The liver recipient was a 40-year-old woman with alcoholic cirrhosis whose early postoperative course was marked by fever, lethargy, and hypotension. Markedly elevated aminotransferase levels, leukopenia, and bilateral pulmonary infiltrates with respiratory failure developed. Liver biopsy revealed focal centrilobular coagulative necrosis. On post-transplantation day 14, a perincisional petechial rash was noted; skin biopsy revealed chronic inflammation and hemorrhage. She died on day 17 after transplantation. An autopsy revealed extensive hepatic necrosis without evidence of infection.

A common source of infection in these recipients was suspected, all of whom underwent transplantation at the same facility. Therefore, the Department of Public Health of the Wisconsin Department of Health and Family Services and the organ-procurement organization (OPO) coordinating the transplantations were notified for assistance.

The lung recipient, who had undergone transplantation at a different facility, was a 46-year-old man with chronic obstructive pulmonary disease who had been receiving prednisolone daily for three months before transplantation. Within four days after transplantation, hypotension, bilateral pulmonary infiltrates, and leukocytosis developed; broad-spectrum antimicrobial agents were administered. Fever (temperature, 38.3°C), hypoxia, and refractory hypotension ensued. He died on day 9 after transplantation. An autopsy revealed diffuse alveolar damage without evidence of rejection.

The donor was a 51-year-old man who had been found unresponsive, with apparent head trauma. Computed tomography (CT) of the brain revealed a large, right-sided subdural hematoma with a midline shift. There was no improvement in his neurologic status, and he was declared brain-dead on hospital day 2. He received no blood products and was afebrile throughout his hospitalization. Donor-eligibility screening and testing detected no infection precluding organ or tissue donation. His liver, lungs, kidneys, and multiple musculoskeletal and vascular tissues were recovered for transplantation. Tissue specimens from the donor and recipients were submitted to the Centers for Disease Control and Prevention (CDC) for additional testing (Table 1).

Table 1. Summary of Laboratory Evaluations for Lymphocytic Choriomeningitis Virus Infection in the 2003 Cluster.*

Patient	Outcome or Status	Immunohistochemical Staining	Serologic Testing		Culture
			IgM	IgG	
Donor†	No reported disease	–	–	–	–
Lung recipient‡	Death 9 days after transplantation	+	NT	NT	NT
Liver recipient§	Death 17 days after transplantation	+	NT	NT	NT
Kidney Recipient 1¶	Death 53 days after transplantation	+	–	–	+
Kidney Recipient 2‖	Death 76 days after transplantation	+	+	–	+

* NT denotes not tested.

† Specimens obtained at autopsy that tested negative included serum (serologic testing and virus isolation); bone marrow and blood vessel (virus isolation); and heart, stomach, tongue, thyroid gland, kidney, prostate, cerebral cortex, midbrain, pons, medulla, cerebellum, and spinal cord (immunohistochemical analysis).

‡ Specimens that tested positive by immunohistochemical analysis included lung, kidney, spleen, liver, and lymph node obtained at autopsy. No brain tissue was available for testing.

§ Specimens that tested positive by immunohistochemical analysis included skin obtained on day 15 and brain, lung, spleen, liver, heart, and adrenal gland obtained at autopsy.

¶ Specimens that tested positive included bone marrow, heart, kidney, liver, adrenal gland, and lung obtained at autopsy (immunohistochemical analysis); cerebrospinal fluid and a nasopharyngeal wash obtained on post-transplantation day 42 (viral culture); and leptomeninges in a brain-biopsy specimen obtained on post-transplantation day 47. Brain tissue obtained at autopsy tested negative.

‖ Specimens that tested positive included serum obtained on day 76 (serologic testing), skin on day 27 (immunohistochemical analysis), and blood on day 42 and cerebrospinal fluid on days 31 and 36 (viral culture). Bronchoalveolar-lavage fluid was positive on immunofluorescence assay. Brain tissue obtained at autopsy was negative.

The 2005 Cluster

Kidney Recipient A was a 48-year-old man admitted to a hospital in Rhode Island in late April 2005, 17 days after undergoing cadaveric renal transplantation (Fig. 2). He had been discharged home on post-transplantation day 7 with a creatinine level of 1.6 mg per deciliter (141 μmol per liter). At the time of readmission, he had had right-lower-quadrant pain in the area of the allograft for four or five days, as well as nausea, anorexia, diarrhea, fever, and chills. He was febrile (temperature, 38.7°C), and there was tender erythema over the area of the allograft, without incisional dehiscence or drainage. His creatinine level was 2.6 mg per deciliter (230 μmol per liter), and proteinuria, hematuria, a prolonged prothrombin time, and slightly elevated aminotransferase levels were present. Mycophenolate mofetil was discontinued, and administration of broad-spectrum antimicrobial agents was initiated. CT and ultrasonography of the abdomen and pelvis were unrevealing. Routine cultures of urine, blood, and stool were negative, as were studies of the stool for leukocytes, ova, parasites, *Clostridium difficile*, giardia, cryptosporidium, *Yersinia enterocolitica*, and rotavirus. Tacrolimus was discontinued because of concern about the worsening infection of uncertain cause. His temperature rose to 40.4°C, and he had copious diarrhea, dyspnea, and tender erythema extending from the area over the allograft to the right flank. Examination of biopsy specimens of the colon and kidney revealed no inflammation or viral inclusions.

