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SEXUAL HEALTH

Why risk matters for STI control: who are those at greatest risk and how are they identified?

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ABSTRACT

Identifying groups most at risk of sexually transmissible infections (STIs) is important for prioritising screening, targeting prevention strategies and alleviating the burden of STIs. However, identifying those at risk of STIs is complicated by stigma associated with STIs, undisclosed risk behaviour, and the fact that STI epidemics are diversifying beyond traditional risk groups typically characterised by demographics and sexual behaviours alone. In this review, we describe the epidemiology of STIs among traditional and emerging risk groups, particularly in the context of uptake of HIV pre-exposure prophylaxis (PrEP), increasing STI transmission among heterosexual people, and the concentration of STI burden among specific subgroups not readily identifiable by health services. Risk diversification poses significant challenges, not only for risk-based testing, but also for the costs and resources required to reach a broader range of constituents with preventive and health promotion interventions. As drivers of STI risk are not purely behavioural, but relate to relative STI prevalence within sexual networks and access to sexual health care and testing, localised surveillance and research is important in ensuring risk is appropriately understood and addressed within local contexts. Here, we review the evidence on the benefits and harms of risk-guided versus population-based screening for STIs among key populations, discuss the importance of risk-guided interventions in the control of STIs, and explore contemporary approaches to risk determination.

Keywords: chlamydia, gonorrhoea, risk assessment, risk populations, screening, sexual health, STIs, syphilis.

Introduction

There are an estimated 374 million new infections of curable sexually transmissible infections (STIs), such as chlamydia, gonorrhoea, syphilis and trichomoniasis, annually.[1] If left untreated, these infections can lead to serious sequelae, including pelvic inflammatory disease (PID), infertility, increased risk of HIV acquisition and, in pregnancy, neonatal death. With the majority of acute bacterial STIs being asymptomatic, identifying groups most at risk of infection is important for prioritising screening, targeting prevention strategies and alleviating the burden of STIs. Not adequately identifying people at high risk of STIs can limit the effectiveness of preventive interventions and lead to unnecessary testing and health-systems costs. Identifying those at risk of STIs risk is also complicated by the stigma associated with STIs and associated behaviours that limit individuals' disclosure of information about risk practices. Risk-based STI testing guidelines have traditionally centred on grouping people according to demographics and behaviours that have been identified in research and clinical practice as being associated with greater likelihood of STI diagnosis. However, the periodic emergence of STI epidemics among non-traditional risk populations, and the clustering of STIs in behaviourally specific subgroups within traditional risk populations, complicates the delivery of preventive interventions and care.

In this review, we describe the epidemiology of STIs among traditional and emerging risk groups, and explore contemporary approaches to risk determination. We review the evidence on the benefits and harms of risk-guided versus population-based screening for

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STIs among key populations, describe novel methods to identify risk, and discuss the importance of risk-guided interventions in the control of STIs.

Traditional and emerging risk populations

The burden of STIs has historically been concentrated among what are typically referred to as 'key populations'. The World Health Organization's (WHO) global health sector strategy on STIs suggests that each country needs to 'define the specific populations that are most affected by STI epidemics' and that their response should be 'based on epidemiological and social context'.[1] These key populations are broadly categorised based on demographics such as gender and age, and specific sexual behaviours, such as number and gender of sexual partners. Specific populations that are highlighted in WHO guidance include adolescents and young people, men who have sex with men (MSM), transgender people, sex workers, and people who use drugs.

Adolescents

Although young people and adolescents have been long recognised as a priority population for STIs,[2] targeted approaches are challenged by the fact they represent a substantial percentage of the general population and a behaviourally heterogeneous group. An analysis of data from the Global Burden of Diseases study found that adolescents have a higher STI burden than other age groups, and although overall the age-standardised incidence rate of STIs is trending down globally, the actual number of incident infections is increasing, likely due to the growth in the sexually active population and an increasing number of infections in adolescents.[3] Although there are biological factors which increase risk (e.g. young females can be more susceptible to chlamydia and HPV due to lower production of cervical mucous and increased cervical ectopy[4]), key drivers of risk among young people and adolescents include simultaneously being more likely to engage in sexual risk behaviour (e.g. concurrent partners and condomless sex)[2] and less likely to access sexual health services.[5] Low rates of seeking sexual health care among adolescents are likely, in part, to be associated with concerns about confidentiality and discomfort in discussing sexual health concerns, as well as lack of knowledge about available services.[6] Typically lower rates of general health-seeking behaviours among males drive lower rates of STI screening in general practice,[7] with testing among heterosexual males more likely to be driven by symptomatic presentation or partner notification.[8]

