Attack rates of human papillomavirus type 16 and cervical neoplasia in primiparous women and field trial designs for HPV16 vaccination


Background: Identification of human papillomavirus type 16 (HPV16) as the major risk factor for cervical neoplasia, and mass production of DNA free HPV capsids have paved the way to preventive vaccination trials. Design of such trials requires reliable attack rate data.

Objective: Determination of (1) HPV16 and (2) cervical neoplasia attack rates in primiparous women. Estimation of actuarial sample sizes for HPV16 vaccination phase IV trials.

Design: A longitudinal cohort study.

Methods: Population based Finnish Maternity Cohort (FMC) and Finnish Cancer Registry (FCR) were linked for the identification of two cohorts of primiparous women: (1) a random subsample of the FMC: 1656 women with two pregnancies between 1983–9 or 1990–6 and living in the Helsinki metropolitan area, and (2) all 72 791 primiparous women living in the same area during 1983–94. Attack rate for persistent HPV16 infection (1) was estimated in 1279 seronegative women by proportion of seroconversions between the first and the second pregnancy. Comparable 10 year cumulative incidence rate (CR) of cervical intraepithelial neoplasia grade III and cervical cancer (CIN III+) (2) was estimated based on cases registered at the FCR during 1991–4.

Results: The HPV16 attack rates were 13.8% (<18 years), 7.0% (18–19 years), 2.3% (21 years), 2.4% (23 years), and 4.5% (<25 years). Number of vaccinees required for a 5 year efficacy trial with persistent HPV16 infection as the end point ranged between 1000 and 3900, assuming 80% power, 90%–70% vaccine efficacy (VE), and misclassification. The CRs of CIN III+ were 0.3% (<18 years), 0.44% (18–19 years), 0.21% (20–24 years), and 0.28% (<25 years). Number of vaccinees required for a 10 year efficacy trial with HPV16 positive CIN III+ as the end point was 15 000 assuming 80% power, 90% VE, and 75% aetiological fraction of CIN III+ for HPV16.

Conclusions: The attack rates of HPV16 and CIN III+ identify primiparous women under 25 years of age among target populations for postnatal HPV vaccination at phase II/III trials.

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Keywords: attack rate; cervical neoplasia; human papillomavirus; vaccination

Introduction

Epidemiological studies have found human papillomavirus type 16 (HPV16) to be the major aetiological factor for cervical intraepithelial neoplasia (CIN) grade III and cervical cancer.1–2 HPV16 and other HPV DNA is found in more than 90% of the tumours.1 Infection with HPV16 is associated with an increased risk for the subsequent development of squamous intraepithelial lesions,3 cervical cancer,4,5 and other anogenital cancers.6 This has stimulated development of preventive vaccines against the virus to control cervical cancer, a common cancer in women worldwide.1 Production of empty capsids or virus-like particles (VLPs), in different expression vector systems was a breakthrough.7 Papillomavirus VLPs induce protection against experimental infection and tumour development in rabbits, dogs, and cows.8,9 A vaccine against another human tumour virus, hepatitis B virus (HBV), is based on the same principle.10 This vaccine has greatly reduced incidence of hepatitis B infection and number of chronic viral carriers in high endemic areas.11–13 The exclusive sexual transmission of HPV infection makes it an attractive target for vaccination since even low efficacy vaccines to STDs have a substantial effect at the population level provided wide coverage of the vaccination programme is guaranteed.14

Annually 65 000 pregnant Finnish women participate in screening for congenital infections7 with an option for postnatal immunisation. Of the primiparous women, about 50% become pregnant again/are rescreened within 5 years thus forming Finnish Maternity Cohort (FMC) of the National Public Health Institute (NPHI). Population based registration of cervical neoplasia by the Finnish Cancer Registry (FCR) was established in the 1950s and has 100% coverage.15 We exploited linkage of the FMC and FCR data files for the determination HPV16 and cervical neoplasia attack rates in primiparous women.
Table 1  HPV16 seroprevalence at the first pregnancy, number of seroconversions, and attack rates in age stratified primiparous women resident in the Helsinki metropolitan area during 1983–9 (A) and 1990–6 (B)

