Immunization Completeness of Children Under Two Years of Age in Nova Scotia, Canada

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ABSTRACT

Objectives: Canada's progress in establishing a national immunization registry and coordinated immunization schedule across provinces has been slow. The absence of a centralized registry means there are only limited data available on childhood immunization coverage in Canada. The aim of this study was to estimate the completeness and timeliness of immunization for two year-old children in Nova Scotia.

Methods: The study included 8,245 babies born in Nova Scotia during 2006. Immunization data were derived from three sources: Provincial Medical Insurance Physician Billing data, public health records, and self-report by parents. Immunization uptake rates for vaccines included in the Nova Scotia immunization schedule were calculated at ages 12, 18 and 24 months. Logistic regression was used to analyze vaccine uptake in relation to socio-economic factors. A telephone survey of a sample of parents of study children was completed.

Results: The overall immunization completeness rate was 49% at 12 months, 40% at 18 months and 58% at 24 months of age. Immunization completeness was significantly higher in more socially disadvantaged communities.

Conclusions: Nova Scotia spends many millions of dollars on vaccine purchase and administration, but, as with numerous Canadian jurisdictions, there is no accurate system for monitoring or evaluating the program. The timeliness and completeness of immunization administration to pre-school children in Nova Scotia is inadequate. Further work should elucidate the barriers and enablers to immunization to ensure that public health education targets those most likely to be under-immunized. A provincial vaccination database should be established to monitor and evaluate the system.

Key words: Immunization; program evaluation; child; information systems

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Childhood immunization is a key component of Canada's public health strategy. Immunization aims to control vaccine-preventable diseases. Childhood immunization has had many successes, including a 90-95% decline in measles and pertussis and the global eradication of polio.¹ The Canadian National Immunization Strategy (NIS) was launched in 2003 to develop a national immunization infrastructure.² The federally funded NIS has successfully reduced inequitable access to vaccines.³ Four recently developed vaccines – acellular pertussis, meningococcal C conjugate, pneumococcal conjugate and varicella – are now provided free at the point of delivery to children in almost all Canadian jurisdictions.⁴ However, progress on a national immunization registry and coordinated vaccine schedules across all jurisdictions has been slow.⁵

Information on vaccine coverage is fundamental to immunization program evaluation.⁶ Currently, Canada lacks a central immunization register. Vaccine completeness assessments rely on cross-sectional surveys, such as the Canadian National Reports on Immunization,⁷ provincial monitoring system reports,⁸ and regional surveys.¹ A limitation of much of these data is the reliance on cross-sectional questionnaire designs and small samples. Many immunization coverage studies estimate vaccine completeness based on accumulation of doses by age, without considering timeliness with respect to age.^{9,10} Ensuring all doses are administered at the appropriate age is critically important to ensure the effectiveness of vaccine programs in preventing disease.⁹ Therefore, assess-

ing the timeliness of immunization administration is crucial for evaluating immunization delivery programs, and these data are sparse in Canada.

Publicly funded vaccines are available in Nova Scotia according to the Nova Scotia Immunization Schedule.¹¹ The budget for vaccine purchase alone in 2011-12 was \$9.9M. The province has a dual system of vaccine administration: family physicians provide approximately 80% of immunizations and Public Health Services, located in nine District Health Authorities (DHAs), provide the remaining immunizations. Payment to physicians for the administration of publicly funded vaccines is through the Medical Services Insurance (MSI) program. The electronic data from this system can be used to identify physician-administered vaccinations. Immunizations are also recorded by the public health services using a paper-based system, and this provides immunization information for vaccines administered by public health nurses. The study aim was to estimate immunization completeness and timeliness in pre-

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Conflict of Interest: None to declare.

Table 1. Nova Scotia Immunization Schedule for Children Under Two Years of Age

Vaccine	Age				
	2 months	4 months	6 months	12 months	18 months
DaPTP+Hib (Diphtheria, acellular pertussis, tetanus, polio, and Haemophilus influenzae type b)	✓	✓	✓		✓
PNEU (Pneumococcal conjugate)	✓	✓	✓		✓
MENC (Meningococcal group C conjugate)				✓	
MMR (Measles, mumps and rubella)				✓	

Note: Varicella is also included in the schedule and available at 12 months of age if the child has not already had chicken pox. Varicella was not included in this analysis.

