agent, noncompliance that was not reported, or community cooperation in eradicating the disease. One can expect all of these to be issues in the future. Suspicion of health workers and government in general, failure to comply with recommendations, and alternative belief systems have been documented in past attempts to deal with public health initiatives such as vaccination, fluoridation, and quarantine. The reported success of prophylaxis and the reported compliance suggest that inadequate prophylaxis did not play a role in the extent of the outbreak.

**PUBLIC HEALTH MANAGEMENT**

Based on our review, the ADH and CDC staff responded quickly with specific plans once an epidemic was recognized. However, a rapid systematic response to an infectious disease outbreak was not achieved from disease surveillance but by the fortunate observations of a single clinician. Communications with local providers were recognized to be hit or miss, and there was no clear and dependable way to reach every health care worker. In addition, communications with the CDC were difficult and were fully dependent on e-mail. One could draw the conclusion that an appropriate step in the future for state health departments would be to require an e-mail, fax, or other electronic communications network for health care providers and municipal leaders. This network would correspond to civil defense networks and allow instant communications. Still, vulnerability in this plan would be the Internet itself, which can be targeted for computer viruses, “spamming,” or other attacks. Ironically, one of us (J.G.W.) received a forwarded e-mail from the CDC (October 17, 2001) on anthrax information for physicians that contained a corrupting virus that disabled a home computer. Future planning should provide secure e-mail addresses and a sufficient diversity of servers to circumvent such attacks that might be concurrent with biological attacks.

Strategic planning is a necessity in the current environment at federal and state levels. During the pertussis outbreak in Arkansas, CDC support was markedly reduced when the anthrax attacks occurred. At a federal level, sufficient backup for multiple outbreaks needs to be developed. This requires funding and again something analogous to a group of “reservists” who could be called up from private life to serve in the public health arena. As a baseline, the funding for ongoing nonterrorist biological investigations is marginal. It became totally inadequate during the anthrax attacks and needs to be expanded by congressional action. Similar actions on a long-term basis need to be taken at the state level with either federal or state dollars; if funds are put in an emergency fund, they need to be immediately accessible. The issue of the Office of Homeland Security and its role in coordinating and developing strategies for the CDC, health departments, local hospitals, and professional health provider associations is beyond the scope of this article but is an implicit necessity for any organized response to state or national crises.

At the state level, additional lessons were learned. The reorganization of the ADH left the department less able to quickly respond to some of the needs during the pertussis outbreak. Departments will always need overhauls. During these reorganizations, clear policy and leadership to address infectious and ecologic disasters should be left intact.

The infrastructure of the ADH was also hindered by the transition to a new computing system. Case identification in the field by hand is no longer appropriate, and the state departments should rapidly correct computer infrastructural problems that will allow in-the-field computing and immediate data entry and analysis. This should be a federal and state priority. Finally, health departments need adequate budgets to succeed in their mission to protect the public health. Federal support needs to be present if states individually cannot provide this revenue. Implicit in these budgetary issues is the relationship of the state health department, the state citizenry, and the legislature that funds the department. Building public relations is critical in preparation for a crisis. The public must trust the health department and follow its instructions to successfully combat an outbreak. In Arkansas, this was suggested by the response in county A, where cooperation was high and the outbreak was
quickly eliminated, vs county B, where trust and cooperation were reported to be low and the outbreak continued for months. Federal and state health departments must strive for excellence and must be quickly responsive to their customers (citizens and health providers) to garner trust. The trust must be built during times of noncrisis. This tension is not new to this epidemic but has existed throughout the history of public health departments in this country. We believe that lack of communication and universal cooperation with providers at the local level may have contributed to the extent of this outbreak. In addition, physicians must be trained to accept responsibility and partnerships as part of the public health team.

A pertussis outbreak in Arkansas was successfully managed during a period of maximal institutional and national stress. Barriers were overcome in some situations and discovered in others. It is clear that new infrastructural and strategic plans will address and resolve these problems under the direction of the ADH leadership. The problems identified in the Arkansas 2001-2002 pertussis outbreak are not unique. Virtually all state government and health agencies are in a budget crisis and have increased demands. Multiple outbreaks of pertussis and emerging pathogens (SARS [severe acute respiratory syndrome] and monkeypox) have recently occurred. Vaccine supply shortages have occurred during the past 3 years for multiple agents as well.

Lessons learned for future containment of epidemics (introduced naturally or of bioterrorist origin) include the necessity for (1) adequate funding of our state health departments to carry out epidemiologic and microbiologic investigation and response; (2) systematic strategic planning for outbreaks to include adequate federal support for diagnosis and testing, systematic state communications plans for health care, and municipal providers with backups and reserve staff for periods of transition and crisis; and (3) security and development capacity for vaccines and antimicrobial agents. With these forward-looking approaches, the safety of state citizens can be ensured. It is gratifying to know that many of these issues are currently being addressed at the federal and state levels.

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