

<https://doi.org/10.1038/s43856-024-00585-w>

Parental vaccine hesitancy and influenza vaccine type preferences during and after the COVID-19 Pandemic

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Abstract

Background Seasonal influenza vaccine (SIV) greatly reduces disease burden among school-aged children, yet parental vaccine hesitancy remains a persistent challenge. Two types of SIV are available for children in Hong Kong and other locations: inactivated influenza vaccine (IIV), administered through intramuscular injection, and live attenuated influenza vaccine (LAIV), administered via nasal spray. We aimed to understand how vaccine hesitancy shaped parental preference for LAIV versus IIV, particularly amidst important public health events, such as the COVID-19 pandemic and the massive rollout of COVID-19 vaccination campaigns.

Methods We employed a concurrent mixed-methods design. The quantitative part involves longitudinal surveys spanning three years, from pre-pandemic to post-pandemic periods, tracking parental vaccine hesitancy and preference for SIV types. The qualitative part involves 48 in-depth interviews, providing insights into parental preference for SIV types, underlying reasons, and related values.

Results Our quantitative analyses show an overall increase in parental vaccine hesitancy and preference for LAIV over IIV after the onset of the COVID-19 pandemic and especially after the rollout of the COVID-19 vaccination campaign. Further logistic regression modelling based on the cohort data shows that higher vaccine hesitancy, coupled with the COVID-19 vaccination campaign rollout, predicts a greater preference for LAIV over IIV. The qualitative analysis complements these results, highlighting that LAIV's non-invasive nature aligns with parental values of prioritizing natural immunity and concerns about overmedication, leading to a more acceptable attitude towards LAIV.

Conclusions Leveraging the higher acceptability of LAIV compared to IIV among parents with high vaccine hesitancy could promote childhood vaccination uptake.

Plain language summary

We examined how parents' concerns about vaccines and major public health events affected their preference for different types of seasonal influenza vaccines for children. Currently, children can receive either an injected vaccine or a nasal-spray vaccine. We tracked parental vaccine hesitancy and their preferences for different types of vaccines over three years covering a period before the COVID-19 pandemic and a period during the pandemic. Parents became more hesitant about seasonal influenza vaccines for children after the start of the COVID-19 pandemic and the rollout of COVID-19 vaccines. Higher vaccine hesitancy and the rollout of COVID-19 vaccines predicted a greater preference for nasal-spray vaccines for children among parents. Parents preferred the non-invasive nature of the nasal-spray vaccines and were concerned about overmedication, particularly vaccines that were administered via injection. We suggest that the nasal-spray vaccines could be one option offered to address high parental vaccine hesitancy.

Seasonal influenza epidemics have a substantial attack rate amongst children under 18 annually^{1,2}. According to findings from a multi-country meta-analysis study spanning 25 years, the overall pooled influenza-associated hospitalization rate was 40.5 per 100,000 persons, with young children aged 0–4 years having a significantly higher rate at 224.0 per 100,000 persons². Another study conducted in Hong Kong found that in the

early phase of the 2018/19 winter influenza season, 21.2% of children aged 6–17 admitted to hospitals with febrile acute respiratory illness tested positive for influenza A or B³. Robust evidence supports the effectiveness of seasonal influenza vaccine (SIV) in reducing influenza-related illnesses among children of all ages and reducing influenza transmission within the community⁴. Specifically, SIV uptake greatly lowers the risk of influenza-

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related hospitalization by 53.7–64.3% compared to unvaccinated children aged 3 to 5 years. For children aged 6–17 years, the reduction in hospitalization risk ranged from 36.6% to 51.3% compared to their unvaccinated counterparts⁴. Recognizing the high vaccine effectiveness, important initiatives, such as providing free SIV through school outreach vaccination programs, have been implemented in Hong Kong⁵. Due to these endeavours, the estimated vaccine coverage rates reached 48.5% for children under 5 years old and 69.3% for primary school children in 2020. Nevertheless, the persistent parental vaccine hesitancy due to episodic events and vaccine-resistant values and beliefs can challenge the continuous success of existing influenza vaccination programs for children^{6,7}.

Two types of SIV are widely available: the inactivated influenza vaccine (IIV), administered through intramuscular injection, and the live attenuated influenza vaccine (LAIV), administered through nasal spray and has been approved for use in children aged over 2 years⁸. While previous research has extensively explored the multifaceted factors contributing to parental vaccine hesitancy regarding the influenza vaccine for their children^{9,10}, most of these studies have predominantly focused on IIV, often overlooking the distinct characteristics of LAIV. Many contributing factors, including concerns about the general safety and efficacy of vaccines^{11,12}, perceptions of an excessive number of childhood vaccines¹³, preference for natural immunity¹⁴, vaccine-specific issues such as administrative barriers (e.g., time constraints and access issues), and contextual factors such as trust in the healthcare system^{15,16}, have commonly been examined. However, it remains unknown how the unique features associated with LAIV can help parents overcome these concerns and barriers to children's vaccination uptake. Given that LAIV offers a different mode of administration that is notably more convenient^{17,18} and less painful^{19,20}, it may elicit more favorable attitudes toward vaccination, especially in existing hesitant groups. For example, one previous study revealed a direct association between hesitant attitudes and a preference for nasal administration¹⁹. However, this study was based on a cross-sectional design, and the causal relationship between vaccine hesitancy and the preference for LAIV warrants further investigation. Moreover, there is a growing body of evidence suggesting that LAIV has comparable efficacy to IIV in children^{21–24}. However, there may be challenges in expanding the use of LAIV due to logistical issues such as cold chain requirements, vaccine production complexity, and specific storage conditions, as well as potential differences in cost²⁵. Nonetheless, the potential of LAIV in addressing parental vaccine hesitancy is a crucial factor that should not be overlooked. Therefore, it underscores the urgent need for further investigation into the relationship between parental vaccine hesitancy and preference for different vaccine types. This could contribute to a more comprehensive understanding of vaccine hesitancy and provide valuable insights into how to effectively address parental vaccine hesitancy by considering their preferences for vaccine types.