Kidney Recipient B was a 54-year-old man who was admitted to the same hospital with fever. He had undergone cadaveric renal transplantation 17 days previously and had been discharged home on post-transplantation day 8 with a creatinine level of 3.3 mg per deciliter (292 μmol per liter). On post-transplantation day 14, mycophenolate mofetil was discontinued because of diarrhea. Fever and pain developed in the right lower quadrant over the area of the allograft, and he was readmitted for evaluation. He was lethargic and febrile (temperature, 38.4°C) and had tender erythema overlying the allograft, without incisional drainage. His creatinine level was 4.0 mg per deciliter (354 μmol per liter), with a platelet count of 113,000 per cubic millimeter and an alanine aminotransferase level of 298 IU per liter. Routine cultures of urine, blood, and stool were negative, and ultrasonography and CT of the abdomen and pelvis were unrevealing. Fever, diarrhea, and pain persisted, despite empirical use of broad-spectrum antimicrobial agents. A percutaneous liver biopsy was performed on post-transplantation day 23 because of worsening hepatitis and leukocytosis. Multiple foci of hepatocellular necrosis without inflammation or viral inclusions were noted. Later that day, he had a cardiac arrest and died. An autopsy revealed coronary artery disease and diffuse cerebral edema without meningitis or encephalitis.

A review of the records of the hospital's transplantation center revealed that the kidney recipients shared a common donor who had also been hospitalized there. The donor was a 45-year-old woman with hypertension who had presented to the emergency department with a five-day history of right-sided headache and acute left-sided weakness. She was alert and afebrile and had left-sided hemiparesis. CT of the brain revealed an infarct in the distribution of the right middle cerebral artery, and tissue plasminogen activator was administered. Throughout her hospitalization, she was afebrile and received no blood products or antimicrobial agents. She had a normal white-cell count on admission, with normal hepatic enzyme levels and platelet counts throughout her course. Intracerebral and subarachnoid hemorrhages with uncal herniation subsequently developed, and she was declared brain-dead. The donor met the screening criteria for organ and tissue donation, and surgical teams procured the lungs, kidneys, liver and associated blood vessels, skin, and corneas. Cultures of urine and blood performed at the time of organ procurement were negative. Examination of preimplantation biopsy specimens of the liver and kidney revealed no inflammation or granulomas. An autopsy revealed infarction in the distribution of the right middle cerebral artery, subarachnoid and left frontal intracerebral hemorrhages, and a patent foramen ovale. There was no evidence of infection.

The OPO coordinating the transplantations was contacted to obtain additional information about the donor. Physicians caring for the liver and lung recipients were contacted for information on their clinical status.

The liver recipient was a 54-year-old man with cirrhosis and chronic hepatitis B and C. In the initial days after the transplantation, he had head-

ache, fever (temperature, 39.1°C), and abdominal and right-shoulder pain. Leukopenia, thrombocytopenia, rising aminotransferase levels, and prolongation of the prothrombin time were noted. Administration of broad-spectrum antimicrobial agents was initiated; multiple cultures were negative. Exploratory laparotomy revealed intraabdominal hematoma without evidence of infection. The patient had a single, generalized seizure with hypotension and subsequent worsening of renal, hepatic, and respiratory function. No seizure focus was identified on radiologic imaging or electroencephalography. Examination of a liver-biopsy specimen revealed mild portal inflammation, liver-cell regeneration, cholestasis, and mild steatosis; these findings were interpreted as transplant-associated ischemia. Left bundle-branch block and atrial fibrillation developed. The patient became obtunded, with worsening coagulopathy and multiorgan failure. On post-transplantation day 21, high-dose methylprednisolone and antithymocyte globulin were administered for suspected acute graft rejection. Fever and hypotension persisted, with increases in aminotransferase and lactate dehydrogenase levels. The cause of his multiorgan failure was unclear. He had a cardiac arrest and died on post-transplantation day 26. An autopsy revealed extensive hepatic necrosis, bronchopneumonia, pulmonary edema, and subarachnoid hemorrhage.

The lung recipient was a 41-year-old man with cystic fibrosis. He was extubated on post-transplantation day 2 but became delirious the following day and had leukocytosis and thrombocytopenia. Chest radiographs revealed right-lower-lobe infiltrates. His temperature rose to 37.9°C, and diffuse abdominal pain and respiratory distress developed. CT of the chest on post-transplantation day 16 showed bilateral air-space disease, a finding interpreted as evidence of acute rejection, and high-dose methylprednisolone was administered. His creatinine level, prothrombin time, and aminotransferase levels steadily increased, and intermittent atrial fibrillation developed. On post-transplantation day 19, a pustular rash was noted on the face and trunk; examination of a skin-biopsy specimen revealed folliculitis, and aerobic, fungal, and viral cultures were negative. Symmetric effusions of the knees, elbows, and ankles developed. The hypoxemia and acidemia progressed, and the patient died on post-transplantation day 23. An autopsy revealed organizing diffuse alveolar damage and extensive geographic hepatic necrosis without inflammation or viral cytopathic changes.

Figure 2 (facing page). Clinical Course of Lymphocytic Choriomeningitis Virus (LCMV) Infection in the 2005 Cluster.

MMF denotes mycophenolate mofetil, TMP-SMX trimethoprim–sulfamethoxazole, CVVH continuous venous–venous hyperfiltration, and X death. Immunosuppressive agents are shown in red, and antimicrobial agents in blue.

Because of concern about transplant-transmitted infection in the organ recipients, the Rhode Island Department of Health, the Massachusetts Department of Public Health, and the CDC were contacted for assistance in investigating the causes of the recipients' illnesses. Causes considered included acute hepatitis A, leptospirosis, toxoplasmosis, enterovirus infection, and flavivirus infection. Tissue specimens from the donor and recipients were submitted to the CDC for additional testing.

