

1 **Sexually Transmitted Infections: Challenges Ahead**

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44 **Executive Summary**

45 WHO estimates that nearly one million people become infected every day with any of four
46 curable sexually transmitted infections (STIs; chlamydia, gonorrhoea, syphilis,
47 trichomoniasis). Despite their high global incidence, STIs remain a neglected area of research.
48 In this *Commission* we have prioritised five areas that represent particular challenges in STI
49 treatment and control. Chlamydia remains the most commonly diagnosed bacterial STI in
50 high income countries despite widespread testing recommendations, sensitive and specific
51 non-invasive testing techniques and cheap effective therapy. We discuss the challenges for
52 chlamydia control and evidence to support a shift from the current focus on infection-based
53 screening to improved management of diagnosed cases and of chlamydial morbidity such as
54 pelvic inflammatory disease. The emergence and spread of antimicrobial resistance in
55 *Neisseria gonorrhoeae* is globally recognised. We review current and potential future control
56 and treatment strategies, including novel antimicrobials. Bacterial vaginosis (BV) is the most
57 common vaginal disorder in women, yet current treatments are associated with high rates of
58 recurrence. This might relate to evidence that suggests sexual transmission is integral to the
59 pathogenesis of BV, which has significant implications for the development of effective
60 management approaches. STIs disproportionately affect low and middle income settings. We
61 review strategies for case management, focusing on point-of-care tests that hold considerable
62 potential for improving STI control. Lastly, STIs in men who have sex with men (MSM) have
63 increased since the late 1990s. We discuss the contribution of new biomedical HIV prevention
64 strategies and risk compensation. Overall this *Commission* aims to enhance our understanding
65 of some of the key challenges facing us in the field, and outlines new approaches to improve
66 the clinical management of STIs and public health.

67

68 **Introduction**

69 Sexually transmitted infections (STIs) are amongst the most common acute conditions
70 worldwide.¹ The World Health Organization (WHO) estimated that there were 357 million
71 new cases of four common curable STIs; trichomoniasis (143 million cases), chlamydia (131
72 million), gonorrhoea (78 million), and syphilis (5.6 million) globally in 2012 (Figure 1).² In
73 addition, there are alarming increases in antimicrobial resistance (AMR) in *Neisseria*
74 *gonorrhoeae* and *Mycoplasma genitalium*.³ Although most STIs are not usually fatal, they
75 result in a significant burden of disease.¹ The complications of curable STIs include pelvic
76 inflammatory disease (PID), ectopic pregnancy, infertility, chronic pelvic pain, seronegative
77 arthropathy, neurological and cardiovascular disease;⁴ STIs in pregnancy can cause foetal or
78 neonatal death, premature delivery, neonatal encephalitis, eye infections and pneumonia;⁴ and
79 STIs increase the infectiousness of and susceptibility to HIV.⁵ Despite this burden, STIs
80 remain a neglected field for clinical and public health practice and for research.⁶ People with
81 STIs experience stigma, STIs disproportionately affect marginalised groups such as sex
82 workers and men who have sex with men (MSM) and condemnatory moral attitudes towards
83 STIs result in unwillingness to prioritise STI control policies.⁶⁻⁸ In this *Commission of Lancet*
84 *Infectious Diseases*, we have selected five key issues for STI control that face major
85 challenges globally and for which action is imperative.

86 This *Commission* addresses current challenges for research, practice and policy that we
87 selected because they are common, are important global health priorities, or because new
88 evidence is emerging in the area. Of necessity, this *Commission* has excluded important
89 subjects. *M. genitalium* was not included, despite the rapid emergence of resistance to both
90 first and second line treatments, but *M. genitalium* AMR and clinical management options
91 have been recently reviewed elsewhere.^{3,9} We also omitted herpes simplex virus, for which
92 vaccine development is progressing rapidly,¹⁰ human papillomavirus (HPV), for which

93 vaccination is highly effective,¹¹ but for which implementation is now the key challenge, and
94 *Trichomonas vaginalis* infections because there are no new strategies for treatment or control.
95 Partner notification is an essential part of the management of most STIs and is mentioned in
96 several parts of the *Commission*. We use the term to include all processes involved in
97 informing the sex partners or needle-sharing contacts of persons with STIs of their potential
98 exposure to an infectious disease and ensuring their evaluation and/or treatment.⁴ We consider
99 partner management, partner services and partner information to be synonymous.

100 Part 1 of the *Commission* addresses *Chlamydia trachomatis*, commonly known as
101 chlamydia. Chlamydia is the most common bacterial STI globally¹ and causes serious
102 reproductive tract complications in women.¹² Yet, 20 years after the first randomised
103 controlled clinical trial (RCT) of an intervention to reduce its complications,¹³ we remain
104 unsure how to reduce its prevalence and impact on society. Indeed, the most recent RCT of a
105 screening intervention did not find a marked effect on prevalence despite a substantial
106 increase in the proportion of the target population that received screening.¹⁴ *Hocking and Low*
107 assess the latest research about screening, treatment and management of chlamydia and
108 suggest a way forward to define chlamydia control priorities for the future.

109 In Part 2 of the *Commission*, *Unemo* addresses the globally recognised threat of the
110 emergence and spread of AMR in *N. gonorrhoeae*. This organism has become resistant to
111 virtually all antibiotics that have been used to treat it since sulphonamides were first used in
112 the 1930s. The first clinical failure using dual therapy with ceftriaxone and azithromycin was
113 verified in 2015.¹⁵ For this reason, we focus on current and future treatment strategies,
114 including three novel antimicrobials that are being evaluated in phase 2 or 3 RCTs. We also
115 report on novel strategies that aim to reduce the incidence and prevalence of gonorrhoea in
116 MSM, which should also reduce the probability of AMR developing. Ultimately, the
117 development of vaccines against both *N. gonorrhoeae* and *C. trachomatis* are likely to be the
118 only sustainable solutions to control these infections.¹⁰

119 The *Commission* chose to include bacterial vaginosis (BV) for three main reasons, even
120 though it is not considered a traditional STI. First, an accumulating body of epidemiological
121 and microbiological evidence suggests that sexual transmission is integral to its
122 pathogenesis.^{16,17} Second, BV has been neglected, although it is the most prevalent urogenital
123 disorder amongst women of reproductive age worldwide and is associated with serious
124 reproductive and obstetric sequelae, including preterm delivery and increased risk of STI and
125 HIV acquisition and HIV transmission.^{18,19} Third, treatment failure rates are unacceptably
126 high; more than half of women have a recurrence after recommended therapy but neither BV
127 treatment efficacy nor outcomes have improved for decades.²⁰ In Part 3 of the *Commission*,
128 *Bradshaw* and colleagues summarise the research implicating sexual transmission and
129 propose combination approaches to management that include antimicrobials, biofilm-
130 disrupting agents and partner treatment.

131 Part 4 of the *Commission* addresses STIs in low and middle income settings where more
132 than 90% of curable STIs and almost all of the global burden of STIs occur. *Francis* and
133 colleagues review key strategies for STI case management and control, including syndromic
134 management, presumptive periodic treatment and partner notification. But they focus on rapid
135 diagnostic tests and point of care (POC) tests within a published framework; being affordable,
136 sensitive, specific, user-friendly, rapid and robust, equipment-free and delivered to end-users
137 (ASSURED).²¹ POC tests have considerable implications for STI control in high-income
138 settings too, but their potential benefits are greatest in resource constrained settings where
139 healthcare infrastructure is most limited.

140 Part 5 of the *Commission* discusses epidemics of STIs in MSM in high income settings in
141 the context of three biomedical treatment strategies that use antiretroviral therapies (ART) to
142 prevent HIV infection. Two strategies are prophylactic treatments to reduce susceptibility in
143 HIV-uninfected individuals: post-exposure prophylaxis (PEP) given after specific high risk
144 exposures and pre-exposure prophylaxis (PrEP), given to HIV-uninfected individuals for

145 continuous periods of high risk exposure to prevent acquisition of HIV. The third strategy,
146 known as treatment as prevention (TasP), reduces HIV infectiousness and involves starting
147 ART as soon as HIV infection is diagnosed to prevent transmission to uninfected partners.
148 These interventions have all been suggested to increase risky sexual behaviours through risk
149 compensation and to result in increased transmission of STIs.²² *de Vries* and colleagues
150 review the evidence linking PEP, TasP and PrEP strategies to risk compensation and
151 increasing STI rates.

152 The *Commission* ends with a ‘call to action’, in which we ask policy makers to rise to the
153 public health challenge of effective STI control. Our call includes a broad suite of approaches
154 that are often shared across infections or risk groups. They involve the optimisation of:
155 surveillance for behaviours, infections and AMR; access to health services, early diagnosis,
156 appropriate treatment and partner notification, and also intensified research into: rapid POC
157 tests to detect both STIs and AMR; novel antimicrobials and/or treatment approaches; and the
158 understanding of STI transmission or pathogenesis.

159

160 **Part 1. Chlamydia control – what should we do?**

161 Twenty years after the publication of the first RCT of an intervention to reduce the incidence
162 of PID by screening for asymptomatic chlamydia infection in young women,¹³ we still need to
163 ask, “what should we do?” about chlamydia control. Three linked factors make this an
164 important question. First, *C. trachomatis* remains the most commonly diagnosed bacterial
165 STI, despite chlamydia testing recommendations that have been in place for years in several
166 high income countries.²³⁻²⁷ Second, whilst infection might be asymptomatic in over 80% of
167 cases,^{28,29} chlamydia can cause tissue damage, particularly in the female reproductive tract
168 where ascending infection can cause PID, which contributes to chronic pelvic pain, ectopic
169 pregnancy and tubal factor infertility (Figure 2).¹² Third, technological advances make

170 chlamydia diagnosis ever easier (if not cheaper): nucleic acid amplification tests (NAATs)
171 using self-collected specimens, online test kits, mobile phones for receiving results and rapid
172 tests.³⁰ However, the diagnosis of PID still relies on insensitive and non-specific clinical
173 signs.²⁷

174 Chlamydia control requires “a broad range of deliberate sustained activities that aim to
175 reduce the incidence and prevalence of chlamydia and the incidence of reproductive tract
176 complications”.³¹ The general definition of infectious disease control involves agreement on
177 locally acceptable levels,³² and makes a distinction between the infection and the disease(s)
178 that it causes. But an acceptable level of genital chlamydia infection or chlamydia-associated
179 PID, ectopic pregnancy or tubal factor infertility has not been defined in any setting. The
180 range of chlamydia control activities is broad (Figure 3) and countries should have a
181 chlamydia control strategy that defines primary and secondary prevention activities and
182 systems for monitoring and evaluation.³¹ Secondary prevention starts with case detection and
183 management to prevent complications; case management includes history-taking and clinical
184 examination, diagnostic tests, treatment, partner notifications, health promotion advice,
185 follow-ups and surveillance.³¹ Over time, particularly in high income countries, discussions
186 about chlamydia control have come to focus more on screening for asymptomatic infections
187 in young sexually active adults, rather than clinical case management of infection or PID.

188 The WHO Global Health Sector Strategy on STIs 2016-2021 states that, “because best
189 strategies to control and measure chlamydia infections are still to be defined, further research
190 and cost-effectiveness analyses are to be encouraged”(p17).³³ With this in mind, in this
191 section of the *Commission* we first outline the global epidemiology of genital chlamydia and
192 its complications. We review evidence about current chlamydia control activities and the
193 effects of screening interventions on chlamydia prevalence and PID. We then discuss the
194 challenges ahead for chlamydia control and question whether we should shift from an
195 infection-based focus on screening uptake to a health outcomes-based focus with improved

196 case management and investment in research to further our understanding about the
197 epidemiology of PID and other chlamydia associated morbidity.

198

199 **Global epidemiology of chlamydia infections**

200 WHO estimated that, in 2012, about 131 million people worldwide became newly infected
201 with chlamydia (Figure 1) and that 4.2% of women and 2.7% of men aged 15 to 49 years had
202 a prevalent infection.² In high income countries, chlamydia is most common in young
203 heterosexual adults aged ≤ 26 years with estimates from meta-analysis of population-based
204 surveys of 4.3% (95% confidence interval (CI) 3.6 to 5.0%) in women and 3.6% (95% CI 2.8
205 to 4.4%) in men.³⁴ Chlamydia is also common among MSM attending sexual health clinics
206 amongst whom chlamydia positivity ranges from 2% to 5% for urethral infection and 6% to
207 9% for rectal infection.³⁵⁻³⁷ Few countries have nationally representative surveys of chlamydia
208 prevalence (i.e. random samples of the general population aimed at providing unbiased
209 estimates) but, amongst those that do,³⁸⁻⁴⁴ prevalence is similar in women and men aged ≤ 26
210 years, and appears similar in countries that promote widespread chlamydia testing (e.g. USA
211 and England)^{44,45} and those without recommendations (e.g. Croatia and Slovenia) (Figure
212 4).^{40,46} Within countries, higher chlamydia prevalence is associated with social disadvantage⁴⁷
213 and is higher in people from minority ethnic groups.^{43,48}

214 In low and middle income countries, population-based surveys of chlamydia prevalence
215 are also very uncommon.⁴⁹⁻⁵² Estimates of chlamydia prevalence in the general population in
216 the few countries that have conducted such surveys are mostly similar to those in high income
217 countries (Figure 4).² The lowest estimate was in women in India ($< 1\%$)⁵⁰ and the highest in
218 Papua New Guinea, which estimated a prevalence of 45% among women ≤ 26 years.⁵¹ Data
219 from unselected 15 to 24 year old women attending antenatal clinics in South Pacific Islands
220 also find that around 20% of pregnant women have chlamydia.^{53,54} Whilst we found no

221 nationally representative surveys in South Africa, chlamydia prevalence amongst pregnant
222 women was as high⁵⁵ as that found in the South Pacific Islands. Reasons for regional
223 variations have not been examined in detail. In addition to study design issues, social, cultural
224 and economic conditions, differences in sexual practices, gender inequality and circumcision
225 practices might play a role.^{2,53,56}

226

227 **Global epidemiology of PID and reproductive tract morbidity**

228 Compared with international data about chlamydia infection, very little is known about
229 international variations in the incidence and prevalence of PID and other reproductive tract
230 morbidity caused by chlamydia. WHO estimated that chlamydial infections caused a total of
231 1.43 million disability-adjusted life years (DALYs) in 2012, most in low and middle income
232 countries (36% African Region, 25% South East Asia Region).⁵⁷

233 The rate of hospitalisation for PID from any cause varies from around 37 to 194 per
234 100,000 women aged 15-39 years in different countries.⁵⁸ Chlamydia infection is found in
235 association with about 20% of PID cases; one study at a large sexual health clinic in Australia
236 found no causative organism in over 60% of PID cases.⁵⁹ A major challenge is the lack of
237 consensus about criteria for the diagnosis of upper genital tract chlamydial disease and the
238 lack of non-invasive tests including new radiological imaging. PID is usually diagnosed based
239 on lower abdominal and cervical signs and symptoms and diagnostic criteria lack sensitivity
240 and specificity.²⁷

241

242 **Natural history of *Chlamydia trachomatis* and reproductive complications**

243 The host immune response to chlamydia strongly influences susceptibility, clearance, the
244 probability of upper genital tract pathogenesis and, ultimately, the effectiveness of

245 interventions.^{60,61} Untreated infection that resolves spontaneously might confer some
246 immunity against further infection,⁶² but the duration of immunity is unclear. Antimicrobial
247 treatment, on the other hand, might reduce the immune response and once treated, people
248 become susceptible to infection again, increasing their risk of repeat chlamydia infection, the
249 “arrested immunity hypothesis”.^{63,64} Repeat chlamydia infections after treatment are common;
250 in cohort studies, over 20% of young women enrolled from general practice acquired a repeat
251 infection within 12 months of treatment.^{65,66}

252 Several reviews have examined the risk of sequelae following infection,^{12,67-70} but
253 estimates are limited by diagnostic challenges. Mathematical syntheses of evidence from
254 different types of studies estimate that the probability of clinical PID following infection with
255 chlamydia is about 16% (95% credible interval 6% to 25%)⁷¹ and the probability of tubal
256 factor infertility in women who have ever had a chlamydia infection is about 1% (varies
257 depending on age).⁷² These models also estimate that the proportion of PID, ectopic
258 pregnancy and tubal factor infertility attributable to chlamydia is 20%, 5% and 29% to 45%,
259 respectively.⁷³ The risk of reproductive tract morbidity in women might increase with
260 repeated infection.⁷⁴⁻⁷⁶ It is unclear, however, whether the increase in risk is due to an increase
261 in the cumulative infection time or a higher probability of progression with each subsequent
262 infection.¹² Ascertainment bias in diagnosis might also explain the observations if physicians
263 are more likely to test for chlamydia in previously infected women who attend with lower
264 abdominal pain, or to assign the diagnosis of PID to a woman diagnosed with chlamydia.

265 We do not know how or when chlamydia ascends to the upper genital tract, but there are
266 two key hypotheses.⁶¹ The cellular paradigm assumes that actively infected epithelial cells
267 play the key role and that chemokines secreted by these cells damage the tissues directly. The
268 immunological paradigm assumes that tissue damage occurs due to T cell responses involved
269 in clearing infection after repeat or persistent infection. If the cellular paradigm is the main
270 driver of chlamydia pathogenesis, then identifying and treating infections before they ascend

271 should be the main focus of control programmes. If the immunological paradigm is more
272 important, then prevention of repeat infections should be prioritised.⁶⁰

273 The timing of ascending infection will also affect the impact of a screening intervention. If
274 chlamydia ascends the canal shortly after infection causing immediate tubal inflammation,
275 annual screening and treatment will not stop tubal pathology.⁷⁷ A mathematical model⁷⁸ using
276 data from a RCT,⁷⁹ found that the trial results of the effect of a single chlamydia screen on the
277 cumulative incidence of PID up to one year later, could only be achieved if progression to
278 PID occurred at a constant rate or at the end of infection.

279 Pregnant women infected with chlamydia have an increased risk of pre-term delivery⁸⁰ and
280 vaginally-delivered babies of untreated mothers are at risk of conjunctivitis and pneumonia.⁸¹
281 Among men, chlamydia can cause epididymo-orchitis,⁸² but effects on male fertility are
282 disputed; some have found no effect, some suggest decreased semen quality, or impaired
283 sperm fertilisation capacity and DNA integrity.^{83,84}

284

285 **Current chlamydia control activities**

286 Case detection and management are central to chlamydia control strategy in addition to
287 primary prevention of STIs. Clinical guidelines can include recommendations for
288 opportunistic chlamydia testing to detect asymptomatic infection in people with specified risk
289 factors for infection (Figure 3). Opportunistic testing can also be implemented at a population
290 level as a screening programme. Screening programmes require infrastructure not only for
291 chlamydia testing, but for treatment, partner notification, repeat testing, monitoring and
292 quality control.³¹ Several high income countries including Australia, Canada, England and the
293 USA recommend yearly opportunistic chlamydia screening for all sexually active women or
294 both women and men in the age groups at highest risk of infection.²³⁻²⁷ The coverage of
295 chlamydia testing has been used to monitor performance,⁸⁵⁻⁸⁷ but none of these countries sets
296 targets for chlamydia prevalence or PID incidence.

297 Surveys in Europe show that the number of countries with any chlamydia control activities
298 increased between 2007 and 2012.²⁶ The number of countries reporting the use of chlamydia
299 case management guidelines and opportunistic testing increased but fewer countries reported
300 that they had an ongoing or planned chlamydia screening programme.²⁶ Of note, the
301 Netherlands and Ireland have elected not to implement screening programmes and Sweden
302 and Denmark, both of which have had widespread opportunistic chlamydia screening,
303 reported that their STI control strategies have partly shifted from promoting testing to
304 intensifying primary prevention activities.²⁶ Ongoing debate about the evidence to support
305 chlamydia screening⁸⁸⁻⁹⁰ and its cost effectiveness⁸⁸ might have influenced these decisions.

306

307 **Effectiveness of chlamydia screening in clinical trials**

308 The rationale for chlamydia screening is that testing should detect asymptomatic infections in
309 women before they cause PID or other reproductive complications; if a large enough
310 proportion of the population can be screened, reduced incidence and prevalence of infection
311 ought to further prevent reproductive complications indirectly by reducing exposure to
312 infection.⁹¹

313 A systematic review of chlamydia screening interventions⁸⁹ found four RCTs that looked
314 at the effects on PID incidence after a single offer of a chlamydia screening test.^{13,79,92,93}
315 Overall, the trial results suggest that PID incidence was lower in intervention than control
316 groups (summary risk ratio, RR 0.68, 95% CI 0.49 to 0.94, I² 8%).⁸⁹ However, when
317 stratified by risk of bias, the summary effect was smaller in the two trials at low risk of bias
318 (RR 0.80, 95% CI 0.55 to 1.17)^{79,92} than in those at high or unclear risk of bias (RR 0.42,
319 95% CI 0.22 to 0.83),^{13,93} suggesting the overall result might overestimate the protective
320 effects of a screening test. Another completed cluster RCT will report on the association of up
321 to four rounds of chlamydia testing on the incidence of PID measured in hospitals and
322 primary care clinics.⁹⁴

323 Two cluster RCTs have looked at the effects of repeated rounds of chlamydia testing
324 targeting 16 to 29 year old men and women in the general population.^{14,95} Neither trial found a
325 reduction in estimated prevalence. The trial in the Netherlands invited people each year by
326 post (register-based screening) and the trial in Australia offered opportunistic testing in
327 general practice. Chlamydia test uptake was <20% in both trials, even with individual patient
328 reminders (Netherlands) or further support for clinicians (Australia). In Peru, a cluster RCT
329 among female sex workers found that after four years of a multifaceted intervention,
330 estimated prevalence was 28% lower in women in the intervention areas (RR 0.72, 95% CI
331 0.54 to 0.98).⁹⁶

332 Only one trial reported on the impact of screening on ectopic pregnancy, female infertility
333 and epididymitis in men. The intervention involved a single offer of screening, uptake was
334 low and outcomes did not differ between intervention and control groups.⁹² No RCT to date
335 has reported the effects of an intervention that offers chlamydia screening during pregnancy
336 on pregnancy or neonatal outcomes. One RCT in the USA that compared antibiotic treatment
337 with placebo in women with chlamydia detected at 23 to 29 weeks of gestation, found no
338 reduction in low birth weight, preterm birth or neonatal death in intention to treat analysis.⁹⁷
339 One cluster RCT in Uganda of presumptive antibiotic treatment found reductions in low birth
340 weight, neonatal death and ophthalmia neonatorum; the antibiotic regimen, azithromycin,
341 cefixime and metronidazole covered several genital tract infections other than chlamydia.⁹⁸

342 A review of cost-effectiveness studies found that chlamydia screening might be cost-
343 effective at nationally accepted thresholds of cost per quality adjusted life year in certain
344 circumstances in high income countries.⁸⁸ Incremental cost-effectiveness ratios are sensitive
345 to assumptions about the epidemiology and natural history of chlamydia including the
346 probability of developing sequelae, screening uptake, the type of model used, assumptions
347 about quality of life and the cost of management of the sequelae.^{88,99}

349 Effects of chlamydia control from observational data

350 Whilst RCTs provide data about the efficacy of chlamydia screening interventions under
351 research conditions, surveillance, *ad hoc* surveys and routine data are used to monitor the
352 performance of STI control strategies over time. These sources of data provide valuable
353 information but need to be interpreted carefully, taking into account selection, measurement,
354 ecological and response biases.

355 Chlamydia incidence and prevalence

356 There are no data available to monitor population-based chlamydia incidence over time. In
357 Great Britain and the USA, population-based chlamydia prevalence surveys have been
358 repeated during the time when chlamydia testing rates have increased. In Great Britain, two
359 surveys ten years apart found similar estimates among women and men aged 18 to 24 years in
360 2010-2011 (women, 3.2%, 95% CI 2.2 to 4.6%; men, 2.6%, 95% CI 1.7 to 4.0%) and in
361 1999-2000 (women, 3.1%, 95% CI 1.8 to 5.2%; men, 2.9%, 95% CI 1.3 to 6.3%);⁴⁴
362 chlamydia test coverage increased from about 8% per year in 2008¹⁰⁰ to about 30% in
363 2011.¹⁰¹ In the USA, chlamydia prevalence in women aged 15-24 years was 4.1% (95% CI
364 2.4 to 6.8%) in 1999–2000 and 3.8% (2.4 to 6.0%) in 2007–2008 with fluctuations in the
365 years between;⁴³ chlamydia testing coverage among 16 to 24 year old women was reported to
366 be >35% per year.^{85,102,103} More intensive chlamydia screening in a small cohort of adolescent
367 women in Indiana, USA did not reduce prevalence.¹⁰⁴ The women were tested every three
368 months and treated if they had a positive chlamydia test result; at each interval around 10% of
369 women tested were chlamydia test positive.¹⁰⁴

370 Several factors might help explain why the estimated chlamydia prevalence in the general
371 population does not appear to have declined during a period of increasing chlamydia testing.

372 First, the size of chlamydia prevalence surveys limits statistical precision and modest
373 reductions cannot be ruled out. Second, chlamydia test uptake might not have been
374 sufficiently high for long enough; mathematical modelling studies show that any level of a
375 hypothetical chlamydia screening intervention will reduce prevalence over time, but that
376 coverage of around 35% per year or more would be needed to achieve substantial reductions
377 within a ten-year period.^{105,106} Third, suboptimal case management with low levels of partner
378 notification, antimicrobial treatment failure and an increasing incidence of repeated infection
379 following antimicrobial treatment for chlamydia might sustain levels of prevalent infections.
380 Fourth, it is possible that testing and treatment is reducing levels of immunity against
381 chlamydia in the population leading to increased susceptibility to infection.⁶⁴ Fifth, auto-
382 inoculation in women of cervical chlamydia infection from the rectal site has been suggested
383 as a factor that could contribute to repeated detection of chlamydia in genital samples;¹⁰⁷
384 reports of rectal chlamydial infection in women have increased.^{108,109} Finally, persistent forms
385 of *C. trachomatis* might contribute to sustained prevalence. Chlamydia under the selective
386 pressure of beta-lactam antibiotics,¹¹⁰ interferon-gamma (IFN- γ) or deprivation of nutrients
387 such as iron and amino acids, can enter a persistent, metabolically inactive state^{111,112} where
388 they are viable but semi-refractory to treatment.^{110,113,114}

389 *PID and other reproductive tract complications*

390 Routine data about diagnoses on discharge from hospital have shown declining trends in PID
391 and ectopic pregnancy during periods of increasing chlamydia testing and increasing
392 chlamydia diagnosis rates in several countries.¹¹⁵⁻¹²¹ Ecological associations between
393 chlamydia testing and PID need careful interpretation.⁶⁰ Comparisons across larger numbers
394 of countries and longer time periods show that the degree to which chlamydia control efforts
395 account for the declining trend in PID incidence is not so clear. The Organisation for
396 Economic Cooperation and Development (OECD) collates hospital discharge by diagnostic

397 categories for its member countries.¹²² Figure 5 shows data for “inflammatory diseases of
398 female pelvic organs”, which includes PID from any cause (supplement table 1). There are
399 limitations in comparing the absolute rates between countries because of differences in how
400 the conditions are diagnosed, investigated and coded. However, trends over time show a
401 general decrease in the rate of discharge from hospital for inflammatory diseases of the pelvis
402 over the last two decades in countries that have very different levels of chlamydia control
403 activity. For example, in Belgium, Ireland and Slovenia, countries with little chlamydia
404 testing,²⁶ hospitalisations have dropped by about 30% over the past 15 years. In countries with
405 data from the early 1990s, the biggest declines in hospitalisations coincide with sudden sexual
406 behaviour changes and with falls in the rates of other STIs, which are attributed to responses
407 to the HIV pandemic.^{22,90,123} A cross-country analysis that compared PID, ectopic pregnancy
408 and infertility hospitalisation data⁵⁸ also found similar trends in high chlamydia testing
409 countries (Denmark, New Zealand, Sweden)^{26,124} and low testing countries (Australia,
410 Netherlands, Switzerland)^{26,125} from 1999 to 2008. Whilst inpatient admissions for these
411 conditions have become less common, in countries that collect data from ambulatory and
412 primary care settings, PID diagnoses have also fallen.

413

414 **Future challenges for the control of chlamydia**

415 *Shift of focus from monitoring test uptake to measuring PID incidence*

416 To date, chlamydia control strategies in several high income countries promote screening for
417 asymptomatic infection with a focus on monitoring chlamydia test uptake and chlamydia
418 prevalence. It is surprising therefore, that limited attention has been given to monitoring PID
419 incidence and its complications given that prevention of PID and its associated complications
420 is a key goal of chlamydia control. There has also been limited attention on research to further
421 our understanding of the natural history and immunopathology of *C. trachomatis* infection

422 including the development of non-invasive measures of clinical and subclinical tubal
423 infection, inflammatory and damage and biomarkers to predict upper genital tract pathology.⁶⁰
424 We urgently need investment in research to further our understanding of chlamydia natural
425 history and develop non-invasive tools to detect upper genital tract disease and to establish
426 surveillance systems to record and monitor trends in PID and other chlamydia related
427 complications over time.

428

429 *Realistic targets for chlamydia prevalence and incidence should be established*

430 Strategies for chlamydia control should be appropriate to levels of chlamydia prevalence and
431 incidence in the general population and key populations such as pregnant women, sex workers
432 and MSM. In countries with longstanding case detection activities, including opportunistic
433 testing and screening (mostly high income countries), it is conceivable that chlamydia
434 prevalence has reached an equilibrium and that further investments to increase the overall
435 coverage of chlamydia testing might not achieve additional gains in reducing the burden of
436 infection in the population. Within these countries, however, chlamydia control efforts should
437 focus on reducing social and ethnic inequalities in rates of chlamydia and PID, improving
438 health outcomes through better case management of those diagnosed with chlamydia and
439 establishing surveillance systems to more reliably and accurately monitor PID, ectopic
440 pregnancy and infertility incidence in both primary care, ambulatory and hospital settings.

441 In low and middle income countries efforts should be directed towards strengthening
442 primary prevention and case management for people presenting with symptomatic chlamydia
443 infection (see Part 4), as well as research to better define the prevalence of infection and
444 burden of chlamydial disease. In a limited number of countries, such the South Pacific
445 Islands, chlamydia prevalence in the general population appears to be very high. Here,
446 intensive research is needed to understand the reasons for high chlamydia prevalence and to

447 plan for evidence-based sustainable interventions. Mass drug administration of azithromycin
448 for trachoma control has been associated with a reduction in the prevalence of genital
449 chlamydia.¹²⁶ Given the high probability of re-infection, possible increase in susceptibility to
450 PID after treatment, and selection pressure for antimicrobial resistance (AMR), mass
451 treatment should not be introduced to control genital chlamydia infections in the absence of a
452 sustainable comprehensive chlamydia control strategy and health service infrastructure.
453 Nevertheless, in all countries, there are opportunities to improve case management of
454 diagnosed cases to reduce the risk of chlamydia associated complications.

455

456 *Improved case management*

457 *Use of the most efficacious antimicrobial treatment:* AMR has not been detected in *C.*
458 *trachomatis*, but the widespread use of single dose azithromycin for uncomplicated chlamydia
459 infections is being questioned.¹²⁷⁻¹³⁰ Two meta-analyses comparing a single 1 g azithromycin
460 with seven days of doxycycline (100 mg twice per day) found that azithromycin efficacy was
461 slightly lower for urogenital chlamydia (94% versus 97%)¹³¹ and substantially lower for rectal
462 chlamydia infection (83% versus 99%).¹³² For men, the efficacy of azithromycin for both
463 urogenital and rectal infection was below the WHO threshold of 95% recommended for a first
464 line treatment.¹³³ Furthermore, the widespread use of single dose azithromycin to treat
465 chlamydial infections is likely to have contributed to macrolide resistance in *Treponema*
466 *pallidum*, *N. gonorrhoeae* (see Part 2)¹³⁴⁻¹³⁶ and *M. genitalium*.¹³⁷

467

468 *Partner notification:* Partner notification has been recommended as a part of most STI
469 management strategies, including syndromic management (see Part 4), to help interrupt
470 transmission of infections, prevent potential re-infection, and prevent complications.
471 Improvements in partner notification are vital for chlamydia control. In addition to preventing

472 re-infection and halting ongoing transmission, testing and treating sexual partners of people
473 with chlamydia is efficient for case finding because they are likely to also be infected.¹³⁸
474 From a health economic perspective, doubling the efficacy of partner notification (from 0.4 to
475 0.8 partners per index case) would cost less than increasing the screening coverage of men to
476 the same level as women.¹³⁹ Expedited partner therapy (EPT) and accelerated partner therapy
477 (APT) are partner notification approaches that allow partners to receive treatment without a
478 face-to-face consultation in a health-service setting. A Cochrane review has found that EPT
479 was more successful than simple patient referral in reducing repeat infection in patients with
480 gonorrhoea and chlamydia.¹³⁸ APT, its equivalent in the UK, is acceptable to healthcare
481 providers and patients¹⁴⁰ and an RCT is underway to evaluate its effectiveness in reducing
482 repeated infection. Further work is needed to resolve medico-legal issues that limit wider
483 implementation of these partner notification approaches¹⁴¹ and to ensure that opportunities to
484 test for HIV and other STIs are not missed.¹³⁹

485

486 *Re-testing to detect repeat chlamydia infections early:* There is no evidence from RCTs that
487 repeated testing for chlamydia after treatment has an impact on reducing chlamydia
488 transmission in the population, but re-testing can detect repeat infections early. Guidelines
489 about re-testing intervals vary between countries: some countries recommend a test of cure
490 within three to six weeks after diagnosis,²⁶ others recommend testing to find repeated
491 infections within three to six months.^{26,27,142,143} A mathematical modelling study suggests that
492 an interval of two to five months after treatment optimises the detection of repeat infection.¹⁴⁴
493 Mailed specimen collection kits and mobile phone text messages are effective interventions
494 for increasing re-testing uptake and their impact on reducing chlamydia transmission and PID
495 should be evaluated.^{145,146}

496

497 *Rapid and POC tests*

498 Rapid diagnostic tests and POC tests allow diagnosis and treatment decisions to be made at
499 the same visit, reducing time to treatment and losses to follow up.^{147,148} The status of POC
500 tests for chlamydia and other STIs is discussed in Part 4.

501

502 *Chlamydia vaccine*

503 In all countries, an effective vaccine would overcome many of the problems of chlamydia
504 control. While the profile of a chlamydia vaccine remains to be determined, prioritising high
505 levels of immunity against infection or limited protection against infection but strong
506 protection against upper genital tract disease,¹⁴⁹ the prospects for a chlamydia vaccine are
507 now considered promising.¹⁵⁰ WHO and the US National Institutes of Health have developed
508 a STI vaccine roadmap that identifies priority actions for chlamydia vaccine development.¹⁵⁰
509 Several candidate chlamydia vaccines could enter Phase 1 clinical trials in the next few
510 years.¹⁰

511

512 **Conclusion**

513 Over the last 20 years, awareness about chlamydia as a common STI worldwide has
514 increased.^{2,33} Over the same period, research to increase knowledge about the natural history
515 of chlamydia or its disease burden has not kept up, even though the first RCT of a chlamydia
516 control intervention was primarily focused on the prevention of PID.¹³ The focus of
517 chlamydia control efforts in high income countries has been on increased coverage of testing
518 for asymptomatic chlamydia infection, whilst fewer advances have been made in research to
519 improve primary prevention and case management. Chlamydia control priorities could be set,
520 in future, based on infectious disease principles, to define acceptable levels of chlamydia
521 prevalence and incidence and disease that match the epidemiology in different geographical

522 regions and within different population groups. Priorities for improving case management
523 include effective partner notification strategies and re-testing to detect repeat infections early
524 and reduce the risk of chlamydia associated complications. Surveillance systems could
525 improve to record and monitor trends in PID and other chlamydia related complications over
526 time. The investment and research agendas called for by international experts^{60,150,151} to
527 further our understanding about the natural history of chlamydia and develop non-invasive
528 measures to predict upper genital tract disease should be implemented.

