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Case Study

Clinical Salmonellosis in a Closed Colony of Blood Donor Cats

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An adult feline blood donor, group-housed in a closed colony with other blood donor cats in a laboratory animal facility, developed anorexia, abdominal pain, an abdominal mass effect, and hemorrhagic diarrhea. Ultimately *Salmonella* infection was diagnosed. The index cat and 2 additional cats in the closed colony had clinical signs consistent with *Salmonella* and yielded *Salmonella* serotype 4,12:i:– in fecal cultures. An extensive search for the source of *Salmonella* was unrewarding. With the implementation of individual housing and additional barrier precautions, combined with antibiotic treatment of the index case, all the cats survived and subsequently had multiple, negative *Salmonella* PCR test results. This case report highlights the potential for unlikely infections to occur, even in a closed colony of research animals, as well as the important role of sanitation in the elimination of this enteric pathogen.

Salmonella are ubiquitous pathogens that affect many species of animals. Many *Salmonella* serotypes are host-adapted, whereas others can cross-infect multiple animal hosts; there are no known feline-specific serotypes.[9] In both humans and animals, salmonellae are most commonly acquired from contaminated food and water sources.[9,14,15] In companion cats and dogs, clinical salmonellosis has often been linked to the ingestion of raw-food diets;[6,9,14,15,26] contaminated processed commercial foods have also been implicated.[14] Fecal–oral transmission and spread by means of fomites can occur within groups of animals[9,14,30] and thus complicate the eradication of organisms within this genus.

Because of confinement and prescreening, the risk of acquiring most infectious diseases in a small closed colony of healthy adult purpose-bred cats housed in a research facility is extremely low. Here we describe 3 group-housed blood donor cats that developed clinical salmonellosis, as well as the search for a source and steps taken to eliminate the enteric pathogen from the cats and their environment. This case highlights the vigilance required to identify unlikely infectious organisms, in even the most controlled of environments, as well as the importance of good hygiene and environmental sanitation as a means of eliminating this enteric organism.

Case Report

A 7-y-old castrated male domestic shorthair cat was evaluated for vomiting, anorexia, and lethargy of 6 to 8 h in duration. On physical exam, the cat was in excellent body condition (body condition score, 5/9; weight, 6.3 kg) with a mildly increased rectal temperature (39.4 °C [103 °F]). The cat was lethargic and mentally depressed. Mucous membranes were pink, and the capillary refill time was 1.5 to 2 s. Heart rate was 190 bpm, with strong synchronous pulses and an auscultable grade III/VI left parasternal murmur, consistent with previous physical examinations. A mildly painful midabdominal mass with an irregular margin, thought to be the ileocecocolic junction, was palpated, and the remainder of the bowel was soft, nondistended and nonpainful.

Previous health history included a minimally thickened intraventricular septal wall and systolic anterior motion of the mitral valve, consistent with low-grade hypertrophic cardiomyopathy, which had been present previously and was nonprogressive as monitored through routine echocardiography during the prior 4 y. Routine CBC analysis, serum biochemistry testing, urinalysis, and sodium nitrate fecal flotation for endoparasites had been completed 4 mo earlier, and results were within normal reference ranges.

The index cat had been part of a closed 4- or 5-cat blood donor colony for 6 y, prior to which the cats were part of a larger group of purpose-bred cats acquired from a commercial research animal breeding facility (Liberty Research, Waverly, NY) and subsequently used in a vaccination study. All cats were clinically healthy, and no husbandry, behavioral, or medical problems had been identified in the colony. The cats were housed in an AAALAC-accredited facility and cared for according to the *Guide for the Care of Laboratory Animals*.[13] Under an IACUC-approved Animal Use Protocol, the cats were used as donors of blood for transfusion to feline patients of the University of Georgia Veterinary Teaching Hospital.

