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# Influenza immunisation coverage from 2015 to 2017: A national study of adult patients from Australian general practice

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ABSTRACT

*Objectives:* To assess influenza immunisation rates and coverage in adult patients from Australian general practice and identify whether practice or patients' characteristics are associated with vaccination uptake.
*Design:* Open cohort study.
*Setting:* 550 Australian general practices included in the MedicineInsight database.
*Participants:* Patients aged 18+ years who had at least one consultation during influenza season between 2015 and 2017. Two samples were considered: (1) 'active' patients (at least three consultations in any two consecutive years) and (2) 'every year' patients (at least one consultation per year).
*Main outcome measures:* Influenza vaccination rates per 1,000 consultations and coverage (% vaccinated among those who consulted) from 2015 to 2017.
*Results:* Between 2015 and 2017 the influenza vaccine rate changed from 57.4 to 51.7 and 67.0 per 1,000 consultations, while correspondent values for coverage were 29.3%, 25.2% and 27.6% (in 'active' patients). Vaccine coverage was at least 30% higher in inner regional areas, among patients aged 65+ years or those with comorbidities. Similar associations were found among 'every year' patients, but average coverage across the three years was higher (41% vs 27%). Aboriginal and Torres Strait Islander people, either with or without comorbidity, showed a vaccine coverage 10–30% higher than non-Indigenous people for those aged less than 65 years (p-value for interaction < 0.001).
*Conclusion:* MedicineInsight data is a useful and low-cost method to monitor influenza immunisation coverage. Independent of the sample used, vaccination coverage among Indigenous people or patients with comorbidities could be improved. Targeted strategies for high-risk groups need to be developed.


## 1. Introduction

Influenza is a viral infectious disease which may cause severe illness and even death, especially among high-risk groups. According to the World Health Organization, influenza results in about 290,000 to 650,000 respiratory deaths worldwide [1]. In Australia, approximately 750 deaths were reported among patients with laboratory-confirmed influenza in 2017 [2], with influenza considered to be the most common vaccine-preventable disease [3].

In Australia, the National Immunisation Program (NIP) started funding free annual influenza immunisation for people aged 65 or over [3] and in 2010 included people with comorbidities (i.e., cardiac disease, chronic respiratory, neurological and immunocompromising conditions, diabetes mellitus), pregnant women, and Aboriginal and Torres Strait Islander adults [3].

Monitoring influenza vaccine coverage and investigating how practice or patient's characteristics may affect vaccination uptake is essential for planning purposes. Identifying coverage gaps and developing more effective vaccine strategies can help reduce hospitalisations, deaths and health care costs [4]. Nevertheless, in contrast to countries such as England [5], Northern Ireland [6] and Sweden [7], Australia lacks a national surveillance system for adult influenza vaccination coverage based on primary health medical records. Influenza vaccination coverage in the country has been measured through self-reported data collected via random-digit dialling telephone surveys [8], with some studies using data from hospitalised patients [9] or health insurance records (Medicare) [10]. The Australian government has recently expanded the

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Australian Immunisation Register (AIR) to capture vaccinations given to people of all ages and not only to children, which will allow the identification of vaccinations administered in different settings, within and outside general practice. However, to date no any report on influenza vaccination coverage has been published using that source of data [11].

In 2016, a systematic review of influenza vaccine coverage in Australia reported values ranging between 64% and 82% among those aged 65+ years, whilst in adults with comorbidities, aged less than 65 years, coverage did not reach 50% [12]. Among Aboriginal and Torres Strait Islanders, vaccine coverage showed a wider variation (from 23% to 96%) depending on age, sample size and methods used to measure coverage. Therefore, despite the higher risk of complications among these groups, influenza vaccination uptake was still lower than the 75% recommended by the World Health Organization [13].

Recently, electronic medical records have been suggested as a potential source to monitor influenza vaccination coverage [10,14]. Information obtained from these sources are cheaper than an active surveillance system and comparable to self-reported data (83.8% agreement; Kappa coefficient 0.68, 95% CI: 0.63, 0.72) [14].

Therefore, using data from MedicineInsight, a large electronic medical record database of over four million patients attending 656 general practices across Australia, this study aimed to explore influenza vaccination rates and coverage between 2015 and 2017, and identify whether sociodemographic or health-related factors are associated with vaccination coverage.

