

Effectiveness of Trivalent Flu Vaccine in Healthy Young Children



WHAT'S KNOWN ON THIS SUBJECT: In the United States, given the high burden of disease, influenza vaccine is recommended for all children from age 6 months. The paucity of vaccine effectiveness data in children <2 years has led some to argue against routine vaccination in this age group.



WHAT THIS STUDY ADDS: This study reveals the effectiveness of trivalent influenza vaccine in young children and supports the current Advisory Committee on Immunization Practices recommendation. This study provides the strongest evidence to date confirming the effectiveness of trivalent influenza vaccine in children <2 years of age.

abstract

BACKGROUND: There are few studies evaluating the effectiveness of trivalent influenza vaccination (TIV) in young children, particularly in children <2 years. The Western Australian Influenza Vaccine Effectiveness Study commenced in 2008 to evaluate a program providing TIV to children aged 6 to 59 months.

METHODS: An observational study enrolling children with influenza-like illness presenting to a tertiary pediatric hospital was conducted (2008–2012). Vaccination status was determined by parental questionnaire and confirmed via the national immunization register and/or vaccine providers. Respiratory virus polymerase chain reaction and culture were performed on nasopharyngeal samples. The test-negative design was used to estimate vaccine effectiveness (VE) by using 2 control groups: all influenza test-negative subjects and other-virus-detected (OVD) subjects. Adjusted odds ratios were estimated from models with season, month of disease onset, age, gender, indigenous status, prematurity, and comorbidities as covariates. Subjects enrolled in 2009 were excluded from VE calculations.

RESULTS: Of 2001 children enrolled, influenza was identified in 389 (20.4%) children. Another respiratory virus was identified in 1134 (59.6%) children. Overall, 295 of 1903 (15.5%) children were fully vaccinated and 161 of 1903 (8.4%) children were partially vaccinated. Vaccine uptake was significantly lower in 2010–2012 after increased febrile adverse events observed in 2010. Using test-negative controls, VE was 64.7% (95% confidence interval [CI]: 33.7%–81.2%). No difference in VE was observed with OVD controls (65.8%; 95% CI: 32.1%–82.8%). The VE for children <2 years was 85.8% (95% CI: 37.9%–96.7%).

CONCLUSIONS: This study reveals the effectiveness of TIV in young children over 4 seasons by using test-negative and OVD controls. TIV was effective in children aged <2 years. Despite demonstrated vaccine effectiveness, uptake of TIV remains suboptimal. *Pediatrics* 2014;133:e1218–e1225

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KEY WORDS

influenza, trivalent influenza vaccine, vaccine effectiveness, children

ABBREVIATIONS

ACIP—Advisory Committee on Immunization Practices
CI—confidence interval
ILI—influenza-like illness
LAIV—live-attenuated influenza vaccine
OVD—other virus detected
PCR—polymerase chain reaction
TIV—trivalent influenza vaccine
VE—vaccine effectiveness

Dr Blyth supervised the project, analyzed the data, and wrote the first draft of the manuscript; Mr Jacoby assisted in designing the study, analyzed the data, and assisted with writing the manuscript; Professors Effler, Kelly, Smith, and Richmond designed the study, supervised analysis, and assisted in writing the manuscript; Ms Robins enrolled patients, supervised research assistants, collated and cleaned the data, and assisted with writing the manuscript; Dr Willis assisted in designing the study, collated and cleaned the data, and assisted with writing the manuscript; Dr Levy performed virologic studies, collated and cleaned the data, and assisted with writing the manuscript; Dr Keil assisted in designing the study, supervised laboratory processing, and assisted with writing the manuscript; and all authors reviewed and approved the final manuscript as submitted.