Trends in STI diagnoses among young people are dynamic and fluctuate across many settings. A recent analysis of data from the US found that among the youngest group, those aged 12–17 years, chlamydia and gonorrhoea positivity decreased, whereas it increased for the other age groups.[9] Insights garnered from behavioural epidemiology data can be used to understand such changes and also guide priorities for risk-based screening and other interventions. In this study, the authors suggest decreasing positivity among those aged 12–17 years may be associated with a declining proportion of high school students who report ever having sex, having fallen from 47.4% in 2011 to 39.5% in 2017.[10] In contrast, repeated behavioural surveillance of high school students in Australia found the proportion of students reporting ever having penetrative sex increased from 34.7% in 2002 to 46.6% in 2018.[11] As routine presentation to primary care remains the main access point to the healthcare system for many young people, opportunistic STI screening relies on clinicians being comfortable asking young people about sex and sexual risk, and creating 'safe' clinical environments where young people feel comfortable discussing and disclosing information about sexual practices.

Heterosexuals

Although MSM in high-income countries carry a significant burden of STIs, there is evidence that prevalence of STIs is increasing among heterosexual populations. For example, although gonorrhoea has been historically concentrated among MSM in Australia,[12] there has been a 475% increase in gonorrhoea notifications among females in the state of Victoria, Australia, from 2010 to 2019.[13,14] Similarly, whereas syphilis diagnoses in Australia remains concentrated among MSM residing in inner urban locations, syphilis is increasing in heterosexual men and women in Australia, especially those residing outside of inner-city suburbs.[15] Although the reasons for STI increases among heterosexuals in outer-suburbs are not fully understood, they may be reflective of less access of sexual health services.[14] Australian HIV surveillance data shows that, for HIV, women are often diagnosed late and report no prior history of HIV testing.[16] Genomic analyses also suggest that transmission of gonorrhoea into heterosexual populations may be facilitated through the bridging of sexual networks via populations of men who have sex with men and women.[17]

Further, although the burden of STIs among young heterosexuals has been well described, more evidence is coming to light of emergent STI epidemics among older heterosexual populations. In the US, the Centers for Disease Control and Prevention (CDC) reports a doubling of STIs among those aged >65 over the last 10 years.[18] Reasons for increasing STI rates among older populations may relate to lower levels of sexual health knowledge[19] and inaccurate risk perception[20] among older generations.

Men who have sex with men

Although STI epidemics may be diversifying beyond traditional risk groups, STI burden remains clustered within networks of people who may share specific risk practices

with high rates of assortative partner mixing. MSM are at increased risk of STIs due to a combination of biological and behavioural factors (e.g. more partners, more concurrent partners, type of partners) and the relative prevalence of STIs within sexual networks that contributes transmission risk. Although MSM are recognised as a priority group for STIs globally, the population of MSM comprises a diverse group, with different behaviours, identities and healthcare needs, and consequently risk varies across specific subgroups. For example, MSM living with HIV have historically had higher rates of STIs such as syphilis[21] and sexually acquired hepatitis C,[22] likely associated with smaller sexual networks with high rates of partner mixing, which sustain high prevalence and onward transmission. Given the often differing prevalence of STIs between HIV-negative MSM and MSM living with HIV, and specific sexual network dynamics, behavioural and demographic predictors of STI risk often vary between the two groups.[23] Further, rates of specific STIs within risk populations often vary based on age. For example, among MSM in Australia, gonorrhoea is more common among those aged 20–29 years compared to syphilis, which is most common among those aged 30–39 years.[24]

