Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

ELSEVIER
SAUNDERS

Infect Dis Clin N Am
22 (2008) 755–772

INFECTIOUS
DISEASE CLINICS
OF NORTH AMERICA

Emerging and Zoonotic Infections in Women

Regan N. Theiler, MD, PhD[a,*],
Sonja A. Rasmussen, MD, MS[b],
Tracee A. Treadwell, DVM, MPH[c],
Denise J. Jamieson, MD, MPH[d]

[a]*Department of Obstetrics and Gynecology, University of Texas Medical Branch, 301 University Boulevard, Galveston, TX 77550-0587, USA*
[b]*Division of Birth Defects and Developmental Disabilities, National Center on Birth Defects and Developmental Disabilities, Centers for Disease Control and Prevention, 1600 Clifton Road, Atlanta, GA 30333, USA*
[c]*National Center for Zoonotic, Vectorborne and Enteric Diseases, Centers for Disease Control and Prevention, 1600 Clifton Road, MS D-76, Atlanta, GA 30333, USA*
[d]*Division of Reproductive Health, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, 4770 Buford Highway, NE, MS K-40, Atlanta, GA 30341-3717, USA*

In the inaugural issue of *Emerging Infectious Diseases*, Stephen Morse defined emerging infections as "infections that have newly appeared in the population, or have existed but are rapidly increasing in incidence or geographic range" [1]. Most of the infections to emerge in recent years (1996–2004) (Fig. 1) can be categorized as zoonoses, with West Nile virus (WNV), severe acute respiratory syndrome (SARS) coronavirus, and avian influenza A (H5N1) virus accounting for some recent high-profile zoonotic outbreaks (see Fig. 1) [2]. Nonzoonotic infections deserving mention in any discussion of emerging infectious diseases include previously controlled human pathogens that are re-emerging, and antibiotic-resistant bacteria account for a proportion of these challenging infections. The increasing use of organ transplantation also has resulted in increased susceptibility to and transmission of re-emerging pathogens, most recently exemplified by lymphocytic choriomeningitis virus (LCMV) [3].

Disclaimer: The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention or the Department of Health and Human Services.

* Corresponding author.
E-mail address: rntheile@utmb.edu (R.N. Theiler).

0891-5520/08/$ - see front matter © 2008 Elsevier Inc. All rights reserved.
doi:10.1016/j.idc.2008.05.007 *id.theclinics.com*

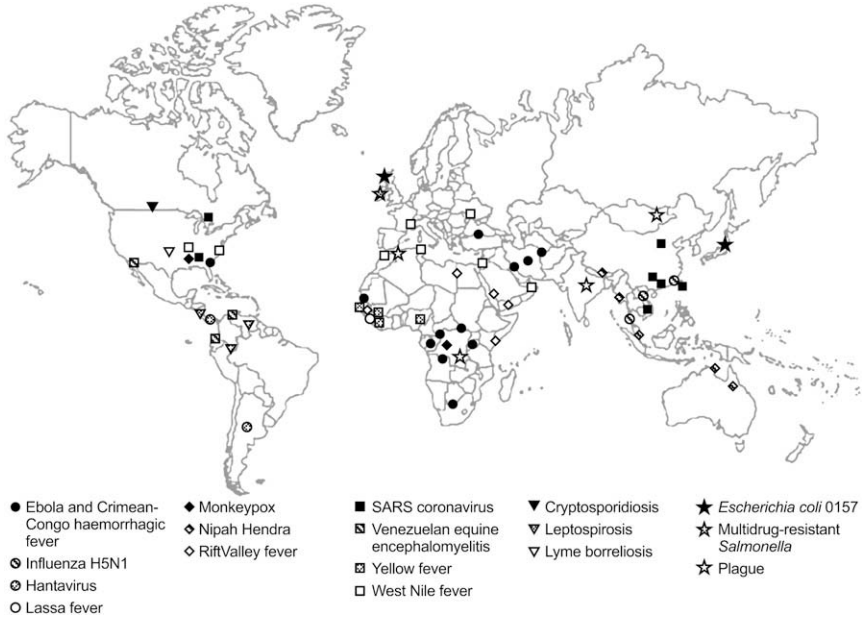

Fig. 1. Selected emerging and re-emerging infectious diseases, 1996–2004. (*Modified from* WHO. The world health report 2007: a safer future: global public health security in the 21st century. Geneva: WHO Press; 2007; with permission.)

In examining the impact of emerging infections on the female population, factors unique to women must be considered. Pregnant women are uniquely susceptible to infectious diseases [4]. Women in general, however, manifest disease differently from men based on anatomic and hormonal factors. Consider the difference in severity of gonorrheal infection, usually asymptomatic, but occasionally manifesting as fertility-threatening pelvic inflammatory disease in women as opposed to the milder urethritis or prostatitis seen in men. In contrast, the female hormonal milieu seems to protect against disease development after infection with some pathogens, including *Coxiella burnetii*, the causative agent of Q fever [5]. Behavioral, cultural, and social factors also must be considered [6]. For example, in cultures where women tend animal herds, they are more likely to be exposed to zoonoses, such as Q fever and Rift Valley fever (RVF) [7]. In addition, health care workers must be prepared to encounter women who have unique combinations of risk factors for emerging infectious diseases, such as the growing population of women who are becoming pregnant after kidney transplantation [8].

Old pathogens, new patterns

In 1999, an outbreak of WNV was identified in New York City, the first time this well-characterized mosquito-borne flavivirus had been found in the

Western hemisphere. Originally isolated from a human in Uganda in 1937, WNV later was shown to be maintained in bird reservoirs through mosquito vectors [9]. Since 1999, the virus has spread throughout the United States, causing more than 27,000 human cases of WNV illness [10]. WNV may be less likely to cause disease in women than in men, as suggested by a study reporting a higher incidence of WNV neuroinvasive disease in men and two others that demonstrated higher rates of mortality in infected men [11,12]. How much of the apparent difference is due to biology is unclear, as behavioral factors resulting in disproportionate exposure of men to the infected mosquito vector may have important roles.