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Influenza viral infections remain a major contributor to the global burden of acute respiratory infection.¹ Young children, the elderly, and others with underlying medical conditions are at greatest risk of hospitalization, morbidity, and death.^{2–4} Annual influenza vaccination is the most effective method for preventing influenza virus infection and its complications.²

National recommendations for influenza vaccination vary significantly between countries, particularly for young children. Since 2003, the Advisory Committee on Immunization Practices (ACIP) in the United States has recommended influenza vaccination for all children from 6 to 23 months of age.² From 2008, the ACIP extended its recommendation to include vaccination of all children with either trivalent influenza vaccine (TIV) from 6 months of age or with live-attenuated influenza vaccine (LAIV) from age 2 years.² Since 2007, Finland has recommended annual TIV in children aged 6 months to 3 years.⁵ Before 2013, the UK Joint Committee on Vaccination and Immunization recommended influenza vaccination in children aged ≥ 6 months with underlying medical conditions associated with severe influenza.⁶ From September 2013, influenza vaccination has been recommended for all children aged 2 to 17 years in the United Kingdom, with LAIV being preferred over TIV⁷; children aged 6 to 23 months with underlying medical conditions are recommended to receive TIV. In Australia, TIV is licensed for all children aged ≥ 6 months. The Australian Technical Advisory Group on Immunization recommends influenza vaccination for children aged ≥ 6 months with underlying medical conditions associated with severe influenza.⁸ LAIV is unavailable in Australia.

There remains ongoing controversy about the role of influenza vaccination in the very young, particularly children < 2 years. Because LAIV is licensed for

children ≥ 2 years, TIV remains the only licensed option in this age group. There is a paucity of published data demonstrating effectiveness of TIV in children younger than 2 years, leading some authors to argue against the recommendation for routine TIV in this age group.^{9–11}

After several influenza-related deaths in previously healthy preschool children in 2007,¹² the state of Western Australia implemented its own pediatric influenza vaccination program. TIV was recommended and provided free for all children aged 6 months to 5 years. This program was in addition to the national program, which recommended vaccination in children ≥ 6 months with underlying medical conditions associated with severe influenza. The Western Australian Influenza Vaccine Effectiveness (WAIVE) Study commenced in 2008 to assess influenza vaccine effectiveness (VE) with the use of the test-negative design, with the outcome being medically attended, laboratory-confirmed influenza. VE estimates from the year 2008 have been presented previously.^{13,14} Influenza-positive cases were compared against 2 different control groups: test-negative and other-virus-detected (OVD) controls. The second analysis was undertaken on the assumption that if any respiratory virus was detected, influenza virus would also have been identified if present (ie, excluding false-negative controls).

We present the estimated VE of TIV in children aged 6 months to 5 years (2008–2012, excluding 2009) calculated from children presenting with an influenza-like illness (ILI) to the major pediatric teaching hospital emergency department in Perth, Western Australia.

METHODS

From 2008 onward, all children in Western Australia aged 6 to 59 months were eligible for free TIV. Children receiving vaccine for the first time were

recommended to receive 2 doses at least 1 month apart.⁸ Princess Margaret Hospital is the sole tertiary pediatric hospital for the state of Western Australia (population 2.4 million people). The hospital manages $> 70\,000$ emergency visits per year ($\sim 25\%$ of pediatric emergency visits in the state), 15% to 20% of which require hospital admission (M. Borland, MBBS and L. Brennan, BSc, MBA, personal communication). The commencement and cessation of the influenza season in Western Australia were determined by using data on influenza virus detection from community influenza surveillance and routine diagnostic samples; these data were analyzed weekly.¹⁵ All children presenting to the Princess Margaret Hospital emergency department during the influenza season (2008–2012) were eligible for enrollment.

All children with an ILI were eligible for enrollment, except for those with a known immunodeficiency disorder, receiving current or who received recent immunosuppressive treatment, or who received immunoglobulin in the previous 3 months.⁸ ILI was defined by at least 1 acute respiratory symptom or sign plus either a documented fever $\geq 37.5^\circ\text{C}$ or history of fever in the past 96 hours. After written consent from parents or guardians, clinical data and nasopharyngeal samples were collected by nurses or medical students who had been instructed on correct sampling techniques. Vaccination status was assessed during the parental interview and then confirmed by either the Australian Childhood Immunization Register or by contacting immunization providers. “Fully vaccinated” was defined as (1) 2 doses of TIV at least 21 days apart and at least 14 days before presentation or (2) 1 dose of TIV at least 14 days before presentation and ≥ 2 doses in a previous year.⁸