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>No of women</th>
<th>No (%) of seropositives</th>
<th>No of seroconversions</th>
<th>Attack rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤17</td>
<td>46</td>
<td>13 (28.3)</td>
<td>3</td>
<td>9.1</td>
</tr>
<tr>
<td>18-19</td>
<td>186</td>
<td>52 (28.0)</td>
<td>10</td>
<td>7.5</td>
</tr>
<tr>
<td>21</td>
<td>153</td>
<td>36 (23.5)</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td>23</td>
<td>183</td>
<td>31 (16.9)</td>
<td>6</td>
<td>3.9</td>
</tr>
<tr>
<td>25</td>
<td>92</td>
<td>18 (19.6)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>30</td>
<td>90</td>
<td>25 (27.8)</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤17</td>
<td>139</td>
<td>27 (19.4)</td>
<td>17</td>
<td>15.2</td>
</tr>
<tr>
<td>18-19</td>
<td>196</td>
<td>44 (22.5)</td>
<td>10</td>
<td>6.6</td>
</tr>
<tr>
<td>21</td>
<td>188</td>
<td>45 (23.9)</td>
<td>3</td>
<td>2.1</td>
</tr>
<tr>
<td>23</td>
<td>191</td>
<td>49 (25.7)</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>25</td>
<td>97</td>
<td>17 (17.5)</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>30</td>
<td>95</td>
<td>30 (31.6)</td>
<td>1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

During 1991–4 the following age stratas: ≤17, 18–19, 20–24, 25–29, and ≥30 years consisting of 14 027, 9092, 28 852, 14 732, and 6088 women, comprised 29 049, 19 149, 59 966, 30 112, and 12 387 person years for the first 5 years of follow up, and 14 275, 9151, 27 550, 13 718, and 5985 person years for the next 5 years of the follow up, respectively.

LABORATORY ANALYSIS
HPV16 IgG antibody analysis was done by a standard ELISA using ultracentrifugation purified baculovirus expressed HPV16 VLPs comprising both the L1 and L2 proteins. An optical density of 0.100, previously shown to discriminate HPV16 infected, sexually experienced women from sexually inexperienced women was used as the cut off level.

STATISTICAL ANALYSES
HPV16 attack rate was defined as the proportion of HPV16 seroconversions between serum sampling at approximately 12 weeks of gestation of the first and the second pregnancy among those seronegative at the first pregnancy. For women under 25 years of age, age-adjusted HPV16 attack rate was estimated using the numbers of corresponding primiparous women resident in the Helsinki metropolitan area in 1990–1 as weights. Overall HPV16 seroprevalence at the first pregnancy was similarly estimated as weighted average of age specific seroprevalences.

CIN III+ attack rate was defined as the 10 year cumulative incidence rate (CR) of cases diagnosed during 1991–4. For women under 25 years of age, age adjusted annual incidence for the first and the last 5 years and the CR of CIN III+ were estimated as weighted averages of the age specific rates using the age specific numbers of corresponding person years as weights.

Trends of the attack rates by age were evaluated using the Cochran–Armitage trend test by STATXAT-3 (Cytel Software Corporation, Cambridge, MA, USA).

Numbers of vaccinees required for a 1:1 placebo controlled efficacy trial were estimated with 80% power (p=0.05) using the observed HPV16 and CIN III+ attack rates, and assuming different levels of vaccine efficacy (VE). The estimates were calculated using a publicly available statistical software (Public Health Laboratory Service, Colindale).

Results
In 1983–4 and 1990–1 the age specific HPV16 seroprevalence among primiparous women varied between 17–28% and 18–32% (table 1). The age adjusted HPV16 seroprevalence was 24% for both time periods. Among the seronegatives, the combined HPV16 attack rates varied between 13.8 and 1.3, and showed statistically an extremely significant decrease by increasing age at
Table 3 Incidence (I/10^5) and 10 year cumulative incidence rate (CR) of cervical intraepithelial neoplasia grade III and invasive cervical cancer in primiparous women resident in the Helsinki metropolitan area during 1983–94

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Follow up time (years)</th>
<th>I/10^5</th>
<th>0–5</th>
<th>6–10</th>
<th>0–10</th>
<th>CR</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–19</td>
<td></td>
<td>7.0</td>
<td>292</td>
<td>56.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–24</td>
<td></td>
<td>2.3</td>
<td>914</td>
<td>1782</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25–29</td>
<td></td>
<td>2.4</td>
<td>876</td>
<td>1706</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–24</td>
<td></td>
<td>1.3</td>
<td>1626</td>
<td>3176</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;25</td>
<td></td>
<td>4.5</td>
<td>460</td>
<td>898</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Between the first and the second pregnancy.