## 2. Methods

### 2.1. Data source

This study included data from the MedicineInsight database, a national general practice data program developed and managed by NPS MedicineWise with funding from the Australian Government Department of Health (https://www.nps.org.au/medicine-insight). De-identified medical records are monthly extracted and securely transferred to NPS MedicineWise. The program includes patients of all ages and socioeconomic status within general practices from all Australian states. Details of data collection are available elsewhere [15,16].

### 2.2. Sample selection

To explore vaccination rates, this open cohort study initially included all patients aged 18+ years who had at least one consultation between 2015 and 2017 within a MedicineInsight practice (Fig. 1). Since immunisation for influenza in Australia mainly occurs between March and August (autumn and winter in the Southern hemisphere) [8], we based estimates for vaccine coverage on patients who attended during that period (i.e., months when they could have been vaccinated). To improve data quality, the sample was also restricted to patients who 'regularly' attended the same practice, as they would be more likely to get the vaccine at that place if they decided to be immunised [12]. Two different definitions for a 'regular' patient were used: (1) the Royal Australian College of General Practitioners defines 'active' patients as any person who has at least three consultation (March-August) in any two consecutive years [17], or (2) we defined 'every year' patients, as those who had at least one consultation (March-August) per year. Replicating the analyses in both samples ('active' or 'every year') allowed us to assess the consistency of the associations and identify which sample provided more comparable results to the available literature [12].

### 2.3. Data extraction

In Australian general practice, when a patient is immunised, general practitioners (GPs) and registered nurses are encouraged to select a code from the "immunisation" field. However, the use of codes is not mandatory, and the name of the vaccines can be recorded as a 'free' text [15]. Therefore, we developed an algorithm to extract the information on influenza vaccine from the immuni-

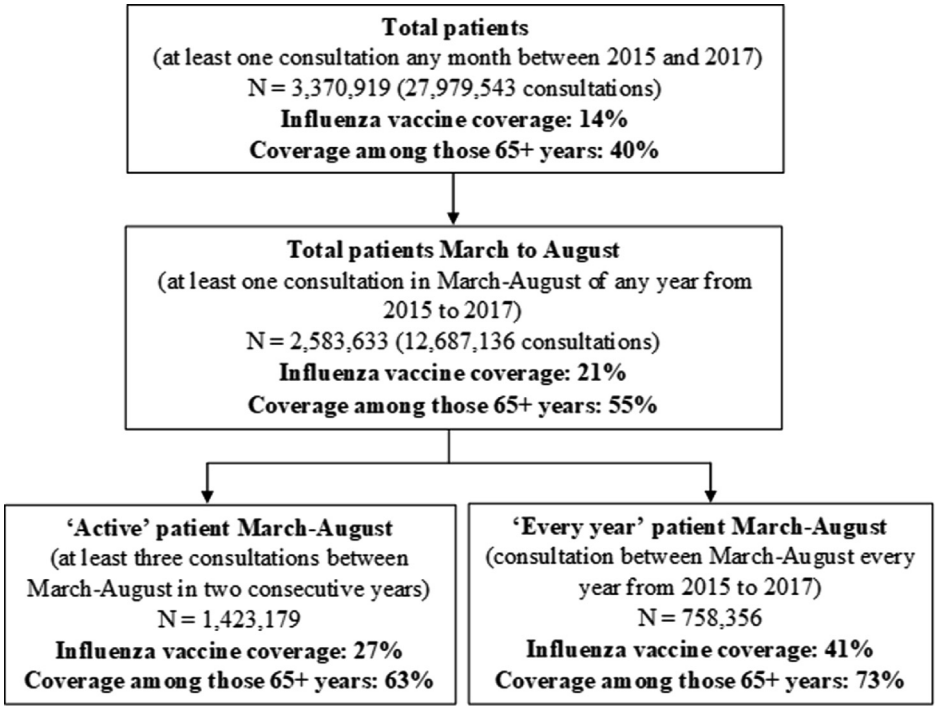


**Fig. 1.** Flowchart of the selection of patients included in the study and the influenza vaccination coverage. Australia, 2015–2017.

sation field in the MedicineInsight database, including the terms 'flu' AND ('vaccine' OR 'vax' OR 'shot' OR 'needle'), synonyms of these terms, and brand names of influenza vaccines available in Australia (i.e., Afluria®, Agrippal®, Fluad®, Fluarix®, FluQuadri™, Influvac®, Vaxigrip®; Supplementary Table 1). To improve data quality, record of any additional influenza vaccination for the same patient within 120 days of the first registered immunisation was considered duplicate and excluded from the analyses (n = 14,383 from 2015 to 2017).