The concentration of STI risk among subgroups of MSM is also diversifying. Advances in biomedical interventions for HIV over the past decade, including Treatment as Prevention (TasP) and pre-exposure prophylaxis (PrEP), have led to changes in behaviour and STI epidemiology among MSM. Although declines in condom use at the population[25,26] and individual level[27–29] associated with the roll-out of PrEP in high-income countries have occurred in parallel to increases in STI incidence,[30,31] disentangling and quantifying the direct effect of PrEP rollout on STI incidence is difficult.[32] Some countries that have seen significant uptake of PrEP were observing increases in STIs and declines in condom use among MSM prior to this scale-up.[33] Even prior to epidemiological evidence emerging, assumptions regarding declines in condom use in the context of PrEP has led to specific STI testing guidelines for PrEP delivery.[34] STI testing guidelines for PrEP also acknowledge the risk-based criteria for PrEP prescribing[35–37] and high rates of STI diagnosis prior to PrEP initiation.[30,38] Surveillance data from Australia, where PrEP has been available since early 2016 through large demonstration projects[39,40] and more widely available since April 2018 when PrEP was approved as a government subsidised medicine, have shown that, although rates of chlamydia and gonorrhoea have stabilised among MSM using PrEP, syphilis continues to increase.[41] Continuing increases in syphilis among PrEP users is likely reflective of greater comfort in,[42] and increased rates of,[43] serodiscordant sex in the era of HIV TasP and PrEP, and the greater differential in syphilis prevalence between MSM living with HIV and HIV-negative MSM compared to chlamydia and gonorrhoea. Further still, within risk groups such as PrEP users, the burden of STIs is highly skewed towards those experiencing repeat or concurrent infections. Analysis of PrEP users enrolled in an early demonstration project in Australia found that 50% of PrEP users were not diagnosed with an STI during follow up, and that one-quarter of PrEP users accounted for three-quarters of STIs.[30] These trends have continued to be observed into the years following widespread PrEP implementation in Australia[41] and in other settings such as the UK.[44]

Travellers and migration

With early detection and treatment of STIs to prevent onwards transmission a key STI prevention strategy, there is an increasing focus on the impact of higher risk behaviours and settings associated with international travel and migration on local STI transmission. International travellers returning from high-prevalence settings are at increased risk of STIs,[45] and if not identified upon arrival, risk introducing new strains of STIs and seeding new clusters of transmission. Pre-emptive sexual risk screening during clinical visits prior to travel, for example for vaccines, could provide an opportunity to offer STI interventions, such as STI immunisation, PrEP or self-initiated antibiotic treatment of bacterial STIs, while also prompting travellers to be screened for STIs when they return.[46]

Migrants arriving in high-income countries often face additional barriers to accessing sexual health care driven by cultural aspects of stigma, knowledge gaps in health literacy, and ineligibility for subsidised care.[47] For example, in Australia, newly arrived Asian-born MSM have been identified as an emerging priority group for HIV,[48] with qualitative work highlighting that lack of access to subsidised PrEP introduces a cost barrier for many newly-arrived MSM.[49] Similar structural barriers exist for access to routine HIV and other STI testing for this group, which potentially contribute to higher observed incidence of HIV among Asian-born MSM and high rates of testing positive for HIV at first presentation for testing.[50] The impact of inequitable access to health care on STI risk may be compounded by changes in sexual risk-taking behaviour following migration, especially among MSM emigrating from countries with typically repressive social norms to countries with more progressive views and greater access to gay venues and community.[51] Similarly, migrant sex workers are often at greater risk of STIs than non-migrant sex workers, although the interaction between migrant status and country income level has been shown to vary depending on local epidemiology and legal contexts.[52] STI risk has been shown to be higher among migrant sex workers who do not have contact with outreach workers,[53] further highlighting the impact of unequal access to health care and harm-reduction services on STI risk among migrant populations. Lastly, movement across communities within countries may also be contributing to STI transmission. Recent modelling work suggests that high population

mobility likely contributes to high levels of STI prevalence among remote indigenous communities in Australia.[54]

Technology and risk environments

Across a diverse range of traditional and non-traditional risk groups, specific behaviours may be associated with particular risk environments or the use of digital technologies to meet partners that pose challenges for risk-based screening in clinics and for targeted interventions and health promotion. For example, among MSM, meeting partners at sex-on-premises venues may be associated with increased risk, as STI prevalence is high among MSM attending these venues.[55] Meeting partners online or through 'hookup' apps has also been shown to be associated with greater STI risk among MSM.[56] For heterosexual people, although a recent review found no evidence of an association between online-partner seeking and lower condom use or STI status,[57] among young heterosexual people, use of geo-social dating apps has been linked to increased rates of casual sex, having multiple partners and having sex without discussion about STI status.[58] Other subcultural behaviours associated with increased STI risk, such as 'swinging',[59] may not be readily identified at STI clinics. Practices such as those mentioned above typically cluster within specific geographic and social or sexual networks, and therefore relative risk can be temporally and significantly elevated in the context of undiagnosed infections entering specific networks, resulting in outbreaks of STI infections.

