Serial Monogamy and Biologic Concurrency: Measurement of the Gaps Between Sexual Partners to Inform Targeted Strategies

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Having multiple sexual partners concurrently increases the risk of transmission of a sexually transmitted infection. Even if partnerships do not overlap, transmission potential exists when the gap between partnerships is shorter than the remaining infectious period. In the present article, we quantify the gap between partners to assess transmission potential using data collected by a cross-sectional survey of 2,203 genitourinary medicine clinic patients in England in 2009. Questionnaires asked about patients’ 3 most recent partnerships. Gaps were calculated as time (days) between the last sexual encounter with a former partner and the first sexual encounter with the next partner. Among 1,875 patients who reported 1 or more partners in the previous 3 months, 47.6% of men and 27.7% of women reported 2 or more partners. Forty-two percent of the gaps were negative (i.e., partnerships that were concurrent); the median gaps were −7 and −17 days for men and women, respectively (i.e., overlaps were 7 and 17 days for men and women, respectively). Although half of the gaps were positive (serially monogamous partnerships), many were of short duration; the median gaps were 14 and 24 days for men and women, respectively. In over half of the gaps, condoms were used inconsistently with one or both partners, and in one-quarter, condoms were never used with either partner. There is thus a high potential for sexually transmitted infections, as even if partnerships are not behaviorally concurrent, they may be biologically concurrent. These data have important implications for designing and targeting effective health promotion messages.

Abbreviations: IQR, interquartile range; HIV, human immunodeficiency virus; MSTIC, Maximising STI Control for Local Populations; STI, sexually transmitted infection.

The transmission of bacterial sexually transmitted infections (STI) occurs during a finite but variable infectious period, during which effective contact with a susceptible individual must occur if infection is to persist in the population (1). In contrast, the potential for transmission of viral STIs depends on the stage of infection at the time of contact with a susceptible individual, as infectivity can vary. For example, the viral load of human immunodeficiency virus (HIV) is considered greatest within the first 3 months of acquisition (2–4), with substantial potential for onward transmission during this period.

Concurrent sexual partnerships are considered an important risk factor for STI transmission (5–9) because they link together otherwise discrete sexual networks. This viewpoint assumes concurrency and serial monogamy to be discrete behaviors. However, if the timing of sexual partnerships is considered as a continuum, there is potential for STI transmission between serially monogamous partnerships when the gap between partners is shorter than the remaining infectious period, as in the case of a bacterial STI, or when infectivity is high, as in the case of a recently acquired viral STI. This suggests that partnerships can be behaviorally serially monogamous but biologically...
concurrent and is further complicated by patterns of condom use that may change over time within a partnership (10).

Few studies have considered concurrency and serial monogamy as a continuum, that is, taken into consideration the impact of the length of the gap between sexual partners (hereafter referred to as “the gap” for brevity) (11–13). This may be because a negative gap, that is, concurrency, is a socially sensitive behavior (14). It may also be because it can be difficult to measure the gap, with recall error being a particular challenge when the reference period is long (11, 15, 16), as in studies of the general population in which partnership change is infrequent (17).

In the present article, we describe recent gaps reported by patients in a genitourinary medicine clinic, who typically report higher numbers of sexual partners than the general population (18), thereby providing a greater opportunity to study the gap and potentially reduce recall error in partnership data. Our objectives were to quantify the gap and its distribution, including the potential for ongoing concurrency, and to examine its association with condom use, thus providing a methodological framework for describing gaps and their relationship to STI/HIV transmission to inform targeted prevention interventions.

MATERIALS AND METHODS

Setting

Between August and December 2009, we surveyed people attending 1 of 4 sociodemographically and geographically contrasting genitourinary medicine clinics across England as part of the Maximising STI Control for Local Populations (MSTIC) Study (19). Clinic reception staff were asked to distribute a pen-and-paper, self-completion questionnaire to all patients over the course of 3 to 8 weeks, depending on the clinic’s size. Questionnaires were anonymous except for the patient’s clinic identification number, which was recorded by reception staff with the attendance date. The questions addressed the reasons for attending the genitourinary medicine clinic, symptoms, and sexual behavior, including 5 questions about the most recent sexual partner in the preceding 3 months, repeated for up to the 3 most recent partners in this timeframe. Detailed descriptions of the study methods and materials have been published previously (19). The research protocol was approved by the London Research Ethics Committee (reference number 09/H0718/1).