### 2.4. Outcomes

Two different outcomes were evaluated: (1) vaccination rates, and (2) vaccination coverage. Vaccination rates, either weekly or annual, were estimated as the total number of influenza vaccinations per 1,000 consultations. The total number of consultations included all clinical visits to the practice when a diagnosis, reason for encounter, immunisation, or medication prescription was recorded in the database. Administrative reason for encounter (e.g. phone calls, emails, reminders) or duplicate registers for the same patient and date were excluded.

Vaccine coverage was estimated as the percentage (%) of patients who received the influenza vaccine divided by the total number of patients who had a consultation between March and August that year. The same equation was used either for 'active' or 'every year' patients.

### 2.5. Covariates

Rurality and the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD, in quintiles) of the practice were defined based on the practice postcode [18].

Patients' variables included gender, age (based on year of birth), Indigenous status and IRSAD quintiles. The presence of comorbidities was also explored as a covariate, as they increase the risk of influenza complications [3]: (1) cardiac disease; (2) chronic respiratory condition; (3) chronic neurological condition; (4) immunocompromising condition; (5) chronic liver disease; or (6) other chronic illnesses (chronic kidney disease, diabetes mellitus, haemoglobinopathies). These comorbidities were extracted from the "diagnosis" and "reason for encounter" fields by using an algorithm including a combination of all possible terms and synonyms (Supplementary Table 2). Individuals with at least one condition were considered as having comorbidity.

### 2.6. Statistical analysis

Influenza vaccination rates per 1,000 consultations in each calendar week from 2015 to 2017 were calculated and the results presented graphically.

The association between influenza vaccination coverage and characteristics of the practice was assessed by using logistic regression models with all variables mutually adjusted. Robust standard errors were used to account for clustering of patients within the practice. A similar analytical procedure was used to evaluate the association with patients' characteristics. In this case, all results were adjusted for age, gender, and characteristics of the practice (rurality and IRSAD). Marginal adjusted probabilities of vaccination coverage in each category of the exposure variables were then estimated and presented with their respective 95% confidence intervals (95% CI).

Finally, we also investigated whether the association between age, comorbidity and vaccination coverage was moderated by Indigenous status. According to the NIP, Aboriginal and Torres Strait Islanders aged 15+ years are eligible to receive annual influenza vaccination. These groups are also more likely to be affected by chronic conditions at younger ages [3,19]. Therefore, multiplicative terms between age, Indigenous status, and the presence of comorbidities were included in the regression models. When the heterogeneity of the effects was verified (p-value for interaction < 0.05), results were stratified and presented graphically with their 95% CI.

Analyses were performed in the statistical software Stata 15.0 (StataCorp, Texas, USA). Coverage estimates considered sampling weights (inverse of the patient's probability of being in the sample = 1/median number of consultations with the GP per year) for data correction [16]. The Independent MedicineInsight Data Governance Committee has approved the study (protocol 2017–007) and the Human Research Ethics Committee of the University of Adelaide exempted it of an ethical review, as only non-identifiable data was used.

## 3. Results

The total number of influenza vaccinations for the period 2015–2017 was 1,445,902 with a total of 27,979,543 consultations. Most vaccines were administered from March to July, with a peak between weeks 15th and 18th in any year (Fig. 2). However, the vaccination rate in 2017 (67.0 per 1,000 consultations) was at least 15% higher than in previous years (57.4 and 51.7 per 1,000 consultations in 2015 and 2016, respectively).

The overall vaccination coverage for the period 2015–2017 was 27% among 'active' patients, but was 1.5 times higher among 'every year' patients (Fig. 1).