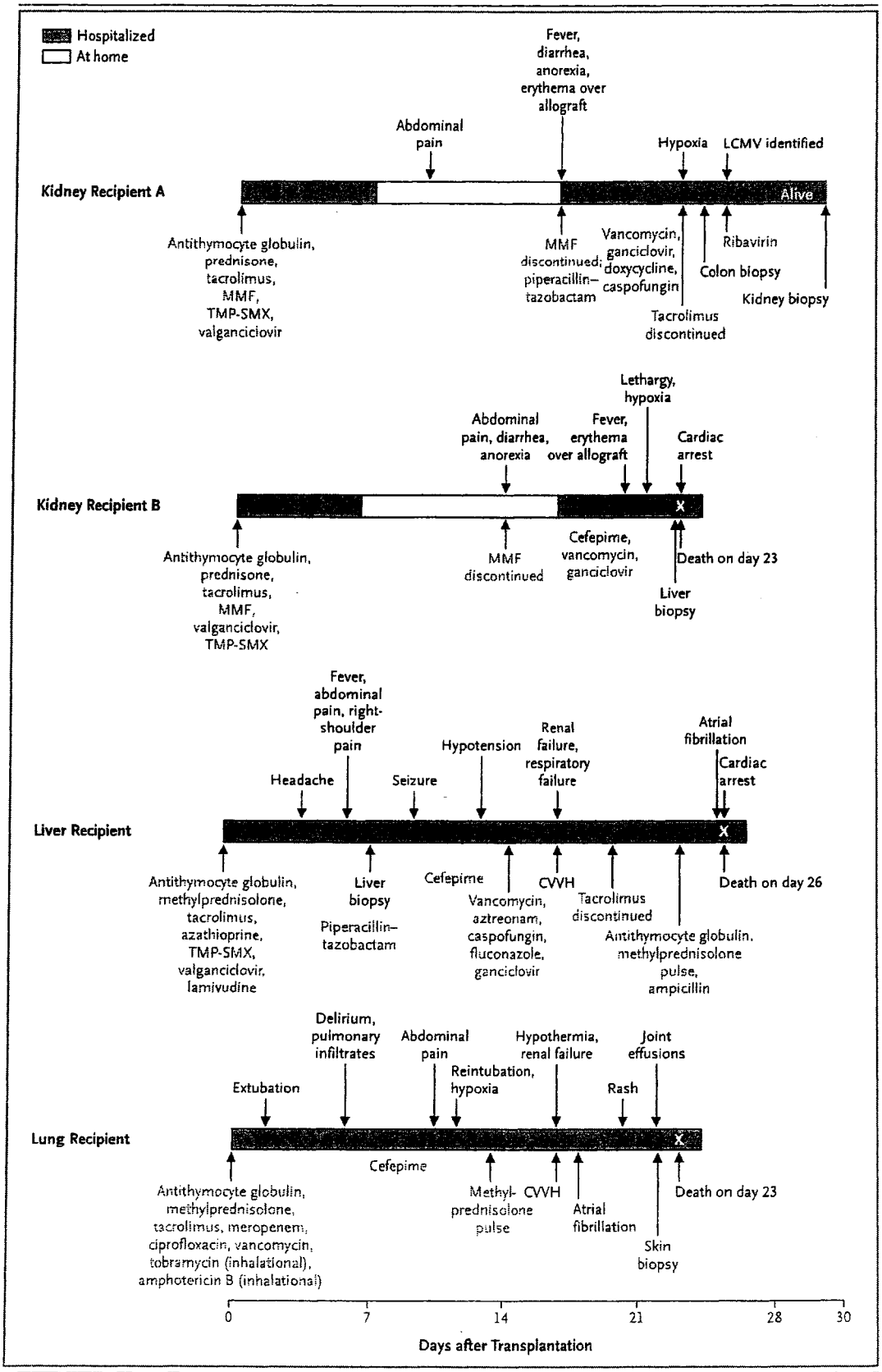
EPIDEMIOLOGIC INVESTIGATIONS

For both clusters, epidemiologic investigations were conducted at the transplantation centers and coordinating OPOs. For the 2005 cluster, epidemiologic investigations were also performed at the donor's home and workplace by state public health authorities and the CDC.

VIRUS ISOLATION AND INDIRECT FLUORESCENCE MICROSCOPY

Virus isolation was attempted by inoculation of Vero E6 cells with cerebrospinal fluid, serum, blood, and 10 percent fresh-tissue suspensions. Cultures were examined by thin-section electron microscopy. "Spot" slides of culture cells were also evaluated by indirect fluorescent antibody testing with the use of specific mouse hyperimmune ascitic fluids prepared against the Armstrong strain of LCMV.[11]

In the 2003 investigation, virus isolation was also attempted by inoculating suckling mice (*Mus musculus*) with fluid specimens (0.03 ml intracranially and 0.1 ml intraperitoneally) or with 10 percent homogenates of frozen tissue. Mice were killed by exposure to isoflurane, and tissues were fixed in 10 percent neutral buffered formalin and evaluated with the use of immunohistochemical stains for LCMV, as described below.



Studies in animals were performed at the CDC and were approved by the CDC Laboratory Animal Care and Use Committee. Animal research was conducted in compliance with the Animal Welfare Act and other federal statutes and regulations relating to animals and experiments involving animals, and it adhered to the principles stated in the *Guide for the Care and Use of Laboratory Animals*, by the U.S. National Research Council.