In 2002, a case of intrauterine transmission of WNV was reported in Syracuse, New York. In this case, a pregnant woman suffered WNV encephalitis at 27 weeks' gestational age and subsequently delivered at 38 weeks. The neonate had neurologic sequelae, including severe bilateral loss of white matter, a cystic lesion with focal cerebral destruction in one temporal lobe, lissencephaly, and chorioretinal scarring [13]. Cord blood from delivery and blood from heel-stick specimens tested positive for WNV-specific IgM, which is consistent with intrauterine infection. The placenta also tested positive for WNV RNA by reverse transcriptase–polymerase chain reaction (RT-PCR) in one of two tests [14,15]. This initial case of congenital WNV infection prompted the Centers for Disease Control and Prevention (CDC) and state health departments to establish a WNV surveillance system for pregnant women. In 2003–2004, 83 pregnant women who had WNV illness were identified through surveillance, and clinical information was available on 77. Although three cases of possible congenital infection were found, intrauterine transmission was not confirmed. All three mothers had acute WNV illness within 3 weeks of delivery, allowing for the possibility of intrapartum or immediate postpartum transmission of infection. Cord blood specimens were not available in two of these cases, and testing for WNV-specific IgM and WNV RNA was negative in the third. One of the infected infants died at 7 weeks of age [16].

During the surveillance efforts, 42 specimens of breast milk from infected women were tested for WNV RNA, and two of these tested positive. One of the infants fed WNV positive breast milk had negative serology at age 7 months, and the other was not available for testing [16]. Earlier, in 2002, a probable case of transmission through breastfeeding was reported in Michigan [17]. Shortly after delivery, a woman received two units of blood from a WNV-infected donor and subsequently developed documented WNV meningoencephalitis. WNV also was isolated from her breast milk, and her breastfed neonate developed WNV-specific IgM antibody but did not become ill. From the limited information available, it seems that WNV is rarely transmitted transplacentally, but that congenital WNV infection may result in severe neurologic sequelae and even death. Mothers who have febrile illnesses suspicious for WNV infection should be counseled regarding the possible risk for transmission during pregnancy and via breast milk [18].

Another previously studied but clinically rare pathogen has re-emerged recently as a cause of disease in the United States. LCMV, an arenavirus carried by house mice and other small rodents, appeared in several recipients of transplanted organs in 2003 and again in 2005. All had received their organs from one of two donors, and the resulting infections were fatal in seven of the eight recipients. The second donor had a history of exposure to a pet hamster with LCMV infection, but the initial donor could not be linked to any rodent exposure and his tissues tested negative for LCMV infection. The sole surviving recipient was treated with ribavirin, shown in vitro to control replication of LCMV, and he improved clinically with therapy. Only one of the recipients was a woman, and she died on post-liver transplantation day 17 with multiorgan LCMV involvement demonstrated immunologically at autopsy [3]. In 2005, the clusters of LCMV infection in transplant recipients prompted the CDC to issue interim guidelines on exposure to LCMV, recommending that immunosuppressed persons and pregnant women or women who may become pregnant avoid exposure to all rodents, including pet hamsters [19]. LCMV is known to infect pregnant women, causing fetal wastage, hydrocephalus, and chorioretinitis in affected offspring [20,21]. Ribavirin, the only therapeutic option for LCMV disease, generally is not recommended in pregnancy because of findings of teratogenicity in animal models [22].

The viral hemorrhagic fevers

The viral hemorrhagic fevers (VHFs) originate from multiple virus families, including the flaviruses (dengue hemorrhagic fever [DHF] and yellow fever), arenaviruses (Lassa fever and Argentine, Bolivian, and Venezuelan hemorrhagic fevers), bunyaviruses (RVF, hantaviruses, and Crimean-Congo hemorrhagic fever), and filoviruses (Ebola and Marburg hemorrhagic fevers). Although evolutionarily divergent, these viruses have in common natural animal reservoirs and rapidly mutating RNA genomes, with humans as incidental victims in the viral life cycle. The possible exception is the flaviviruses, which are believed to survive via arthropod-human-arthropod infectious cycles, the isolation of yellow fever and dengue fever viruses from non-human primates notwithstanding [9]. The sporadic nature of VHF outbreaks—and their often remote locations—makes systematic epidemiologic study difficult. The limited existing data, however, suggest a pattern of increased severity of disease in women and increased mortality in pregnant compared with nonpregnant patients across a range of viruses. Fetal pathology and pregnancy wastage also are documented as sequelae of some VHF infections.

Yellow fever virus, an important tropical mosquito-borne pathogen, remains an important cause of disease. Despite the effectiveness of the available vaccine, the World Health Organization (WHO) [23] estimates that 200,000 cases and 30,000 deaths from yellow fever occur annually

worldwide, and these numbers have been increasing since the 1980s. Endemic to South America, the Caribbean, and Africa, yellow fever case fatality rates are estimated at 10% to 20%. Max Theiler received the 1951 Nobel prize in medicine for development of the vaccine, which in concert with mosquito control measures dramatically decreased the incidence of yellow fever worldwide. Some controversy exists regarding the safety of yellow fever vaccination during pregnancy, because early studies suggested increased risk for miscarriage among women receiving the live attenuated vaccine during the first trimester of pregnancy. For this reason, the WHO recommends vaccinating pregnant women against yellow fever only during an epidemic [23]. Recent data from 480 women who were vaccinated early in pregnancy, however, demonstrate no increase in adverse pregnancy outcomes, including miscarriage, malformations, and preterm delivery. This study also documented 98% seroconversion among the women studied, suggesting that the vaccine is safe and effective in pregnancy [24].

Dengue virus infection manifests clinically as several different entities, including dengue fever, DHF, and dengue shock syndrome (DSS). Four dengue virus serotypes are characterized, and primary infection with any of them generally causes a self-limited mild febrile illness. A history of dengue infection, however, is a risk factor for developing the more severe DHF or DSS on secondary infection with another serotype. This antibody enhancement effect is believed mediated by IgG and has significant implications for pregnant women contracting secondary dengue infection. A disease of the urban tropics, dengue is transmitted from person to person by *Aedes* mosquitoes, with no obligate vertebrate intermediate. Serologic surveys indicate no difference in the prevalence of dengue antibodies between women and men in endemic areas, with seropositivity approaching 100% in adult populations in hyperendemic parts of the world [25,26]. Dengue infection during pregnancy can result in complications for mothers and infants, especially if a mother has been previously infected with another serotype. Dengue infection with manifestations of maternal thrombocytopenia and elevated transaminases may present similarly to HELLP (*h*emolysis, *e*levated *l*iver enzymes, and *l*ow *p*latelets) syndrome, differentiated in the early stages only by the lack of hypertension and the presence of fever. Peripartum DHF can result in life-threatening coagulopathies leading to post partum or intraoperative hemorrhage. The presence of maternal IgG specific to another serotype in the neonatal blood can lead to DHF or DSS during vertically acquired primary dengue infection, with one reported case resulting in death of the infant from intracranial hemorrhage [27]. The mechanism of vertical dengue transmission is unclear, but at least 17 cases are documented in the English-language literature [28]. Transplacental infection has been hypothesized after reports of increased rates of stillbirth in pregnant women who had dengue fever, but fetal and placental dengue virus infections were not documented [29]. One congenitally infected term infant did have dengue virus RNA detected in cord blood by

RT-PCR, suggesting fetal viremia and transplacental infection [30]. Most reported cases of vertical transmission have occurred with maternal infection around the time of delivery, also raising the possibility of transmission to the infant during the intrapartum period or through breastfeeding.

