CONCURRENT NEOCORTICAL BORRELIOSIS AND ALZHEIMER'S DISEASE

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Borrelia spirochetes were directly visualized in autopsy brain tissue from a patient with Alzheimer's disease and were cultured from cerebral cortex in artificial media. The authors propose that, as occurs in tertiary neurosyphilis and general paresis of the insane, Borrelia species may invade the brain, remain in a latent state for many years, and cause dementia in the absence of other focal neurologic deficits. An undetermined fraction of patients with Alzheimer's disease may be shown to have late tertiary neuroborreliosis. HUM PATHOL 18:759–761, 1987.

Diseases of the central nervous system including cranial neuropathies, meningoencephalitis, chronic meningitis, and progressive encephalomyelitis have recently been described in patients showing serologic evidence of infection with the spirochete *Borrelia burgdorferi*.[1–6] Months or years of clinical latency may pass between primary infection with *B. burgdorferi* and the onset of central nervous system disease. The possibility that late tertiary borreliosis might be manifest as dementia without other associated neurologic abnormalities led the authors to undertake this clinicopathologic investigation.

REPORT OF A CASE

A 74-year-old white woman died suddenly at home. Approximately one week previously, she had been evaluated in the hospital for a mild organic mental syndrome of recent onset. After a detailed neuropsychiatric evaluation by an internist, a neurologist, and a psychiatrist, a computed tomogram of the brain was obtained, and a battery of tests excluded biochemical, metabolic, and infectious causes for mental impairment. She was discharged from the hospital with a diagnosis of probable early Alzheimer's disease. After her death, an autopsy was requested by the family and her physicians to determine the neuropathologic basis for her memory disorder. The autopsy was performed by the medical examiner 24 hours after her death to determine that trauma or accident was not a proximate contributing factor in her sudden death.

METHODS

The previous complete neurologic examination had disclosed no deficits in the cranial nerves, sensory or motor function, reflexes, or cerebellar function. Tests of the patient's mental status revealed that she was disoriented as to place and date. Deficits in abstract reasoning were apparent on testing. Her thoughts were vague, and she was unable to concentrate on reading or while watching television.

Laboratory evaluation showed the serum vitamin B_{12} level was 321 ng/l (normal, 200 to 900); thyroxine, 6.0 μg/dl (5 to 12); and triiodothyronine, 2.4 μg/dl (1.5 to 4.8). The VDRL serology was nonreactive.

A standard autopsy disclosed the cause of death was a ruptured abdominal aortic aneurysm. At the request of one of us (ABM), a portion of fresh cerebral cortex (frontal lobe) was placed in sterile phosphate-buffered saline solution and stored at 4°C for special studies.

Under sterile conditions, cubes of fresh washed cerebral cortex gray matter were trimmed to approximately 0.5 cm in size, and these were transferred to sterile Barbour-Stonner-Kelly medium. The cultures were maintained at

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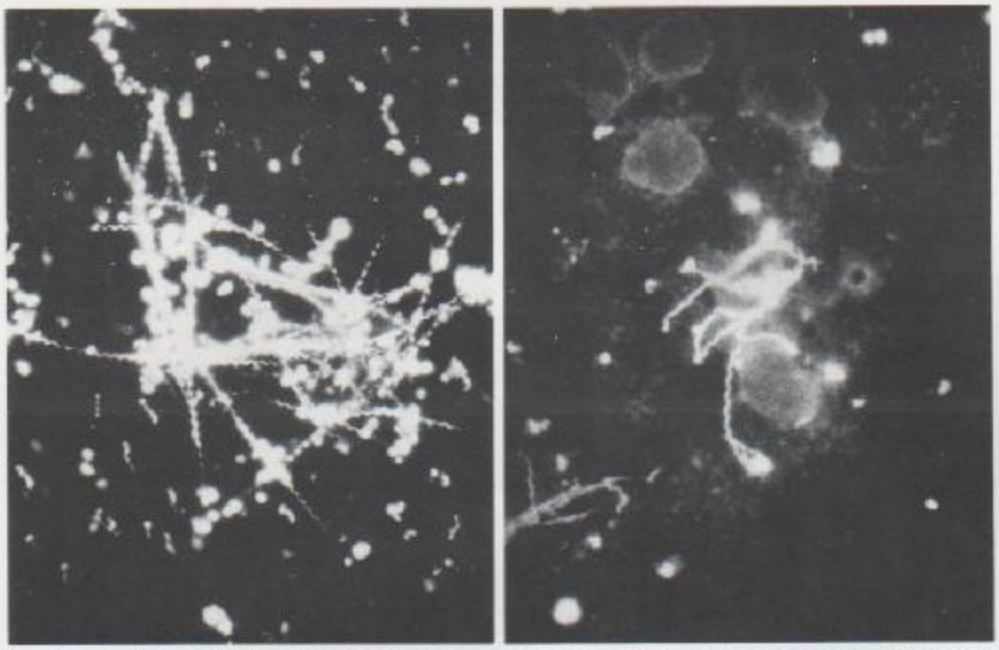