HISTOPATHOLOGICAL AND IMMUNOHISTOCHEMICAL ANALYSES

Multiple formalin-fixed, paraffin-embedded tissue specimens, including biopsy and autopsy tissues from the donors and recipients, were stained with hematoxylin and eosin and various immunohistochemical stains by means of an immunoalkaline phosphatase technique.[12] For both clusters, initial tissue specimens were evaluated with immunohistochemical stains for a number of viral agents, including flaviviruses, adenoviruses, and herpesviruses 1, 2, 3, and 5. In the investigation of the 2003 cluster, immunohistochemical testing for LCMV was performed after identification of this virus by culture, indirect fluorescent antibody testing, and electron microscopy. In the investigation of the 2005 cluster, immunohistochemical testing for LCMV was included in the initial evaluation of tissue specimens. The primary antibodies used for LCMV immunohistochemical detection included hyperimmune rabbit and mouse anti-LCMV antibodies specific for LCMV and an anti–Lassa virus monoclonal antibody reactive with both Lassa virus and LCMV.[13]

GENETIC DETECTION AND CHARACTERIZATION OF VIRUS

RNA was extracted from clinical specimens or viral isolates, and specific molecular targets were amplified by reverse-transcriptase–PCR (RT-PCR) assays with the use of broadly reactive polymerase gene–specific primers for the detection of arenavirus RNA. The resulting complementary DNA products were purified, and nucleotide sequences were determined and analyzed. In the investigation of the 2005 cluster, after LCMV-specific sequences had been obtained from PCR products amplified from clinical specimens, a more sensitive, LCMV-specific, quantitative real-time RT-PCR (TaqMan) technology was developed and used for more extensive analysis of specimens.

Figure 3 (facing page). Pathological Studies Revealing Lymphocytic Choriomeningitis Virus (LCMV) in the 2003 Cluster.

Panel A, an electron micrograph of LCMV isolated in Vero E6 cells from the cerebrospinal fluid of Kidney Recipient 1, shows highly pleomorphic, 50-to-300-nm virions containing electron-dense particles. Panel B shows immunohistochemical staining of LCMV (red) in neurons and choroid-plexus ependymal cells of a mouse inoculated with the virus (immunoalkaline phosphatase with naphthol–fast red and hematoxylin counterstain; monoclonal anti-LCMV antibody). Panel C shows immunohistochemical staining of LCMV antigens in lung tissue from the lung recipient (monoclonal anti-LCMV antibody). The image in Panel D reveals extensive hepatocellular necrosis with minimal inflammatory-cell infiltrates in the liver recipient (hematoxylin and eosin). Panel E shows immunohistochemical staining of viral antigens in the transplanted liver (monoclonal anti–Lassa virus antibody). Panel F shows immunohistochemical staining of LCMV antigens in the donor kidney of Kidney Recipient 1 (monoclonal anti-LCMV antibody). Panel G shows immunohistochemical staining of viral antigens in the skin of Kidney Recipient 2 (monoclonal anti–Lassa virus antibody). All micrographs are shown at low magnification.

