Increasing Influenza and Pneumococcal Vaccination Uptake in Seniors Using Point-of-Care Informational Interventions in Primary Care in Singapore: A Pragmatic, Cluster-Randomized Crossover Trial

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Objectives. To evaluate the effectiveness of point-of-care informational interventions in general practitioner clinics to improve influenza and pneumococcal vaccination uptake among elderly patients.

Methods. We conducted a pragmatic, cluster-randomized crossover trial in 22 private general practitioner clinics in Singapore, from November 2017 to July 2018. We included all patients aged 65 years or older. Clinics were assigned to a 3-month intervention (flyers and posters encouraging vaccination) plus 1-month washout period, and a 4-month control period (usual care). Primary outcomes were differences in vaccination uptake rates between periods. Secondary outcomes were identification of other factors associated with vaccination uptake.

Results. A total of 4378 and 4459 patients were included in the intervention and control periods, respectively. Both influenza (5.9% vs 4.8%; $P = .047$) and pneumococcal (5.7% vs 3.7%; $P = .001$) vaccination uptake rates were higher during the intervention period compared with the control period. On multilevel logistic regression analysis, follow-up for hypertension, diabetes mellitus, hyperlipidemia, or any combination of the 3 was associated with uptake of both vaccines.

Conclusions. Point-of-care informational interventions likely contributed to increased influenza and pneumococcal vaccination uptake. Patients on follow-up for hypertension, diabetes mellitus, hyperlipidemia, or any combination of the 3 were more likely to receive influenza and pneumococcal vaccination and should be actively engaged by physicians.

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Influenza and pneumococcal vaccines have been shown to be effective in reducing the risk of influenza virus and *Streptococcus pneumoniae* bacterial infections, respectively, in elderly persons.[1–3] Current international guidelines recommend that all persons aged 65 years or older receive annual influenza vaccination[4] and pneumococcal vaccination with single doses of PCV13 and PPSV23.[5]

However, vaccination uptake rates among the elderly vary substantially across countries.[6] Barriers to vaccination include a lack of awareness, vaccine misconceptions, doubts about necessity of vaccines, and cost issues.[7–9] Failure of health care workers to provide recommendations also results in missed opportunities to vaccinate eligible patients.[10] Conversely, effective measures to increase vaccination uptake include invitational brochures, brief messages with cues to action, improving accessibility, clinician reminders, and providing information on available financial schemes.[11–13]

Singapore is a tropical country that experiences year-round circulation of influenza viruses. Typically, there are bimodal peaks in annual influenza activity,[14] and an estimated 1 in 5 adults are infected over a 1-year period.[15] Both influenza and pneumococcal disease are important causes of mortality and morbidity among the elderly.[16,17] However, despite national recommendations[18] and the widespread availability of vaccines, vaccination rates in the elderly are low, estimated at 17.0% for influenza and 6.1% for at least 1 pneumococcal vaccination.[19,20]

Private general practitioner (GP) clinics provide 80% of primary care services in Singapore, including 55% of chronic disease care.[21] Each clinic is staffed by 1 or more regular GPs and clinic assistants (CAs) who assist with patient registration, dispensing of medication, and billing of patients. Vaccination services are available on site, and many clinics offer the use of Medisave (a compulsory medical savings scheme for all Singapore residents),[22] which can be used to

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pay for vaccinations, thereby reducing out-of-pocket costs. These clinics are hence well-suited for opportunistic vaccination of patients.

However, current evidence on increasing influenza and pneumococcal vaccination uptake is largely from Western temperate countries, which differ from settings such as Singapore in terms of seasonal patterns, cultural norms, primary care infrastructure, and health care financing. Studies in additional settings are hence needed to verify the effectiveness of specific interventions in different cultures and health systems.

We evaluated the effectiveness of an intervention utilizing informational materials, sited at the point of care in private GP clinics, to improve influenza and pneumococcal vaccination uptake among elderly patients.

METHODS

We conducted a pragmatic, cluster-randomized crossover trial in private GP clinics in Singapore, from November 2017 through July 2018.