Endemic to West Africa, Lassa fever is caused by a zoonotic arenavirus carried by common rodents of the *Mastomys* genus. Transmission is believed to occur via aerosol and direct contact with excreta from the animal. Data demonstrate the increased severity of Lassa fever in pregnancy and the postpartum period, but nonpregnant women infected with the virus fare as well as men in most studies. Case fatality rates in pregnancy and the puerperium are as high as 40%, with the worst prognosis for women in the final trimester [31]. Fetal outcome is even more bleak: first- and second-trimester Lassa infections result in spontaneous abortion in approximately 80% of cases. In the third trimester, stillbirth and neonatal deaths approach 75% [32]. Placental and fetal infection with high-titer Lassa virus has been demonstrated in such cases, suggesting that the virus directly infects and causes disease in the fetus [31,33]. Virus also is shed in the milk of infected mothers, and vertical transmission through breastfeeding is suspected to occur [33]. It is suggested that uterine evacuation improves maternal prognosis at every gestational age, with the highest mortality occurring in those women who have a fetus remaining in utero [32].

Although fewer reports are published about Ebola infection during pregnancy, available evidence suggests that it also can present devastating consequences for mother and fetus. Most of the available data were gathered by retrospective review of 15 Ebola cases in pregnant patients during the 1995 Ebola outbreak in the Democratic Republic of the Congo [34]. Of the 15 pregnant patients, only one survived, for a case fatality rate of 93%. This was not a statistically significant difference from the overall 77% fatality rate during the outbreak. Fetal outcomes were worse than maternal outcomes, however, with only one live birth of a neonate who died of a febrile illness 3 days later. The mother in this case died from postpartum hemorrhage. Four other infected women died during the third trimester. One woman gave birth to a stillborn infant at 32 weeks' estimated gestational age and died herself during the postpartum period. Fetal viral infection was not documented in these cases, but it seems clear that maternal Ebola virus infection results in devastating outcomes for the fetus. As for the effects on nonpregnant women versus men, no survival advantage has been demonstrated for either group. One analysis suggested an increased risk of death for infected men, but this finding was not statistically significant [35]. Ebola virus has been found in semen and vaginal secretions of infected patients even after clinical recovery, suggesting risk for transmission via sexual or occupational exposure to these fluids [36].

For many of the VHFs, few data exist regarding disease in women in general or during pregnancy in particular. Case reports suggest that

hantavirus infection during pregnancy runs essentially the same course as in nonpregnant patients, and fetal infection has not been diagnosed [37]. One case of fetal hypoxic brain injury occurred after maternal hantavirus pulmonary syndrome with acute respiratory distress syndrome (ARDS), but serologic testing of the infant was negative [38]. A case of intrauterine fetal death was reported with hantavirus hemorrhagic renal syndrome, but the fetus was not tested for evidence of infection [39]. One case of congenital RVF has been reported, and women who have RVF infection are believed to have increased rates of spontaneous abortion [40,41]. Little is known about the effect of Marburg hemorrhagic fever on pregnancy outcome. The lessons of Lassa, Ebola, and dengue can be applied to clinical manifestations of other VHFs in pregnancy, however, as all conditions predisposing to hypotension, coagulopathy, and hemorrhage bring compounded risk to the pregnant patient and her fetus.

Avian influenza A virus

The highly pathogenic H5N1 virus has received much attention in recent years because of its widespread infection of bird populations in many countries and its high mortality rate among humans, raising concern for an approaching influenza pandemic. Wild birds are the natural reservoir for influenza A viruses and when infected usually are asymptomatic, but they can infect other birds (eg, domestic poultry) that may develop disease. Subtypes of influenza A virus are identified by two surface proteins (hemagglutinin and neuraminidase), with 16 known hemagglutinin and nine known neuraminidase subtypes. Many combinations of hemagglutinin and neuraminidase proteins are possible, and all known combinations can be found in avian influenza viruses that infect birds. Although avian influenza A viruses primarily affect birds, mutations in genes that produce surface proteins or gene reassortment with human viruses can result in a novel human influenza A subtype virus that can infect humans. If a novel subtype virus to which the human population lacks immunity develops the ability for efficient and sustained transmission among humans, an influenza pandemic could occur [42,43].

The highly pathogenic H5N1 virus first appeared in humans in Hong Kong in 1997, infecting 18 people, six of whom died. Studies of these initial cases demonstrated that exposure to live poultry during the week before the onset of illness was a major risk factor for infection [44]. Culling of poultry in Hong Kong and implementation of other measures contributed to control of the outbreak. Beginning in 2003, however, human cases again were observed [42], and as of January 24, 2008, 353 confirmed human cases of H5N1 from 14 countries with 221 deaths had been reported to the WHO [45]. Cases of probable human-to-human transmission of H5N1 recently have been reported [46], further raising the threat of an influenza pandemic. Although H5N1 virus currently represents the highest threat for a future

pandemic, other avian influenza A viruses that have infected humans also have pandemic potential.

The incubation period for H5N1 seems to be 7 days or less after exposure to infected poultry, and 2 to 5 days in many cases [47]. Patients who have H5N1 virus often develop severe pulmonary disease with rapid clinical deterioration, even previously healthy individuals. They often present with a fever and other symptoms typical of influenza, but manifestations often can extend beyond the lungs to other organ systems (eg, the gastrointestinal tract) [42], and recent pathologic evidence has suggested dissemination to other organs, including the brain [48].

Limited information is available on the effects of H5N1 virus infection specifically on women. A survey of cases reported by the WHO [49] showed a relatively even distribution between men and women, except in two age groups; men were affected more often in the 4- to 6-year-old age group, whereas girls were affected more often in the 25- to 30-year-age group. The investigators hypothesized that the increased risk for exposure in boys aged 4 to 6 was due to their being more active outdoors, whereas in women aged 25 to 30, the increased risk was due to their roles related to feeding, purchasing, or handling sick poultry in the affected countries.

Information on the effects of H5N1 virus infection on pregnant women is limited, but there are several reasons for concern. Pregnant women are shown to be at increased risk for severe complications from seasonal influenza [50–52]. Several reports also suggest that pregnant women were at high risk of severe illness and death during the pandemics of 1918 and 1957 [53–55]. The WHO recently noted that four of the six pregnant women infected with H5N1 virus have died [47,56]. A detailed clinical report of one of these women documents rapid progression to multiorgan failure and death, despite intensive supportive care [57].