Table 4 Number of women required for a double blinded efficacy trial on preventive HPV16 vaccination with cervical intraepithelial neoplasia grade III and invasive cervical cancer as the end point

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>CIN III+ attack rate %</th>
<th>Number of vaccines at a given VE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90%</td>
<td>70%</td>
</tr>
<tr>
<td>≤18</td>
<td>0.33</td>
<td>6446</td>
</tr>
<tr>
<td>18–19</td>
<td>0.44</td>
<td>4832</td>
</tr>
<tr>
<td>20–24</td>
<td>0.25</td>
<td>10158</td>
</tr>
<tr>
<td>&lt;25</td>
<td>0.28</td>
<td>7600</td>
</tr>
</tbody>
</table>

Discussion

No major differences in the age specific HPV16 prevalence or incidence were found between the 1980s and 1990s among primiparous women in the Helsinki metropolitan area. The HPV16 attack rate between samples taken at the first and the second pregnancy (that is, within an average of 2.5 years) for women under 25 years of age was 4.5%. Annual HPV incidence in Finnish women of similar age by cytology is 7%. This is in accordance with our average attack rate assuming that HPV16 accounts for about one third of cytologically detectable HPV infections, and does not suggest major differences between the pregnant and general populations of young women. The HPV16 attack rates rapidly decreased with increasing age at the first pregnancy, although the mean time between the two pregnancies remained comparable (data not shown). This is also in accordance with the PCR studies that show a peak of all genital HPV and HPV16 infections between 20–24 years of age.

HPV VLP serology has been established in numerous studies and shows good inter-laboratory agreement. Persistence of HPV16 IgG antibodies in our material has been assessed in detail elsewhere; briefly, loss of HPV16 antibodies within the 5 year follow up time was extremely rare 0.5%. Compared with polymerase chain reaction (PCR) the sensitivity/specificity of HPV16 serology range from 50%/95% to 99%/90% depending mostly on the study material—for example, population, type of lesions, prevalent versus incident infections. According to our experience the median time from HPV16 acquisition to detectable antibody response is 4 rather than 8 months, which suggests that only a minor proportion of the infections we are identifying by seroconversion may have taken place before the pregnancy. After correction for misclassification, the HPV16 seroprevalence estimates ranged between 17% and 47%. Comparable considerations for the HPV16 attack rate among women under 25 years of age yielded a range of 3.2% to 8.8%. Thus, about every fifth HPV16 infection by the second pregnancy occurs between the first and the second pregnancy.

Persistent HPV infection is considered a prerequisite for development of an HPV associated cancer. Detection of viral DNA at the cervix by PCR has the advantage of a higher sensitivity but without serial sampling will also detect short lived, transient infections. By limiting our study to seronegative women and using seroconversion, a marker that primarily detects persistent HPV infections we were able to estimate the attack rate of biologically relevant infections...
among susceptible women under the closest possible surveillance—that is, in between two pregnancies. Considering the misclassification, and the fact that 50% of the women will be pregnant again within the next 5 years, but that practically none (<2%) of these women will be lost to follow up, 1000 and 3500 are safe estimates of minimum and maximum numbers of vaccinees required for a 5 year efficacy trial with persistent HPV16 infection as the end point.

During the early 1990s the annual incidence of CIN III+ in young primiparous women followed for 6–10 years was relatively high (48.1/100 000). This probably reflects the high HPV16 attack rates in the corresponding age cohort 6–10 years earlier. The first round of the organised mass screening for cervical neoplasia in the Helsinki metropolitan area takes place at the age of 25 years. Since the 1970s the relatively constant protective effect of organised mass screening rounds on the CIN III+ incidence is clearly visible in the oldest age cohort with first pregnancy ≥30 years of age. No CIN III+ cases were found between 6 to 10 years of follow up in these women. Considering future vaccination trials the effect of organised screening is, however, possible to control for by randomisation whereas the effect of opportunistic screening that dominates many developed countries cannot be controlled.

For design of HPV vaccination trials, the choice of time of vaccination and end points is critical. Practically all women who would benefit from preventive HPV vaccination are susceptible to both infection with the genital HPVs and pregnancy. The least likely time period for a woman to be pregnant is the 3 months after delivery. This favours postnatal vaccination in women. Considering the misclassification, among susceptible women under the closest surveillance of cancer, such as CIN III, or cervical cancer as the end point. The Finnish Cancer Registry receives systematic quality controlled information on all cases of CIN III+ diagnosed in Finland precluding losses to any follow up period. Assuming that 65% to 75% of CIN III+ lesions in Finland are HPV16 positive, 15 000 is the best available estimate of the number of HPV16 negative women under 25 years of age required for a long term trial with CIN III+ as the end point. As 65% to 90% of women who will acquire HPV16 infection (as determined by seropositivity) by their second pregnancy had acquired it week 12 of their first pregnancy primiparous women would not be sufficient target group for a phase IV vaccine trial where such high numbers of subjects was required. Enrolment of large numbers of adolescents at different subsidiaries of the organised health care would be required for such a study.

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Further mailings will follow to MSSVD and ASTDA members. People who do not belong to either of these organisations and who would like to receive further information should contact: Dr Keith Radcliffe, Honorary Assistant Secretary, MSSVD (fax: +44 (0) 121-237 5729; email: k.w.radcliffe@bham.ac.uk).
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