Setting

We engaged the senior management of 3 private GP clinic chains (comprising 30 clinics in total) to participate in the study. The senior management subsequently shared the study details (as provided by the study team) with the lead GPs in each clinic during their regular business meetings as well as by e-mail dissemination and sought their agreement to participate.

Of the 3 chains, 1 (comprising 7 clinics) declined participation because of concerns about additional administrative workload. Within the other 2 chains (comprising 23 clinics), 1 clinic was excluded because of differences in clinic software and operational challenges with data extraction. The remaining 22 clinics were included in the study (Figure A, available as a supplement to the online version of this article at http://www.ajph.org). The participating clinics were well-distributed across urban areas and housing estates in the country, providing primary care services to community-dwelling elderly patients with wide demographic variation.

Participants

We included all patients aged 65 years or older, with or without chronic disease, who visited and were registered as clinic patients during the study period.

Randomization and Allocation

We conducted randomization at the clinic level, with each clinic comprising 1 cluster. The study team used a computerized random number generator to allocate clinics to start with either the intervention or control period.

The study comprised 2 phases: a 4-month initial phase followed by a 4-month crossover phase. During the initial phase, half of the clinics underwent a 3-month intervention period (during which patients received the informational intervention), followed by a 1-month washout period. The other half of the clinics underwent the control period (during which patients received usual care) for 4 months. The clinics subsequently switched over in the crossover phase (Figure A). Because of the nature of the intervention, blinding of clinic staff and patients was not possible.

Intervention

The intervention materials comprised informational flyers and posters carrying uncomplicated messages encouraging patients to get vaccinated against influenza and pneumococcal disease (Figure B). These messages stated key benefits identified to be important to seniors from previous qualitative studies.[7] The option to make payment by using Medisave (available in all clinics in our study) was also highlighted. The design and message content of the materials were developed by an external commercial designer and discussed with a health communications expert (M. O. L.), with revisions made to ensure realism and GP clinic context appropriateness before dissemination. Materials were first developed in English, and then translated to Chinese to cater to the large proportion of mainly Chinese-literate elderly patients who were expected to visit the clinics (70% of Singaporeans are Chinese).

Before each study phase, the study team briefed all GPs and CAs from clinics undergoing the intervention period on the workflow (Figure C, available as a supplement to the online version of this article at http://www.ajph.org). In each clinic, CAs managed the distribution of the flyers, and 1 or 2 posters were put up in prominent areas. At the point of registration, CAs identified patients aged 65 years or older and handed each patient a flyer to read while awaiting their turn for medical consultation. Patients were instructed to show the doctor the flyer during consultation, and the doctor would counsel and vaccinate patients who were agreeable and fulfilled eligibility criteria (e.g., no recent similar vaccine given, no previous allergic reactions).

Data Collection

All study data were obtained from the clinics' electronic medical records, extracted with the help of information technology vendors for the clinic management software. All key patient identifiers were anonymized before use by the study team. Within each study phase, each patient was identified by a unique study identity number to match repeat visits. We collected data on age, gender, ethnicity, postal codes (to match housing type, commonly used as a surrogate measure for income status in Singapore as it correlates with household income),[23] and all dispensed medications and vaccines over each study phase for each patient. We considered patients to be on chronic disease follow-up with the clinic if they had been dispensed medications identified to treat hypertension, diabetes mellitus, hyperlipidemia, asthma, or chronic obstructive pulmonary disease at any point over the study period.

Outcomes

Primary outcomes were differences in uptake rates for influenza and pneumococcal vaccinations between the intervention period and the control period. For pneumococcal vaccination, patients could have received either PCV13 or PPSV23 vaccines, based on the clinical management of the GPs. Vaccinations given during the postintervention washout period were considered to be part of the intervention period (to include patients who had received the intervention and were only vaccinated slightly later, for reasons such as needing more time to consider or having acute illness and needing to recover first).

Secondary outcomes were identification of other factors at the individual and cluster levels associated with vaccination uptake.

Statistical Analysis

We originally hypothesized that the intervention would be less effective for pneumococcal vaccination, given its much higher overall cost, and, hence, we based power calculation on estimated pneumococcal vaccination uptake rates. To detect an absolute difference of 5% between the intervention and control periods (10% vs 5%, respectively), at 80% study power, an α level of 5%, an assumed within-cluster, within-period intracluster correlation (ICC) of 0.04 and a within-cluster, between-period ICC of 0, we would require data from a minimum of 200 patients per clinic in each phase, across a total of 22 clinics.