Table 2. Vaccine Completeness at 12, 18 and 24 Months of Age

	DaPTP+HIB			PNEU			MMR			MENC		
	N	%	95% CI	N	%	95% CI	N	%	95% CI	N	%	95% CI
12 months												
None	269	3.3	2.9-3.7	311	3.8	3.4-4.2	2732	33.1	32.1-34.2	3411	41.4	40.3-42.4
Not up-to-date	1186	14.4	13.6-15.2	1379	16.7	15.9-17.5	36	0.4	0.3-0.6	63	0.8	0.6-1.0
Up-to-date	6790	82.4	81.5-83.2	6555	79.5	78.6-80.4	5477	66.4	65.4-67.4	4771	57.9	56.8-58.9
18 months												
None	215	2.6	2.3-3.0	261	3.2	2.8-3.6	1234	15.0	14.2-15.8	1671	20.3	19.4-21.2
Not up-to-date	3956	48.0	46.9-49.1	4108	49.8	48.7-50.9	36	0.4	0.3-0.6	63	0.8	0.6-1.0
Up-to-date	4074	49.4	48.3-50.5	3876	47.0	45.9-48.1	6975	84.6	83.8-85.4	6511	79.0	78.1-79.8
24 months												
None	182	2.2	1.9-2.5	227	2.8	2.4-3.1	1127	13.7	12.9-14.4	1548	18.8	17.9-19.6
Not up-to-date	2352	28.5	27.6-29.5	2587	31.4	30.4-32.4	36	0.4	0.3-0.6	63	0.8	0.6-1.0
Up-to-date	5711	69.3	68.3-70.3	5431	65.9	64.8-66.9	7082	85.9	85.1-86.6	6634	80.5	79.6-81.3

school children up to age two years in Nova Scotia, focussing on the number and timing of vaccine doses.

METHODS

The study cohort consisted of all children born January 1 to December 31, 2006 in Nova Scotia, as identified by the Nova Scotia Department of Health. Children born outside Nova Scotia were excluded. Of the 8,613 Nova Scotia live births identified, 368 (4.3%) did not have a well-baby visit or at least one vaccination recorded during their first 18 months of life. For privacy reasons, details of these babies were not provided to the study team and were excluded. It is likely these children were not immunized.

Vaccination information for each child up to two years of age was derived from the electronic MSI Physician Billings and paper-based public health records, which were entered into a computer database by a researcher. The number of doses of each vaccine received by month of age for each child, and the timeliness of administration, were calculated. Table 1 provides a summary of the four vaccines included: diphtheria, acellular pertussis, tetanus, polio, and haemophilus influenzae type b (DaPTP + Hib); pneumococcal conjugate (PNEU); meningococcal Group C (MENC); and measles, mumps and rubella (MMR). A dose was "up-to-date" if it was administered according to the schedule, defined as within 1 month at ages 2, 4, 6, 12 or 18 months (where age was dependent on specific vaccine). Vaccines administered outside these ages were considered "not up-to-date". Children were stratified into: up-to-date, not up-to-date, and no immunizations.

Four indicators of community socio-economic status (median household income, unemployment rate, high school diploma rate, university degree rate) were derived from 2006 dissemination area (DA) census data. Each indicator was grouped into quintiles, and linked to individuals through their postal code of residence using the Postal Code Conversion File (PCCF+).¹² Urban/rural residential status was assigned to each individual using the population density-based urban/rural indicator available from the PCCF+. The nine DHAs were grouped depending on whether the mode of vaccine provision was i) predominantly family physician ($\geq 98\%$ vaccines

Figure 1. Vaccine completeness by month of age (DaPTP+Hib, Pneumococcal conjugate, Meningococcal Group C and MMR)

by family physician only), ii) predominantly public health (25% vaccines by public health only) or iii) a mix of physician and public health ($>50\%$ vaccines by a mix of physicians and public health). Logistic regression was used to evaluate vaccine completeness in relation to these indicators. The significance of each variable was assessed from the likelihood ratio test statistic.¹³ Statistical analysis was completed in SAS 9.1.¹⁴