With more evidence of diversifying STI risk, there is a need to go beyond broad, risk-group categorisations based on age, sex and sexuality. Risk diversification poses significant challenges, not only in terms of risk-based diagnostic testing, but also in relation to the costs and resources associated with reaching a broader range of constituents with preventive and health promotion interventions. Here, continued STI surveillance and research, including qualitative and ethnographic research to understand contextual factors that drive risk, is important and emerging data need to be monitored closely to guide and inform policy and practice. Early detection of risk diversification is crucial, given STI control becomes increasingly challenging as prevalence increases in emergent risk populations. Strategies must continue to promote high intervention coverage among known risk groups, but also consider targeted interventions that focus on individuals at greatest risk within these groups.

Rethinking risk – more than just behaviours

As described above, defining traditional risk groups on the basis of broad demographic and sexual behaviour may be inadequate for efficient and effective STI prevention and clinical interventions. To guide targeted interventions towards those at greatest risk, strategies that include non-behavioural considerations may be beneficial. For example, although condom use may be strongly associated with HIV risk, there is mixed evidence of the association between condom use and STI risk, relative to other factors; evidence suggests that among MSM using PrEP, condom use is less predictive of STI risk than sexual networks and the practices that contribute to defining these networks.[30] The estimated per-partner effectiveness of condoms for bacterial STIs[60] is also much lower than for HIV,[61,62] and high levels of extra-genital transmission of STIs among MSM have been reported.[63] Practitioners should therefore consider, dependent upon local epidemiology and context, a broader suite of factors when screening for risk, beyond traditional notions of broad demographic risk or condom-based definitions of 'safe sex'.

Neighbourhoods and access to health care

Key drivers of STI risk are not purely behavioural, but relate to STI prevalence within respective communities and sexual networks, as well as individuals' access to sexual health care and testing. Less access to testing and health care means that STIs remain undiagnosed for a long period of time, and individuals have more chance of passing infections on to their sexual partners. This is evident among populations of black MSM in high-income countries such as the US, the UK and Canada, who are at increased risk of HIV compared to white MSM, despite there being no evidence that black MSM have more partners or engage in more serodiscordant condomless sex than other MSM.[64] A wealth of data highlights that black MSM in the US are often faced with poor access to culturally competent health services, including HIV and STI testing, and experience stigma and discrimination that impede access to services.[65] Similarly, Aboriginal communities living in remote regions of Australia experience disproportionately high rates of STIs, with chlamydia and gonorrhoea prevalence among young people in these communities among the highest in the world.[66,67] With others demonstrating similar numbers of sexual partners and a similar average age at sexual debut among young Aboriginal Australians compared to non-Indigenous young people,[68] discrepancies in STI incidence are likely driven by structural barriers (e.g. access to testing affecting rates of undiagnosed infections). Despite clinical guidelines and specialist support for primary healthcare clinicians visiting these remote communities, rates of re-testing and clinical follow up within recommended timeframes in Aboriginal communities are suboptimal.[69] Remote Aboriginal communities are faced with significant clinician-level barriers to STI testing, such as high levels of clinician turnover, a lack of familiarity with STI protocols, and prioirtisation of other urgent health concerns by clinicians.[70] The impact of access to health care on HIV outcomes is also reflected in Australian migrant communities, especially those from South-East Asia and Sub-Saharan Africa and those from countries that

are ineligible for reciprocal healthcare agreements, where larger gaps in the HIV care cascade are observed compared with non-migrants.[71] Lower rates of repeat HIV testing are also observed among HIV-negative migrants.[50] Addressing disproportionate rates of STIs among both Aboriginal and migrant communities will require systemic change and removal of structural barriers to accessing health care.

Further highlighting the important role of environmental and socio-structural factors in contributing to STI risk, differences in laws and practices that maintain racialised inequities (e.g. inequitable urban housing policies) at the neighbourhood level have been shown to be greater predictors of HIV risk than sexual risk behaviours.[72] In the US, higher rates of gonorrhoea have been linked to neighbourhood-level determinants of health, including higher rates of single mothers and lower socio-economic status.[73] Analysis of syphilis distribution in Canada suggests that spatial clustering of syphilis diagnoses is not fully explained by distribution of MSM populations or different rates of testing across areas, suggesting that additional neighbourhood-levels factors are likely driving transmission.[74] These data highlight the importance of localised surveillance and research to ensure risk is appropriately understood and addressed within local contexts.