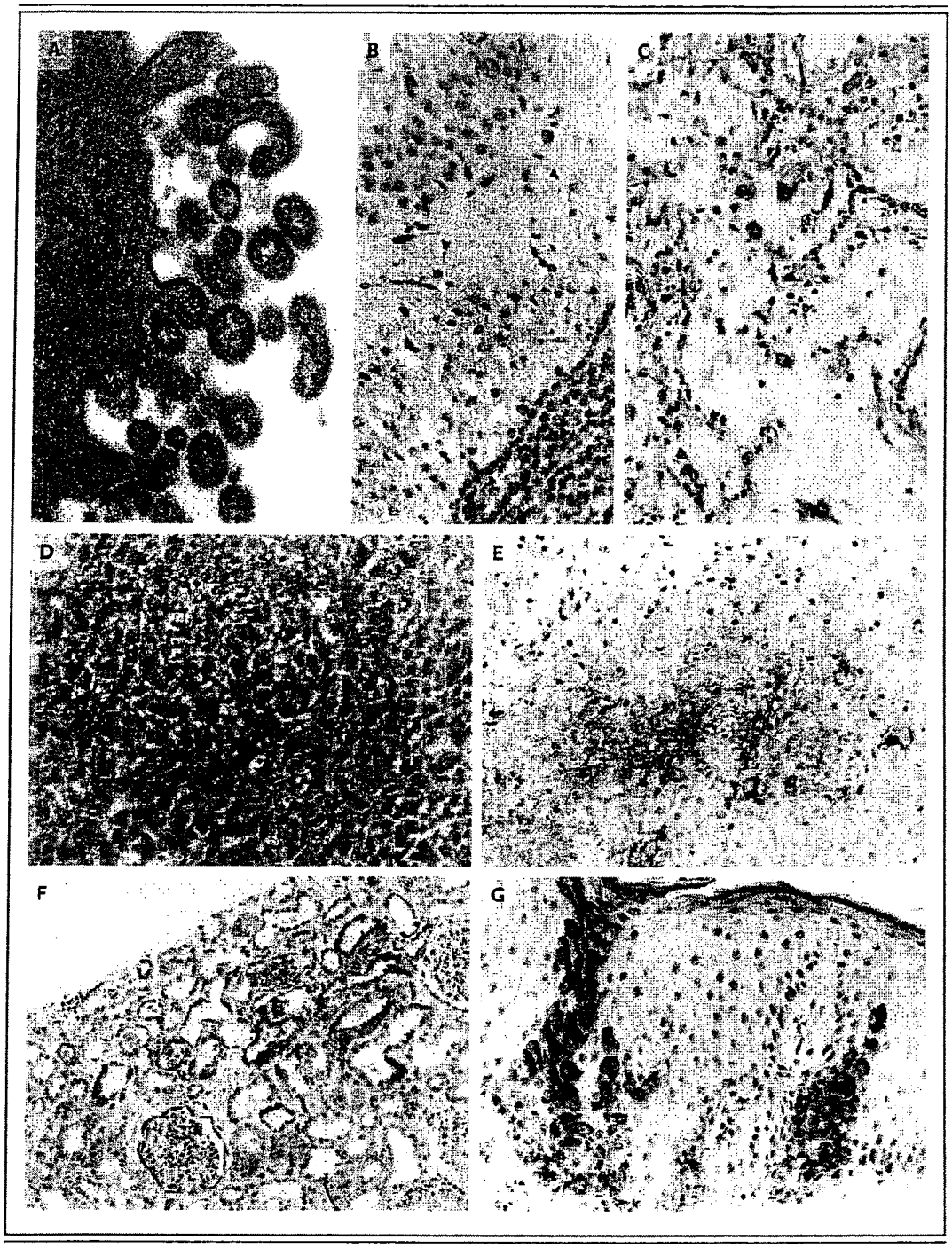
SEROLOGIC TESTING

An enzyme-linked immunosorbent assay was used to detect LCMV-specific IgM and IgG. The assay was performed as previously described,[11] with some modifications in commercially available components, such as microtiter plates and conjugates.

RESULTS

INVESTIGATION OF THE 2003 CLUSTER

Results of testing in the 2003 cluster are summarized in Figure 3 and Table 1. Electron microscopy of Vero E6 cell cultures inoculated with cerebrospinal fluid from Kidney Recipient 1 revealed viral particles compatible with an Old World arenavirus. Indirect fluorescent antibody testing of these cultures confirmed the identity of the arenavirus as LCMV. Subsequently, LCMV was identified by immunohistochemical analysis of the brain tissue of mice inoculated with cerebrospinal fluid from the same patient. LCMV was identified in multiple tissues from each of the four recipients. Nucleotide analysis of PCR products revealed that the viral isolates obtained from the two kidney recipients were identical and were distinct from previously described LCMV strains (Fig. 1 of the Supplementary Appendix). Extensive



testing of multiple donor tissues by means of immunohistochemical analysis, cell culture, and RT-PCR revealed no evidence of LCMV. Neither IgM nor IgG antibodies against LCMV were detected in the donor's serum. Interviews with the donor's family revealed no known rodent exposures. Investigation of procedures, materials, and personnel in hospitals at which the donor and recipients had received care revealed no likely route of LCMV transmission.

INVESTIGATION OF THE 2005 CLUSTER

Results of testing in the 2005 cluster are summarized in Figure 4 and Table 2 (and Fig. 1 of the

Supplementary Appendix). LCMV was detected by immunohistochemical staining, cell culture, and quantitative real-time RT-PCR in multiple tissues from all four recipients. Both kidney recipients had IgM antibodies reactive to LCMV. Extensive testing of multiple donor tissues revealed no evidence of LCMV. No IgM or IgG antibodies against LCMV were detected in the serum of the donor.

The epidemiologic investigation revealed that a member of the donor's household had brought home a pet hamster three weeks before the donor died. Although the donor had not been the primary caretaker of the hamster, she had had contact with the rodent's environment on multiple occasions. Her home and work environment contained no evidence of active rodent infestation. Testing of multiple hamster tissues by immunohistochemical analysis, quantitative real-time RT-PCR, and viral culture detected evidence of LCMV infection (Fig. 4 and Table 2). The primary caretaker of the hamster was asymptomatic but had LCMV-reactive IgG and IgM antibodies present in the serum. Nucleotide analysis of PCR products identified that the viral isolates from all four organ recipients and the hamster were identical, but that they differed from the strain identified in the 2003 cluster and previously described LCMV strains (Fig. 1 of the Supplementary Appendix).

After identification of LCMV as the etiologic agent, intravenous ribavirin (a loading dose of 30 mg per kilogram of body weight, followed by 16 mg per kilogram every six hours for four days and then 8 mg per kilogram every eight hours) was initiated in Kidney Recipient A beginning on post-transplantation day 26 (Fig. 2 of the Supplementary Appendix).[14] The fever and diarrhea decreased; the pain, tenderness, and erythema in the area of the allograft diminished; and the hypoxemia, elevation of aminotransferase levels, thrombocytopenia, and coagulopathy decreased. After the patient's clinical condition had stabilized, ribavirin administration was changed to the oral route (400 mg every morning and 600 mg every evening), and it was discontinued after a renal-biopsy specimen was found to be LCMV-negative by RT-PCR and immunohistochemical staining and after serum IgM became detectable, 63 days after transplantation. During 37 days of ribavirin treatment, clinically significant hemolytic anemia developed and required the transfusion of 19 units of packed red cells. Three hundred eleven days after transplantation, the patient had stable graft function without evidence of infection, after he had restarted immunosuppressive therapy with tacrolimus, mycophenolate mofetil, and prednisolone.

Figure 4 (facing page). Immunohistochemical Staining for Lymphocytic Choriomeningitis Virus (LCMV) in Tissue Samples from the Donor, the Donor's Household Hamster, and Organ Recipients in the 2005 Cluster.

