

Reproductive System Infections in Women: Upper Genital Tract, Fetal, Neonatal and Infant Syndromes

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damage to the delicate structures of the fallopian tube prior to therapy. Future trials of antimicrobial therapies for pelvic inflammatory disease need to include long-term evaluation of determinants of post pelvic inflammatory disease sequelae such as recurrent pelvic inflammatory disease, tubal infertility and ectopic pregnancy. One study that used this type of design noted that polymicrobial tubal infection with abscess formation or *Chlamydia trachomatis* pelvic inflammatory disease had significantly worse fertility outcome than women with gonococcal pelvic inflammatory disease⁸. In large seroepidemiologic studies rates of pregnancy were significantly lower and pelvic inflammatory disease recurrence rates were significantly higher among women with high titers of *Chlamydia trachomatis* antibodies than those without such antibodies among a cohort of women treated for pelvic inflammatory disease suggesting that *Chlamydia trachomatis* pelvic inflammatory disease carries a worse fertility prognosis than other causes of pelvic inflammatory disease⁹.

Since *Chlamydia trachomatis* is such an important cause of pelvic inflammatory disease and sequelae it has been studied in considerable detail from epidemiologic, genomic and immunological points of view. Epidemiological analysis suggests that both duration of infection and reinfection are important in *Chlamydia trachomatis* pelvic inflammatory disease pathogenesis¹⁰⁻¹². Immunoepidemiologic studies suggest that antibodies to *Chlamydia trachomatis* molecular components such as *Chlamydia trachomatis* heat shock protein 60 correlate with sequelae such as tubal infertility, ectopic pregnancy, pelvic inflammatory disease and perihepatitis perhaps as a marker of long duration infection¹³⁻¹⁸. It is unlikely that *Chlamydia trachomatis* heat shock protein 60 is directly involved in disease pathogenesis⁹. Rather antibody responses to *Chlamydia trachomatis* heat shock protein 60 are co-linear with antibody to the whole *Chlamydia trachomatis* bacterial cell. Heat shock protein 60 is a single molecule measure of immune responses to persistent *Chlamydia trachomatis* infection because of its immunodominance during long duration infection¹⁹. In aggregate immunoepidemiological studies of *Chlamydia trachomatis* heat shock protein 60 show that antibody dominant immune responses correlate with diseases such as pelvic inflammatory disease and its sequelae.

double strand DNA breaks in infected host cells a casual pathway may exist where *Chlamydia trachomatis* infection of fallopian tube epithelial cells acts as a co-factor together with other inflammatory oncogenic factors in the genesis of ovarian cancer³¹.

Chorioamnion, Fetus, Neonate and Infant

Reproductive system infections during pregnancy rarely result in pelvic inflammatory disease. Rather ascending infection most commonly infects the chorioamnion and fetus or transmits during birth to cause disease in the neonate or infant. The major diseases produced by infection are chorioamnionitis and prematurity, stillbirth and neonatal and infant infection.

Chorioamnionitis and Prematurity

Chorioamnionitis is pathologically defined as inflammation of the fetal membranes and is the single most important risk factor for preterm birth and can be subclinical or clinical in presentation³². Chorioamnionitis is also the major risk factor for neonatal sepsis and death³³. Organisms associated with bacterial vaginosis (*Gardnerella vaginalis*, *Mobiluncus* sp., *Bacteroides* sp. etc) and the vaginal dysbiosis associated with desquamative inflammatory vaginitis (group B Streptococci, *Escherichia coli* etc) are commonly isolated from fetal membranes when chorioamnionitis is found pathologically³⁴. Treatment during later months of pregnancy for bacterial vaginosis does not prevent preterm birth whereas treatment during early pregnancy may do so³⁵. Intrapartum antimicrobial treatment for group B Streptococci reduces the risk of neonatal sepsis due to this microbe. Intrapartum gonococcal infection is also a major cause of pre term birth in areas where untreated maternal gonorrhoea is common³⁶.

Stillbirth

Intrauterine fetal death can result from maternal reproductive system infection. Blood borne spread of human immunodeficiency virus or syphilis to the placenta and fetus are the major microbial causes of stillbirth in Africa³⁷.

Neonatal Infection

Maternal infection with *Chlamydia trachomatis* or *Neisseria gonorrhoeae* frequently results in ophthalmia neonatorum^{36, 38}. Thirty to 40% of neonates exposed to *Chlamydia trachomatis* or *Neisseria gonorrhoeae* intrapartum become infected postpartum³⁹. Neonates with gonococcal ophthalmia neonatorum can be successfully treated with antimicrobials including ceftriaxone^{40, 41}. Ocular prophylaxis dramatically reduces the incidence of gonococcal and chlamydial ophthalmia neonatorum⁴². Neonates exposed during birth to maternal *Chlamydia trachomatis* infection are also at increased risk of developing infant pneumonia⁴³. All these risks for neonatal and infant infectious disease can be prevented by maternal screening for reproductive system infections during and prior to pregnancy.