FIGURE 1. Borrelia spirochetes. **Left,** Subculture of frontal lobe of brain in Barbour-Stonner-Kelly medium. (Darkfield microscope image. × 500.) **Right,** Cytologic preparations from fresh frontal lobe cortex (touch preparations) stained with mouse monoclonal antibody H5332, IgG (outer envelope epitope). (Indirect immunofluorescence microscope image. × 1000.)

24°C. Subcultures were prepared from aliquots of the original material two months later.

The Krajian, Warthin-Starry, and Dieterle silver stains were performed on tissue imprints and paraffin sections. Control materials consisted of autopsy tissues from a patient with fetal borreliosis (positive control), autopsy brain from a 74-year-old man with no evidence of dementia (negative control), and the B 31 strain of *B. burgdorferi* obtained from the American Type Culture Collection.

An indirect immunofluorescent assay for detection of *B. burgdorferi* in tissue sections and in imprint preparations used serial incubations of the monoclonal antibody H5332 followed by incubations with staphylococcal protein A conjugated to fluorescein isothionate (Cappel Laboratories, Cochranville, Pennsylvania). Tissue controls for these studies were the same materials as used in the silver staining procedures.

RESULTS

Spirochetes were demonstrated with the H5332 monoclonal antibody in the tissue imprints in a bandlike distribution that corresponded to the gray matter region of the cortex. More than 100 spirochetes were photographed in aggregates, small clusters, and solitarily in various microscopic fields in the cortex imprints. Fragments of spirochetes were photographed in frozen tissue sections from the cortex using the H5332 monoclonal antibody–fluorescent method. Spirochetes were also demonstrated with the Krajian silver stain in tissue sections.

Cultures of brain tissue yielded spirochetes after two months of incubation at room temperature, but excessive contamination with other bacterial flora has so far prevented us from obtaining a pure culture of the spirochete. The subcultures have yielded corkscrew-shaped spirochetes that react with the monoclonal antibody H5332 on indirect immunofluorescence (fig. 1). Silver impregnation of the frontal lobe cortex demonstrated neurofibrillary change in neurons and an excess of argyrophilic plaques consistent with a pathologic diagnosis of Alzheimer's disease.

DISCUSSION

This report describes the discovery of *Borrelia burgdorferi* in brain tissue preparations from a patient with dementia. Although previous clinical studies using serologic tests have linked *B. burgdorferi* with various categories of neurologic illness, this is the first report of direct visualization of the spirochete in the brain. The immunofluorescent method is more specific than traditional histochemical methods using silver stains to demonstrate spirochetes in tissue. All of the previous reports that have demonstrated *B. burgdorferi* in various human tissues have relied on silver impregnation methods (Dieterle stain or Warthin-Starry stain). In only rare instances have *Borrelia* spirochetes been cultured from the tissues in which the spirochete has been seen in tissue sections.

Dr. Hideyo Noguchi established the link between the presence of the spirochete *Treponema pallidum* in the brain and the clinical illness general paresis of the insane. Noguchi's 1913 report described spirochetes in 12 of 70 cases of general paresis and ended the dispute between those who believed that general paresis was a type of late tertiary neurosyphilis and those who asserted that the association between the two diseases was only coincidental. A prolonged period of clinical latency and the gradual development of impairment of higher cognitive functions in the patient with general paresis parallel the developmental stages of pathologic processes in other organ sytems in tertiary syphilis and late tertiary borrelia infection.

Evidence accumulated from a novel approach to the

pathologic examination of the frontal lobe cortex from one extremely carefully documented case of senile dementia of the Alzheimer's type has provided circumstantial evidence that the spirochete *B. burgdorferi* was present in the neocortex, where higher cognitive functions are resident and where neuropathologic evidence of Alzheimer's disease is virtually always present. Further work is needed to determine whether the presence of the *Borrelia* spirochete in the neocortex and the development of dementia in the human host are linked.