529

530 **Part 2. Gonorrhoea – inevitable antimicrobial resistance – current and** 531 **future treatment options?**

532 Of the 78 million estimated new gonorrhoea cases among adults globally in 2012, the highest
533 number was in the WHO Western Pacific Region (35.2 million, Figure 1). Accordingly, the
534 vast majority of the gonorrhoea burden globally is in low and middle income countries.²
535 There is no vaccine against *N. gonorrhoeae* so effective, accessible and inexpensive
536 antimicrobial treatment is an essential part of gonorrhoea control measures together with
537 primary prevention, diagnostics, partner notification and epidemiological surveillance. If *N.*
538 *gonorrhoeae* infections become untreatable, the numbers of people that experience
539 complications of infection, such as PID, ectopic pregnancy and infertility, and the facilitation
540 of HIV transmission and acquisition, will substantially increase.^{2,152-154} *N. gonorrhoeae* has
541 developed antimicrobial resistance (AMR) to all drugs previously or currently recommended
542 for treatment. This section of the present *Commission* reviews and discusses the emergence
543 and spread of AMR in *N. gonorrhoeae*, current and future treatment options, with a focus on
544 novel antimicrobials, and additional actions to control gonorrhoea and AMR in *N.*
545 *gonorrhoeae*.

546

547 **Emergence and spread of AMR in *N. gonorrhoeae***

548 Since the first antimicrobials, sulphonamides, were introduced for the treatment of gonorrhoea
549 in the mid-1930s gonococci have repeatedly shown an extraordinary ability to develop
550 resistance to all antimicrobials that have been introduced, using almost all known AMR
551 mechanisms.¹⁵³ The hypothesis is that, in modern times, AMR in gonococci has usually
552 developed first in the WHO Western Pacific Region (frequently Japan) followed by
553 international spread.^{153,155,156} For many infectious diseases including gonorrhoea, overuse and
554 misuse (including unrestricted access, suboptimal quality and dosing) of antimicrobials has
555 resulted in AMR in bacterial species that share their AMR determinants through horizontal
556 gene transfer and subsequent recombination. Horizontal gene transfer is particularly likely in
557 the pharynx, which harbours many non-gonococcal *Neisseria* species, and can facilitate the
558 emergence and spread of AMR¹⁵⁷ particularly in high-frequency populations such as MSM
559 and commercial sex workers. Inadequate monitoring of *in vitro* AMR,
560 pharmacokinetics/pharmacodynamics, and clinical efficacy of antimicrobials facilitate both
561 the initial emergence of AMR and the subsequent spread of resistant strains, particularly in
562 settings with a high incidence of gonorrhoea and ineffective control measures.^{152,153,155,156,158}
563 It is crucial to improve the understanding of the dynamics and drivers of the emergence of
564 AMR as well as transmission of gonococcal strains and their AMR, which can provide an
565 enhanced rationale for antimicrobial stewardship and management. Whole-genome
566 sequencing and other new molecular technologies will be invaluable to elucidate the evolution
567 and transmission of gonococcal strains and their AMR, locally, nationally and
568 internationally.¹⁵⁹

569 Many countries already have high prevalence rates of gonococcal resistance to all
570 antimicrobials that have been used for treatment, including sulphonamides, penicillins,
571 tetracyclines, fluoroquinolones and early generation macrolides and cephalosporins.^{152-154,158}

572 The prevalence of multidrug-resistant (MDR)¹⁵⁵ gonococcal strains significantly increased
573 during the last decade.^{152-154,158} Resistance to extended-spectrum cephalosporins (ESCs), the
574 last remaining options for empiric first-line monotherapy, has also been detected in many
575 countries. The first extensively drug-resistant (XDR)¹⁵⁵ gonococcal strains, displaying high-
576 level resistance to ceftriaxone (minimum inhibitory concentration (MIC)s 2-4 mg/L) and
577 retained resistance to previously used therapeutic antimicrobials, have also been verified in
578 Japan, France and Spain.¹⁶⁰⁻¹⁶² Fortunately, these “superbugs” have not spread further,
579 suggesting significantly decreased biological fitness. Some additional ceftriaxone-resistant
580 strains isolated in Japan and Australia during recent years have also been studied in detail,¹⁶³⁻
581 ¹⁶⁵ showing that both ceftriaxone-resistant strains and ceftriaxone resistance-determining
582 penicillin-binding protein 2 (PBP2) segments (lethal target for ESCs) are spreading.¹⁶⁵
583 Additional sporadic gonococcal strains with low-level ceftriaxone resistance have been
584 described internationally.^{158,166} Importantly, strains with non-mosaic PBP2s can also develop
585 ceftriaxone resistance, as described particularly in Asia, e.g. China, Korea, and Vietnam, but
586 also in Argentina.^{158,166} Many additional ceftriaxone-resistant strains might already be
587 circulating but are undetected due to the suboptimal AMR surveillance in many settings.
588 Ceftriaxone or dual antimicrobial therapy (mainly ceftriaxone 250-500 mg×1 plus
589 azithromycin 1-2 g×1) are currently the only options for empirical first-line therapy in most
590 countries.^{158,167-172}

591

592 **Current treatment of gonorrhoea**

593 *Principles and definitions used in conventional antimicrobial treatment*

594 Empirical therapy is treatment given at the first health care visit before any laboratory results
595 are available, following recommendations in evidence-based treatment guidelines. The ideal
596 characteristics of a first-line therapy are that it: has high efficacy (cures >95% of urogenital

597 and extragenital infections), includes multiple targets (to increase activity and delay resistance
598 development), has no or minimal cross-resistance with other antimicrobials, is showing slow
599 selection/induction of resistance determinants in *N. gonorrhoeae*, has different mechanisms of
600 action for drugs included in dual therapy, is available as a single oral dose, with a fixed-dose
601 combination (FDC) for dual oral therapy, is widely available and affordable in appropriate
602 quality and dose, has an appropriate paediatric formulation (e.g. suspension or syrup), is
603 stable (at high temperature and humidity levels), has no or minimal drug-drug interactions, is
604 safe (including during pregnancy and lactation), is well tolerated, and is also active against
605 concurrent *C. trachomatis* and *M. genitalium* infections (make it useful in syndromic
606 management).

607 Treatment guidelines should be informed by up-to-date, local and quality-assured
608 AMR surveillance data. AMR can emerge quickly and patterns vary geographically so large
609 RCTs are rarely conducted. Changes in recommended treatments are mostly based on
610 laboratory-based AMR surveillance data (the point estimate of tested strains should show that
611 $\geq 95\%$ are susceptible), rather than clinical surveillance of cure rates. Alternative criteria for
612 changing a recommended first-line therapy have been suggested, for example that the lower
613 95% CI rather than the point estimate should be $\geq 95\%$, or that $>99\%$ or $>97\%$ of strains from
614 high-frequency transmitting populations should be susceptible.¹⁷³⁻¹⁷⁵ Ideally, additional
615 factors should also be taken into consideration, including prevalence, local epidemiology,
616 diagnostics used, transmission frequency, partner notification and management strategies,
617 treatment strategies (strategies used and antimicrobials available), and cost-effectiveness,
618 should be considered.^{153,158,176}

619

620 *Antimicrobial monotherapy*

621 Cefixime 400 mg×1 orally and especially ceftriaxone 125-1000 mg×1 intramuscularly (IM) or
622 intravenously (IV) have been the last options for empirical first-line monotherapy in many
623 countries.^{152-156,158,170} Unfortunately, treatment failures with cefixime have been verified in
624 many countries worldwide, and rare failures following treatment of pharyngeal gonorrhoea
625 with ceftriaxone (250-1000 mg×1) have also been verified in several countries.^{156,158} Verified
626 ceftriaxone treatment failures are probably the tip of the iceberg because few countries
627 conduct active surveillance and confirm treatment failures according to international
628 recommendations.

629 To avoid treatment failures, increased doses of ceftriaxone (1 g×1 IM/IV) have been used
630 in some countries.¹⁷⁷⁻¹⁸⁰ Based on the dosages administered for community-acquired
631 pneumonia, up to 2 g×1 of ceftriaxone would likely be tolerated. Increased doses of
632 ceftriaxone are probably only a short-term solution based on current knowledge of gonococcal
633 AMR emergence, ESC MICs of gonococcal “superbugs” and other ESC-resistant strains,
634 verified ESC treatment failures and ESC pharmacokinetic/pharmacodynamic simulations. For
635 example, 20-24 hours of free ESC above MIC ($fT_{>MIC}$) can be required for effective treatment
636 with ESCs.¹⁸¹ According to Monte Carlo simulations, reflecting the diversity inherent within
637 patient populations, of ceftriaxone 1 g×1, sufficient $fT_{>MIC}$ (20-24 hours) might not be
638 achieved in up to 5% of patients even for gonococcal strains with ceftriaxone MICs as low as
639 0.125 mg/L, which are relatively common in many countries. The median $fT_{>MIC}$ is
640 therefore 40.3 hours but the lower 95% CI of $fT_{>MIC}$ (19.6 hours) is below the required 20-
641 24 hours.¹⁸¹ These findings might overestimate the number of treatment failures because few
642 failures have been identified, but they show the wide circulation of gonococcal strains that
643 could cause ceftriaxone treatment failures.

644

645 *Dual antimicrobial therapy*

646 Several agencies and countries recommend dual antimicrobial therapy for empirical first-line
647 gonorrhoea treatment in response to emerging ESC resistance, including WHO (global
648 recommendations), Europe, Germany, United Kingdom, Australia, USA, and Canada.^{27,167-172}
649 To summarise, all these guidelines, except those of WHO¹⁷² and Canada,¹⁷¹ recommend only
650 ceftriaxone plus azithromycin as first-line for uncomplicated anogenital gonorrhoea in adults.
651 There are no RCTs that provide optimal doses of ceftriaxone and azithromycin for currently
652 circulating gonococcal strains and recommendations vary: ceftriaxone doses range from 250
653 mg×1 IM (WHO, USA and Canada) to 1 g×1 IM (Germany); and doses of azithromycin range
654 from 1 g×1 orally (WHO, USA, Canada, UK and Australia) to 2 g×1 orally (Europe).^{27,167-172}
655 WHO¹⁷² and Canadian¹⁷¹ guidelines additionally recommend an oral first-line dual therapy,
656 cefixime 400 mg×1 (WHO) or 800 mg×1 (Canada) plus azithromycin 1 g×1.^{171,172}
657 Pharmacodynamic studies have shown that cefixime 800 mg (especially 400 mg×2, given 6
658 hours apart) increases the cefixime $fT_{>MIC}$ compared to 400 mg×1.¹⁸¹ In most countries,
659 however, only cefixime 400 mg×1 is licensed because gastrointestinal adverse events are
660 more common with 800 mg×1.¹⁸² Many clinical failures have been verified with cefixime 400
661 mg×1,^{156,158} but also with cefixime 800 mg×1.¹⁸² Finally, WHO also recommends
662 monotherapy with ceftriaxone 250 mg×1, cefixime 400 mg×1, or spectinomycin 2 g×1, but
663 only if up-to-date, local, high-quality AMR surveillance data support their use.¹⁷² Owing to
664 low cure rates, spectinomycin monotherapy should only be used if pharyngeal gonorrhoea has
665 been excluded; otherwise, azithromycin should also be given.¹⁵²

666 The recommendations for dual therapy with ceftriaxone plus azithromycin are not based on
667 evidence from RCTs. The selection of these antimicrobials and their doses has been based on
668 AMR surveillance data, predicted AMR trends, old clinical trials, case reports of clinical
669 failures with ESCs,^{156,158} pharmacokinetic/pharmacodynamic simulations,¹⁸¹ and expert
670 opinion.¹⁷⁰ Unfortunately, these recommended antimicrobials might not protect each other
671 from the development of resistance.¹⁸³ However, in practice the combination of ceftriaxone

672 and azithromycin appears to cure almost all gonorrhoea cases, concomitant resistance to
673 ceftriaxone and azithromycin is exceedingly rare and consequently the spread of any emerged
674 ceftriaxone resistance appears to have been mitigated so far. In addition, dual therapy
675 eradicates concurrent *C. trachomatis* and many *M. genitalium* infections. However,
676 susceptibility to ceftriaxone is decreasing and azithromycin resistance is increasing in many
677 settings internationally, and concomitant resistance to both antimicrobials has
678 emerged.^{152,153,158} Gonococcal strains with high-level azithromycin resistance (MIC \geq 256
679 mg/L) have been isolated in several countries worldwide and an outbreak of such strains is
680 ongoing in the UK.^{134,158} All the recommended and alternative dual antimicrobial regimens
681 include azithromycin 1-2 g \times 1 and due to the azithromycin resistance, in practice many
682 gonorrhoea cases will be administered ceftriaxone monotherapy. Furthermore, the first global
683 treatment failure with dual therapy (ceftriaxone 500 mg \times 1 IM plus azithromycin 1 g \times 1
684 orally), due to a ceftriaxone- and azithromycin-resistant gonococcal XDR strain, was recently
685 verified in the UK.¹⁵ The higher cost and inconvenience of dual therapy also render it less
686 suitable for low and middle income countries, where also high-quality ceftriaxone can be
687 lacking, which will limit the mitigation of emergence and spread of gonococcal AMR
688 globally.

689

690 **Future treatment of gonorrhoea**

691 *Improved dual antimicrobial therapy*

692 Dual antimicrobial therapy^{27,167-172} is recommended for treatment where up-to-date, local, and
693 high-quality AMR surveillance data do not support other therapy. Ideally, owing to the rapid
694 emergence of azithromycin resistance in *N. gonorrhoeae* (and also additional STIs such as *M.*
695 *genitalium* infections), at least as a temporary solution azithromycin could be replaced by
696 solithromycin if the ongoing Phase 3 RCT provides evidence of effectiveness, tolerability and

697 safety. Furthermore, susceptibility to spectinomycin is exceedingly high
698 globally,^{152,153,158,170,172} and it would be valuable to have this drug widely available again.
699 There are concerns that spectinomycin resistance would be rapidly selected if it was more
700 frequently used but it has been used in Korea for decades (52%-73% of treatments in 2009-
701 2012) and no resistant isolates have been found since 1993.¹⁸⁴ Nevertheless, spectinomycin
702 only eradicates a proportion of pharyngeal gonorrhoea (52%)¹⁸⁵ and should, ideally, be used
703 in a dual therapy combination, e.g. with solithromycin, which might protect it from resistance
704 development.

705 Novel accessible and cost-effective antimicrobials are essential. Ideally, these should be
706 used in new dual therapies, to preserve their effectiveness, and, if there are oral preparations,
707 in FDCs that increase activity and adherence and mitigate resistance development. One RCT
708 has evaluated two novel dual regimens, gentamicin (240 mg×1 IM) plus azithromycin (2 g×1
709 orally), and gemifloxacin (320 mg×1 orally) plus azithromycin (2 g×1 orally), for the
710 treatment of uncomplicated urogenital gonorrhoea in men and women.¹⁸⁶ Gentamicin plus
711 azithromycin cured 100% of cases (202/202) and gemifloxacin plus azithromycin 99.5% of
712 cases (198/199). No serious adverse events occurred, but mild-moderate gastrointestinal
713 adverse events such as nausea and diarrhoea were frequent. Of concern, 3.3% and 7.7% of
714 patients, respectively, vomited within one hour and might have lost a substantial amount of
715 the drugs.¹⁸⁶ Consequently, these two regimens should mainly be considered for treatment of
716 ceftriaxone-resistant cases, treatment failures with recommended regimen, or ESC allergy.

717

718 *Repurposing old antimicrobials*

719 Old antimicrobials, such as gentamicin, ertapenem, and fosfomycin, have been suggested for
720 future therapy. Several shortcomings with these antimicrobials have been previously
721 reviewed. Briefly, clinical data are lacking (ertapenem) or old, incomplete, mainly low-
722 quality, and only from limited geographic areas, patient populations (only males), and

723 anatomical sites (only urogenital); <95% cure rate; appropriate
724 pharmacokinetic/pharmacodynamic parameters for gonorrhoea, relationship between MIC
725 and treatment outcome, and resistance breakpoints are lacking.^{152,153,156,158,176,187-189} These
726 limitations preclude their widespread use as empirical monotherapies, but particularly in new
727 dual antimicrobial regimens they might be useful in case of ceftriaxone resistance or ESC
728 allergy. A multi-centre (n=8) non-inferiority Phase 3 RCT, aiming to enrol 718 participants,
729 evaluating gentamicin 240 mg×1 IM plus azithromycin 1 g×1 orally for treatment of
730 uncomplicated anogenital and pharyngeal gonorrhoea is ongoing
731 (www.research.uhb.nhs.uk/gtog); the comparator is ceftriaxone 500 mg×1 IM plus
732 azithromycin 1 g×1 orally. Finally, using timely molecular prediction of resistance to
733 ciprofloxacin, based on targeting *gyrA* mutation(s), this old antimicrobial can be used as
734 personalised treatment for patients in whom ciprofloxacin susceptibility has been
735 confirmed.¹⁹⁰⁻¹⁹³

736

737 *New antimicrobials with only in vitro data available*

738 Several new antimicrobials (derivates of earlier developed antimicrobials or new
739 antimicrobial classes) have proven relatively potent *in vitro* activity against gonococcal
740 strains, but clinical data are lacking. These antimicrobials include the fluoroquinolones
741 avarofloxacin (JNJ-Q2), delafloxacin (RX-3341), sitafloxacin (DU-6859), and WQ-3810;
742 bicyclic macrolides (bicyclolides) modithromycin (EDP-420/EP-013420/S-013420) and EDP-
743 322; tetracyclines eravacycline (TP-434) and tigecycline (fluorocycline and glycylicycline,
744 respectively); 2-acyl carbapenems SM-295291 and SM-369926; aminomethyl
745 spectinomycin;¹⁹⁴ lipoglycopeptide dalbavancin, pleuromutilin lefamulin (BC-3781), boron-
746 containing inhibitor AN3365, LpxC inhibitors, FabI inhibitor e.g. MUT056399, tricyclic
747 topoisomerase inhibitor REDX05931 (evaluated also in mice),^{195,196} and topoisomerase II
748 inhibitor VXc-486 (VT12-008911), which all have been recently reviewed.^{152,153,156,158,176,194-}

749 ¹⁹⁶ A Phase 3 RCT designed to evaluate delafloxacin (2×450 mg×1 orally) compared to
750 ceftriaxone (250 mg×1 IM) for treatment of uncomplicated gonorrhoea was recently
751 terminated (<http://clinicaltrials.gov/show/NCT02015637>).

752

753 *Novel antimicrobials in clinical trial evaluation*

754 Solithromycin (CEM-101), zoliflodacin (AZD0914/ETX0914), and gepotidacin
755 (GSK2140944) are novel orally administered antimicrobials in clinical evaluation for
756 treatment of gonorrhoea.¹⁹⁷⁻²¹⁷ The main characteristics of these antimicrobials are
757 summarised in table 1.

758 Solithromycin: The first fluoroketolide solithromycin is structurally similar to the ketolide
759 telithromycin but it is less toxic and has increased stability and activity.^{202,208,212}
760 Solithromycin, like other macrolides and ketolides, inhibits protein synthesis, but
761 solithromycin has three bacterial 23S rRNA binding sites that increase the activity and delay
762 development of resistance.²⁰⁸ Solithromycin has proven a high *in vitro* activity against
763 geographically, temporally and genetically diverse wild type, MDR and XDR international
764 gonococcal reference strains and clinical isolates, with *in vitro* and clinical resistance to all
765 currently and previously recommended antimicrobials.^{202,212} No major cross-resistance with
766 other antimicrobials has been observed, but strains with high-level azithromycin resistance
767 (MIC₂≥256 mg/L) can be resistant to solithromycin (MICs=4-32 mg/L).²⁰²

768 Administering a single solithromycin dose (50-1600 mg) to healthy adults, the time-to-
769 peak concentration (T_{max}) was 1.5-6 hours and the plasma half-life (T_{1/2}) 3.2-7.4 hours.²¹⁴ A
770 Phase 1 study evaluating pharmacokinetic properties, safety and tolerability of a 1 g oral dose
771 within plasma, vaginal, cervical, seminal, rectal, and pharyngeal samples is ongoing
772 (<https://clinicaltrials.gov/ct2/show/NCT02348424>).

773 A Phase 2 clinical trial evaluating the efficacy of solithromycin 1 g×1 or 1.2 g×1 orally in
774 the treatment of males and females with uncomplicated urogenital gonorrhoea was performed

775 (<https://clinicaltrials.gov/ct2/show/NCT01591447>).²⁰³ Forty-six patients received
776 solithromycin and were evaluable for microbiological cure (1 g×1 (n=22) and 1·2 g×1
777 (n=24)). All (100%) were subsequently culture negative at all sites examined. Solithromycin
778 additionally cured 82% of *C. trachomatis* infections (n=11) and 70% of *M. genitalium*
779 infections (n=10). The adverse effects were dose-dependent and giving 1 g×1 the most
780 prevalent were mild diarrhoea (42%), nausea (26%), and fatigue/asthenia (10%). However,
781 most nausea and vomiting (3%) appeared ≥ 1 hour after ingestion and the drug was likely
782 already absorbed.²⁰³ Additional data are needed and, to further increase gastrointestinal
783 tolerability, an extended-release formulation of solithromycin might be valuable.
784 Solithromycin (1 g×1 orally) is currently in a Phase 3 non-inferiority RCT for treatment of
785 uncomplicated urogenital gonorrhoea in males and females (SOLITAIRE-U;
786 <https://clinicaltrials.gov/ct2/show/NCT02210325>), evaluating efficacy, tolerability and safety
787 (table 1). Of concern, analysing the data from the initial patient cohort of 262 patients
788 solithromycin demonstrated high success rates of 80·5 percent in the microbiological intent to
789 treat population but only 91·3 percent in the microbiologically evaluable population (100%
790 success rate for females). Consequently, solithromycin did not demonstrate non-inferiority to
791 standard of care treatment. No *N. gonorrhoeae* isolates demonstrated solithromycin resistance
792 at baseline or test-of-cure. Thus, the solithromycin treatment failures were most likely related
793 to the duration of solithromycin exposure at the site of infection and adjustments to the dosing
794 regimen (and/or possibly formulation), without substantially increasing the dose-dependent
795 adverse effects observed in the Phase 2 study, might need to be considered.

796 (<http://investor.cempra.com/releasedetail.cfm?ReleaseID=1014807>; February 28, 2017).

797 Zoliflodacin: The first spiropyrimidinetrione (non-fluoroquinolone topoisomerase II
798 inhibitor) zoliflodacin targets DNA gyrase (specifically GyrB), but likely also topoisomerase
799 IV, and has novel mechanisms of action different from all other available
800 antimicrobials.^{197,198,201} Zoliflodacin initially showed high *in vitro* activity against 250

801 geographically, temporally and genetically diverse wild type, MDR and XDR international
802 gonococcal reference strains and clinical isolates, with *in vitro* and clinical resistance to all
803 currently and previously recommended antimicrobials.²⁰⁶ Additionally, consecutive,
804 contemporary and clinical isolates in Europe (873 isolates from 21 European countries), USA
805 (100 isolates), and China (187 isolates) have been examined.^{211,215,216} The main zoliflodacin
806 target in GyrB is highly conserved in clinical isolates.²⁰⁶ No cross-resistance with other
807 available antimicrobials, including the frequently used topoisomerase II inhibitor
808 ciprofloxacin, has been observed and no zoliflodacin resistant clinical gonococcal isolate has
809 been identified.^{206,211,215,216} The frequency of induced or selected zoliflodacin resistance
810 mutations is very low and, interestingly, some of the selected *gyrB* resistance mutations
811 appear to increase ciprofloxacin susceptibility.^{197,201}

812 Administering doses ranging between 200-4000 mg to healthy volunteers (18-55 years) in
813 a Phase 1 study (<https://clinicaltrials.gov/ct2/show/NCT02298920>),²⁰⁷ dose-proportional
814 increases in plasma concentration up to 800 mg were observed. Doses >800 mg resulted in
815 slightly smaller dose-proportional increases up to 4000 mg. The median T_{max} was 1.5-2.3
816 hours, and the mean terminal elimination T_{1/2} was reasonably consistent, ranging between 5.3-
817 6.3 hours. There were no serious adverse events, or drug discontinuations due to adverse
818 events. Transient dysgeusia (60%), attributed to suspension formulation, followed by mild
819 transient headache (38%) were the most common adverse events.^{198,207}

820 A Phase 2 RCT evaluating the efficacy, tolerability and safety of zoliflodacin 2 g×1 or 3
821 g×1 orally for treatment of uncomplicated urogenital gonorrhoea in men and women has been
822 performed (<https://clinicaltrials.gov/ct2/show/NCT02257918>).²¹⁷ In total, 48/49 (98%)
823 patients and 47/47 (100%) patients achieved microbiological cure with zoliflodacin 2 g×1 and
824 zoliflodacin 3 g×1, respectively. Only 12% of patients reported any adverse events, i.e. mostly
825 mild gastrointestinal adverse events.²¹⁷ Accordingly, single oral dose of zoliflodacin was
826 effective and safe for treatment of uncomplicated urogenital gonorrhoea. However, it is

827 crucial to examine additional cases of extragenital gonorrhoea, particularly pharyngeal
828 infection.

829 Gepotidacin: Gepotidacin is a new non-fluoroquinolone topoisomerase II inhibitor
830 (triazacenaphthylene) targeting DNA gyrase (GyrA subunit) and topoisomerase IV (ParC
831 subunit), but with a different binding mode compared to fluoroquinolones.^{200,213} The
832 gepotidacin MICs have been shown relatively low, however, the MIC₉₀ was 0.25 mg/L for
833 108 ciprofloxacin-susceptible isolates and 1 mg/L for 37 ciprofloxacin non-susceptible ones,
834 indicating some level of cross-resistance to fluoroquinolones.²¹³ *In vitro* studies examining
835 geographically, temporally and genetically diverse resistant, including MDR and XDR,
836 gonococcal isolates are ongoing.

837 The pharmacokinetic profile of gepotidacin was examined in a study including healthy
838 subjects receiving gepotidacin 800, 1500, 2300, and 3000 mg×1 orally. There are limited
839 reported data; a reported clearance of ~84 L/hour, 9.4-51% variability in clearance, zero-order
840 absorption, and an absorption lag time.²⁰⁴ Administering 2 g×1 orally in six males, ~50% was
841 absorbed. Faecal elimination (53%) predominated, but ~20% of total dose was eliminated
842 unchanged in urine.²⁰⁹

843 A Phase 2 RCT evaluating the optimal oral dose of gepotidacin (1.5 g×1 or 3 g×1 orally)
844 and efficacy, safety, and tolerability in males and females with uncomplicated urogenital
845 gonorrhoea has recently been finalised (<https://clinicaltrials.gov/ct2/show/NCT02294682>), but
846 the results of this RCT are not publicly available.

847

848 **Conclusions**

849 Gonorrhoea is a major public health concern and emergence of gonococcal AMR is
850 significantly compromising the effectiveness of treatment globally. Improvements in

851 treatment, together with clinical and public health actions (table 2), are needed to control
852 gonorrhoea and AMR in *N. gonorrhoeae*. Dual antimicrobial therapy (ceftriaxone 250-500
853 mg×1 plus azithromycin 1-2 mg×1) is recommended for treatment where up-to-date, local,
854 and high-quality AMR data do not support other therapy.^{27,167-172} This antimicrobial
855 combination appears to treat almost all gonorrhoea cases and inhibit the spread of AMR
856 gonococcal strains. Nevertheless, wider availability internationally of other effective
857 antimicrobials, such as spectinomycin, further studies of the repurposing of old
858 antimicrobials, particularly gentamicin and ciprofloxacin (following timely molecular
859 prediction of ciprofloxacin resistance/susceptibility¹⁹²), and *in vitro* and clinical evaluation
860 and subsequent licensing of novel accessible and affordable antimicrobials are imperative.
861 Ideally, these antimicrobials should be used in new dual therapies, in order to preserve them,
862 and, if oral drugs, in FDCs providing advantages such as increased activity, tolerance,
863 compliance, lower cost of manufacturing, simpler distribution, and mitigated resistance
864 development. Several new antimicrobials have proven relatively potent *in vitro* activity
865 against gonococcal strains, but clinical data about their effects in gonorrhoea treatment are
866 lacking.^{152,153,156,158,176} Solithromycin, gepotidacin and particularly zoliflodacin can be
867 promising for gonorrhoea treatment and deserve further attention.¹⁹⁷⁻²¹⁷ Ultimately, as for
868 chlamydia, a gonococcal vaccine might be the only sustainable solution for gonorrhoea
869 control.¹⁵⁰

870

871 **Part 3. Bacterial vaginosis: reconsidering the evidence for sexual** 872 **transmission and implications for research and management**

873 Bacterial vaginosis (BV) is one of the great conundrums in sexual and reproductive health. At
874 the time of its discovery in the 1950s, “non-specific bacterial vaginitis” was considered likely
875 to be sexually transmitted. Studies by Gardner and Dukes established the clinical and

876 microbiological features of BV in uninfected women following direct inoculation of vaginal
877 secretions from infected women.²¹⁸ Subsequent work, however, altered this belief. The
878 apparent absence of an obvious disease counterpart in males, the failure of male partner
879 treatment trials to consistently reduce BV recurrence in women,²¹⁹ and inability to identify a
880 sole pathogenic microorganism all contributed. While the approaches used in studies that
881 treated the male sex partners of women with BV—including study designs, dosing regimens
882 for male partners and endpoints in female partners—have been criticised,^{220,221} the general
883 consensus that BV is not sexually transmitted has persisted.

884 Advances in molecular techniques, such as 16S rRNA gene sequencing, have confirmed
885 that BV involves a profound shift in the vaginal microbiota to a dysbiotic state, characterised
886 by high bacterial species diversity and increased loads of both aerotolerant and strict
887 anaerobes including *Gardnerella vaginalis*, *Atopobium vaginae* and other fastidious BV-
888 associated bacteria such as *Megasphaera*, *Sneathia* and *Clostridiales* species (spp.).²²² This
889 change is accompanied by production of volatile amines, a rise in vaginal pH and marked
890 depletion of key *Lactobacillus* spp. such as *L. crispatus*. *L. crispatus* appears to play an
891 important role in defence against pathogens through the production of lactic acid, bacteriocins
892 and other antimicrobial molecules.^{223,224} Recent studies have detected a polymicrobial biofilm
893 in women with BV that is adherent to vaginal epithelial cells and absent in healthy
894 controls.^{225,226} But the actual event that triggers this adverse shift in the vaginal microbiota
895 and the development of biofilm remains elusive. In this section of the *Commission*, we discuss
896 the epidemiological and microbiological evidence that supports the role of sexual
897 transmission in the pathogenesis of incident and recurrent BV. We relate this evidence to the
898 high recurrence rates following recommended antimicrobial therapy and other treatment
899 approaches, and discuss the need for novel approaches and combined strategies to address the
900 burden of disease in women.

901

902 **BV is common and associated with serious reproductive and obstetric sequelae**

903 Globally, women of reproductive age bear a high burden of BV. Prevalence estimates range
904 from 12% in Australian women,²²⁷ to 29% in North-American women,^{228,229} to >50% in Sub-
905 Saharan Africa.²³⁰ When present, symptoms typically include an abnormal vaginal discharge
906 and an unpleasant fishy malodour. Qualitative studies show that BV is associated with a
907 significant negative impact on self-esteem, sexual relationships and quality of life.²³¹
908 Although women commonly seek medical evaluation, many report misdiagnosis and
909 inconsistent clinical management, compounding their distress and confusion.^{232,233} BV is
910 considered a benign condition, but is associated with serious reproductive and obstetric
911 sequelae including: a two-fold increased risk of acquiring other STIs; chlamydia, gonorrhoea,
912 herpes simplex virus type 2 and HIV infection;^{18,234-236} increased risk of transmission of HIV
913 to male partners,¹⁹ and increased risk of PID, spontaneous abortion, preterm delivery, low
914 birthweight, and post-partum endometritis.²³⁷⁻²³⁹

915

916 **Epidemiological evidence for sexual transmission of BV**

917 While the weight and strength of available data support that BV can be acquired through
918 sexual activity, there has been slow progress in determining the actual transmitted agent or
919 agents. Epidemiological data have consistently linked sexual exposure to the development of
920 BV in cross-sectional and longitudinal studies. Detection of BV has been associated with
921 inconsistent condom use and increased numbers of sexual partners in meta-analyses.¹⁶
922 Women with BV have an earlier median age of sexual debut than women without BV.²⁴⁰
923 Although several studies reported BV in “virgins”, the definition was limited to women with
924 no history of penile-vaginal sex and self-report from potentially vulnerable populations.²⁴¹⁻²⁴³
925 In contrast, a study of 500 female students collected detailed data on sexual behaviours via

926 self-completed questionnaire and employed self-sampling. BV was not detected in women
927 without a history of sexual activity with others, was uncommon in women who had only
928 engaged in non-coital sexual activities, and was associated with the practice of penile-vaginal
929 sex.²⁴⁴ Incident BV has been associated with exposure to a new sexual partner,^{227,240,245} while
930 recurrence after treatment has been associated with sex with an ongoing male partner,^{20,246}
931 suggesting that men may serve as a reservoir for infection and reinfection. Several studies
932 have found inconsistent condom use increased the risk of recurrence following
933 treatment.^{20,247,248} Although other behaviours have been associated with BV, including
934 smoking,²⁴⁹⁻²⁵² douching,²⁵³ dietary factors,²⁵⁴ and stress,²⁵⁵ only smoking has been
935 consistently associated with BV in adjusted analyses. The role of these other practices as
936 potential co-factors in the development of BV should not be discounted, however.

937 Epidemiological data consistently show high rates of concordance of BV within female
938 partnerships.^{251,256-259} BV has been associated with practices that implicate sexual
939 transmission between women,^{251,260} with incident BV associated with exposure to a new
940 female sexual partner, a female partner with BV symptoms or a history of BV, and receptive
941 oral sex in two prospective cohorts.^{259,261} Marrazzo and colleagues showed that monogamous
942 female couples share *Lactobacillus* strain types,²⁶² and Vodstrcil and colleagues found co-
943 enrolled female couples who did not have BV at enrolment remained with a stable healthy
944 vaginal microbiota over 24 months in the absence of new partnerships.²⁵⁹ Overall, these data
945 provide evidence to support dynamic exchange of both protective and detrimental vaginal
946 bacterial species between women in sexual relationships, or transmission of other agents that
947 directly influence the composition of the vaginal microbiota.