Donor cats typically donated 50 mL blood every 6 wk or less frequently, and the last blood donation from the index cat was 8 wk prior to the onset of the current illness. At that time, the colony contained 4 group-housed cats that were allowed to roam in and out of their cages for social enrichment. They were fed a dry commercial cat food (OM, Nestlé Purina, St Louis, MO) twice daily and received an additional quantity of the same kibble placed in enrichment toys (Activity Fun Board, Trixie Pet Products, Fort Worth, TX; Catch Interactive Feeder, Northmate, Aarslev, Denmark). Four litter pans were exchanged daily for washed and heat-sanitized pans, and litter was a commercial corncob bedding (Bed-o'cobs combo, The Andersons, Maumee, OH). Food and water bowls were hand-washed daily and

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replaced with washed and heat-sanitized bowls every 2 wk. The cages were washed and heat-sanitized every 2 wk, and the room was sanitized monthly by using a quaternary ammonium disinfectant (Process NPD One-Step Germicidal Detergent, Steris, St Louis, MO).

Caretaker staff working in the facility wore dedicated clothing and shoes in the animal facilities and were instructed to practice good hand hygiene (use of hand washing and hand sanitizers) between rooms. Investigators visiting the facility were required to wear a facility-dedicated lab coat over clothing and to practice good hand hygiene. Dedicated shoes or shoe covers were not required routinely, except in designated rooms.

At the time of the initial physical examination, abnormal CBC findings were neutrophilia with a left shift and moderate Döhle bodies; in addition, 3 abnormalities on a complete biochemical profile were insignificantly beyond reference ranges. Urine specific gravity of a voided sample collected off a table was greater than 1.050. No ova were observed on microscopic examination of feces taken from the litter pan and processed according to the zinc sulfate flotation technique. A heterogenous population of bacteria with no observed organism morphologies suggestive of *Campylobacter* spp. or *Clostridium* spp. was seen on a Romanowski-stained cytologic exam of feces. No abnormalities were detected on abdominal radiography. The abdominal mass was confirmed on ultrasonography to be the cecum, which was mildly corrugated with a mildly thicken mucosa and altered wall layering (Figure 1). Focally within the mucosa, a moderate-sized (0.4 cm) hypoechoic nodule was present. The colic lymph node was hypoechoic, although its size and shape were within reference limits. Results of cytologic examination of Wright-stained mesenteric lymph node aspirates were inconclusive, due to poor cellularity. A fecal sample was submitted for evaluation in a PCR panel testing for feline enteric pathogens including *Campylobacter* spp., feline panleukopenia virus, *Tritrichomonas fetus*, *Clostridium difficile* toxins A and B, *Clostridium perfringens* enterotoxin, *Salmonella* spp., and *Lawsonia intracellularis*.

Owing to the results of clinical and diagnostic testing, the cat was separated from the other cats by placing it into a 0.71 × 1.4 × 0.71 m (floor space, 1 m^2) cage, with its own food and water and an extra-large litter box, within the colony room. Management of the other clinically healthy cats within the room was unchanged. Empirical therapy of the ill cat included: maropitant (1 mg/kg SC daily; Cerenia, Zoetis, Florham Park, NJ), lactated Ringer solution (100 mL SC daily), ampicillin–sulbactam (22 mg/kg SC every 8 h; Unasyn, Pfizer, New York, NY), and buprenorphine (0.01 mg/kg buccally every 6 to 8 h). On day 2, the cat had a rectal temperature of 39.6 °C (103.3 °F), had no interest in eating, and displayed moderate discomfort on palpation of the cecum. Abnormal findings on a recheck ultrasound were a moderately thick cecal mucosa and many hypoechoic mucosal nodules. In addition, the muscularis layer of the ileum was moderately thick (0.2 cm) and hypoechoic. The colic lymph nodes were enlarged (0.3 to 0.4 cm), hypoechoic, and round. The mesentery in the region of the ileocolic junction and colic lymph nodes was moderately hyperechoic. CBC results included a normal WBC count and no band neutrophils. The same therapies were continued with the addition of metronidazole (62.5 mg PO every 24 h). During days 3 through 5, all therapies remained the same, and the cat only nibbled at food, exhibited signs of discomfort with palpation of the abdomen, and had moderate quantities of green mucoid diarrhea with admixed frank blood.

On Day 6, the cat was still exhibiting discomfort on cecal palpation. Ultrasonographically, a progressively larger cecum was identified, and the cat was not ingesting sufficient calories, risking the development of hepatic lipidosis. The cat was anesthetized for an exploratory laparotomy and typhlectomy, placement of an esophageal feeding tube, and biopsy of the liver, jejunum, and colic lymph node. Evaluation of a Wright-stained smear of a scraping from a lymph node biopsied at surgery revealed a reactive lymph node with evidence of recent hemorrhage and mildly increased numbers of nondegenerate neutrophils and eosinophils. Postoperatively, intravenous fluids (25 mL/h lactated Ringer solution containing 20 mEq KCl/L) and intravenous fentanyl (2 to 5 µg/kg/h) were administered overnight, and treatment with intravenous ampicillin–sulbactam was continued.