The potential for effects of H5N1 virus infection on the fetus also needs to be considered. An increased risk for some birth defects after seasonal influenza infection or its associated fever has been observed in some studies [58,59]. High rates of spontaneous pregnancy loss and preterm birth were reported during the influenza pandemic of 1918 [54,55], and possible increases in defects of the nervous system, spontaneous pregnancy loss, fetal death, and preterm delivery were reported after the pandemic of 1957 [60,61]. The effects of H5N1 virus on the fetus are unknown; however, in the two pregnant women who had H5N1 virus who survived, both had spontaneous abortions [47]. In addition, transmission of H5N1 virus from mother to fetus recently has been documented in one case [48]. During infection with other influenza viruses, viremia and placental transmission seem to occur infrequently [62,63], so the finding of vertical transmission of H5N1 virus infection might suggest a higher risk for adverse fetal effects with H5N1 virus compared with other influenza viruses [63].

Severe acute respiratory syndrome coronavirus

The 2003 epidemic of SARS started in China and spread rapidly throughout the world, affecting more than 8000 people and claiming at least 750 lives. A novel coronavirus, SARS, was isolated from patients and identified as the causative agent in the epidemic. This virus is believed originally transmitted to humans from the palm civet, a feline found in food markets in China [64]. The epidemic in Hong Kong involved 1755 patients diagnosed with SARS, resulting in 302 deaths. In this cohort, the rates of ARDS and overall case mortality among women were significantly lower than those in men after adjustment for multiple variables, including age [65]. The basis for the more benign course in female SARS patients is not known.

Twelve pregnant women were known to be infected with SARS in Hong Kong, and most information regarding the course of SARS in pregnancy comes from this cohort. When compared with matched nonpregnant SARS patients, the pregnant women who were studied demonstrated more severe pulmonary disease and higher case fatality rates and were more likely to develop renal failure and disseminated intravascular coagulopathy [66]. Perinatal outcomes in these women were dismal, with four of seven early trimester patients spontaneously aborting and four of five whose pregnancy continued beyond 24 weeks gestation delivering preterm. Two infants who were born to mothers who had acute illness showed intrauterine growth restriction but no evidence of vertical transmission. Systematic evaluation failed to detect any evidence of neonatal or placental infection, even in babies born during acute maternal SARS infection with demonstrable viral shedding [67]. Two women who had pregnancy-associated SARS in the United States and one in Canada recovered from their acute illness and went on to deliver healthy, uninfected neonates [68–70]. Eleven of the 12 pregnant patients in Hong Kong received intravenous ribavirin therapy versus none of the three North American patients, leaving the possibility that the difference in perinatal outcomes is related to the drug rather than the virus. The differences in outcome noted for pregnant women (in a comparison with nonpregnant women), however, in the Hong Kong case-control study were independent of ribavirin, as it was used equally in the two groups [66]. Ribavirin is a known teratogen in animals, and toxicity has not been systematically evaluated in human pregnancy because of its category X status as designated by the Food and Drug Administration [22].

Spirochetes

Less commonly categorized as emerging infections, nonviral pathogens nonetheless are described as the source of newly discovered or newly expanding diseases. The spirochetes comprise a group of bacterial pathogens with a particular tendency for perinatal transmission; the best known of this group, *Treponema pallidum*, is the causative agent of syphilis. The

impact of syphilis on women historically has been substantial because of its sexual transmission and association with stillbirth and other adverse pregnancy outcomes. Since the advent of penicillin in the twentieth century, however, this disease largely has been brought under control. Other spirochetal illnesses, however, still fall into the category of emerging infectious diseases. During the 1970s, *Borrelia burgdorferi* was identified as the cause of a chronic, relapsing febrile illness, named Lyme disease, after the Connecticut town where it was discovered. The Lyme spirochete was found to be disseminated through bites from species of deer tick found throughout North America. During the subsequent epidemiologic characterization of Lyme disease, it was shown to cause transplacental infection of the fetus and was associated with stillbirth [71,72]. Multiple reports of congenital Lyme disease prompted large serosurveys of pregnant women; these studies also suggested a link with pregnancy wastage and congenital defects. Subsequent systematic inquiries, however, have failed to show any significant relationship between Lyme serostatus and adverse pregnancy outcomes [73]. Thus, although *B burgdorferi* has been shown to cause fetal infection, the combination of low disease prevalence and poor sensitivity of diagnostic tests has left doubt as to the clinical significance of these findings. Current recommendations suggest symptom-based antibiotic treatment of pregnant women who have suspected Lyme disease before serologic results are available.

Tick-borne relapsing fever (TBRF), endemic worldwide as a cause of severe intermittent febrile illness, is caused by multiple spirochete species of the *Borrelia* genus. There is now believed a rodent reservoir of *Borrelia* infection, making TBRF another zoonotic disease [74]. The tick vector thrives in poor housing conditions, often causing outbreaks of TBRF in villages with tick-infested huts. That phenomenon makes epidemic TBRF more common in economically disadvantaged areas, such as sub-Saharan Africa, but recent cases also are reported in women throughout the western United States [75,76]. In endemic areas, the incidence of TBRF can be as great as 11 cases per 100 person-years—the highest of any known bacterial pathogen in Africa—making it a major public health concern [74]. *Borrelia* infection has for years been known to cause severe disease in pregnant women, manifesting as stillbirth, preterm birth, neonatal death, and maternal death [77,78]. Adverse pregnancy outcomes occur in as many as 50% of patients, and the prevalence of TBRF among pregnant hospitalized patients at a hospital in southern Zaire was estimated at 6% [79]. Diagnosis can be made on clinical grounds in areas of high prevalence, but demonstration of spirochetemia on peripheral blood smear is the diagnostic criterion of choice. Treatment is with penicillin, doxycycline (contraindicated in the pregnant woman), or erythromycin. Especially during spirochetemia, treatment can be associated with Jarisch-Herxheimer reactions; thus, intensive monitoring is recommended [75]. It is not clear that antibiotic therapy improves short-term maternal or fetal outcomes [78].