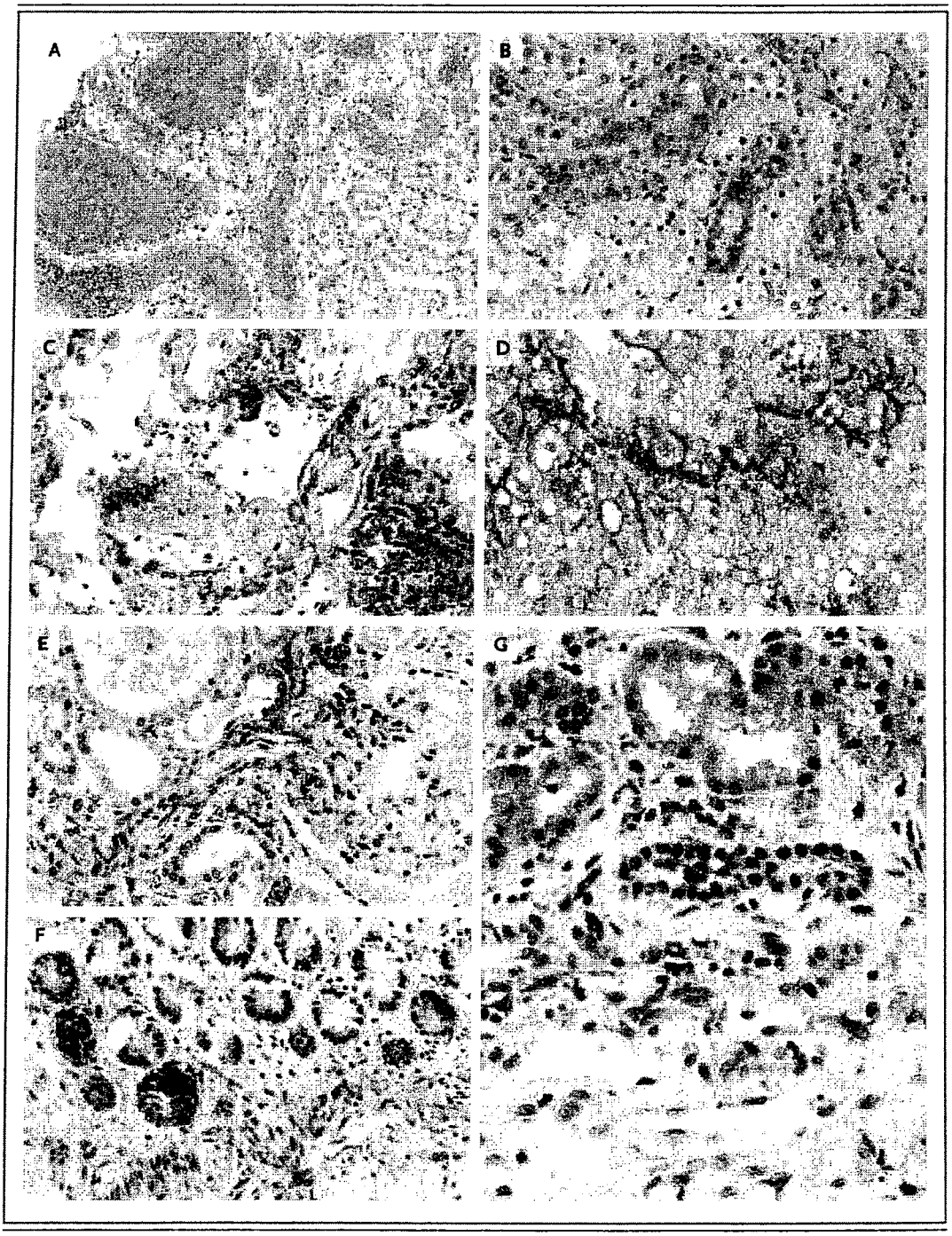
Red staining indicates the presence of LCMV antigens. The image in Panel A contains no immunohistochemical evidence of LCMV in choroid plexus from the donor. Panel B shows antigens in the kidney tubules of the donor's household hamster. Panel C shows LCMV antigens in lung tissue obtained at autopsy from the lung recipient; there are extensive hyaline-membrane formation and viral antigens in the interstitium. Panel D shows LCMV antigens in liver tissue obtained at autopsy from the liver recipient; viral antigens delineate the hepatocyte cytoplasmic membrane. Panel E shows LCMV antigens in a kidney specimen obtained at autopsy from Kidney Recipient B; viral antigens in endothelial cells are entering and exiting the glomerulus. Panel F shows LCMV antigens in a colon sample obtained at autopsy from Kidney Recipient B, with viral antigens in the muscularis mucosae and mucous cells of colonic glands. Panel G shows LCMV antigens in a kidney-biopsy specimen from Kidney Recipient A, who survived; viral antigens are in endothelial cells of the renal interstitium. (The studies shown in Panels A, B, E, and G used a rabbit anti-LCMV antibody, those in Panels C and D a mouse anti–Lassa virus antibody, and that in Panel F a mouse ascitic-fluid anti-LCMV antibody in an immunohistochemical assay with naphthol–fast red substrate and hematoxylin counterstain.) All micrographs are shown at low magnification.

TISSUE DISPOSITION

In the 2003 cluster, no additional tissues from the donor were transplanted. In the 2005 cluster, the corneas were transplanted into a 4-year-old girl and a 29-year-old woman in Algeria, neither of whom required systemic immunosuppression. Two hundred thirteen days after transplantation, neither patient had reported symptoms of infection or graft loss. The skin and liver-associated blood vessels were not transplanted.