Changes in risk

It is also important to consider that risk changes over time, and that if an individual does not meet certain risk criteria for screening or a prevention intervention, they may in the future. For example, early PrEP guidelines in Australia recommended prescribing PrEP even in the absence of recent risk, if individuals anticipated risky behaviour in the near future.[34] Similar considerations for STI interventions should be considered. Latent transition analysis among both heterosexuals[75] and gay and bisexual men[76] show that individuals' allocation into specific risk groups remains relatively stable. However, changes in risk are often observed when people move out of monogamous relationships. This is reflected in risk-based STI guidelines for young heterosexuals,[77] and latent transition analysis of MSM regularly attending for STI testing.[76] Further, these data reflect states of risk prior to the introduction of PrEP. Given the evidence of changes in STI risk follow PrEP initiation,[27] and that people transition in and out of PrEP use based on personal risk perception over time,[78] regular assessment of current risk among people presenting to health services with any history of PrEP use is warranted. Further, the coronavirus disease 2019 (COVID-19) pandemic and associated public health orders have led to significant changes in sexual behaviour[79] and breaks in PrEP use[80,81] among MSM, decreases in casual sex among heterosexuals,[82] and significant declines in the frequency of STI testing.[83] Drops in testing in the presence of ongoing sexual risk have the potential to increase pools of undiagnosed infection.

Screening for STIs

Although testing is crucial for the control of STIs, guidelines on who to test, and how often, vary. Many guidelines highlight specific populations that should be considered for STI screening, or recommend clinicians take a sexual history to determine if individuals should be screened. Among populations where STIs are highly asymptomatic (e.g. extra-genital infections among MSM), informed decisions around how to screen in the absence of symptoms rely on understanding epidemiological contexts (historical and emerging). Although broad-based guidelines, which recommend testing of entire populations (e.g. regular testing of all sexually active MSM or STI testing at each PrEP prescribing visit), may lead to greater testing coverage and frequency, they present challenges for managing clinic capacity and may impact the cost and cost-effectiveness of sexual health services. Such strategies consume a lot of resources and are not often feasible in resource-constrained settings or where testing is not fully subsidised. Further, broad-based recommendations obfuscate the need for nuanced risk screening and targeted higher frequency testing for those at particularly high risk or those who are diagnosed with STIs recurrently.

Opportunistic testing during routine visits

Opportunistic testing, when a test if offered in-clinic during a routine patient visit, often occurs after clinicians take a sexual history, following an electronic prompt, or if the patient is identified as belonging to a specific high-risk group for which STI testing is recommended. For example, in the US, the CDC and US Preventive Services Task Force recommend annual chlamydia and gonorrhoea screening for all sexually active females aged <25 years, and annual screening for women aged >25 years with a risk factor (more than one sex partner, a sex partner with concurrent partners, a new partner).[84] Although such recommendations allow clinicians to assess risk on an individual basis, significant challenges associated with risk screening exist. Clinician barriers include discomfort around engaging in sexual health discussion or asking sensitive questions, feeling inadequately trained, and difficulty incorporating a sexual screen into a regular visit due to time constraints.[85] Barriers may also be magnified among doctors who serve ethnically diverse populations.[86] Patient sexual history may also be hindered due to patient concerns around confidentiality and stigma, lack of perceived risk and lack of sexual health awareness.[87] Some of these barriers can be overcome by implementing computer-assisted self-interviewing in clinic waiting rooms, where patients

complete an electronic survey that asks about their sexual history and specific risk factors.[88]

Universal screening of key populations

In contrast to its screening recommendations for women (women aged <25 years screened annually, those aged >25 years only screened if a risk factor is present), the US CDC recommends annual screening for all sexually active MSM, and more frequent screening (3–6 months) for MSM at increased risk (defined has having multiple partners or persistent risk behaviours).[89] In Australia, guidelines were updated in 2019 by removing specific risk-based recommendations for screening frequency among MSM and recommending uniform 3-monthly testing for bacterial STIs for all sexually active MSM, regardless of the number of partners, STI history or presence of specific risk behaviours.[90] Although increasing rates of STIs among MSM may warrant high-frequency screening, in the context of highly skewed STI incidence among certain subgroups of MSM[41] and resource and time constrains in general practice, not distinguishing between high- and low-risk MSM may lead to ineffective or less cost-effective STI screening practices.

It is not clear whether the implementation of ambitious guidelines, which recommend high-frequency screening for all MSM regardless of risk-factors, such as those in Australia, will lead to greater increases in testing frequency among those already being tested, or in testing coverage across the whole population, with little evidence to suggest this strategy would have an impact on STI prevalence. Although sexual health clinics may be able to achieve such testing rates, in jurisdictions where STI testing is mainly conducted in general practice, the burden of trying to screen all MSM four times a year might mean adequate screening is not achieved among those who it would benefit the most, and universal screening at high frequency is likely not feasible in settings where testing is not covered by universal healthcare arrangements.

