Vaccine 30 (2012) 3459–3462

Contents lists available at SciVerse ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Health and economic impact of the seasonal influenza vaccination programme in England

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ARTICLE INFO

Article history:
Received 15 December 2011
Received in revised form 17 February 2012
Accepted 8 March 2012
Available online 22 March 2012

Keywords:
Influenza
Vaccine
Cost-effectiveness

ABSTRACT

Background: The seasonal influenza vaccination programme in England targets individuals over 65 years old and in clinical risk groups.
Methods: A model of influenza transmission and disease was fitted to weekly primary care consultations due to influenza in a typical pre-pandemic season (2006/2007). Different scenarios were constructed about influenza severity and how well vaccines match circulating strains to assess the impact and cost-effectiveness of the current vaccination programme.
Results: A well-matched vaccine may reduce the incidence of laboratory-confirmed influenza illness from 8.2% (95% range 4.3–13%) to 5.9% (95% range 2.9–9.7%), with 56–73% of this due to indirect protection. The programme is likely to be cost-effective unless both low severity and poor matching is assumed.
Conclusion: The current seasonal influenza vaccination programme appears to substantially reduce disease burden and provides good value for money.

1. Introduction

Annual seasonal influenza vaccination is recommended for people most at risk of infection and its complications in many high-income countries [1]. In England, vaccination is recommended for individuals aged 65 years and over, health care workers, pregnant women and those in clinical risk groups (people of all ages with chronic respiratory, heart and renal diseases, diabetes and immunosuppression due to disease or treatment).

However, the age and clinical risk groups considered most at risk of infection and hence targeted by vaccination differ widely between countries [1]. The impact and economic rationale of country-specific recommendations is not always well established, and indeed was recently debated in the United Kingdom. Some economic models have examined the impact of extending recommendations to other groups such as children under 12 years or adults 50–64 years [2,3]. However, most of these are static models that do not realistically model infection transmission, and hence indirect protection in non-vaccinated individuals such as household members of vaccinated children. Some models have tried to estimate the magnitude of such indirect protection based on household secondary attack rates in household studies [4,5], but these estimates will inevitably have limited validity outside the study population.

Any model considering the health and economic impact of options for influenza vaccination would first need to establish the burden of influenza in the absence of vaccination, then the (direct and indirect) benefit of vaccination. The burden of influenza-related disease in the absence of vaccination largely depends on the pre-existing level of immunity in the population (as a result of vaccination or infection in previous years), the rate at which influenza is transmitted between different groups in the population and the severity of disease caused by the circulating strains. The impact of vaccination depends on the coverage of the vaccine in a non-linear way because of the effect of indirect protection (herd immunity). Disentangling the effect of the vaccination programme and estimating how many cases and deaths might have occurred had the programme not been in place is therefore not straightforward and subject to considerable uncertainty.

Here we assess the impact and cost-effectiveness of the existing seasonal influenza vaccination programme in England, in the period 2000–2009 with relatively high influenza vaccine coverage. We use as an exemplar the 2006/2007 epidemic year, a "typical" recent (post-2000) year, which has a relatively low level of influenza infection and one type of strain circulating.

Abbreviations: GP, general practitioner; GPRD, General Practice Research Database; ILI, influenza-like illness; QALY, quality-adjusted life year; RCGP, Royal College of General Practitioners.

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doi:10.1016/j.vaccine.2012.03.019

2. Methods

2.1. Transmission dynamic modelling

A previously described [6] age-structured dynamic model of influenza transmission was adapted to describe the dynamics of influenza transmission, disease and vaccination during the 2006/2007 influenza season in England (population 51 million). To capture the uncertainty around the natural history and transmission of influenza, key model parameters were determined by randomly sampling from their plausible probability distributions to generate 600 epidemic time series (weekly number of infections by age and risk group). These parameters are the latent and infectious period of influenza, contact rate between people of different ages, proportion of people who are immune to influenza at the start of the influenza season, initial reproduction number at the start of the influenza season and timing of the epidemic peak. We assume that people in risk groups do not differ from people not in risk groups in terms of their contact behaviour. The epidemic time series are combined with the proportion of individuals with serologically confirmed influenza who consult a general practitioner (GP) to generate 30,000 possibilities for the time series of clinical influenza in the population.

The model was then used to evaluate vaccination of clinical risk groups and those at least 65 years old, but not of pregnant women (who were not recommended for vaccination until 2010) or health care workers (due to low uptake and lack of data). For each epidemic time series, a fraction of the population in each age and risk group was assumed to be vaccinated, based on weekly vaccine uptake data for 2006/2007 (from Health Protection Agency reports and publications [7]). Vaccine wastage of 10%, and a 2-week delay between vaccination and immunity onset was assumed. Vaccine efficacy was assumed to be 70% in vaccinees under 65 years and 46% in older vaccinees, when the vaccine is well matched to the circulating strain [8]. While this may overestimate protection in young children, vaccine coverage in these children with the existing risk-based strategy is low (3% of under 15 s). If the vaccine is poorly matched, efficacy was scaled down by 40% to reflect the ratio of efficacy in studies with poorly matched and well-matched vaccines reported in a systematic review [9].