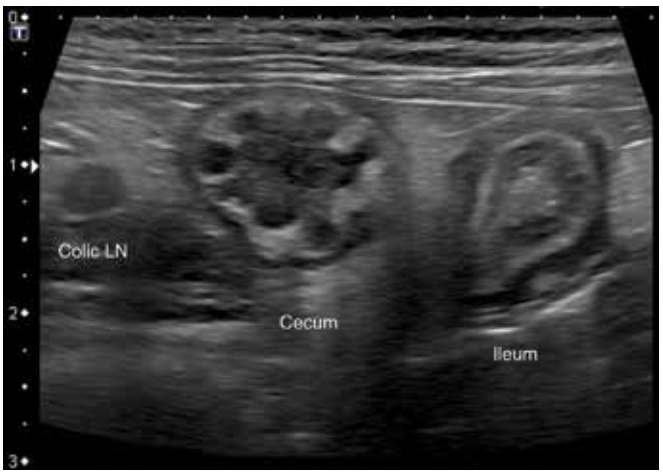

Figure 1. Transverse ultrasound image. The cecum has several round hypoechoic nodules in the wall, the colic lymph node is round and hypoechoic, and the adjacent mesentery is hyperechoic. These findings are consistent with the histologic diagnosis of typhlitis. The changes in the lymph node and mesentery are attributed to reactive lymphadenopathy, mesenteric inflammation, and local peritonitis.

Postoperatively and late on day 6, fecal PCR test results from the specimen submitted on day 1 were reported as positive for *Salmonella* spp. and negative for the other potential pathogens. In light of these results, shoe covers and disposable gowns were added to the required gloves worn by attending personnel.

On day 7, intravenous fluids and fentanyl were discontinued, and the index cat was returned to the colony room but remained singly housed. Metronidazole and ampicillin–sulbactam were discontinued, and enrofloxacin (5 mg/kg SC every 24 h) was initiated. Subcutaneous lactated Ringer solution (100 mL SC every 12 h) was administered on days 7 and 8, and buprenorphine (0.01 mg/kg SC every 6 to 8 h) was administered on days 7 through 10. The cat was offered a variety of canned and dried foods, and its voluntary intake was supplemented with esophagostomy tube feedings of blenderized canned food (Science Diet a/d, Hill's Pet Nutrition, Topeka, KS) to achieve a total daily caloric intake equivalent to its resting energy requirement. The index cat progressively improved, eating its usual type and quantity of food by day 10 (4 d postoperative), at which time the esophageal feeding tube was removed. Stool color and consistency were normal on day 12, and enrofloxacin was discontinued on day 17, after 10 d of administration.

Histopathologic abnormalities of the biopsies taken at surgery were consistent with a diagnosis of enteric salmonellosis as reported in cats,[26,29] including typhlitis characterized by diffuse, moderate, subacute lymphoplasmacytic and neutrophilic inflammation with ulceration (Figure 2); crypt abscessation and herniation; lymphoid hyperplasia; and multifocal pyogranulomas. Mild, diffuse, subacute neutrophilic and lymphoplasmacytic jejunitis and moderate to marked hyperplasia with mild histiocytic

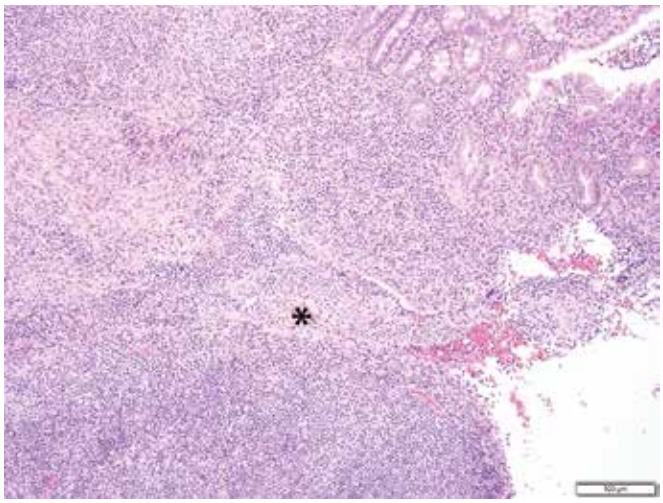

Figure 2. Photomicrograph of the cecum of the index cat. There is ulceration of the mucosa, with infiltration by neutrophils. The adjacent lamina propria and underlying submucosa are markedly expanded by lymphocytes and plasma cells (*). Hematoxylin and eosin stain; bar, 100 µm.