We performed descriptive analysis of participant characteristics, with categorical variables presented as proportions. We described age by using ordered categories or as a continuous variable with nonparametric properties and summarized by using the median value with interquartile ranges. To evaluate primary outcomes, we constructed separate multilevel logistic regression models for influenza and pneumococcal vaccination uptake. In both models, we used vaccination uptake within the period (intervention or control) as the outcome and included as covariates a fixed intervention effect, a fixed study phase effect (to control for changes occurring over time that were unrelated to the intervention), a random cluster effect, and a random cluster-by-study phase effect.[24,25] The latter 2 variables were included to adjust for similarities likely present among patients within clusters, both within the same study phase and across study phases.

To assess secondary outcomes, we added to these models other independent individual-level variables, including age, gender, ethnicity, housing type, and follow-up for various chronic diseases. We also added in 1 cluster-level variable (i.e., number of unique elderly patients seen by each clinic over each 4-month phase [as a measure of clinic workload]).

We present measures of association as adjusted odds ratios (AORs) with 95% confidence intervals (CIs). We performed statistical analysis by using Stata version 13 (StataCorp LP, College Station, TX) with P values of less than .05 regarded as statistically significant.

We calculated the actual within-cluster, within-period ICC and the within-cluster, between-period ICC by using the linear regression approach outlined by Morgan et al.[24] These approaches used an analysis of variance and pairwise estimating approach, respectively, and were coded in R (2018; R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

The study had 1 major deviation. Originally, the initial phase was to run from November 2017 to February 2018, and the crossover phase from March to June 2018. However, because of logistics issues faced by all clinics with obtaining seasonal influenza vaccine supplies ahead of the midyear season, commencement of the crossover phase was delayed by 1 month. We retained the study design of two 4-month phases and ran the initial and crossover phases from November 2017 to February 2018 and from April to July 2018, respectively.

A total of 4378 and 4459 patients visited the clinics during the intervention and control periods, respectively. Distributions of age, gender, housing type, and follow-up for chronic diseases were generally comparable between intervention and control periods, as well as initial and crossover phases (Table 1). There were slightly more persons of Chinese origin in control period clinics and a higher percentage of persons of Malay origin in intervention period clinics during the initial phase, with the reverse observed during the crossover phase. This reflected variations in the ethnic composition of patients across different clinics.

Primary Outcomes

Figure 1 shows the influenza and pneumococcal vaccination uptake rates, respectively. Overall uptake rates were significantly higher in clinics during the intervention period compared with the control period for both influenza (5.9% vs 4.8%; $P = .047$) and pneumococcal (5.7% vs 3.7%; $P = .001$) vaccines. A large proportion of patients had concurrent receipt of vaccines: of 602 patients receiving any vaccination, 286 (47.5%) received both vaccinations within the same period, 187 (31.1%) received influenza vaccination only, and 129 (21.4%) received pneumococcal vaccination only.

On multivariable analysis (Tables 2 and 3), patients who visited the clinic during the intervention period were more likely to receive influenza vaccination (AOR = 1.43; 95% CI = 0.99, 2.07; $P = .06$) than were those who visited during the control period. They were also more likely to receive pneumococcal vaccination (AOR = 1.78; 95% CI = 1.28, 2.48; $P < .01$).

Secondary Outcomes

Being on follow up for hypertension, diabetes mellitus, hyperlipidemia, or any combination of the 3 was significantly associated with both influenza and pneumococcal vaccinations. As compared with the persons of Chinese origin, persons of Malay origin were less likely to receive influenza vaccination, whereas Indian and other ethnic groups were less likely to receive pneumococcal vaccination. Pneumococcal vaccination was also positively associated with male gender and follow up for asthma or COPD or both. By contrast, influenza vaccination was negatively associated with being aged 85 years or older (vs being aged 65–69 years).