Furthermore, amidst the global prevalence of COVID-19, research has shown that parental attitudes towards influenza vaccination may be largely influenced by the pandemic, the pandemic control measures, and vaccine-related policies especially the introduction of mandatory COVID-19 vaccination. For instance, a study conducted in the USA during the 2020–2021 and 2021–2022 influenza seasons identified a consistent decline in influenza vaccine uptake among children, regardless of their COVID-19 vaccine status²⁶. This suggests that factors associated with COVID-19 vaccination, such as safety concerns and mistrust in COVID-19 vaccines or the government²⁷, have had a spill-over effect on SIV uptake in children. Meanwhile, the introduction of mandatory COVID-19 vaccination in Hong Kong may add additional pressure and concerns for parents who have already perceived an overabundance of childhood immunization schedules. Consequently, the interplay of these factors holds the potential to shape parents' preferences regarding SIV between different vaccine types.

To our knowledge, no studies have systematically examined the dynamic relationships between parental vaccine hesitancy and major public health events, such as the COVID-19 pandemic and the rollout of the vaccination program, in shaping parental preferences for influenza vaccine types and the underlying reasons for these choices. To bridge this critical

research gap, our study implemented a concurrent mixed-methods design, encompassing both quantitative (longitudinal surveys) and qualitative (semi-structured interviews) components, which were conducted in parallel. The school-based seasonal influenza vaccination program (SIVP) in Hong Kong had reached over 80% of primary schools and 70% of kindergartens by 2021⁵. Carried out from September 2019 to December 2021, the study spanned two key events: the start of the COVID-19 pandemic in early 2020 and the massive rollout of the COVID-19 vaccination campaign in March 2021, which was expanded to include children later in early 2022 in stages with children as young as three years old being able to receive vaccination starting from 15 February 2022²⁸. This allowed us to examine the impact of these two public health events on parental vaccine hesitancy and their preference for LAIV or IIV. To enhance clarity and reference, we designated three distinct periods: Pre-pandemic, marking the timeframe before the onset of the COVID-19 pandemic; Pandemic Pre-vaccine, denoting the period between the pandemic onset and the initiation of the vaccination rollout; and Pandemic Post-vaccine, indicating the timeframe following the widespread rollout of the COVID-19 vaccines.

This study has two main objectives. Objective 1 was to explore the temporal evolution of parental vaccine hesitancy and parental preference for different types of SIV over three years and examine their relationship. For this objective, we utilized the longitudinal data to investigate whether parental vaccine hesitancy and major public health events including the COVID-19 pandemic and the rollout of COVID-19 vaccines could predict parental preferences for specific SIV types (LAIV vs. IIV) for their young children by testing several hypotheses. First, that parental vaccine hesitancy shows an increase from the Pandemic Pre-vaccine period to the Pandemic Post-vaccine period within the pandemic context. Second, that the proportion of parents preferring LAIV increases from the Pre-pandemic period to the pandemic period, and from the Pandemic Pre-vaccine period to the Pandemic Post-vaccine period within the pandemic context. Third, that parents with higher vaccine hesitancy are more likely to prefer LAIV over IIV to those with lower vaccine hesitancy. Fourth, that parents' preference for LAIV increases more from the Pandemic Pre-vaccine period to the Pandemic Post-vaccine period among those vaccine-hesitant parents. The second objective was to combine the open-ended questions in the questionnaire-based surveys across three years and in-depth qualitative interview data over two years for a more comprehensive analysis of the reasons behind parents' choices between IIV and LAIV.

Our quantitative analyses show an overall increase in parental vaccine hesitancy and preference for LAIV over IIV after the onset of the COVID-19 pandemic and especially after the rollout of the COVID-19 vaccination campaign. Further logistic regression modelling based on the cohort data shows that higher vaccine hesitancy, couples with the COVID-19 vaccination campaign rollout, predicts a greater preference for LAIV over IIV. The qualitative analysis complements these results, highlighting that LAIV's non-invasive nature aligns with parental values of prioritizing natural immunity and concerns about overmedication, leading to a more acceptable attitude towards LAIV.

Methods

This study was approved by the Institutional Review Board of the University of Hong Kong (reference number: UW19-200). The longitudinal survey and in-depth interviews were parts of the project to monitor parents' acceptability of the school-based SIV in Hong Kong and their preference for LAIV and IIV⁵. Figure 1 depicts the study timelines and the context of the expansion of the school-based SIVP in Hong Kong.

Participants from the longitudinal survey

Participants were recruited by a local survey company between September and December 2019 using random-digital-dialed household interviews. Eligible participants were required to meet the following criteria: (1) being adult parents with at least one child enrolled in a kindergarten or primary school in Hong Kong; (2) reporting that their school-aged child had no medical contraindication to vaccines, and (3) being capable to understand

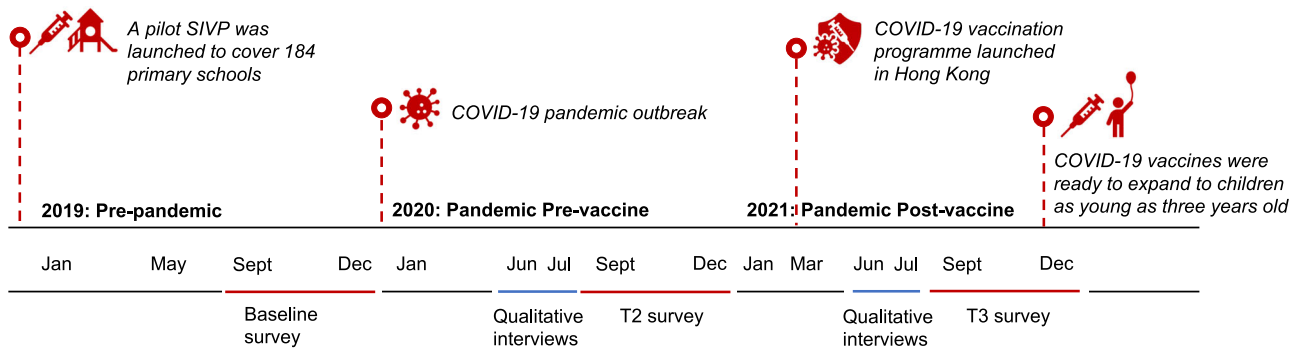


Fig. 1 | Overview of the study procedures and the major public health events. “SIVP”: seasonal influenza vaccination program. The icons represent the key events during our study period. The red solid line represents the survey period, while the

blue solid line represents the in-depth interview period. The key milestones of SIVP and COVID-19-related events in Hong Kong were labeled in corresponding months.