Conclusions

Viewing reproductive system infections in women as encompassing diseases of the vulva, vagina, cervix, endometrium, fallopian tubes and ovaries and the chorioamnion, fetus, neonate and infant shows how they share common epidemiology, microbial etiologies and pathogenic mechanisms. The syndrome, etiologic agent, treatment and prevention modalities are summarized in table 1.

Existing disease control programs based on screening and treatment remain effective and important in improving the reproductive health of women. The impact of the absence of reproductive health services is seen in epidemiological settings where sexually transmitted infections are common and untreated. In such settings

tubal factor infertility is tragically common, maternal syphilis or human immunodeficiency virus infection increase stillbirth rates 3 to 5 fold and 3 to 5 % of newborns develop gonococcal or chlamydial ophthalmia neonatorum. In particular screening and treatment for *Chlamydia trachomatis* and *Neisseria gonorrhoeae*, syphilis and human immunodeficiency virus substantially improves the reproductive health of women as well as reduces the risk of fetal, neonatal and infant disease. Ocular prophylaxis at birth prevents ophthalmia neonatorum. Rolling out and supporting these programs at a global level is a major goal for global health programs best done within a comprehensive reproductive system framework.

An important realization has been that control programs for the bacterial sexually transmitted pathogens profoundly alter the clinical features and patterns of disease. Because of the extended duration of time post infection that it takes to acquire immunity to these pathogens, shortening the duration of infection by screening and antimicrobial treatment reduces herd immunity and shifts the clinical features of infection towards subclinical infection. Thus disease control programs based on screening and antimicrobial treatment have important limits. The major sexually transmitted bacterial pathogens *Chlamydia trachomatis*, *Neisseria gonorrhoeae* and *Treponema pallidum* will require vaccines to fully achieve control. Fortunately molecular study of these pathogens has generated promising candidates that can soon be brought forward for clinical evaluation as was successfully done for human papilloma virus. Vaccines are at the forefront of research to prevent reproductive system infections of women.

Despite advancements in understanding reproductive system infections in women much remains incompletely known. For instance the causes of vulvar vestibulitis need to be understood at a microbial and immunological level because it is such a common cause of painful intercourse. An understanding of the cause of recurrent vulvovaginal candidiasis may well improve prevention of vulvar vestibulitis. Why a Lactobacilli dominant microbiome is lost in some women resulting in susceptibility to bacterial vaginosis, trichomoniasis and desquamative inflammatory vaginitis needs to be understood. Diagnostic test development is needed to improve control of reproductive system infection in women. In particular

molecular tests for the microbial composition of the vaginal microbiome would improve the recognition of bacterial vaginosis, desquamative inflammatory vaginitis, trichomoniasis and candidiasis. Additionally improved imaging modalities of the uterus, fallopian tubes and ovaries would advance diagnosis of clinical and subclinical pelvic inflammatory disease and its sequelae. Current evidence suggests that magnetic resonance imaging has the resolution necessary to image the pelvis including the fallopian tubes and should be used in future studies of pelvic inflammatory disease^{44, 45}. Lastly tests that diagnose subclinical chorioamnionitis have the potential to have a major impact on preterm birth^{46, 47}.

Recurrent infection remains a major problem for reproductive system infection in women. Randomized clinical trials using antimicrobials, sex steroids and immune modulators for vulvar vestibulitis, bacterial vaginosis, desquamative inflammatory vaginitis, vulvovaginal candidiasis and pelvic inflammatory disease may lead to therapies which reduce relapse rates and/or post disease sequelae. Strategies that stabilize a Lactobacilli vaginal microbiome may prevent recurrences of bacterial vaginosis, desquamative inflammatory vaginitis and protect against a broad variety of sexually transmitted pathogens. Strategies that enhance the proportion of male sexual partners who are treated will be particularly important to reducing recurrence rates for the sexually transmitted pathogens.

Additional antimicrobial interventions in pregnancy are needed to address the continuing problem of prematurity. It is remarkable that despite the continuing improvement in survival of neonates born prematurely the rates of prematurity have not changed. The impact of treatment of vaginal dysbiosis in pregnancy on preterm birth remains incompletely defined. Treatment of bacterial vaginosis in late pregnancy does not prevent preterm birth however treatment in early pregnancy may do so³⁵. Studies should focus on early interventions, use of probiotics with antimicrobials and evaluate effects on both preterm birth and histopathologic evidence of chorioamnionitis. Given the propensity of bacterial vaginosis to produce endometrial biofilm formation, evaluation of treatment prior to pregnancy may even be useful.