DISCUSSION

We describe the transmission of LCMV by solid-organ transplantation. In both clusters, disseminated infection developed in the recipients of organs from a common donor who had no clini-



cal or laboratory evidence of infection. In the 2003 cluster, no rodent exposures could be identified, whereas the 2005 cluster was associated with recent donor exposure to an LCMV-infected pet hamster. The isolation of identical virus strains from the two kidney recipients in the 2003 cluster and from all the organ recipients and the donor household's pet hamster in the 2005 cluster indicates that in both clusters, LCMV was transmitted through organ transplantation.[15]

LCMV infection in humans is sporadic, is generally benign, and can be asymptomatic.[4,16,17] Serologic surveys suggest that up to 5 percent of adults in the United States have been infected with LCMV.[18,19] Humans become infected with LCMV by direct contact with rodents or through

Table 2. Summary of Laboratory Evaluations for Lymphocytic Choriomeningitis Virus Infection in the 2005 Cluster.*

Patient or Source of Specimen	Outcome or Status	Immunohistochemical Staining	Quantitative Real-Time RT-PCR†	Blood and Serum Testing		Culture
				IgM	IgG	
Donor‡	No reported disease	–	–	–	–	–
Liver recipient§	Death 26 days after transplantation	+	+	–	–	+
Lung recipient¶	Death 23 days after transplantation	+	+	–	–	+
Kidney Recipient B‖	Death 23 days after transplantation	+	+	+	–	+
Kidney Recipient A**	Survival	+	+	+	–	+
Hamster in donor's household††	No reported disease	+	+	NT	–	+
Hamster's caregiver‡‡	No reported symptoms	NA	–	+	+	–

* RT-PCR denotes reverse-transcriptase polymerase chain reaction, NT not tested, and NA not applicable.

† Quantitative real-time RT-PCR (TaqMan) assays were carried out as follows: complementary DNA was synthesized with a High Capacity cDNA Archive Kit (Applied Biosystems) and used as a template in a second reaction involving TaqMan Universal PCR Master Mix (Applied Biosystems), forward primer 5′TGGGACTCCATTCGCTATGG3′ at 1 μM per reaction, reverse primer 5′TTAAGTGCAAGGAACCACATCAA at 1 μM per reaction, and probe FAM 5′TGGTCAGCAATCGTGTCTATTGTTTCACAAA at 0.1 μM per reaction. Samples with a cycle-threshold value below 40 were considered positive.

‡ Autopsy specimens that tested negative by one or more tests included central nervous system tissue, heart, spleen, liver, pancreas, uterus, thyroid, gastrointestinal tract, muscle, skin, kidney, blood, and serum.

§ Autopsy specimens that tested positive by one or more tests included central nervous system tissue, lung, heart, kidney, skin, liver, spleen, gastrointestinal tract, adrenal gland, pancreas, testis, blood, and serum. Liver- and colon-biopsy specimens obtained on days 16 and 19, respectively, were also positive by immunohistochemical analysis.

¶ Autopsy specimens that tested positive by one or more tests included central nervous system tissue, lung, heart, kidney, skin, liver, spleen, gastrointestinal tract, blood, and serum.

‖ Autopsy specimens that tested positive by one or more tests included spleen, heart, lung, kidney, gastrointestinal tract, pancreas, liver, blood, and serum. Blood and serum samples obtained on day 17 were positive by PCR, serologic testing for IgM, and culture.

** A colon-biopsy specimen obtained on day 26 was positive, a kidney-biopsy specimen on day 31 was positive, and a kidney-biopsy specimen on day 56 was negative by immunohistochemical analysis. Serial blood or serum samples obtained on days 16 to 50 were positive, blood and serum obtained on days 52 and 85 were negative, urine obtained on days 24 and 37 was positive, urine obtained on day 85 was negative, and a kidney-biopsy specimen obtained on day 55 was negative by PCR and culture. Serial blood and serum samples obtained on days 16 to 39 were IgM negative, on days 52 and 85 IgM positive, and on days 16 to 85 IgG negative by serologic testing.

†† Necropsy specimens that were positive on one or more tests included urinary bladder, skin, muscle, testis, central nervous system tissue, heart, lung, kidney, adrenal gland, salivary gland, pancreas, liver, and spleen.

‡‡ Blood and serum specimens were evaluated.

aerosolized droplets from rodent secretions and excretions, including urine or feces.[20,21] Reports of sporadic infection have most frequently implicated the common house mouse, although outbreaks of infection have been reported after exposure to infected pet hamsters and laboratory rodents.[17,20-28]

In clinically apparent infection, the incubation period is 5 to 13 days, with subsequent fever, headache, and myalgias. Abdominal pain, diarrhea, and rash have been described.[16,20,22,26,29] A second phase of illness may be seen five to nine days after convalescence, with meningitis or, rarely, encephalomyelitis, orchitis, parotitis, pneumonitis, arthritis, myocarditis, or alopecia.[16,22,30] Recognized LCMV infection carries a mortality rate of less than 1 percent.[3]

The marked severity of LCMV-related illness in transplant recipients is probably the result of intensive immunosuppression, including T-cell depletion, coincident with direct viral inoculation by way of the transplanted organs. There are few data on the clinical behavior and outcomes of LCMV infection in immunocompromised patients. However, three patients with advanced lymphoma experimentally inoculated with the virus in a trial investigating its antitumor effect died with disseminated infection within 14 to 45 days after inoculation[31] — a pattern similar to that seen in the current clusters after solid-organ transplantation.