and communicate in either Cantonese or Mandarin. In each eligible household, only one parent was invited to participate in the baseline survey with responses based on their youngest eligible child. At the end of the baseline survey, participants were asked about their willingness to take part in our follow-up survey in the following year. In September and October 2020, those who agreed to be re-contacted were approached for a follow-up survey. Notably, we experienced a substantial loss of participants in the second year, with a follow-up rate of 56.5%, primarily due to disruptions caused by the pandemic and ineligibility (e.g., the participant’s youngest child entering a secondary school particularly among parents who had only one young child). To obtain an adequate sample size for the third-year survey, we opted to newly recruit more parents from a random online panel using an online survey. All participants who had completed the second-year follow-up survey were queried about their willingness to participate in an additional survey in the third year. In September–October 2021, we re-contacted both those who had completed the second-year follow-up survey and those who had completed the baseline survey but did not respond to the second-year survey. Informed consent was obtained verbally for the telephone survey or electronically for the online survey before the interviews started. A supermarket coupon valued at approximately USD 6 was provided to participants upon completion of each survey. A detailed flow chart outlining our recruitment procedures is provided in Supplementary Fig. 1.

Measures for longitudinal survey

The primary outcome was the preferred SIV type selected by parents, with participants being presented with the choice between an intramuscular injection vaccine (IIV), a nasal-spray vaccine (LAIV), or neither type. Notably, considering only a limited number of schools opted to provide LAIV within the school outreach program, we chose not to use the actual SIV type received by children as our primary outcome measure. The primary outcome remained consistent across the three-year surveys with the same question: If you can freely choose between a needle-injected vaccine and a nasal-spray vaccine, which type of flu vaccine will you choose for your child? A four-item scale of parental vaccine-hesitant attitudes (e.g., I dislike giving my child any vaccine except for the compulsory ones) adapted from the Parent Attitudes about Childhood Vaccines Short Scale (PACV-5) was used consistently over the three years²⁹. A set of demographic variables were also collected in each survey, including parental age, sex, educational attainment, monthly household income, and number of children entering a primary school or kindergarten. Information concerning the eligible child’s previous SIV uptake experience was collected. In addition, a multiple-choice question was presented in the three-year surveys to gain insights into parents’ perceptions of LAIV compared to IIV. For example, parents were asked: Compared to IIV, children’s acceptance of LAIV is? Response options ranged from 1 (Much lower) to 5 (Much higher). A detailed description of our measurement instruments is provided in Supplementary Table 1.

Statistics and reproducibility

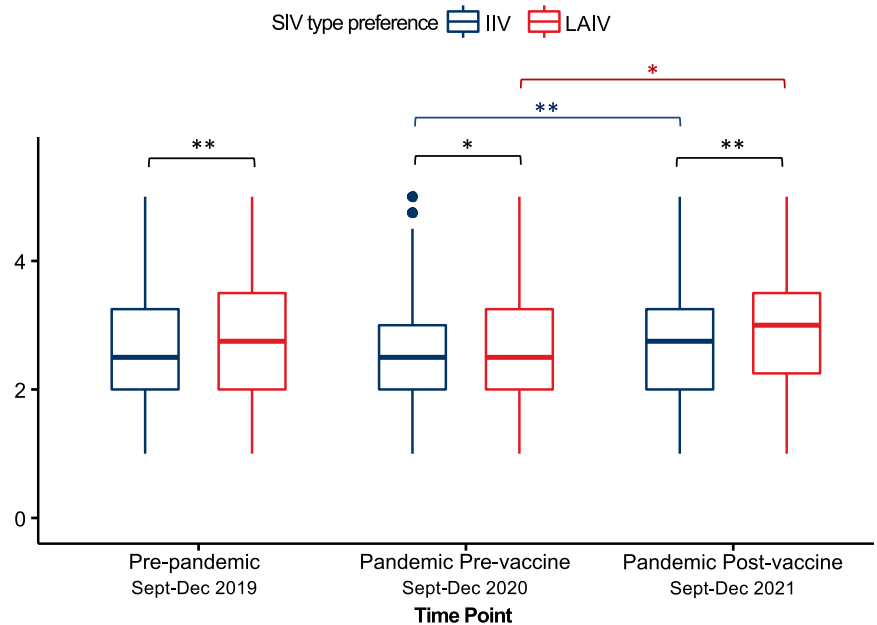
First, we conducted descriptive analyses to compare participants’ key demographic characteristics, vaccine-hesitant attitudes (VH score, computed as the average score from the four-item Likert-scale questions), preferred SIV types and actual received vaccine types over the three-year period. We extracted records of participants who consistently attended the surveys across all three time points, forming a distinct cohort for examining the causal relationship between key variables. Specifically, we first checked the normality of the distribution of the vaccine-hesitant attitudes scores by examining kurtosis statistics. Given the kurtosis scores were less than 3, indicative of a non-normally distributed variable for VH scores. To test H1 and H2, the average VH scores were stratified by SIV type preference (LAIV or IIV) and survey period. One-way Wilcoxon signed-rank tests were used to analyse differences between groups based on type preferences and time periods, with Bonferroni correction to account for multiple comparisons. For testing H3 and H4, the whole sample was categorized into three distinct groups: low vaccine hesitancy (VH scores ranging from 1.0 to 2.0), moderate (VH scores from 2.1 to 3.0), and high (VH scores from 3.1 to 5.0). Binary logistic regression was used to measure the association between SIV type preferences (LAIV vs. IIV) and vaccine hesitancy category as well as study periods. Regression models were adjusted for selected covariates determined a priori based on previously described differences in cohorts and model fits, including age, gender, educational attainment and family monthly income. To offer stronger evidence on the causal association between vaccine-hesitant attitudes and vaccine type preference, in our subsequent analysis, we leveraged the advantage of our longitudinal design by conducting a Generalized Estimating Equation (GEE) model to provide further support for H3 and H4. Specifically, we aimed to assess whether higher levels of vaccine hesitancy, the launch of a mass injection-based vaccination program, and their potential interactions could predict parents’ preference for an LAIV. The GEE analysis was performed among the cohort with repeated measures for these variables. The Neither option of preference for vaccine type was coded as a missing value (11.9% in the total sample, and 8.8% in the longitudinal cohort) in both our logistic regression and GEE models considering our primary interest was to predict parents’ preference of LAIV over IIV. Lastly, we presented descriptive statistics pertaining to the reasons endorsed by parents for selecting LAIV instead of IIV. Our statistical analyses were carried out using SPSS26.0 and RStudio 2023.6.1, data visualizations were performed using RStudio 2023.6.1 and Tableau Desktop 2021.4.3. Codes and data for replicating all the results are available on the Open Science Framework³⁰.