Bilateral midturbinate nasal swabs (Copan Diagnostics, Murrieta, CA) placed into viral transport medium or

nasopharyngeal aspirates were collected for all enrolled children. With the use of previously published methods, nasopharyngeal samples were tested by polymerase chain reaction (PCR) assay for respiratory viruses including influenza A/B/C, respiratory syncytial virus A/B, human metapneumoviruses, human parainfluenza virus types 1 to 4, picornaviruses (including human rhinoviruses and enteroviruses), human adenoviruses B through D, human coronaviruses OC43/229E, and human bocaviruses.^{16,17} Viral culture was performed by using centrifuge-enhanced inoculation onto Madin-Darby canine kidney cells and diploid human lung fibroblasts and confirmed by using immunofluorescent antibody detection with monoclonal antibodies directed at influenza A or B (Oxoid Microbiology; ThermoFisher, Waltham, MA). In addition, hospital inpatients underwent antigen detection by using a standard direct immunofluorescence method (Chemicon; Millipore Corporation, Billerica, MA).

With the use of the test-negative design,^{18–20} children testing positive for influenza viruses (PCR and/or viral culture) were identified as cases. These were compared with 2 different control groups. The first control group included all enrolled children testing negative for influenza viruses (test-negative controls). The second control group comprised enrolled children who tested positive for respiratory viruses other than influenza (OVD controls). Statistical analysis was performed by using SPSS 20.0.0 (IBM SPSS Statistics, IBM Corporation, Armonk, NY). Differences in categorical variables were tested by χ^2 test or Fisher's exact test. With laboratory-confirmed influenza as the primary outcome and vaccine status as the primary exposure, odds ratios and 95% confidence intervals (CIs) were calculated by using logistic regression models. Season, month of disease onset, age, gender, indigenous

status, prematurity, and the presence of comorbidities (yes/no) were included as covariates on the basis of their theoretical potential as confounders and/or effect modifiers. VE was calculated as 1-OR. In addition, VE was assessed by year, in specific age groups, and for individual influenza types/subtypes.

Ethical approval for the study was obtained from the ethics committees of Princess Margaret Hospital for Children (1673/EP), the South Metropolitan Area Health Service, and the Western Australian Aboriginal Health Information and Ethics Committee.

RESULTS

A total of 2001 children were recruited for the study between 2008 and 2012, of whom 98 (4.9%) were excluded from the analysis (consent was withdrawn in 38, 50 were older than 59 months, 4 had no respiratory sample obtained, 6 had unknown vaccination status). The numbers of children enrolled each year varied from 169 in 2010 to 643 in 2012 (Table 1). The median age of children enrolled was 1.9 years. The majority of children had no preexisting conditions associated with severe influenza: comorbidities were present in 219 of 1855 (11.8%), with chronic asthma ($n = 156$), other chronic respiratory disease ($n = 22$), chronic neurologic disease ($n = 20$), and heart disease ($n = 17$) being most common.

Influenza was identified in 389 children (20.4%; influenza A: 14.1%; influenza B: 6.3%; Table 1). Another respiratory virus was identified in 1134 children (59.6%; Fig 1). The most frequently detected noninfluenza viruses were human picornaviruses ($n = 673$), respiratory syncytial virus A/B ($n = 312$), human parainfluenza virus types 1 to 4 ($n = 193$), adenoviruses B through D ($n = 157$), bocaviruses ($n = 126$), and coronaviruses OC43/229E ($n = 61$). Two or more respiratory viruses were

detected in 467 children, including 115 children with influenza, and another respiratory virus detected in the same sample.

Vaccine uptake was 24.0% overall (fully vaccinated: 295 of 1903, 15.5%; partially vaccinated: 161 of 1903, 8.5%) and decreased significantly from 2008–2009 (329 of 597, 55.1%) to 2010–2012 (127 of 1306, 9.7%; $P < .001$). Vaccine uptake in children with comorbidities was higher than in children without comorbidities (66 of 219 [30.1%] vs 389 of 1635 [23.8%]; $P = .045$), yet remained low.

Seventy-five children were identified as having influenza in 2009, of whom 72 were infected with the 2009 pandemic influenza A/H1N1 (2009), 2 with A/H3N2, and 1 with both A/H1N109 and A/H3N2 viruses. Given the significant mismatch between the seasonal influenza vaccine and the 2009 pandemic influenza A/H1N1 strain, all 2009 cases and controls were excluded from VE calculations.