Calculating the gap between sexual partners

Respondents were asked, “Thinking about the person you most recently had sex with: When did you first have sex with this person?” and then, “When did you most recently have sex with this person?” Respondents specified a number of days, weeks, months, and/or years in response to each question. These questions were repeated for a maximum of the 3 most recent partners in the 3 months before the clinic visit, with partnership recency based on the date of the last sexual encounter. The reported data were then converted into a number of days before the clinic visit so that the gap between partners could be quantified as the number of days since the last sexual encounter with a former partner and the first sexual encounter with the next partner (Figure 1). Positive gaps denoted serially monogamous partnerships, whereas negative gaps denoted concurrent or overlapping partnerships.

Respondents were then asked whether they expected to have sex again with each of their 3 most recent partners. If they responded “yes” or “probably,” the partnership was categorized as ongoing, denoting the potential for sexual partnership concurrency.

Study population

A total of 2,203 patients completed the questionnaire, of whom 1,875 reported at least 1 partner in the preceding 3 months. Patients who reported at least 2 partners and partnership-specific data on up to 3 recent partners were included in the analysis, for which the denominator is 789 gaps (Figure 2).
Statistical analysis

Sample size calculations were not undertaken for the MSTIC Study because its primary aim was to develop and demonstrate an audit tool capable of rapidly gathering epidemiologic data to inform service planning. However, power calculations were undertaken post hoc for the comparisons presented here. Using data on 463 gaps reported by men and 326 gaps reported by women and assuming that 40% of all gaps are negative, there was adequate statistical power (80%) to detect as significant a gender difference of approximately 10% in the proportion of gaps that are negative ($P < 0.05$).

**Figure 2.** Flowchart showing the number of patients, partners, and gaps included in the analysis, by gender and reported partner numbers, Maximising STI Control for Local Populations Study, England, 2009. Men’s partners and gaps are shown in the 2 left columns, and women’s partners and gaps are shown in the 2 right columns.
We calculated percentages and percentiles to describe the sample of patients, stratified by gender. We used the $\chi^2$ statistic to compare patients who reported 1 partner with those who reported at least 2 partners, the latter forming the denominator for the analysis of the gap. We then used descriptive statistics and graphical displays to describe the distribution of the gap, stratified by gender and age group. Among men, we also performed analysis stratified by whether they reported having 1 or more same-sex partners in the previous year.

Median negative and positive gaps with interquartile ranges were calculated, as well as the 95th percentile as a measure of extremity. The results of nonparametric K-sample tests on the equality of medians between different sample subgroups (e.g., age groups) are presented. We used Excel (Microsoft, Redmond, Washington) and Stata, version 10.1 (StataCorp LP, College Station, Texas) for these analyses.

RESULTS

Response rates

The response rate was estimated from attendance data and varied by clinic, ranging from 24.9% to 76.1%. The overall response rate when pooling data from all patients in all clinics was 37.0%. However, aggregate routinely collected data (20) on gender, age, ethnicity, and STI diagnoses were used to compare participants who completed the questionnaire with the general clinic population, and respondents were only found to be slightly younger on average than patients in the clinic population (40.8% vs. 35.4%, respectively, were less than 25 years of age) (19).

Sample characteristics

On average, men were 4 years older than women and more likely than women to be white (Table 1). These characteristics did not vary by the number of partners reported in the previous 3 months, although male patients who reported 2 or more partners were more likely to report a same-sex partner(s) in the past year (22.5% vs. 8.9%; $P = 0.009$). The 1,875 patients reported having a total of 3,469 partners in the past 3 months. Among patients who reported 2 or more sexual partners, the median number of partners was 3 among men and 2 among women, with fourth quartile values of 4 and 3, respectively. Patients were asked partnership-specific questions about only their 3 most recent partners in the past 3 months ($n = 2,856$ partners). Because 8.2% of patients reported having more than 3 partners during this period, it was possible to collect data on all partners for only 91.8% of the 1,875 patients included in our analyses (85.3% of men, 96.7% of women). Patients answered partnership-specific questions for 2,481 (86.9%) of these 2,856 partners (Figure 2).

