Female-only vaccination programmes for human papillomavirus (HPV) have been introduced in many countries aimed at the prevention of cervical cancer in women. One HPV vaccine is registered for male vaccination, but boys, men, or both, are not yet included in nationally funded HPV vaccination programmes. In this Review we discuss the different considerations relevant to the introduction of population-wide HPV vaccination of boys in Australia, which was the first country to publicly fund HPV vaccination of girls. Several factors need to be taken into account during decision making around the introduction of population-based vaccination programmes, such as local disease burden, vaccine efficacy, vaccine safety, and cost-effectiveness. Social and ethical factors are also important. Although evidence for men is increasing in these areas, uncertainties need to be kept in mind. The features discussed in this Review are likely to be applicable, with caveats, to policy making in other developed countries.

Introduction

Australia was the first country to introduce a government-funded national human papillomavirus (HPV) vaccination programme aimed at reducing the incidence of cervical cancer in women. More than 70% of invasive cervical cancers are associated with HPV types 16 and 18, against which the bivalent (Cervarix, GlaxoSmithKline, Brentford, UK) and quadrivalent (Gardasil, Merck, Whitehouse Station, NJ, USA) HPV vaccines provide protection.\(^1\) The Australian HPV vaccination programme was started in 2007. Through this programme the quadrivalent vaccine, which also protects against HPV types 6 and 11, is delivered in schools to girls aged 12–13 years. Vaccines provided by the Australian National Immunisation Program, such as the quadrivalent HPV vaccine, are free at the point of care and achieve high coverage among adolescents via school-based delivery.\(^2\) A funded catch-up programme for older girls and women aged up to 26 years, delivered in schools and via community-based immunisation providers, was in place until the end of 2009. A national HPV vaccination register has been established to monitor vaccine coverage and the effects of the programme.\(^3\)

Despite the introduction of HPV vaccination programmes for girls and young women in many countries, few have recommendations for HPV vaccination of boys and young men. Since December, 2011, both the US Advisory Committee on Immunization Practices and the Canadian National Advisory Committee on Immunization have recommended vaccination of adolescent boys and young men with the quadrivalent vaccine.\(^4,5\) In mid-2010 the Australian regulatory agency, the Therapeutic Goods Administration, extended the registration of the quadrivalent vaccine to include its use in boys and men up to age 26 years for the prevention of external genital lesions and infection with HPV types 6, 11, 16, and 18. This decision prompted consideration of how best to use this vaccine in boys and men in Australia. The criteria for the integration of new vaccines or extension of existing publicly funded immunisation programmes are complex and few analytical frameworks exist to assist decision making.\(^6,7\) Factors that have affected the introduction of HPV vaccination programmes for girls and women in European countries have been reported,\(^8,9\) but comprehensive assessments of the addition of boys, men, or both, to existing female vaccination programmes have not.

In this Review we discuss the available data on the key factors related to the introduction of routine male HPV vaccination in Australia. The considerations are likely to be applicable to policy making in other developed countries, with caveats, which we discuss.

Epidemiology of HPV infection and disease in men

Knowledge of the natural history of HPV infection and associated diseases in men is increasing, but remains less extensive than that for women. As in women, most HPV infections in men are transient, asymptomatic, and resolve spontaneously. However, evidence suggests that in women peak prevalence of HPV infection is seen in adults younger than 25 years—ie, generally in the period after sexual activity begins\(^10,11\)—but in men HPV infection is evident at all ages and the risk of acquiring new HPV infections remains stable over time.\(^11,12\) The point prevalence of HPV infection in asymptomatic men varies with age, risk status, geographical location, and anatomical location screened.\(^12,13\) Similar to women, the most important risk factor for external genital HPV infection in men is the number of sexual partners.\(^13,14\) Although HPV infection is common, only a small proportion of infections persist and have the potential to give rise to non-cancerous or cancerous lesions. The HPV-associated disease that is unique to men is penile intraepithelial neoplasia (PIN), which, overall, progresses to cancer of the penis in less than 1% of cases.\(^15,16\) As in women, men also develop HPV-attributable cancers of the anus, the oral cavity, and the oropharynx, as well as non-cancerous lesions, such as genital warts and recurrent respiratory papillomatosis. All cases of genital warts and most anal cancers are attributed to HPV infection, but the reported estimates for penile cancers and oral and oropharyngeal cancers vary notably.
The incidence of HPV-associated cancers in Australian men is low compared with that for cervical cancer before the introduction of HPV vaccination.22 The incidence of anal squamous cell carcinoma in men in 2005 was marginally lower than that in women (1.5 per 100 000 vs 1.6 per 100 000).23 The average annual increase in incidence of anal cancer in men, however, has been almost twice that in women over the period 1982–2005.27 The incidence of cancers of the oropharynx associated with HPV has also increased in men, whereas it remained stable in women.28 By contrast, the incidence of cancers in men not related to HPV in sites in the head and neck has declined.22,23,29 The estimated number of new cases of cancers associated with HPV 16 and 18 in Australian men in 2005 (before the female vaccination programme was started) was 280 (31 cases of penile cancer, 131 cases of oropharyngeal cancer, and 118 cases of anal cancer), which is around a quarter of the total number of diagnosed cancers associated with HPV 16 and 18.22