Effect of screening on STI prevalence

Evidence for the effectiveness of broad-based population-level screening on test uptake and STI prevalence is mixed, and the benefits and harms of broad-based population testing versus more specific risk-guided testing protocols vary between population. Risk-based opportunistic screening in the US, based on taking a sexual history, has largely not been successful in achieving high rates of chlamydia screening among high-risk young women,[91] largely due to low rates of practitioners in general practice undertaking a sexual history. A 2006 survey found that only 55% of primary care physicians asked about sexual histories as part of regular examinations.[92] Data from Australia reports that 46% of general practice clinicians would not take a sexual history of MSM presenting for a routine check up.[85]

Even if clinician- and patient-level barriers are overcome, there is little evidence to suggest that high coverage of opportunistic screening among heterosexuals has an impact on STI prevalence. A large cluster randomised controlled trial of opportunistic chlamydia testing in rural GP services in Australia, which implemented a protocol involving clinician education, computer alert prompting and reimbursements, found that even with increased testing of eligible patients, the intervention was not associated with a decline in chlamydia prevalence.[93] However, it was associated with a decline in PID presentations at nearby hospitals. Additional data from the US shows that although screening among heterosexuals may not reduce chlamydia prevalence, it is a potentially effective approach to reduce PID.[94] Another large cluster-randomised controlled trial, which assessed a multi-pronged intervention of continuous quality improvement (review of clinical data, education, implementation of systems-level changes aimed at improving STI practice) in general practice clinics serving remote indigenous populations in Australia, again found increases in testing, but no changes in population-level prevalence of STIs.[95]

Strategies to increase STI testing capacity

Consideration of adapted service models and strategies to enhance STI testing efficiency in established services may be required to maintain capacity for broad risk-based STI screening practices, while also increasing testing coverage and frequency among those at particularly high risk. Although technology-based systems to reduce the burden of high frequency testing on patients have been implemented at the clinic and laboratory level (e.g. results delivered by SMS[96]), frequent testing can be challenging because of restricted clinic operating times. These types of health systems barriers make increasing patient-driven demand for STI testing difficult. For example, evaluation of a large Australian health promotion campaign targeting MSM for HIV and STI testing found that despite substantial investment in health promotion and a high proportion of MSM recalling campaign messages, only a modest increase in chlamydia and gonorrhoea testing was achieved, and the campaign had minimal impact on HIV or syphilis testing.[97] Social marketing initiatives aimed at creating demand for testing must also be accompanied by structural changes that make STI testing more convenient.

In order to achieve high rates of testing, adaptive and convenient service models that reduce the burden on patients will be required. A recent scoping review of HIV and STI testing preferences among MSM in high-income countries identified the convenience and privacy of self-testing, and the need to provide a variety of testing options, as key themes of testing preferences.[98] A 2016 review of interventions aimed at increasing STI screening found that

the most effective interventions included incorporating collection of STI specimens as standard procedure regardless of the reason for the visit, and the use of electronic health records as a reminder to offer screening.[99] Models that streamline clinic visits, including patients self-collecting specimens, computer-assisted questionnaires, test-and-go services, and rapid testing with same-day results, have been shown to increase screening while also reducing costs and time between testing and treatment.[100] The incorporation of all these elements into a single, free, express testing service, Dean Street Express in London, was shown to reduce mean time between test and notification to 0.27 days, compared to the standard clinic's 8.95 days, which was projected to have prevented 196 chlamydia and/or gonorrhoea infections over 1 year after implementation.[101] Nurse-led test-and-go services, which remove the need for doctor consultation and reduce testing times, have also been shown to capture clients with different demographics, yet still detect a similar rate of STI positivity, compared to standard doctor-led testing.[102]

Opt-out testing

Another strategy, opt-out testing, involves testing all patients in a specific risk group, regardless of the presence of sexual risk factors, with the aim of increasing screening rates. Population-based opt-out screening methods remove the burden of clinicians to initiate sexual history taking, and decide if a test is appropriate or needed. However, opt-out testing does place the burden on clinicians to ensure appropriate disclosure of the test to patients in pre-test discussions to ensure they are aware of the implications of a positive result and have the opportunity to opt out. Surveillance data from Australia showed opt-out testing increased rates of syphilis testing among MSM living with HIV.[103] Modelling work suggests that an opt-out testing strategy for all women aged 15–24 years in the US would likely reduce chlamydia prevalence, and be more cost-effective compared to a risk-based screening strategy; however, this was dependent on individuals' insurance coverage.[104] In limited-resource settings or where universal health care is not available, overall effectiveness and cost-effectiveness of such strategies would be significantly reduced.