Participants from the in-depth interviews

We conducted qualitative interviews in both 2020 and 2021 using separate samples. Participants’ characteristics are provided in Supplementary Data 2³⁰. In 2020, participants were identified from the 2019 survey (baseline survey), while in 2021, participants were identified from the 2020 survey.

Fig. 2 | Overall Vaccine-hesitant attitudes scores stratified by SIV type preferences and the three time periods based on the whole sample

(N = 1302). “SIV”: seasonal influenza vaccine; “IIV”: inactivated influenza vaccine; “LAIV”: live attenuated influenza vaccine. The VH score is determined by calculating the mean of the IIV group (Blue) and the LAIV group (Red), stratified by time periods. One-way Wilcoxon signed-rank tests were employed to test differences between groups for each SIV type preference and time point. The statistical details for the mean, median, and IQR can be found in Supplementary Table 2. P-values have undergone Bonferroni correction to account for multiple comparisons, denoted as follows: * for $P < 0.01$, ** for $P < 0.05$, and *** for $P < 0.001$. Insignificant comparisons ($P > 0.05$) were not shown.



We used purposive sampling to select parents with heterogeneous demographics, vaccine-hesitant attitudes, status of their children SIV, and the type of SIV (IIV vs. LAIV) received from the pool to increase variability in parents’ opinions and discussion. The current study focused on the underlying reasons of parental preference for different types of SIV to supplement understanding of the quantitative part. Therefore, we only presented results regarding parental preference for SIV type obtained from the qualitative data. After obtaining verbal consent from each participant, in-depth interview was conducted over the telephone one by one. A total of 48 qualitative interviews were conducted over the two years. Each interview lasted ~50 minutes and was audiotaped. Participants provided consents for publishing their responses anonymously later. We incentivized each participant with a supermarket coupon valued at USD 13 to compensate for their time.

Thematic analysis of in-depth interviews

Each interview was transcribed verbatim first, then two researchers (JY & MD) independently coded the interviews. Afterward, the two researchers discussed the codes together and resolved any disagreements by iteratively going back to the data until a seminal codebook was created. A third researcher (QL) reviewed the main categories and codes and finalized the thematic framework. To facilitate interpretation, we organized our qualitative results by parental vaccine-hesitant or refusal status. Specifically, parents were categorized into either SIV acceptor or SIV hesitator/refuser groups based on their self-reported SIV uptake status for their children in the past 12 months. All the data were organized using NVivo 12.0 (QSR International, Melbourne, Australia). Data of qualitative interviews for this study is not publicly available for privacy reasons but may be made available to qualified researchers on reasonable request from the corresponding author.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Results

Participants characteristics

Our quantitative data involved 1302 respondents in the Pre-pandemic period, 958 respondents in the Pandemic Pre-vaccine period, and 566 responses in the Pandemic Post-vaccine period, with response rates of

62.9%, 56.5%, and 47.2%, respectively. Among them, a subset of 376 participants were followed up across all three rounds. Parents aged 35-44 years, females, and those with tertiary or higher educational level were more likely to respond to the survey across the three years. More than 60% of the participants reported having only one child. It’s worth noting that while more than one-third of participants intended to receive the LAIV, the actual receipt of LAIV remained relatively low, with rates below 3% in both 2019 and 2020, though this slightly increased to 8.4% in 2021 (Supplementary Data 1)³⁰. This is mainly due to only a limited number of schools opting to provide LAIV within the school outreach program³⁰.

Changes in vaccine hesitancy and preference for LAIV and IIV over time

Considering that only a limited number of schools opted to provide LAIV within the school outreach program, we chose not to use the actual SIV type received by children as our primary outcome measure. This was aimed to mitigate the impact of school choices on the type of SIV used, thus preventing an underestimation of parental acceptability of LAIV. Alternatively, our study focused on the preferred SIV type selected by parents, with participants given the choices of a needle-injected vaccine (IIV), a nasal-spray vaccine (LAIV), or neither type. The overview of vaccine-hesitant attitudes (VH) score data, stratified by SIV preference group and survey period, is presented in Fig. 2. Overall, the results supported the H1, a significant increase in average VH scores from 2020 [IIV: median (IQR) = 2.50 (1.00); LAIV: median (IQR) = 2.50 (1.25)] to 2021 [IIV: median (IQR) = 2.75 (1.25); LAIV: median (IQR) = 3.00 (1.50)] was observed. We also observed a significant increase in preference for LAIV over IIV from the Pandemic Pre-vaccine period (IIV: 50.3%, LAIV: 34.3%) to the Pandemic Post-vaccine period (IIV: 44.0%, LAIV: 49.3%, $p < 0.05$, tested using the chi-square test). This indicates a noteworthy dual escalation in vaccine hesitancy and preference for LAIV over time, particularly after a mass COVID-19 vaccination campaign rolled out. Remarkably, across the three time periods, parents who had higher levels of VH scores were more likely to report preferring LAIV over IIV compared to those who had lower VH scores.

Do vaccine hesitancy and public health events predict parental SIV type preferences?