Among 'active' patients (Table 1), the mean age was 48.7 ± 18.3 years (22% were 65+ years), 57% were women, 2% were classified as Aboriginal/Torres Strait Islander, 24% had at least one comorbidity, and 38% were patients from a practice located in rural Australia. Vaccination coverage from 2015 to 2017 ranged from 25% to 29% in 'active' patients. The proportion of immunised 'active' patients in inner regional areas was 30% higher than in major cities and was at least three times higher among patients aged 65+ year than in younger patients. Vaccine coverage was approximately 15% higher in Aboriginal and Torres Strait Islanders and 40% more frequent among patients with comorbidities. Differences in vaccine coverage according to gender, practice or patients' IRSAD were less marked.

Among 'every year' patients (Table 2), the distribution according to rurality, IRSAD, gender or aboriginality was similar to 'active' patients, but there was a higher proportion of elderly individuals (mean age of the sample 58.1 ± 18.5 years) or those with comorbidities. Although vaccination coverage in 'every year' patients remained steady at 41% between 2015 and 2017, the associations with practice and patients' characteristics were similar to those found among 'active' patients (Table 2).

Fig. 3 shows immunisation coverage in 2017 according to Indigenous status, age and presence of comorbidities, as well as the prevalence of comorbidities in each age group. Aboriginal and Torres Strait Islanders, either with or without comorbidity, showed a vaccine coverage 10–30% higher than non-Indigenous people, but only when they were aged < 65 years (p-value for interaction < 0.001). Among those aged 65+ years, vaccination coverage was higher in non-Indigenous people than in their peers, especially if affected by some comorbidity.

## 4. Discussion

This study investigated influenza vaccination rates and coverage using electronic medical records from a large national general practice database to help determine if it could be used to monitor adult immunisation coverage in Australia on a regular basis. Using

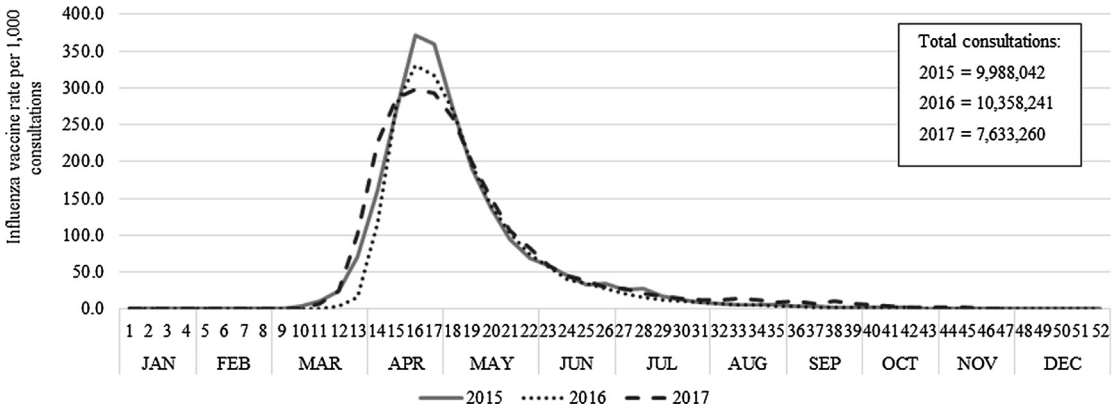


**Fig. 2.** Weekly Influenza vaccine rate per 1,000 consultations in Australian general practices from 2015 to 2017.

**Table 1**
Influenza vaccine coverage among 'active' patients[a] according to practice and patient's characteristics. Australia, 2015–2017.

