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Impact of the addition of new vaccines in the early childhood schedule on vaccine coverage by 24 months of age from 2006 to 2016 in Quebec, Canada

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ABSTRACT

Context: Between 2004 and 2016, in the province of Quebec (Canada), 4 new antigens were added in the early childhood vaccine schedule from birth to 18 months, increasing the number of injections or doses needed from 7 to 12. These additions may have decreased the proportion of children who had received all recommended vaccines.
Objectives: To assess the impact of the introduction of new vaccines to the childhood schedule on the 24-month vaccine coverage from 2006 to 2016 and identify factors associated with incomplete vaccination status by 24 months of age.
Methods: We used the data from six cross-sectional vaccine coverage surveys conducted every two years which included a total of 3515 children aged 2 years old and randomly selected from the Quebec public health insurance database. Factors associated with an incomplete vaccine status by 24 months were identified with multivariable logistic regression.
Results: Despite the addition of 4 new vaccine antigens since 2004, the vaccine coverage remained high from 2006 (82.4%) through 2016 (88.3%) for vaccines present in the schedule since 2006. In 2016, vaccine coverage was 78.2% for all vaccines included in the schedule. The vaccine coverage of new vaccines increases rapidly within 2 years of their introduction. For both new and older vaccines, incomplete vaccine status by 24 months of age is associated with a delay of 30 days or more in receiving the vaccines scheduled at 2 and 12 months of age.
Conclusions: Increasing to 12 the number of doses in the recommended schedule has slightly reduced the vaccine coverage by 24 months of age and the vaccine coverage of vaccines already in the schedule remained stable over the years. Future additions to the vaccine schedule may not be similarly accepted by the population and this will require continuing the monitoring of vaccine coverage.

1. Introduction

Before 2004, the childhood vaccine schedule in the province of Quebec (Canada) included 7 injections from birth to 18 months of age. Between 2004 and 2016, four new vaccine antigens (pneumococcal, varicella, rotavirus and hepatitis B) were added to the vaccination schedule. Despite the use of combined vaccines for varicella and hepatitis B, the number of recommended vaccine doses increased to 12 (including 2 oral doses of rotavirus vaccine) [1] (Fig. 1). While combined vaccines reduce the number of injections, improve vaccine coverage as well as on-time vaccination

Abbreviations: CHU, *Centre hospitalier universitaire* (University-affiliated hospital); CI, 95% Confidence interval; DTaP-IPV-Hib, Diptheria, tetanus, acellular pertussis, polio virus and *Haemophilus influenzae* type b vaccine; DTaP-IPV-Hib-HB, Diptheria, tetanus, acellular pertussis, polio virus, *Haemophilus influenzae* type *b* and hepatitis B vaccine; Men-C-C, Meningococcal conjugate vaccine (strain C); MMR, Measles, mumps and rubella vaccine; MMRV, Measles, mumps, rubella and varicella vaccine; NACI, National Advisory Committee on Immunization; OR, Odds ratio; PCV, Pneumococcal conjugate vaccine; Rota, Rotavirus vaccine; UTD, Up-to-date; VC, Vaccine coverage; VC-Common, Vaccine coverage for common antigens from 2006 to 2016; VC-All, Vaccine coverage for all antigens included in the vaccine schedule each year; VPD, vaccine-preventable disease.

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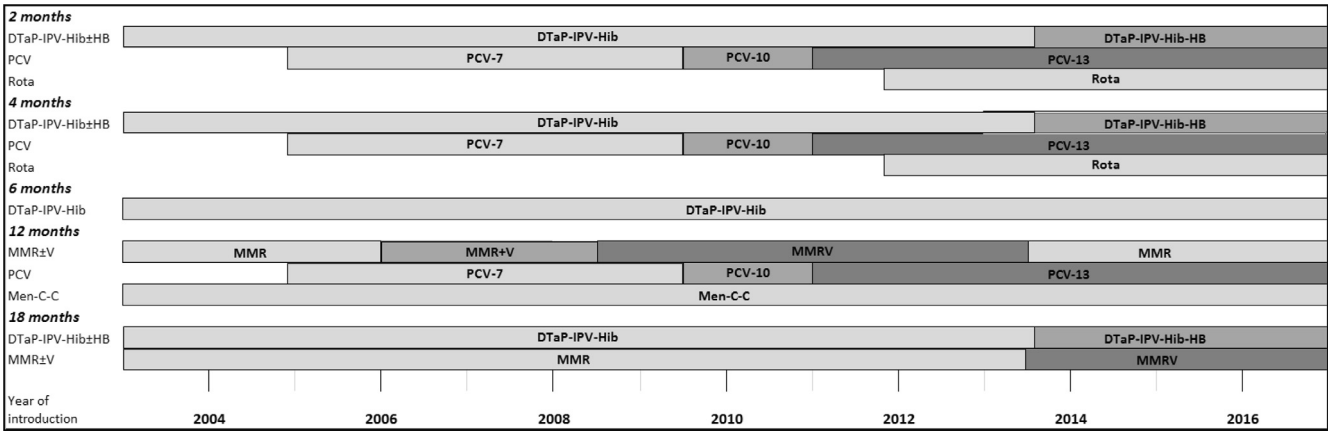