To answer this question, we conducted analyses for the whole sample and the cohort data (repeated measures across three years). We first used a multivariable logistic model to examine the associations of parental SIV type

Table 1 | Multivariable logistic regression of parental SIV type preferences and associated determinants conducted in the whole sample (N = 1302)

Determinants	Unadjusted analysis		Adjusted analysis	
	OR	95%CI	aOR ^a	95%CI
Vaccine hesitancy level				
Low vaccine hesitancy	Ref	Ref	Ref	Ref
Moderate vaccine hesitancy	1.12	0.92, 1.36	1.14	0.93, 1.40
High vaccine hesitancy	1.65***	1.34, 2.03	1.69***	1.36, 2.10
Time period ^b				
Pre-Pandemic	Ref	Ref	Ref	Ref
Pandemic Pre-vaccine	0.94	0.78, 1.13	0.97	0.80, 1.17
Pandemic Post-vaccine	1.54***	1.25, 1.90	1.53***	1.23, 1.89
Age (year)				
18-34	Ref	Ref	Ref	Ref
35-44	1.27*	1.02, 1.59	1.13	0.90, 1.43
45 or above	1.34*	1.04, 1.72	1.26	0.96, 1.65
Self-reported gender				
Male	Ref	Ref	Ref	Ref
Female	0.75***	0.64, 0.88	0.77**	0.65, 0.92
Educational attainment				
Secondary or below	Ref	Ref	Ref	Ref
Tertiary or above	1.48***	1.26, 1.74	1.33**	1.09, 1.62
Monthly household income (HKD)				
Below 30,000	Ref	Ref	Ref	Ref
30,000-59,999	1.42***	1.16	1.26*	1.02, 1.57
60,000 or above	1.75***	1.42	1.45**	1.13, 1.86

95%CI: 95% Confidence Interval. Ref: Reference group.

^a aORs for SIV type preferences compared with reference group adjusted for key covariates (age, gender, education and income).

^b COVID-19 pandemic periods: Pre-pandemic (Sept-Dec 2019); Pandemic Pre-vaccine (Sept-Dec 2020); and Pandemic Post-vaccine (Sept-Dec 2021).

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$. Bold values are significant.

preference with vaccine hesitancy levels and periods (indicators of public health events) adjusting for demographic factors, including age, gender, educational attainment, and income for the whole sample (N = 1302). As is shown in Table 1, vaccine hesitancy level is significantly associated with parental SIV type preference. Parents with high vaccine hesitancy were more likely to prefer LAIV (adjusted odds ratio [aOR] = 1.69, 95% confidence interval [95% CI] = 1.36-2.10). Parental SIV type preferences in the Pandemic Pre-vaccine period were not significantly different from that in the Pre-pandemic period (aOR = 0.97, 95% CI = 0.80-1.17), but significantly different from that in the later Pandemic Post-vaccine period (aOR = 1.53, 95% CI = 1.23-1.89). Additionally, there were significant differences in the odds of parental SIV type preferences by gender, educational attainment, and monthly household income. Specifically, there was a lower likelihood of preferring LAIV among those who were female (aOR = 0.77; 95% CI = 0.65-0.92), but a higher likelihood of preferring LAIV among those with a higher monthly income (aOR = 1.26; 95% CI = 1.02-1.57 for a monthly income of 30,000 and 59,999 and aOR = 1.45; 95% CI = 1.13-1.86 for a monthly income of above 60 000), and those with tertiary or above educational attainment (aOR = 1.33; 95% CI = 1.09-1.62). The breakdown of variable details can be found in Supplementary Table 3.

To offer stronger evidence on the causal relationship of SIV type preferences with vaccine hesitancy levels and time periods, Generalized Estimating Equation (GEE) model was conducted in the cohort who participated in all three waves of the survey (N = 376). Table 2 shows that, parents having high vaccine hesitancy had 1.9 times higher odds of preferring LAIV than those with low vaccine hesitancy (95%CI: 1.02-3.59,

Table 2 | GEE logistic regression on predicting parental preferred type of SIV (N = 376)

Determinants	Odds Ratio	SE	95% CI
Baseline vaccine hesitancy			
Low vaccine hesitancy	Ref	Ref	Ref
Moderate vaccine hesitancy	1.22	0.25	0.75, 2.00
High vaccine hesitancy	1.92*	0.32	1.02, 3.59
Time period ^a			
Pre-pandemic	Ref	Ref	Ref
Pandemic Pre-vaccine	0.61	0.21	0.60, 1.35
Pandemic Post-vaccine	1.63*	0.20	1.09, 2.42
Vaccine hesitancy * Time period	1.13	0.38	0.54, 2.38
Age (year)			
18-34	Ref	Ref	Ref
35-44	1.14	0.23	0.72, 1.78
45 or above	1.39	0.28	0.81, 2.40
Self-reported gender			
Male	Ref	Ref	Ref
Female	0.58**	0.18	0.41, 0.83
Educational attainment			
Secondary or below	Ref	Ref	Ref
Tertiary or above	1.28	0.20	0.86, 1.90
Monthly household income (HKD)			
Below 30,000	Ref	Ref	Ref
30,000-59,999	1.64*	0.22	1.07, 2.53
60,000 or above	1.59	0.27	0.93, 2.70

"GEE": Generalized Estimating Equation; "SIV": seasonal influenza vaccine.

SE: Standard Error. 95%CI: 95% Confidence Interval. Ref: Reference group.

^a COVID-19 pandemic periods: Pre-pandemic (Sept-Dec 2019); Pandemic Pre-vaccine (Sept-Dec 2020); and Pandemic Post-vaccine (Sept-Dec 2021).