| | Sample | Coverage 2015 | | Coverage 2016 | | Coverage 2017 | |
|---|---|---|---|---|---|---|---|
| Variable | Distribution (%) | % | (95% CI) | % | (95% CI) | % | (95% CI) |
| **Practice characteristics** | | | | | | | |
| **Rurality** | | | | | | | |
| Major cities | 61.6 | 27.5 | (27.4;27.6) | 23.5 | (23.4;23.6) | 25.4 | (25.2;25.5) |
| Inner regional | 23.2 | 35.4 | (35.1;35.6) | 31.0 | (30.8;31.2) | 34.6 | (34.3;34.8) |
| Outer regional/Remote/Very remote | 15.2 | 26.7 | (26.4;27.0) | 23.1 | (22.9;23.3) | 26.0 | (25.8;26.3) |
| **IRSAD quintile** | | | | | | | |
| Very high | 27.1 | 31.0 | (30.8;31.3) | 27.0 | (26.8;27.2) | 29.6 | (29.4;29.8) |
| High | 18.0 | 27.9 | (27.7;28.1) | 23.8 | (23.6;24.0) | 26.2 | (26.0;26.5) |
| Middle | 21.2 | 30.5 | (30.3;30.7) | 26.5 | (26.4;26.7) | 28.9 | (28.7;29.1) |
| Low | 13.7 | 28.1 | (27.9;28.4) | 23.7 | (23.5;24.0) | 24.7 | (24.5;25.0) |
| Very Low | 20.1 | 27.9 | (27.7;28.1) | 24.0 | (23.8;24.2) | 27.0 | (26.7;27.2) |
| **Patient's characteristics** | | | | | | | |
| **Gender** | | | | | | | |
| Male | 43.1 | 28.6 | (28.5;28.7) | 24.6 | (24.5;24.7) | 27.0 | (26.9;27.1) |
| Female | 56.9 | 29.9 | (29.8;30.0) | 25.8 | (25.7;25.9) | 28.1 | (28.0;28.2) |
| **Age** | | | | | | | |
| 18–44 | 44.4 | 10.9 | (10.7;11.0) | 9.0 | (8.9;9.1) | 9.4 | (9.3;9.5) |
| 45–64 | 33.4 | 22.0 | (21.8;22.1) | 19.2 | (19.0;19.3) | 20.4 | (20.3;20.6) |
| 65+ | 22.2 | 65.3 | (65.1;65.5) | 61.2 | (61.0;61.4) | 64.0 | (63.8;64.2) |
| **Aboriginal/Torres strait islander** | | | | | | | |
| No | 74.8 | 29.5 | (29.4;29.6) | 25.6 | (25.5;25.6) | 27.9 | (27.8;28.0) |
| Yes | 1.6 | 34.0 | (33.2;34.7) | 29.6 | (29.0;30.2) | 32.0 | (31.3;32.7) |
| Not recorded | 23.6 | 28.2 | (28.0;28.4) | 24.0 | (23.9;24.2) | 26.3 | (26.1;26.5) |
| **IRSAD quintile** | | | | | | | |
| Very high | 26.1 | 28.2 | (28.0;28.4) | 24.7 | (24.5;24.9) | 27.2 | (26.9;27.4) |
| High | 19.2 | 28.5 | (28.3;28.8) | 24.4 | (24.2;24.6) | 27.1 | (26.9;27.3) |
| Middle | 21.7 | 29.3 | (29.1;29.6) | 25.5 | (25.3;25.6) | 27.7 | (27.5;27.9) |
| Low | 16.8 | 29.2 | (28.9;29.4) | 25.1 | (24.9;25.4) | 27.4 | (27.1;27.7) |
| Very Low | 16.2 | 31.9 | (31.6;32.2) | 27.0 | (26.7;27.2) | 29.1 | (28.8;29.4) |
| **Comorbidities**[b] | | | | | | | |
| No | 76.5 | 26.1 | (26.0;26.3) | 22.3 | (22.2;22.4) | 24.6 | (24.5;24.7) |
| Yes | 23.5 | 36.1 | (36.0;36.3) | 32.0 | (31.8;32.1) | 34.4 | (34.3;34.6) |
| *Total number of patients* | | *1,197,045* | | *1,423,179* | | *1,183,372* | |
| **Total** | | **29.3** | **(29.2;29.3)** | **25.2** | **(25.1;25.3)** | **27.6** | **(27.5;27.7)** |

IRSAD: Index of Relative Socio-economic Advantage and Disadvantage.
[a] At least three consultations between March-August in any two consecutive years from 2015 to 2017.
[b] Comorbidities include: cardiac disease, chronic neurological disease, chronic respiratory disease, chronic liver disease, immunocompromising conditions or other chronic diseases (including chronic renal failure, diabetes mellitus or haemoglobinopathies).