A telephone questionnaire was administered to parents/guardians of a sample of the cohort to determine vaccine completeness based on parental knowledge. First, a random sample of 1,500 babies was generated comprising an equal number from each of the nine DHAs to ensure geographic representativeness. Letters were sent to the parents/guardians of each child in the sample. Those who did not decline were telephoned by a researcher. Three attempts were made to make contact. Those agreeing to participate were asked to provide information from the child's vaccine record if available; otherwise the information was provided from memory. Vaccine completeness rates were stratified by whether or not the respondent was in possession of the written record. These data were used to validate the information derived from the administrative

Table 3. Logistic Regression of Vaccine Completeness in Relation to Socio-demographic and Provider Information

	N	12 months		18 months		24 months	
		OR	95% CI	OR	95% CI	OR	95% CI
Mode of vaccine administration within DHA							
Predominantly physician (2 DHAs)	4290	1	–	1	–	1	–
Predominantly Public Health (2 DHAs)	1100	1.3	1.1-1.5	1.4	1.2-1.6	1.8	1.6-2.1
Mix of physician and Public Health (5 DHAs)	2090	1.9	1.7-2.2	2.0	1.8-2.3	2.1	1.9-2.4
			p<0.01		p<0.01		p<0.001
Unemployment rate							
1 low	1600	1.5	1.3-1.8	1.5	1.3-1.7	1.7	1.4-2.0
2	1563	1.1	0.9-1.3	1.1	1.0-1.3	1.2	1.0-1.4
3	1583	1.1	0.9-1.3	1.1	0.9-1.2	1.1	0.9-1.2
4	1509	1.0	0.9-1.2	1.0	0.9-1.1	1.0	0.8-1.1
5 high	1643	1	–	1	–	1	–
			p<0.001		p<0.001		p<0.001
Education rate (proportion with a minimum of high school diploma)							
1 low	1578	1.7	1.5-2.1	1.7	1.5-2.0	2.0	1.7-2.3
2	1559	1.7	1.5-2.0	1.5	1.3-1.7	1.5	1.3-1.7
3	1604	1.2	1.0-1.4	1.7	1.5-1.9	1.7	1.5-1.9
4	1673	1.5	1.3-1.7	1.4	1.2-1.6	1.3	1.2-1.7
5 high	1484	1	–	1	–	1	–
			p<0.001		p<0.001		p<0.001
Higher education rate (proportion with university degree/diploma)							
1 low	1589	1.6	1.4-1.9	1.7	1.5-2.0	2.0	1.7-2.3
2	1606	1.5	1.3-1.8	1.5	1.3-1.7	1.5	1.3-1.7
3	1502	1.7	1.5-2.0	1.7	1.5-1.9	1.7	1.5-1.9
4	1636	1.3	1.1-1.5	1.4	1.2-1.6	1.5	1.3-1.7
5 high	1565	1	–	1	–	1	–
			p<0.001		p<0.001		p<0.001

Table 4. Vaccine Completeness at 12, 18 and 24 Months of Age, Parental Questionnaire Compared to Health Record Data

Age	Parents With Vaccine Record During Survey				Parents Without Vaccine Record During Survey			
	Survey		Health Record Data		Survey		Health Record Data	
	N	% Complete	% Complete	Variance*	N	% Complete	% Complete	Variance*
12 Months								
None	0	0	2	-2	40	17	2	15
Not up-to-date	35	27	42	-15	19	8	45	-37
Up-to-date	95	73	57	16	181	75	54	22
18 Months								
None	0	0	1	-1	40	17	1	15
Not up-to-date	30	23	42	-18	30	13	56	-43
Up-to-date	100	77	58	19	170	71	43	28
24 Months								
None	0	0	1	-1	40	17	1	15
Not up-to-date	14	11	27	-16	22	9	36	-27
Up-to-date	116	89	72	17	178	74	63	11

* The variance is the difference in percentage points between the parental survey and the health record data.

health dataset. Ethics approval was provided by the IWK Health Centre, Halifax.