and neutrophilic lymphadenitis of the cecal lymph node were present also. Hepatic histopathology was unremarkable.

Feces obtained from the remaining 3 colony cats, which were clinically healthy, were submitted on day 7 for *Salmonella* testing. Results from 2 of the 3 cats were PCR-positive for *Salmonella*, and feces from the index cat and the 2 PCR-positive cats subsequently yielded positive culture results for *Salmonella* serotype 4,12:i:–, all with identical antibiograms (Table 1). On day 11, additional *Salmonella*-positive PCR results prompted individual housing of the 3 remaining colony cats in $0.71 \times 1.4 \times 0.71$ m (floor space, 1 m^2 floor space) cages, each containing its own food, water, and litter box, within the colony room. None of these 3 nonindex cats received antibacterial therapy. Between days 11 and 14, all 3 of the nonindex cats displayed intermittent vomiting, 2 of the 3 cats had a decreased appetite, and 1 cat developed soft stool.

On days 7 through 9, multiple areas in and around the cat room were swabbed with sterile, moistened sponges (Speci-Sponge Sterile Sampling System, Nasco, Fort Atkinson, WI), which were submitted to the Athens Veterinary Diagnostic Laboratory (Athens, GA) for microbiologic analysis. Results of environmental samples, including those from a foam rubber play mat in the cats' room, 2-floor samples in the turtle room, 2 drains in the turtle room, and the hallway and drain in the hallway outside the cat room, were negative for *Salmonella* by PCR analysis. Results from water specimens taken from 2 turtle tanks in a room across the hall, pooled used mouse bedding and pooled used rat bedding from nearby rooms, the water supply for the cat room, and unused cat litter also were negative for *Salmonella* by PCR analysis. Two lots of cat food, including the bag that had been open and fed for 2 wk prior to illness, yielded *Salmonella* culture-negative results.

All 4 cats were kept singly housed through day 22 when their feces were retested, at which point *Salmonella* PCR and bacteriologic culture results remained positive for only 1 of the cats (a nonindex cat; Table 2), which remained singly housed for an additional week. The entire room and all cages were sanitized prior to the cats' release. All cats had negative PCR test results at day 35. PCR results from additional samples, taken from all 4 cats approximately 9 mo and 1 y after the outbreak, were negative also. The potential (albeit unlikely) for the cats to be persistent carriers of *Salmonella*, develop intermittent bacteremia, and transmit the organism through blood transfusion contributed to their retirement as blood donors.

Table 1. Antibiogram of the *Salmonella enterica* 4,12,i:– cultured from the 3 cats.

Antimicrobial	Sensitivity
Ampicillin	resistant
Cefovecin	sensitive
Cefpodoxime	sensitive
Chloramphenicol	sensitive
Doxycycline	resistant
Enrofloxacin	sensitive
Nitrofurantoin	sensitive
Orbifloxacin	sensitive
Tetracycline	resistant
Ticarcillin	resistant
Tobramycin	resistant
Trimethoprim sulfa	sensitive

Subsequently, all 4 cats were adopted to private homes approximately 1 y after the *Salmonella* outbreak. Fecal samples from the 3 cats previously diagnosed with *Salmonella* were collected at 1 and 3 wk after rehoming, and all were PCR-negative for *Salmonella*. In addition, gastrointestinal signs were not observed in any of the cats for at least 6 mo after adoption.

Discussion

Salmonella spp. are enteric pathogens that cause enteritis, typhlitis, and hemorrhagic diarrhea. The organism undergoes fecal–oral transmission and is usually ingested with contaminated food or water. Three of the 4 cats in a closed colony of blood donor cats developed clinical *Salmonella* infection; the source of the infection was not identified. The infection was eliminated from all cats through the implementation of individual housing and additional barrier precautions, as well as antibiotic treatment of the index case. This case report highlights the potential for unlikely infections to occur, even in a closed colony of research animals, as well as the important role of sanitation in elimination of this enteric pathogen.