948

949 **The elusive male factor**

950 The apparent lack of symptoms in male partners and the fact that no single transmissible
951 aetiologic agent has been identified have greatly challenged progress in determining if BV is
952 sexually transmitted. There is, however, evidence to suggest that BV-associated bacteria or
953 bacterial communities, perhaps in biofilm form, are transferred between sexual partners.
954 Molecular sequencing analysis has shown that the sub-preputial space and distal urethra of
955 men can harbour a broad range of BV-associated bacteria.^{263,264} These BV-associated species
956 are more prevalent in the male partners of women with BV than without.¹⁷ In monogamous
957 couples, specific BV-associated species are highly concordant between women with BV and
958 their male partners.²⁶⁵ Concordance of oligotypes of *G. vaginalis* has also been reported
959 among heterosexual couples,²⁶⁶ confirming earlier culture-based studies showing concordance
960 of biotypes of *G. vaginalis* among heterosexual partners.²⁶⁷ Overall, these data indicate sexual
961 exchange of BV-associated bacterial taxa between heterosexual partners is common,²⁶⁵
962 although it is unclear whether men are actively infected or just transiently colonised. Only one
963 small study examined male carriage prospectively and the results suggested these organisms
964 spontaneously cleared over time in men without ongoing sexual exposure.²⁶⁸

965 The composition of the coronal sulcus microbiota is not only influenced by sexual activity
966 but also by male circumcision.²⁶⁹ Male circumcision has been prospectively associated with a
967 significant reduction in BV-associated genera,^{263,264} and a striking 40-60% reduction in BV
968 incidence in female partners over 12 months.²⁷⁰ Although there are few studies, BV-
969 associated biofilm has been detected in male urine and semen, and more commonly found in
970 male partners of women with BV than healthy controls.^{225,271,272} Collectively, these data
971 provide evidence for a sanctuary or reservoir of BV-associated species in men from which
972 women may either acquire disease, or be reinfected after treatment. Conversely, BV-infected
973 women may infect or colonise uninfected men, who could be particularly susceptible if
974 uncircumcised. It is quite plausible that the moist microenvironment of the sub-preputial
975 space could enhance the susceptibility of uncircumcised men, and could support a higher

976 organism load that may facilitate persistence and enhance transmission to women. This
977 explanation might underpin the ecological association seen in sub-Saharan Africa, where
978 populations with low rates of male circumcision also exhibit a high prevalence of BV in
979 women.²³⁰

980 The concept of a “symptomatic male disease counterpart” has not received much attention.
981 In two small studies in the 1980s, however, Keane and colleagues reported that non-
982 gonococcal urethritis (NGU) was more common in male partners of women with BV than in
983 male partners of women without BV, and that men with NGU were more likely to have
984 female partners with BV than men without NGU.²⁷³ In an attempt to explore this further,
985 Bradshaw and colleagues examined two key BV-associated bacteria, *G. vaginalis* and *A.*
986 *vaginae* in a case control study of NGU using quantitative PCR, but found neither was
987 associated with NGU and both were more commonly detected in the urethra of asymptomatic
988 controls than in men with NGU.²⁷⁴ Manhart and colleagues examined the association between
989 NGU and a broader range of BV-associated bacteria,²⁷⁵ and confirmed there was no
990 association with *G. vaginalis* or *A. vaginae*, but found that *Leptotrichia/Sneathia* were
991 significantly associated with NGU. BVAB-2, BVAB-3 and *Megasphaera* were only detected
992 in men with NGU, but they were uncommon, and there was no statistical evidence of an
993 association. The only other clinical presentation that has been reported in men is the syndrome
994 of *G. vaginalis*-associated balanoposthitis. In a single case report,²⁷⁶ three men presented with
995 a fishy odour, and erythema and irritation of the glans, sulcus and prepuce, all had female
996 partners with BV, and *G. vaginalis* isolated from the glans. So, although a “BV equivalent”
997 male syndrome does not appear to be common, NGU and perhaps balanoposthitis might be
998 associated with some BV-associated bacterial species.

999

1000 **Does treating sexual partners of women with BV improve cure?**

1001 RCTs conducted in the 1980 and 1990s did not provide consistent evidence for a reduction in
1002 BV recurrence in women when their male partners were concurrently treated.²⁷⁷⁻²⁸² These data
1003 formed the evidence base for subsequent BV treatment guidelines that do not recommend
1004 partner treatment, however, these trials have recently been examined in two systematic
1005 reviews.^{220,221} Mehta reported that none of the trials had sufficient power to detect reasonable
1006 effect sizes, randomisation methods were deficient or insufficiently reported, adherence to
1007 therapy was only reported in males in two trials, and many of the treatment regimens,
1008 including single dose therapy, would not now be considered effective.²²¹ A Cochrane review
1009 by Amaya-Guio and colleagues concluded that low to very low quality evidence suggests that
1010 antibiotic treatment does not lead to a lower recurrence rate.^{220,221} Overall the trials are
1011 considered inconclusive by current standards. The inconsistency between trial findings and
1012 epidemiological and microbiological data may be explained by a number of factors. The
1013 findings were clearly influenced by issues in trial design,²²¹ but these trials were also
1014 conducted prior to advances in molecular methods that have provided evidence of detection of
1015 BV-associated bacteria in the sub-preputial space of males. It is possible that optimal therapy
1016 to promote clearance of BV-associated bacteria from penile and urethral sites requires a
1017 combination of both topical and oral antibiotics. Alternatively, it is possible that non-bacterial
1018 agents such as viruses or bacteriophages, which have been implicated in the pathogenesis of
1019 BV, are being sexually transmitted, and if this is the case these agents will not be influenced
1020 by male partner treatment with antimicrobials.

1021

1022 **Do bacteriophages play a role in bacterial vaginosis?**

1023 Phage mediated lysis of lactobacilli has been postulated as a cause of BV, but there have been
1024 very few publications in this area. Kilic and Pavlova reported that lysogeny of *Lactobacillus*
1025 species (infection with bacteriophages) in women was common, but that the rate of

1026 lactobacillus phage detection was higher in women with BV than without.^{283,284} In *in vitro*
1027 studies they demonstrated that phages could infect lactobacilli both from the host and
1028 different women.²⁸⁴ Following this work, Blackwell hypothesised that a sexually transmitted
1029 lactobacillus phage might destroy healthy lactobacilli allowing secondary overgrowth of
1030 anaerobes, which could explain why BV behaves epidemiologically like an STI but BV
1031 recurrence rates were unaffected by male partner treatment.²⁸⁵ The phage theory can be
1032 biologically linked to the association between BV and smoking,²⁴⁹⁻²⁵² as tobacco products
1033 accumulate in cervical secretions, and the cigarette product benzol(a)pyrone diol epoxide
1034 promotes phage induction.^{249,285} Blackwell again hypothesized that smoking in women or
1035 their partners might be associated with BV through tobacco product induction of endogenous
1036 bacteriophages or sexually acquired phages.²⁸⁵ Further studies to clarify if bacteriophages
1037 play a role in the pathogenesis of BV in women and their male partners are clearly needed.

1038

1039 **Limitations of current management and the need for new approaches**

1040 *Antimicrobial therapy*

1041 Figure 6 provides a schematic representation of the broad range of approaches that have been
1042 attempted for the management and prevention of BV. As the inciting event that results in the
1043 development of BV is unknown, traditional treatment approaches have aimed to reduce the
1044 vaginal burden of anaerobes and to ameliorate concomitant symptoms. Overall, antimicrobial
1045 compounds with broad activity against most anaerobic bacteria—metronidazole and
1046 clindamycin—administered for 5-7 days, appear to achieve relatively high short term cure
1047 rates (80-90%),^{27,286,287} with use of intravaginal formulations resulting in fewer systemic side
1048 effects.²⁸⁸ Symptomatic BV persists or recurs in 50%-70% of women within 3-6 months,
1049 however, and long-term recurrence rates approach 80% in certain populations.^{246,289-291}
1050 Possible reasons for this include: re-inoculation with these organisms from an exogenous

1051 source (i.e. sexual partner) or an endogenous source (i.e. rectal reservoir); failure to
1052 completely suppress the growth of BV-associated bacteria (i.e. located within a biofilm);
1053 persistence of host risk factors (for example, douching or smoking); failure to recolonise the
1054 vagina with desirable lactobacilli; and transmission of or activation of *Lactobacillus* phages
1055 that destroy vaginal lactobacilli.^{283-285,292} None of these mechanisms has been conclusively
1056 shown to explain the high rates of BV recurrence, or to identify women at increased risk for
1057 BV incidence, recurrence, or sequelae. If sexual transmission is involved in the pathogenesis
1058 of BV, as hypothesised, it is still not clear what is being transmitted - a single founder
1059 organism (a bacterium or virus), a bacteriophage that lyses protective lactobacillus species or
1060 a polymicrobial bacterial consortium in the form of biofilm.

1061 Factors that determine whether a woman with BV will respond to standard antimicrobial
1062 regimens are also not clear. One prospective study indicated that detection of specific BV-
1063 associated bacteria prior to treatment with intravaginal metronidazole predicted treatment
1064 failure at 30 days.²⁹¹ Investigators have examined whether AMR plays a role and, while
1065 clindamycin-resistant bacteria have been detected among women treated with vaginal
1066 clindamycin, their presence was not associated with reduced cure rates.^{293,294} Metronidazole is
1067 active against Gram-negative anaerobes and *Mobiluncus mulieris*, but it is less active against
1068 *G. vaginalis*, anaerobic Gram-positive cocci and *Mobiluncus curtisii*, and inactive against *M.*
1069 *hominis* and *A. vaginae*.^{293,294} Despite that, many of these *in vitro* non-susceptible species are
1070 eradicated following metronidazole therapy, indicating that inhibition or elimination of
1071 metronidazole-susceptible members of the vaginal bacteria in BV might result in a decline in
1072 some non-susceptible members as well. In an attempt to effect higher BV cure rates,
1073 investigators have increased the dose and duration of nitroimidazoles. Metronidazole, when
1074 used as monthly presumptive therapy, was effective in preventing BV over 12 months of
1075 use.²⁹⁵ Twice weekly vaginal metronidazole gel was also found to be effective in suppressing
1076 BV during use, with the rationale being that suppression of overgrowth of BV-associated

1077 bacteria may offer greater symptom relief, and eventually increase the chance of restoration of
1078 a normal vaginal microbiota.²⁹⁶ While a number of prolonged or intermittent suppressive
1079 regimens appear effective during use, relapse on discontinuation remains common, and none
1080 has improved long term cure rates in women. Whether treating women with recurrent BV
1081 with a longer initial course of metronidazole (10-14 days with vaginal gel or oral tablets) or a
1082 one week course of oral tinidazole will improve cure rates has not been established. One study
1083 that compared 14 days with seven days of metronidazole treatment found statistical evidence
1084 of a benefit when cure was assessed seven days after completion of therapy, but not at 21
1085 days.²⁴⁸

1086

1087 *Biofilm disruption*

1088 The presence of a BV-associated biofilm might also contribute to the high rates of failure of
1089 antimicrobial therapy. Biofilms not only reduce antimicrobial penetration enabling susceptible
1090 microbes to persist, but contain microbes in varying states of metabolic activity with some in
1091 more dormant inactive states.^{292,297,298} When visualised with specific fluorescent probes, *G.*
1092 *vaginalis* has been detected in large quantities within adherent biofilms among women with
1093 BV, and some studies indicate that these biofilms persist in women experiencing treatment
1094 failure.^{299,300} Biofilm disruption might be necessary to achieve optimal efficacy of
1095 antimicrobials. Agents that display activity against biofilms include: octenidine, boric acid,
1096 DNAses, retrocycline, and naturally occurring antimicrobials (subtilosin, ploy-L-lysine, and
1097 lauramide arginine ethyl ester).³⁰¹⁻³⁰⁶ Boric acid and octenidine are currently the only agents
1098 to have been evaluated in human studies. While use of metronidazole after 21 days of boric
1099 acid reduced BV recurrence on treatment, late post-treatment recurrence was common.³⁰¹
1100 Similarly, early BV cure rates looked promising with intravaginal octenidine, but BV
1101 recurrence occurred in a significant proportion of women and bacterial resistance to
1102 octenidine also emerged.³⁰² A recent *in vitro* study showed that metronidazole and tobramycin

1103 were highly effective against biofilm formation but ineffective against established biofilm.
1104 Amphoteric tenside sodium cocoamphoacetate was, however, highly effective in disrupting
1105 biofilm, reducing biomass by 51% and augmented the effect of metronidazole, indicating that
1106 this might have potential as a combination approach for BV.³⁰⁷ As *G. vaginalis* biofilms
1107 contain extracellular DNA, enzymatic disruption by DNase has been shown to inhibit *G.*
1108 *vaginalis* biofilm formation and to disrupt biofilms *in vitro*.³⁰³ DNase appears to be even more
1109 effective *in vitro* when combined with metronidazole,³⁰³ but has not yet been subject to
1110 human studies for BV. RC101, a retrocycline and potent inhibitor of vaginolysin (a toxin
1111 produced by *G. vaginalis*), also inhibits the formation of *G. vaginalis* biofilms *in vitro*,^{305,306}
1112 and might be another potential candidate for human studies in BV. Lastly, an emerging area
1113 of research involves inhibition of quorum sensing, a strategy that some bacteria use to
1114 coordinate expression of genes involved in virulence, biofilm formation and
1115 pathogenicity.^{298,308} While quorum sensing inhibitors have not been evaluated in human
1116 studies, they are active *in vitro* against biofilms produced by *Pseudomonas aeruginosa* and
1117 *Staphylococcus spp.*^{308,309} Overall, the development of safe and effective topical biofilm-
1118 disrupting agents that can be combined with antimicrobials has been suggested as an
1119 important area of current research.²⁹⁸

1120

1121 *Approaches to restore a healthy vaginal microbiota*

1122 Because of the apparent ecological shift in the vaginal microflora in BV, therapies that either
1123 act as vaginal disinfectants or aim to restore the vaginal ecosystem have been evaluated.
1124 Although repletion of desirable *Lactobacillus* species would seem to be key, this strategy has
1125 presented challenges, and probiotic trials to date have not demonstrated consistent benefit.³¹⁰
1126 One of the barriers to progress has been lack of suitable vaginal species for probiotic
1127 formulations, but a *L. crispatus* vaginal capsule, first known as CTV 05 and now termed

1128 LACTIN-V, has recently been shown to achieve vaginal colonisation, to be safe³¹¹⁻³¹³ and to
1129 prevent recurrent urinary tract infections in a Phase 2B RCT;³¹⁴ it is now under study for
1130 treatment of BV. The efficacy of vaginal acidifiers such as lactic acid, in the form of gels,
1131 suppositories and acid-soaked tampons, has varied widely. Vaginal acidifiers will suppress,
1132 but not kill, vaginal anaerobes, so may suppress without affecting a cure. A systematic review
1133 of these agents found they were either ineffective or not adequately tested due to limitations in
1134 study size, design or analysis, and that more data are needed.³¹⁵

1135

1136 **Conclusion**

1137 The adverse impact of BV is felt by the women who experience it, their partners and infants,
1138 and their health care providers who struggle to effectively treat it. As we have discussed, the
1139 available epidemiological and microbiological data provide strong evidence of carriage of
1140 BV-associated bacteria in male genitalia and exchange of either these species within sexual
1141 partnerships or another agent capable of inciting BV. There is also compelling evidence for
1142 the impact of male circumcision and condom use on reducing the risk of BV acquisition and
1143 recurrence. Overall, these data strongly suggest that sexual transmission is an integral
1144 component of the pathogenesis of incident and recurrent BV. Earlier partner treatment trials
1145 had substantial methodologic limitations, and do not provide an adequate body of proof to
1146 discount the possibility that male partner treatment may reduce BV recurrence in women.
1147 New partner treatment trials, conducted in accordance with current clinical trial standards, and
1148 employing modern microbiologic tools, are needed to determine the contribution of
1149 reinfection to recurrence, and to provide an accurate evidence base for treatment guidelines.
1150 Given the data supporting an anatomic reservoir of BV-associated bacteria in male genitalia, a
1151 logical approach might emphasise trials that study a potential role of topical antimicrobials in
1152 addition to oral agents; eradication of cutaneous carriage of these bacteria from the penile skin

1153 may reduce the risk of reinfection and optimise BV cure. Female partner treatment trials could
1154 also facilitate understanding of pathogenesis, and identify new approaches to management.
1155 While the relative contribution of persistence of BV-associated bacteria versus reinfection to
1156 BV recurrence is not clear, both mechanisms are likely to play a role. It is also possible that
1157 other factors including failure to recolonise the vagina with desirable lactobacilli, persistence
1158 of host risk factors or lactobacillus phages contribute. Ultimately, optimal treatment strategies
1159 are likely to require combination approaches such as use of antimicrobials, biofilm-disrupting
1160 agents and partner treatment. Efforts to optimise the therapeutic and preventive approach to
1161 this complex syndrome will, however, require allocation of the necessary resources and
1162 commitment be made to a disease that remains largely hidden from public view. Yet BV is
1163 not rare or benign, it is a condition of high global burden in women of reproductive age and is
1164 associated with serious and costly sequelae, including preterm delivery and increased risk of
1165 HIV acquisition and transmission. Recognition for this neglected condition—in the form of a
1166 coherent, progressive research agenda and concomitant resource allocation—is well past due.

1167

1168 **Part 4. STI case management and control in low and middle income** 1169 **countries: the role of point of care tests**

1170 In 2012, over 90% of new estimated cases of gonorrhoea, chlamydia, trichomoniasis and
1171 syphilis were from low and middle income countries (Figure 1).² These curable STIs can lead
1172 to severe complications and long-term sequelae, burdening already over-stretched health care
1173 systems. Primary prevention of STIs in low and middle income countries has shown some
1174 success with vaccines against human papillomavirus (HPV) and hepatitis B and with male
1175 circumcision, but less so with interventions to promote sustained behaviour change and
1176 condom promotion.³¹⁶ STI case management and secondary prevention by screening and/or

1177 treatment to prevent complications have been hampered largely by the lack of affordable and
1178 accessible diagnostic tests. Case management of STIs in low and middle income countries has
1179 relied on syndromic management for patients presenting with symptoms;^{133,317} syndromic
1180 management, however, has poor specificity, results in overtreatment with antibiotics and does
1181 not disrupt transmission among those with asymptomatic infection.

1182 Most low and middle income countries have policies for universal syphilis screening
1183 during pregnancy for secondary prevention of congenital syphilis. WHO has prioritised the
1184 elimination of congenital syphilis and Cuba became the first country to achieve the targets for
1185 elimination of mother-to-child transmission of both syphilis and HIV in June 2015.³³
1186 Nevertheless, implementation of antenatal syphilis screening policies is weak in many
1187 countries. The highest estimates of syphilis prevalence were found in the WHO African
1188 Region (estimated prevalence amongst antenatal attendees is from 4.6 to 6.5%); the median
1189 reported proportion of antenatal attendees tested for syphilis was 58% in the African Region,
1190 versus 83-99% in other regions.^{2,318} The proportion of pregnant women not tested for syphilis
1191 in antenatal care fell from 2008 to 2012 in all regions except Africa.³¹⁹ The Joint United
1192 Nations Programme on HIV/AIDS (UNAIDS) published data on the Global Plan towards the
1193 elimination of new HIV infections and reported that mother-to-child transmission rates of
1194 HIV were reduced by 71-86% in African countries between 2009 and 2015.³²⁰ The lack of
1195 similar progress in syphilis screening in Africa illuminates the tragic reality that many babies
1196 will have avoided HIV, but died from syphilis.^{321,322} There are few other specific policies for
1197 control of STIs in low and middle income countries. While most syndromic management
1198 guidelines include partner notification and treatment, this is often weakly implemented.³²³
1199 Periodic presumptive treatment in targeted populations, such as commercial sex workers, has
1200 shown promise but overtreatment with antibiotics is still a concern.³²⁴

1201 Rapid and simple POC tests might provide solutions for both STI case management and
1202 control. The key features of POC tests are turnaround times that are fast enough to allow

1203 completion of testing, communication of results that guide clinical decisions and follow-up to
1204 take place at the same clinical encounter.¹⁴⁷ There are affordable highly sensitive and specific
1205 POC tests for syphilis. While there are several hopeful tests in the pipeline for chlamydia and
1206 gonorrhoea, the available POC tests have low accuracy or require expensive equipment.³²⁵
1207 Yet, even with well performing, affordable POC tests, challenges will remain for
1208 implementing POC testing into national health systems. This section of the *Commission*
1209 reviews current challenges facing case management and STI control related to secondary
1210 prevention of curable STIs in low and middle income countries, and provides an update of the
1211 state of the art of POC tests.

1212

1213 **Case management of symptomatic STIs in low and middle income countries**

1214 Case management is the treatment of infections to alleviate signs and symptoms, and to
1215 prevent sequelae, and includes history-taking and clinical examination, diagnostic tests,
1216 treatment, partner notification, health promotion advice, follow-up and surveillance.³¹ Case
1217 management is an integral part of an STI control strategy; early treatment can disrupt onward
1218 transmission if treatment and partner notification are successful. The treatment of clinical
1219 syndromes, commonly called syndromic management, was developed in the late 1970s and
1220 early 1980s to address the practical difficulties of managing STIs where diagnostic tests are
1221 not available.³²⁶ In 1985, the first WHO guidelines for STI management included four simple
1222 algorithms for the management of syndromes that are associated with common STIs: genital
1223 ulcers, urethral discharge, vaginal discharge and PID. Patients are treated for all the probable
1224 causes of these syndromes. These guidelines gained recognition in the growing HIV epidemic
1225 in the early 1990s, when the link between STI and HIV became clear, and have become the
1226 backbone of case management for STIs in many low and middle income countries. The
1227 current WHO syndromic management guidelines have algorithms for six syndromes: urethral

1228 discharge, genital ulcers, scrotal swelling, vaginal discharge, low abdominal pain, and
1229 neonatal conjunctivitis.¹³³

1230 The advantages of syndromic management include low cost, modest training requirements
1231 and provision of immediate treatment. The main disadvantage is that syndromic management
1232 unnecessarily treats for infections that are not present, and misses asymptomatic infections,
1233 which are the majority of STIs globally.³²⁷ This is especially true for vaginal discharge
1234 syndrome which is more commonly caused by BV, candidiasis or trichomoniasis, than by
1235 chlamydia and gonorrhoea.⁴³ Several studies have shown poor sensitivity and specificity of
1236 syndromic management for chlamydia and gonorrhoea in women.³²⁸⁻³³¹ Efforts to increase
1237 accuracy for the vaginal discharge syndrome with a risk assessment were evaluated, but
1238 sensitivity and specificity remained poor.³³² This is because most women with vaginal
1239 discharge do not have these infections, and most women (up to 70%) with chlamydia and
1240 gonorrhoea have no symptoms.¹⁷ Unfortunately, asymptomatic infection is still likely to cause
1241 harmful sequelae. A study among female sex workers in South Africa has shown that
1242 cervicovaginal inflammatory markers were elevated in women with an STI whether or not it
1243 was symptomatic.³³¹ Previous studies have suggested that elevated inflammatory markers may
1244 facilitate HIV transmission,³³³ and thus, women with asymptomatic STIs might be as
1245 susceptible to HIV infection as those with symptoms. Additionally, it is estimated that the use
1246 of syndromic management results in the unnecessary treatment of 60-98% of women
1247 presenting with vaginal discharge for chlamydia and gonorrhoea.³³⁴ Any use of antibiotics
1248 encourages resistance, so it is important that the unnecessary use of antibiotics is limited. As
1249 noted by *Unemo* in Part 2, increased resistance to most antibiotics used to treat gonococcal
1250 infections has been reported worldwide, raising concerns about the eventual development of
1251 untreatable gonococcal infections with serious sexual and reproductive health consequences.

1252

1253 **Partner notification**

1254 In Part 1, *Low and Hocking* discuss partner notification strategies for the management of
1255 diagnosed chlamydia. In the context of syndromic management in low and middle income
1256 countries, partner treatment often results in over-prescription of antibiotics, especially of
1257 partners of women with vaginal discharge, most of whom do not have an STI.³³⁵ A systematic
1258 review of partner notification in developing countries found that partner notification for STIs
1259 was feasible in low and middle income countries and that most patients diagnosed with STIs
1260 were willing to self-notify their regular partners.³³⁶ There are, however, major barriers to
1261 successful partner notification, including fear of abuse and rejection resulting from partner
1262 referral, especially for women. Economic vulnerability of women must be considered in the
1263 design of partner notification strategies in low and middle income countries in which female
1264 partners may be blamed for the infection.³³⁵ There is a need for the development and
1265 evaluation of partner notification strategies in low and middle income countries using
1266 biological outcomes, such as reinfection.¹³⁸

1267

1268 **Targeted presumptive treatment**

1269 Presumptive treatment is the treatment for a presumed infection in populations with a high
1270 burden of STIs without confirmation of infection by an examination or laboratory test.
1271 Presumptive treatment for STIs may be given at repeated intervals, in which case it is known
1272 as periodic presumptive treatment. Periodic presumptive treatment is complementary to
1273 syndromic management and targets asymptomatic infection in high burden, key populations –
1274 many of whom are stigmatised and hard to reach, such as female sex workers. Most periodic
1275 presumptive treatment targets chlamydia, gonorrhoea and syphilis, and it has been most
1276 extensively evaluated in sex worker populations. In 2005, a WHO consultation reviewed

1277 experience from nine countries and recommended that periodic presumptive treatment be
1278 considered as a part of the package of services to rapidly reduce STI prevalence in sex worker
1279 settings, particularly where STI control is poor.³³⁷ In 2012, a systematic review reported the
1280 results from 15 studies and showed consistent reductions of about 50% prevalence in
1281 populations with high chlamydia and gonorrhoea prevalence. There was limited evidence for
1282 chancroid - one study showed rapid decline of chancroid – and mixed evidence for syphilis.³³⁸
1283 Modelling studies have shown that, if sufficient coverage is achieved (>30% of the target
1284 population), periodic presumptive treatment interventions can effectively reduce the STI
1285 prevalence among the target population, and that interventions with sufficient coverage
1286 ($\geq 40\%$) and follow-up (≥ 2 years) could significantly decrease HIV incidence ($> 20\%$).³³⁹

1287 Presumptive treatment can be an effective approach to the treatment of asymptomatic
1288 infection among women (at least those at high risk) and may interrupt transmission between
1289 sex workers and their clients, but needs evaluation in other populations. Importantly,
1290 presumptive treatment must be sustained; once stopped, infections recur. In addition, a
1291 disadvantage is unnecessary treatment of people who are not infected with an STI and the
1292 contribution to the development of AMR, as discussed above.

1293

1294 **Screening programmes**

1295 Antenatal syphilis screening and treatment is effective and cost-effective for the prevention of
1296 adverse pregnancy outcomes.³⁴⁰ Fifty-two low and middle income countries reported testing
1297 coverage for syphilis during antenatal care for 2012, however, only about a third reported
1298 coverage of at least 95%, whereas another third reported coverage of less than 50%.^{317,341} Of
1299 14 countries that report current policies for antenatal screening of *C. trachomatis* and *N.*
1300 *gonorrhoeae* infections, only two (Romania and Bulgaria) are in the category of low and

1301 middle income; most low and middle income countries use WHO recommended syndromic
1302 management for the treatment of symptoms during antenatal care.³⁴²

1303 Screening of high-risk populations, including sex workers has shown some success in
1304 research studies and demonstration projects,^{343,344} but has not been widely replicated in low
1305 and middle income countries due to the cost of diagnostics and laboratory capacity.³⁴³
1306 Evidence about chlamydia screening is discussed in detail in Part 1.

1307

1308 **The use of POC testing for case management and STI control**

1309 POC tests provide prompt diagnosis for case management, provide a definite diagnosis of an
1310 STI which can further justify and facilitate partner notification, and can be used for screening
1311 antenatal care attendees and populations at high risk for STIs. There are several low cost
1312 techniques for STI diagnosis that can be done at the POC, including wet mount and Gram
1313 stain microscopy, but they require laboratory equipment and lack sensitivity, particularly for
1314 diagnosing infections in women. Rapid plasma reagin (RPR), a non-treponemal test for
1315 syphilis, can also be done at the POC, but it requires separation of serum, refrigeration and
1316 equipment, and has low accuracy in settings with insufficient training or facilities.³⁴⁵⁻³⁴⁷ In
1317 addition, RPR tests are often batched or sent to a central laboratory, resulting in patients not
1318 returning or staying for treatment.^{345,348,349}

1319 To guide the development of simple and rapid POC tests, WHO developed the ASSURED
1320 benchmarking in 2006. ASSURED POC tests are Affordable by those who are at risk for the
1321 infection; Sensitive, very few false negatives; Specific, very few false positives; User-
1322 friendly, very simple to perform (minimal steps required with minimal training); Rapid and
1323 Robust, to enable treatment at visit of diagnosis (rapid) and does not require refrigeration
1324 storage (robust); Equipment free, easily collected non-invasive specimens (e.g. saliva and
1325 urine) and not requiring complex equipment; and Delivered to end users.³⁵⁰ Three recent

1326 systematic reviews summarise the available information on POC tests for STIs: Tucker and
1327 colleagues;³⁵¹ Gaydos and Hardick;³⁵² and Herbst de Cortina and colleagues.³⁵³ Reviews
1328 evaluated available POC tests and those in the pipeline. The WHO landscape analysis of POC
1329 tests by Murtagh provides a listing of currently available POC tests and those in the
1330 pipeline;³²⁵ this analysis will be updated annually by WHO. Available POC tests have been
1331 summarised in table 3.

1332

1333 *POC tests for chlamydia and gonorrhoea*

1334 Most POC tests currently available for the detection of *C. trachomatis* or *N. gonorrhoeae* are
1335 based on antigen detection in lateral flow devices and do not meet ASSURED criteria because
1336 of low sensitivity and/or specificity. While the aQcare Chlamydia TRF and BioStar Optical
1337 Immunoassay for gonorrhoea have been shown to be highly sensitive and specific, both have
1338 only been evaluated in one study each (for BioStar Optical Immunoassay only a pilot study
1339 including five confirmed *N. gonorrhoeae* positive specimens).^{354,355} There is general
1340 agreement that most current POC tests for the detection of *C. trachomatis* or *N. gonorrhoeae*
1341 do not perform well, and there is a need for improved assays. Nevertheless, modelling studies
1342 have suggested that even insensitive POC tests may increase the proportion of infections
1343 treated in scenarios where it would be difficult to ensure a high patient return rate, and in
1344 populations where there is potential for further STI transmission during the delay in treatment
1345 from using laboratory STI tests.³⁵⁶⁻³⁵⁸

1346 GeneXpert (Cepheid, Inc), a NAAT-based test with high sensitivity and specificity for
1347 detection of *C. trachomatis* and *N. gonorrhoeae* has been termed a *near*-POC test as it
1348 requires equipment, is expensive and has a relatively long turnaround time (approximately 90
1349 minutes). There are many new technologies in the pipeline (Figure 7) which are likely to be
1350 highly accurate and require minimal training and processing time including the io® Platform
1351 (Atlas Genetics), GeneXpert® Omni (Cepheid), RT Cross-priming Amplification CT Test

1352 (Ustar Biotechnologies), Truelab™ Real Time micro PCR System (Molbio Diagnostics Pvt.
1353 Ltd), Alere™-i Platform (Alere, Inc), CT/NG MAMEF-based detection, and MobiLab (Johns
1354 Hopkins University BioMEMS Lab).^{325,351,353} The latter test employs smartphones for reading
1355 results.

1356

1357 *POC tests for trichomoniasis*

1358 The OSOM® Trichomonas Test (Sekisui Diagnostics) for detection of *T. vaginalis* infection
1359 has been shown to perform well against wet mount and culture (83.3-90.0% sensitivity and
1360 98.8-100% specificity).^{325,353} The OSOM test for detection of *T. vaginalis* meets the
1361 ASSURED benchmark by having few steps and taking only 10 minutes to perform.
1362 GeneXpert platform also has an assay to detect *T. vaginalis* and this test has been evaluated in
1363 two studies and found to be sensitive and specific (95.0-95.6% and 95.7-100%
1364 respectively);^{359,360} however, the GeneXpert platform does not meet ASSURED
1365 benchmarking as stated above. In the pipeline, Atlas io™ has an assay in development as well
1366 as AmpliVue® (Quidel Corporation).³²⁵

1367

1368 *POC tests for syphilis*

1369 Four treponemal POC tests for syphilis have been evaluated and met the ASSURED criteria,
1370 and these are recommended in resource-limited settings: Determine™ Syphilis TP (Alere,
1371 Inc), SD Syphilis 3.0 (Alere SD Bioline), Syphicheck® WB (The Tulip Group/Qualpro), and
1372 Visitect® Syphilis (Omega Diagnostics).^{350,361} These tests are accurate, cost less than \$1 if
1373 purchased through the WHO bulk procurement programme for low and middle income
1374 countries, can provide results in 15 to 20 minutes, and are easy to use with minimal training.
1375 In addition to these tests that have been extensively evaluated, other POC tests for syphilis are
1376 on the market including Crystal TP Syphilis Test (Span Diagnostics), *OnSite*™ Syphilis Ab

1377 Combo rapid Test (CTK Biotech Inc.), Syphilis Health Check™ (Diagnostics Direct), and
1378 Uni-Gold™ Syphilis Treponemal (trinity Biotech).³²⁵

1379 Treponemal POC tests have been implemented and evaluated in rural antenatal care clinics
1380 in Tanzania, Uganda and China; both rural and urban clinics in Peru and Zambia; and in
1381 remote indigenous communities in Brazil.³⁶² The introduction of POC tests increased the
1382 proportion of antenatal care attendees screened for syphilis to 90%, and the proportion of
1383 pregnant women with syphilis who were treated the same day exceeded 90% in all countries.
1384 Modelling from this study has shown that POC tests are more cost-effective in screening and
1385 treating syphilis than laboratory-based testing methods such as the RPR.³⁶³

1386 Treponemal POC tests have also been used in hard-to-reach populations. In Brazil, health
1387 care workers in remote communities succeeded in screening 55% of the sexually active
1388 population (defined as ≥ 10 years of age) for syphilis, exceeding the 30%–40% target
1389 originally set.³⁶² Modelling studies have estimated the impact of using rapid POC tests to
1390 screen female sex workers for syphilis and shown that rapid POC test screening could
1391 dramatically reduce syphilis prevalence amongst this hard-to-reach group, but strategies to
1392 reduce re-infection from regular non-commercial partners are needed to maximise impact.³⁶⁴

1393 Once a person has been infected with *T. pallidum*, all future treponemal tests will be
1394 positive; therefore, there is concern that treponemal POC tests cannot distinguish between
1395 current and past infection, resulting in over treatment for syphilis. This is particularly
1396 important in settings in which access to confirmatory testing using non-treponemal tests is
1397 limited. Therefore, combination POC platform tests have been developed which include both
1398 treponemal and non-treponemal antigens. The Dual Path Platform test is the first of these, and
1399 has good sensitivity and specificity for both treponemal (90.1–98.2% and 91.8–98.0%,
1400 respectively) and non-treponemal (80.6–98.2% and 89.4%, respectively) tests.³⁶⁵

1401

1402 *POC tests for syphilis and HIV*

1403 There is also a need for dual syphilis and HIV tests. These could be used in populations at
1404 high risk for both HIV and syphilis, and accelerate programmes for the elimination of mother
1405 to child transmission of both HIV and syphilis, especially in countries in Africa that have
1406 made excellent progress towards the elimination of mother to child transmission of HIV but
1407 not syphilis. In 2017, WHO published an information note to provide advice for countries
1408 using or planning to introduce dual HIV/syphilis POC tests in antenatal services and other
1409 testing sites.³⁶⁶ There are currently five combination HIV/syphilis POC tests on the market
1410 (Figure 8), of which three have published data on sensitivity and specificity: Standard
1411 Diagnostics (SD) Bioline HIV/Syphilis Duo Rapid Test; Chembio DPP® HIV-Syphilis
1412 Assay; and Medmira Multiplo Rapid TP/HIV Antibody Test.³²⁵ In addition to these, there is
1413 an innovative dual POC test in the pipeline, mChip Assay (Junco Labs and Columbia
1414 University in collaboration with OPKO Health, Inc), which uses a microfluidic mChip and a
1415 smart phone for reading results.³²⁵

1416

1417 *POC tests for AMR gonorrhoea*

1418 There are, as yet, no commercially available diagnostic assays that detect gonococcal
1419 AMR.¹⁹¹ There is an urgent need for the development of these diagnostics with a focus
1420 towards POC tests. Detection of both *N. gonorrhoeae* and its main resistance determinants at
1421 the POC would improve management and help to slow the spread of AMR, particularly in low
1422 and middle income countries.¹⁹¹

1423

1424 **Challenges for the implementation of POC tests**

1425 POC tests have the potential to transform case management and STI control in low and
1426 middle income countries. To be effective at the population level, however, they must be
1427 adopted by national health systems and this requires careful consideration. Decentralising

1428 testing from the laboratory can put tremendous stresses on fragile health care systems in terms
1429 of supply chain management, training, quality assurance and monitoring impact.