Vaccine Effectiveness

Summary VE was calculated from the remaining 1514 children (Table 2). Unadjusted VE was calculated by season by using both test-negative and OVD controls (Table 3). After adjustment for season, month of disease onset, age, gender, indigeneity, prematurity, and comorbidities, fully vaccinated and unvaccinated children were compared (Table 4).

The overall adjusted VE using test-negative controls was 64.7% (95% CI: 33.7% to 81.2%). No difference in VE was observed when OVD controls were used: VE = 65.8% (95% CI: 32.1% to 82.8%). In children aged <2 years, VE was calculated to be 85.8% (95% CI: 37.9% to 96.7%) for test-negative controls and as 85.5% (95% CI: 34.7% to 96.8%) for OVD controls.

VE was calculated by influenza type/subtype. With the use of test-negative controls, a trend toward greater VE was observed for influenza A compared with

TABLE 1 Season of Enrollment, Virology, and Vaccination Status

	2008 (n = 208)	2009 (n = 389)	2010 (n = 169)	2011 (n = 494)	2012 (n = 643)	Total (N = 1903), n (%)
Virology, n						
Influenza virus detected	33	75	29	59	193	389 (20.4)
Influenza A/H1N1 (nonpandemic)	6	0	0	0	0	6 (0.3)
Influenza A/H1N1 (pandemic)	0	73 ^a	16	41	0	130 ^a (6.8)
Influenza A/H3N2	5	3 ^a	2	13	111	134 ^a (7.0)
Influenza B	22	0	11	5	82	120 (6.3)
Other virus detected ^b	124	226	109	325	236	1134 (59.6)
No respiratory virus detected	51	88	31	110	214	493 (25.9)
Vaccination status, n (%)						
Fully vaccinated	77 (37.0)	153 (39.3)	9 (5.3)	23 (4.7)	33 (5.1)	295 (15.5)
Partially vaccinated	28 (13.5)	71 (18.3)	17 (10.0)	13 (2.6)	32 (5.0)	161 (8.5)
Unvaccinated	103 (49.5)	165 (42.4)	143 (84.6)	458 (92.7)	578 (89.9)	1447 (76.0)

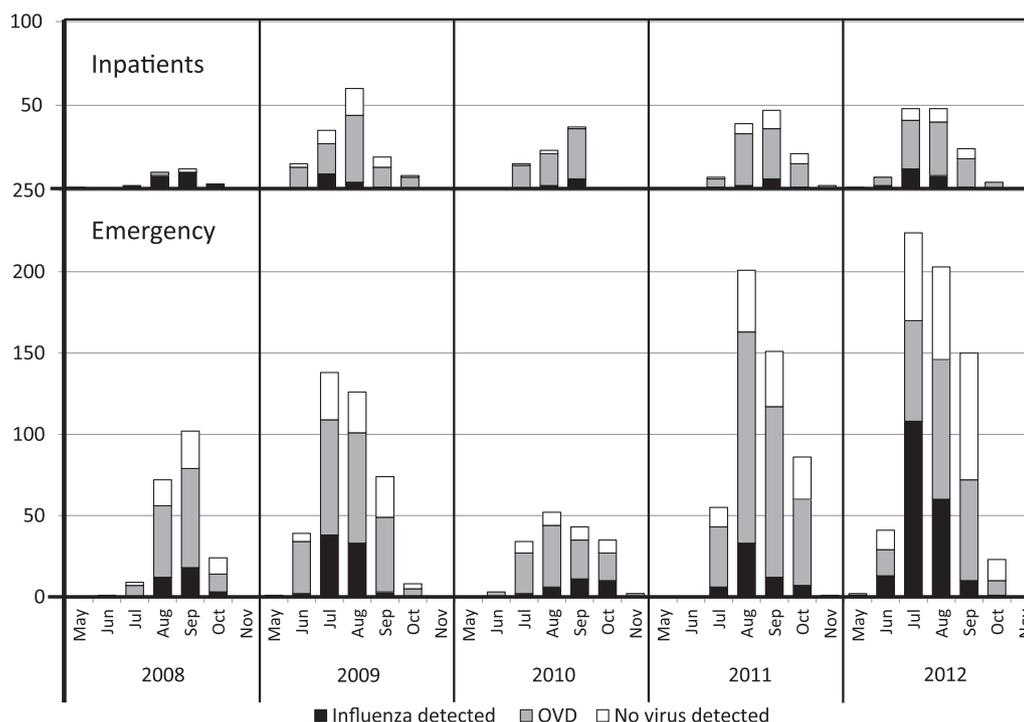
^a One patient had mixed influenza A/H1N1 (pandemic) and A/H3N2 infection.