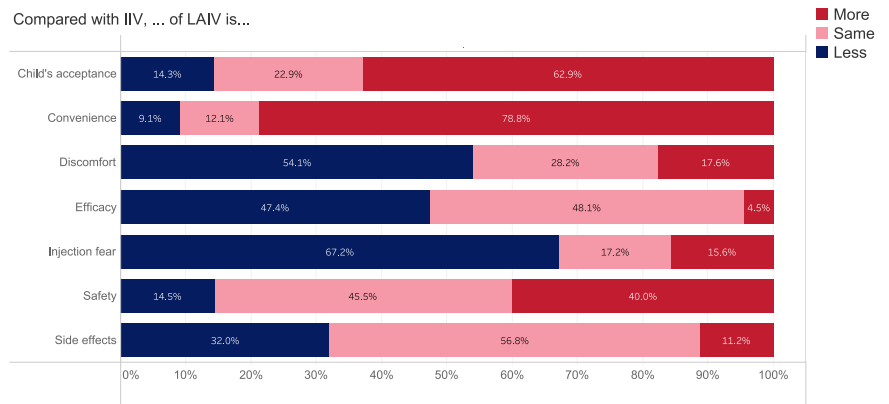
** $P < 0.01$; * $P < 0.05$. Bold values are significant.

$p = 0.042$). In addition, parents reporting LAIV as their preferred SIV type had 1.6 times higher odds of reporting such preference type in the later COVID-19 vaccine rollout period, compared to the Pre-pandemic period (95%CI: 1.09-2.42, $p = 0.017$). Furthermore, female parents showed lower odds of reporting LAIV as their SIV preference type compared to male parents (95%CI: 0.41-0.83, $p = 0.003$). Parents with a higher household income (ranging between 30,000 and 59,999) also had higher odds of preferring LAIV than those with lower household income (95%CI: 1.07-2.53, $p = 0.024$). We did not observe a significant interaction effect between vaccine hesitancy and the survey period, which means that H4 is not supported. Overall, the results suggest that parents with higher levels of vaccine hesitancy consistently favored LAIV over IIV throughout the pandemic.

Qualitative Insights Behind Vaccine-hesitant Parents

To gain a deeper understanding of the reasons for parental preferences for different SIV types, we combined data from a set of multiple-choice questions included in our three-year surveys with qualitative insights obtained through in-depth interviews conducted over a two-year period. In the questionnaire-based survey, parents were asked to compare LAIV with IIV on several attributes, including administration mode-related attributes such as acceptability for children, convenience, discomfort, and vaccination-related fear, and vaccine-specific attributes such as efficacy, safety, and side effects. Parents who reported choosing neither type of SIV for children in the next 12 months were identified and categorized as either vaccine hesitators or refusers. As illustrated in Fig. 3, parents who were vaccine hesitators or refusers perceived that LAIV had more favorable attributes than IIV. Overall, 62.9% of the parents who were vaccine hesitators or refusers

Fig. 3 | Assessment of attributes by parents who chose neither type of SIV types preference across three years (N = 227). “IIV”: inactivated influenza vaccine; “LAIV”: live attenuated influenza vaccine. The data has been filtered to show only those who prefer neither as their preferred vaccine type. The bar chart displays the percentage of responses for each vaccine-specific attribute over three years. The color-coding indicates whether each attribute of LAIV is more (red), the same (pink), or less (blue) than IIV.



believed that LAIV was more acceptable for children compared to IIV. They also had more positive attitudes toward LAIV, except that almost half of the parents (47.4%) believed that LAIV would be less effective compared to IIV. Supplementary Data 3 illustrates the assessment of attributes by parents who had a particular preference for IIV or LAIV³⁰. Results found that parents who favored IIV predominantly believed that IIV was more effective than LAIV. In contrast, parents who preferred LAIV cited several factors, including the perception that LAIV was less invasive and less uncomfortable for children. Moreover, those preferred LAIV perceived that LAIV was more readily accepted by children and more convenient for administration.

Additionally, we integrated insights from the 48 qualitative interviews, during which we specifically inquired about parents’ reasons for choosing either LAIV or IIV, or neither. Likewise, we classified parents into either SIV hesitator/refuser or SIV acceptor. SIV hesitator/refuser was identified from the interviewee’s self-reported vaccination status of their children (those who reported that their child didn’t receive any type of SIV in the past year). To ease interpretation, we presented the major themes relating to preference for LAIV or no vaccination among SIV hesitators/refusers as our primary results, while findings for SIV acceptors are included in Supplementary Data 3³⁰. Below we present four major themes related to preferring LAIV or no vaccines among parents who were hesitant or refused to vaccinate their children.

Preference for naturalness. Our qualitative interviews consistently found that parents who were vaccine-hesitant or refusal often grounded their reluctance in their preference for naturalness. Specifically, these parents preferred relying on their children’s immune systems to combat viruses rather than opting for a vaccine, especially one involving invasive medical procedures. Preference for naturalness was also intertwined with the concern about excessive medication of giving multiple shots to children which was perceived to potentially compromise children’s natural immunity. Such naturalness value and concern about excessive medication drove their preference for LAIV over IIV.

“I believe children themselves already have some immunity. If I can make sure they are (children) eating healthily and exercise regularly, I believe such natural defence could be better. This is my personal belief... If I have to choose, I think LAIV will be more acceptable. You know, children are afraid about pain and needles, but if they (schools) change to (offer) LAIV, maybe they can encourage more parents like me to take a flu vaccine.” (PS06).

Fear of needles. When asked to choose between LAIV and IIV, SIV hesitator/refuser indicated that LAIV caused less needle fear in children, making it potentially more acceptable for them. Some vaccine-hesitant or refusal parents automatically differentiated nasal-spray vaccines and needle-injection vaccines by claiming that LAIV would not directly go into child’s body as would a needle injection, which appeared linking to their preference for naturalness.

“I don’t think they (children) need a vaccine. But if I must (let my child) receive (a vaccine), maybe I will choose the LAIV, because children will have less fear about nasal spray...Also, I think LAIV will not directly go into the body like the needle injection.” (PS16).

“I find LAIV should be easier to administer because it causes less pain. I believe LAIV is more acceptable both for me as a parent and for my child.” (PR11).

Ignorance to LAIV. Very few participants automatically mentioned LAIV. When prompted by the interviewer, three parents from the SIV hesitator/refuser group mentioned that they knew little about the nasal-spray LAIV, or had never heard about it. The ignorance to the alternative vaccine led to choosing no vaccination among these parents.