two different patient samples ('active' or 'every year' patients) and restricting the inclusion period to March to August, the results consistently identified a higher vaccination coverage among those aged 65+ years, Aboriginal and Torres Strait Islander people, or patients with comorbidities. However, our estimates for vaccination coverage were lower among 'active' patients than in 'every year' patients (27% vs 41%, respectively). Comparisons of these estimates to previous findings, to identify which is the most consistent, are difficult because standardised methods for estimating coverage across studies are lacking [8,12,20]. Estimates based on self-reported data or extracted from health records can provide discrepant results. A study investigating a sample of 'active' patients attending general practices in Western Australia in 2014 found a seasonal influenza vaccination coverage of 51% based on self-reported data and 37% when the information was gathered from electronic health records [14]. The age and sex distribution of the investigated samples are additional sources of bias, as they are closely related to health service use and vaccination uptake

**Table 2**
Influenza vaccine coverage among 'every year' patients[a] according to practice and patient's characteristics. Australia, 2015–2017.

| Variable | Sample distribution (%) | 2015 % | 2015 (95% CI) | 2016 % | 2016 (95% CI) | 2017 % | 2017 (95% CI) |
|---|---|---|---|---|---|---|---|
| **Practice characteristics** | | | | | | | |
| **Rurality** | | | | | | | |
| Major cities | 59.9 | 37.9 | (37.7;38.1) | 38.0 | (37.8;38.2) | 37.6 | (37.4;37.8) |
| Inner regional | 25.8 | 49.4 | (49.1;49.7) | 49.5 | (49.2;49.8) | 48.8 | (48.5;49.1) |
| Outer regional/remote/very remote | 14.3 | 39.8 | (39.3;40.2) | 40.1 | (39.7;40.6) | 39.4 | (39.0;39.8) |
| **IRSAD quintile** | | | | | | | |
| Very high | 26.2 | 44.4 | (44.0;44.7) | 44.4 | (44.1;44.8) | 44.2 | (43.9;44.5) |
| High | 16.7 | 39.6 | (39.2;39.9) | 39.7 | (39.4;40.1) | 39.2 | (38.9;39.6) |
| Middle | 22.4 | 41.5 | (41.2;41.8) | 42.0 | (41.7;42.3) | 41.7 | (41.4;42.0) |
| Low | 14.2 | 38.1 | (37.8;38.5) | 38.1 | (37.8;38.5) | 36.5 | (36.2;36.9) |
| Very low | 20.5 | 40.1 | (39.8;40.5) | 39.9 | (39.6;40.3) | 39.5 | (39.1;39.8) |
| **Patient's characteristics** | | | | | | | |
| **Gender** | | | | | | | |
| Male | 41.9 | 40.7 | (40.5;40.8) | 41.0 | (40.8;41.2) | 40.5 | (40.4;40.7) |
| Female | 58.1 | 41.5 | (41.4;41.7) | 41.5 | (41.3;41.6) | 40.9 | (40.7;41.0) |
| **Age** | | | | | | | |
| 18–44 | 29.4 | 14.8 | (14.6;15.0) | 14.0 | (13.9;14.2) | 13.4 | (13.2;13.6) |
| 45–64 | 33.8 | 29.6 | (29.4;29.8) | 29.5 | (29.3;29.8) | 29.1 | (28.9;29.4) |
| 65+ | 36.7 | 72.7 | (72.5;72.9) | 73.7 | (73.5;73.9) | 73.1 | (72.9;73.3) |
| **Aboriginal/Torres strait islander** | | | | | | | |
| No | 77.8 | 41.1 | (41.0;41.3) | 41.2 | (41.1;41.3) | 40.7 | (40.6;40.9) |
| Yes | 1.4 | 44.9 | (43.9;45.9) | 45.4 | (44.5;46.4) | 44.4 | (43.4;45.3) |
| Not recorded | 20.8 | 40.9 | (40.6;41.2) | 41.1 | (40.8;41.4) | 40.4 | (40.1;40.7) |
| **IRSAD quintile** | | | | | | | |
| Very high | 24.7 | 39.6 | (39.3;40.0) | 40.2 | (39.9;40.6) | 40.0 | (39.6;40.4) |
| High | 18.1 | 40.4 | (40.1;40.7) | 40.3 | (40.0;40.6) | 39.9 | (39.6;40.3) |
| Middle | 22.5 | 40.9 | (40.6;41.3) | 41.1 | (40.8;41.4) | 40.4 | (40.1;40.7) |
| Low | 17.1 | 40.9 | (40.5;41.3) | 41.0 | (40.6;41.3) | 40.3 | (39.9;40.7) |
| Very low | 17.6 | 44.5 | (44.1;44.9) | 44.1 | (43.7;44.5) | 43.4 | (43.0;43.8) |
| **Comorbidities**[b] | | | | | | | |
| No | 66.3 | 37.9 | (37.7;38.0) | 38.0 | (37.9;38.2) | 37.7 | (37.5;37.8) |
| Yes | 33.7 | 47.1 | (46.9;47.3) | 47.1 | (46.9;47.4) | 46.2 | (46.0;46.4) |
| *Total number of patients* | | *758,356* | | *758,356* | | *758,356* | |
| **Total** | | **41.1** | **(41.0;41.2)** | **41.2** | **(41.1;41.3)** | **40.7** | **(40.5;40.8)** |