Another zoonotic spirochetal illness, leptospirosis, has been strongly associated with spontaneous abortion. *Leptospirosa* species generally are transmitted through ingestion of water contaminated with infected animal urine or feces, and transmission may be associated with farm animals during outbreaks. Infection results in jaundice, malaise, fever, and myalgias but usually is self-limiting. The organism is endemic to Latin America; however, it is found sporadically worldwide. As early as the 1960s, leptospires were observed in aborted fetal tissues from infected women, and the infection was believed to cause pregnancy wastage [80]. Multiple case reports have confirmed this association, but large studies have not been performed to further characterize the phenomenon. From case reports, it seems that first- and second-trimester maternal infection is associated more strongly with poor pregnancy outcome (50% or greater loss rate) than third-trimester infection [81]. Congenital transmission to live-born infants has been documented after third-trimester maternal infection [81]. It is not known whether or not early treatment of maternal leptospirosis can prevent spontaneous abortion, but antimicrobial therapy is recommended to decrease the duration and severity of the illness.

Chagas' disease

Chagas' disease, endemic to South America, Central America, and Mexico, recently has become a concern in the United States because of the large immigrant population [82]. The disease is caused by infection with *Trypanosoma cruzi,* a blood-borne protozoan parasite transmitted most commonly to humans from vertebrate intermediates via the reduviid bug vector. The vector is found throughout the endemic areas, and infected insects also have been identified across the southern United States [82]. Asymptomatic, seropositive women can transmit the parasite transplacentally, with a congenital transmission rate of 1% to 10% [83]. Clinical manifestations in the infected neonate range from asymptomatic infection in the majority to hepatosplenomegaly, hydrops, and neonatal death in some cases. In recent years, cases of adult Chagas' disease increasingly have been diagnosed in the United States, even appearing in recipients of transplants from an infected donor [84]. Concern now exists regarding the safety of the United States blood supply, as newly approved screening tests yielded more than 300 positive results in selected donors in 2007 [84–86]. One recent study found a 0.3% seroprevalence among the asymptomatic maternal population in Houston, Texas, suggesting that many cases of congenital Chagas' disease are undiagnosed each year in the United States [87]. Neonatal cure rates as high as 90% are achieved when appropriate antimicrobial therapy is initiated during the first year of life, so early diagnosis is imperative [88]. Maternal implications of chronic infection also must be considered, as *T cruzi* chronically infects the myocardium and can lead to cardiomyopathy, a particularly dangerous condition in pregnancy. Cardiomyopathy or

cardiac conduction defects of unknown etiology in a pregnant woman from an endemic area should prompt testing for *T cruzi* antibodies, followed by testing and, if necessary, treatment of the neonate with benznidazole or nifurtimox [88]. In the United States, benznidazole and nifurtimox are not approved by the Food and Drug Administration but can be obtained under investigational new drug protocols through the CDC Drug Service (telephone number: 404-639-3670) [88,89].

Bioterrorism

Most potential biologic weapons agents also are emerging or zoonotic diseases that can be found regularly under natural conditions. The CDC has compiled a list of select agents [90] whose propagation and possession are regulated by federal law based on their lethality and potential for use as biologic weapons [91]. Possession, use, and transfer of select agents and toxins that pose a severe threat to public health and safety are regulated by federal law to protect the public and laboratory workers. Many zoonotic diseases appear on the overlapping select agent list, meaning they are regulated by the CDC, under the Department of Health and Human Services or the Department of Agriculture, based on human or agricultural risk, respectively. The agents that cause VHFs and 1918 pandemic influenza virus are included, along with many bacterial pathogens that offer better environmental stability for weaponization. The ideal weapons agents offer a low infectious dose, high case fatality rate, environmental stability, and efficient human-to-human transmission, allowing a small inoculum to infect a large population.

Smallpox has been widely discussed as a biologic weapons agent, having been actually weaponized by the former Soviet Union. After the worldwide eradication of smallpox in 1950, the need to vaccinate the population was deemed outweighed by the adverse effects of the vaccine. Thus, since the 1970s, people no longer are routinely immunized against smallpox. After the 2001 anthrax attacks in the United States, the military once again started vaccinating its personnel with the live attenuated vaccinia virus vaccine (a closely related virus), which provides 95% protection against smallpox infection for at least 5 years. Adverse effects include myocarditis, pericarditis, and occasional dilated cardiomyopathy [92]. Because this is a live attenuated vaccine, its routine prophylactic use is contraindicated in pregnancy. Rarely, the vaccination of pregnant women causes fetal vaccinia infection, which can cause pregnancy loss or neonatal death. During times of known exposure or outbreak, however, the vaccine should be administered to all exposed persons because the risk for smallpox in pregnancy far outweighs that for fetal vaccinia [93]. From limited historical data it is clear that smallpox infection in pregnancy results in case fatality rates as high as 50% and at least a 50% rate of pregnancy loss regardless of gestational age [94]. Pregnant women also are significantly more likely to develop a fatal form of smallpox, known as hemorrhagic smallpox, than their nonpregnant

counterparts [93]. Given the severity of disease, when planning for a possible smallpox attack, authorities must prioritize early vaccination strategies for pregnant women.

Another biologic warfare agent of concern, *C burnetii*, poses a disproportionate threat to women. *C burnetii* is the causative agent of Q fever, a zoonotic disease generally acquired by handling or inhaling contaminated material from infected cattle or sheep [95]. The economic impact of endemic Q fever results from recurrent abortion in animal herds, with large numbers of bacteria demonstrable in the products of conception. Contact with infected sheep placenta historically has been the greatest risk factor for acute Q fever in humans [95]. Q fever is attractive as a bioterror agent because the bacterium forms environmentally stable spores with a low inhalational infectious dose [96]. The disease generally is not fatal but causes pneumonia with weeks of disability during the acute phase and can cause chronic infection associated with treatment-resistant bacterial endocarditis. Human-to-human transmission of Q fever is rare. After zoonotic acquisition, male-to-female sexual transmission of *C burnetii* has been documented, with bacterial DNA found in semen months after the acute infection [97]. Infection of the female genital tract can be chronic but it rarely has been associated with fetal infection and pregnancy loss in humans [98]. *C burnetii*–infected women are less likely than infected men to manifest the symptoms of acute Q fever, and pregnancy reduces the rates even more [99]. Pregnant women, however, are more likely to develop chronic Q fever with endocarditis than are infected nonpregnant women [99]. Chronic infection is believed to result from a diminished cell-mediated immune response to the intracellular bacteria, helping to explain the predisposition to chronic rather than acute disease during pregnancy [4,96]. Although no prospective data are available, it has been recommended that pregnant women and immunosuppressed people receive prophylactic antibiotic therapy in the case of a bioterror attack [96]. Trimethoprim-sulfamethoxazole is recommended as first-line prophylaxis and treatment of Q fever in pregnancy, but chronic infection may require long-term treatment with doxycycline and rifampin after delivery [96]. No vaccine for Q fever is available in the United States.

