MBE, 20 (9): 16131–16147.
DOI: 10.3934/mbe.2023720
Received: 01 June 2023
Revised: 17 July 2023
Accepted: 30 July 2023
Published: 09 August 2023

http://www.aimspress.com/journal/MBE

***Research article***

**The effect of screening on the health burden of chlamydia: An evaluation of compartmental models based on person-days of infection**

Jack Farrell, Owen Spolyar and Scott Greenhalgh\*

Department of Mathematics, Siena College, Loudonville, NY, USA

**\* Correspondence:** Email: sgreenhalgh@siena.edu.

This appendix provides further details for the analysis of our compartmental model of chlamydia transmission. We outline the calculation of average duration of complications associated with chlamydial infection, give details behind our disability adjusted life-years (DALYs) calculation, and provide details on the formulation of the mean residual waiting-time used in model dynamics.

**S.1 Parameter estimation.** Here we outline the derivation of the duration of sequelae due to chlamydial infection, including the duration of moderate-to-severe pelvic inflammatory disease (PID), the duration of epididymo-orchitis, and the duration of primary and secondary infertility. We also provide details on the reproductive capabilities of both men and women and how these sequelae impact their ability to optimally reproduce within the window of average reproductive capability.

**S.1.1 The transmission rate of chlamydia.** From our model, we estimate the average duration of moderate PID, , and severe PID, , due to infection

Table S.1. Estimated transmission rates for SEAIR and gSEAIR models

|  |  |
| --- | --- |
|  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  | 0.0524 | 0.0498 | 0.0565 | 0.0555 | 0.0615 | 0.0607 | 0.0611 | 0.0616 | 0.0617 | 0.0614 |

**S.1.2 The duration of moderate and severe pelvic inflammatory disease.** From our model, we estimate the average duration of moderate PID, , and severe PID, , due to infection in women by

|  |  |
| --- | --- |
|  | (S1) |

where represents the number of years a female is able to reproduce, represents the average time that a female is able to reproduce before potentially contracting chlamydial infection, and represents the years lost in reproductivity due to PID (see Table 1 for details).

We also assume that the time when a female begins being fertile is at the onset of menarche, which on average begins at 12.5 years [1]. From the literature, the average length of reproductive capability in females is 39 years [2]. It also follows that there are 8.5 years of reproductive capability in women before the average age that a female contracts chlamydial infection, which is at 21 years, assuming uniformity across the United States population [3]. Thus, it follows that

 years and years.

To determine , we estimate the average time for a woman asymptomatically infected with chlamydia to develop PID. As 1 in 10 women infected with chlamydia develops PID within a year [4], assuming an exponential distribution, we have that

It follows that the rate of PID is

year

and consequently,

years.

Substituting into (S1) yields

years.

Furthermore, because PID is most common in individuals aged 15-24, we assume the average age of PID onset is . Thus, the years of life lost from death due to PID is

where years is the average lifespan in the U.S. [5].

**S.1.3 The proportion of cases classified as severe PID**. We estimate the proportion of moderate and severe PID cases based on published data, which estimates that 15%-20% of PID cases are severe [6]. Thus, we assume

The proportion of moderate PID cases are taken as .

**S.1.4** **The duration of epididymo-orchitis.** Epididymo-orchitis is a common complication of chlamydial infection in males [7], which causes infertility [8].

To determine the average duration of complications associated with epididymo-orchitis, , we assume that

|  |  |
| --- | --- |
|  | (S2) |

where represents the number of years a male is capable of reproducing, represents the average age that a male contracts chlamydial infection, and represents the years lost in reproductivity due to epididymo-orchitis infection (see Table 1 for more details).

We define the ability of a male to reproduce as the time when sperm are most motile and representative of optimal fertility. We assume this time begins at the onset of spermarche, which on average begins at 13.4 years [9] and continues to age 55, which is when motility counts begin to diminish [10]. It follows that

 years.

In addition, we base on the highest prevalence between 20 to 24 years old [11]. Taking the average, it follows that the average age a male contracts chlamydial infection is 22 years. Thus, it follows that

 years [11].

To determine , we estimate the average time for a male asymptomatically infected with chlamydia to develop epididymo-orchitis. Based on the literature, 12.3% of infected men develop epididymo-orchitis within a year [12]. Assuming an exponential distribution, this would imply that

Thus, it follows that the rate of epididymo-orchitis is

 year.