1430 A study in Peru has shown that the use of POC tests offers an opportunity to improve
1431 screening coverage for syphilis and other aspects of health systems.^{362,367} Widespread
1432 adoption and use depends on engaging the authorities; dissipating tensions between providers
1433 and identifying champions; training according to the needs identified; providing monitoring,
1434 supervision, support and recognition; sharing results and discussing actions together;
1435 consulting and obtaining feedback from users; and integrating with other services such as with
1436 rapid HIV testing.^{362,367} As countries begin to implement POC testing, adequate training and
1437 quality assurance programmes must be developed in parallel. Smit and colleagues evaluated
1438 the use of dry blood spots to evaluate quality of POC syphilis and HIV tests in Tanzania, and
1439 found that quality varied between clinics, which helped to identify which clinics needed
1440 remedial training.³⁵⁷

1441 Ultimately, POC tests pave the way for self-sampling and self-testing outside of a clinical
1442 setting including community-based organisations, pharmacies and at home. Home-based
1443 testing for HIV has been shown to reach wide sections of communities in a diverse range of
1444 contexts and settings, and is viewed to be the gateway to accessing early treatment and
1445 care.³⁶⁸ However, important lessons can be learned from the roll out of simple and rapid HIV
1446 POC tests in which the major challenges have been well recognised including poor quality
1447 control, unreliable supply chains, non-standardised training, and limited number of healthcare
1448 workers.³⁶⁹ Decentralising testing for curable STIs might increase access to testing and
1449 awareness of STIs, but linkage to the health care system will be critical for diagnostic
1450 confirmation, treatment, counselling and follow-up.³⁵¹ POC tests that meet ASSURED
1451 benchmarks are likely to fill an important gap for STI control in low and middle income
1452 countries, yet the technological innovation of POC tests needs to be mirrored by innovation in
1453 health care delivery and careful planning for implementation.

1454

1455 **Conclusion**

1456 Low and middle income countries shoulder the majority of global incident cases of STIs,
1457 yet national health systems are less resourced to manage STI cases or carry out secondary
1458 prevention. POC tests that meet the WHO ASSURED benchmark could bridge the gap for
1459 STI case management and control in these settings. Currently there are POC tests for
1460 syphilis and trichomoniasis which meet the ASSURED benchmark. In contrast, there are no
1461 ASSURED POC tests for chlamydia or gonorrhoea, and there is an urgent need for the
1462 development and evaluation of POC tests for these infections, as well as for AMR *N.*
1463 *gonorrhoeae*. Importantly, while development of ASSURED POC tests is a crucial target,
1464 the successful implementation of POC tests into health care systems for the prevention and
1465 control STIs is the goal. Indeed, the goal for the implementation of POC tests into antenatal
1466 screening for syphilis is 100% screening and treatment of syphilis worldwide. Future
1467 ASSURED POC tests for curable STIs will need to be integrated into syndromic
1468 management guidelines as well as control strategies such as partner notification and
1469 targeted presumptive treatment. It will be essential that implementation research guides
1470 integration of POC tests into current strategies for STI case management and control in low
1471 and middle income countries.

1472

1473 **Part 5. STIs in MSM in the era of biomedical interventions for HIV**

1474 **prevention**

1475 A historical perspective provides insights into the epidemiology of STIs in MSM in the 21st
1476 century as we enter a new era of antiretroviral-based biomedical interventions for HIV
1477 prevention in high income countries. The first relevant trend was the rise in notification rates

1478 of gonorrhoea and syphilis in men from the 1960s onwards in countries such as England and
1479 Wales (Figure 9A) and the USA (Figure 9B). The increase in infections amongst MSM is
1480 reflected in the rising ratio of male to female notifications in surveillance systems that do not
1481 record the route of acquisition of STIs. Sexual acts between men were illegal in these
1482 countries in the 1960s and levels of stigma towards both homosexuality and STIs were still
1483 extremely high.³⁷⁰ The availability of penicillin was already stated to have encouraged
1484 morally sanctioned behaviours by removing fear as a deterrent, particularly of syphilis.⁸

1485 Feldman remarked that “to the astute venereologist AIDS is an almost inevitable
1486 consequence of the increase in sexually transmitted diseases”.³⁷¹ Rates of gonorrhoea and
1487 syphilis, and the male to female ratio of infections, reached a peak in the late 1970s (Figures 9
1488 and 10). Other STIs were also common; 50-70% of MSM had serological evidence of
1489 hepatitis B infection³⁷² and outbreaks of infections, such as lymphogranuloma venereum
1490 (LGV) were reported.³⁷³ Infections such as hepatitis A and enteric pathogens, such as *Giardia*
1491 *lamblia*, *Entamoeba histolytica* and *Shigella* spp., were common causes of gastrointestinal
1492 disease in MSM and resulted in terms (now considered inappropriate) such as ‘gay bowel
1493 syndrome’.³⁷⁴ Given what is now known about the biological effects of STIs to increase both
1494 infectiousness of, and susceptibility to, HIV,⁵ these infections are likely to have facilitated the
1495 early spread of HIV before it became clinically manifest as opportunistic infections and
1496 cancers.

1497 Links between the opportunistic conditions comprising AIDS, risky sexual practices and a
1498 history of multiple STIs in MSM were noted early on,³⁷⁵ well before a retrovirus was
1499 discovered as the cause of AIDS. Rates of gonorrhoea and syphilis actually began to fall in
1500 the late 1970s but the rate of decline accelerated rapidly after the first deaths from AIDS were
1501 reported in the early 1980s.^{123,376,377} Campaigns that arose in the gay community advised
1502 MSM to reduce numbers of partners and to use condoms, resulting in the development of the
1503 terminology of ‘safer sex’ within the context of harm reduction. Government-sponsored

1504 public health campaigns for the general population followed.¹²³ Figure 9A shows the large
1505 decline in syphilis notifications in England from 1983 onwards, but notifications of other STIs
1506 including LGV and other enteric pathogens also fell.^{123,373} By 1994, rates of syphilis and
1507 gonorrhoea were at their lowest levels since surveillance began (Figures 9A and 10).

1508 Trends in STIs and sexual behaviour in MSM since the mid-1990s have occurred in the
1509 context of continued developments and improvements in antiretroviral therapies (ARTs) for
1510 both HIV treatment and for prevention. Notification rates of syphilis, gonorrhoea and
1511 chlamydia in MSM have all risen (Figure 10).³⁷⁸⁻³⁸¹ A review of syphilis in 31 high income
1512 countries between 2000 and 2013 showed that the male to female ratio increased in all
1513 geographical regions from 4.1 in 2000 to 7.9 in 2013.³⁸¹ New outbreaks of LGV,³⁷³ hepatitis
1514 C, and shigellosis have also appeared, particularly in HIV-infected MSM.³⁷⁹ Combination
1515 ART (cART) became available in the mid-1990s and drastically improved the prognosis for
1516 people with HIV infection,³⁸² changing the nature and course of HIV from a deadly infection
1517 to a chronic disease. Further advances in the efficacy of cART with less toxic drugs and less
1518 complicated dosing schedules, together with improvements in monitoring viral load and
1519 resistance, prompted recommendations for earlier commencement of therapy for HIV-infected
1520 people.³⁸³ The first use of cART to prevent, rather than treat, HIV was post-exposure
1521 prophylaxis (PEP), for short-term prophylaxis to reduce the risk of HIV acquisition after a
1522 substantial risk of exposure to infection.³⁸⁴ Since the mid-2000s, the potential for cART to be
1523 used to prevent HIV transmission followed research showing that cART reduces HIV
1524 infectiousness and when HIV replication is suppressed to undetectable levels in plasma,
1525 transmission can be virtually eliminated.^{385,386} Treatment as prevention (TasP; also known as
1526 “test and treat”³⁸⁷) refers to a population-level strategy of starting cART as soon as HIV is
1527 diagnosed, irrespective of CD4 cell count, to suppress viral load and prevent transmission to
1528 sexual partners.³⁸⁸ A regimen of two antiretrovirals, taken as pre-exposure prophylaxis (PrEP)
1529 to prevent acquisition of HIV during periods of regular high risk exposures, overcomes the

1530 limitations of PEP and is the third and most recent way of using cART for MSM to prevent
1531 HIV.³⁸⁹⁻³⁹¹

1532 All three uses of cART for HIV prevention have been accompanied by concern about their
1533 possible unintended negative consequences for sexual behaviour and STIs,³⁹² in an analogy
1534 with earlier fears about penicillin and syphilis.⁸ These concerns have been framed within the
1535 risk compensation hypothesis, which was first applied to sexual behaviour to explain why
1536 increases in condom use were not reflected in reductions in HIV incidence.³⁹³ Risk
1537 compensation occurs when an intervention prevents an adverse outcome, paradoxically
1538 making risk-taking behaviour more attractive; compensatory increases in risky behaviours
1539 then result in a failure to reduce the adverse outcome. The links between biomedical HIV
1540 treatment and prevention strategies and sexual risk are dynamic and complex.^{22,392}
1541 Behavioural surveillance amongst MSM, such as surveys carried out yearly in Sydney,
1542 Australia for 20 years (Figure 11) and the US National HIV Behavioral Survey (NHBS)
1543 conducted using venue-based sampling in 21 cities in the USA every three years since
1544 2005,^{394,395} show a gradual decline in condom use could be a manifestation of risk
1545 compensation with several contributing factors over time. “Treatment optimism” about the
1546 benefits of improved cART has been associated with increased risky behaviour; MSM with
1547 stronger perceptions that cART has reduced the threat from HIV and that cART reduces the
1548 need for safer sex engage more often in risky behaviours such as non-condom receptive anal
1549 intercourse.^{396,397} “Safer sex fatigue”³⁹⁸ and the adverse effects of HIV on mental health³⁹⁹
1550 also contribute to sexual risk taking. Serosorting (choosing sexual partners with the same HIV
1551 serostatus) results in sexual networks stratified by HIV serostatus with reduced condom use³⁹⁵
1552 and increased risk of STI transmission.⁴⁰⁰ In this section of the *Commission* we give an
1553 overview of the HIV prevention strategies of PEP, TasP and PrEP and examine evidence of
1554 whether their use results in risk compensation and increases in STI prevalence in MSM. In the
1555 discussion, we speculate on the potential influence of biomedical interventions on future STI

1556 epidemiology in MSM once implemented more broadly and discuss alternative options for
1557 STI prevention other than condom use.

1558

1559 **Post-exposure prophylaxis (PEP)**

1560 Guidelines for the use of PEP recommend it after both occupational and non-occupational
1561 exposures with a ‘substantial risk’ of HIV acquisition and with an HIV-positive index or an
1562 index with an unknown HIV status belonging to a high risk group.^{401,402} The efficacy of PEP
1563 has not been studied in RCTs, but there is a wide consensus about its effectiveness, based
1564 mainly on one case-control study in a hospital setting, which found an 81% reduction of HIV
1565 transmission in the group that used PEP.³⁸⁴ The increased availability of PEP led to concern
1566 that it may increase in risk taking.⁴⁰³ Two studies did find a higher risk of non-condom sexual
1567 behaviour and a higher incidence of HIV in the group of MSM after receipt of PEP but these
1568 studies did not find a correlation between PEP use and changes in risk behaviour.^{404,405} The
1569 authors concluded that many MSM requesting PEP simply already belong to a high-risk
1570 group.⁴⁰⁵ In high income countries, most PEP requests come from MSM, but uptake remains
1571 low; 183 requests from one large public health centre in Amsterdam, The Netherlands, over a
1572 five-year period.⁴⁰⁶ Successful awareness campaigns have increased uptake of PEP.⁴⁰³ The
1573 limitations associated with ascertaining exposure and eligibility, and suboptimal effectiveness,
1574 mean that PEP use is unlikely to have any impact on sexual risk behaviour or STIs at the
1575 population level.

1576

1577 **Treatment as prevention (TasP)**

1578 The concept of using cART to prevent sexual transmission of HIV began with the finding that
1579 transmission between serodiscordant heterosexual couples was rare when the HIV-infected
1580 partner had a very low or undetectable level of HIV-1 RNA.^{385,386} Based on these

1581 observational studies, the Swiss AIDS Commission stated in 2008 that a serodiscordant
1582 couple could have non-condom sex if the HIV-infected partner was taking cART with
1583 sustained viral suppression and no other STI.⁴⁰⁷ The “Swiss statement” in effect promoted
1584 widespread HIV testing and immediate treatment to reduce HIV transmission and catalysed
1585 the initiation of RCTs to examine the impact of TasP at the population level.³⁸⁷ Mathematical
1586 modelling studies showed how, assuming zero transmissibility with suppressed viral load,
1587 universal HIV testing and immediate cART could eliminate HIV within ten years of
1588 implementation.⁴⁰⁸ In 2012, an individual-level RCT in nine countries (HPTN 052, Botswana;
1589 Kenya; Malawi; South Africa; Zimbabwe; Brazil; India; Thailand; USA) showed that early
1590 diagnosis and initiation of cART reduced the risk of sexual transmission within stable, mostly
1591 heterosexual, HIV-serodiscordant couples by 96% (95% CI 73 to 99%) compared with later
1592 treatment.⁴⁰⁹ To extrapolate these benefits to a whole population, a sufficiently high
1593 proportion of all HIV-infected individuals would need receive and adhere to effective cART
1594 from very early in the course of infection.⁴¹⁰ The first of the population level trials, a cluster
1595 RCT in Kwazulu-Natal, South Africa, did not find a reduction in HIV incidence in
1596 communities that received the TasP intervention.⁴¹¹ Suboptimal uptake of testing, particularly
1597 in young men, and delays in linkage to care are likely to have limited the public health
1598 benefits of TasP,⁴¹² even though an earlier ecological study in the same population had
1599 suggested that HIV-incidence was lower in people living in communities with higher cART
1600 coverage.⁴¹³

1601 *Risk compensation, STIs and the TasP strategy*

1602 There is little published about the effects of the TasP strategy on sexual behaviour and on the
1603 incidence of bacterial STIs in MSM. In most countries; ART recommendations have moved
1604 gradually towards starting treatment at high CD4 counts. At the individual level, in the HPTN
1605 052 RCT, the frequency of new STIs (syphilis, gonorrhoea, chlamydia infections, and

1606 trichomoniasis) detected among heterosexual participants treated immediately was low and
1607 similar to that in those who received deferred treatment after a median 1.7 years of follow up;
1608 98% of participants were heterosexual and >95% in both groups reported using condoms.⁴⁰⁹
1609 At the population level, the effects in the TasP trial in Kwazulu-Natal on behavioural
1610 outcomes, including condom use, have not yet been published.⁴¹¹

1611 An examination of data from San Francisco, USA provides some insight at the population
1612 level because the city has both biological and behavioural surveillance data spanning the
1613 introduction of TasP.⁴¹⁴ The San Francisco Department of Public Health implemented a TasP
1614 strategy; cART for all HIV-infected persons regardless of CD4 cell count at publicly funded
1615 HIV clinics and an expansion of HIV testing services, in 2010, two years before US national
1616 recommendations changed.⁴¹⁴ We aggregated published STI surveillance data from 2005 to
1617 2014 and compared the positivity rates of HIV, syphilis and gonorrhoea and mean numbers of
1618 partners among self-identified gay and bisexual men before the introduction of the TasP
1619 strategy nationally (from 2005 to 2009) with the period afterwards (from 2010 to 2014).^{329,415-}
1620 ⁴¹⁷ Figure 12 shows that the percentage of HIV tests with a positive result was already falling
1621 and declined from 4.5% in 2005 to 2.5% in 2010. HIV positivity dropped further, from 2.5%
1622 in 2010 to 1.1% in 2014. In contrast, the positivity rate of early syphilis infections rose
1623 consistently from 1.9% in 2005 to 4.4% in 2014.^{329,415-417} The gonorrhoea positivity rate
1624 dropped during the period 2005-2009, but increased from 9.7% to 11.2% in the period 2010-
1625 2014. Behavioural surveillance data show that the mean number of sex partners in the prior
1626 three years decreased from 5.0 in 2007 to 4.4 in 2009 and then increased from 4.6 in 2010 to
1627 6.1 in 2013.⁴¹⁸ The recommendation about TasP in San Francisco was thus temporally
1628 associated with increases in gonorrhoea, syphilis and partner numbers. Risk compensation
1629 might have contributed to these trends, although the increase in syphilis began before TasP
1630 began. In Switzerland, the proportion of HIV-infected MSM in the Swiss HIV Cohort Study
1631 reporting non-condom sex with both occasional and stable partners had increased slightly

1632 from 2000 onwards. A piecewise linear regression analysis showed a sudden change with a
1633 marked increase in non-condom sex from 2008 to 2013, after the publication of the Swiss
1634 statement that promoted TasP.⁴¹⁹ Data from the US NHBS surveys amongst MSM, showed
1635 that condom use has decreased from 2005 up to 2014 over a large geographic area and that
1636 these trends were not explained by serosorting, seropositioning, PrEP use or cART
1637 treatment.³⁹⁵ Figures 10 and 11, show rates in the bacterial STI notifications in England and
1638 the fall in condom use in Sydney, Australia, suggest that opposing trends in STI rates and in
1639 condom use have taken place over a 20 year period and cannot be attributed to any one factor,
1640 such as TasP. Nevertheless, there is a consensus that knowledge about the effects of cART on
1641 reduced infectiousness of HIV have contributed to risk compensation.²² A disadvantage
1642 inherent to TasP is that its success depends on the behaviour of others.⁴²⁰ The uninfected
1643 person has to trust that their HIV-infected sexual partners are adherent to cART and that the
1644 cART is sufficiently effective to mitigate transmission risk. In contrast, with PrEP and PEP,
1645 the at-risk individual takes the preventive treatment.

1646

1647 **Pre-exposure prophylaxis (PrEP)**

1648 Three RCTs have studied the effects of PrEP on the acquisition of HIV infection as part of an
1649 HIV prevention package for MSM that includes risk reduction counselling, condom provision
1650 and regular HIV and STI testing.³⁸⁹⁻³⁹¹ Across these trials, the use of tenofovir disoproxil
1651 fumarate/emtricitabine (TDF/FTC), in combination with comprehensive sexual health care,
1652 reduced HIV incidence ranging from 44% to 86%. Two of the RCTs studied daily use of
1653 TDF/FTC^{389,390} and one studied intermittent use (two tablets between 24 and 2 hours before
1654 sex, followed by two times one tablet at 24 and 48 hours after sex).³⁹¹ The first landmark
1655 study, the Preexposure Prophylaxis Initiative (iPrEX), looked at the effect of daily TDF/FTC
1656 among 2499 MSM from six countries (Peru, Ecuador, South Africa, Brazil, Thailand and the

1657 USA) and was published in 2010.³⁸⁹ The Pre-exposure option for reducing HIV in the UK,
1658 immediate or Deferred (PROUD) trial enrolled 544 MSM in the UK and randomised them to
1659 immediate or a one year delayed start of daily oral TDF/FTC.³⁹⁰ In the Intervention
1660 Préventive de l'Éxposition aux Risques avec et pour les Gays (Ipergay) trial, 414 MSM were
1661 randomised to either TDF/FTC or placebo for intermittent use in France and Canada.³⁹¹ In all
1662 PrEP trials, adherence was a strong determinant of PrEP effectiveness.⁴²¹

1663 These trials showed that it is feasible to identify and enrol MSM at high risk of acquiring
1664 HIV infection, with HIV incidence rates in the placebo arm of 9.0 per 100 person years in
1665 PROUD and 6.6 per 100 person years in Ipergay. Open label studies, demonstration projects
1666 and cohort studies provide additional evidence that PrEP roll-out to MSM at high risk for HIV
1667 infection is feasible, safe and prevents HIV.⁴²¹⁻⁴²⁴ Eligibility criteria in most PrEP trials and
1668 demonstration projects include well-known determinants for HIV acquisition in MSM such as
1669 recent rectal or urethral STIs, a recent use of PEP, reporting anal intercourse with casual
1670 partners and having an HIV-positive partner with a detectable viral load.⁴²¹ International
1671 guidelines for PrEP from the US Centers for Disease Control and Prevention and WHO
1672 reflect these eligibility criteria.^{329,425}

1673

1674 *Risk compensation, STIs and PrEP*

1675 PrEP is a powerful intervention for HIV prevention among MSM, but it has the potential to
1676 reduce commitment to primary prevention strategies, result in risk compensation³⁹² and
1677 increase rates of STIs. The role of PrEP in relation to sexual behaviour and STI rates is
1678 somewhat easier to assess than with TasP because PrEP is an individual intervention rather
1679 than a population-based one. PrEP is, however, only in the early stages of implementation.

1680 In the placebo-controlled trials iPrEx and Ipergay, condom use and STI incidence were
1681 similar in participants allocated to PrEP and to placebo. These findings are expected because

1682 participants were blinded and all received the same risk reduction advice. The PROUD RCT
1683 was designed as a pragmatic open-label study that would allow risk compensation to be
1684 observed. The total number of different anal sex partners was similar in the two groups, but a
1685 larger proportion of participants allocated to immediate than deferred PrEP reported non-
1686 condom receptive anal sex with ten or more partners (21% vs. 12%, $p=0.03$). The proportions
1687 diagnosed with STIs during the 12 month follow-up period were similar in men receiving
1688 immediate and deferred PrEP, however; rectal gonorrhoea or chlamydia, 36% vs. 32% (odds
1689 ratio, OR 1.00, 95% CI 0.72 to 1.38), syphilis, 11% vs. 9% (OR 1.32, 95% CI 0.79 to 2.10).

1690 Open-label studies should allow a more realistic assessment of the influence of PrEP on
1691 sexual behaviour. In an open-label observational study that included MSM who had taken part
1692 in the iPrEx trial and two other studies, the proportions reporting non-condom receptive anal
1693 intercourse, non-condom insertive anal intercourse, and numbers of sexual partners all
1694 decreased to a similar extent during follow-up in both groups and syphilis incidence (7.2
1695 infections per 100 person years in PrEP recipients and 5.4 per 100 person years, hazard ratio
1696 1.35, 95% CI 0.83 to 2.19) was also similar.⁴²² The authors concluded that there was no
1697 evidence of risk compensation during open label access to PrEP use, but that cohort
1698 participation and access to comprehensive prevention services might have encouraged other
1699 safer sexual behaviours. In the Demo project in San Francisco, Washington DC and Miami,
1700 USA, early findings (up to 48 weeks) amongst men receiving PrEP have shown a stable
1701 proportion overall reported having had non-condom receptive anal sex in the previous three
1702 months (65.5%; 365/557), although the mean number of condom-protected sex acts
1703 decreased. The proportions with early syphilis, gonorrhoea and chlamydia at quarterly visits
1704 initially fell and then returned to baseline values.⁴²³ Qualitative data from participants suggest
1705 that men integrate PrEP in a dynamic way into existing risk reduction strategies, rather than
1706 relying on it as a solitary method of HIV prevention.⁴²⁶

1707 The longer term impact of PrEP for risk compensation and STI rates are not yet known.
1708 Taken together, trials of PrEP with one to two years of follow up show a large reduction in
1709 HIV incidence in MSM who adhere to the regimen, high but similar levels of bacterial STIs in
1710 MSM who received and did not receive PrEP and mixed effects on sexual
1711 behaviours.³⁹⁵ Additional studies suggest that increasing use of PrEP as a method of
1712 biomedical HIV prevention could change patterns of sexual partner seeking and condom
1713 use.^{394,427} Newcomb and colleagues have coined the term “Biomed-matching” as a new
1714 strategy amongst MSM who meet up using geosocial networking applications and disclose
1715 their use of biomedical HIV prevention medication; they then have non-condom anal sex
1716 when the partner is also taking PrEP or has undetectable viral load on cART.⁴²⁷ MSM who
1717 receive PrEP will need to be followed carefully over time using both quantitative and
1718 qualitative research methods to determine whether and how risk compensation and changing
1719 patterns of sexual partnerships and practices are affecting STI rates.

1720

1721 **STI prevention in the era of biomedical HIV prevention**

1722 The use of cART to prevent HIV acquisition and transmission, TasP and PrEP in particular,
1723 are changing the HIV prevention landscape for MSM. The continued fall in HIV positivity in
1724 San Francisco, USA has been attributed to TasP and a rapid increase in the number of MSM
1725 using PrEP in London, UK might have influenced a 40% reduction in new HIV diagnoses in
1726 2016 compared with 2015.⁴²⁸ Trends in HIV infection and other STIs seem to have been
1727 decoupled. STI rates in MSM have been rising since the late 1990s (Figure 10).^{427,429} The
1728 increases in notifications of bacterial STI appear to be accelerating (Figures 9, 10 and 12). In
1729 England, HIV-infected MSM account for almost all of the increase in STI notifications in
1730 MSM; for syphilis, the proportion diagnosed in HIV-infected MSM increased from around
1731 25% in 2009 to around 40% in 2013.³⁷⁹ In the absence of denominator data, how much of the

1732 increase is the result of more frequent testing is not known. Widening PrEP use, together with
1733 other behavioural changes, including an increase in the adoption of seroadaptive
1734 behaviours^{394,395} and use of geosocial networking mobile applications, such as Grindr,^{427,429}
1735 could affect sexual networks and influence rates and patterns of STI. For example, if non-
1736 condom sex partnerships between HIV-uninfected MSM using PrEP and HIV-infected MSM
1737 on cART become more common, outbreaks of syphilis, LGV, hepatitis, and shigellosis that
1738 have occurred mostly amongst HIV-infected MSM could spread to networks of HIV-
1739 uninfected MSM. STIs that increase HIV infectiousness through inflammatory mechanisms⁵
1740 could then reduce the impact of biomedical HIV prevention methods. Additional surveillance
1741 and interventions to control STIs amongst MSM in this new era are needed, especially if
1742 behavioural risk reduction interventions cannot reverse trends in condom use.

1743 Treatment of curable STIs has long been considered an integral component of combination
1744 HIV prevention packages.⁴³⁰ Regular STI testing to detect and treat asymptomatic infections
1745 is now widely recommended for STI control in MSM. MSM starting PrEP are advised to be
1746 tested for bacterial STIs every three months and MSM in general are usually advised to be
1747 tested every year, although only about 40% of at-risk MSM in Australia were receiving
1748 annual screening in 2014.⁸⁷ One mathematical modelling study suggested that screening
1749 MSM for chlamydia could reduce the prevalence of both chlamydia and HIV.⁴³¹ These
1750 findings should be considered in the light of evidence presented in two other sections of the
1751 *Commission*. First, modelling studies also suggest that chlamydia screening in heterosexual
1752 populations will reduce chlamydia prevalence,^{105,106} but evidence from RCTs^{14,95} and repeated
1753 population-based cross-sectional studies^{43,44} have not found appreciable reductions in
1754 chlamydia prevalence in the target populations (Part 1). Second, as AMR in *N. gonorrhoeae*
1755 spreads (Part 2), the potential impact of increasing STI testing rates also needs to be
1756 considered. Mathematical modelling studies of MSM populations show that, at least for some
1757 antimicrobials, increasing the rate of gonorrhoea treatment might reduce prevalence

1758 temporarily, but that the increased selection pressure accelerates the spread of AMR, resulting
1759 in increased prevalence over time.^{432,433} On the other hand, models of syphilis transmission
1760 have shown a reduction in incidence with frequent testing and one ecological study using
1761 national surveillance data in Australia showed that when syphilis testing rose from 1.6 tests a
1762 year to 2.3 tests a year, there was a reduction in secondary syphilis cases (from 45% to
1763 26%).^{434,435} There was also a commensurate rise in early late infections (from 23% to 45%)
1764 suggesting that frequent testing was detecting syphilis infection before it reached the
1765 secondary stage.⁴³⁴

1766 Another possible STI intervention that has undergone limited investigation is daily use of
1767 doxycycline.⁴³⁶ A single small double blind randomised trial of 30 individuals followed for
1768 one year showed lower rates of STI in the doxycycline arm.⁴³⁷ Interventions involving
1769 prophylactic use of antimicrobials have not been pursued further because of concern about
1770 AMR. One group is investigating the use of antibacterial mouthwash for the prevention of
1771 pharyngeal gonorrhoea. The hypothesis is that saliva, used as a lubricant for both anal sex and
1772 oral sex, gives pharyngeal gonorrhoea a central role in the persistence of gonorrhoea at all
1773 anatomical sites in MSM, even though relatively little is known about the transmission of
1774 STIs between anatomical sites in MSM.⁴³⁸ Mouthwash has been shown in laboratory
1775 experiments to inhibit *N. gonorrhoeae* growth and when used in individuals with pharyngeal
1776 gonorrhoea, it reduces the chance of detecting *N. gonorrhoeae* five minutes later.⁴³⁹ Longer
1777 term prevention studies are underway using mouthwash. More research is required on STI
1778 control in MSM that does not rely on condom use including a better understanding of
1779 infectiousness and transmission between anatomical sites in men.

1780

1781 **Conclusions**

1782 Rates of bacterial STIs in MSM have been rising for about 20 years now and are approaching
1783 the levels seen in the late 1970s before HIV first appeared. During this time ART strategies
1784 have become powerful and important methods for HIV prevention. Evidence for a major
1785 contribution of TasP and PrEP to reductions in future HIV incidence and prevalence is
1786 accumulating. Risk compensation in response to the success of cART in reducing the
1787 infectiousness of and susceptibility to HIV, mediated through increases in non-condom sexual
1788 intercourse or increased numbers of sexual partners, has occurred.^{22,390} The contributions of
1789 behavioural responses to the biomedical HIV prevention strategies and of other factors
1790 influencing sexual behavioural change remain unknown.^{394,423,427} Quantifying the effect of
1791 biomedical HIV prevention interventions on STI rates is methodologically difficult.^{377,379}
1792 Based on surveillance data from places with large populations of MSM,^{329,379} it is likely that
1793 the incidence and prevalence of STI in MSM will continue to increase.

1794 STI control interventions that complement the highly effective biomedical interventions for
1795 HIV prevention are needed as part of combination prevention packages. Indeed, biomedical
1796 HIV interventions play a positive role in STI control through frequent contacts with sexual
1797 health services that allow regular continued opportunities for primary prevention and
1798 comprehensive case management of STIs including prompt diagnosis and treatment, partner
1799 notification, condom promotion and risk reduction interventions.⁴⁴⁰

1800 Nevertheless, continued research is needed to investigate and understand the effects of
1801 TasP and PrEP on sexual behaviours and networks that might increase STI transmission and,
1802 through STI-HIV interactions, might drive renewed HIV transmission. Enhanced biological
1803 and behavioural surveillance activities are needed to monitor changes in STIs in HIV-
1804 uninfected and HIV-infected MSM, AMR, and the emergence or re-emergence of new
1805 sexually transmissible pathogens including enteric infections and Ebola and Zika viruses.⁴⁴¹

1806

1807 **Call to action**

1808 Action is required to address the substantial challenges facing STI control globally (table 4).
1809 AMR in *N. gonorrhoeae* is increasing relentlessly and adverse consequences of chlamydia
1810 infection remain prevalent. STIs in MSM are rising rapidly, new sexually transmissible
1811 infections are emerging or re-emerging and there is evidence that BV, one of the most
1812 common, but often ignored, genital conditions in women, might also be sexually
1813 transmissible. These issues are magnified in low and middle income countries that bear the
1814 burden of STIs worldwide. To address these issues we need to reach our policy makers and to
1815 convince them to invest in clinical and public health strategies to improve the control of STIs,
1816 based on carefully considered analytical decisions, founded in science. If they do not, we may
1817 suffer more than we should, and spend more than we need.⁴⁴² In putting this case, we
1818 recognise that social, cultural and structural conditions are major determinants of sexual
1819 behaviour, sexual risk and STIs.⁴⁴³ Research evidence provides the scientific support for
1820 prioritising interventions, but successfully influencing health policy will require the
1821 involvement of stakeholders, including researchers, clinicians, and members of civil society
1822 as well as policy makers themselves.⁴⁴⁴

1823 One of the most important messages about STI control is that good policy decisions matter
1824 much more than poor individual ones.^{442,445,446} This is because effective policy interventions
1825 can put strong downward pressure on STI incidence,³³ while individual behaviour has a
1826 relatively weak effect on the population prevalence of STIs and sustained and substantial
1827 behaviour change is difficult to achieve.^{442,446,447} We need to make the case to policy makers
1828 that STIs cost less to keep under control than to treat, and manage their sequelae, when
1829 endemic levels are high.⁴⁴²

1830 The cornerstone of the health sector response to effective STI control is easily accessible
1831 quality health care, and is the principle behind the provision of free STI services in many

1832 countries.⁴⁴⁵ Accessible health care helps to ensure that STIs are treated early, before
1833 substantial transmission can occur.³³ Communities with poor access to health care have high
1834 rates of symptomatic STIs such as gonorrhoea or trichomoniasis, and those with accessible
1835 health care have much lower rates, even though the number of sexual partners in both
1836 communities might be similar.⁴⁴⁸ For example, gonorrhoea in heterosexuals is relatively easy
1837 to control with accessible primary health care and, as a result, most high income countries
1838 rates of reported gonorrhoea are well below 100 per 100,000 population. Rates in
1839 heterosexuals exceed these levels in high income countries in populations whose access to
1840 health care is limited, such as among uninsured Americans or Indigenous Australians living in
1841 remote communities.^{448,449} STI services are a key goal of the WHO strategy to help achieve
1842 universal health coverage, a key target of the 2030 Agenda for Sustainable Development.³³
1843 We call on policy makers to ensure their citizens have accessible, affordable and quality STI
1844 care.