The distribution of gaps between sexual partners

In total, 48.4% of all men’s gaps and 54.3% of all women’s gaps were positive and thus corresponded to serially monogamous partnerships. However, these positive gaps were largely of short duration, especially among men, which was evident from the steeper gradient in Figure 3 for men than for women.

The median positive gap for men was 14 days in contrast to 24 days for women ($P = 0.008$ for gender difference; interquartile ranges (IQRs), 7–31 and 12–40, respectively). The gap between serially monogamous partnerships was shorter for women less than 25 years of age than for older women, with medians of 19 and 30 days, respectively ($P = 0.042$; IQRs, 10–39 and 14–41, respectively, Figure 4). No such age difference was observed for men’s partnerships (Figure 5), but men who reported 1 or more same-sex partners had a shorter median positive gap of 12 days than did men who only had female partners, who had a median gap of 17 days ($P = 0.006$; IQRs, 6–24 and 8–32, respectively; Figure 6). Fewer than 5% of all gaps were more than 2 months long.

Of all 789 reported gaps, 42.0% were negative, which indicated that the corresponding partnerships were concurrent. This proportion did not vary significantly by patient gender or age group; it also did not vary significantly among men by whether or not they reported a same-sex partner(s). However, differences were observed in the duration of concurrency. Among men, the median gap was 7 days among men less than 25 years of age, whereas the median gap was 17 days for women ($P = 0.049$; IQRs, 8–19 vs. 1 to 15, respectively). There was a trend of increasing duration of concurrency with age among men, with a median of 1 day among men less than 25 years of age, 7 days among men 25–34 years of age, and 14 days among men at least 35 years of age (Figure 5). No age differences were seen among women (Figure 4) or by men’s sexual orientation (Figure 6).

Compared with women, men had a larger proportion of gaps that lasted zero days (11.2% vs. 7.4%), but this did not reach statistical significance ($P = 0.143$). Among men, differences by age group in the proportion of zero-day gaps were evident, ranging from 8.2% of gaps between partners of men aged 25–34 years to 16.3% of gaps of men 35 years of age or older.

Ongoing partnerships and the potential for future concurrency

Among all patients, 277 (14.8% of 1,875 patients) experienced a total of 324 episodes of concurrency between their most recent partners. Both of the concurrent partnerships were reported as ongoing in 71 (21.9%) of these episodes, such that the duration of concurrency at the time of the clinic visit (median gap, 33 days; IQR, 16 to 77 days) was likely to be a minimum estimate. In terms of serial monogamy, 313 patients (16.7% of 1,875 patients) had experienced a total of 373 serially monogamous gaps between their most recent partners. Both partnerships were reported as ongoing in 22 (5.8%) such gaps, such that although these partnerships had not yet been sexually concurrent, there was a possibility that they would become concurrent. There were no significant differences by gender (Web Tables 1 and 2, available at http://aje.oxfordjournals.org/).

Condom use and the gap between partners

In one fifth of all gaps between men’s partners, condoms were reported to have always been used with both partners (Table 2). This was significantly greater among men who reported sex with men (42.0% vs. 14.0%; $P < 0.001$). For men
who only had sex with female partners, this was more frequent than it was for women (9.5%; $P < 0.001$). In over half of all gaps (54.6% of men’s and 62.2% of women’s, $P = 0.028$), condoms were not used consistently with either partner, whereas in one quarter of all gaps, condoms were never used with either partner, a proportion that did not vary by gender.

**DISCUSSION**

**Statement of principal findings**

Our analyses of data collected from a large survey of patients who attended contrasting genitourinary medicine clinics in England suggested that although patients typically report few sexual partners, multiple recent partnerships are as likely to have been concurrent as they are to have been serially monogamous. Furthermore, the reported gap between serially monogamous partners was often very short, such that although these partnerships were not behaviorally concurrent, they could be considered as biologically concurrent. Indeed, the probability of onward transmission was increased because consistent condom use with both partners was seldom reported. Although partners were more likely to be serially monogamous when condoms were never used with the more recent partner than when condom use with this partner was reported as inconsistent, there was typically less than a 1-week gap between partners. As the duration of infectivity of many STIs is typically expressed in weeks if not months (12, 21, 22), our findings have important epidemiologic implications.