Men who have sex with men (MSM) have consistently been identified in Australia and other developed countries as being at increased risk of HPV infection and HPV-related disease. The reported point prevalence values for anal HPV infection in HIV-negative MSM range from 32.8% to 93.5%.24,30,35 By contrast, a study of intra-anal HPV infection among 902 men who have sex with women reported a prevalence of 12%.17 Infection with multiple HPV genotypes, a large diversity of HPV types, and a long time to clear infection are frequent features of HPV infection in MSM.22,31,34 An incidence of anal cancer in MSM more than 30 times higher than that in other men has been reported.22,25 In Australia, the proportion of men classified as MSM (identified as homosexual or bisexual, rather than reporting some same-sex sexual experience) is estimated to be 2.5–8.6% of the general population.19 Thus, the incidence of anal cancer among MSM in Australia can be estimated to be similar to that of cervical cancer before the cervical cancer screening programme was introduced. MSM are also at increased risk of developing cancers in sites that are associated with HPV in the oral cavity and the oropharynx compared with other men.36,40

Non-cancerous HPV-associated lesions, such as genital warts, are much more common than HPV-associated cancers. The estimated annual incidence of anogenital warts among Australian men is 2.06 per 1000 of the general population. This value is marginally lower than that for women (2.31 per 1000).41 HPV types 6 and 11 are associated with more than 90% of genital warts in men and women.42 The estimated incidence of anogenital warts in MSM is almost ten times that in the general population.43

Vaccine efficacy

In men aged 16–26 years

The efficacy of HPV vaccination in men has been assessed only for the quadrivalent vaccine. One international, randomised, double-blind, placebo-controlled trial was done in 4065 boys and men aged 16–26 years, who received a three-dose course of the quadrivalent vaccine or placebo and were followed up for 3 years.42 The primary efficacy outcome was development of external genital lesions (genital warts, PIN, or penile cancers) related to HPV infection (with type 6, 11, 16, or 18). Vaccine efficacy against a second composite outcome of anal intraepithelial neoplasia and anal cancer was assessed separately in a subpopulation of 602 MSM.43,44 The per-protocol population comprised study participants who were negative for HPV types 6, 11, 16, and 18 on serology and DNA testing at baseline and throughout the vaccination course, and who correctly completed the course of all three doses. In this population, the quadrivalent vaccine showed high efficacy for the primary outcome, but most (28 [90%] of 31) external genital lesions prevented were genital warts.42 In the MSM substudy, efficacy was also high for the combined endpoint of anal intraepithelial neoplasia and anal cancer (table 2).43–45 Of note, however, is that no cases of penile, perineal, perianal, or anal cancer were reported, which is consistent with the low incidence of these cancers and their development times. Vaccine efficacy in the per-protocol population was suggested to reflect the maximum efficacy that would be achievable with vaccination of preadolescent boys not yet exposed to vaccine HPV types. Completion of a three-dose vaccine course would, however, be less likely in a real-life setting.