1845 Largely asymptomatic STIs such as chlamydia provide a much greater challenge to
1846 control. Despite substantial proportions of the population being tested for chlamydia in some
1847 high income countries it has proven difficult to reduce the prevalence and we remain
1848 uncertain about the long term impact that widespread testing for chlamydia has on the key
1849 health outcomes including PID, ectopic pregnancy and infertility. Chlamydia control
1850 strategies should define acceptable local targets for chlamydia prevalence, so that appropriate
1851 interventions can be prioritised. Improving case management of those diagnosed with
1852 chlamydia and PID (e.g. effective antimicrobial treatment, partner notification and retesting to
1853 detect repeated infection) might achieve more than promoting widespread testing alone. We
1854 should also establish and adapt surveillance systems so that we know what impact our
1855 chlamydia control activities are having on PID and its complications. We call on policy
1856 makers to invest in the research agendas that has been repeatedly called for by international
1857 experts,^{60,150,151,450} to further our understanding about the natural history of chlamydia and

1858 develop non-invasive measures of tubal infection, inflammation and damage and biomarkers
1859 to predict upper genital tract pathology. Further we must invest in chlamydia vaccine research
1860 because without an effective vaccine, it is unlikely that we will be able to control it.

1861 The effective control of gonorrhoea is a global health priority³³ because of the relentless
1862 rise in AMR, and the high incidence in low and middle income countries and increasing
1863 incidence in key populations, including MSM (Figure 10).³⁷⁹ In this context we call on policy
1864 makers to ensure adequate and sensitive surveillance programmes are in place and industry to
1865 support the development of effective agents should the current ones fail. The control of
1866 gonorrhoea in MSM presents a similar problem to chlamydia because asymptomatic
1867 pharyngeal and rectal infection are common and frequently occur in the absence of concurrent
1868 symptomatic urethral infection, so cases are only detected through testing or partner
1869 notification.⁴⁵¹ Some have advocated more frequent screening, but at least with some
1870 antimicrobials an increased rate of gonorrhoea treatment might accelerate the spread of AMR
1871 and might outweigh any gains in reducing prevalence.⁴³³ Another problem with gonorrhoea
1872 control in MSM is that it is not prevented by consistent condom use for anal sex, because the
1873 pharynx appears to play a key role in transmission of both infection and AMR.^{157,452,453}
1874 Effective control will require understanding how gonorrhoea is transmitted between MSM so
1875 evidence-based interventions can be developed just as interventions for HIV control were
1876 developed by understanding its transmission. Ideally condoms should not be a critical part of
1877 these interventions given condoms rates are falling and may fall further.⁴⁵³ Recent research
1878 has suggested a potential non-condom based intervention.⁴³⁹ Researchers have found that *N.*
1879 *gonorrhoeae* is commonly present in the saliva of men with pharyngeal infection, and that
1880 saliva is frequently used as a lubricant for anal sex.⁴⁵⁴ Early work has shown that antibacterial
1881 mouthwash might inhibit *N. gonorrhoeae* growth and studies of mouthwash for gonorrhoea
1882 prevention are underway.⁴³⁹ We call on policy makers to fund research to better understand

1883 how STIs are transmitted between MSM to allow the development of new control
1884 programmes not based only around condoms.

1885 BV in women is another commonly asymptomatic infection with a substantial global
1886 burden that poses similar control issues to chlamydia but has the additional problem that there
1887 is a lack of a proven transmitted pathogen. Effective control is complicated by its high relapse
1888 rate which is likely to be due, at least in part, to our failure to recognise the importance of
1889 sexual transmission in its pathogenesis and the contribution of reinfection to recurrence.^{20,246}
1890 Current treatment strategies are entirely focused on the female partner, while accumulating
1891 epidemiological and microbiological data provide evidence of male carriage and exchange of
1892 BV-associated bacteria within sexual partnerships.^{265,423} In order to make significant advances
1893 in the treatment and prevention of BV and its costly sequelae we need to better understand the
1894 contribution of persistence of BV-associated bacteria versus reinfection to BV recurrence.
1895 New treatment strategies are required but we also need to revisit male partner treatment trials
1896 with more evidence-based approaches.

1897 Effective STI control in low and middle income settings provide a particular challenge
1898 because of the high cost of diagnostic tests and limited laboratory capacity that accompany
1899 weak health service infrastructure. POC tests that fulfil the WHO ASSURED benchmarking
1900 programme can play an important role in effective STI control, but understanding their
1901 limitations is critical. Policy makers should fund programmes that optimise and evaluate all
1902 aspects of STI control in low and middle income counties with the implementation of the
1903 validated POC tests including, but not limited to, screening of antenatal care attendees and
1904 high risk populations, improved partner notification strategies, and symptomatic case
1905 management. Policy makers should fund programmes that optimise and evaluate all aspects of
1906 STI control including, but not limited to, improved partner notification programmes,
1907 presumptive treatment, POC tests, syndromic management and combinations of all of these.

1908 It is important to acknowledge that STI control strategies that rely *only on reducing sexual*
1909 *risk practices* at a population level will not work well because on their own, they afford a
1910 relatively modest effect on STI prevalence. Large multicentre studies of behavioural
1911 interventions for condom use for example have relatively modest effect sizes (~20% effective
1912 at one year).^{446,447} In contrast, biomedical interventions such as the HPV vaccine programme
1913 in women have been outstandingly successful and resulted in almost complete elimination of
1914 the oncogenic HPV in the vaccine in both vaccinated women and unvaccinated heterosexual
1915 men in Australia.^{11,455} Similarly large effect sizes for reducing HIV acquisition are seen in
1916 RCTs of PrEP when adherence levels are high.³⁸⁹⁻³⁹¹ Biomedical methods to prevent HIV
1917 have, however, contributed to increased rates of STIs amongst MSM as a result of risk
1918 compensation. No single measure will effectively control all STIs at a population level.
1919 Effective STI control will require the political will to prioritise and invest in new
1920 interventions together with the optimisation of both primary and secondary prevention
1921 strategies including; integrated sex education programmes in schools, strong partner
1922 notification programmes that utilise the latest information technology systems and legislative
1923 changes for partner delivered antibiotic treatment where appropriate, legalised frameworks for
1924 sex work, active targeted health promotion, accurate surveillance programmes and of course
1925 accessible health care for all.

1926

1927 **FIGURE LEGENDS**

1928 **Figure 1: WHO estimates of the number of cases (in millions) of four curable STIs**
1929 **trichomoniasis (TV), chlamydia (CT), gonorrhoea (NG), and syphilis (TP) globally in**
1930 **2012. Source: reference²**

1931 **Figure 2: Natural history and sequelae of *Chlamydia trachomatis* infection in women.**
1932 **Length of arrows are not proportional to time. Dotted lines are conditions that can**
1933 **resolve.**

1934 **Figure 3: Interventions for the control of chlamydia in the population. Source:**
1935 **reference³¹**
1936 Evidence³¹-based case management includes partner notification, prevention of re-infection
1937 [advice on sexual behaviour and condom use] and re-testing within a recommended time
1938 period after treatment)

1939 **Figure 4: Chlamydia prevalence estimates among sexually experienced women ≤ 26**
1940 **years estimated in cross sectional suveys of randomly sampled individuals from the**
1941 **general population in WHO regions.**

1942 **Source:**

1943 Europe

1944 Croatia (N=151);⁴⁶ France (N=106);³⁸ The Netherlands (N=2626);⁴¹ Norway (N=930);⁴²
1945 Slovenia (N=265);⁴⁰ Spain (N=157);⁴⁹ United Kingdom (N=992)⁴⁴

1946 Americas

1947 USA (N=unavailable);⁴⁵ Argentina (N=148);⁴⁹ Colombia (N=278)⁴⁹

1948 Africa

1949 Nigeria (N=120)⁴⁹

1950 South-East Asia

1951 China 1 (N=194);⁵² China 2 (N=46);⁴⁹ India;⁵⁰ Thailand 1 (N=69);⁴⁹ Thailand 2 (N=129);⁴⁹

1952 Vietnam 1 (N=158);⁴⁹ Vietnam 2 (N=123)⁴⁹

1953 Western Pacific

1954 Australia (N=135);³⁹ Papua New Guinea (PNG; N=73)⁵¹

1955 **Figure 5: Hospital discharge rates for inflammatory disease in female pelvic organs.**

1956 **Source: reference¹²²**

1957 See supplementary table 1 for further detail.¹²²

1958 **Figure 6: Interventions attempted for the management and prevention of bacterial**
1959 **vaginosis**

1960 **Figure 7: Point-of-care (POC) or near-POC tests for STIs that are available or in the**
1961 **pipeline. The dotted line means that no market launch date has been set by the**
1962 **company. Source: updated from reference³²⁵ XenoStrip-TVTM rapid diagnostic test for *T.*
1963 *vaginalis* (Xenotope Diagnostics, Inc, San Francisco, USA), OSOM[®] rapid diagnostic test for
1964 *T. vaginalis* (Sekisui Diagnostics, Lexington, USA); GeneXpert[®] for *C. trachomatis*, *N.*
1965 *gonorrhoeae*, duplex *C. trachomatis* and *N. gonorrhoeae*, *T. vaginalis*, HPV (Cepheid Inc.,**

1966 Sunnyvale, USA); AmpliVue® for *T. vaginalis* (Quidel Corporation, San Diego, USA); Atlas
1967 io™ for *C. trachomatis*, duplex *C. trachomatis* and *N. gonorrhoeae*, *T. vaginalis* (Atlas
1968 Genetics, Trowbridge, UK); Truelab™ Real Time micro PCR System for *C. trachomatis*, *N.*
1969 *gonorrhoeae* (Molbio Diagnostics Pvt. Ltd., Goa, India); Alere™-i for duplex *C. trachomatis*
1970 and *N. gonorrhoeae* (Alere Inc., Waltham USA); GeneXpert® Omni for duplex *C.*
1971 *trachomatis* and *N. gonorrhoeae*, HPV (Cepheid Inc., Sunnyvale, USA); Cobas® Liat
1972 Analyser (Roche, Basel, Switzerland); RT CPA *C. trachomatis* (Ustar Biotechnologies,
1973 Hangzhou, China); PanNAT® (Micronics, Inc., Portsmouth, USA).

1974 **Figure 8: Point-of-care tests for dual syphilis and HIV diagnosis that are available.**

1975 **Source: updated from reference**³²⁵ Standard Diagnostics (SD) Bioline HIV/Syphilis Duo
1976 Rapid Test (Alere, Waltham USA)/(Standard Diagnostics, Republic of Korea); DDP
1977 ®HIV-Syphilis Assay (Chembio Diagnostic Systems, Inc., Medford, USA); Multiplo Rapid
1978 TP/HIV Antibody test (MedMira, Inc., Halifax, Canada); INSTI Combined HIV/Syphilis
1979 test (Biolytical Laboratories Inc., Richmond, Canada); mChip Assay (Junco Labs,
1980 Columbia University, New York, USA in collaboration with OPKO Health, Inc., Miami,
1981 USA).

1982 **Figure 9A: Notifications of infectious syphilis 1950-2015 by sex and male:female ratio**
1983 **in England and Wales. Source: Public Health England.**

1984 **Figure 9B: Primary and Secondary Syphilis in the US 1995-2015 by sex and**
1985 **male:female ratio in United States. Source: Centres for Disease Control and**
1986 **Prevention.**

1987 **Figure 10: Notifications of HIV, syphilis (primary, secondary, early latent), gonorrhoea**
1988 **and chlamydia, 1996-2015 in men who have sex with men, England. Source: 2001-2015,**
1989 **Public Health England (<https://www.gov.uk/government/statistics/hiv-annual-data-tables>),**
1990 **2000 and earlier, National Archive (<http://webarchive.nationalarchives.gov.uk/>). cART,**
1991 **combination antiretroviral therapy; cPEP, combination post-exposure prophylaxis; Swiss**
1992 **statement; TasP, treatment as prevention; PROUD results made public.**

1993 **Figure 11: Condom use for anal sex among men who have sex with men in Sydney,**
1994 **Australia 1997-2016. Source: Gay Community Periodic Survey**

1995 **Figure 12: Percentage of tests positive for HIV, primary and secondary syphilis and**
1996 **gonorrhoea, 2005-2014, and mean number of sexual partners in last three months, 2008-**
1997 **2013, San Francisco, USA. Source: San Francisco Department of Health.**

1998

1999

2000 **Contributors**

2001 Each group of authors takes responsibility for the text and views expressed in their individual
2002 sections. CKF conceived the *Commission* and coordinated its preparation. CSB wrote the
2003 executive summary together with MU and CKF. MU and CSB wrote the introduction; JSH
2004 and NL wrote Part 1; MU wrote Part 2; CSB, JAS and JMM wrote Part 3; SCF, RWP and
2005 DM wrote Part 4; HJCV, GJBS, EH, SSP, CKF and NL wrote Part 5; CKF wrote the call for
2006 action. NL, CSB, CKF and MU were involved in editing the final *Commission*. All authors
2007 approved the final manuscript.

2008

2009 **Declaration of interests**

2010 We declare that we have no conflicts of interest.

2011

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2014 the final document.

2015

Antimicrobial (other names)	Class	Mode of action	Bacterial target (known resistance mutations)	<i>In vitro</i> activity against <i>Neisseria gonorrhoeae</i> (MIC range/MIC ₅₀ /MIC ₉₀ (mg/L))	Phase of clinical trial (aimed size)	Dose	Comparator	Adverse effects
Solithromycin (CEM-101)	Fluoroketolide	Binds to the 50S ribosomal subunit, inhibiting protein synthesis	23S rRNA (A2059G in 23S rRNA alleles, overexpressed MtrCDE increases MIC ^{202,457})	0.001-32/0.064-0.125/0.125-0.25 ^{202,210}	Phase 3 (300 participants)	1 g×1 p.o.	Ceftriaxone 500 mg×1 IM PLUS Azithromycin 1 g×1 p.o.	Diarrhoea, nausea and fatigue/asthenia ^a
Zoliflodacin (AZD0914, ETX0914)	Spiropyrimidinetrone	DNA biosynthesis inhibition and accumulation of double-strand cleavages	DNA gyrase and Topoisomerase IV? (D429N, D429A, and K450T in GyrB, ^{197,201} overexpressed MtrCDE increases MIC ²⁰¹)	≤0.002-0.25/0.064-0.125/0.125-0.25 ^{206,211,215,216}	Phase 2 (180 participants)	2 g×1 p.o. or 3 g×1 p.o.	Ceftriaxone 500 mg×1 IM	Transient dysgeusia, mild headache
Gepotidacin (GSK2140944)	Topoisomerase II inhibitor	Inhibits DNA replication through interactions with GyrA (subunit of DNA gyrase) and ParC (subunit of Topoisomerase IV)	DNA gyrase and Topoisomerase IV (data not available)	≤0.015-1/0.25/0.5 ²¹³	Phase 2 (100 participants)	1.5 g×1 p.o. or 3 g×1 p.o.	-	Data not available

^aAdverse events observed in $\geq 10\%$ of patients using solithromycin 1 g \times 1 in published Phase 2 trial. Most nausea and vomiting appeared ≥ 1 hour after ingestion of solithromycin, which indicates that the drug was already absorbed.²⁰³

Table 1: Novel antimicrobials in different stages of clinical trial evaluation for treatment of gonorrhoea

-
- Comprehensive case management: primary prevention (e.g. public health campaigns, sexual education, behavioural counselling, condom use), screening (where feasible, effective and cost-effective), early diagnosis, treatment (including test of cure); partner notification and treatment; reporting and epidemiological surveillance, to reduce the global burden of urogenital and extragenital gonorrhoea;
 - Strict adherence to international/national evidence-based prevention and management guidelines: including introduction of dual antimicrobial therapy where up-to-date, local, and high-quality AMR data do not support other therapy;
 - Enhanced focus on prevention, early diagnosis (screening of high-risk groups, e.g., men who have sex with men (MSM) in some settings), and appropriate treatment of pharyngeal gonorrhoea, which is more difficult to eradicate than anogenital gonorrhoea, mostly asymptomatic, and a reservoir for development of AMR;¹⁵⁷
 - Enhanced testing and appropriate use of nucleic acid amplification tests (NAATs) but maintain (and strengthen in some settings) capacity for culture and AMR testing;
 - Effective drug regulations, prescription policies, and increased awareness on correct use of antimicrobials;
 - Monitoring, early detection and follow-up of failures with recommended treatment; using standard case definition and protocols for verification, management of failure and reporting;
 - Strengthened quality assured surveillance of gonorrhoea, antimicrobial use/misuse and AMR globally (including international rapid communication networks);
 - Capacity building to establish regional networks of laboratories to perform quality-assured gonococcal culture and AMR testing;
 - Research to identify novel antimicrobials (or other effective compounds) for treatment of urogenital and extragenital gonorrhoea (consider to include any new antimicrobials in a dual antimicrobial regimen),^{152,153,158,458} a gonococcal vaccine,¹⁵⁰ rapid molecular methods for predicting AMR (for AMR surveillance but ideally also to inform individualized treatment),¹⁹⁰⁻¹⁹² rapid point of care tests for diagnosis of gonorrhoea (ideally with combined prediction of AMR);^{190,191} ideal phylogenomics of gonococci and their AMR (also in non-cultured samples);^{159,457,459-464} and appropriate models for pharmacokinetics/pharmacodynamics (urogenital and extragenital sites) and prediction of AMR induction/selection, evolution and biological fitness.
-

Table 2: Actions to control the emergence, spread and impact of antimicrobial resistance (AMR) in *Neisseria gonorrhoeae* (public and private sectors)

Organism, Test	Sample type	Sensitivity (%)	Specificity (%)
<i>Chlamydia trachomatis</i>^a			
Biostar OIA Chlamydia test ^b	Endocervical swabs	59.4-73.8	98.4-100
Clearview Chlamydial test ^b	Endocervical swabs	49.7	97.9
	Vaginal swabs	32.8	99.2
Quick Vue Chlamydia rapid test ^b	Endocervical swabs	25.0-65.0	100
	Vaginal swabs	83.5	98.9
aQcare Chlamydia TRF ^c	Endocervical and urethral swabs	93.8	96.8
	Urine	88.2	94.7
Chlamydial Rapid Test, Diagnostics for the Real World ^c	Male urine	41.4	89.0
	Vaginal swabs	39.4-74.2	94.4-96.8
ACON Chlamydia Rapid Test Device ^c	Vaginal swabs	66.7	91.3
	Endocervical swabs	22.7-30.5	99.8-100
	Male urine	43.8	98.3
GeneXpert CT/NG ^b	Endocervical swabs	97.4	99.6
	Vaginal swabs	98.7	99.4
	Female urine	97.6	99.8
	Male urine	97.8	99.9
<i>Neisseria gonorrhoeae</i>^a			
Biostar OIA GC Test ^b	Endocervical swabs	60.0	89.9
	Urine	100	93.0-98.0
ACON Duo CT/NG ^c	Endocervical swabs	12.5	99.8
GeneXpert CT/NG ^b	Endocervical swabs	100	100
	Vaginal swabs	100	99.9
	Female urine	95.6	99.9
	Male urine	98.9	99.9
<i>Trichomonas vaginalis</i>			
OSOM TV rapid test ^b	Vaginal swabs	83.3-90	98.8-100

GeneXpert TV ^d	Vaginal swabs	95·0-95·6	95·7-100
Affirm VPIII microbial identification test ^{a,b}	Vaginal swabs	46·3	100
<i>Treponema pallidum</i> (syphilis)			
Alere Determine Syphilis TP ^e	Whole blood/serum/plasma	59·6-100	95·7-100
Omega VisiText Syphilis ^e	Whole blood/serum/ plasma	72·7-98·2	98·1-100
Qualpro Syphichk-WB ^e	Whole blood/serum/ plasma	64-97·6	98·4-99·7
SD Bioline Syphilis 3·0 ^e	Whole blood/ serum/plasma	85·7-100	95·5-99·4
Span Diagnostics Crystal TP Syphilis Test	Whole blood/ serum/plasma	Not available	Not available
CTK Biotech OnSite TM Syphilis Ab combo Rapid	Whole blood	Not available	Not available
Diagnostics Direct Syphilis Health Check TM	Whole blood/ serum/plasma	Not available	Not available
Uni-Gold TM syphilis Treponemal	Whole blood/ serum/plasma	Not available	Not available
Dual Path Platform (DDP [®]) Syphilis Test ^f (Chembio Diagnostic Systems, Inc)	Treponemal antibody	90·1-98·2	91·2-98·0
	Non-Treponemal	80·6-98·2	89·4
Dual HIV/TP Syphilis			
SD Bioline HIV/Syphilis Duo Rapid Test ^g (Alere/Standard Diagnostics, Inc)	Whole blood/ serum/plasma	97·9-99·0	99·0-100
	Whole blood/ serum/plasma	93·0-99·6	99·1-100
DPP [®] HIV-Syphilis Assay ^g (Chembio Diagnostic Systems, Inc)	Whole blood/ serum/plasma	98·9	97·9-99·6
	Whole blood/ serum/plasma	95·3	97·0-99·6
Multiplo Rapid TP/HIV Antibody Test ^g (MedMira, Inc)	Whole blood/ serum/plasma	97·9	94·2-99·5
	Whole blood/ serum/plasma	94·1	94·2-99·1
INSTI TM HIV/Syphilis Multiplex Test (Biolytical Laboratories, Inc)	Whole blood/ serum/plasma	Not available	Not available
	Whole blood/ serum/plasma	Not available	Not available
OnSite TM HIV/Syphilis Ab Combo Rapid Test (CTK Biotech)	Whole blood/ serum/plasma	Not available	Not available
	Whole blood/ serum/plasma	Not available	Not available

a= Sensitivity and specificity compared with nucleic acid amplification tests; b= Data taken from³⁵²; c= Data taken from^{359,360}; d = Data taken from³⁵³; e= Data taken from³⁵⁰; f=Data taken from³⁶⁵; g= Data taken from³²⁵

Table 3: Point-of-care tests for sexually transmitted infections currently on the market with available sensitivities and specificities

Table 4: Call to Action

Policy Priorities	Research Priorities
Ensure accessible health care for early treatment of symptomatic STIs	Develop measures of 'access to health care services' and set minimum benchmarks
Improve health outcomes from chlamydia, such as pelvic inflammatory disease by better case management	Robust trials of strategies to increase chlamydia re-testing and partner notification and treatment
Enhance surveillance of pelvic inflammatory disease, ectopic pregnancy and infertility	Develop non-invasive tools to detect upper genital tract infection and disease
Develop and implement effective partner treatment	Robust trials of innovative partner treatment strategies with biological outcomes (e.g. reinfection rates)
New antimicrobials and/or other treatments for gonorrhoea	Fund research into new antimicrobials and treatments for gonorrhoea
Reduce gonorrhoea prevalence	Identify key drivers of gonorrhoea prevalence and effective interventions to reduce it
Develop treatments for bacterial vaginosis (BV) with low relapse rates	Explore new agents that target the biofilm; re-evaluate the role of treatment of male sex partners
Evaluate partner treatment for BV	New partner treatment trials and identify the transmissible agent(s) responsible for BV
Ensure 100% of pregnant women are screened and treated for syphilis at the first prenatal visit	Increase implementation research to strengthen health systems to effectively identify and manage syphilis using simple and rapid POC tests

Point-of-care (POC) tests for STIs	Identify the key health systems required for effective use of POC tests, Develop new POC tests for STIs, Evaluate the use of POC tests for STIs
Pre-exposure prophylaxis (PrEP) and STI testing	Identify the effect that frequent STI screening has on STI incidence
Vaccines for STIs ¹⁵⁰	Undertake the laboratory and subsequent clinical research necessary for successful vaccines

¹⁵⁰Footnote. The elements of this panel assume that other elements of an effective STI control program are already in place including; sound sex education programme throughout school, strong partner notification programmes that use the latest information technology systems and legislative changes for partner delivered antibiotic treatment where appropriate, legalised frameworks for sex work, active targeted health promotion, accurate surveillance programmes.

Supplementary Table 1: Explanatory notes on hospital discharge rates presented in Figure 5.¹²²

Country	Source	Comment
Australia	Australian Institute of Health and Welfare Hospital Morbidity Database	<p>Reference period: 1 July to 30 June.</p> <p>Coverage:</p> <ul style="list-style-type: none"> - Data are derived using AIHW analysis of the AIHW National Hospital Morbidity Database (NHMD). Please see http://meteor.aihw.gov.au/content/index.php/tml/itemId/611030 for the data quality statement for the 2013–14 NHMD. For each reference year, these data are based on hospital separations from 1 July to 30 June. - Data are for principal diagnosis, recorded using the ICD-9-CM from 1993-94 to 1997-98, and recording using the ICD-10-AM (Australian modification) from 1998-99. For 2013-14, principal diagnoses were recorded using the ICD-10-AM 8th edition. - Data presented are based on overnight admitted patient separations. They exclude same-day separations.
Austria	Statistics Austria, Hospital discharge database; raw data: Austrian Ministry of Health	<p>Reference period: 31 December.</p> <ul style="list-style-type: none"> - <i>Coverage by hospital type</i>: The Austrian hospital discharge database covers all inpatient institutions classifiable as HP.1 according to SHA/OECD. - <i>Missing records</i>: The database includes all inpatient discharges and day cases: <ul style="list-style-type: none"> - Day cases are all cases admitted and discharged on the same day (before midnight). - Inpatients include discharges to home, other inpatient-institutions and deaths in hospitals. <p>The Austrian hospital discharge database is based on the Austrian DRG system (DRG =</p>

Country	Source	Comment
Belgium	The Federal Public Service of Health, Food Chain Safety and Environment, Directorate 1 -Minimal Clinical Data.	<p>diagnosis related group).</p> <p>Reference period: during the year.</p> <p>Coverage:</p> <ul style="list-style-type: none"> - The Federal Public Service of Health, DG 1 "Organisation of health institutions" is responsible for the registration of the Minimal Hospital Data. - Hospital days for inpatients concern only acute admissions in acute hospitals (with at least 1 overnight stay in the hospital). - Patient data in psychiatric hospitals are NOT included. - Long lasting stays are excluded (more than 6 months or 184 days). - Deceased patients are included.
Canada	<p>Statistics Canada, <i>Hospital Morbidity Database</i>, 1980/81 to 1993/94.</p> <p>- Canadian Institute for Health Information, <i>Discharge Abstract Database</i> and <i>Hospital Morbidity Database</i> starting in 1994/95 (the Hospital Morbidity Database was transferred from Statistics Canada to the Canadian Institute for Health Information in 1994/95), <i>Ontario Mental Health Reporting System</i> starting in 2006/07 until 2012/13, and <i>Hospital Mental Health Database</i> starting in 2013/14.</p>	<p>Reference period: April 1 to March 31st</p> <p>Coverage:</p> <ul style="list-style-type: none"> - Data are calculated on a fiscal year basis (April 1st to March 31st). All ten Canadian provinces are included for all years. In 1994/95, one territory is included while for 1995/96 to 2012/13 all territories are included, except in 2002/03 when the territory of Nunavut is excluded. - Separations in Canada include discharges both alive and dead for the condition most responsible for the length of stay. - Data are for acute care hospitals only, except for the data on mental and behavioural disorders which include psychiatric hospitals starting in 2013/14. - The data are reported as per ICD-9 until 2000/01. In 2001/02, five provinces and one territory provided their data for the first time, according to ICD-10-CA; in 2002/03 two

Country	Source	Comment
		<p>more provinces and two more territories reported according to ICD-10-CA. In 2003/04, only Manitoba and Quebec did not submit their data according to ICD-10-CA. In 2004/05, Manitoba adopted the ICD-10-CA and Quebec did the same in 2006/07.</p> <p>- The total count of separations in provinces that still reported according to ICD-9, for each diagnostic category was added to the count for the provinces and territories that reported according to ICD-10-CA.</p>
Chile	Ministry of Health (MINSAL), Department of Health Statistics and Information (DEIS).	<p>Hospital discharges from 2001-2013</p> <p>Coverage:</p> <p>- Data coverage is nationwide. Data include both public and private sectors.</p> <p>- Data include same-day separations and deaths.</p> <p>- Annual periodicity. Data are automatically collected monthly from the health establishments' information systems and validated and published by the Department of Health Statistics and Information (DEIS).</p>
Estonia	<p>Ministry of Social Affairs, Department of Health Information and Analysis, routinely collected aggregate hospital statistics.</p> <p>- Since 1st January 2008: National Institute for Health Development, Department of Health Statistics</p>	<p>Reference period: Calendar year.</p> <p>Coverage:</p> <p>- <i>Coverage by hospital type</i>: All hospitals (HP.1), public and private, are covered.</p> <p>- ICD-10 is used for data collection.</p> <p>- <i>Inpatient cases</i>: Data on discharges are collected in two ways: 1) Discharges according to ICD-10 main chapters by sex and age groups include deceased patients but not bed-days; 2) Hospital discharges by selected ICD-10 subgroups/single diagnoses and corresponding bed-days.</p>

Country	Source	Comment
France	Ministère du Travail, de l'Emploi et de la Santé, Drees (Direction de la recherche, des études, de l'évaluation et des statistiques) - BESP; National databases from the "programme de médicalisation des systems d'information (PMSI)" (since 1997).	<p>Reference period: Calendar year.</p> <p>Coverage:</p> <p>- French data cover residents of Metropolitan France and/or overseas Départements (Guadeloupe, Martinique, French Guyana and Réunion Island but not Mayotte), who were hospitalised in the public and private hospitals of the same area. They refer to hospitalisations (and not to patients) in the units delivering acute care in medicine, medical specialties, surgery, surgical specialties, gynecology and obstetrics (MCO). Database contains all inpatient hospitalisations, including iterative care, and ambulatory cases except haemodialysis, chemotherapy, radiotherapy and other iterative treatments.</p>
Ireland	The data presented are derived from the HIPE (Hospital In-Patient Enquiry) data set, which records data on discharges from all publicly funded acute hospitals. HIPE is operated by the Healthcare Pricing Office (www.hpo.ie).	<p>Reference period: Data are based on the year of discharge.</p> <p>Coverage:</p> <p><i>Coverage by hospital type</i></p> <p>- HIPE data covers all inpatients and day cases receiving curative and rehabilitative care in publicly funded acute hospitals in the State.</p> <p>Data for 1995 to 2004 were classified using ICD-9-CM. All HIPE discharges from 2005 are now coded using ICD-10-AM (The Australian Modification of ICD-10 incorporating the Australian Classification of Health Interventions). Although the ISHMT is used for categorising diagnoses, there are still some minor changes in the classification of diagnoses. The HMT shortlist is based on ICD-9 and ICD-10 codes, but the classification used for diagnoses in HIPE was changed from ICD-9-CM to ICD-10-AM including the</p>

Country	Source	Comment
		Australian Coding Standards.
Slovenia	National Institute of Public Health, Slovenia; National Hospital Health Care Statistics Database.	<p>Reference period: During the year.</p> <p>Coverage:</p> <ul style="list-style-type: none"> - <i>Coverage by hospital type</i>: data include all private and public hospitals, all types (general and university - HP.1.1, psychiatric - HP.1.2, and specialty hospitals - HP.1.3). - Data include: <ul style="list-style-type: none"> - Inpatient discharges - Day-cases discharges - All patients (including uninsured, foreigners) - Long duration stays in hospitals - Palliative care in hospitals - Healthy newborn babies (since 2003) <p><i>Definition of main diagnosis</i>: the main diagnosis is defined as that which was responsible for the patient's admission at the hospital, which best reflects the main reason for admission, or that which is the main reason for treatment. If there is a multiple-episode case the main diagnosis is taken from the first episode.</p>
Switzerland	FSO Federal Statistical Office, Neuchâtel. Medical Statistics of Hospitals, 2002 and following years.	<p>Reference period: Annual census.</p> <p>Coverage:</p> <ul style="list-style-type: none"> - <i>Coverage by hospital type</i>: The data cover all inpatient institutions (public and private hospitals) which are classifiable as HP.1 providers. However, military and prison hospitals are not included. - <i>Definition of main diagnosis</i>: The main diagnosis is defined as the condition

Country	Source	Comment
United Kingdom	<p>Data have been aggregated by the NHS Information Centre for Health and Social Care from the following sources:</p> <ul style="list-style-type: none"> - <i>England</i>: Hospital Episode Statistics (HES); Inpatients, Health & Social Care Information Centre (HSCIC), England. http://www.hscic.gov.uk. - <i>Wales</i>: Patient Episode Database for Wales (PEDW), NHS Wales Informatics Service (NWIS). http://www.statswales.wales.gov.uk/index.htm. - <i>Scotland</i>: Information Services Division (ISD), National Health Service Scotland (SMR01 records). http://www.isdscotland.org/Health-Topics/Hospital-Care/Data_Sources_and_Clinical_Coding.doc. - <i>Northern Ireland</i>: Hospital Inpatient System (HIS), The Department for Health, Social Services and Public Safety in Northern Ireland (DHSSPSNI). http://www.dhsspsni.gov.uk/hospital-activity. 	<p>diagnosed at the end of the hospitalisation period, primarily responsible for the patient's need for treatment or examination at the hospital.</p> <p>Reference period:</p> <ul style="list-style-type: none"> - <i>England, Wales and Scotland</i>: Data is based on Financial Discharge Years 1st April to 31st March. - <i>Northern Ireland</i>: Data have been tabled by calendar year. - Includes records for discharge dates occurring in the reference year, regardless of admission date. <p>Coverage:</p> <ul style="list-style-type: none"> - <i>Coverage by hospital type</i>: <ul style="list-style-type: none"> ☑ <i>England</i>: Inpatient data cover activity in English NHS Hospitals and English NHS commissioned activity in the independent sector. ☑ <i>Scotland</i>: Data collected on discharges from non-obstetric and non-psychiatric hospitals (SMR01) in Scotland. Only patients treated as inpatients or day cases are included. The specialty of geriatric long stay is excluded. ☑ <i>Wales</i>: All NHS commissioned data carried out in private sector hospitals is included. ☑ <i>Northern Ireland</i>: Inpatient data cover activity in Northern Ireland HSC hospitals including independent sector activity carried out in HSC hospitals.
USA	Centers for Disease Control and Prevention/National Center for Health Statistics/National Hospital Discharge	<p>Coverage:</p> <ul style="list-style-type: none"> - National representative sample of the U.S.

Country	Source	Comment
	<p data-bbox="341 264 791 459">Survey Annual Summary, Advance Data from Vital and Health Statistics Summary (published annually). Vital and Health Statistics, Series 13, completed by unpublished tables.</p> <p data-bbox="341 495 791 566">http://www.cdc.gov/nchs/about/major/hdasd/nhds.htm.</p>	<p data-bbox="831 264 1375 293">civilian non-institutionalised population.</p> <ul style="list-style-type: none"> <li data-bbox="831 331 1375 730">- The National Hospital Discharge Survey (NHDS) defines a hospital discharge as the formal release of an inpatient by a hospital, terminating of the period of hospitalisation (including stays of 0 nights) by death or by disposition to the place of residence, nursing home, or another hospital; survey of discharges from non-federal hospitals in which the Average Length of Stay is less than 30 days. <li data-bbox="831 768 1375 1084">- The National Hospital Discharge Survey (NHDS) is a continuing nationwide sample survey of short-stay hospitals in the United States. The scope of NHDS encompasses patients discharged from non-institutional hospitals located in the 50 States and the District of Columbia, excluding military and Department of Veteran’s Affairs hospitals. <li data-bbox="831 1122 1375 1234">- All U.S. discharges were coded to the International Classification of Diseases, Ninth Revision (ICD-9). <li data-bbox="831 1272 1375 1384">- A hospital discharge is the completion of any continuous period of stay in a hospital as an inpatient.