Other high-profile biologic weapons agents include tularemia, plague, and anthrax. Treatment of pregnant women in the event of an attack with these agents recently has been reviewed [100], and the clinical manifestations in pregnancy generally do not differ from those in the general population. Several principles guide the treatment of pregnant women in the event of a biologic weapons attack. Most important, maternal health must be considered the first priority. Second, live attenuated vaccines are to be avoided except in the case of smallpox exposure. Finally, quinolones, tetracyclines, and ribavirin are associated with fetal toxicity and alternative drugs should be used when available. In the case of maternal exposure to life-threatening infectious agents, however, prophylaxis or treatment with these drugs may be indicated [100].

Summary

As recently recognized by the American Medical Association and the American Veterinary Medical Association, the majority of emerging threats to humans are zoonotic infections [2]. Others pose no danger for reservoir animals but when transmitted to humans they cause devastating disease. Because animals serve as the main natural reservoirs for emerging infections, the organisms can be maintained in nature for long periods in-between human outbreaks. Thus, when outbreaks occur, they confront health care workers with clusters of severe disease they likely have never before encountered and may have difficulty diagnosing. In the case of a bioterrorist attack, the mass casualties could be abrupt and catastrophic. Physicians must recognize the atypical manifestations of emerging infectious threats in female patients and accord special emphasis to the unique immunologic state of pregnancy as it relates to fetal and maternal risk. When outbreaks occur, systematic and prospective collection of data, including patient gender, pregnancy status, and complications, must accompany epidemiologic characterization of disease [101].

Acknowledgment

R.N.T. is supported by National Institutes of Health Women's Reproductive Health Research grant number NICHD5K12 HD001269-08.

References

[1] Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis 1995;1(1):7–15.
[2] A.M.A. Resolution 530 American Medical Association House of Delegates 2007.
[3] Fischer SA, Graham MB, Kuehnert MJ, et al. Transmission of lymphocytic choriomeningitis virus by organ transplantation. N Engl J Med 2006;354(21):2235–49.
[4] Jamieson DJ, Theiler RN, Rasmussen SA. Emerging infections and pregnancy. Emerg Infect Dis 2006;12(11):1638–43.
[5] Leone M, Honstettre A, Lepidi H, et al. Effect of sex on *Coxiella burnetii* infection: protective role of 17 beta-estradiol. J Infect Dis 2004;189(2):339–45.
[6] WHO. Addressing sex and gender in epidemic-prone infectious diseases. Geneva: WHO Press; 2007.
[7] LaBeaud AD, Ochiai Y, Peters CJ, et al. Spectrum of rift valley fever virus transmission in Kenya: insights from three distinct regions. Am J Trop Med Hyg 2007;76(5):795–800.
[8] Josephson MA, McKay DB. Considerations in the medical management of pregnancy in transplant recipients. Adv Chronic Kidney Dis 2007;14(2):156–67.
[9] Tsai TF, Vaughn DW, Solomon T, et al. Flaviviruses. Mandell, Douglas, and Bennett's principles and practice of infectious diseases. 6th edition. Philadelphia: Elsevier; 2005. p. 1926–50.
[10] Centers for Disease Control and Prevention. West Nile virus: statistics, surveillance, and control. Available at: www.cdc.gov/ncidod/dvbid/westnile/surv&control.htm. Accessed September 16, 2008.
[11] Warner RD, Kimbrough RC, Alexander JL, et al. Human West Nile virus neuroinvasive disease in texas, 2003 epidemic: regional differences. Ann Epidemiol 2006;16(10):749–55.

[12] O'Leary DR, Marfin AA, Montgomery SP, et al. The epidemic of West Nile virus in the united states, 2002. Vector Borne Zoonotic Dis 2004;4(1):61–70.
[13] Alpert SG, Fergerson J, Noel LP. Intrauterine west nile virus: ocular and systemic findings. Am J Ophthalmol 2003;136(4):733–5.
[14] Nguyen Q, Morrow C, Novick L, et al. Intrauterine West Nile virus infection—New York, 2002. JAMA 2003;289(3):295–6.
[15] CDC. Intrauterine West Nile virus infection—New York, 2002. MMWR Morb Mortal Wkly Rep 2002;51(50):1135–6.
[16] O'Leary DR, Kuhn S, Kniss KL, et al. Birth outcomes following West Nile virus infection of pregnant women in the United States: 2003–2004. Pediatrics 2006;117(3):e537–45.
[17] CDC. Possible West Nile virus transmission to an infant through breast-feeding: Michigan, 2002. MMWR Morb Mortal Wkly Rep 2002;51:877–8.
[18] Hinckley AF, O'Leary DR, Hayes EB. Transmission of west nile virus through human breast milk seems to be rare. Pediatrics 2007;119(3):e666–71.
[19] CDC. Update: interim guidance for minimizing risk for human lymphocytic choriomeningitis virus infection associated with pet rodents. MMWR Morb Mortal Wkly Rep 2005; 54(32):799–801.
[20] Barton LL, Mets MB, Beauchamp CL. Lymphocytic choriomeningitis virus: emerging fetal teratogen. Am J Obstet Gynecol 2002;187(6):1715–6.
[21] Jamieson DJ, Kourtis AP, Bell M, et al. Lymphocytic choriomeningitis virus: an emerging obstetric pathogen? Am J Obstet Gynecol 2006;194(6):1532–6.
[22] Thomson Healthcare I. Physicians' desk reference. 62nd edition. Montvale (NJ): Thomson Healthcare, Inc; 2008.
[23] Yellow fever fact sheet. World Health Organization. Available at: http://www.who.int/mediacentre/factsheets/fs100/en/. Accessed September 24, 2007.
[24] Suzano CE, Amaral E, Sato HK, et al. The effects of yellow fever immunization (17dd) inadvertently used in early pregnancy during a mass campaign in Brazil. Vaccine 2006; 24(9):1421–6.
[25] Goncalves NV, Rebelo JM. Epidemiological characteristics of dengue in the municipality of Sao Lluis, Maranhao, Brazil, 1997–2002. Cad Saude Publica 2004;20(5):1424–31 [in Spanish].
[26] Yamashiro T, Disla M, Petit A, et al. Seroprevalence of IgG specific for dengue virus among adults and children in Santo Domingo, Dominican Republic. Am J Trop Med Hyg 2004; 71(2):138–43.
[27] Chye JK, Lim CT, Ng KB, et al. Vertical transmission of dengue. Clin Infect Dis 1997;25(6): 1374–7.
[28] Sirinavin S, Nuntnarumit P, Supapannachart S, et al. Vertical dengue infection: case reports and review. Pediatr Infect Dis J 2004;23(11):1042–7.
[29] Carles G, Peiffer H, Talarmin A. Effects of dengue fever during pregnancy in French Guiana. Clin Infect Dis 1999;28(3):637–40.
[30] Kerdpanich A, Watanaveeradej V, Samakoses R, et al. Perinatal dengue infection. Southeast Asian J Trop Med Public Health 2001;32(3):488–93.
[31] Monson MH, Cole AK, Frame JD, et al. Pediatric Lassa fever: a review of 33 Liberian cases. Am J Trop Med Hyg 1987;36(2):408–15.
[32] Price ME, Fisher-Hoch SP, Craven RB, et al. A prospective study of maternal and fetal outcome in acute Lassa fever infection during pregnancy. BMJ 1988;297(6648):584–7.
[33] Walker DH, McCormick JB, Johnson KM, et al. Pathologic and virologic study of fatal Lassa fever in man. Am J Pathol 1982;107(3):349–56.
[34] Mupapa K, Mukundu W, Bwaka MA, et al. Ebola hemorrhagic fever and pregnancy. J Infect Dis 1999;179(Suppl 1):S11–2.
[35] Sadek RF, Khan AS, Stevens G, et al. Ebola hemorrhagic fever, Democratic Republic of the Congo, 1995: determinants of survival. J Infect Dis 1999;179(Suppl 1):S24–7.