The clinical presentation of LCMV infection in the recipients was variable and included fever, diarrhea, peri-incisional erythema and tenderness, altered mental status, and respiratory insufficiency (as noted in the table of the Supplementary Appendix). Leukopenia or leukocytosis, thrombocytopenia, coagulopathy, renal insuf-

ficiency, and progressive liver dysfunction dominated the laboratory findings. Histopathological findings in all the recipients were characterized by necrotic and occasionally hemorrhagic foci in multiple tissues, with a notable absence of inflammatory infiltrates and viral inclusions. LCMV antigens present in some tissues (e.g., the gastrointestinal tract and skin) correlated with clinical symptoms (e.g., diarrhea and erythema or pustular rash, respectively). Antigens were identified in the leptomeninges of some patients in both clusters. However, signs of meningeal inflammation, though prominent in the 2003 cluster, were generally absent in the 2005 cluster. Clinical manifestations and pathological findings in all the cases were probably altered by immunosuppression.

To our knowledge, there have been no trials of antiviral agents in human LCMV disease. Ribavirin has demonstrated efficacy in the treatment of Lassa fever and possesses in vitro activity against LCMV infection, which prompted its use in the renal-transplant recipient who survived.[14,32] The role of ribavirin in this patient's improvement is unclear, since the level of immunosuppression was also considerably reduced, as it was for all four kidney recipients in the two clusters.

Rapid evaluation of organ-donor suitability is essential in transplantation to minimize the duration of ischemia and to preserve allograft function. Therefore, assays used to screen potential donors for transmissible infections must be rapid, sensitive, reproducible, and readily available to OPOs. The Food and Drug Administration has not approved any diagnostic tests for LCMV infection. Furthermore, the sensitivity of currently available assays is not adequate for routine donor screening, as demonstrated by the negative results of tests on a wide array of clinical specimens from the donors in both clusters. The use of information pertaining to recent rodent exposure for donor-suitability screening may exclude healthy donors from an already limited organ-donor pool. However, the collection of additional epidemiologic information on donors' exposures may be useful, notably for the investigation of unusual outcomes after transplantation. Zoonotic-disease transmission after transplantation is also a concern; immunosuppressed persons should take special care and limit exposure to some animals, including certain pets (additional information is available from the CDC at www.cdc.gov/healthypets).

Transplant recipients are susceptible to infection with a variety of donor-derived pathogens, including West Nile virus, *Trypanosoma cruzi*, rabies virus, and now LCMV.[33-36] Although such infections are probably uncommon, outcomes can be fatal, and diagnosis is feasible with specialized laboratory testing. Diagnosis of LCMV infection is usually made by serologic testing, isolation of the virus from the blood or cerebrospinal fluid, or PCR testing.[37-39] Because immunohistochemical staining revealed LCMV in multiple biopsy specimens obtained to evaluate unexplained post-transplantation symptoms in the clusters described in the current report, such testing might be beneficial in the early diagnosis of LCMV infection.

Each year, approximately 25,000 organ transplantations are performed at more than 250 transplantation centers throughout the United States.[40] Allocation policies commonly result in the distribution of organs from a single donor to multiple transplantation centers. It is unlikely that either LCMV-illness cluster would have been identified without the allocation of kidneys to two recipients in whom similar symptoms simultaneously developed after undergoing transplantation at the same hospital. Similar chance clinical observations have been critical in the recognition of recent transplant-associated outbreaks of rabies and West Nile virus infection.[33,35]

The Organ Procurement and Transplantation Network (OPTN), which is operated by the United Network for Organ Sharing, requires transplantation centers to report certain outcomes, including allograft failure and the death of transplant recipients, in a timely manner. In April 2005, the OPTN revised its policies to require the reporting of suspected donor-transmitted medical conditions (including cancers and infections) to the procuring OPO, which is then responsible for investigating and communicating with the transplantation centers caring for the recipients of other transplants from the donor and the involved tissue and eye banks.[41]

Investigation of potential donor-transmitted infection requires rapid communication among physicians in multiple transplantation centers, OPOs, and public health authorities. An immediate system for tracking and disseminating pertinent patient data is needed. Until such a system can be established, clinicians must recognize that the presence of an unusual constellation of

symptoms, particularly during the first few weeks after transplantation, should raise the possibility of donor-transmitted infection. Prompt notification of the OPO and public health authorities can help facilitate rapid investigation and discovery of these events.

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The views expressed herein are those of the authors and not necessarily those of the Department of Health and Human Services.

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APPENDIX

The members of the LCMV in Transplant Recipients Investigation Team are as follows: *Brigham and Women's Hospital*: D.A. Milner and M. Wilck; *Centers for Disease Control and Prevention*: C. Albarino, B. Amman, M. Bell, B. Bird, B. Holloway, J. Mills, and J. Towner; *Massachusetts Department of Public Health*: C. Daniel, S. Fleming, P. Kludt, and B.T. Matyas; *Massachusetts General Hospital*: R. Chung, A.B. Cosimi, N. Elias, N. Goes, M. Hertl, A. Reid, E.S. Rosenberg, and R.N. Smith; *Medical College of Wisconsin*: C.P. Johnson, S.C. Kehl, and C. Schultzenberg; *New England Organ Bank*: R.S. Luskin and K.J. O'Connor; *Rhode Island Department of Health*: C. Hannafin and C. Vanner; and *Rhode Island Hospital*: R. DeLellis, A. Gautam, R. Gohh, K. Kurek, P. Morrissey, and A. Yango.

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