The clinical trial of the quadrivalent vaccine in men has shown efficacy against genital warts but not directly against HPV-associated anogenital cancers in men.46 Vaccine efficacy against persistent infection and precancerous lesions might be plausible as surrogate endpoints for efficacy against anogenital cancers. This approach was adopted when a female-only vaccination programme was being considered, after a preventive effect was seen for high-grade cervical intraepithelial neoplasia, which is evident before progression to cervical cancer. However, the reliability of such inferences, when based on surrogate clinical outcomes might be less certain for men than for women because the course of HPV-associated disease in men is less-well understood than that of cervical HPV infection progression to cervical cancer in women. For example, the proportion of persistent HPV infections that progress into intraepithelial neoplasia and the subsequent proportion of these lesions that progress into cancer is not well defined.47 Giuliano and colleagues48 reported a trend towards reduction in PIN for the quadrivalent vaccine, but the low absolute incidence of cases (none in vaccine recipients and three in controls) meant the estimates
were non-significant (table 2). Although anal intraepithelial neoplasia was not a prespecified study endpoint, significant protection against lesions in stage 2 or higher was seen in the MSM subgroup (efficacy 74·9%, 95% CI 8·8–95·4%).

The protective efficacy of the quadrivalent vaccine against anal intraepithelial neoplasia among MSM study participants is expected to be due to prevention of persistent infection with high-risk HPV types in the anal epithelium. As with cervical cancer, persistent HPV infection is probably a necessary precursor for progression to invasive disease in men. Among the MSM cohort studied by Palefsky and colleagues, persistent intra-anal infection, defined as the detection of HPV DNA by PCR for the same HPV type in two consecutive swabs taken from multiple genital sites or biopsy samples, related to infection with HPV types 6, 11, 16, or 18 was lowered by 95% (95% CI 80·0–99·0; table 2). Likewise, good efficacy was seen for protection against persistent external genital infection in the penile, scrotal, and perineal or perianal areas in the entire study cohort (85·6%, 95% CI 73·4–92·9; table 2). Thus, a subsequent reduction in PIN and penile cancers would be expected in a study that was adequately powered and that had a follow-up period long enough for high-grade disease to develop.

The efficacy of HPV vaccine against HPV-related oral cavity and oropharyngeal lesions, such as head and neck cancers and recurrent respiratory papillomatosis, is yet to be assessed in clinical trials. The translocation of HPV 16 L1-specific serum IgG into oral cavity fluid has been reported in women after vaccination with the quadrivalent vaccine. If the disease course of HPV infection is similar in oropharyngeal epithelia to that in anogenital sites, vaccination might protect against oral cavity and oropharyngeal lesions. At a population level, the reduction in the reservoir of HPV in genital sites by population-wide vaccination is likely to lower the rates of oral cavity and oropharynx HPV infections; evidence indicates that markers of sexual history that correspond to an increased likelihood of genito-oral HPV transmission are also risk factors for HPV-related cancers of the head and neck.

**Extrapolation to adolescent boys**
The efficacy of HPV vaccines has not been assessed in young adolescent boys, who would be the expected target group for prophylactic male HPV vaccination programmes. However, immunogenicity, as measured by antibody titres after vaccination can be viewed as a reasonable proxy with which to predict protection in this age group, as was previously accepted for girls: the immunogenicity of the quadrivalent vaccine in adolescent boys was non-inferior to that in men aged 16–26 years, in whom vaccine efficacy has been reported. The bivalent vaccine is also highly immunogenic in boys aged 10–18 years, although clinical efficacy has not been reported.

### Table 2: Summary of published data on HPV-associated diseases in Australian men before the introduction of female HPV vaccination

<table>
<thead>
<tr>
<th>Disease</th>
<th>Annual Incidence (per 100 000 population)</th>
<th>Annual Number of New Cases</th>
<th>Approximate Proportion Attributable to HPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genital warts</td>
<td>206</td>
<td>20 550</td>
<td>100%</td>
</tr>
<tr>
<td>Anal cancer</td>
<td>15</td>
<td>149</td>
<td>85%</td>
</tr>
<tr>
<td>Penile cancer</td>
<td>0.7</td>
<td>69</td>
<td>20–60%</td>
</tr>
<tr>
<td>Oral and oropharyngeal cancer</td>
<td>2.5</td>
<td>264</td>
<td>12–63%</td>
</tr>
</tbody>
</table>

HPV=human papillomavirus. *Data from the Bettering the Evaluation of Care and Health General Practice, primary care, cross-sectional database, in 2000–06, extrapolated to the entire Australian population, with adjustment for genital warts managed at sexual health clinics. Annual incidence is calculated on the basis of the estimated Australian population in 2004. 12005 data sourced from the Australian Institute of Health and Welfare. Annual incidence was standardised for age with the 2001 Australian population estimates. Codes from the Australian Modification of the International Classification of Diseases, 10th revision, are used for malignant neoplasms: anus and anal canal, C21; penis, C60; oropharynx comprising tonsil, C09, and oropharynx, C10. †Range includes cancers of the base of the tongue in addition to the tonsils and oropharynx.