RESULTS

Overall vaccine completeness was 49%, 40% and 58% at 12, 18 and 24 months of age, respectively. Individually, DaPTP+Hib (82%) and pneumococcal conjugate (80%) had reasonable completeness at 12 months of age (Table 2), when the schedule for these two vaccines required doses administered at 2, 4 and 6 months (Figure 1). The rate for these two vaccines declined to around 50% complete at 18 months, when a fourth dose was due, before rising to just below 70% at 24 months. MMR (66%) and meningococcal Group C (58%) completeness was low at 12 months (Table 2). Uptake of these vaccines improved substantially in the following six months – 24-month completeness rates were 86% for MMR and 81% for MENC (Figure 1). A small proportion of children (0.5-1%, depending on vaccine) received vaccinations early and these were classified as not up-to-date.

There was no significant variation in vaccine completeness in relation to the child's sex, urban/rural residence, or income (results not presented). DHAs with a mix of public health- and physician-administered vaccines had the highest completeness rates, followed

by DHAs with vaccines predominantly administered through public health. The lowest rates were in DHAs with mostly physician-administered vaccines (Table 3). Vaccine completeness was significantly higher in the least-educated communities and in areas of higher unemployment.

Approximately 50% of the eligible telephone sample (1,500) could not be contacted. A total of 370 telephone questionnaires were completed (25% response); 130 (35%) of the respondents had a copy of the vaccine record. Survey respondents reported higher vaccine completeness compared to the corresponding administrative data (Table 4).

DISCUSSION

Childhood immunization rates in Nova Scotia are suboptimal, putting many children at risk of potentially severe but preventable diseases. By the 24 months of age mark of the sample, none of the vaccines included in this study had coverage rates approaching the 90-95% rate recommended by the World Health Organization (WHO).^{15,16} Timeliness of vaccine administration was a major issue. The fourth dose of DaPTP+Hib and pneumococcal conjugate at 18 months was especially problematic and for many children provided late or not at all. Timely administration of the vaccines requir-

ing one dose at 12 months was also poor and many children were under-immunized for MMR and meningococcal group C for many months following their first birthday. Immunization rates were consistently higher in areas of higher unemployment and lower educational attainment. DHAs where vaccines were provided by a mix of public health nurses and family physicians had the best completeness rates; by contrast, vaccine completeness was lowest where vaccines were provided predominantly by family physicians.

Survey respondents indicated higher vaccine completeness compared to the administrative data. While many respondents relied on memory, one third had access to the vaccine record and completeness rates were between 16-19 percentage points higher than that recorded in the administrative data. However, even these rates are well below the recommended rate. The majority of parents answered the survey from memory and indicated higher completeness rates than the administrative data. We cannot state with certainty that the telephone survey was any more accurate than the administrative health data, although we would suggest that respondents providing data from the vaccine record provide the "gold standard". It is a concern that even for this subset of children, vaccine completeness rates were low.

Canada has no integrated surveillance system for monitoring vaccine uptake or co-ordinated schedule and hence comparison between provinces is problematic. The Nova Scotia overall immunization rate at 24 months (58%) was similar to that of Manitoba (61%)¹⁷ but lower than that of British Columbia (66.5%)¹⁸ and Ontario (70%).¹⁹ The 24-month MMR rate compared favourably with that of Alberta (91%)²⁰ and British Columbia (75.3%),¹⁸ but the DaPTP+Hib rate was lower than that of Alberta (90%)²⁰ and British Columbia (74.6%).¹⁸ The Canadian National Reports on Immunization show much higher vaccine completeness rates across all antigens, including 94% for MMR. Indeed, in 2006, around 90% of respondents stated that their children were up-to-date with all immunizations.⁷ However, the national survey is a random survey of just 499 parents of children aged 20-40 months using parental self-report and is not directly comparable to our data (although it does include an unspecified number from Nova Scotia).⁷

Vaccine completeness is generally reported to be lower in children from lower-income families or those with less-educated parents.²¹⁻²³ However, our findings in relation to unemployment and education are consistent with a study showing higher immunization rates in poorer, less-educated families.²⁴ This suggests that parents from poorer communities can be motivated and educated to follow immunization guidelines diligently. Conversely, individuals more educated and affluent may interpret or follow immunization guidelines differently. In Nova Scotia, the involvement of the public health service in vaccinations, alongside family doctors, improved completeness rates. This suggests that the public health service has an important role in vaccine provision. In some communities, public health may provide immunizations to families who cannot access a family physician.