Salmonella spp. are gram-negative, motile, nonspore forming bacillae of the family Enterobacteriaceae. Nearly all salmonellae are believed to belong to the same species (*enterica*),[5] and serotypes of *Salmonella* are identified through the agglutination reactions of their somatic (O) and flagellar (H) antigens.[5] More than 2500 serotypes of *Salmonella enterica* are known[5] to exist. Although some *Salmonella* serotypes are adapted to specific animal hosts, *Salmonella* that are feline-specific are unknown.[9] *Salmonella enterica* 4,12,i:– is believed to be a variant of *Salmonella typhimurium* (*Salmonella enterica* subspecies *enterica* serotype Typhimurium).[17,27] This particular serotype has been an emerging pathogen since the 1990s and has caused multiple outbreaks associated with a variety of meat and plant food sources.[1,3,4,10,16,18]

Salmonellosis is a relatively uncommon overt clinical condition in cats, despite a reported prevalence of 0.36% to 51.4%, depending on health status, origin of the cat, population size, diet, housing conditions, and method of detection.[6,11,20,21,23,24,28] In 1979, 10.6% of random-source research cats from pounds, holding facilities, and auctions yielded *Salmonella*-positive fecal cultures.[8] Now that most research cats are purpose-bred, this proportion is expected to be lower. In addition, clinically overt *Salmonella* outbreaks have been reported in humans and animals at 3 veterinary hospitals and an animal shelter.[30]

Infection with *Salmonella* typically occurs through the gastrointestinal tract after oral contact with fecally contaminated water, food, or fomites. In experimental infections, large numbers

Table 2. Results of *Salmonella* PCR testing

	Day 1	Day 7	Day 22	Day 35	9 mo after outbreak	12 mo after outbreak	1 and 3 wk after adoption (13 mo after outbreak)
Cat 1 (index case)	Positive	Not tested	Negative	Negative	Negative	Negative	Negative
Cat 2	Not tested	Positive	Negative	Negative	Negative	Negative	Negative
Cat3	Not tested	Positive	Positive	Negative	Negative	Negative	Negative
Cat 4	Not tested	Negative	Negative	Negative	Negative	Negative	Negative

'Day' indicates the day on which the sample was obtained for testing, counted from the date of initial signs of illness in the index case. All samples that yielded positive PCR test results were subsequently cultured and serotyped.

of *Salmonella* are needed to colonize the gastrointestinal tract,[9,15] in part because gastric acid destroys most of the organisms during transit.[9] Organisms that pass into the intestines, where they preferentially attach to and invade ileal villi. Localization, multiplication, and persistence in the intestinal epithelium and lymph nodes facilitate shedding, which usually occurs for 3 to 6 wk. The organism can be persistently harbored by phagocytic cells in intestinal lymph nodes, liver, and spleen and can be reactivated and shed intermittently during periods of stress.[9]

Clinical signs of salmonellosis vary with the number of organisms ingested and their virulence, as well as with host immune competence and other host factors. Symptoms usually occur 3 to 5 d after exposure to the organism and include fever, lethargy, abdominal pain, vomiting, and diarrhea. Diarrhea may be watery to mucoid and may contain frank blood in severe cases. Marked gastrointestinal fluid losses accompanied by lack of water intake can rapidly lead to asymptomatic carriers, signs of hypovolemic shock, and dehydration. Bacteremia and endotoxemia are usually subclinical but can result in death in as many as 10% of animals, particularly those in immunocompromised states.[2,7,12,22,25] Less commonly, bloodborne *Salmonella* can localize in other organs and lead to pneumonia, osteomyelitis, pyothorax, meningitis, abscessation, and bacteriuria, with or without concurrent gastrointestinal signs.[6,9,15] Finally, some infected animals manifest no or mild transient clinical illness or can be long-term chronic carriers.[9]