### Table 2: Efficacy of quadrivalent vaccine in men aged 16–26 years in a randomised controlled trial

<table>
<thead>
<tr>
<th>Vaccine group</th>
<th>Controls</th>
<th>Efficacy (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persistent</td>
<td>95%</td>
<td>100%</td>
</tr>
<tr>
<td>Persistent intra-anal*</td>
<td>77.5%</td>
<td>90·4% (69·2–98·1)</td>
</tr>
<tr>
<td>Incident</td>
<td>44·7%</td>
<td>100%</td>
</tr>
</tbody>
</table>

HPV=human papillomavirus. PIN=penile intraepithelial neoplasia. NA=not applicable (no cases of specified endpoint). AIN=anal intraepithelial neoplasia. Vaccine efficacy was determined in a substudy of men who have sex with men and data were obtained from references 43–45. 1A 97·5% CI is reported because a multiplicity adjustment is applied.
Cross-protection
Immunity after natural HPV infection is generally specific to the HPV type. Nevertheless, some low-level vaccine-induced cross-protection against phylogenetically related non-vaccine HPV types has been noted in post-hoc analyses in clinical trials of the bivalent and quadrivalent vaccines in women.62,63 Similar cross-protection in men seems likely. In a clinical trial of the quadrivalent vaccination in men, evidence at the end of the study period (36 months) was insufficient to show protection against non-vaccine HPV types, because most cases of disease in the control and vaccine groups were caused by vaccine HPV types.64 The extent to which cross-protection could affect the burden of HPV-associated disease is unclear, but it is likely to be less important for male cancers than for cervical cancer because a much greater proportion of disease is related to HPV types 16 and 18.65

Requirement for a booster dose
The efficacy of the quadrivalent vaccine in men has been assessed up to 36 months after the first dose. On the basis of the similarity of geometric mean titres after vaccination in men and women, the expectation that protection will be maintained for similar periods in both sexes seems reasonable. Protection after immunisation of women with the quadrivalent vaccine has been reported for as long as 5 years.65 Longer-term protection (8-5 years) has been seen in women who were vaccinated with a monovalent HPV 16 prototype vaccine.66 Since antibody titres seem to plateau and breakthrough disease has not been reported, the need for a booster dose within 5 years of vaccination in men or women is unlikely. The need for a booster dose at any time will need to be reassessed as vaccinated cohorts from trials done before licensing are monitored over increasing periods of time. Should a booster dose ever be required, recipients of the quadrivalent and bivalent vaccines have shown marked anamnestic responses to booster doses in clinical trials.62,63

Safety
Clinical trial data available for male participants aged 9–26 years show a similar safety profile for the quadrivalent vaccine to that seen in girls and young adult women.66 Postmarketing surveillance of the quadrivalent vaccine in women worldwide, who have received more than 65 million doses of vaccine, has revealed no major safety issues. Vaccination would be expected to have a similar safety profile in men.62,63

Benefits to women from male vaccination
Because male vaccination reduces the risk of incident and persistent infection with vaccine HPV types, the assumption that transmission will also be lowered seems reasonable. Thus, in addition to the direct benefit that HPV vaccination will provide to male recipients, a population benefit to unvaccinated members of both sexes through herd immunity seems likely. Herd immunity after the introduction of population-based HPV vaccination in girls and young women (age 12–26 years in 2007) has been suggested. A retrospective sentinel surveillance study of new cases of genital warts diagnosed at eight sexual health services across Australia, between 2004 and 2009, showed a 59% reduction in the number of new diagnoses in resident women eligible for vaccination.64 Additionally, a 39% reduction in genital warts cases was recorded among age-matched heterosexual men who were resident in Australia and ineligible for HPV vaccination. No decline in the number of cases was seen in non-resident women, women who were ineligible for free vaccination, or in MSM.

Whether routine vaccination of boys will result in any benefit over and above that which is already achieved through existing female vaccination programmes will need to be considered. In Australia the coverage with a three-dose vaccination course in girls aged 12–13 years was estimated in 2011 to be 73%. A dynamic model of HPV transmission has estimated that a male vaccination programme introduced in 2010 with similar coverage to that achieved in women (71–78%) would be expected to prevent an additional 24% of new HPV infections by 2050 compared with the current female programme alone. The additional long-term reduction in the rate of HPV-associated cancers in men is estimated to be 6–8%.62 The incremental benefit in reduction of disease burden would be larger for men than for women, but slight overall. This model did not take into account HPV transmission among MSM. The proportion of male cancers prevented by a female-only programme could, therefore, have been overestimated.