“I never heard about LAIV. I would not read school’s notifications carefully. I will not let my child take the vaccine anyway.” (PS18).

Misperceptions about the efficacy of LAIV. Since many schools didn’t offer LAIV as an alternative vaccine for children’s influenza vaccination, most parents lacked understanding about and experience with LAIV. Misperceptions about the efficacy of LAIV were consistently identified due to lacking information and experiences. For example, one parent who was hesitant or refused to vaccinate her child with SIV expressed concerns about the low dosage of LAIV which was perceived to be less effective.

“I am uncertain about the effectiveness of LAIV for primary school children. I noticed that doctors administered only small doses of the vaccine...” (PS16).

Some parents misbelieved that LAIV could not be fully absorbed by children as it was administered through nasal spray, which was perceived to have reduced protective effects.

In contrast, if a child had previously been vaccinated with the LAIV, parents seldom had such misperceptions about the efficacy of LAIV. This may be because that an enhanced understanding had gained from the experience or that good understanding about LAIV drove choosing LAIV. For example, one parent with two children attending schools that provided both IIV and LAIV was more positive about LAIV and paid more attention to its greater acceptance in children (more details in Supplementary Data 3)³⁰.

Discussion

In this longitudinal, mixed-methods study, our primary findings revealed an increase in parental vaccine hesitancy and preference for LAIV over IIV after the onset of the COVID-19 pandemic and especially after the rollout of the COVID-19 vaccination campaign. Further examination of their relationships indicates that high vaccine hesitancy and the massive rollout of the COVID-19 vaccination campaign predict a greater preference for LAIV over IIV. An in-depth exploration into the underlying reasons behind the preference for LAIV by vaccine-hesitant or refusal parents supplemented

our interpretation of the quantitative results. The qualitative analyses revealed that the injection-free and less intrusive characteristics of LAIV aligned with parental core values of prioritizing children's natural immunity and concerns about overmedication. As a result, LAIV was perceived as less invasive and more acceptable for parents who were indecisive of getting SIV for their children or refused to do so.

Existing cross-sectional studies have observed a growing parental willingness to get SIV for their children, from before the pandemic to during the pandemic^{31,32}. However, a recent longitudinal study did not find a significant change in overall parental vaccine hesitancy after the onset of the COVID-19 pandemic or the launch of the COVID-19 vaccination program³³. Instead, they identified changes in parents' specific vaccine attitudes. Notably, following the widespread availability of COVID-19 vaccines, parents became more concerned about taking multiple vaccinations for their children simultaneously. They also showed an increasing willingness to rely on natural infection for developing children's immunity rather than vaccination²⁹. Our study observed an increase in parental vaccine hesitancy after the rollout of a citywide COVID-19 vaccination campaign. This suggests that the introduction of a new vaccine could be the primary factor for increasing parental vaccine hesitancy, possibly stemming from concerns about overmedication or excessive reliance on medical interventions for their children²⁹. The widespread misinformation and negative news about COVID-19 vaccines³⁴ and the extensive promotion of a new vaccine especially the introduction of vaccine pass may further intensify parental concerns that multiple vaccines could strain children's immunity, ultimately leading to an increase in parental vaccine hesitancy. Additionally, regarding demographic factors, our findings indicate that individuals with higher income and educational attainment express a stronger preference for choosing LAIV. Notably, in Hong Kong, the subsidized program for LAIV is exclusive to kindergartens, requiring parents to incur additional costs if they choose LAIV for primary school children. This financial aspect sheds light on the prevalence of primary schools in Hong Kong offering IIV instead of LAIV in their school-based SIVP, as the extra charges could pose additional challenges for the schools' logistical arrangements³⁵.

Our cohort data revealed that parents with higher vaccine hesitancy had a greater preference for choosing LAIV over IIV for their children. In Hong Kong, LAIV was initially available from 2009 to 2013 but was discontinued for use after 2013, possibly due to concerns stemming from its reported low effectiveness during the 2013-2016 seasons in the United States³⁶. It was later recommended for children starting from the 2018/2019 season due to an observed improvement in antibody response compared to previous seasons³⁶. It was suggested that the ease of administration by nasal spray and readily acceptability by children³⁷ made LAIV an ideal choice for rapid deployment with a high coverage rate for annual immunization in the school-based setting^{23,38}. A study in France found that parents preferred LAIV due to various advantages, including the absence of needles, reduced pain, and easier administration¹⁸. Additionally, nearly 80% of children indicated a preference for vaccination via nasal spray³⁹. All this existing evidence helps to explain why parents with high vaccine hesitancy tend to prefer LAIV. Needle and injection fear has been identified as one critical attitude root contributing to vaccine hesitancy^{40,41}. This attitude root has been found to explain approximately 10% of cases of COVID-19 vaccine hesitancy⁴¹. Furthermore, it is twice as prevalent in parents with non-vaccinated children compared to those whose children have already been vaccinated⁴². A recent systematic review identified needle-related fears and phobias as one of the top three reasons behind anti-vaccination arguments⁴³. All these findings highlight the need to address parental vaccine hesitancy by targeting their needle-related fear and phobia. However, in the context of the pandemic, the introduction of additional injection-based vaccinations has added further challenges in addressing parental vaccine hesitancy. Therefore, the needle-free delivery mode of LAIV, which is perceived as less intrusive¹⁹, may help to address parents' vaccine hesitancy due to worry about multiple injections and the overmedicalization of vaccination.