^b One hundred fourteen children had influenza and another respiratory virus detected.

influenza B (overall influenza A: VE = 79.6%; 95% CI: 41.6% to 92.9%; influenza B: VE = 47.8%; 95% CI: -12.4% to 75.8%). When influenza A/H1N1 and influenza A/H3N2 were compared using test-negative controls, VE was 86.5% (95% CI: -4.2% to 98.2%) for A/H1N1 and 74.8% (95% CI: 13.5% to 92.7%) for A/H3N2. Insufficient cases were available to calculate VE against separate influenza B lineages.

When partially vaccinated and unvaccinated children were compared (ie, excluding fully vaccinated children), VE was 81.5% (95% CI: 54.7% to 92.4%) for test-negative controls and 83.8% (95% CI: 58.8% to 93.2%) for OVD controls. Receipt of ≥ 1 doses of seasonal influenza vaccine in the year of presentation (ie, fully and partially vaccinated children) had a VE of 72.2%

(95% CI: 52.7% to 83.6%) in test-negative controls and 74.4% (95% CI: 54.5% to 85.5%) in OVD controls. Significant VE of ≥ 1 doses of seasonal influenza vaccine was shown in both the younger and older age groups (VE = 78.4% [95% CI: 43.2% to 94.8%] and 78.4% [95% CI: 41.6% to 92.0%] for age < 2 years and VE = 69.3% [95% CI: 41.1% to 84.0%] and 73.3% [95% CI:

**FIGURE 1**

The number of positive specimens by month: 2008–2012. Children with both influenza and other respiratory virus are included in the influenza-detected group only.

TABLE 2 Demographic Characteristics, Risk Factors, and Vaccination Status in Cases and Controls (2008, 2010–2012)

	Influenza-Positive Cases (<i>n</i> = 314)	Test-Negative Controls (<i>n</i> = 1200)	OVD Controls (<i>n</i> = 794)	Total (<i>N</i> = 1514)	Cases Versus Test-Negative Controls; Cases Versus OVD Controls, <i>P</i>
Demographic characteristics and risk factors, <i>n/n</i> (%)					
Age <2 years	105/314 (33.4)	701/1200 (58.5)	481/794 (60.7)	806/1514 (53.3)	<.001; <.001
Male gender	156/311 (50.2)	650/1187 (54.8)	435/785 (55.4)	806/1498 (53.8)	NS; NS
Indigenous	22/305 (7.2)	51/1165 (4.4)	38/773 (4.9)	73/1470 (5.0)	NS; NS
Preterm birth	33/304 (10.9)	154/1162 (13.3)	103/766 (13.4)	187/1466 (12.8)	NS; NS
Any comorbidities	27/303 (8.9)	137/1162 (11.8)	85/769 (11.1)	164/1465 (11.2)	NS; NS
Asthma	21/303 (6.9)	102/1162 (8.8)	61/769 (7.9)	123/1514 (8.1)	NS; NS
Other chronic respiratory disease	3/303 (1.0)	15/1162 (1.3)	11/769 (1.4)	18/1514 (1.2)	NS; NS
Chronic cardiac disease	1/303 (0.3)	12/1162 (1.0)	9/769 (1.1)	13/1514 (0.9)	NS; NS
Chronic neurologic disease	3/303 (1.0)	11/1162 (0.9)	7/769 (0.9)	14/1514 (0.9)	NS; NS
Vaccination status, <i>n</i> (%)					
Fully vaccinated	14 (4.5)	128 (10.7)	85 (10.7)	142 (9.4)	
Partially vaccinated	6 (1.9)	84 (7.0)	57 (7.2)	90 (5.9)	<.001; <.001
Unvaccinated	294 (93.6)	988 (82.3)	652 (82.1)	1282 (84.7)	

NS, not significant.