**Findings in relation to other studies**

Behavioral and biologic concurrency are more common than generally reported (11, 13, 23). This may in part reflect the fact that our sample consisted of participants who visited a genitourinary medicine clinic rather than the general population.
However, we also measured the gap in days rather than months, which allowed us to identify gaps in which one partnership ended and another began in the same month. Studies in which gaps are measured in months may exclude these because concurrency cannot be established. Our more precise measurement of the reported gap is relevant to the

![Figure 3](image-url). Cumulative percentage distribution of the gap between recent sexual partners in the 3 months before genitourinary medicine clinic attendance by gender, Maximising STI Control for Local Populations Study, England, 2009.

![Figure 4](image-url). Cumulative percentage distribution of the gap between women’s recent sexual partners in the 3 months before genitourinary medicine clinic attendance by age group, Maximising STI Control for Local Populations Study, England, 2009.
transmission of STIs with short infectivity periods, such as gonorrhea, and those with greater infectivity in the acute phase, such as HIV, syphilis, and hepatitis B (12, 21, 22). Only one other study has measured the gap in days (genitourinary medicine clinic attendees in Malawi (24)). Because there was a high prevalence of monogamy (86% reported 0 or 1 partner), the authors could only study gaps between partners reported by 42 women and 119 men. However, despite their small sample

**Figure 5.** Cumulative percentage distribution of the gap between men’s recent sexual partners in the 3 months before genitourinary medicine clinic attendance by age group, Maximising STI Control for Local Populations Study, England, 2009.

**Figure 6.** Cumulative percentage distribution of the gap between recent sexual partners in the 3 months before genitourinary medicine clinic attendance by whether men reported same-sex partners in the past year, Maximising STI Control for Local Populations Study, England, 2009.

and contrasting geographic setting, positive gaps were also found to be short, but periods of overlap were much longer (mean, 246 days) (24). This is likely to be due in part to overestimation of the gap when the first sexual encounter with a more recent partner occurred before the first sexual encounter with a former partner (Figure 7), which has been labeled by others as “experimental concurrency” (6). Furthermore, the Malawi study did not report partnership-specific data, such as condom use or whether the partnerships were ongoing (24).

The reported use of condoms inconsistently, if at all, mirrors findings for the British general population in which condoms were reported as not having been used at the first sexual encounter in over half of partnerships (15). A study of adolescents found that even when condoms were used in a new partnership, use quickly waned, and condom use frequency after just 21 days was reported to be similar to condom use in established partnerships (10). Thus, even in serially monogamous partnerships, there is potential for biologic concurrency and onward transmission of many STIs (12, 22).

Strengths and weaknesses of the study

Although we have a relatively large sample of patients recruited from contrasting genitourinary medicine clinics across England that included different types of population, we used convenience sampling and therefore we cannot consider our data to be fully representative of the population of genitourinary medicine clinic patients. We also acknowledge the substantial variation in the response rate at the different clinics, which we attribute, in part, to reception staff not offering questionnaires to all patients, reflecting how enthusiasm for the

Table 2. Variation in the Gap Between Sexual Partners by Patterns of Condom Use With the Corresponding Partners by Gender, England, 2009