To determine , it follows that

years.

Substituting into (S2) yields

years.

**S.2. Disability adjusted life-years.** We quantify the health burden caused by chlamydia using the health metric Disability adjusted life-years (DALYs). Specifically, we calculate time-discounted DALYs through years lived with disability (YLD) and the years of life lost (YLL):

and

Here, , , and are the proportion, DALY weight, and average duration of the outcome associated to chlamydia infection, as outlined in Table 1, and is the proportion of chlamydial infections held by women. It follows that the total DALYs for the scenario is

The DALYs averted from the scenario are then determined by subtracting the total DALYS of a scenario from the baseline:

**S.3 A class of distributions with periodic hazard rate.** The distribution for our model’s infectious period is based on a extending the Probability density function (PDF) [13]

where , , and to that of a Fourier cosine series:

where and

Our distribution exhibits several convenient properties, including a closed-form Cumulative distribution function (CDF)

It also has a closed-form (and periodic) mean residual waiting-time

and hazard rate

On account that , it follows that the average infectious period for our distribution is

and that the variance can be computed using

**References**

1. S.E. Anderson, G.E. Dallal, A. Must, Relative Weight and Race Influence Average Age at Menarche: Results From Two Nationally Representative Surveys of US Girls Studied 25 Years Apart, Pediatrics. 111 (2003) 844–850. https://doi.org/10.1542/peds.111.4.844.

2. D. Appiah, C.C. Nwabuo, I.A. Ebong, M.F. Wellons, S.J. Winters, Trends in Age at Natural Menopause and Reproductive Life Span Among US Women, 1959-2018, JAMA. 325 (2021) 1328. https://doi.org/10.1001/jama.2021.0278.

3. C.A. Gaydos, M. Barnes, B. Aumakhan, N. Quinn, C. Wright, P. Agreda, et al., Chlamydia trachomatis Age-Specific Prevalence in Women Who Used an Internet-Based Self-screening Program Compared to Women Who Were Screened in Family Planning Clinics, Sex. Transm. Dis. 38 (2011) 74.

4. S.A. Herzog, C.L. Althaus, J.C.M. Heijne, P. Oakeshott, S. Kerry, P. Hay, et al., Timing of progression from Chlamydia trachomatis infection to pelvic inflammatory disease: a mathematical modelling study, BMC Infect. Dis. 12 (2012) 187. https://doi.org/10.1186/1471-2334-12-187.

5. Centers for Disease Control and Prevention, National Vital Statistics System (NVSS) Mortality Data, (n.d.). Available from: https://www.cdc.gov/nchs/nvss/deaths.htm (accessed June 3, 2022).

6. Centers for Disease Control and Prevention, Pelvic Inflammatory Disease (PID) - Detailed Fact Sheet, 2022. Available from: https://www.cdc.gov/std/pid/stdfact-pid-detailed.htm.

7. T.H. Trojian, T.S. Lishnak, D. Heiman, Epididymitis and Orchitis: An Overview, Afp. 79 (2009) 583–587.

8. H. Zhao, C. Yu, C. He, C. Mei, A. Liao, D. Huang, The Immune Characteristics of the Epididymis and the Immune Pathway of the Epididymitis Caused by Different Pathogens, Front. Immunol. 0 (2020).

9. C.T. Nielsen, N.E. Skakkebaek, D.W. Richardson, J.A. Darling, W.M. Hunter, M. Jørgensen, et al., Onset of the release of spermatozoa (spermarche) in boys in relation to age, testicular growth, pubic hair, and height, J. Clin. Endocrinol. Metab. 62 (1986).

10. R.N. Rachel Gurevich, Does Age Affect Male Fertility?, Verywell Fam. (2008).

11. C.L. Shannon, J.D. Klausner, The Growing Epidemic of Sexually Transmitted Infections in Adolescents: A Neglected Population, Curr. Opin. Pediatr. 30 (2018) 137.

12. M. Bonner, J.M. Sheele, S. Cantillo-Campos, J.M. Elkins, A Descriptive Analysis of Men Diagnosed With Epididymitis, Orchitis, or Both in the Emergency Department, Cureus. 13 (2021).

13. H.S. Bakouch, C. Chesneau, J. Leao, A new lifetime model with a periodic hazard rate and an application, J. Stat. Comput. Simul. 88 (2018) 2048–2065.