[36] Peters CJ, LeDuc JW. An introduction to Ebola: the virus and the disease. J Infect Dis 1999; 179(Suppl 1):ix–xvi.
[37] Howard MJ, Doyle TJ, Koster FT, et al. Hantavirus pulmonary syndrome in pregnancy. Clin Infect Dis 1999;29(6):1538–44.
[38] Gilson GJ, Maciulla JA, Nevils BG, et al. Hantavirus pulmonary syndrome complicating pregnancy. Am J Obstet Gynecol 1994;171(2):550–4.
[39] Ma RM, Xiao H, Jing XT, et al. Hemorrhagic fever with renal syndrome presenting with intrauterine fetal death. A case report. J Reprod Med 2003;48(8):661–4.
[40] Arishi HM, Aqeel AY, Al Hazmi MM. Vertical transmission of fatal rift valley fever in a newborn. Ann Trop Paediatr 2006;26(3):251–3.
[41] Niklasson B, Liljestrand J, Bergstrom S, et al. Rift valley fever: a sero-epidemiological survey among pregnant women in Mozambique. Epidemiol Infect 1987;99(2): 517–22.
[42] Avian influenza (''Bird flu'') fact sheet. Available at: www.who.int/mediacentre/factsheets/avian_influenza/en/print.html. Accessed January 24, 2008.
[43] Hhs pandemic influenza plan. Available at: http://www.hhs.gov/pandemicflu/plan/pdf/HHSPandemicInfluenzaPlan.pdf. Accessed February 27, 2008.
[44] Mounts AW, Kwong H, Izurieta HS, et al. Case-control study of risk factors for avian influenza A (H5N1) disease, Hong Kong, 1997. J Infect Dis 1999;180(2):505–8.
[45] Cumulative number of confirmed human cases of avian influenza A/H5N1 reported to WHO. Available at: www.pandemicflu.gov. Accessed January 4, 2008.
[46] Ungchusak K, Auewarakul P, Dowell SF, et al. Probable person-to-person transmission of avian influenza A (H5N1) [see comment]. N Engl J Med 2005;352(4):333–40.
[47] Writing Committee of the Second World Health Organization Consultation on Clinical Aspects of Human Infection with Avian Influenza A (H5N1) Virus. Update on avian influenza A (H5N1) virus infection in humans. N Engl J Med 2008;358(3):261–73.
[48] Gu J, Xie Z, Gao Z, et al. H5N1 infection of the respiratory tract and beyond: a molecular pathology study [see comment]. Lancet 2007;370(9593):1137–45.
[49] Chen JM, Chen JW, Dai JJ, et al. A survey of human cases of H5N1 avian influenza reported by the WHO before June 2006 for infection control. Am J Infect Control 2007; 35(7):467–9.
[50] Dodds L, McNeil SA, Fell DB, et al. Impact of influenza exposure on rates of hospital admissions and physician visits because of respiratory illness among pregnant women. CMAJ 2007;176(4):463–8.
[51] Neuzil KM, Reed GW, Mitchel EF, et al. Impact of influenza on acute cardiopulmonary hospitalizations in pregnant women. Am J Epidemiol 1998;148(11):1094–102.
[52] Schanzer DL, Langley JM, Tam TW. Influenza-attributed hospitalization rates among pregnant women in Canada 1994–2000. J Obstet Gynaecol Can 2007;29(8):622–9.
[53] Freeman DW, Barno A. Deaths from Asian influenza associated with pregnancy. Am J Obstet Gynecol 1959;78:1172–5.
[54] Harris J. Influenza occurring in pregnant women. JAMA 1919;72:978–80.
[55] Nuzum J, Pilot I, Stangl F, et al. Pandemic influenza and pneumonia in a large civilian hospital. JAMA 1918;71:1562–5.
[56] Clinical management of human infection with avian influenza A (H5N1) virus. Available at: www.who.int/csr/disease/avian_influenza/guidelines/ClinicalManagement07.pdf. Accessed January 24, 2008.
[57] Shu Y, Yu H, Li D. Lethal avian influenza a (H5N1) infection in a pregnant woman in Anhui province, China. N Engl J Med 2006;354(13):1421–2.
[58] Acs N, Banhidy F, Puho E, et al. Maternal influenza during pregnancy and risk of congenital abnormalities in offspring. Birth Defects Research 2005;73(12):989–96.
[59] Moretti ME, Bar-Oz B, Fried S, et al. Maternal hyperthermia and the risk for neural tube defects in offspring: systematic review and meta-analysis. Epidemiology 2005; 16(2):216–9.