<table>
<thead>
<tr>
<th>Condom Use</th>
<th>Partners Corresponding to Men’s 463 Gaps</th>
<th>Partners Corresponding to Women’s 326 Gaps</th>
<th>Median Gap, days</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Always</td>
<td>101</td>
<td>21.8</td>
<td>31</td>
<td>9.5</td>
</tr>
<tr>
<td>Almost always</td>
<td>16</td>
<td>3.4</td>
<td>14</td>
<td>4.3</td>
</tr>
<tr>
<td>First few times</td>
<td>7</td>
<td>1.5</td>
<td>8</td>
<td>2.3</td>
</tr>
<tr>
<td>Not at all</td>
<td>23</td>
<td>4.9</td>
<td>18</td>
<td>5.5</td>
</tr>
<tr>
<td>All condom use</td>
<td>147</td>
<td>31.7</td>
<td>79</td>
<td>24.2</td>
</tr>
<tr>
<td>Always</td>
<td>23</td>
<td>4.9</td>
<td>22</td>
<td>6.7</td>
</tr>
<tr>
<td>Almost always</td>
<td>16</td>
<td>3.4</td>
<td>18</td>
<td>5.5</td>
</tr>
<tr>
<td>First few times</td>
<td>5</td>
<td>1.1</td>
<td>6</td>
<td>1.7</td>
</tr>
<tr>
<td>Not at all</td>
<td>14</td>
<td>3.0</td>
<td>6</td>
<td>1.7</td>
</tr>
<tr>
<td>All condom use</td>
<td>58</td>
<td>12.5</td>
<td>52</td>
<td>16.0</td>
</tr>
<tr>
<td>Always</td>
<td>22</td>
<td>4.7</td>
<td>13</td>
<td>4.1</td>
</tr>
<tr>
<td>Almost always</td>
<td>13</td>
<td>2.8</td>
<td>7</td>
<td>2.0</td>
</tr>
<tr>
<td>First few times</td>
<td>31</td>
<td>6.8</td>
<td>25</td>
<td>7.8</td>
</tr>
<tr>
<td>Not at all</td>
<td>36</td>
<td>7.8</td>
<td>27</td>
<td>8.4</td>
</tr>
<tr>
<td>All condom use</td>
<td>102</td>
<td>22.0</td>
<td>72</td>
<td>22.1</td>
</tr>
<tr>
<td>Always</td>
<td>20</td>
<td>4.2</td>
<td>19</td>
<td>5.8</td>
</tr>
<tr>
<td>Almost always</td>
<td>9</td>
<td>1.9</td>
<td>10</td>
<td>3.2</td>
</tr>
<tr>
<td>First few times</td>
<td>20</td>
<td>4.2</td>
<td>20</td>
<td>6.1</td>
</tr>
<tr>
<td>Not at all</td>
<td>111</td>
<td>23.9</td>
<td>83</td>
<td>25.4</td>
</tr>
<tr>
<td>All condom use</td>
<td>160</td>
<td>34.6</td>
<td>132</td>
<td>40.4</td>
</tr>
</tbody>
</table>

* P value for the difference in the gap by pattern of condom use with the more recent partner. There was no significant gender difference in the gap unless stated.

b Significant gender difference (P = 0.026): median gap for men, −1 day; median gap for women, 8 days.
research varied between reception staff teams, and in some services, short-staffing (19). However, we observed only one statistically significant sociodemographic difference between our sample and the participating clinics’ patient populations, which suggests that our data may be considered as broadly representative of patients who attended the clinics studied.

Asking patients partnership-specific questions about their 3 most recent partners provided us with detailed partnership data on over 2,000 partners, and because patients reported few partners on average, we had complete recent partnership histories for the majority of the participating patients. Nonetheless, we investigated the impact of using statistical weighting to weight the partners with detailed data to additionally represent those (of order greater than 3) for which these data were not collected, as described in previous publications (15, 25), so that our estimates were broadly representative of all partnerships in the 3 months before clinic attendance. However, weighting made very little difference to the distribution of the gap or our estimate of the proportion of gaps that were negative (data not shown).

Focusing on the 3 months before clinic attendance facilitated low item non-response, in contrast to an earlier study of the gap that excluded almost two thirds of its sample because of missing data (11). Our recent timeframe is also likely to have reduced recall error, and it provided a contemporary picture of the gap that was unaffected by temporal changes in partnership formation and partnership dynamics more generally. Using a pen-and-paper self-completion questionnaire meant that, in contrast to a face-to-face interview, we were not able to use prompts to help orient patients in sociotemporal space, which has been shown to assist with recall (16). We also acknowledge that limiting our sample to those patients who reported multiple partners in this timeframe led to underestimation of the gaps, as we excluded patients with reported gaps of more than 3 months between their partners.