References

1. G. B. D. Disease Injury Incidence Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016; **388**(10053): 1545-602.
2. Newman L, Rowley J, Vander Hoorn S, et al. Global Estimates of the Prevalence and Incidence of Four Curable Sexually Transmitted Infections in 2012 Based on Systematic Review and Global Reporting. *PLOS ONE* 2015; **10**(12): e0143304.
3. Unemo M, Jensen JS. Antimicrobial-resistant sexually transmitted infections: gonorrhoea and *Mycoplasma genitalium*. *Nat Rev Urol* 2017; **14**(3): 139-52.
4. Holmes KK, Sparling PF, Stamm WE, et al. Sexually Transmitted Diseases. New York: McGraw-Hill; 2008.
5. Galvin SR, Cohen MS. The role of sexually transmitted diseases in HIV transmission. *Nat Rev Microbiol* 2004; **2**(1): 33-42.
6. Low N, Broutet N, Adu-Sarkodie Y, Barton P, Hossain M, Hawkes S. Global control of sexually transmitted infections. *Lancet* 2006; **368**(9551): 2001-16.
7. Wu D, Hawkes S, Buse K. Prevention of mother-to-child transmission of syphilis and HIV in China: What drives political prioritization and what can this tell us about promoting dual elimination? *Int J Gynaecol Obstet* 2015; **130 Suppl 1**: S32-6.
8. Fee E. Sin versus Science: Venereal Disease in Twentieth-Century Baltimore. In: Fee E, Fox DM, eds. *AIDS: The Burdens of History*. Berkeley and Los Angeles: University of California Press; 1988: 121-46.
9. Jensen JS, Bradshaw C. Management of *Mycoplasma genitalium* infections - can we hit a moving target? *BMC Infect Dis* 2015; **15**: 343.
10. Gottlieb SL, Johnston C. Future prospects for new vaccines against sexually transmitted infections. *Curr Opin Infect Dis* 2017; **30**(1): 77-86.
11. Chow EP, Danielewski JA, Fehler G, et al. Human papillomavirus in young women with *Chlamydia trachomatis* infection 7 years after the Australian human papillomavirus vaccination programme: a cross-sectional study. *Lancet Infect Dis* 2015; **15**(11): 1314-23.
12. Haggerty CL, Gottlieb SL, Taylor BD, Low N, Xu F, Ness RB. Risk of sequelae after *Chlamydia trachomatis* genital infection in women. *J Infect Dis* 2010; **201 Suppl 2**: S134-55.
13. Scholes D, Stergachis A, Heidrich FE, Andrilla H, Holmes KK, Stamm WE. Prevention of pelvic inflammatory disease by screening for cervical chlamydial infection. *N Engl J Med* 1996; **334**(21): 1362-6.
14. Hocking JS. Chlamydia control - where to from here? Results of the Australian Chlamydia Control Effectiveness Pilot. World STI and AIDS. Brisbane; 2015.

15. Fifer H, Natarajan U, Jones L, et al. Failure of Dual Antimicrobial Therapy in Treatment of Gonorrhoea. *N Engl J Med* 2016; **374**(25): 2504-6.
16. Fethers KA, Fairley CK, Hocking JS, Gurrin LC, Bradshaw CS. Sexual risk factors and bacterial vaginosis: a systematic review and meta-analysis. *Clin Infect Dis* 2008; **47**(11): 1426-35.
17. Liu CM, Hungate BA, Tobian AA, et al. Penile Microbiota and Female Partner Bacterial Vaginosis in Rakai, Uganda. *MBio* 2015; **6**(3): e00589.
18. Brotman RM, Klebanoff MA, Nansel TR, et al. Bacterial vaginosis assessed by gram stain and diminished colonization resistance to incident gonococcal, chlamydial, and trichomonal genital infection. *J Infect Dis* 2010; **202**(12): 1907-15.
19. Cohen CR, Lingappa JR, Baeten JM, et al. Bacterial Vaginosis Associated with Increased Risk of Female-to-Male HIV-1 Transmission: A Prospective Cohort Analysis among African Couples. *PLoS Med* 2012; **9**(6): e1001251.
20. Bradshaw CS, Vodstrcil LA, Hocking JS, et al. Recurrence of Bacterial Vaginosis Is Significantly Associated With Posttreatment Sexual Activities and Hormonal Contraceptive Use. *Clin Infect Dis* 2013; **56**(6): 777-86.
21. Peeling RW, Holmes KK, Mabey D, Ronald A. Rapid tests for sexually transmitted infections (STIs): the way forward. *Sex Transm Infect* 2006; **82 Suppl 5**: v1-6.
22. Eaton LA, Kalichman S. Risk compensation in HIV prevention: implications for vaccines, microbicides, and other biomedical HIV prevention technologies. *Curr HIV/AIDS Rep* 2007; **4**(4): 165-72.
23. Royal Australian College of General Practitioners. Guidelines for preventive activities in general practice ("The Red Book"). 8th ed. Melbourne: Royal Australian College of General Practitioners, 2012.
24. Public Health Agency of Canada. Canadian Guidelines on Sexually Transmitted Infections 2010. <http://www.phac-aspc.gc.ca/std-mts/sti-its/index-eng.php>
25. Public Health England. National chlamydia screening programme standards. London: Public Health England, 2014.
26. van den Broek IV, Sfetcu O, van der Sande MA, et al. Changes in chlamydia control activities in Europe between 2007 and 2012: a cross-national survey. *Eur J Public Health* 2016; **26**(3): 382-8.
27. Workowski KA, Bolan GA. Sexually Transmitted Diseases Treatment Guidelines, 2015. *Morbidity and Mortality Weekly Report* 2015; **64**(3): 1-135.
28. Sutton T, Martinko T, Hale S, Fairchok M. Prevalence and high rate of asymptomatic infection of *Chlamydia trachomatis* in male college reserve officer training corps cadets. *Sex Transm Dis* 2003; **30**: 901-4.
29. Peipert JF. Genital Chlamydial Infections. *New Engl J Med* 2003; **349**(25): 2424-30.

30. Hocking JS, Guy R, Walker J, Tabrizi SN. Advances in sampling and screening for chlamydia. *Future Microbiol* 2013; **8**: 367-86.
31. European Centre for Disease Prevention and Control. Guidance on chlamydia control in Europe – 2015. Stockholm: ECDC, 2016.
32. Dowdle WR. The principles of disease elimination and eradication. *Bull World Health Organ* 1998; **2**: 22-5.
33. World Health Organization. Global Health Sector Strategy on Sexually Transmitted Infections 2016-2021. Geneva: WHO, 2016.
34. Redmond SM, Alexander-Kisslig K, Woodhall SC, et al. Genital chlamydia prevalence in Europe and non-European high income countries: systematic review and meta-analysis. *Plos One* 2015; **10**(1): e0115753.
35. Mimiaga MJ, Helms DJ, Reisner SL, et al. Gonococcal, chlamydia, and syphilis infection positivity among MSM attending a large primary care clinic, Boston, 2003 to 2004. *Sex Transm Dis* 2009; **36**(8): 507-11.
36. van Liere GAFS, Hoebe CJPA, Dukers-Muijters NHTM. Evaluation of the anatomical site distribution of chlamydia and gonorrhoea in men who have sex with men and in high-risk women by routine testing: cross-sectional study revealing missed opportunities for treatment strategies. *Sex Transm Infect* 2014; **90**(1): 58-60.
37. Lewis D, Newton D, Guy R, et al. The prevalence of Chlamydia trachomatis infection in Australia: a systematic review and meta-analysis. *BMC Infectious Diseases* 2012; **12**(113): doi:10.1186/471-2334-12-113.
38. Goulet V, de Barbeyrac B, Raheison S, et al. Prevalence of Chlamydia trachomatis: results from the first national population-based survey in France. *Sex Transm Infect* 2010; **86**(4): 263-70.
39. Hocking J, Willis J, Tabrizi S, Hellard M, Garland S, Fairley CK. A chlamydia prevalence survey of young women living in Melbourne, Victoria. *Sexual Health* 2006; **3**: 235-40.
40. Klavs I, Rodrigues LC, Wellings K, Kese D, Hayes R. Prevalence of genital Chlamydia trachomatis infection in the general population of Slovenia: serious gaps in control. *Sex Transm Infect* 2004; **80**(2): 121-3.
41. van Bergen J, Gotz HM, Richardus JH, et al. Prevalence of urogenital Chlamydia trachomatis increases significantly with level of urbanisation and suggests targeted screening approaches: results from the first national population based study in the Netherlands. *Sex Transm Infect* 2005; **81**: 17-23.
42. Klovstad H, Grjibovski A, Aavitsland P. Population based study of genital Chlamydia trachomatis prevalence and associated factors in Norway: a cross sectional study. *BMC Infect Dis* 2012; **12**: 150.

43. Datta SD, Torrone E, Kruszon-Moran D, et al. Chlamydia trachomatis trends in the United States among persons 14 to 39 years of age, 1999-2008. *Sex Transm Dis* 2012; **39**(2): 92-6.
44. Sonnenberg P, Clifton S, Beddows S, et al. Prevalence, risk factors, and uptake of interventions for sexually transmitted infections in Britain: findings from the National Surveys of Sexual Attitudes and Lifestyles (Natsal). *Lancet* 2013; **382**(9907): 1795-806.
45. Torrone E, Papp J, Weinstock H, Centers for Disease C, Prevention. Prevalence of Chlamydia trachomatis genital infection among persons aged 14-39 years--United States, 2007-2012. *MMWR Morbidity and mortality weekly report* 2014; **63**(38): 834-8.
46. Bozicevic I, Grgic I, Zidovec-Lepej S, et al. Urine-based testing for Chlamydia trachomatis among young adults in a population-based survey in Croatia: feasibility and prevalence. *BMC Public Health* 2011; **11**: 230.
47. Crichton J, Hickman M, Campbell R, Batista-Ferrer H, Macleod J. Socioeconomic factors and other sources of variation in the prevalence of genital chlamydia infections: A systematic review and meta-analysis. *BMC Public Health* 2015; **15**(729): doi:10.1186/s12889-015-2069-7.
48. Op de Coul EL, Gotz HM, van Bergen JE, et al. Who participates in the Dutch Chlamydia screening? A study on demographic and behavioral correlates of participation and positivity. *Sex Transm Dis* 2012; **39**(2): 97-103.
49. Franceschi S, Smith JS, van den Brule A, et al. Cervical infection with Chlamydia trachomatis and Neisseria gonorrhoeae in women from ten areas in four continents. A cross-sectional study. *Sex Transm Dis* 2007; **34**(8): 563-9.
50. Joyee AG, Thyagarajan SP, Rajendran P, et al. Chlamydia trachomatis genital infection in apparently healthy adult population of Tamil Nadu, India: a population-based study. *Int J STD AIDS* 2004; **15**(1): 51-5.
51. Passey M, Mgone CS, Lupiwa S, et al. Community based study of sexually transmitted diseases in rural women in the highlands of Papua New Guinea: prevalence and risk factors. *Sex Transm Infect* 1998; **74**(2): 120-7.
52. Parish WL, Laumann EO, Cohen MS, et al. Population-based study of chlamydial infection in China: a hidden epidemic. *Journal of the American Medical Association* 2003; **289**(10): 1265-73.
53. Vallely A, Page A, Dias S, et al. The prevalence of sexually transmitted infections in Papua New Guinea: a systematic review and meta-analysis. *Plos One* 2010; **5**(12): e15586.
54. World Health Organization Western Pacific Region. Second generation surveillance surveys of HIV, other STIs and risk behaviours in 6 Pacific Island countries: 2004-2005. Geneva: WHO, 2006.
55. Moodley D, Moodley P, Sebitloane M, et al. High prevalence and incidence of asymptomatic sexually transmitted infections during pregnancy and postdelivery in KwaZulu Natal, South Africa. *Sex Transm Dis* 2015; **42**(1): 43-7.

56. Bingham AL, Kavanagh AM, Fairley CK, Keogh LA, Bentley RJ, Hocking JS. Income inequality and *Neisseria gonorrhoeae* notifications in females: a country-level analysis. *Sexual Health* 2014; **11**(6): 556-60.
57. World Health Organization. Global Health Estimates 2014 Summary Tables: DALY by cause, age and sex, by WHO region, 2000-2012. In: World Health Organisation, editor. Geneva; 2014.
58. Bender N, Herrmann B, Andersen B, et al. Chlamydia infection, pelvic inflammatory disease, ectopic pregnancy and infertility: cross-national study. *Sex Transm Infect* 2011; **87**(7): 601-8.
59. Goller JL, De Livera AM, Fairley CK, et al. Characteristics of pelvic inflammatory disease where no sexually transmitted infection is identified: a cross-sectional analysis of routinely collected sexual health clinic data. *Sex Transm Infect* 2017; **93**(1): 68-70.
60. Gottlieb SL, Martin DH, Xu F, Byrne GI, Brunham RC. Summary: The natural history and immunobiology of *Chlamydia trachomatis* genital infection and implications for *Chlamydia* control. *J Infect Dis* 2010; **15**(201): S190-204.
61. Darville T, Hiltke TJ. Pathogenesis of genital tract disease due to *Chlamydia trachomatis*. *J Infect Dis* 2010; **201 Suppl 2**: S114-25.
62. Geisler WM, Lensing SY, Press CG, Hook EW, 3rd. Spontaneous resolution of genital *Chlamydia trachomatis* infection in women and protection from reinfection. *J Infect Dis* 2013; **207**(12): 1850-6.
63. Brunham RC, Pourbohloul B, Mak S, White R, Rekart ML. The unexpected impact of a *Chlamydia trachomatis* infection control program on susceptibility to reinfection. *J Infect Dis* 2005; **192**(10): 1836-44.
64. Brunham RC, Rekart ML. The arrested immunity hypothesis and the epidemiology of chlamydia control. *Sex Transm Dis* 2008; **35**(1): 53-4.
65. Walker J, Fairley C, Bradshaw C, et al. *Chlamydia trachomatis* Incidence and Re-Infection among Young Women - Behavioural and Microbiological Characteristics. *Plos One* 2012; **7**(5): e37778.
66. LaMontagne D, Baster K, Emmett L, et al. Incidence and reinfection rates of genital chlamydia infection among women aged 16 to 24 years attending general practice, family planning and genitourinary medicine clinics in England: a prospective cohort study by the *Chlamydia Recall Study Advisory Group*. *Sex Transm Infect* 2007; **83**: 282-303.
67. van Valkengoed IGM, Morre SA, van den Brule AJC, Meijer CJLM, Bouter LM, Boeke AJP. Overestimation of complication rates in evaluations of *Chlamydia trachomatis* screening programmes - implications for cost-effectiveness analyses. *Int J Epidemiol* 2004; **33**: 416-25.
68. Wallace LA, Scoular A, Hart G, Reid M, Wilson P, Goldberg DJ. What is the excess risk of infertility in women after genital chlamydia infection? A systematic review of the evidence. *Sex Transm Infect* 2008; **84**(3): 171-5.

69. Land JA, Van Bergen JE, Morre SA, Postma MJ. Epidemiology of Chlamydia trachomatis infection in women and the cost-effectiveness of screening. *Hum Reprod Update* 2010; **16**(2): 189-204.
70. Risser W, Risser J. The incidence of pelvic inflammatory disease in untreated women infected with Chlamydia trachomatis: a structured review. *Int J STD AIDS* 2007; **18**: 727-31.
71. Price MJ, Ades AE, De Angelis D, et al. Risk of pelvic inflammatory disease following Chlamydia trachomatis infection: analysis of prospective studies with a multistate model. *American Journal of Epidemiology* 2013; **178**(3): 484-92.
72. Kavanagh K, Wallace LA, Robertson C, Wilson P, Scoular A. Estimation of the risk of tubal factor infertility associated with genital chlamydial infection in women: a statistical modelling study. *Int J Epidemiol* 2013; **42**(2): 493-503.
73. Price MJ, Ades AE, Soldan K, et al. The natural history of Chlamydia trachomatis infection in women: a multi-parameter evidence synthesis. *Health technology assessment (Winchester, England)* 2016; **20**(22): 1-250.
74. Davies B, Turner KM, Frolund M, et al. Risk of reproductive complications following chlamydia testing: a population-based retrospective cohort study in Denmark. *Lancet Infect Dis* 2016; **8**(16): 30092-5.
75. Davies B, Ward H, Leung S, et al. Heterogeneity in risk of pelvic inflammatory diseases after chlamydia infection: a population-based study in Manitoba, Canada. *J Infect Dis* 2014; **210 Suppl 2**: S549-55.
76. Bakken IJ, Skjeldestad FE, Lydersen S, Nordbo SA. Births and ectopic pregnancies in a large cohort of women tested for Chlamydia trachomatis. *Sex Transm Dis* 2007; **34**(10): 739-43.
77. Smith KJ, Cook RL, Roberts MS. Time from sexually transmitted infection acquisition to pelvic inflammatory disease development: influence on the cost-effectiveness of different screening intervals. *Value Health* 2007; **10**(5): 358-66.
78. Herzog SA, Althaus CL, Heijne JC, et al. Timing of progression from Chlamydia trachomatis infection to pelvic inflammatory disease: a mathematical modelling study. *BMC Infect Dis* 2012; **12**: 187.
79. Oakeshott P, Kerry S, Aghaizu A, et al. Randomised controlled trial of screening for Chlamydia trachomatis to prevent pelvic inflammatory disease: the POPI (prevention of pelvic infection) trial. *British Med J* 2010; **340**: c1642. doi: 10.136/bmj.c.
80. Rours GIJG, Duijts L, Moll HA, et al. Chlamydia trachomatis infection during pregnancy associated with preterm delivery: a population-based prospective cohort study. *European journal of epidemiology* 2011; **26**(6): 493-502.
81. Rours GIJG, Hammerschlag MR, Van Doornum GJJ, et al. Chlamydia trachomatis respiratory infection in Dutch infants. *Archives of disease in childhood* 2009; **94**(9): 705-7.
82. Trojian TH, Lishnak TS, Heiman D. Epididymitis and orchitis: an overview. *American Family Physician* 2009; **79**(7): 583-7.

83. Gimenes F, Souza RP, Bento JC, et al. Male infertility: a public health issue caused by sexually transmitted pathogens. *Nat Rev Urol* 2014; **11**(12): 672-87.
84. Eley A, Pacey AA, Galdiero M, Galdiero F. Can Chlamydia trachomatis directly damage your sperm? *Lancet Infect Dis* 2005; **5**(1): 53-7.
85. Khosropour CM, Broad JM, Scholes D, Saint-Johnson J, Manhart LE, Golden MR. Estimating Chlamydia Screening Coverage A Comparison of Self-report and Health Care Effectiveness Data and Information Set Measures. *Sex Transm Dis* 2014; **41**(11): 665-70.
86. Public Health England. Sexually transmitted infections and chlamydia screening in England, 2015. *Health Protection Report* 2016; **10**(22).
87. Kirby Institute. HIV/AIDS, viral hepatitis and sexually transmissible infections in Australia Annual Surveillance Report 2015. Sydney: Kirby Institute, UNSW, 2015.
88. European Centre for Disease Prevention and Control. Chlamydia control in Europe: literature review. Stockholm: ECDC, 2014.
89. Low N, Redmond SM, Uusküla A, et al. Screening for genital chlamydia infection. *Cochrane Database Syst Rev* 2016; (8): Art. No: CD010866.
90. Low N. Screening programmes for chlamydial infection: when will we ever learn? *British Med J* 2007; **334**: 725-8.
91. Low N, Geisler W, Stevenson J, Hook III E. Chlamydia control: a comparative review from the USA and UK. In: Aral S, Fenton K, Lipshutz J, eds. *The New Public Health and STD/HIV Prevention* New York: Springer; 2013: 401-29. New York: Springer; 2013.
92. Andersen B, van Valkengoed I, Sokolowski I, Moller JK, Ostergaard L, Olesen F. Impact of intensified testing for urogenital Chlamydia trachomatis infections: a randomised study with 9-year follow-up. *Sex Transm Infect* 2011; **87**(2): 156-61.
93. Ostergaard L, Andersen B, Moller JK, Olesen F. Home Sampling versus Conventional Swab Sampling for Screening of Chlamydia trachomatis in Women: A Cluster Randomised 1 Year Follow-up Study. *Clin Infect Dis* 2000; **31**: 951-7.
94. Hocking JS, Low N, Guy R, et al. 12 PRT 09010: Australian Chlamydia Control Effectiveness Pilot (ACCEPt): a cluster randomised controlled trial of chlamydia testing in general practice (ACTRN1260000297022). *Lancet* 2013; **Accepted protocol summary**(<http://www.thelancet.com/protocol-reviews-list>).
95. van den Broek IVF, van Bergen JEAM, Brouwers EEHG, et al. Effectiveness of yearly, register based screening for chlamydia in the Netherlands: controlled trial with randomised stepped wedge implementation. *BMJ (Clinical research ed)* 2012; **345**: e4316.
96. Garcia PJ, Holmes KK, Carcamo CP, et al. Prevention of sexually transmitted infections in urban communities (Peru PREVEN): a multicomponent community-randomised controlled trial. *Lancet (London, England)* 2012; **379**(9821): 1120-8.

97. Martin DH, Eschenbach DA, Cotch MF, et al. Double-Blind Placebo-Controlled Treatment Trial of Chlamydia trachomatis Endocervical Infections in Pregnant Women. *Infect Dis Obstetr and Gynecol* 1997; **5**(1): 10-7.
98. Gray RH, Wabwire-Mangen F, Kigozi G, et al. Randomized trial of presumptive sexually transmitted disease therapy during pregnancy in Rakai, Uganda. *American Journal of Obstetrics and Gynecology* 2001; **185**(5): 1209-17.
99. Ong KJ, Soldan K, Jit M, Dunbar JK, Woodhall SC. Chlamydia sequelae cost estimates used in current economic evaluations: does one-size-fit-all? *Sex Transm Infect* 2016; **9**(052597): 2016-052597.
100. Sheringham J, Simms I, Riha J, et al. Will chlamydia screening reach young people in deprived areas in England? Baseline analysis of the English National Chlamydia Screening Programme delivery in 2008. *Sex Transm Dis* 2011; **38**(8): 677-84.
101. Health Protection Agency. Primary Care Trust (PCT) and Strategic Health Authority (SHA) specific tables 2011/2012. In: Employers N, editor.; 2012.
102. Tao G, Hoover KW, Leichter JS, Peterman TA, Kent CK. Self-reported Chlamydia testing rates of sexually active women aged 15-25 years in the United States, 2006-2008. *Sex Transm Dis* 2012; **39**(8): 605-7.
103. Hoover KW, Leichter JS, Torrone EA, et al. Chlamydia screening among females aged 15-21 years--multiple data sources, United States, 1999-2010. *MMWR supplements* 2014; **63**(2): 80-8.
104. Batteiger BE, Tu W, Ofner S, et al. Repeated Chlamydia trachomatis genital infections in adolescent women. *J Infect Dis* 2010; **201**(1): 42-51.
105. Althaus CL, Heijne JCM, Roellin A, Low N. Transmission dynamics of Chlamydia trachomatis affect the impact of screening programmes. *Epidemics* 2010; **2**(3): 123-31.
106. Regan D, Wilson D, Hocking J. Coverage is the key for effective screening of Chlamydia trachomatis in Australia. *J Infect Dis* 2008; **198**(3): 349-58.
107. Rank RG, Yeruva L. Hidden in plain sight: chlamydial gastrointestinal infection and its relevance to persistence in human genital infection. *Infection and Immunity* 2014; **82**(4): 1362-71.
108. Musil K, Currie M, Sherley M, Martin S. Rectal chlamydia infection in women at high risk of chlamydia attending Canberra Sexual Health Centre. *Int J STD AIDS* 2016; **27**(7): 526-30.
109. Danby CS, Cosentino LA, Rabe LK, et al. Patterns of Extragenital Chlamydia and Gonorrhoea in Women and Men Who Have Sex With Men Reporting a History of Receptive Anal Intercourse. *Sex Transm Dis* 2016; **43**(2): 105-9.
110. Kintner J, Lajoie D, Hall J, Whittimore J, Schoborg RV. Commonly prescribed β -lactam antibiotics induce *C. trachomatis* persistence/stress in culture at physiologically relevant concentrations. *Front Cell Infect Microbiol* 2014; **4**: 44.

111. Hogan RJ, Mathews SA, Mukhopadhyay S, Summersgill JT, Timms P. Chlamydial Persistence: beyond the biphasic paradigm. *Infection and Immunity* 2004; **72**(4): 1843-55.
112. Wyrick PB. Chlamydia trachomatis persistence in vitro: an overview. *J Infect Dis* 2010; **201**(S2): S88-S95.
113. Phillips-Campbell R, Kintner J, Schoborg RV. Induction of the Chlamydia muridarum stress/persistence response increases Azithromycin-treatment failure in a murine model of infection. *Antimicrob Agents Chemother* 2014; **58**(3): 1782-4.
114. Reveneau N, Crane DD, Fischer E, Caldwell HD. Bactericidal activity of first-choice antibiotics against gamma interferon-induced persistent infection of human epithelial cells by Chlamydia trachomatis. *Antimicrob Agents Chemother* 2005; **49**(5): 1787-93.
115. Sutton MY, Sternberg M, Zaidi A, St Louis ME, Markowitz LE. Trends in pelvic inflammatory disease hospital discharges and ambulatory visits, United States, 1985-2001. *Sex Transm Dis* 2005; **32**(12): 778-84.
116. Chen M, Pan Y, Britt H, Donovan B. Trends in clinical encounters for pelvic inflammatory disease and epididymitis in a national sample of Australian general practices. *Int J STD AIDS* 2006; **17**: 384-86.
117. Scholes DP, Satterwhite CLP, Yu OMS, Fine DP, Weinstock HMDMPH, Berman SMDMPH. Long-Term Trends in Chlamydia trachomatis Infections and Related Outcomes in a US Managed Care Population. *Sex Transm Dis* 2012; **39**(2): 81-8.
118. French CE, Hughes G, Nicholson A, et al. Estimation of the rate of pelvic inflammatory disease diagnoses: trends in England, 2000-2008. *Sex Transm Dis* 2011; **38**(3): 158-62.
119. Moore MS, Golden MR, Scholes D, Kerani RP. Assessing Trends in Chlamydia Positivity and Gonorrhea Incidence and Their Associations With the Incidence of Pelvic Inflammatory Disease and Ectopic Pregnancy in Washington State, 1988-2010. *Sex Transm Dis* 2016; **43**(1): 2-8.
120. Rekart ML, Gilbert M, Meza R, et al. Chlamydia public health programs and the epidemiology of pelvic inflammatory disease and ectopic pregnancy. *J Infect Dis* 2013; **207**(1): 30-8.
121. Moss NJ, Ahrens K, Kent CK, Klausner JD. The decline in clinical sequelae of genital Chlamydia trachomatis infection supports current control strategies. *J Infect Dis* 2006; **193**(9): 1336-8.
122. Organisation for Economic Co-operation and Development (OECD). Hospital discharge rates (indicator). . In: OECD, editor.; 2016.
123. Nicoll A, Hughes G, Donnelly M, et al. Assessing the impact of national anti-HIV sexual health campaigns: trends in the transmission of HIV and other sexually transmitted infections in England. *Sex Transm Infect* 2001; **77**(4): 242-7.
124. Morgan J, Bell A. The highs and lows of opportunistic Chlamydia testing: uptake and detection in Waikato, New Zealand. *Sex Transm Infect* 2009; **85**(6): 452-4.

125. Kong FYS, Guy RJ, Hocking JS, et al. Australian general practitioner chlamydia testing rates among young people. *Med J Aust* 2011; **194**(5): 249-52.
126. Marks M, Bottomley C, Tome H, et al. Mass drug administration of azithromycin for trachoma reduces the prevalence of genital Chlamydia trachomatis infection in the Solomon Islands. *Sex Transm Infect* 2016; **92**(4): 261-5.
127. Handsfield HH. Questioning azithromycin for chlamydial infection. *Sex Transm Dis* 2011; **38**(12).
128. Hocking JS, Kong F, Timms P, Huston W, Tabrizi S. Treatment for rectal chlamydia infection may be more complicated than we originally thought. *J Antimicrob Chemother* 2015; **70**(4): 961-4.
129. Horner PJ. Azithromycin antimicrobial resistance and genital Chlamydia trachomatis infection: duration of therapy may be the key to improving efficacy. *Sex Transm Infect* 2012; **88**(3): 154-6.
130. Horner P, Saunders J. Should azithromycin 1 g be abandoned as a treatment for bacterial STIs? The case for and against. *Sex Transm Infect* 2017; **93**(2): 85-7.
131. Kong FYS, Tabrizi SN, Law M, et al. Azithromycin versus doxycycline for the treatment of genital chlamydia infection: a meta-analysis of randomized controlled trials. *Clin Infect Dis* 2014; **59**(2): 193-205.
132. Kong FY, Tabrizi S, Fairley C, et al. The efficacy of azithromycin and doxycycline for the treatment of rectal chlamydia infection: a systematic review and meta-analysis. *J Antimicrob Chemother* 2015; **70**(5): 1290-7.
133. World Health Organization. Guidelines for the Management of Sexually Transmitted Infections. Geneva: WHO, 2004.
134. Chisholm SA, Wilson J, Alexander S, et al. An outbreak of high-level azithromycin resistant Neisseria gonorrhoeae in England. *Sex Transm Infect* 2016; **92**(5): 365-7.
135. Chen XS, Yin YP, Wei WH, et al. High prevalence of azithromycin resistance to Treponema pallidum in geographically different areas in China. *Clin Microbiol Infect* 2013; **19**(10): 975-9.
136. Read P, Tagg KA, Jeffreys N, Guy RJ, Gilbert GL, Donovan B. Treponema pallidum Strain Types and Association with Macrolide Resistance in Sydney, Australia: New TP0548 Gene Types Identified. *J Clin Microbiol* 2016; **54**(8): 2172-4.
137. Lau A, Bradshaw CS, Lewis D, et al. The Efficacy of Azithromycin for the Treatment of Genital Mycoplasma genitalium: A Systematic Review and Meta-analysis. *Clin Infect Dis* 2015; **61**(9): 1389-99.
138. Ferreira A, Young T, Mathews C, Zunza M, Low N. Strategies for partner notification for sexually transmitted infections, including HIV. *Cochrane Database Syst Rev* 2013; (10): CD002843.

139. Althaus CL, Turner KME, Mercer CH, et al. Effectiveness and cost-effectiveness of traditional and new partner notification technologies for curable sexually transmitted infections: observational study, systematic reviews and mathematical modelling. *Health Technol Assess* 2014; **18**(2): 1-100, vii-viii.
140. Estcourt CS, Sutcliffe LJ, Copas A, et al. Developing and testing accelerated partner therapy for partner notification for people with genital *Chlamydia trachomatis* diagnosed in primary care: a pilot randomised controlled trial. *Sex Transm Infect* 2015; **91**(8): 548-54.
141. Pavlin N, Parker R, Hopkins C, Temple-Smith M, al e. Better than nothing? Patient-delivered partner therapy and partner notification for chlamydia: the views of Australian general practitioners. *BMC Infect Dis* 2010; **10**(274).
142. Australasian Sexual Health Alliance. Australian STI management guidelines for use in primary care. September 2014 2014. <http://www.sti.guidelines.org.au/sexually-transmissible-infections/chlamydia#management>
143. Lanjouw E, Ouburg S, de Vries HJ, Stary A, Radcliffe K, Unemo M. 2015 European guideline on the management of *Chlamydia trachomatis* infections. *Int J STD AIDS* 2016; **27**(5): 333-48.
144. Heijne JCM, Herzog SA, Althaus CL, Tao G, Kent CK, Low N. Insights into the timing of repeated testing after treatment for *Chlamydia trachomatis*: data and modelling study. *Sex Transm Infect* 2013; **89**(1): 57-62.
145. Kampman C, Koedijk F, Driessen-Hulshof H, Hautvast J, van den Broek I. Retesting young STI clinic visitors with urogenital *Chlamydia trachomatis* infection in the Netherlands; response to a text message reminder and reinfection rates: a prospective study with historical controls. *Sex Transm Infect* 2016; **92**(2): 124-9.
146. Smith KS, Hocking JS, Chen MY, et al. Dual Intervention to Increase Chlamydia Retesting: A Randomized Controlled Trial in Three Populations. *American Journal of Preventive Medicine* 2015; **49**(1): 1-11.
147. Pai NP, Vadnais C, Denkinger C, Engel N, Pai M. Point-of-care testing for infectious diseases: diversity, complexity, and barriers in low- and middle-income countries. *PLoS Med* 2012; **9**(9): e1001306.
148. Wingrove I, McOwan A, Nwokolo N, Whitlock G. Diagnostics within the clinic to test for gonorrhoea and chlamydia reduces the time to treatment: a service evaluation. *Sex Transm Infect* 2014; **90**(6): 474.
149. Hafner LM, Wilson DP, Timms P. Development status and future prospects for a vaccine against *Chlamydia trachomatis* infection *Vaccine* 2014; **32**(14): 1563-71.
150. Gottlieb SL, Deal CD, Giersing B, et al. The global roadmap for advancing development of vaccines against sexually transmitted infections: Update and next steps. *Vaccine* 2016; **34**(26): 2939-47.
151. Darville T, Pelvic Inflammatory Disease Workshop Proceedings C. Pelvic inflammatory disease: identifying research gaps--proceedings of a workshop sponsored by

Department of Health and Human Services/National Institutes of Health/National Institute of Allergy and Infectious Diseases, November 3-4, 2011. *Sex Transm Dis* 2013; **40**(10): 761-7.

152. Unemo M, Del Rio C, Shafer WM. Antimicrobial Resistance Expressed by *Neisseria gonorrhoeae*: A Major Global Public Health Problem in the 21st Century. *Microbiol Spectr* 2016; **4**(3).

153. Unemo M, Shafer WM. Antimicrobial resistance in *Neisseria gonorrhoeae* in the 21st century: past, evolution, and future. *Clin Microbiol Rev* 2014; **27**(3): 587-613.

154. World Health Organization, Department of Reproductive Health and Research. Global action plan to control the spread and impact of antimicrobial resistance in *Neisseria gonorrhoeae*. Global action plan to control the spread and impact of antimicrobial resistance in *Neisseria gonorrhoeae*. Geneva: WHO; 2012: 1-36.

155. Tapsall JW, Ndowa F, Lewis DA, Unemo M. Meeting the public health challenge of multidrug- and extensively drug-resistant *Neisseria gonorrhoeae*. *Expert Rev Anti Infect Ther* 2009; **7**(7): 821-34.

156. Unemo M, Nicholas RA. Emergence of multidrug-resistant, extensively drug-resistant and untreatable gonorrhoea. *Future Microbiol* 2012; **7**(12): 1401-22.

157. Lewis DA. Will targeting oropharyngeal gonorrhoea delay the further emergence of drug-resistant *Neisseria gonorrhoeae* strains? *Sex Transm Infect* 2015; **91**(4): 234-7.

158. Unemo M. Current and future antimicrobial treatment of gonorrhoea - the rapidly evolving *Neisseria gonorrhoeae* continues to challenge. *BMC Infect Dis* 2015; **15**: 364.

159. De Silva D, Peters J, Cole K, et al. Whole-genome sequencing to determine transmission of *Neisseria gonorrhoeae*: an observational study. *Lancet Infect Dis* 2016; **16**(11): 1295-303.

160. Camara J, Serra J, Ayats J, et al. Molecular characterization of two high-level ceftriaxone-resistant *Neisseria gonorrhoeae* isolates detected in Catalonia, Spain. *J Antimicrob Chemother* 2012; **67**(8): 1858-60.