Fig. 1. Changes in the Quebec's vaccination schedule for children aged under 24 months from 2004 to 2016. * (*In the Quebec's vaccine schedule before 24 months of age, all vaccine doses are recommended at a specific age and not within an age range)

[2,3], a higher number of doses may increase concerns from parents and providers and may decrease the proportion of children who receive all recommended doses by 24 months of age [4,5].

The impact of vaccination programs on the population's susceptibility and the reduction of disease depends upon the vaccine coverage and the timeliness of immunization [6,7]. Vaccine coverage (VC) or being up-to-date (UTD) at a certain age evaluate the percentage of children who receive all recommended vaccines by a certain age (e.g. 24 months) regardless of the timeliness of immunization. Timeliness for a specific dose evaluates the number of days between the recommended age and the actual administration of this dose. If this number is 30 days or more, this dose is generally considered delayed [8–16]. In the province of Quebec, immunization is voluntary and all vaccines in the recommended schedule are free of charge either at public health clinics or at physician or nurse offices. Interventions to improve timeliness of vaccination, such as reminders, recalls, allowing more time for vaccination, administration of all vaccines due at the same visit and accepting vaccine visits without appointment were implemented since 2006 [17]. Because the provincial immunization registry is not completely operational, vaccine coverage surveys are conducted every two years since 2006 among children aged 1 and 2 years of age.

The objective of this study was to assess if the addition of 5 doses of vaccines to the childhood schedule between 2004 and 2016 has reduced the vaccine coverage by 24 months of age and identify the factors associated with an incomplete vaccination status by 24 months of age.

2. Methods

2.1. Study population and survey design

The analysis was based on data from six cross-sectional postal surveys conducted in 2006, 2008, 2010, 2012, 2014 and 2016 [18–23]. Children were randomly selected from the universal Quebec public health insurance registration database with the authorization of the Quebec Access to Information Commission. Each survey targeted two cohorts: the "1 year cohort" included children aged 15–17 months at the time of the survey and the "2 year cohort" included children aged 24 to 26 months. As vaccine coverage by 24 months of age is the standard indicator to measure the full series of childhood vaccines, this article presents only data from the "2 year cohort" [24]. The surveys invited approximately 1000 children in each cohort (only 600 for 2006), a number sufficient to obtain a precision of ±3% in the vaccine coverage assuming a 60% response rate [25]. Children whose parents or guardians couldn't communicate either in French or in English were excluded as well as those born outside Quebec given that they were exposed to different vaccine schedules.

Questionnaires were sent by mail and completed by parents or guardians. For non-respondents, a postal reminder was sent 1-week later and 3-weeks later. In the absence of response, parents were called directly 2-weeks after the last reminder. Respondents were invited to transcribe on the questionnaire the information available in the vaccination booklet of their child or to send a copy of the booklet. The questionnaire collected information on vaccines received, the child's characteristics, the mother's characteristics and on the family type (i.e. living with or without a spouse) (Supplementary file 1). For children without vaccination booklets or whose information was incomplete or not consistent with the provincial vaccine schedule the vaccine providers were contacted to collect/validate the vaccination history. Validation increased the vaccine coverage from 8% to 25%. Similar questionnaires were used from 2006 to 2016. Each survey was approved by the Ethic Board Committee of the CHU de Quebec-Université Laval *Hospital* and written consent was obtained from all participants.

2.2. Common, new and all antigen definitions

Antigens common to all surveys included antigens for complete vaccination status for the 2006 surveys: diphteria, tetanus, acellular pertussis, polio virus, *Haemophilus influenzae* type b (DTaP-IPV-Hib), measles-mumps-rubella (MMR) and meningococcal strain C. New antigens included only antigens added over the years since 2008 and used for the calculation of vaccine status: pneumococcal, varicella, rotavirus and hepatitis B. All antigens included common and new antigens.

2.3. Outcomes

The primary outcome was the vaccination status by 24 months of age defined as "complete" if a child had received all recommended doses of vaccines before 24 months of age or as "incomplete" otherwise. Given that the Quebec vaccine schedule has changed over the years, the number of vaccines or doses required to comply with the definition of a complete vaccination status differed from one survey to another. Two main definitions were used for this outcome: (1) Complete vaccine status for common antigens to all surveys, which included 4 doses of DTaP-IPV-Hib vaccine, 2

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