In addition, patients in clinics that saw 201 to 300 elderly patients over a 4-month study phase were more likely to receive influenza and pneumococcal vaccination, compared with those in clinics that saw fewer elderly patients (0–100 or 101–200 over the same duration), or clinics that saw more (although results were not significantly different for both types of vaccination).

For influenza vaccination, the estimated within-cluster, within-period ICC was 0.044, and the within-cluster, between-period ICC was 0.024. For pneumococcal vaccination, the corresponding ICCs were 0.057 and 0.040.

DISCUSSION

Our point-of-care study intervention appeared to contribute to modest but

TABLE 1—Baseline Characteristics of Patients in Intervention- and Control-Period Clinics, by Study Phases: Singapore, November 2017–July 2018

Patient Characteristic	Initial Phase			Crossover Phase		
	Intervention-Period Clinics (n = 2267), Median (IQR) or No. (%)	Control-Period Clinics (n = 2277), Median (IQR) or No. (%)	*P*[a]	Intervention-Period Clinics (n = 2111), Median (IQR) or No. (%)	Control-Period Clinics (n = 2182), Median (IQR) or No. (%)	*P*[a]
Age, y	70 (67–76)	71 (68–77)	.41	71 (68–77)	71 (68–76)	.41
Age group, y			.7			.58
65–69	944 (41.6)	925 (40.6)		849 (40.2)	879 (40.3)	
70–74	621 (27.4)	602 (26.4)		565 (26.8)	623 (28.6)	
75–79	355 (15.7)	372 (16.3)		333 (15.8)	334 (15.3)	
80–84	195 (8.6)	214 (9.4)		197 (9.3)	181 (8.3)	
≥ 85	152 (6.7)	164 (7.2)		167 (7.9)	165 (7.6)	
Gender = male	1021 (45.0)	1021 (44.8)	.89	950 (45.0)	996 (45.6)	.68
Ethnic group			<.01			<.01
Chinese	1779 (78.5)	1864 (81.9)		1770 (83.8)	1670 (76.5)	
Malay	217 (9.6)	116 (5.1)		100 (4.7)	211 (9.7)	
Indian	93 (4.1)	83 (3.6)		94 (4.5)	84 (3.8)	
Others	52 (2.3)	57 (2.5)		58 (2.7)	59 (2.7)	
Not stated	126 (5.6)	157 (6.9)		89 (4.2)	158 (7.2)	
Rental or smaller housing flats	143 (6.3)	141 (6.2)	.46	111 (5.3)	134 (6.1)	.15
On follow-up with clinic for						
Diabetes	120 (5.3)	111 (4.9)	.52	114 (5.4)	113 (5.2)	.75
Hypertension	435 (19.2)	400 (17.6)	.16	390 (18.5)	441 (20.2)	.15
Hyperlipidemia	311 (13.7)	300 (13.2)	.59	300 (14.2)	319 (14.6)	.7
Asthma or COPD or both	24 (1.1)	22 (1.0)	.76	18 (0.9)	27 (1.2)	.22

Note. COPD = chronic obstructive pulmonary disease; IQR = interquartile range.

[a]*P* values compare differences in characteristics of patients from clinics undergoing intervention versus control periods during the initial phase and crossover phase, respectively.