[60] Coffey VP, Jessop WJ. Maternal influenza and congenital deformities. A follow-up study. Lancet 1963;1:748–51.
[61] Hardy JM, Azarowicz EN, Mannini A, et al. The effect of Asian influenza on the outcome of pregnancy, Baltimore, 1957–1958. Am J Public Health Nation's Health 1961;51:1182–8.
[62] Zou S. Potential impact of pandemic influenza on blood safety and availability. Transfus Med Rev 2006;20(3):181–9.
[63] Irving WL, James DK, Stephenson T, et al. Influenza virus infection in the second and third trimesters of pregnancy: a clinical and seroepidemiological study. BJOG 2000;107(10): 1282–9.
[64] Guan Y, Zheng BJ, He YQ, et al. Isolation and characterization of viruses related to the SARS coronavirus from animals in southern china. Science 2003;302(5643):276–8.
[65] Leung GM, Hedley AJ, Ho LM, et al. The epidemiology of severe acute respiratory syndrome in the 2003 Hong Kong epidemic: an analysis of all 1755 patients [summary for patients in ann intern med. 2004 nov 2;141(9):I63; pmid: 15520417]. Ann Intern Med 2004;141(9):662–73.
[66] Lam CM, Wong SF, Leung TN, et al. A case-controlled study comparing clinical course and outcomes of pregnant and non-pregnant women with severe acute respiratory syndrome. BJOG 2004;111(8):771–4.
[67] Wong SF, Chow KM, Leung TN, et al. Pregnancy and perinatal outcomes of women with severe acute respiratory syndrome. Am J Obstet Gynecol 2004;191(1):292–7.
[68] Yudin MH, Steele DM, Sgro MD, et al. Severe acute respiratory syndrome in pregnancy. Obstet Gynecol 2005;105(1):124–7.
[69] Robertson CA, Lowther SA, Birch T, et al. SARS and pregnancy: a case report [see comment]. Emerg Infect Dis 2004;10(2):345–8.
[70] Stockman LJ, Lowther SA, Coy K, et al. SARS during pregnancy, United States [comment]. Emerg Infect Dis 2004;10(9):1689–90.
[71] Schlesinger PA, Duray PH, Burke BA, et al. Maternal-fetal transmission of the Lyme disease spirochete, *Borrelia burgdorferi*. Ann Intern Med 1985;103(1):67–8.
[72] MacDonald AB, Benach JL, Burgdorfer W. Stillbirth following maternal Lyme disease. N Y State J Med 1987;87(11):615–6.
[73] Elliott DJ, Eppes SC, Klein JD. Teratogen update: lyme disease. Teratology 2001;64(5): 276–81.
[74] Vial L, Diatta G, Tall A, et al. Incidence of tick-borne relapsing fever in west Africa: longitudinal study. Lancet 2006;368(9529):37–43.
[75] Guggenheim JN, Haverkamp AD. Tick-borne relapsing fever during pregnancy: a case report. J Reprod Med 2005;50(9):727–9.
[76] Anonymous. Acute respiratory distress syndrome in persons with tickborne relapsing fever–three states. 2004–2005. MMWR Morb Mortal Wkly Rep 2007;56(41):1073–6.
[77] Shirts SR, Brown MS, Bobitt JR. Listeriosis and borreliosis as causes of antepartum fever. Obstet Gynecol 1983;62(2):256–61.
[78] Jongen VH, van Roosmalen J, Tiems J, et al. Tick-borne relapsing fever and pregnancy outcome in rural tanzania. Acta Obstet Gynecol Scand 1997;76(9):834–8.
[79] Dupont HT, La Scola B, Williams R, et al. A focus of tick-borne relapsing fever in southern zaire. Clin Infect Dis 1997;25(1):139–44.
[80] Coghlan JD, Bain AD. Leptospirosis in human pregnancy followed by death of the foetus. Br Med J 1969;1(5638):228–30.
[81] Shaked Y, Shpilberg O, Samra D, et al. Leptospirosis in pregnancy and its effect on the fetus: case report and review. Clin Infect Dis 1993;17(2):241–3.
[82] Diaz JH. Chagas disease in the United States: a cause for concern in Louisiana? J La State Med Soc 2007;159(1):21–3.
[83] Torrico F, Alonso-Vega C, Suarez E, et al. Maternal *Trypanosoma cruzi* infection, pregnancy outcome, morbidity, and mortality of congenitally infected and non-infected newborns in Bolivia. Am J Trop Med Hyg 2004;70(2):201–9.

[84] Anonymous. Chagas disease after organ transplantation—United States, 2001. MMWR Morb Mortal Wkly Rep 2002;51(10):210–2.
[85] Ritter J. New test scans for blood parasite. Chicago sun times. Chicago: Sun Times News Group; 2007.
[86] Available at: http://www.aabb.org/Content/Programs_and_Services/Data_Center/Chagas/chagas.htm Accessed January 24, 2008.
[87] Di Pentima MC, Hwang LY, Skeeter CM, et al. Prevalence of antibody to *Trypanosoma cruzi* in pregnant hispanic women in Houston. Clin Infect Dis 1999;28(6):1281–5.
[88] Bern C, Montgomery SP, Herwaldt BL, et al. Evaluation and treatment of Chagas disease in the United States: a systematic review. JAMA 2007;298(18):2171–81.
[89] Chagas disease. Available at: http://www.cdc.gov/chagas/hcp.html. Accessed January 12, 2008.
[90] Available at: www.cdc.gov. Accessed January 24, 2008.
[91] Pastel RH, Demmin G, Severson G, et al. Clinical laboratories, the select agent program, and biological surety (biosurety). Clin Lab Med 2006;26(2):299–312.
[92] Poland GA, Grabenstein JD, Neff JM. The U.S. smallpox vaccination program: a review of a large modern era smallpox vaccination implementation program. Vaccine 2005; 23(17–18):2078–81.
[93] Suarez VR, Hankins GD. Smallpox and pregnancy: from eradicated disease to bioterrorist threat [see comment]. Obstet Gynecol 2002;100(1):87–93.
[94] Nishiura H. Smallpox during pregnancy and maternal outcomes. Emerg Infect Dis 2006; 12(7):1119–21.
[95] Parker NR, Barralet JH, Bell AM. Q fever. Lancet 2006;367(9511):679–88.
[96] Madariaga MG, Rezai K, Trenholme GM, et al. Q fever: a biological weapon in your backyard. Lancet Infect Dis 2003;3(11):709–21.
[97] Milazzo A, Hall R, Storm PA, et al. Sexually transmitted Q fever. Clin Infect Dis 2001; 33(3):399–402.
[98] Stein A, Raoult D. Q fever during pregnancy: a public health problem in southern France. Clin Infect Dis 1998;27(3):592–6.
[99] Tissot-Dupont H, Vaillant V, Rey S, et al. Role of sex, age, previous valve lesion, and pregnancy in the clinical expression and outcome of Q fever after a large outbreak. Clin Infect Dis 2007;44(2):232–7.
[100] Cono J, Cragan JD, Jamieson DJ, et al. Prophylaxis and treatment of pregnant women for emerging infections and bioterrorism emergencies. Emerg Infect Dis 2006;12(11):1631–7.
[101] Anker M. Pregnancy and emerging diseases. Emerg Infect Dis 2007;13(3):518–9.