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Concurrent Neocortical Borreliosis and Alzheimer's Disease

Demonstration of a Spirochetal Cyst Form

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A 71-year-old man died in Arizona 3 years after the onset of progressive dementia. A diagnosis of probable Alzheimer's disease was based on clinical criteria. The brain was removed at autopsy, frozen (unfixed), and transported to the Department of Pathology, University of California, San Diego, School of Medicine where it was stored at −70°C for further study. The author received the frozen brain and utilized methods previously described[1] for *in vitro* culture, cytologic, immunohistochemical, and silver impregnation studies. Argyrophilic plaques and neurofibrillary tangles were found in the frontal lobe and hippocampal formation in sufficient number to establish the neuropathologic diagnosis of Alzheimer's disease (FIG. 1A). Spirochetes were visualized in imprint preparations of freshly thawed frontal lobe cortex with monoclonal antibody H5332, which specifically binds to the outer surface membrane of *Borrelia burgdorferi* (FIG. 2). *Borrelia* spirochetes were recovered from cultures of freshly thawed cerebral cortex and hippocampus in Barbour-Stoenner-Kelly medium. An unexpected observation was the identification of cystic forms of the *Borrelia* spirochete in dark-field preparations of cultured hippocampus, and in imprints of hippocampus using the monoclonal antibody H9724, which binds to class-specific axial filament proteins of *Borrelia* spirochetes. Oil immersion examination of sections from the hippocampus impregnated with silver disclosed a rare cystic structure (FIG. 1B). Previous workers have identified spirochetal cyst forms in cultures of nonpathogenic treponemal spirochetes and have suggested that spirochetes have a complex life cycle.[2-5] Dark-field examination of aged cultures of the B31 reference strain of *Borrelia burgdorferi* disclosed cystic structures similar to the cysts found in the autopsy brain culture.

The following hypothesis is offered based on these observations. Borrelia spirochetes have a complex life cycle which includes corkscrew-shaped forms, uncoiled filamentous forms, L-forms lacking a cell wall, cystic and ameboid forms, and granular forms. These forms may exist as either extracellular or intracellular pathogens. The cystic form of *Borrelia* may explain the Pick body, which is found in Pick's disease, and the granular form of *Borrelia* may explain granulovacuolar degeneration of nerve cells in the hippocampal formation in Alzheimer's disease. A cystic form of the *Borrelia* spirochete would explain the ability of the microbe to persist in the host during a prolonged period of asymptomatic clinical latency, which spans the period between primary infection and the expression of tertiary manifestations of neuroborreliosis.

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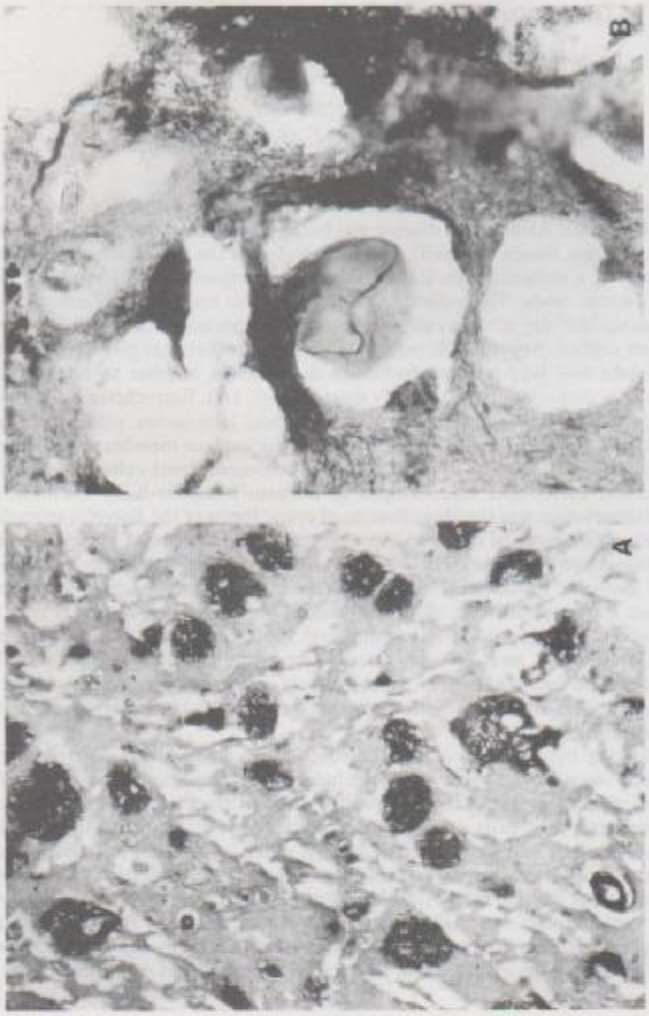

FIGURE 1. Autopsy hippocampus, ammoniacal silver stain. (A) Argyrophilic plaques; magnification: 100×. (B) Cyst form near plaque; magnification: 500×.

FIGURE 2. *Borrelia* spirochete in imprint of unfixed frontal lobe of brain, revealed using murine monoclonal antibody H5332 for outer surface membrane of *Borrelia burgdorferi*. Magnification: 1000×.

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