161. Ohnishi M, Golparian D, Shimuta K, et al. Is *Neisseria gonorrhoeae* initiating a future era of untreatable gonorrhoea?: detailed characterization of the first strain with high-level resistance to ceftriaxone. *Antimicrob Agents Chemother* 2011; **55**(7): 3538-45.

162. Unemo M, Golparian D, Nicholas R, Ohnishi M, Galloway A, Sednaoui P. High-level cefixime- and ceftriaxone-resistant *Neisseria gonorrhoeae* in France: novel penA mosaic allele in a successful international clone causes treatment failure. *Antimicrob Agents Chemother* 2012; **56**(3): 1273-80.

163. Deguchi T, Yasuda M, Hatazaki K, et al. New Clinical Strain of *Neisseria gonorrhoeae* with Decreased Susceptibility to Ceftriaxone, Japan. *Emerg Infect Dis* 2016; **22**(1): 142-4.

164. Lahra MM, Ryder N, Whiley DM. A new multidrug-resistant strain of *Neisseria gonorrhoeae* in Australia. *N Engl J Med* 2014; **371**(19): 1850-1.

165. Nakayama S, Shimuta K, Furubayashi K, Kawahata T, Unemo M, Ohnishi M. New Ceftriaxone- and Multidrug-Resistant *Neisseria gonorrhoeae* Strain with a Novel Mosaic penA Gene Isolated in Japan. *Antimicrob Agents Chemother* 2016; **60**(7): 4339-41.
166. Gianecini R, Oviedo C, Stafforini G, Galarza P. *Neisseria gonorrhoeae* Resistant to Ceftriaxone and Cefixime, Argentina. *Emerg Infect Dis* 2016; **22**(6): 1139-41.
167. AWMF-Register. Nr. 059/004 – S2k-Leitlinie: Gonorrhoe bei Erwachsenen und Adoleszenten aktueller Stand. [In German]. 2013: 1-31.
168. Australasian Sexual Health Alliance (ASHA). Australian STI Management Guidelines for Use in Primary Care.
169. Bignell C, Fitzgerald M, Guideline Development G, British Association for Sexual H, Hiv UK. UK national guideline for the management of gonorrhoea in adults, 2011. *Int J STD AIDS* 2011; **22**(10): 541-7.
170. Bignell C, Unemo M, European STIGEB. 2012 European guideline on the diagnosis and treatment of gonorrhoea in adults. *Int J STD AIDS* 2013; **24**(2): 85-92.
171. Public Health Agency of Canada. Canadian Guidelines on Sexually Transmitted Infections. Gonococcal Infections Chapter 5.
172. World Health Organization, Department of Reproductive Health and Research. WHO Guidelines for the Treatment of *Neisseria gonorrhoeae*. 2016. <http://www.ncbi.nlm.nih.gov/pubmed/27512795>.
173. World Health Organization. Strategies and laboratory methods for strengthening surveillance of sexually transmitted infections.
174. Centers for Disease Control and Prevention. Antibiotic-resistant strains of *Neisseria gonorrhoeae*. Policy guidelines for detection, management, and control. *MMWR Suppl* 1987; **36**(5): 1S-18S.
175. Moran JS, Levine WC. Drugs of choice for the treatment of uncomplicated gonococcal infections. *Clin Infect Dis* 1995; **20 Suppl 1**: S47-65.
176. Ison CA, Deal C, Unemo M. Current and future treatment options for gonorrhoea. *Sex Transm Infect* 2013; **89 Suppl 4**: iv52-6.
177. Japanese Society of Sexually Transmitted Infection. Gonococcal infection. Sexually transmitted infections, diagnosis and treatment guidelines 2011. *Jpn J Sex Transm Dis* 2011; **22 (Suppl 1)**: 52-9.
178. Ito S, Yasuda M, Hatazaki K, et al. Microbiological efficacy and tolerability of a single-dose regimen of 1 g of ceftriaxone in men with gonococcal urethritis. *J Antimicrob Chemother* 2016; **71**(9): 2559-62.
179. Tapsall JW. Implications of current recommendations for third-generation cephalosporin use in the WHO Western Pacific Region following the emergence of multiresistant gonococci. *Sex Transm Infect* 2009; **85**(4): 256-8.

180. Unemo M, Shipitsyna E, Domeika M, Eastern European Sexual and Reproductive Health Network Antimicrobial Resistance Group. Recommended antimicrobial treatment of uncomplicated gonorrhoea in 2009 in 11 East European countries: implementation of a *Neisseria gonorrhoeae* antimicrobial susceptibility programme in this region is crucial. *Sex Transm Infect* 2010; **86**(6): 442-4.
181. Chisholm SA, Mouton JW, Lewis DA, Nichols T, Ison CA, Livermore DM. Cephalosporin MIC creep among gonococci: time for a pharmacodynamic rethink? *J Antimicrob Chemother* 2010; **65**(10): 2141-8.
182. Singh AE, Gratrix J, Martin I, et al. Gonorrhoea Treatment Failures With Oral and Injectable Expanded Spectrum Cephalosporin Monotherapy vs Dual Therapy at 4 Canadian Sexually Transmitted Infection Clinics, 2010-2013. *Sex Transm Dis* 2015; **42**(6): 331-6.
183. Rice LB. Will use of combination cephalosporin/azithromycin therapy forestall resistance to cephalosporins in *Neisseria gonorrhoeae*? *Sex Transm Infect* 2015; **91**(4): 238-40.
184. Lee H, Unemo M, Kim HJ, Seo Y, Lee K, Chong Y. Emergence of decreased susceptibility and resistance to extended-spectrum cephalosporins in *Neisseria gonorrhoeae* in Korea. *J Antimicrob Chemother* 2015; **70**(9): 2536-42.
185. Moran JS. Treating uncomplicated *Neisseria gonorrhoeae* infections: is the anatomic site of infection important? *Sex Transm Dis* 1995; **22**(1): 39-47.
186. Kirkcaldy RD, Weinstock HS, Moore PC, et al. The efficacy and safety of gentamicin plus azithromycin and gemifloxacin plus azithromycin as treatment of uncomplicated gonorrhoea. *Clin Infect Dis* 2014; **59**(8): 1083-91.
187. Dowell D, Kirkcaldy RD. Effectiveness of gentamicin for gonorrhoea treatment: systematic review and meta-analysis. *Sex Transm Infect* 2012; **88**(8): 589-94.
188. Hathorn E, Dhasmana D, Duley L, Ross JD. The effectiveness of gentamicin in the treatment of *Neisseria gonorrhoeae*: a systematic review. *Syst Rev* 2014; **3**: 104.
189. Hauser C, Hirzberger L, Unemo M, Furrer H, Endimiani A. In vitro activity of fosfomycin alone and in combination with ceftriaxone or azithromycin against clinical *Neisseria gonorrhoeae* isolates. *Antimicrob Agents Chemother* 2015; **59**(3): 1605-11.
190. Goire N, Lahra MM, Chen M, et al. Molecular approaches to enhance surveillance of gonococcal antimicrobial resistance. *Nat Rev Microbiol* 2014; **12**(3): 223-9.
191. Low N, Unemo M. Molecular tests for the detection of antimicrobial resistant *Neisseria gonorrhoeae*: when, where, and how to use? *Curr Opin Infect Dis* 2016; **29**(1): 45-51.
192. Allan-Blitz LT, Humphries RM, Hemarajata P, et al. Implementation of a Rapid Genotypic Assay to Promote Targeted Ciprofloxacin Therapy of *Neisseria gonorrhoeae* in a Large Health System. *Clin Infect Dis* 2016; pii: ciw864.

193. Allan-Blitz LT, Klausner JD. Codon 91 Gyrase A Testing Is Necessary and Sufficient to Predict Ciprofloxacin Susceptibility in *Neisseria gonorrhoeae*. *J Infect Dis* 2017; **215**(3): 491.
194. Bruhn DF, Waidyarachchi SL, Madhura DB, et al. Aminomethyl spectinomycins as therapeutics for drug-resistant respiratory tract and sexually transmitted bacterial infections. *Sci Transl Med* 2015; **7**(288): 288ra75.
195. Savage VJ, Charrier C, Salisbury AM, et al. Efficacy of a Novel Tricyclic Topoisomerase Inhibitor in a Murine Model of *Neisseria gonorrhoeae* Infection. *Antimicrob Agents Chemother* 2016; **60**(9): 5592-4.
196. Savage VJ, Charrier C, Salisbury AM, et al. Biological profiling of novel tricyclic inhibitors of bacterial DNA gyrase and topoisomerase IV. *J Antimicrob Chemother* 2016; **71**(7): 1905-13.
197. Alm RA, Lahiri SD, Kutschke A, et al. Characterization of the novel DNA gyrase inhibitor AZD0914: low resistance potential and lack of cross-resistance in *Neisseria gonorrhoeae*. *Antimicrob Agents Chemother* 2015; **59**(3): 1478-86.
198. Basarab GS, Kern GH, McNulty J, et al. Responding to the challenge of untreatable gonorrhea: ETX0914, a first-in-class agent with a distinct mechanism-of-action against bacterial Type II topoisomerases. *Sci Rep* 2015; **5**: 11827.
199. Basarab GS, McNulty J, Gales S. Non-clinical safety profile of a novel gyrase inhibitor for treatment of *Neisseria gonorrhoeae* infections. 54th Intersci Conf Antimicrob Agents Chemother American Society for Microbiology. Washington, DC, USA; 2014.
200. Biedenbach DJ, Bouchillon SK, Hackel M, et al. In Vitro Activity of Gepotidacin, a Novel Triazaacenaphthylene Bacterial Topoisomerase Inhibitor, against a Broad Spectrum of Bacterial Pathogens. *Antimicrob Agents Chemother* 2016; **60**(3): 1918-23.
201. Foerster S, Golparian D, Jacobsson S, et al. Genetic Resistance Determinants, In Vitro Time-Kill Curve Analysis and Pharmacodynamic Functions for the Novel Topoisomerase II Inhibitor ETX0914 (AZD0914) in *Neisseria gonorrhoeae*. *Front Microbiol* 2015; **6**: 1377.
202. Golparian D, Fernandes P, Ohnishi M, Jensen JS, Unemo M. In vitro activity of the new fluoroketolide solithromycin (CEM-101) against a large collection of clinical *Neisseria gonorrhoeae* isolates and international reference strains, including those with high-level antimicrobial resistance: potential treatment option for gonorrhea? *Antimicrob Agents Chemother* 2012; **56**(5): 2739-42.
203. Hook EW, 3rd, Golden M, Jamieson BD, et al. A Phase 2 Trial of Oral Solithromycin 1200 mg or 1000 mg as Single-Dose Oral Therapy for Uncomplicated Gonorrhea. *Clin Infect Dis* 2015; **61**(7): 1043-8.
204. Hossain M, Tiffany CA, McDonald M, Dumont EF. Safety and pharmacokinetics of repeat escalating oral doses of GSK2140944, a novel bacterial topoisomerase inhibitor. 54th Interscience Conference on Antimicrobial Agents and Chemotherapy. Washington, DC, USA; 2014.

205. Huband MD, Bradford PA, Otterson LG, et al. In vitro antibacterial activity of AZD0914, a new spiroprimidinetriene DNA gyrase/topoisomerase inhibitor with potent activity against Gram-positive, fastidious Gram-Negative, and atypical bacteria. *Antimicrob Agents Chemother* 2015; **59**(1): 467-74.
206. Jacobsson S, Golparian D, Alm RA, et al. High in vitro activity of the novel spiroprimidinetriene AZD0914, a DNA gyrase inhibitor, against multidrug-resistant *Neisseria gonorrhoeae* isolates suggests a new effective option for oral treatment of gonorrhea. *Antimicrob Agents Chemother* 2014; **58**(9): 5585-8.
207. Lawrence K, O'Connor K, Atuah K, Matthews D, Gardner H. Safety and pharmacokinetics of single escalating oral doses of AZD0914: a novel spiroprimidinetriene antibacterial agent. 54th Intersci Conf Antimicrob Agents Chemother American Society for Microbiology. Washington, DC, USA; 2014.
208. Llano-Sotelo B, Dunkle J, Klepacki D, et al. Binding and action of CEM-101, a new fluoroketolide antibiotic that inhibits protein synthesis. *Antimicrob Agents Chemother* 2010; **54**(12): 4961-70.
209. Negash K, Andonian C, Felgate C, et al. The metabolism and disposition of GSK2140944 in healthy human subjects. *Xenobiotica* 2016; **46**(8): 683-702.
210. Olsen B, Pham TL, Golparian D, Johansson E, Tran HK, Unemo M. Antimicrobial susceptibility and genetic characteristics of *Neisseria gonorrhoeae* isolates from Vietnam, 2011. *BMC Infect Dis* 2013; **13**: 40.
211. Papp JR, Lawrence K, Sharpe S, Mueller J, Kirkcaldy RD. In vitro growth of multidrug-resistant *Neisseria gonorrhoeae* isolates is inhibited by ETX0914, a novel spiroprimidinetriene. *Int J Antimicrob Agents* 2016; **48**(3): 328-30.
212. Putnam SD, Castanheira M, Moet GJ, Farrell DJ, Jones RN. CEM-101, a novel fluoroketolide: antimicrobial activity against a diverse collection of Gram-positive and Gram-negative bacteria. *Diagn Microbiol Infect Dis* 2010; **66**(4): 393-401.
213. Scangarella-Oman NE, Dixon P, Koeth LM, DiFranco-Fisher J, Miller LA. Analysis of agar dilution MIC testing methods and variables and in vitro activity of gepotidacin (GSK2140944) against *Neisseria gonorrhoeae*. ASM Microbe 2016. Boston, USA; 2016.
214. Still JG, Schranz J, Degenhardt TP, et al. Pharmacokinetics of solithromycin (CEM-101) after single or multiple oral doses and effects of food on single-dose bioavailability in healthy adult subjects. *Antimicrob Agents Chemother* 2011; **55**(5): 1997-2003.
215. Su XH, Wang BX, Le WJ, et al. Multidrug-Resistant *Neisseria gonorrhoeae* Isolates from Nanjing, China, Are Sensitive to Killing by a Novel DNA Gyrase Inhibitor, ETX0914 (AZD0914). *Antimicrob Agents Chemother* 2015; **60**(1): 621-3.
216. Unemo M, Ringlander J, Wiggins C, Fredlund H, Jacobsson S, Cole M. High in vitro susceptibility to the novel spiroprimidinetriene ETX0914 (AZD0914) among 873 contemporary clinical *Neisseria gonorrhoeae* isolates from 21 European countries from 2012 to 2014. *Antimicrob Agents Chemother* 2015; **59**(9): 5220-5.

217. Taylor SN, Marrazzo J, Batteiger BE, et al. A phase II trial of single-dose oral ETX0914 (AZD0914) for treatment of uncomplicated urogenital gonorrhea. 2016 STD Prevention Conference. Atlanta, GA, USA; 2016.
218. Gardner HL, Dukes CD. Haemophilus vaginalis vaginitis: a newly defined specific infection previously classified non-specific vaginitis. *Am J Obstet Gynecol* 1955; **69**(5): 962-76.
219. Potter J. Should sexual partners of women with bacterial vaginosis receive treatment? *Br J Gen Pract* 1999; **49**(448): 913-8.
220. Amaya-Guio J, Viveros-Carreno DA, Sierra-Barrios EM, Martinez-Velasquez MY, Grillo-Ardila CF. Antibiotic treatment for the sexual partners of women with bacterial vaginosis. *Cochrane Database Syst Rev* 2016; **10**: CD011701.
221. Mehta SD. Systematic Review of Randomized Trials of Treatment of Male Sexual Partners for Improved Bacterial Vaginosis Outcomes in Women. *Sex Transm Dis* 2012; **39**(10): 822-30.
222. Fredricks DN, Fiedler TL, Marrazzo JM. Molecular identification of bacteria associated with bacterial vaginosis. *N Engl J Med* 2005; **353**(18): 1899-911.
223. Boskey ER, Cone RA, Whaley KJ, Moench TR. Origins of vaginal acidity: high D/L lactate ratio is consistent with bacteria being the primary source. *Hum Reprod* 2001; **16**(9): 1809-13.
224. Aroutcheva A, Gariti D, Simon M, et al. Defense factors of vaginal lactobacilli. *Am J Obstet Gynecol* 2001; **185**(2): 375-9.
225. Swidsinski A, Doerffel Y, Loening-Baucke V, et al. Gardnerella biofilm involves females and males and is transmitted sexually. *Gynecol Obstet Invest* 2010; **70**(4): 256-63.
226. Swidsinski A, Mendling W, Loening-Baucke V, et al. Adherent biofilms in bacterial vaginosis. *Obstet Gynecol* 2005; **106**(5): 1013-23.
227. Bradshaw CS, Walker J, Fairley CK, et al. Prevalent and incident bacterial vaginosis are associated with sexual and contraceptive behaviours in young Australian women. *PLoS One* 2013; **8**(3): e57688.
228. Allsworth JE. Bacterial vaginosis--race and sexual transmission: issues of causation. *Sex Transm Dis* 2010; **37**(3): 137-9.
229. Koumans EH, Sternberg M, Bruce C, et al. The prevalence of bacterial vaginosis in the United States, 2001-2004; associations with symptoms, sexual behaviors, and reproductive health. *Sex Transm Dis* 2007; **34**(11): 864-9.
230. Chico RM, Mayaud P, Ariti C, Mabey D, Ronsmans C, Chandramohan D. Prevalence of malaria and sexually transmitted and reproductive tract infections in pregnancy in sub-Saharan Africa: a systematic review. *JAMA* 2012; **307**(19): 2079-86.

231. Bilardi JE, Walker S, Temple-Smith M, et al. The burden of bacterial vaginosis: women's experience of the physical, emotional, sexual and social impact of living with recurrent bacterial vaginosis. *PLoS One* 2013; **8**(9): e74378.
232. Bilardi J, Walker S, McNair R, et al. Women's Management of Recurrent Bacterial Vaginosis and Experiences of Clinical Care: A Qualitative Study. *PLoS One* 2016; **11**(3): e0151794.
233. Bilardi J, Walker S, Mooney-Somers J, et al. Women's Views and Experiences of the Triggers for Onset of Bacterial Vaginosis and Exacerbating Factors Associated with Recurrence. *PLoS One* 2016; **11**(3): e0150272.
234. Peipert JF, Lapane KL, Allsworth JE, Redding CA, Blume JD, Stein MD. Bacterial vaginosis, race, and sexually transmitted infections: does race modify the association? *Sex Transm Dis* 2008; **35**(4): 363-7.
235. Myer L, Kuhn L, Stein ZA, Wright TC, Jr., Denny L. Intravaginal practices, bacterial vaginosis, and women's susceptibility to HIV infection: epidemiological evidence and biological mechanisms. *Lancet Infect Dis* 2005; **5**(12): 786-94.
236. Chernes TL, Meyn LA, Krohn MA, Lurie JG, Hillier SL. Association between acquisition of herpes simplex virus type 2 in women and bacterial vaginosis. *Clin Infect Dis* 2003; **37**(3): 319-25.
237. Hay PE, Lamont RF, Taylor-Robinson D, Morgan DJ, Ison C, Pearson J. Abnormal bacterial colonisation of the genital tract and subsequent preterm delivery and late miscarriage. *BMJ* 1994; **308**(6924): 295-8.
238. Hillier SL, Nugent RP, Eschenbach DA, et al. Association between bacterial vaginosis and preterm delivery of a low-birth-weight infant. The Vaginal Infections and Prematurity Study Group. *N Engl J Med* 1995; **333**(26): 1737-42.
239. Koumans EH, Markowitz LE, Berman SM, St Louis ME. A public health approach to adverse outcomes of pregnancy associated with bacterial vaginosis. *Int J Gynaecol Obstet* 1999; **67**: S29-33.
240. Hawes SE, Hillier SL, Benedetti J, et al. Hydrogen peroxide-producing lactobacilli and acquisition of vaginal infections. *J Infect Dis* 1996; **174**(5): 1058-63.
241. Vaca M, Guadalupe I, Erazo S, et al. High prevalence of bacterial vaginosis in adolescent girls in a tropical area of Ecuador. *BJOG* 2010; **117**(2): 225-8.
242. Bump RC, Buesching WJ, 3rd. Bacterial vaginosis in virginal and sexually active adolescent females: evidence against exclusive sexual transmission. *Am J Obstet Gynecol* 1988; **158**(4): 935-9.
243. Yen S, Shafer MA, Moncada J, Campbell CJ, Flinn SD, Boyer CB. Bacterial vaginosis in sexually experienced and non-sexually experienced young women entering the military. *Obstet Gynecol* 2003; **102**(5 Pt 1): 927-33.
244. Fethers KA, Fairley CK, Morton A, et al. Early sexual experiences and risk factors for bacterial vaginosis. *J Infect Dis* 2009; **200**(11): 1662-70.

245. Schwebke J, Desmond RA. Risk Factors for bacterial vaginosis in women at high risk for sexually transmitted diseases. *Sex Transm Dis* 2005; **32**(11): 654-8.
246. Bradshaw CS, Morton AN, Hocking J, et al. High recurrence rates of bacterial vaginosis over the course of 12 months after oral metronidazole therapy and factors associated with recurrence. *J Infect Dis* 2006; **193**: 1478-89.
247. Sanchez S, Garcia PJ, Thomas KK, Catlin M, Holmes KK. Intravaginal metronidazole gel versus metronidazole plus nystatin ovules for bacterial vaginosis: a randomized controlled trial. *Am J Obstet Gynecol* 2004; **191**(6): 1898-906.
248. Schwebke JR, Desmond RA. A randomized trial of the duration of therapy with metronidazole plus or minus azithromycin for treatment of symptomatic bacterial vaginosis. *Clin Infect Dis* 2007; **44**(2): 213-9.
249. Hellberg D, Nilsson S, Mardh PA. Bacterial vaginosis and smoking. *Int J STD AIDS* 2000; **11**(9): 603-6.
250. Brotman RM, He X, Gajer P, et al. Association between cigarette smoking and the vaginal microbiota: a pilot study. *BMC Infect Dis* 2014; **14**: 471.
251. Bradshaw CS, Walker SM, Vodstrcil LA, et al. The influence of behaviors and relationships on the vaginal microbiota of women and their female partners: the WOW Health Study. *J Infect Dis* 2014; **209**(10): 1562-72.
252. Bradshaw CS, Morton AN, Garland SM, Morris MB, Moss LM, Fairley CK. Higher-risk behavioral practices associated with bacterial vaginosis compared with vaginal candidiasis. *Obstet Gynecol* 2005; **106**(1): 105-14.
253. Ness RB, Hillier SL, Richter HE, et al. Douching in relation to bacterial vaginosis, lactobacilli, and facultative bacteria in the vagina. *Obstet Gynecol* 2002; **100**(4): 765.
254. Neggers YH, Nansel TR, Andrews WW, et al. Dietary intake of selected nutrients affects bacterial vaginosis in women. *J Nutr* 2007; **137**(9): 2128-33.
255. Paul K, Boutain D, Manhart L, Hitti J. Racial disparity in bacterial vaginosis: the role of socioeconomic status, psychosocial stress, and neighborhood characteristics, and possible implications for preterm birth. *Soc Sci Med* 2008; **67**(5): 824-33.
256. Berger BJ, Kolton S, Zenilman JM, Cummings MC, Feldman J, McCormack WM. Bacterial vaginosis in lesbians: a sexually transmitted disease. *Clin Infect Dis* 1995; **21**(6): 1402-5.
257. Evans AL, Scally AJ, Wellard SJ, Wilson JD. Prevalence of bacterial vaginosis in lesbians and heterosexual women in a community setting. *Sex Transm Infect* 2007; **83**(6): 470-5.
258. Marrazzo JM, Koutsky LA, Eschenbach DA, Agnew K, Stine K, Hillier SL. Characterization of vaginal flora and bacterial vaginosis in women who have sex with women. *J Infect Dis* 2002; **185**(9): 1307-13.

259. Vodstrcil LA, Walker SM, Hocking JS, et al. Incident bacterial vaginosis (BV) in women who have sex with women is associated with behaviors that suggest sexual transmission of BV. *Clin Infect Dis* 2015; **60**(7): 1042-53.
260. Marrazzo JM, Thomas KK, Agnew K, Ringwood K. Prevalence and risks for bacterial vaginosis in women who have sex with women. *Sex Transm Dis* 2010; **37**(5): 335-9.
261. Marrazzo JM, Thomas KK, Fiedler TL, Ringwood K, Fredricks DN. Risks for acquisition of bacterial vaginosis among women who report sex with women: a cohort study. *PLoS One* 2010; **5**(6): e11139.
262. Marrazzo JM, Antonio M, Agnew K, Hillier SL. Distribution of genital Lactobacillus strains shared by female sex partners. *J Infect Dis* 2009; **199**(5): 680-3.
263. Liu CM, Hungate BA, Tobian AA, et al. Male circumcision significantly reduces prevalence and load of genital anaerobic bacteria. *MBio* 2013; **4**(2): e00076.
264. Price LB, Liu CM, Johnson KE, et al. The effects of circumcision on the penis microbiome. *PLoS One* 2010; **5**(1): e8422.
265. Zozaya M, Ferris MJ, Siren JD, et al. Bacterial communities in penile skin, male urethra, and vaginas of heterosexual couples with and without bacterial vaginosis. *Microbiome* 2016; **4**(1): 16.
266. Eren AM, Zozaya M, Taylor CM, Dowd SE, Martin DH, Ferris MJ. Exploring the diversity of Gardnerella vaginalis in the genitourinary tract microbiota of monogamous couples through subtle nucleotide variation. *PLoS One* 2011; **6**(10): e26732.
267. Piot P, Van Dyck E, Peeters M, Hale J, Totten PA, Holmes KK. Biotypes of Gardnerella vaginalis. *J Clin Microbiol* 1984; **20**(4): 677-9.
268. Holst E. Reservoir of four organisms associated with bacterial vaginosis suggests lack of sexual transmission. *J Clin Microbiol* 1990; **28**(9): 2035-9.
269. Nelson DE, Dong Q, Van Der Pol B, et al. Bacterial communities of the coronal sulcus and distal urethra of adolescent males. *PLoS One* 2012; **7**(5): e36298.
270. Gray RH, Kigozi G, Serwadda D, et al. The effects of male circumcision on female partners' genital tract symptoms and vaginal infections in a randomized trial in Rakai, Uganda. *Am J Obstet Gynecol* 2009; **200**(1): 42 e1-7.
271. Swidsinski A, Dorffel Y, Loening-Baucke V, et al. Desquamated epithelial cells covered with a polymicrobial biofilm typical for bacterial vaginosis are present in randomly selected cryopreserved donor semen. *FEMS Immunol Med Microbiol* 2010; **59**(3): 399-404.
272. Swidsinski A, Loening-Baucke V, Mendling W, et al. Infection through structured polymicrobial Gardnerella biofilms (StPM-GB). *Histol Histopathol* 2014; **29**(5): 567-87.
273. Keane FE, Thomas BJ, Whitaker L, Renton A, Taylor-Robinson D. An association between non-gonococcal urethritis and bacterial vaginosis and the implications for patients and their sexual partners. *Genitourin Med* 1997; **73**(5): 373-7.

274. Bradshaw CS, Tabrizi SN, Read TRH, et al. Etiologies of non-gonococcal urethritis: bacteria, viruses and the association with oro-genital exposure. *J Infect Dis* 2006; **193**: 336-45.
275. Manhart LE, Khosropour CM, Liu C, et al. Bacterial vaginosis-associated bacteria in men: association of *Leptotrichia/Sneathia* spp. with nongonococcal urethritis. *Sex Transm Dis* 2013; **40**(12): 944-9.
276. Burdge DR, Bowie WR, Chow AW. Gardnerella vaginalis-associated balanoposthitis. *Sex Transm Dis* 1986; **13**(3): 159-62.
277. Swedberg J, Steiner JF, Deiss F, Steiner S, Driggers DA. Comparison of single-dose vs one-week course of metronidazole for symptomatic bacterial vaginosis. *JAMA* 1985; **254**(8): 1046-9.
278. Colli E, Landoni M, Parazzini F. Treatment of male partners and recurrence of bacterial vaginosis: a randomised trial. *Genitourin Med* 1997; **73**(4): 267-70.
279. Moi H. Prevalence of bacterial vaginosis and its association with genital infections, inflammation, and contraceptive methods in women attending sexually transmitted disease and primary health clinics. *Int J STD AIDS* 1990; **1**(2): 86-94.
280. Mengel MB, Berg AO, Weaver CH, et al. The effectiveness of single-dose metronidazole therapy for patients and their partners with bacterial vaginosis. *J Fam Pract* 1989; **28**(2): 163-71.
281. Vejtorp M, Bollerup AC, Vejtorp L, et al. Bacterial vaginosis: a double-blind randomized trial of the effect of treatment of the sexual partner. *Br J Obstet Gynaecol* 1988; **95**(9): 920-6.
282. Vutyavanich T, Pongsuthirak P, Vannareumol P, Ruangsri RA, Luangsook P. A randomized double-blind trial of tinidazole treatment of the sexual partners of females with bacterial vaginosis. *Obstet Gynecol* 1993; **82**(4 Pt 1): 550-4.
283. Kilic AO, Pavlova SI, Alpay S, Kilic SS, Tao L. Comparative study of vaginal Lactobacillus phages isolated from women in the United States and Turkey: prevalence, morphology, host range, and DNA homology. *Clin Diagn Lab Immunol* 2001; **8**(1): 31-9.
284. Pavlova SI, Kilic AO, Mou SM, Tao L. Phage infection in vaginal lactobacilli: an in vitro study. *Infect Dis Obstet Gynecol* 1997; **5**(1): 36-44.
285. Blackwell AL. Vaginal bacterial phaginosis? *Sex Transm Infect* 1999; **75**(5): 352-3.
286. Koumans EH, Markowitz LE, Hogan V. Indications for therapy and treatment recommendations for bacterial vaginosis in nonpregnant and pregnant women: a synthesis of data. *Clin Infect Dis* 2002; **35**(Suppl 2): S152-72.
287. Oduyebo OO, Anorlu RI, Ogunsola FT. The effects of antimicrobial therapy on bacterial vaginosis in non-pregnant women. *Cochrane Database Syst Rev* 2009; (3): CD006055.

288. Hanson JM, McGregor JA, Hillier SL, et al. Metronidazole for bacterial vaginosis. A comparison of vaginal gel vs. oral therapy. *J Reprod Med* 2000; **45**(11): 889-96.
289. Sobel JD, Schmitt C, Meriwether C. Long-term follow-up of patients with bacterial vaginosis treated with oral metronidazole and topical clindamycin. *J Infect Dis* 1993; **167**(3): 783-4.
290. Sobel JD. Vaginitis. *N Engl J Med* 1997; **337**(26): 1896-903.
291. Marrazzo JM, Thomas KK, Fiedler TL, Ringwood K, Fredricks DN. Relationship of specific vaginal bacteria and bacterial vaginosis treatment failure in women who have sex with women. *Ann Intern Med* 2008; **149**(1): 20-8.
292. Bradshaw CS, Brotman RM. Making inroads into improving treatment of bacterial vaginosis - striving for long-term cure. *BMC Infect Dis* 2015; **15**: 292.
293. Beigi RH, Austin MN, Meyn LA, Krohn MA, Hillier SL. Antimicrobial resistance associated with the treatment of bacterial vaginosis. *Am J Obstet Gynecol* 2004; **191**(4): 1124-9.
294. Austin MN, Beigi RH, Meyn LA, Hillier SL. Microbiologic response to treatment of bacterial vaginosis with topical clindamycin or metronidazole. *J Clin Microbiol* 2005; **43**(9): 4492-7.
295. McClelland RS, Balkus JE, Lee J, et al. Randomized Trial of Periodic Presumptive Treatment With High-Dose Intravaginal Metronidazole and Miconazole to Prevent Vaginal Infections in HIV-negative Women. *J Infect Dis* 2015; **211**(12): 1875-82.
296. Sobel JD, Ferris D, Schwebke J, et al. Suppressive antibacterial therapy with 0.75% metronidazole vaginal gel to prevent recurrent bacterial vaginosis. *Am J Obstet Gynecol* 2006; **194**(5): 1283-9.
297. Bradshaw CS, Sobel JD. Current Treatment of Bacterial Vaginosis: Limitations and need for Innovation. *J Infect Dis* 2016; **214**(Suppl 1): 14-20.
298. Muzny CA, Schwebke JR. Biofilms: An Underappreciated Mechanism of Treatment Failure and Recurrence in Vaginal Infections. *Clin Infect Dis* 2015; **61**(4): 601-6.
299. Swidsinski A, Dorffel Y, Loening-Baucke V, Schilling J, Mendling W. Response of *Gardnerella vaginalis* biofilm to 5 days of moxifloxacin treatment. *FEMS Immunol Med Microbiol* 2011; **61**(1): 41-6.
300. Swidsinski A, Mendling W, Loening-Baucke V, et al. An adherent *Gardnerella vaginalis* biofilm persists on the vaginal epithelium after standard therapy with oral metronidazole. *Am J Obstet Gynecol* 2008; **198**(1): 97 e1-6.
301. Reichman O, Akins R, Sobel JD. Boric acid addition to suppressive antimicrobial therapy for recurrent bacterial vaginosis. *Sex Transm Dis* 2009; **36**(11): 732-4.
302. Swidsinski A, Loening-Baucke V, Swidsinski S, Verstraelen H. Polymicrobial *Gardnerella* biofilm resists repeated intravaginal antiseptic treatment in a subset of women with bacterial vaginosis: a preliminary report. *Arch Gynecol Obstet* 2015; **291**(3): 605-9.