The clinical course observed in the cats we describe here reflected that in previous reports.[21,26,30] Attempts to identify the point source of the *Salmonella* outbreak were unrewarding and left many possibilities regarding its origin, including an asymptomatic carrier cat within the colony, fomites, and caretakers. The presence of a carrier cat that harbored *Salmonella* asymptomatically for 7 y in this cohoused group was unlikely. Although some animals can be asymptomatic carriers and shed *Salmonella* periodically when stressed or ill,[9,11,21,23,25] these cats were obtained as kittens from a commercial breeding facility, had no previous outbreaks of illness, and had no comorbid illnesses or stressful events at the time of the outbreak. The organism likely was carried into the room by means of fomites or people. Although fomites such as food bowls and cages can serve as a source of *Salmonella,* the entire cat enclosure was cleaned and hosed daily, the litter pans replaced daily, the caging sanitized in a cage washer every 2 wk, and the entire room sanitized every 4 wk. Therefore the window for transfer of organisms due to fomites in the room would have been narrow.

It seems unlikely that correctly washed and sanitized hands covered with gloves would have carried a sufficiently large dose of S*almonella* to infect the cats. In addition, this blood donor room consisting of clinically healthy cats was routinely the first room entered for morning feeding, prior to handling of waste from any other room. *Salmonella* might have been brought into the facility on contaminated shoes. In most other research animal rooms, this event would likely not have been a problem; however, *Salmonella* on the floor in the blood donor room might have easily been ingested by the comingled cats in one of several ways. The cats used food puzzles as enrichment devices from which they pulled out kibble with their paws, often tossing it onto the floor prior to eating it. In addition, cats are fastidious groomers and might have groomed *Salmonella* from their contaminated fur or paws. Furthermore, it is easy to appreciate that only 1 cat in the group could have been infected and then spread the organism to the other cats through their close interactions and shared litter pans. If the organism was carried in by people, the source is still unknown. The organism might have simply been transferred from a fomite, or perhaps a person with cat contact had clinical or subclinical salmonellosis or was a chronic asymptomatic carrier. Multiple cultures of the feline room and floor, as well as floors and fomites in surrounding animal rooms, yielded negative results for *Salmonella* by PCR testing. These findings suggest that either fomites were not the source; that incorrect fomites were tested; or that the areas had been sanitized between contamination and subsequent sampling. Testing people with recent contact with the cats for their carriage of *Salmonella* was not an option, although it would have been ideal.

Therapy for animals with clinical salmonellosis varies with the severity of illness. For most patients, supportive care focusing on fluid and electrolyte balance is sufficient.[9,15] Antibacterial treatment of *Salmonella* is advocated for animals with systemic signs or sepsis, those with involvement of nongastrointestinal organs, and those with concurrent immunosuppression.[9,15] The decision was made to continue the index cat on antibacterial therapy due to the severity of clinical signs and with the purpose of reducing *Salmonella*-induced intestinal inflammation that might hamper healing after the recent surgical biopsies. *Salmonella* organisms are usually sensitive to multiple commonly used antimicrobials, including chloramphenicol, trimethoprim-sulfonamides, amoxicillin or ampicillin, and fluoroquinolones, although drug resistance to all of these drugs has been documented in *Salmonella* spp.[19,27,28,30] The index cat received an ampicillin-containing antimicrobial preoperatively. The treatment was changed to enrofloxacin, because fluoroquinolones were thought to be less likely to induce plasmid-mediated bacterial resistance,[9,19] although such resistance has been identified.[19,27] The isolate was later identified as being amoxicillin-resistant, thus perhaps explaining the initial lack of clinical improvement after therapy. The infected nonindex cats were not treated with antibacterials because we considered that these minimally symptomatic animals would clear the infection without them and because antimicrobials carry the risk of inducing antibacterial drug resistance.[9]

Unfortunately, because some animals can become chronic *Salmonella* carriers, eliminating the organism from a population can be difficult. Prevention of infection then becomes important, particularly in the absence of an identified source. Thorough and frequent environmental disinfection, consistent approved

hand hygiene on the part of care staff, and isolation of infected animals, particularly during the outbreak, are helpful. Cats in the present report remained singly housed for several weeks, and the environment was thoroughly cleaned and disinfected several times during that interval. The use of additional personal protective equipment was required during the outbreak, including shoe covers, disposable single-use gowns, and gloves. For subsequent donors, the care and handling protocol has been amended to include use of donor room-dedicated shoes or shoe covers at all times in addition to continued use of dedicated lab coats and the practice of good hand hygiene.

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