Targeted testing of those at greatest risk

A modelling study of syphilis among Canadian MSM found that increasing screening frequency among those already engaged in testing had a greater reduction on syphilis incidence than increasing screening coverage (i.e. the proportion of the population tested).[105] Another modelling study of MSM in the US found that both increasing the rate of screening from current levels to biannual among all sexually active MSM currently being tested, and increasing the coverage of biannual screening to 30% of all 'high-risk' MSM, each reduced chlamydia and gonorrhoea incidence by approximately a 75% reduction over 10 years. The authors suggest that more frequent screening for all MSM, and scaling up targeted screening for men with multiple recent partners, were the most effective strategies.[106] US guidelines recommend syphilis screening in MSM, people with HIV and pregnant women, but do not provide routine screening recommendations for HIV-negative heterosexual populations. Modelling work suggests that achieving such a strategy may have an impact on transmission in states with more MSM-focused outbreaks, but would have little or no impact on transmission in states where syphilis is more evenly distributed between MSM and heterosexual populations.[107]

Guiding public health strategies to increase active case-finding using epidemiological trends can quickly and efficiently respond to new STI outbreaks. For example, many countries utilise existing networks of general practice clinicians to issue alerts around increasing rates of STIs in certain geographical areas or subpopulations. In the UK, outbreaks are detected by local surveillance undertaken by clinicians or health protection teams via the detection of higher than expected numbers of diagnoses.[108] These are sometimes supplemented by more systematic approaches that utilise automated spatiotemporal detection tools to routinely analyse notification data.[109] Following an investigation to declare and determine the spread of an outbreak, initial stages of outbreak response usually involve alerting clinicians and appropriate organisations through established communication systems. Similar alerts in Australia are commonly issued through the general practitioner network.[110] Sustained outbreak control can then include strategies such as active case-finding, qualitative data collection to understand drivers of the outbreak, outreach programs targeting specific venues or populations, and widespread promotion through social and traditional media.[108] These strategies can also facilitate targeted communication to non-primary care clinicians who may not be routinely involved in STI care. For example, recent increases in congenital syphilis, likely related to low rates of syphilis screening and issues with continuity of care and treatment during pregnancy among patients tested in antenatal hospital clinics in Australia,[111] led to specific guidance targeted at increasing syphilis testing during pregnancy. The success of such strategies relies on surveillance infrastructure to identify and characterise new STI outbreaks in a reliable and timely manner, and appropriate levels of funding and technical support to resource a timely response.

Over-screening

In addition to the burden of frequent STI testing incurred by the patient, there are potential harms associated with over-screening for STIs, including anxiety, psychological harm

associated with false positives or negatives, or possible change in risk behaviour. However, the US CDC reports there is currently limited data on psychological or other harms associated with screening for chlamydia and gonorrhoea among women and heterosexual men.[112] Among MSM, there is growing evidence that high antibiotic consumption among PrEP users may be driving antibiotic resistance. Given high rates of bacterial STIs among PrEP users, and high frequency screening and treatment, PrEP users have high levels of macrolide consumption, as well as for cephalosporins, fluoroquinolones and tetracyclines.[113] In some European countries, consumption of macrolides is 52-fold higher among PrEP users compared to community-level consumption.[113] Cohorts of PrEP users around the world are commonly characterised by having high rates of partner change,[27] translating to high and stable prevalence of chlamydia and gonorrhoea. Long-term surveillance data in Australia suggest that sustained high-frequency testing of PrEP users (3-monthly) for >4 years has not curbed rates of chlamydia or gonorrhoea in this group.[41] In contrast, such high-frequency screening is costly and may be driving antimicrobial resistance.[114] Modelling work suggests that even low levels of screening for the largely asymptomatic STI *Mycoplasma genitalium* among MSM is leading to increased antibiotic resistance through increased, arguably unnecessary treatment.[115] In its resistance threats 2019 report, the US CDC has listed drug-resistant gonorrhoea on its Urgent Threats list, and *Mycoplasma genitalium* on its watch list.[116] Surveillance of antimicrobial resistance is crucial in the context of high-frequency screening and transmission. In light of the threat of antimicrobial resistance, there is a growing case for reconsidering the evidence base for high-frequency screening of STIs, which are mostly asymptomatic, among populations with high and stable prevalences.[117]

Identifying risk

With the aforementioned barriers to clinician-led discussions on sexual history during routine care, and the need for increased client-driven demand for testing, methods to appropriately and efficiently identify risk, both from the clinician perspective and including individuals' self-perception of risk, are crucial.