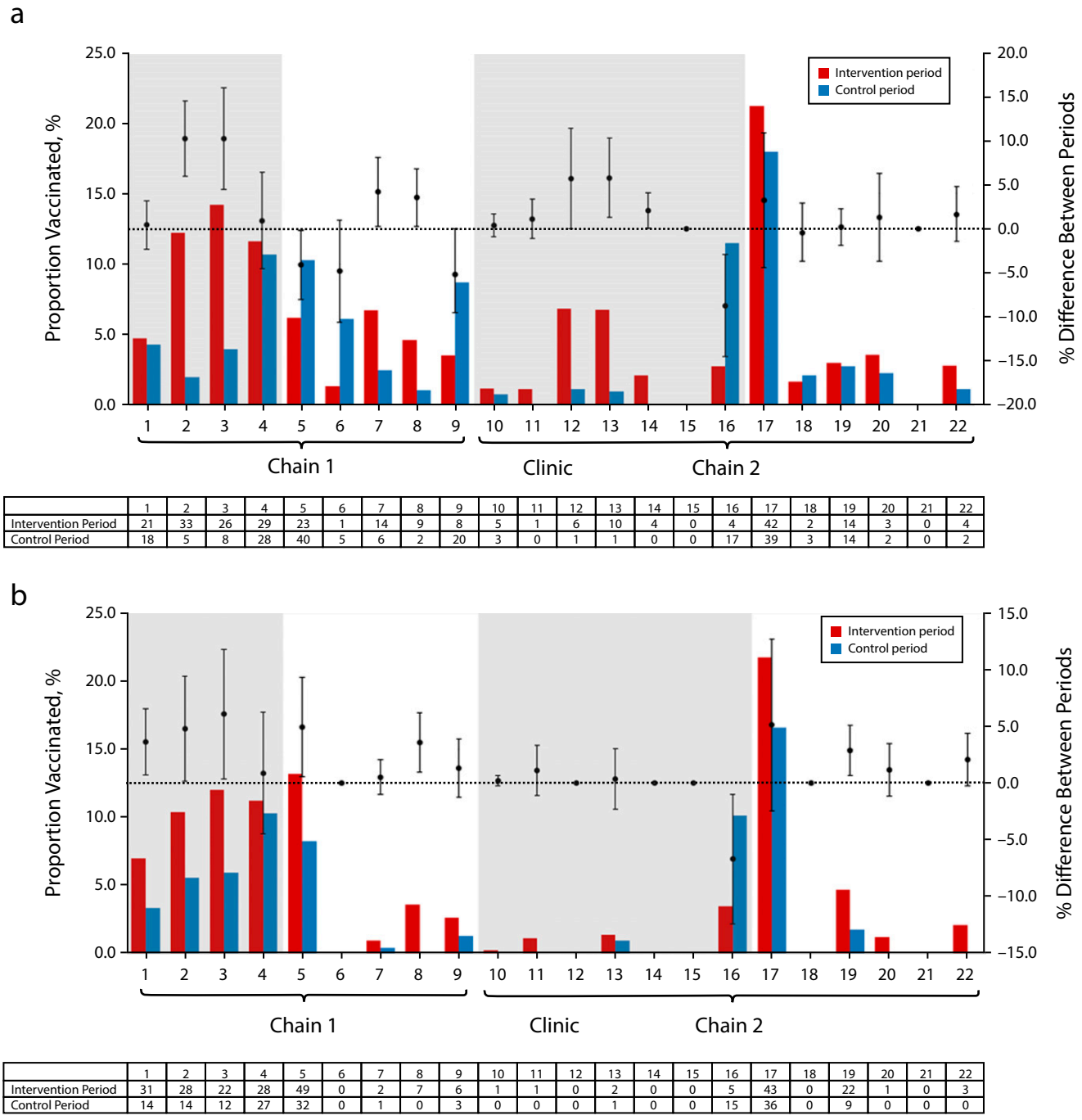
significantly increased vaccination rates among elderly primary care patients. While there were variations in both influenza and pneumococcal vaccination uptake rates across clinics and study phases, our analysis took into account key variables to be included when evaluating a cluster randomized crossover trial to ensure that we accurately assessed the overall effect of our intervention.

The effect size of our intervention was greater for pneumococcal vaccination compared with influenza vaccination, possibly because low awareness was a more important barrier toward pneumococcal vaccination,[7] and this was easily addressed by our intervention. In contrast, while patients were more likely to know about influenza vaccination, they might not have viewed it as a necessity because of low perceived susceptibility to infection or perceived severity of health complications.[26,27]

Among vaccinated patients, a high proportion received both influenza and pneumococcal vaccines, which has been similarly observed in previous studies.[28] Concurrent recommendations of influenza and pneumococcal vaccinations to elderly patients would help reduce missed opportunities for vaccination. The safety profile of concurrent vaccination has been established.[29]

Vaccination uptake varied widely across clinics, likely reflective of differing practices among GPs. Absolute differences in vaccination rates between intervention and control periods were higher by up to 10% for influenza vaccination and 6% for pneumococcal vaccination. At the cluster level, influenza and pneumococcal vaccination uptake appeared to be most strongly associated with clinics that saw a moderate number of elderly patients (201–300 unique patients over a 4-month period, or about 3 per work day), compared with those that saw greater or lesser numbers of elderly. This may reflect a balance between clinics' experience in elderly management and proactiveness in preventive care, and operational constraints limiting consult time and quality of counseling for each patient.