44.8% to 87.1%] for age ≥ 2 years in test-negative and OVD controls, respectively).

VE against non-influenza virus infection was calculated by comparing other virus-positive cases with all virus-negative controls; VE was calculated to be -0.5% (95% CI: -56.1% to 34.3%).

DISCUSSION

Studies assessing TIV VE against laboratory-confirmed influenza in older children and adults have frequently revealed a protective effect.^{9–11} In children <2 years of age, there are fewer studies to guide immunization practice. Only 1 randomized controlled trial has been performed: Hoberman et al²¹ esti-

mated TIV VE against laboratory-confirmed influenza in children aged 6 to 23 months with acute otitis media during 2 North American influenza seasons to be -7% (95% CI: -247% to 67%) and 66% (95% CI: 34% to 84%). A number of prospective observational studies of TIV VE against laboratory-confirmed influenza have been performed: Heinonen et al⁵ estimated VE in fully vaccinated Finnish children aged 9 to 23 months enrolled in a single influenza season to be 67% (95% CI: 0 to 89). Of note, the dose of TIV administered in this study was double the dose recommended in other settings.^{2,8} Eisenberg et al²² estimated VE in children aged 6 to 23 months presenting to

3 US centers in 2 seasons to vary from 28% (95% CI: -130% to 77%) to 55% (95% CI: 13% to 77%). Shuler et al²³ estimated VE in children aged 6 to 23 months enrolled in a single influenza season to be 52% (95% CI: 20% to 70%). Maeda et al²⁴ failed to show protection against laboratory-proven influenza in children aged 6 to 24 months over 3 influenza seasons in Japan.

The paucity of published data in this age group has led to suggestions that there are insufficient data to support the routine use of TIV in children aged <2 years.^{9,10} Despite the paucity of data, given the high burden of influenza infection in this population, many international immunization advisory bodies

TABLE 3 VE by Year Against Laboratory-Confirmed Influenza Using Test-Negative and OVD Controls (unadjusted)

Season	Number of Cases and Controls				Unadjusted VE, % (95% CI)
	Fully Vaccinated Cases	Unvaccinated Cases	Fully Vaccinated Controls	Unvaccinated Controls	
Test-negative controls					
2008	9	21	68	82	48.3 (-20.2 to 77.8)
2010	0	29	9	114	100.0 (-64.5 to 100.0)
2011	2	57	21	401	33.0 (-194.4 to 84.7)
2012	3	187	30	391	79.1 (30.6 to 93.7)
Total	14	294	128	988	63.2 (35.2 to 79.1)
OVD controls					
2008	9	21	53	54	56.3 (-4.0 to 81.7)
2010	0	29	6	92	100.0 (-117.1 to 100.0)
2011	2	57	13	300	19.0 (-268.5 to 82.2)
2012	3	187	13	206	74.6 (9.4 to 92.9)
Total	14	294	85	652	63.5 (34.6 to 79.6)

TABLE 4 Pooled VE Against Laboratory-Confirmed Influenza Using All Influenza Test-Negative and OVD Controls

Population	VE, ^a % (95% CI)	
	All Influenza-Negative Controls	OVD Controls
All children	64.7 (33.7 to 81.2)	65.8 (32.1 to 82.8)
Children <2 years	85.8 (37.9 to 96.7)	85.5 (34.7 to 96.8)
Children ≥2 years	52.1 (−0.1 to 77.1)	55.0 (−3.6 to 80.5)
Influenza A	79.6 (41.6 to 92.9)	78.3 (34.8 to 92.8)
Influenza B	47.8 (−12.4 to 75.8)	53.2 (9.4 to 79.6)

^a VE compares fully vaccinated with unvaccinated children.

recommend influenza vaccine for young children. In the absence of a randomized controlled trial (which may be considered unethical in populations for whom vaccination is already recommended²), we are reliant on observational studies that assess outcomes associated with laboratory-confirmed influenza infection. This study reveals the effectiveness of TIV against medically attended, laboratory-proven influenza in Australian children aged 6 months to 5 years over 4 seasons. Of particular importance, this study provides the strongest evidence to date supporting the effectiveness of TIV in children younger than 2 years of age.