Other models based on international data have also predicted that the greatest benefit of HPV vaccination will be achieved through vaccination of girls alone. Nevertheless, model parameters have been identified that increase the predicted benefit of extending HPV vaccination to include men: when vaccine coverage in women is lowered, the duration of anticipated vaccine-induced immunity in women is shortened, and when the benefits of vaccination on an increased number of HPV diseases are considered. Each of these features needs to be considered specifically for individual settings. For example, in countries with low vaccine uptake, male vaccination might have greater benefits than in countries with high uptake. In many settings, however, where female vaccine uptake is low, attempts to increase female vaccine coverage might be more efficient to prevent cervical cancer than the addition of male vaccination, since the latter would in most populations effectively double the number of vaccinations that needed to be delivered.64 The accuracy of model-based predictions for HPV, particularly in men, is limited by a high degree of uncertainty for many factors, including the estimated proportion of disease associated with HPV among men, the disease course of HPV infection, and the efficacy of HPV vaccines.
Cost-effectiveness

Published mathematical models have been used to assess the cost-effectiveness of various male and female HPV vaccination scenarios. Several models have shown that vaccination of boys is not cost effective compared with vaccination of girls alone, on the basis of an incremental cost-effectiveness ratio threshold of US$50 000 (or local currency equivalent) per quality-adjusted life-year. This threshold is often used arbitrarily for cost-effectiveness analyses. Gained quality-adjusted life-years align with estimates of health benefit and, therefore, several common factors have been shown to affect cost-effectiveness, including the level of coverage, vaccine efficacy, and duration of vaccine-induced immunity achieved in women.

The other factors that ultimately and substantially affect the cost-effectiveness of introducing HPV vaccination to one or both sexes are the vaccine and programme-implementation costs. Many models had previously assessed cost-effectiveness of male vaccination only in relation to a reduction in cervical cancer in women, but newer models have begun to take into account the benefit that would be directly gained in male outcomes, which also affects estimates of cost-effectiveness.

Only one published independent study has compared the cost-effectiveness of female-only vaccination with that of male and female vaccination in the Australian setting. The cost-effectiveness of different HPV vaccination strategies was compared with that for cervical screening alone. The incremental cost-effectiveness ratio almost doubled when vaccination of boys was included, compared with female-only vaccination, when the same vaccine cost was assumed. However, the model of the dual-sex programme only considered the benefit of vaccination against HPV infection in male recipients, whereas all vaccination strategies modelled the benefit against both infection and cervical cancer in female recipients.

In Australia, the process for assessing and recommending new vaccines for public funding under the National Immunisation Program includes an evaluation of cost by the Pharmaceutical Benefits Advisory Committee. Although no absolute threshold of willingness to pay is reported, published experience suggests that a pharmaceutical application with an incremental cost-effectiveness ratio of less than around AU$60 000 (roughly AU$42 000 in 1998) is unlikely to be rejected. The Pharmaceutical Benefits Advisory Committee requires a vaccine sponsor—generally a pharmaceutical company—to submit economic analyses of the proposed vaccination programme scenario. The analyses must take into account the epidemiology of the disease in the Australian population, as well as all relevant data on the vaccine and its delivery in the local context. Input on factors around clinical use is provided by the Australian Technical Advisory Group on Immunisation.

In late 2011, a manufacturer application made to the Pharmaceutical Benefits Advisory Committee to include the quadrivalent vaccine for administration to boys aged 12–13 years via the National Immunisation Program (with a catch-up programme over 2 years for boys aged 14–15 years) resulted in a positive recommendation by the Pharmaceutical Benefits Advisory Committee on the basis of acceptable cost-effectiveness compared with female-only vaccination, although the cost-effectiveness modelling provided, including the vaccine cost, is not available in the public domain and the final decision is awaited. An application earlier the same year had been rejected on the basis of unacceptably high and uncertain cost-effectiveness.