Our results are not generalizable to the general population, as our target population was genitourinary medicine clinic patients. Although our respondents do not have the classic attributes of a “core group” of individuals who contribute disproportionately to STI transmission through high partnership numbers and connectedness (26), because they are attendees of a genitourinary medicine clinic, an understanding of their patterns of risk and exposure to risk of infection is particularly important. In addition, genitourinary medicine clinics constitute the main setting for STI and HIV diagnosis in the United Kingdom (27), such that genitourinary medicine clinics provide opportunities for behavioral intervention. Despite using a relatively large sample of patients recruited from contrasting genitourinary medicine clinics across England to capture different types of population, we acknowledge that because we used convenience sampling, it is also not possible to consider our data as fully representative of the genitourinary medicine clinic population.

Although we had data on acute STI diagnoses made during the patients’ episodes of care, for some patients we had insufficient statistical power to examine their relationship

Figure 7. Calculating the gap between partners when the first sexual encounter with a more recent partner occurred before the first sexual encounter with a former partner. Maximising STI Control for Local Populations Study, England, 2009. Calculating the gap as the number of days since the last sexual encounter with a former partner minus the number of days since the first sexual encounter with the next partner assumes that the first sex with a more recent partner occurred after the first sex with a former partner. However, in some instances, first sex with a more recent partner occurred before first sex with a former partner, for example, when there was a long-term partner alongside one or more briefer partnerships. If the gap is calculated as described (A), this will overestimate the negative gap, reflecting the long duration of the more recent partnership. As this is misleading, we propose that the gap should instead be calculated as the number of days the 2 partnerships were concurrent (B).
with the gap (although we would not have been able to establish causality because of cross-sectional survey data). However, as numerous previous studies have demonstrated concurrency as a risk factor for STI acquisition (5–8), we focused on assessing the role of the gap for transmission potential and relevance to health-promotion strategies.

Regarding the direction of transmission, our proposal that serial monogamy may equate to biologic concurrency applies to the onward transmission of STIs, that is, from a former partner to a more recent partner. This is not identical to behavioral concurrency because the sequential nature of serial monogamy means that transmission can only occur in one direction, regardless of the length of the gap.

Meaning of the study: possible mechanisms and implications for clinicians or policymakers

Our findings have implications for STI risk behavior research, including transmission modeling, and for developing and targeting STI prevention efforts. Concurrency and serial monogamy are not discrete and should be conceptualized as a continuum because the capacity for STI transmission within a population depends both on the length of gaps (positive or negative) and the extent to which negative and short positive gaps are protected against transmission by consistent condom use.

Distinguishing between behavioral concurrency (partnership overlap) and biologic concurrency (either overlap or gaps shorter than the remaining duration of infectivity) enables us to assess the capacity for transmission and sensitivity to changes in patterns of condom use for a population. Because HIV infectivity is greatest within the first 3 months of acquisition (2–4), the potential for HIV transmission in this population appears to be high given the high prevalence of concurrent partnerships (both behavioral and biologic) coupled with low consistent condom use. Indeed, Powers et al. suggested that short gaps between partners “provide an alternative explanation for rapid HIV spread and the corresponding importance of early infection” (28, p. 265) in Malawi, but this also applies to England.

Health professionals need to be aware that although patients may not have had behaviorally concurrent partnerships, the gap between partners may be sufficiently small that their partnerships were biologically concurrent. Assessment of gaps is therefore important in assessing individual risk and the risk profile of the population attending any health care setting. Prevention messages must emphasize the need for ongoing consistent condom use with new partners and encourage STI screening either before starting a new sexual partnership or before condoms are abandoned to reduce transmission through biologic concurrency.

It is difficult to study the impact of concurrency and serial monogamy on STI risk because there is no scope for randomization, and individual factors, such as sexual orientation, ethnicity, and differences in force of infection by epidemic phase and social structure (22), limit potential for generalizable studies. Nevertheless, there is growing interest in the measurement of transmission-relevant determinants and outcomes of partner notification (29, 30). Optimizing data collection practices at the time of partner notification would provide good opportunities to explore patterns of concurrency and could provide a robust basis for observational studies that focus on the relationship of serial monogamy and concurrency with STI outcomes. Some services in the United Kingdom already have excellent systems (31), whereas electronic health records are increasingly providing new opportunities for data collection and analysis (32).

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