Further details about model structure, the way the prior distributions of its parameters were constructed and the way it was fitted to data are provided in Supplemental Appendix 1.

2.2. Clinical disease

The proportion of individuals infected with influenza that gives rise to clinical disease was determined from a review of the proportion of such individuals who have ILI symptoms [10].

A proportion of these people are assumed to consult a GP. The weekly incidence of influenza-like illness (ILI) consulting in general practice in 5 age groups (1–4, 4–14, 15–44, 45–64 and 65+ years) in 2006/2007 reported by the Royal College of General Practitioners (RCGP) Weekly Returns Service was multiplied by the viral positivity of samples in each age group [8] to obtain the incidence of strain-confirmed GP consultations for ILI. However, GP consultations with influenza may not necessarily be classified as ILI. Hence, the 50 clinical time series from the transmission model which fitted data on ILI consultations multiplied by a variable factor were chosen, with this factor representing the proportion of all GP consultations for influenza that were recorded as ILI.

The proportion of influenza-attributable ILI that results in hospitalisations and deaths is poorly characterised. We developed two approaches for estimating these figures.

(a) *Low severity scenario*. The number of deaths by age and risk group was estimated by multiplying the number of GP consultations due to clinical diagnoses of influenza or influenza-like illness by the fraction of these that are expected to die within 30 days estimated from a study of the General Practice Research Database (GPRD) [11]. The number of hospitalised cases per GP case was estimated from the ratio of expected influenza related hospitalisations and GP consultations by age from that study. The relative risk of complications by risk group and age in the GPRD-based study [11] was used to attribute hospitalisations to risk group.

The above procedure gives an estimate of GP consultations, hospitalisations and deaths by age and risk group. The overall burden estimated by this method was lower than has been published previously. In particular, estimated number of deaths is very low (particularly in the elderly) using this method. For instance, the method estimates 179 deaths in the 65+ age group which compares with estimates from a burden of disease study by Pitman et al. [12] of 9200 deaths from influenza A annually in the same age group (albeit from a slightly earlier time period). For this reason, we derived a high severity scenario.

(b) *High severity scenario*. We assumed that 10% of cases with ILI due to influenza consult GPs, based on data from an internet-based cohort (Flusurvey) from 2010/2011 [13], and applied the ratios of hospitalisations and deaths to GP consultations for acute respiratory illness in the Pitman study, rather than from the previously mentioned GPRD-based study [11]. This gives a median estimate of approximately 8600 deaths annually (incidence 0.11%) in the elderly. However, the proportion of hospitalisations in risk groups was still determined from the GPRD-based study [11].

2.3. Economic modelling

Health and economic parameter distributions used were taken from our previous cost-effectiveness evaluation of pandemic influenza vaccination [6], and are summarised in Table 1. Loss in quality adjusted life years (QALYs) as a result of an influenza death was estimated from the average age-specific life expectancy in 2009 (using data from the Office for National Statistics), adjusted by age-specific quality of life norms [14] and discounted by 3.5% per annum as recommended by the National Institute for Health and Clinical Excellence (NICE) [15]. All other benefits from one season's vaccination are assumed to occur in a single year, so any other discounting is unnecessary. Costs are given in 2008 pounds. Uncertainty in epidemiological parameters governing influenza natural history and epidemiology was combined with uncertainty in economic parameters by Monte Carlo sampling from their joint distributions. Separate sensitivity analyses were conducted for the high/low severity scenarios and the well-matched/poorly matched vaccine scenarios described above.

3. Results

The model suggests that without vaccination, the incidence of influenza-attributable ILI over the course of a single season may range from a median of 17% (95% interval 6–21%) in 15–24 year olds to 3% (95% interval 2–6%) in 65+ year olds. Based on English coverage and population figures, around 20% of the population (10.5 million individuals) are vaccinated against influenza annually (3% of under 15 s, 13% of 15–65 s and 74% of over 65 s). The model estimates that such a large fraction of the population being vaccinated, mostly before the annual influenza season, results in substantial direct and indirect (herd) protection. Around 1000–2700 cases per 100,000 people prevented annually depending on how well the vaccine is matched, of which 56–73% are due to indirect protection.

Given a well-matched vaccine, the incidence of influenza-attributable ILI falls to a median of 13% (95% interval 5–20%) for the 5–14 years age group and 2% (95% interval 1–3%) for the 65+