The Australian National Immunization Program strongly recommends and provides free influenza vaccine in all children and adults with risk factors for severe disease.⁸ In Australia, uptake of influenza vaccination in the elderly (≥65 years) is ~75%.²⁵ Current uptake of TIV in Australian children with risk factors for severe disease is uncertain: in this cohort, only 30% of those with preexisting risk factors for severe influenza infection had previously received TIV in the year of enrolment. Because Western Australia is the only Australian state with a publicly funded preschool influenza vaccination program, uptake in other states is expected to be even lower. The optimal methods to improve vaccine uptake in children have not been defined and are likely to vary in different jurisdictions. As has been observed in other countries, a recommendation for annual influenza vaccination is likely to improve coverage.²⁶

Public and provider confidence in the safety of influenza vaccination is also paramount to the success of any vaccination program.²⁷

Immunogenicity studies with both pandemic and seasonal vaccines reveal that young children frequently require a second dose of vaccine to achieve protective anti-influenza antibody levels.^{28–30} It is therefore recommended that children <9 years (ACIP, United States; Joint Committee on Vaccination and Immunization, United Kingdom) or ≤9 years (Australian Technical Advisory Group on Immunization, Australia) receive 2 doses of vaccine in the first year they are immunized. In our setting, partial immunization had demonstrable vaccine effectiveness (VE: 81.5%–83.8%). This result needs to be interpreted with caution and requires confirmation in other populations and over multiple influenza seasons.

Our intent in including both the test-negative and OVD control groups was to reduce the number of control children who may have had false-negative influenza results due to inadequate specimen collection, storage, and/or transport and to reduce the number whose symptoms were due to noninfectious causes. All viruses were detected by using the most sensitive and specific tests available. Because another respiratory virus was detected by PCR in OVD controls, we expect our methods were sufficiently sensitive to detect influenza should it have been present in the nasopharynx (ie, a low rate of false-negative influenza tests).

Similar to the findings of Sundaram et al,³¹ we found little difference in VE when both test-negative and OVD controls were used. These results are consistent with the assumption that influenza vaccination has little impact on infection with other respiratory viruses. This finding is contrary to the trend observed in our previous study,¹⁴ and results from a small trial published by Cowling et al.^{32,33} The similarity of the VE calculations for the 2 control groups may reflect the setting in which samples were collected, specifically experienced staff within a pediatric emergency department testing a carefully recruited patient population, so that deficiencies in sample collection were uncommon. Samples from young children are known to contain high levels of virus compared with older children and adults, and therefore sample collection methods may have been less critical. Additional studies on samples collected in other clinical settings and from older children and adults are needed to further compare the 2 control groups.

The strengths of this study include the number of children enrolled, particular children <2 years of age; the evaluation of TIV over 4 influenza seasons; the use of multiple methods to confirm immunization status; highly sensitive and specific laboratory diagnoses; and inclusion of other laboratory-confirmed respiratory pathogens. The identification of another pathogen in 59.6% of children presenting with an ILI reveals the limitations of the clinical definition of influenza³⁴ and further highlights the difficulty in interpreting studies calculating VE against ILI.

This study was limited by the significant decrease in vaccine uptake during and after 2010. In 2010, the Western Australian preschool influenza vaccination program was temporarily suspended after a significant increase in the rate of febrile adverse events after immunization.^{35,36}

These adverse events were attributed to 1 manufacturer's brands of influenza vaccine (Fluvax and Fluvax Junior; CSL Biotherapies Australia, now bioCSL). In 2010, the administration of FluVax and FluVax Junior was associated with a 44-fold increase in febrile convulsion compared with previous seasons.³⁵ Despite this dramatic decrease in vaccination, we were able to show significant VE in preschool children by increased re-cruiting in the latter years of the study.

CONCLUSIONS

Influenza vaccination in children aged <2 years has been a contentious issue due to the paucity of data showing VE. Our findings reveal the effectiveness of TIV in healthy young children, including

those younger than 2 years of age and support the current ACIP recommendations for young children. Consistent results were shown by using 2 different control groups. The inclusion of influenza vaccine in routine childhood immunization schedules will result in increased vaccine uptake. Ensuring access to a safe TIV is paramount to the successful implementation of a pediatric influenza vaccination program.

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