Privacy issues raised by the Provincial Health Department resulted in the exclusion of 368 children from the study for whom no well-baby visit or vaccinations were recorded. This resulted in a slight overestimate of vaccine completeness and an underestimate of children with no vaccines, although this small number of children will not materially affect the findings. It is a limitation that we

were not able to include details of the subcohort of unvaccinated children, which is a small but potentially vulnerable population.²⁵ We utilized administrative health records to estimate vaccine uptake and these data underestimated vaccine completeness compared to the parent survey, although the self-reported rates were still low. It is a limitation that individual-level data on income, education or employment were not available. We used DA-level socio-economic census data. DAs are the smallest unit of census geography – consisting of between 400-700 individuals²⁶ – but not all individuals in a DA defined as low income will necessarily be poor. Although there will be a degree of misclassification in the socio-economic information, this would likely reduce the magnitude of the socio-economic association with vaccination.

Childhood immunization uptake in Canada is suboptimal. Few studies report immunization completeness at the level recommended by the WHO. Nova Scotia has a multi-million-dollar system of vaccine purchase and delivery but, as with many Canadian jurisdictions, no system for monitoring or evaluating uptake. We cannot state with certainty immunization rates in Nova Scotia, but both timeliness and completeness of childhood immunizations are of serious concern in the province. It is important that the NIS establish a common Canada-wide immunization schedule, and that appropriate recording systems to support monitoring of immunization coverage be established provincially. Work is required to elucidate the barriers and enablers to immunization to ensure that public health activities target families and communities most likely to be under-immunized.

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RÉSUMÉ

Objectifs : Le Canada est lent à établir un registre d'immunisation national et un calendrier vaccinal coordonné entre les provinces. En l'absence d'un registre centralisé, nous ne disposons que de données limitées sur la couverture vaccinale des enfants au pays. Nous avons cherché à estimer si, en Nouvelle-Écosse, les enfants de deux ans reçoivent tous leurs vaccins dans les délais prescrits.

Méthode : L'étude a porté sur 8 245 bébés nés en Nouvelle-Écosse en 2006. Les données de vaccination provenaient de trois sources : les données de facturation des médecins à l'assurance-maladie provinciale, les registres de santé publique et les données autodéclarées par les parents. Les taux de recours aux vaccins inclus dans le calendrier vaccinal de la Nouvelle-Écosse ont été calculés à l'âge de 12, 18 et 24 mois. Par régression logistique, nous avons analysé le recours aux vaccins par rapport à des facteurs socioéconomiques. Nous avons mené une enquête téléphonique auprès d'un échantillon de parents des enfants étudiés.

Résultats : Le taux global des bébés ayant reçu tous leurs vaccins était de 49 % à 12 mois, de 40 % à 18 mois et de 58 % à 24 mois. Ce taux était sensiblement plus élevé dans les communautés socialement défavorisées.

Conclusion : La Nouvelle-Écosse dépense des millions de dollars pour l'achat et l'administration des vaccins, mais comme de nombreuses provinces canadiennes, elle n'a pas de système précis de contrôle et d'évaluation du programme. L'administration des vaccins aux enfants d'âge préscolaire en Nouvelle-Écosse a des carences : trop d'enfants ne reçoivent pas tous leurs vaccins dans les délais prescrits. Il faudrait en faire plus pour élucider les éléments qui favorisent et qui nuisent à la vaccination, afin que l'éducation à la santé publique cible les personnes les plus susceptibles d'être sous-immunisées. Il faudrait établir une base de données provinciale sur la vaccination afin de contrôler et d'évaluer le système.

Mots clés : vaccination; évaluation de programme; enfant; systèmes d'information