Male vaccination outside a population-based programme

In the absence of universally funded vaccination of adolescent boys, the question of who should receive HPV vaccine remains. Clinical trial data suggest that vaccination of adolescent boys or young adult men before sexual activity begins would be of potential benefit on an individual level. In Australia, however, vaccination in this age group is unlikely to reach the levels required to achieve population benefits in the absence of a funded programme.

Vaccination seems particularly compelling for MSM, who are anticipated to receive the least indirect benefit from the female-only programme, yet are at increased risk of HPV infection and disease. Such a targeted approach was predicted in the USA to be cost effective in terms of prevention of genital warts and anal cancer.

Implementation of such a strategy would, however, be complex, for instance in relation to reaching MSM before or at an early stage of sexual activity. A survey of MSM attending a sexual health clinic in Melbourne, Australia, showed that most would be willing to disclose their sexual orientation to receive free HPV vaccine, but they would not feel comfortable doing so until at least age 20 years; by this age a median of 15 sexual partners was reported. More data are required on the potential effects of vaccination on disease rates in MSM.

Acceptability of male vaccination

The success of any future male HPV vaccination programme (either targeted or population wide) will largely be affected by the degree of knowledge that adolescent boys, parents and guardians, and health-care providers have about HPV-related diseases and the available vaccines. In Australia and in other countries, communication efforts surrounding HPV vaccination programmes have largely framed HPV vaccination as an intervention for the prevention of cervical cancer. Hence, by comparison with women, boys and men generally have poor understanding of HPV, its associated diseases, and the available vaccines. For instance, a population-based survey done in Australia after the introduction of the school-based HPV vaccination programme, showed higher awareness of HPV among women than men (62.8% vs 38.3%). In addition, more
Review

Search strategy and selection criteria

We searched for articles published from January, 2006, to June, 2011, in Medline, Embase, and the Cochrane Library, with the search terms “human papillomavirus”, “HPV”, “papillomavirus infections”, “papillomavirus vaccines”, “Gardasil”, “Cervarix”, “immunization”, “male”, “men”, and “boy”. To keep bias to a minimum we applied no language parameters. We also searched ClinicalTrials.gov and manually searched conference abstracts, personal files, and reference lists of retrieved papers to identify additional trials.

respondents were aware of the association between HPV and cervical cancer than of its association with genital warts. Because the degree of acceptance for vaccination correlates with knowledge of HPV, if a dual-sex HPV vaccination programme were implemented, communication and education strategies would need to promote vaccination as a preventive measure against HPV-associated cancers in both sexes. Measures would be required, though, to protect against dilution of the highly targeted and successful message about prevention of cervical cancer.

Awareness of HPV and available vaccines is higher among MSM than among heterosexual men in Australia.81 This finding supports differences reported in international qualitative studies of HPV acceptability among men.82–85 Despite the greater acceptability among MSM, however, good communication and education strategies would still be required as part of a targeted vaccination programme to ensure that vaccine uptake is achieved before or soon after the onset of sexual activity and exposure to HPV. Such strategies would, however, be more complex to implement than dissemination of the message about male vaccination in a population programme, and would have several additional social considerations.

Conclusions

Although the data on HPV-related disease in men are increasing, understanding is still less than that for women. Nevertheless, the evidence for efficacy of the quadrivalent vaccine in boys suggests that male HPV vaccination in Australia and other countries is worthy of consideration. Extension of the Australian National Immunisation Program to include HPV vaccination for boys has been shown to be cost effective and is under consideration by the Australian Government. In the context of existing uncertainties, decisions on the introduction of male vaccination in other developed countries require consideration of cost-effectiveness, whether benefits over and above those gained by female-only vaccination are anticipated, disease epidemiology, programme costs, and other local factors. Additionally, social and ethical considerations that are not factored in to existing cost-effectiveness models should be taken into account. The experiences and data gained over time from countries where universal male vaccination is introduced will be essential to further understand the impact of dual-sex HPV vaccination.

Contributors

All authors were involved in conception of this paper. MG, SJ, and CC reviewed the literature and wrote the initial draft. JB, NG, and KM provided critical revisions.

Conflicts of interest

NG is the Chair and KM and JB are members of the Australian Technical Advisory Group on Immunisation HPV working party. JB is an investigator on an Australian Research Council Linkage Grant, for which CSL Biotherapies is a partner organisation, and on a national HPV prevalence study (2005–08) that received partial, equal, and unrestricted funding from CSL Biotherapies and GlaxoSmithKline. The other authors declare that they have no conflicts of interest.

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