Service-identified risk

For clinical services aiming to identify risk, strategies can go beyond broad testing protocols based on risk group and the use of clinical data and automated screening tools. For example, previous infection can be used as an indicator of risk. History of an STI has consistently been shown to be one of the strongest indicators of future risk among both MSM[118] and adolescent heterosexuals.[119] The strong predictive value of a previous diagnosis is reflective of high rates of reinfection, such as that of syphilis reinfection widely observed among MSM,[120] especially those living with HIV.[118] It is unsurprising then that modelling work suggests that increasing screening frequency among MSM with a prior syphilis diagnosis is equally effective in reducing syphilis prevalence as testing focused on those reporting high partner numbers, and far more effective than distributing testing equally among all MSM.[121] Targeting individuals with a prior diagnosis of syphilis can be done through clinician-led history taking, patient management system alerts or through demand-creation approaches such as community-driven awareness-raising of reinfection risk.

Novel methods for identifying those at risk, including machine learning and prediction modelling using electronic medical records, have also been explored, with varying levels of efficacy. For example, the use of computer-assisted sexual history taking allows data on behavioural risk factors to be analysed using risk prediction models and machine learning. Machine learning has been successfully used to identify those who are eligible for PrEP based on medical records;[122] however, the use of machine algorithms of structured health record data have been shown to poorly differentiate patients with and without repeat STI diagnosis, indicating that they may be less useful for predicting STI risk.[123] Prediction models of routinely collected healthcare data have been used in emergency room settings where laboratory variables are collected and can be used for risk prediction.[124] Despite growing work on machine learning, such techniques require technical capacity, education and training, and access to 'big data' through which to generate predictive algorithms. Also, as prediction methods rely on patient history, they would likely provide less benefit in determining STI risk for patients attending clinics sporadically or for the first time.

Risk self-identification

Along with clinical services being able to adequately identify STI risk, patient-driven demand for STI testing relies heavily on individuals recognising their own risk, and seeking STI testing. An analysis of adults in the UK found that both men and women underestimate their self-risk of STIs, and that many who did perceive themselves as at-risk had not recently accessed STI care.[125] Health promotion, therefore, should not only focus on improving self-identification of risk, but also encourage people to act on their perceived self-risk by accessing care. Perception of the seriousness of STIs has been shown to vary considerably among specific subgroups of MSM at high risk of STIs,[126] and may influence an individual's decision to present for testing following possible exposure to an STI or following windows of risk, if they perceive the health risk of an STI going undiagnosed to be low. Along with perceptions of risk, STI knowledge has also been linked to recent STI testing,[127]

highlighting the importance of health promotion campaigns for increasing STI awareness and access to information on STIs. Peer-led models of care have been shown to provide opportunities for MSM to enhance their risk-reduction knowledge around STIs, with greater benefits among young and less gay community-attached MSM.[128]

Finally, technology is also playing a role in the self-identification of STI risk. As described earlier, MSM who use geo-social networking apps are at increased risk of STIs. This highlights a potential opportunity for community and health organisations to deliver reliable, trusted and easily accessible sexual health information at scale to those at greatest risk via social networking apps. Further, specific mobile phone applications have been designed to screen for STI risk, as well as to help users identify STI symptoms. Although mobile phone apps for the care and prevention of STIs are of high interest to the general public,[129] a 2016 review of available STI-related apps found that many contained incorrect and potentially harmful information.[130] Recent data also suggest that although digital methods of sexual healthcare delivery (i.e. through video consultation) may be acceptable, many still prefer human interaction over automated chat-bots when accessing sexual health information.[131] Further, disparities in utility and uptake of digital health information and interventions exist, with older people[132] and those from racial and ethnic minorities less likely to engage in technology-based interventions.[133]

Conclusion: adopting an adaptive risk-guided approach to STI control

Alongside historically high-risk groups, new risk groups for STIs continue to emerge and diversify. Although the evidence for the effect of population-based screening compared to higher frequency, targeted screening strategies on STI prevalence varies within and across MSM and heterosexual populations and for specific STIs, strategies that reduce clinician- and patient-level barriers, and are adaptive to local epidemiological contexts, have the greatest potential for achieving optimal screening rates and controlling new outbreaks. Such strategies need to remove the burden on clinicians and the assumption of risk, and improve patient convenience in order to increase testing coverage, while still including sufficient nuances to identify those at greatest risk for targeted testing and prevention.

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