303. Hymes SR, Randis TM, Sun TY, Ratner AJ. DNase inhibits *Gardnerella vaginalis* biofilms in vitro and in vivo. *J Infect Dis* 2013; **207**(10): 1491-7.
304. Turovskiy Y, Cheryian T, Algburi A, et al. Susceptibility of *Gardnerella vaginalis* biofilms to natural antimicrobials subtilosin, epsilon-poly-L-lysine, and lauramide arginine ethyl ester. *Infect Dis Obstet Gynecol* 2012; **2012**:284762.: 284762.
305. Eade CR, Cole AL, Diaz C, et al. The anti-HIV microbicide candidate RC-101 inhibits pathogenic vaginal bacteria without harming endogenous flora or mucosa. *Am J Reprod Immunol* 2013; **69**(2): 150-8.
306. Hooven TA, Randis TM, Hymes SR, Rampersaud R, Ratner AJ. Retrocyclin inhibits *Gardnerella vaginalis* biofilm formation and toxin activity. *J Antimicrob Chemother* 2012; **67**(12): 2870-2.
307. Gottschick C, Szafranski SP, Kunze B, et al. Screening of Compounds against *Gardnerella vaginalis* Biofilms. *PLoS One* 2016; **11**(4): e0154086.
308. Brackman G, Coenye T. Quorum sensing inhibitors as anti-biofilm agents. *Curr Pharm Des* 2015; **21**(1): 5-11.
309. Deng Y, Lim A, Lee J, et al. Diffusible signal factor (DSF) quorum sensing signal and structurally related molecules enhance the antimicrobial efficacy of antibiotics against some bacterial pathogens. *BMC Microbiol* 2014; **14**: 51.
310. Senok AC, Verstraelen H, Temmerman M, Botta GA. Probiotics for the treatment of bacterial vaginosis. *Cochrane Database Syst Rev* 2009; (4): CD006289.
311. Hemmerling A, Harrison W, Schroeder A, et al. Phase 1 dose-ranging safety trial of *Lactobacillus crispatus* CTV-05 for the prevention of bacterial vaginosis. *Sex Transm Dis* 2009; **36**(9): 564-9.
312. Hemmerling A, Harrison W, Schroeder A, et al. Phase 2a study assessing colonization efficiency, safety, and acceptability of *Lactobacillus crispatus* CTV-05 in women with bacterial vaginosis. *Sex Transm Dis* 2010; **37**(12): 745-50.
313. Ngugi BM, Hemmerling A, Bukusi EA, et al. Effects of bacterial vaginosis-associated bacteria and sexual intercourse on vaginal colonization with the probiotic *Lactobacillus crispatus* CTV-05. *Sex Transm Dis* 2011; **38**(11): 1020-7.
314. Stapleton AE, Au-Yeung M, Hooton TM, et al. Randomized, placebo-controlled phase 2 trial of a *Lactobacillus crispatus* probiotic given intravaginally for prevention of recurrent urinary tract infection. *Clin Infect Dis* 2011; **52**(10): 1212-7.
315. Verstraelen H, Verhelst R, Roelens K, Temmerman M. Antiseptics and disinfectants for the treatment of bacterial vaginosis: a systematic review. *BMC Infect Dis* 2012; **12**: 148.
316. Wetmore CM, Manhart LE, Wasserheit JN. Randomized controlled trials of interventions to prevent sexually transmitted infections: Learning from the past to plan for the future. *Epidemiologic Reviews* 2010; **32**: 121-36.

317. Global Health Sector on Sexually Transmitted Infections, 2016-2021 - Towards Ending STIs. June 2016. World Health Organization . Geneva Switzerland.
318. Joseph Davey DL, Shull HI, Billings JD, Wang D, Adachi K, Klausner JD. Prevalence of Curable Sexually Transmitted Infections in Pregnant Women in Low- and Middle-Income Countries From 2010 to 2015: A Systematic Review. *Sex Transm Dis* 2016; **43**(7): 450-8.
319. Wijesooriya NS, Rochat RW, Kamb ML, et al. Global burden of maternal and congenital syphilis in 2008 and 2012: a health systems modelling study. *The Lancet Global Health* 2016; **4**: e525-e33.
320. UNAIDS. On the Fast-Track To an Aids Free Generation. 2016; Geneva; 2016.
321. Peeling RW, Mabey D, Fitzgerald DW, Watson-Jones D. Avoiding HIV and dying of syphilis. *Lancet* 2004; **364**: 1561-3.
322. Peeling RW, Mabey D. Celebrating the decline in syphilis in pregnancy: a sobering reminder of what's left to do. *The Lancet Global Health* 2016; **4**(8): e503-e4.
323. Hawkes S, Mabey D, Mayaud P. Partner notification for the control of sexually transmitted infections. *BMJ* 2003; **327**(7416): 633-4.
324. Steen R, Chersich M, Gerbase A, et al. Periodic presumptive treatment of curable sexually transmitted infections among sex workers: a systematic review. *AIDS* 2012; **26**(4): 437-45.
325. Murtagh MM. The Point-of-Care Diagnostic Landscape for Sexually Transmitted Infections (STIs).
http://www.who.int/reproductivehealth/topics/rtis/Diagnostic_Landscape_2016.pdf, 2016.
326. Lush L, Walt G, Ogden J. Transferring policies for treating sexually transmitted infections: What's wrong with global guidelines? *Health Policy and Planning* 2003; **18**: 18-30.
327. Farley TA, Cohen DA, Elkins W. Asymptomatic sexually transmitted diseases: The case for screening. *Preventive Medicine* 2003; **36**: 502-9.
328. Vickerman P, Watts C, Peeling RW, Mabey D, Alary M. Modelling the cost effectiveness of rapid point of care diagnostic tests for the control of HIV and other sexually transmitted infections among female sex workers. *Sex Transm Infect* 2006; **82**: 403-12.
329. San Francisco Sexually Transmitted Disease Annual Summary, 2014. San Francisco, California: San Francisco Department of Public Health, 2015.
330. Das A, Pathni AK, Narayanan P, et al. High rates of reinfection and incidence of bacterial sexually transmitted infections in a cohort of female sex workers from two Indian cities: need for different STI control strategies? *Sex Transm Infect* 2013; **89**: 5-10.
331. Mlisana K, Naicker N, Werner L, et al. Symptomatic vaginal discharge is a poor predictor of sexually transmitted infections and genital tract inflammation in high-risk women in South Africa. *J Infect Dis* 2012; **206**: 6-14.

332. Mayaud P, Ka-Gina G, Cornelissen J, et al. Validation of a WHO algorithm with risk assessment for the clinical management of vaginal discharge in Mwanza, Tanzania. *Sex Transm Infect* 1998; **74 Suppl 1**: S77-84.
333. Iqbal SM, Kaul R. Mucosal innate immunity as a determinant of HIV susceptibility. *Am J Reprod Immunol* 2008; **59**: 44-54.
334. Peeling RW, Mabey D, Herring A, Hook EW. Why do we need quality-assured diagnostic tests for sexually transmitted infections? *Nat Rev Microbiol* 2006; **4**(12 Suppl): 7-9.
335. Mayaud P, Mabey D. Approaches to the control of sexually transmitted infections in developing countries: old problems and modern challenges. *Sex Transm Infect* 2004; **80**: 174-82.
336. Alam N, Chamot E, Vermund SH, Streatfield K, Kristensen S. Partner notification for sexually transmitted infections in developing countries: a systematic review. *BMC public health* 2010; **10**: 19.
337. World Health Organization. Periodic Presumptive treatment for sexually transmitted infections: Experience from the field and recommendations for research. Geneva, 2008.
338. Steen R, Chersich M, de Vlas SJ. Periodic presumptive treatment of curable sexually transmitted infections among sex workers: recent experience with implementation. *Current Opin Infect Dis* 2012; **25**: 100-6.
339. Vickerman P, Ndowa F, O'Farrell N, Steen R, Alary M, Delany-Moretlwe S. Using mathematical modelling to estimate the impact of periodic presumptive treatment on the transmission of sexually transmitted infections and HIV among female sex workers. *Sex Transm Infect* 2010; **86**: 163-8.
340. Watson-Jones D, Gumodoka B, Weiss HA, et al. Syphilis in pregnancy in Tanzania. II. The effectiveness of antenatal syphilis screening and single-dose benzathine penicillin treatment for the prevention of adverse pregnancy outcomes. *J Infect Dis* 2002; **186**: 948-57.
341. Swartzendruber A, Steiner RJ, Adler MR, Kamb ML, Newman LM. Introduction of rapid syphilis testing in antenatal care: A systematic review of the impact on HIV and syphilis testing uptake and coverage. *Int J Gynaecol Obstet* 2015; **130**: S15-S21.
342. Medline A, Joseph Davey D, Klausner JD. Lost opportunity to save newborn lives: variable national antenatal screening policies for *Neisseria gonorrhoeae* and *Chlamydia trachomatis*. *Int J STD AIDS* 2016; pii: **095646241666048**.
343. Steen R, Dallabetta G. Control Infection with Sex Workers : Transmitted Sexually Treatment and Presumptive Augment Screening Regular Risk and Vulnerability Efforts to Reduce. *Reprod Health matters* 2003; **11**: 74-90.
344. Chersich MF, Luchters S, Ntaganira I, et al. Priority interventions to reduce HIV transmission in sex work settings in sub-Saharan Africa and delivery of these services. *J Int AIDS Soc* 2013; **16**: 17980.

345. Watson-Jones D, Oliff M, Terris-Prestholt F, et al. Antenatal syphilis screening in sub-Saharan Africa: Lessons learned from Tanzania. *Tropical Medicine and International Health* 2005; **10**: 934-43.
346. West B, Walraven G, Morison L, Brouwers J, Bailey R. Performance of the rapid plasma reagin and the rapid syphilis screening tests in the diagnosis of syphilis in field conditions in rural Africa. *Sex Transm Infect* 2002; **78**: 282-5.
347. Patel A, Moodley D, Moodley J. An evaluation of on-site testing for syphilis. *Tropical doctor* 2001; **31**: 79-82.
348. Jenniskens F, Obwaka E, Kirisuah S, et al. Syphilis control in pregnancy: decentralization of screening facilities to primary care level, a demonstration project in Nairobi, Kenya. *Int J Gynaecol Obstet* 1995; **48 Suppl**: S121-8.
349. Fonn S. A blood-result turn-around time survey to improve congenital syphilis prevention in a rural area. *South African medical journal = Suid-Afrikaanse tydskrif vir geneeskunde* 1996; **86**: 67-71.
350. Mabey D, Peeling RW, Ballard R, et al. Prospective, multi-centre clinic-based evaluation of four rapid diagnostic tests for syphilis. *Sex Transm Infect* 2006; **82 Suppl 5**: v13-6.
351. Tucker JD, Bien CH, Peeling RW. Point-of-care testing for sexually transmitted infections: recent advances and implications for disease control. *Curr Opin Infect Dis* 2013; **26**: 73-9.
352. Gaydos C, Hardick J. Point of care diagnostics for sexually transmitted infections: perspectives and advances. *Expert Rev Anti-Infect Ther* 2014; **12**: 657-72.
353. Herbst de Cortina S, Bristow CC, Joseph Davey D, Klausner JD. A Systematic Review of Point of Care Testing for Chlamydia trachomatis, Neisseria gonorrhoeae, and Trichomonas vaginalis. *Infect Dis Obstetr Gynecol* 2016; **2016**: 4386127.
354. Ham JY, Jung J, Hwang BG, et al. Highly sensitive and novel point-of-care system, aQcare Chlamydia TRF kit for detecting Chlamydia trachomatis by using europium (Eu) (III) chelated nanoparticles. *Annals of Lab Med* 2015; **35**: 50-6.
355. Samarawickrama A, Cheserem E, Graver M, Wade J, Alexander S, Ison C. Pilot study of use of the BioStar Optical ImmunoAssay GC point-of-care test for diagnosing gonorrhoea in men attending a genitourinary medicine clinic. *J Med Microbiol* 2014; **63**: 1111-2.
356. Vickerman P, Watts C, Alary M, Mabey D, Peeling RW. Sensitivity requirements for the point of care diagnosis of Chlamydia trachomatis and Neisseria gonorrhoeae in women. *Sex Transm Infect* 2003; **79**: 363-7.
357. Smit PW, Mabey D, Vlis TVD, et al. The implementation of an external quality assurance method for point- of- care tests for HIV and syphilis in Tanzania. *BMC Infect Dis* 2013; **13**: 1.

358. Gift TL, Pate MS, Hook EW, Kassler WJ. The rapid test paradox: when fewer cases detected lead to more cases treated: a decision analysis of tests for Chlamydia trachomatis. *Sex Transm Dis* 1999; **26**(4): 232-40.
359. Badman SG, Causer LM, Guy R, et al. A preliminary evaluation of a new GeneXpert (Gx) molecular point-of-care test for the detection of *Trichomonas vaginalis*: Table 1. *Sex Transm Infect* 2016; **92**: 350-2.
360. Pearce DM, Styles DN, Hardick JP, Gaydos CA. A new rapid molecular point-of-care assay for *Trichomonas vaginalis*: preliminary performance data. *Sex Transm Infect* 2013; **89**: 495-7.
361. Jafari Y, Peeling RW, Shivkumar S, Claessens C, Joseph L, Pai NP. Are Treponema pallidum Specific Rapid and Point-of-Care Tests for Syphilis Accurate Enough for Screening in Resource Limited Settings? Evidence from a Meta-Analysis. *PLoS ONE* 2013; **8**: 1-8.
362. Mabey DC, Sollis KA, Kelly HA, et al. Point-of-care tests to strengthen health systems and save newborn lives: The case of syphilis. *PLoS Medicine* 2012; **9**: 8.
363. Terris-Prestholt F, Vickerman P, Torres-Rueda S, et al. The cost-effectiveness of 10 antenatal syphilis screening and treatment approaches in Peru, Tanzania, and Zambia. *Int J Gynaecol Obstet* 2015; **130**: S73-S80.
364. Mitchell KM, Cox AP, Mabey D, Tucker JD, Peeling RW, Vickerman P. The Impact of Syphilis Screening among Female Sex Workers in China: A Modelling Study. *PLoS ONE* 2013; **8**.
365. Marks M, Yin YP, Chen XS, et al. Meta-analysis of the performance of a combined treponemal and non-treponemal rapid diagnostic test for syphilis and yaws. *Clin Infect Dis* 2016; **63**: 627-33.
366. World Health Organization. WHO Information Note on the Use of Dual HIV / Syphilis Rapid Diagnostic Tests (RDT). Geneva: WHO, 2017.
367. García PJ, Cárcamo CP, Chiappe M, et al. Rapid Syphilis Tests as Catalysts for Health Systems Strengthening: A Case Study from Peru. *PLoS ONE* 2013; **8**: e66905.
368. Sabapathy K, Van den Bergh R, Fidler S, Hayes R, Ford N. Uptake of home-based voluntary HIV testing in sub-Saharan Africa: a systematic review and meta-analysis. *PLoS Med* 2012; **9**: e1001351.
369. Fonjungo PN, Boeras DI, Zeh C, Alexander H, Parekh BS, Nkengasong JN. Access and quality of HIV-related point-of-care diagnostic testing in global health programs. *Clin Infect Dis* 2016; **62**: 369-74.
370. Brown G, Leonard W, Lyons A, et al. Stigma, gay men and biomedical prevention: the challenges and opportunities of a rapidly changing HIV prevention landscape. *Sex Health* 2016; **10.1071/SH16052**.
371. Feldman DA, Johnson TM. Introduction. In: Feldman DA, Johnson TM, eds. *The Social Dimensions of AIDS Method and Theory*. New York: Praeger Publishers; 1986.

372. Kingsley LA, Rinaldo CR, Jr., Lyter DW, Valdiserri RO, Belle SH, Ho M. Sexual transmission efficiency of hepatitis B virus and human immunodeficiency virus among homosexual men. *JAMA* 1990; **264**(2): 230-4.
373. Public Health England. Syphilis and Lymphogranuloma Venereum: Resurgent Sexually Transmitted Infections in the UK: 2009 report.: Health Protection Agency, 2013.
374. Quinn TC. Gay bowel syndrome. The broadened spectrum of nongenital infection. *Postgrad Med* 1984; **76**(2): 197-8, 201-10.
375. Hymes KB, Cheung T, Greene JB, et al. Kaposi's sarcoma in homosexual men-a report of eight cases. *Lancet* 1981; **2**(8247): 598-600.
376. Judson FN. Fear of AIDS and gonorrhea rates in homosexual men. *Lancet* 1983; **2**(8342): 159-60.
377. Rietmeijer CA, Patnaik JL, Judson FN, Douglas JM, Jr. Increases in gonorrhea and sexual risk behaviors among men who have sex with men: a 12-year trend analysis at the Denver Metro Health Clinic. *Sex Transm Dis* 2003; **30**(7): 562-7.
378. Fennema JS, Cairo I, Coutinho RA. [Substantial increase in gonorrhea and syphilis among clients of Amsterdam Sexually Transmitted Diseases Clinic]. *Ned Tijdschr Geneeskd* 2000; **144**(13): 602-3.
379. Malek R, Mitchell H, Furegato M, et al. Contribution of transmission in HIV-positive men who have sex with men to evolving epidemics of sexually transmitted infections in England: an analysis using multiple data sources, 2009-2013. *Euro Surveill* 2015; **20**(15).
380. Klausner JD, Kent CK, Wong W, McCright J, Katz MH. The public health response to epidemic syphilis, San Francisco, 1999-2004. *Sex Transm Dis* 2005; **32**(10 Suppl): S11-8.
381. Read P, Fairley CK, Chow EP. Increasing trends of syphilis among men who have sex with men in high income countries. *Sex Health* 2015; **12**(2): 155-63.
382. HIV-Causal Collaboration, Ray M, Logan R, et al. The effect of combined antiretroviral therapy on the overall mortality of HIV-infected individuals. *AIDS* 2010; **24**(1): 123-37.
383. Severe P, Juste MA, Ambroise A, et al. Early versus standard antiretroviral therapy for HIV-infected adults in Haiti. *N Engl J Med* 2010; **363**(3): 257-65.
384. Cardo DM, Culver DH, Ciesielski CA, et al. A case-control study of HIV seroconversion in health care workers after percutaneous exposure. Centers for Disease Control and Prevention Needlestick Surveillance Group. *N Engl J Med* 1997; **337**(21): 1485-90.
385. Quinn TC, Wawer MJ, Sewankambo N, et al. Viral load and heterosexual transmission of human immunodeficiency virus type 1. Rakai Project Study Group. *N Engl J Med* 2000; **342**(13): 921-9.

386. Attia S, Egger M, Muller M, Zwahlen M, Low N. Sexual transmission of HIV according to viral load and antiretroviral therapy: systematic review and meta-analysis. *AIDS* 2009; **23**(11): 1397-404.
387. Cohen MS. HIV Treatment as Prevention and “The Swiss Statement”: In for a Dime, in for a Dollar? *Clin Infect Dis* 2010; **51**(11): 1323-4.
388. Cohen MS, Smith MK, Muessig KE, Hallett TB, Powers KA, Kashuba AD. Antiretroviral treatment of HIV-1 prevents transmission of HIV-1: where do we go from here? *Lancet* 2013; **382**(9903): 1515-24.
389. Grant RM, Lama JR, Anderson PL, et al. Preexposure chemoprophylaxis for HIV prevention in men who have sex with men. *N Engl J Med* 2010; **363**(27): 2587-99.
390. McCormack S, Dunn DT, Desai M, et al. Pre-exposure prophylaxis to prevent the acquisition of HIV-1 infection (PROUD): effectiveness results from the pilot phase of a pragmatic open-label randomised trial. *Lancet* 2016; **387**(10013): 53-60.
391. Molina JM, Capitant C, Spire B, et al. On-Demand Preexposure Prophylaxis in Men at High Risk for HIV-1 Infection. *N Engl J Med* 2015; **373**(23): 2237-46.
392. Blumenthal J, Haubrich RH. Will risk compensation accompany pre-exposure prophylaxis for HIV? *Virtual Mentor* 2014; **16**(11): 909-15.
393. Richens J, Imrie J, Copas A. Condoms and seat belts: the parallels and the lessons. *Lancet* 2000; **355**(9201): 400-3.
394. Chen YH, Snowden JM, McFarland W, Raymond HF. Pre-exposure Prophylaxis (PrEP) Use, Seroadaptation, and Sexual Behavior Among Men Who Have Sex with Men, San Francisco, 2004-2014. *AIDS Behav* 2016; **20**(12): 2791-7.
395. Paz-Bailey G, Mendoza MC, Finlayson T, et al. Trends in condom use among MSM in the United States: the role of antiretroviral therapy and seroadaptive strategies. *AIDS* 2016; **30**(12): 1985-90.
396. Stolte IG, Dukers NH, Geskus RB, Coutinho RA, de Wit JB. Homosexual men change to risky sex when perceiving less threat of HIV/AIDS since availability of highly active antiretroviral therapy: a longitudinal study. *AIDS* 2004; **18**(2): 303-9.
397. Crepaz N, Hart TA, Marks G. Highly active antiretroviral therapy and sexual risk behavior: a meta-analytic review. *JAMA* 2004; **292**(2): 224-36.
398. Stolte IG, de Wit JB, Kolader M, Fennema H, Coutinho RA, Dukers NH. Association between 'safer sex fatigue' and rectal gonorrhoea is mediated by unsafe sex with casual partners among HIV-positive homosexual men. *Sex Transm Dis* 2006; **33**(4): 201-8.
399. Mayer KH, Mimiaga MJ. Past as Prologue: The Refractory and Evolving HIV Epidemic Among Men Who Have Sex With Men. *Clin Infect Dis* 2011; **52**(11): 1371-3.
400. Marcus U, Schmidt AJ, Hamouda O. HIV serosorting among HIV-positive men who have sex with men is associated with increased self-reported incidence of bacterial sexually transmissible infections. *Sexual Health* 2011; **8**(2): 184-93.

401. World Health Organization. Guidelines on Post-Exposure Prophylaxis for HIV and the Use of Co-Trimoxazole Prophylaxis for HIV-Related Infections Among Adults, Adolescents and Children: Recommendations for a Public Health Approach: December 2014. Supplement to the 2013 consolidated guidelines on the use of antiretroviral drugs for treating and preventing HIV infection. Geneva; 2014.
402. Cresswell F, Waters L, Briggs E, et al. UK guideline for the use of HIV Post-Exposure Prophylaxis Following Sexual Exposure, 2015. *Int J STD AIDS* 2016; **27**(9): 713-38.
403. Lert F. Advances in HIV treatment and prevention: should treatment optimism lead to prevention pessimism? *AIDS Care* 2000; **12**(6): 745-55.
404. Poynten IM, Jin F, Mao L, et al. Nonoccupational postexposure prophylaxis, subsequent risk behaviour and HIV incidence in a cohort of Australian homosexual men. *AIDS* 2009; **23**(9): 1119-26.
405. Heuker J, Sonder GJ, Stolte I, Geskus R, van den Hoek A. High HIV incidence among MSM prescribed postexposure prophylaxis, 2000-2009: indications for ongoing sexual risk behaviour. *AIDS* 2012; **26**(4): 505-12.
406. Sonder GJ, van den Hoek A, Regez RM, et al. Trends in HIV postexposure prophylaxis prescription and compliance after sexual exposure in Amsterdam, 2000-2004. *Sex Transm Dis* 2007; **34**(5): 288-93.
407. Vernazza P, Hirschel B, Bernasconi E, Flepp M. HIV- infizierte Menschen ohne andere STD sind unter wirksamer antiretroviraler Therapie sexuell nicht infektiös. *Schweizerische Ärztezeitung* 2008; **89**(5): 165-9.
408. Granich RM, Gilks CF, Dye C, de Cock KM, Williams BG. Universal voluntary HIV testing with immediate antiretroviral therapy as a strategy for elimination of HIV transmission: a mathematical model. *Lancet* 2009; **373**(9657): 48-57.
409. Cohen MS, Chen YQ, McCauley M, et al. Prevention of HIV-1 infection with early antiretroviral therapy. *N Engl J Med* 2011; **365**(6): 493-505.
410. Bacaer N, Pretorius C, Auvert B. An age-structured model for the potential impact of generalized access to antiretrovirals on the South African HIV epidemic. *Bull Math Biol* 2010; **72**(8): 2180-98.
411. Iwuji C, Orne-Gliemann J, Balestre E, et al. The impact of universal test and treat on HIV incidence in a rural South African population: ANRS 12249 TasP trial, 2012-2016 AIDS 2016; 2016; Durban, South Africa [<http://programme.aids2016.org/Abstract/Abstract/10537>]; 2016.
412. Iwuji CC, Orne-Gliemann J, Larmarange J, et al. Uptake of Home-Based HIV Testing, Linkage to Care, and Community Attitudes about ART in Rural KwaZulu-Natal, South Africa: Descriptive Results from the First Phase of the ANRS 12249 TasP Cluster-Randomised Trial. *PLoS Med* 2016; **13**(8): e1002107.
413. Tanser F, Barnighausen T, Grapsa E, Zaidi J, Newell ML. High coverage of ART associated with decline in risk of HIV acquisition in rural KwaZulu-Natal, South Africa. *Science* 2013; **339**(6122): 966-71.

414. Schwarcz S, Hsu LC, Scheer S. Disparities and Trends in Viral Suppression During a Transition to a "Test and Treat" Approach to the HIV Epidemic, San Francisco, 2008-2012. *J Acquir Immune Defic Syndr* 2015; **70**(5): 529-37.
415. San Francisco Sexually Transmitted Disease Annual Summary, 2005. San Francisco, California: San Francisco Department of Public Health, 2006.
416. San Francisco Sexually Transmitted Disease Annual Summary, 2009: San Francisco, California, 2010.
417. San Francisco Sexually Transmitted Disease Annual Summary, 2010. San Francisco, California: San Francisco Department of Public Health, 2011.
418. STDs among Men who Have Sex with Men (MSM) San Francisco 2007—2013. San Francisco, 2014.
419. Kouyos RD, Hasse B, Calmy A, et al. Increases in Condomless Sex in the Swiss HIV Cohort Study. *Open Forum Infect Dis* 2015; **2**(2): ofv077.
420. Sugarman J. Bioethical challenges with HIV treatment as prevention. *Clin Infect Dis* 2014; **59** Suppl 1: S32-4.
421. Fonner VA, Dalglish SL, Kennedy CE, et al. Effectiveness and safety of oral HIV pre-exposure prophylaxis (PrEP) for all populations: A systematic review and meta-analysis. *AIDS* 2016; **30**(12): 1973-83.
422. Grant RM, Anderson PL, McMahan V, et al. Uptake of pre-exposure prophylaxis, sexual practices, and HIV incidence in men and transgender women who have sex with men: a cohort study. *Lancet Infect Dis* 2014; **14**(9): 820-9.
423. Liu AY, Cohen SE, Vittinghoff E, et al. Preexposure Prophylaxis for HIV Infection Integrated With Municipal- and Community-Based Sexual Health Services. *JAMA Intern Med* 2016; **176**(1): 75-84.
424. Volk JE, Marcus JL, Phengrasamy T, et al. No New HIV Infections With Increasing Use of HIV Preexposure Prophylaxis in a Clinical Practice Setting. *Clin Infect Dis* 2015; **61**(10): 1601-3.
425. Centers for Disease Control and Prevention. Update to Interim Guidance for Preexposure Prophylaxis (PrEP) for the Prevention of HIV Infection: PrEP for injecting drug users. *MMWR Morb Mortal Wkly Rep* 2013; **62**(23): 463-5.
426. Carlo Hojilla J, Koester KA, Cohen SE, et al. Sexual Behavior, Risk Compensation, and HIV Prevention Strategies Among Participants in the San Francisco PrEP Demonstration Project: A Qualitative Analysis of Counseling Notes. *AIDS Behav* 2016; **20**(7): 1461-9.
427. Newcomb ME, Mongrella MC, Weis B, McMillen SJ, Mustanski B. Partner Disclosure of PrEP Use and Undetectable Viral Load on Geosocial Networking Apps: Frequency of Disclosure and Decisions About Condomless Sex. *J Acquir Immune Defic Syndr* 2016; **71**(2): 200-6.

428. Wilson C. Massive drop in London HIV rates may be due to internet drugs. 09.01.2017 2017. <https://www.newscientist.com/article/2117426-massive-drop-in-london-hiv-rates-may-be-due-to-internet-drugs/>
429. Phillips G, Grov C, Mustanski B. Engagement in group sex among geosocial networking mobile application-using men who have sex with men. *Sexual Health* 2015; **12**(6): 495-500.
430. Kurth AE, Celum C, Baeten JM, Vermund SH, Wasserheit JN. Combination HIV prevention: significance, challenges, and opportunities. *Curr HIV/AIDS Rep* 2011; **8**(1): 62-72.
431. Xiridou M, Vriend HJ, Lugner AK, et al. Modelling the impact of chlamydia screening on the transmission of HIV among men who have sex with men. *BMC Infect Dis* 2013; **13**: 436.
432. Xiridou M, Soetens LC, Koedijk FD, MA VDS, Wallinga J. Public health measures to control the spread of antimicrobial resistance in *Neisseria gonorrhoeae* in men who have sex with men. *Epidemiol Infect* 2014: 1-10.
433. Fingerhuth SM, Bonhoeffer S, Low N, Althaus CL. Antibiotic-Resistant *Neisseria gonorrhoeae* Spread Faster with More Treatment, Not More Sexual Partners. *PLoS Pathog* 2016; **12**(5): e1005611.
434. Chow EPF, Callander D, Fairley CK, et al. Increased syphilis testing of men who have sex with men: greater detection of asymptomatic early syphilis and relative reduction in secondary syphilis. *Clin Infect Dis* 2017 - Inpress.
435. Gray RT, Hoare A, Prestage GP, Donovan B, Kaldor JM, Wilson DP. Frequent testing of highly sexually active gay men is required to control syphilis. *Sex Transm Dis* 2010; **37**(5): 298-305.
436. Bolan RK, Beymer MR, Weiss RE, Flynn RP, Leibowitz AA, Klausner JD. Doxycycline prophylaxis to reduce incident syphilis among HIV-infected men who have sex with men who continue to engage in high-risk sex: a randomized, controlled pilot study. *Sex Transm Dis* 2015; **42**(2): 98-103.
437. Golden MR, Handsfield HH. Preexposure prophylaxis to prevent bacterial sexually transmitted infections in men who have sex with men. *Sex Transm Dis* 2015; **42**(2): 104-6.
438. Fairley CK, Hocking JS, Zhang L, Chow EPF. Transmission of gonorrhoea in men who have sex with men; why it is common. *Emerg Infect Dis* 2016; **23**(1): 102-4.
439. Chow EPF, Howden BP, Walker S, et al. Antiseptic mouthwash against pharyngeal *Neisseria gonorrhoeae*: a randomised controlled trial and an in-vitro study. *Sex Trans Infect* 2016 - Inpress.
440. Noori T, Pharris A. Meeting report: Pre-exposure Human Immunodeficiency Virus Prophylaxis in the EU/EEA: Challenges and Opportunities, Stockholm April 2016. *Euro Surveill* 2016; **21**(25).

441. Deckard DT, Chung WM, Brooks JT, et al. Male-to-Male Sexual Transmission of Zika Virus - Texas, January 2016. *MMWR Morb Mortal Wkly Rep* 2016; **65**(14): 372-4.
442. White PJ, Ward H, Cassell JA, Mercer CH, Garnett GP. Vicious and virtuous circles in the dynamics of infectious disease and the provision of health care: gonorrhoea in Britain as an example. *J Infect Dis* 2005; **192**(5): 824-36.
443. Johnson AM, Mercer CH, Cassell JA. Social determinants, sexual behaviour, and sexual health. In: Marmot M, Wilkinson R, eds. *Social Determinants of Health*. Oxford; 2005: 318-40.
444. Hawkes S, Zaheer HA, Tawil O, O'Dwyer M, Buse K. Managing research evidence to inform action: influencing HIV policy to protect marginalised populations in Pakistan. *Glob Public Health* 2012; **7**(5): 482-94.
445. Fairley CK, Chow EP, Hocking JS. Early presentation of symptomatic individuals is critical in controlling sexually transmissible infections. *Sex Health* 2015; **12**(3): 181-2.
446. Kamb ML, Fishbein M, Douglas JM, Jr., et al. Efficacy of risk-reduction counseling to prevent human immunodeficiency virus and sexually transmitted diseases: a randomized controlled trial. Project RESPECT Study Group. *JAMA* 1998; **280**(13): 1161-7.
447. The EXPLORE Study Team*. Effects of a behavioural intervention to reduce acquisition of HIV infection among men who have sex with men: the EXPLORE randomised controlled study. *Lancet* 2004; **364**(9428): 51-40.
448. Fairley CK, Hocking JS. Sexual health in indigenous communities. *MJA* 2012; **197**(11): 597-8.
449. Miller WC, Ford CA, Morris M, et al. Prevalence of Chlamydial and Gonococcal Infections Among Young Adults in the United States. *JAMA* 2004; **291**(18): 2229-36.
450. Wang SA, Papp JR, Stamm WE, Peeling RW, Martin DH, Holmes KK. Evaluation of antimicrobial resistance and treatment failures for *Chlamydia trachomatis*: A meeting report. *J Infect Dis* 2005; **191**(6): 917-23.
451. Barbee LA, Dombrowski JC, Kerani R, Golden MR. Effect of nucleic acid amplification testing on detection of extragenital gonorrhoea and chlamydial infections in men who have sex with men sexually transmitted disease clinic patients. *Sex Transm Dis* 2014; **41**(3): 168-72.
452. Hui B, Fairley CK, Chen M, et al. Oral and anal sex are key to sustaining gonorrhoea at endemic levels in MSM populations: a mathematical model. *Sex Transm Infect* 2015; **91**(5): 365-9.
453. Zhang L, Regan D, Chow C, et al. Transmission of *Neisseria Gonorrhoea* among men who have sex with men: an anatomical site-specific mathematical model and impact of mouthwash. In: Richardson D, editor. *British Association for Sexual Health and HIV (BASSH) Conference*. Oxford, United Kingdom: Sexually Transmitted Infections; 2016. p. A41.

454. Chow EP, Cornelisse VJ, Read TR, et al. Saliva use as a lubricant for anal sex is a risk factor for rectal gonorrhoea among men who have sex with men, a new public health message: a cross-sectional survey. *Sex Transm Infect* 2016 - Ahead of Print.
455. Chow EP, Machalek DA, Tabrizi SN, et al. Quadrivalent vaccine-targeted human papillomavirus genotypes in heterosexual men after the Australian female human papillomavirus vaccination programme: a retrospective observational study. *Lancet Infect Dis* 2016 - Online First.
456. Hogben M, Collins D, Hoots B, O'Connor K. Partner Services in Sexually Transmitted Disease Prevention Programs: A Review. *Sex Transm Dis* 2016; **43**(2 Suppl 1): S53-62.
457. Golparian D, Shafer WM, Ohnishi M, Unemo M. Importance of multidrug efflux pumps in the antimicrobial resistance property of clinical multidrug-resistant isolates of *Neisseria gonorrhoeae*. *Antimicrob Agents Chemother* 2014; **58**(6): 3556-9.
458. Taneja N, Kaur H. Insights into Newer Antimicrobial Agents Against Gram-negative Bacteria. *Microbiol Insights* 2016; **9**: 9-19.
459. Demczuk W, Lynch T, Martin I, et al. Whole-genome phylogenomic heterogeneity of *Neisseria gonorrhoeae* isolates with decreased cephalosporin susceptibility collected in Canada between 1989 and 2013. *J Clin Microbiol* 2015; **53**(1): 191-200.
460. Demczuk W, Martin I, Peterson S, et al. Genomic Epidemiology and Molecular Resistance Mechanisms of Azithromycin-Resistant *Neisseria gonorrhoeae* in Canada from 1997 to 2014. *J Clin Microbiol* 2016; **54**(5): 1304-13.
461. Grad YH, Kirkcaldy RD, Trees D, et al. Genomic epidemiology of *Neisseria gonorrhoeae* with reduced susceptibility to cefixime in the USA: a retrospective observational study. *Lancet Infect Dis* 2014; **14**(3): 220-6.
462. Graham RM, Doyle CJ, Jennison AV. Epidemiological typing of *Neisseria gonorrhoeae* and detection of markers associated with antimicrobial resistance directly from urine samples using next generation sequencing. *Sex Transm Infect* 2016; **93**(1): 65-7.
463. Jacobsson S, Golparian D, Cole M, et al. WGS analysis and molecular resistance mechanisms of azithromycin-resistant (MIC >2 mg/L) *Neisseria gonorrhoeae* isolates in Europe from 2009 to 2014. *J Antimicrob Chemother* 2016; **71**(11): 3109-16.
464. Unemo M, Golparian D, Sanchez-Buso L, et al. The novel 2016 WHO *Neisseria gonorrhoeae* reference strains for global quality assurance of laboratory investigations: phenotypic, genetic and reference genome characterization. *J Antimicrob Chemother* 2016; **71**(11): 3096-108.