IRSAD: Index of Relative Socio-economic Advantage and Disadvantage.
[a] At least one consultation per year between March-August from 2015 to 2017.
[b] Comorbidities include: cardiac disease, chronic neurological disease, chronic respiratory disease, chronic liver disease, immunocompromising conditions or other chronic diseases (including chronic renal failure, diabetes mellitus or haemoglobinopathies).

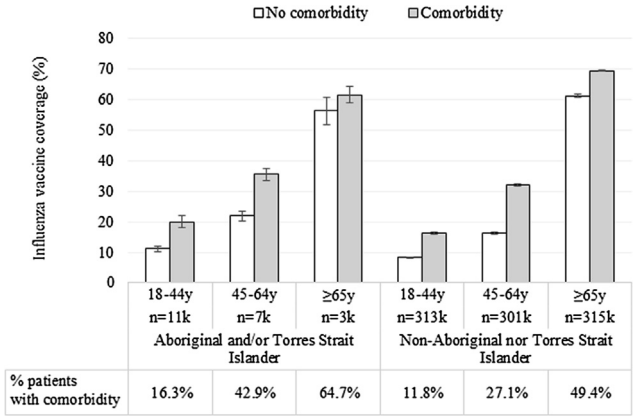


**Fig. 3.** Influenza vaccine coverage (% and respective 95% confidence interval) according to Indigenous status and presence of comorbidities in each age group among 'active' patients. Australia, 2015–2017.

[12,21]. In the former study, 65% of the participants were females and 28% were aged 65+ years [14]. According to the last census, 51% of Australian adults are women and 21% are 65+ years [22]. In our sample, 'active patients' more closely resemble census data than the 'every year' cohort. Elderly individuals were overrepresented in the 'every year' cohort which explains their higher vaccination coverage and prevalence of comorbidities compared with the 'active' cohort.

Furthermore, vaccination coverage among 'active' patients showed a wider oscillation between 2015 and 2017 than in 'every year' patients. The same oscillations were identified in our results for influenza vaccination rates (lower rates in 2016) and are consistent with the more intense influenza seasons observed in 2015 and 2017 as reported by three different Australian surveillance systems [23–25]. Therefore, estimates of influenza vaccination coverage based on samples of 'active' patients seems more accurate than those from 'every year' patients. As new data becomes available, further studies including additional years would allow users of MedicineInsight data to investigate time-trend patterns.

Regarding estimates for higher risk groups, a systematic review published in 2016 [12] showed vaccine coverage among Australians aged 65+ years ranged from 64% to 82% depending on the methodology used, while among Aboriginal and Torres Strait Islander there was an even wider variation (from 23% to 96%). Overall, our results from either 'active' or 'every year' patients provided estimates within these ranges (63% and 73% for vaccination in the elderly and 32% and 41% among Indigenous people, respectively). Among those with some comorbidity, between one third and a half of them have been vaccinated, depending on the sample used. The findings suggest influenza vaccination coverage among higher risk groups is well below expectations.

Coverage among Australians aged 65+ years is lower than in other high-income countries with funded vaccination programs (e.g. England and the United States) [5,26], and this has been consistently identified in previous studies [12]. However, even though

these countries have well-defined strategies for improving influenza vaccination uptake, they have not reached the recommended 75% coverage for elderly individuals [5,26].