Multivariable analysis showed that patients on follow up for hypertension, diabetes mellitus, hyperlipidemia, or any combination of the 3 conditions were more likely to receive influenza and pneumococcal vaccination. Those on follow-up for asthma or COPD or both were also more likely to receive pneumococcal vaccine. Vaccination is associated with having a regular family doctor and receiving recommendations by health care professionals[19,20,26] and is also more



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Intervention Period	21	33	26	29	23	1	14	9	8	5	1	6	10	4	0	4	42	2	14	3	0	4
Control Period	18	5	8	28	40	5	6	2	20	3	0	1	1	0	0	17	39	3	14	2	0	2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Intervention Period	31	28	22	28	49	0	2	7	6	1	1	0	2	0	0	5	43	0	22	1	0	3
Control Period	14	14	12	27	32	0	1	0	3	0	0	0	1	0	0	15	36	0	9	0	0	0

Note. Shaded background indicates clinics that underwent the intervention period during the initial phase (Nov 2017–Feb 2018). White backgrounds indicate clinics that underwent the intervention period during the crossover phase (Apr–Jul 2018). Error bars indicate 95% confidence intervals for differences in vaccination rates between periods. Tables show total vaccines given in each clinic during intervention and control periods.

FIGURE 1—Rates Across Clinics, by Period, of (a) Influenza Vaccination and (b) Pneumococcal Vaccination: Singapore, November 2017–July 2018

likely in adult patients with comorbidities.[26,30] These suggest that the therapeutic relationship can influence patients' decisions to receive vaccination. Hence, primary care physicians should actively engage elderly patients on their regular follow up on the topic of vaccination.

However, the oldest patients were less likely to take influenza vaccine, probably because of financial constraints (including less Medisave to utilize) and low perceived benefits of the vaccine. There were also differences among the ethnic groups. Persons of Malay origin were less likely to receive influenza vaccine, and persons of Indian and

TABLE 2—Factors Associated With Influenza Vaccination Uptake: Singapore, November 2017–July 2018

Variable	Vaccinated (n = 473), No. (%)	Not Vaccinated (n = 8364), No. (%)	AOR (95% CI)
Clinic undergoing intervention period (vs control period)	259 (54.8)	4119 (49.2)	1.43 (0.99, 2.07)
Study phase Nov–Feb (vs Apr–Jul)	272 (57.5)	4272 (51.1)	1.27 (0.86, 1.87)
Age group, y			
65–69	211 (44.6)	3386 (40.5)	1 (Ref)
70–74	128 (27.1)	2283 (27.3)	0.98 (0.77, 1.23)
75–79	70 (14.8)	1324 (15.8)	0.99 (0.74, 1.32)
80–84	44 (9.3)	743 (8.9)	1.00 (0.70, 1.42)
≥ 85	20 (4.2)	628 (7.5)	0.58 (0.35, 0.94)
Male gender	221 (46.7)	3767 (45.0)	1.08 (0.89, 1.31)
Ethnic group			
Chinese	413 (87.3)	6670 (79.7)	1 (Ref)
Malay	20 (4.2)	624 (7.5)	0.63 (0.39, 1.00)
Indian	13 (2.8)	341 (4.1)	0.70 (0.39, 1.25)
Others	9 (1.9)	217 (2.6)	0.67 (0.33, 1.33)
Not stated	18 (3.8)	512 (6.1)	0.85 (0.51, 1.41)
Rental or smaller housing flats	19 (4.0)	510 (6.1)	0.63 (0.39, 1.03)
On follow-up for diabetes, hypertension, or hyperlipidemia	170 (35.9)	1868 (22.3)	1.61 (1.29, 2.00)
On follow-up for COPD or asthma	8 (1.7)	83 (1.0)	1.27 (0.60, 2.72)
No. of elderly patients (≥ 65 y) seen by clinic over 4 mo			
0–100 (5 clinics)	18 (3.8)	573 (6.9)	0.28 (0.09, 0.88)
101–200 (8 clinics)	93 (19.7)	2344 (28.0)	0.39 (0.16, 0.94)
201–300 (5 clinics)	224 (47.4)	2135 (25.5)	1 (Ref)
> 300 (4 clinics)	138 (29.2)	3312 (39.6)	0.41 (0.16, 1.10)