Two Nobel Prizes in Medicine and Physiology have been awarded to scientists for advances they have made in women's reproductive health. In 2008, Nobel Prizes were awarded to Harald zur Hausen for the discovery of human papilloma viruses causing cervical cancer and to Françoise Barre-Sinoussi and Luc Montagnier for their discovery of the human immunodeficiency virus. In 2010 the Nobel Prize was given to Robert Edwards for the development of human in vitro fertilization therapy initially used in the treatment of post pelvic inflammatory disease tubal infertility. Despite the awarding of Nobel Prizes, this class of infectious diseases remains under-studied, under-appreciated, under-diagnosed and inconsistently treated. Future research which addresses the major questions are likely to improve the reproductive health of women and the population health of humanity⁴⁸.

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Table 1: Reproductive system infection syndromes in women and their recommended treatment and prevention.

Syndrome	Etiology	Treatment	Prevention
Genital ulcer disease	<i>Treponema pallidum</i>	Penicillin	
	<i>Haemophilus ducreyi</i>	Ceftriaxone	
	<i>Klebsiella granulomatis</i>	Azithromycin	
	<i>Chlamydia trachomatis</i> (Lymphogranuloma venerum)	Doxycycline	
	Herpes simplex virus	Acyclovir	
Genital warts	Human papilloma virus	Topical Podofilox	HPV vaccine
Vulvar vestibulitis	Cutaneous hypersensitivity to microbial antigens	Surgery	
Vulvovaginitis	<i>Candida albicans</i>	Fluconazole	
Bacterial vaginosis	<i>Gardnerella vaginalis</i>	Topical clindamycin	
	<i>Atopobium</i>		
	<i>Mobiluncus</i>		
	Other anaerobes		
Desquamative inflammatory vaginitis	Group B Streptococci	Topical clindamycin	
	<i>E. coli</i>		
	<i>Staph aureus</i>		
	Other facultative anaerobes		
Trichomoniasis	<i>Trichomonas vaginalis</i>	Metronidazole	
Mucopurulent cervicitis	<i>Chlamydia trachomatis</i>	Azithromycin	
	<i>Neisseria gonorrhoeae</i>	Ceftriaxone plus Azithromycin	
	<i>Mycoplasma genitalium</i>	Moxifloxacin	
	Herpes simplex virus	Acyclovir	
Cervical neoplasia	Human papilloma virus	Surgery	HPV vaccine, Pap smears

Table 1 Continue

Syndrome	Etiology	Treatment	Prevention
Pelvic inflammatory disease	<i>Chlamydia trachomatis</i> <i>Neisseria gonorrhoeae</i> <i>Mycoplasma genitalium</i> <i>Peptostreptococci</i> <i>Prevotella</i> <i>Sneathia</i> Other anaerobes β - <i>Streptococci</i> <i>E. coli</i> <i>Haemophilus influenza</i> <i>Staph aureus</i>	Ceftriaxone plus Azithromycin plus Metronidazole	Condom Screening and treatment for <i>Chlamydia trachomatis</i> and <i>Neisseria gonorrhoeae</i>
Tubal infertility	<i>Chlamydia trachomatis</i> <i>Neisseria gonorrhoeae</i> <i>Mycoplasma genitalium</i> Polymicrobial abscess	in vitro fertilization	Screening and treatment for <i>Chlamydia trachomatis</i> and <i>Neisseria gonorrhoeae</i>
Ectopic pregnancy	<i>Chlamydia trachomatis</i> <i>Neisseria gonorrhoeae</i>	Methotrexate or surgery	Screening and treatment for <i>Chlamydia trachomatis</i> and <i>Neisseria gonorrhoeae</i>
Ovarian cancer	Post pelvic inflammatory disease	Surgery Chemotherapy Immunotherapy	
Prematurity	Subclinical Chorioamnionitis		Screening and treating bacterial vaginosis in early pregnancy
Clinical amnionitis	Group B <i>Streptococci</i> <i>E. coli</i> <i>Prevotella</i> <i>Bacteroides</i> <i>Neisseria gonorrhoeae</i> <i>Chlamydia trachomatis</i>	Cefoxitin plus doxycycline	
Stillbirth	<i>Treponema pallidum</i> Human immunodeficiency virus	Penicillin Antiretroviral therapy	Screening and treatment for syphilis and HIV in pregnancy

Table 1 Continue

Syndrome	Etiology	Treatment	Prevention
Congenital or Perinatal infection	<i>Treponema pallidum</i>	Penicillin	Screening and treatment for syphilis and HIV in pregnancy
	Human immunodeficiency virus	Antiretroviral therapy	
	Herpes simplex virus	Acyclovir	
Neonatal sepsis	Group B Streptococci <i>E. coli</i>	Cefotaxime	
Ophthalmia Neonatum	<i>Chlamydia trachomatis</i>	Erythromycin	Ocular prophylaxis
	<i>Neisseria gonorrhoeae</i>	Ceftriaxone	Erythromycin
Laryngeal Papillomatosis	Human papilloma virus	Surgery	HPV vaccine
Infant pneumonia	<i>Chlamydia trachomatis</i>	Erythromycin	Screening and treatment for <i>Chlamydia trachomatis</i> and <i>Neisseria gonorrhoeae</i>

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