According to our results, Aboriginal and Torres Strait Islanders or those with coexisting chronic medical conditions should be targeted by new strategies that aim to improve vaccination coverage. Aboriginal and Torres Strait Islanders have higher vulnerability to respiratory illnesses, higher influenza-related hospitalisations rates and a greater prevalence of chronic conditions than non-Indigenous people [19,27]. Nonetheless, we identified that vaccination coverage for Aboriginal and Torres Strait Islanders aged 65+ years was lower than in non-Indigenous people, even among those affected by some comorbidity. The United States seems to face the same issue, as influenza vaccination coverage among American Indian or Alaska Native adults is lower than in white people [26].

Considering influenza immunisation among high-risk groups is funded by the Australian government [3], GPs have an essential role in improving the vaccine uptake. Approximately 90% of all Australians visit a GP annually [21], most individuals are immunised at a general practice [20], and one of the main reasons for being immunised is health professional recommendation [12,20]. In our study, the median number of visits to the practice was 4 among 'active' patients and 5 among 'every year' patients, and it was 1.7 times higher among elderly patients or those with some comorbidity. Therefore, these encounters should be opportunities for GPs to identify these individuals and provide recommended immunisations.

We also identified a similar vaccination coverage in both sexes, although studies conducted before 2010 reported a higher frequency in females [8,12]. Consistent with the literature, we also identified higher coverage among individuals living in lower socioeconomic areas [8,12]. However, immunisations were more likely in practices located in areas with the highest IRSAD quintile or in inner regional Australia. Results from Australia and other high-income countries regarding these associations are discrepant and require further exploration [28–32]. However, these discrepancies may reflect methodological differences between studies or changes in these relationships over time.

The consistency of our findings suggests that MedicineInsight is a valuable and low-cost source of data to monitor vaccine uptake. It includes a very large sample of patients, including individuals and practices from all Australian regions and socioeconomic levels. The systematic data extraction process used in this study also increases the likelihood of data quality [33]. However, there are some limitations. First, vaccination coverage might be underestimated among adults, as up to half of them get the vaccine at their workplace, compared to only 3% in the elderly [20]. Vaccinations out of general practice (i.e. non-traditional locations such as workplace, nursing homes, pharmacies) are not captured by MedicineInsight, and these events are rarely recorded by GPs (i.e. only 17 cases identified in the database for the investigated period). Second, one out of five patients have no information about their Indigenous status. However, it is less likely this lack of information affected our results, as the coverage for these individuals was similar than for non-Indigenous people. Third, MedicineInsight reflects real clinical practice data, with immunisations recorded by GPs or registered nurses. Therefore, data quality and accuracy rely on general practice's routine, since the information can be registered as free text. In this sense, the record of comorbidities can also be affected, as showed in previous studies using electronic medical records [14]. However, the prevalence of some chronic conditions using MedicineInsight resemble data from the National Health Survey, such as heart disease (4.1% vs 5.2%), diabetes mellitus (5.1% in both), or chronic kidney disease (1.5% vs 0.9%) [16,34]. Fourth, the investigated associations are limited to those variables available in the dataset, and factors such as reasons for receiving or refusing the vaccine are not systematically recorded. Finally, MedicineInsight used a non-random technique to select practices. However, using the definition of 'active' patients allows obtaining a sample that resembles more the Australian distribution [22].

## 5. Conclusion

The use of electronic general practice medical records may be a useful and low-cost method to monitor annual influenza immunisation coverage, compared to surveys that tend to be more expensive when larger samples are investigated and performed over longer time intervals (every five years in Australia). Further studies using a similar source of data should be aware that methodological decisions such as the sample selection may bias the results and affect the accuracy of the estimates. At least for annual influenza vaccinations, using the definition of 'active' patients seems to provide results that are more consistent with the published literature. Independent of the sample used, vaccination coverage among Aboriginal and Torres Strait Islanders or patients with comorbidities was lower than recommended targets. Strategies to improve influenza immunisation coverage in these high-risk groups should be developed.

## Declaration of Competing Interest

None.

## Acknowledgment

C.O.B., D.A.G., N.S. contributed to the conception and design of the study, acquisition of data, analysis and interpretation of data, and participated in drafting and revision of the submitted article. M.C. contributed to the drafting and revision of the submitted article. The authors have no conflict of interest.

## Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2019.06.057.

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