Note. AOR = adjusted odds ratio; CI = confidence interval; COPD = chronic obstructive pulmonary disease. Multilevel logistic regression model with fixed intervention effect, fixed period effect, random cluster effect (by clinic), and random cluster-by-period effect.

other ethnic origins were less likely to receive pneumococcal vaccine as compared with persons of Chinese origin. The effects of ethnicity may be mediated through language barriers and cultural receptiveness to vaccines. It could also have reflected confounding by socioeconomic factors such as educational level and household income. These were not collected as part of this study but have been shown to be positively associated with influenza and pneumococcal vaccine uptake rates.[31,32]

Interestingly, some clinics assigned to the control period during the initial phase (November–February) had higher influenza vaccination uptake during the control compared with the intervention period. Although there is year-round risk of influenza in tropical Singapore, some patients might have associated influenza vaccination with pretravel preparations and, hence, timed their vaccination around the year-end holiday season, independent of the intervention.

Current recommendations in Singapore are that the elderly (aged ≥ 65 years) and those with key medical conditions should receive annual influenza vaccination.[18] There is currently debate on whether vaccinating the elderly twice a year in the tropics may be necessary[33] to counteract observed waning of antibody titers and effectiveness in older individuals.[34,35] Overall, public education should target the oldest elderly and lower income subgroups and aim to change perceptions regarding the benefit of repeat influenza vaccination, as well as highlight the risk of severe influenza-associated outcomes in vulnerable persons who do not travel.

Strengths and Limitations

Our study had a number of strengths. We systematically collected routine data from clinic electronic medical records (a robust resource for patients' clinical and demographic data) to conduct and evaluate our study. This method may also be more acceptable to GPs who are considering participating in research, as it reduces additional administrative workload of clinic staff.[36] We recruited patients with wide demographic variation, from clinics sited across different localities, which increases the generalizability of our findings. We relied on nonphysician staff (CAs) to drive our intervention by activating patients through personal contact, which has been shown to be effective and more likely to be sustainable.[11,12] Our interventions were brief and low-cost, and we believe them to be practically implementable in the GP clinic setting.

Our study also had some limitations. We were unable to determine the baseline vaccination rates of the clinics (including records from other health care institutions) because of absence of a comprehensive national adult vaccination database. High baseline rates would have placed a ceiling effect on the

TABLE 3—Factors Associated With Pneumococcal Vaccination Uptake: Singapore, November 2017–July 2018

Variable	Vaccinated (n = 415), No. (%)	Not Vaccinated (n = 8422), No. (%)	AOR (95% CI)
Clinic undergoing intervention period (vs control period)	251 (60.5)	4127 (49.0)	1.78 (1.28, 2.48)
Study phase Nov–Feb (vs Apr–Jul)	199 (48.0)	4345 (51.6)	0.75 (0.51, 1.11)
Age group, y			
65–69	176 (42.4)	3421 (40.6)	1 (Ref)
70–74	112 (27.0)	2299 (27.3)	1.04 (0.80, 1.35)
75–79	66 (15.9)	1328 (15.8)	1.13 (0.83, 1.54)
80–84	42 (10.1)	745 (8.8)	1.25 (0.87, 1.82)
≥ 85	19 (4.6)	629 (7.5)	0.72 (0.44, 1.20)
Gender = male	201 (48.4)	3787 (45.0)	1.25 (1.01, 1.55)
Ethnic group			
Chinese	373 (89.9)	6710 (79.7)	1 (Ref)
Malay	26 (6.3)	618 (7.3)	0.90 (0.59, 1.39)
Indian	8 (1.9)	346 (4.1)	0.47 (0.23, 0.99)
Others	2 (0.5)	224 (2.7)	0.16 (0.04, 0.67)
Not stated	6 (1.4)	524 (6.2)	0.38 (0.16, 0.89)
Rental or smaller housing flats	32 (7.7)	497 (5.9)	1.32 (0.88, 1.99)
On follow-up for diabetes, hypertension, or hyperlipidemia	199 (48.0)	1839 (21.8)	2.64 (2.10, 3.31)
On follow-up for COPD or asthma	13 (3.1)	78 (0.9)	2.81 (1.47, 5.37)
No. of elderly patients (≥ 65 y) seen by clinic over 4 mo			
0–100 (5 clinics)	1 (0.2)	590 (7.0)	0.02 (0.00, 0.40)
101–200 (8 clinics)	68 (16.4)	2369 (28.1)	0.28 (0.05, 1.56)
201–300 (5 clinics)	188 (45.3)	2171 (25.8)	1 (Ref)
> 300 (4 clinics)	158 (38.1)	3292 (39.1)	0.51 (0.07, 3.51)

Note. AOR = adjusted odds ratio; CI = confidence interval; COPD = chronic obstructive pulmonary disease. Multilevel logistic regression model with fixed intervention effect, fixed period effect, random cluster effect (by clinic), and random cluster-by-period effect.

effectiveness of our intervention. However, the clinic chains had never participated in any adult vaccination-related programs before this study, and we believe that baseline vaccination rates were low (similar to national estimates around the time of the study), with a large proportion of patients still requiring vaccination. By including the post-intervention washout period as part of the intervention period, we might have captured patients who did not receive the intervention at all in our intervention period group; this would have caused a bias toward the null in terms of estimating the effect of the intervention on our study outcomes.

We were unable to control for other external factors that may have acted as possible confounders toward vaccination uptake, such as the content and quality of any health counseling by GPs or the CAs. However, we verified that, over the study period, there were no other major factors—such as use of other educational materials on vaccination, changes in the lead GPs for each clinic, widespread campaigns on vaccination, or changes in funding mechanisms—which could have affected the way health counseling was conducted.

We were also unable to measure the true compliance of each clinic to the intervention because of limitations in staff capacity (both for the study team and the clinics) for collecting these data. Similar pragmatic trials have demonstrated study compliance to be as low as 21.0%.[13] Nevertheless, the study intent was to evaluate the real-world impact of such an intervention, which likely played a contributory role in modestly increasing vaccination uptake.

Public Health Implications

Point-of-care informational interventions delivered in private GP clinics likely contributed to modest increases in influenza and pneumococcal vaccination uptake. Concurrent administration of both vaccinations should be recommended to reduce missed opportunities. Clinics seeing moderate elderly patient loads were most likely to have high vaccination rates. Health promotion efforts should also target the oldest elderly subgroup and emphasize the importance of annual influenza vaccination. Patients on follow-up for hypertension, diabetes mellitus, hyperlipidemia, or any combination of the 3 conditions were more likely to receive influenza and pneumococcal vaccination and should be actively engaged by physicians. AJPH

CONTRIBUTORS

H. J. Ho conceptualized and designed the study, contributed to intervention design and implementation, organized data collection, analyzed and interpreted data, and drafted the article. Y. Tan contributed to intervention design and implementation, performed data collection, and drafted the article. A. R. Cook contributed to study design and data analysis and interpretation and critically reviewed the article. G. Koh contributed to study design and interpretation of data and critically reviewed the article. T. Y. Tham contributed to study design and data collection and interpretation and critically reviewed the article. E. Anwar contributed to data collection and

interpretation and critically reviewed the article. G. S. H. Chiang contributed to interpretation of data and critically reviewed the article. M. O. Lwin contributed to intervention design and critically reviewed the article. M. I. Chen contributed to study conceptualization and design and data analysis and interpretation and critically reviewed the article. All authors approved the final version of the article submitted for publication.

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CONFLICTS OF INTEREST

All authors declare no conflict of interest.

HUMAN PARTICIPANT PROTECTION

The National Healthcare Group Domain Specific Review Board approved the study, with waiver of informed consent from patients (DSRB number: 2017/00441). This study was registered at https://www.clinicaltrials.gov (trial registry number: NCT03445117).

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