A deeper exploration of the underlying reasons found that parents who are vaccine-hesitant or refusing tended to evaluate LAIV as a safer, more convenient, less uncomfortable, and thereby more acceptable alternative compared to IIV. Our survey found that 85.5% of vaccine-hesitant or refusing parents believed that LAIV was either more or equally safe as IIV. Our qualitative interviews further revealed that their perception of high safety for LAIV was influenced by their preference for natural options, specifically a reliance on children's natural immunity. In the context of vaccines, this preference may be challenged as vaccines typically contain a weakened form of the virus and vaccines given by injection involve breaking the body's membrane to stimulate an immune response⁴⁴. Driven by the naturalness value, parents tended to avoid invasive medical interventions and prefer the more natural methods of health management such as relying on children's innate immune defences^{45,46}, contributing to heightened vaccine delay or refusal⁴⁷. In addition, this underlying preference for naturalness was closely linked to parents' concern that the multiple vaccinations would overwhelm children's immunity^{48,49}. LAIV emerged as a promising alternative to align with parental underlying naturalness preference. A recent study suggested that in comparison with IIV, LAIV was perceived as more controllable, less threatening, and less invasive to the immune system, making it more appealing especially to the vaccine-hesitant groups¹⁹. Building on this, our study contributes to a more nuanced understanding of parental preference for LAIV through in-depth qualitative analyses. Some parents believed that LAIV would not directly enter children's bodies thereby was less invasive. Although this perception was a misinterpretation of LAIV, the nasal spray mode and the perceived less invasiveness of LAIV coincided with the parents' underlying values of prioritizing naturalness, alleviating their concerns about overmedication and invasiveness. However, despite LAIV being considered a probable option for vaccine-hesitant or refusal parents, most vaccine acceptors still chose IIV over LAIV. In Hong Kong, IIV remained the dominant option in school-based SIV programs. School's choice strongly influenced parental preference for SIV types. Parents who chose IIV over LAIV often based their evaluation on a hypothetical understanding of LAIV, leading to misperceptions about LAIV, including low efficacy, poor absorption, safety concerns due to novel technology, and discomfort caused by nasal spray. We also found that 47.4% of parents who did not choose any type of SIV believed that LAIV was less effective than IIV due to misperceptions such that vaccines given through nasal spray could not be fully absorbed. This suggests that misunderstanding and a lack of experience regarding LAIV could diminish parental acceptability of LAIV. Notably, parents who had direct experiences with both IIV and LAIV did not have such misperceptions about LAIV. Instead, they tend to favor LAIV more. This suggests that parents are more likely to choose the vaccine type that aligns better with their values by comparing the nature of the two vaccine types once they have obtained relevant experiences.

Our findings provide several implications for addressing parental vaccine hesitancy and refusal. First, LAIV can be one promising option for promoting SIV uptake among children, especially among hesitant and refusing parents who are concerned about multiple injections and have a strong purity value⁴¹. Some vaccination programs have already leveraged the benefits of nasal spray administration to increase vaccine uptake rates (e.g.⁵⁰). However, instead of solely introducing LAIV as a nasal spray vaccine in children's influenza vaccination program, communication to emphasize its painless, injection-free, and easy-to-administer features is equally important as these features strongly resonate with the underlying values of hesitant parents. In our qualitative interviews, we also encountered some vaccine-hesitant or refusing parents who remained reluctant to choose either type of SIV. Additionally, some parents held misconceptions about LAIV due to a lack of knowledge and experience, even though LAIV is actually more effective than IIV in protecting children against influenza, as demonstrated in a recent meta-analysis study²⁴. This underscores the importance of addressing the knowledge deficit regarding LAIV among parents. Specifically, messages should leverage parents' existing high safety perception of LAIV by emphasizing its easy-to-administer and low

intrusiveness characteristics, while also reassuring parents of its high efficacy. Furthermore, IIV remains the predominant option in most schools. This indicates that many schools remain hesitant to introduce LAIV due to a lack of understanding about its characteristics, challenges in effectively communicating its features to parents, and concerns related to additional costs and administrative barriers²⁰. IIV remains the most conventional choice and has been familiar and a more trustworthy one for parents who have gotten used to this vaccine type. However, to enhance parental vaccination willingness, especially among vaccine-hesitant or refusing parents, LAIV can be introduced as an option in school-based SIV programs. It's equally important to incorporate LAIV into free-of-charge initiatives, reinforcing schools' confidence in managing both vaccines. This will broaden the choices available to parents at no additional cost, enabling them to align their vaccination decisions with individual preferences and concerns.

Our study used a longitudinal design, spanning from the pre-pandemic to the post-pandemic periods, with repeated assessments of parental preferences for different types of SIV. This study design allowed us to track the temporal evolution of parental vaccine hesitancy and preference for SIV types along with the occurrence of important public health events. Furthermore, longitudinal analyses provided robust evidence to examine a longitudinal relationship between vaccine hesitancy and the preference for different vaccine types. In addition, we complemented our study with qualitative analyses to enhance our understanding of parental preferences for SIV types. Despite this, the current study has several limitations. First, a large proportion of participants were lost during the three-year follow-up, primarily due to the disruptions of the pandemic during which people lost interest in other health topics other than COVID-19. Second, although the qualitative data indicated perceived controllability and the preference for naturalness may contribute to higher acceptability for LAIV, the associations cannot be verified in the quantitative data because naturalness preference was not measured in the survey. Third, parental preferences for SIV types could be different from their actual choice. We only examined parental preference regarding specific SIV types because the majority of schools in our study exclusively offered IIV in their SIV programs. Fourth, the lack of differentiation in parental vaccine preference questions for each child restricted our ability to explore the effect of children's ages or educational levels on parental vaccine preference. Future studies could employ a more nuanced questionnaire design to investigate the potential variations. Fifth, one potential limitation of this study is self-selection bias. Participants were given the choice to opt-in for the follow-up study, which could introduce a bias in the sample composition. To address this concern, we compared the demographic characteristics of participants who completed the follow-up surveys with those who did not. The results showed no significant differences, except that those who completed the follow-up tended to be younger and had lower household income levels ($p < 0.05$, tested using the chi-square test).

Conclusion

Our quantitative data revealed that higher parental vaccine hesitancy was associated with a preference for LAIV over IIV for their children's SIV uptake. A significant increase in parental vaccine hesitancy was observed following the launch of the mass COVID-19 vaccination program. Moreover, heightened levels of vaccine hesitancy, coupled with the pandemic post-vaccine rollout period, emerged as predictive factors for a stronger preference for LAIV over injection-based IIV. Our qualitative data further indicate that the preference for LAIV is rooted in the parental value of prioritizing natural options, which encompasses a preference for relying on natural immunity and a desire to avoid overmedication. Parents who were hesitant or refused to take the SIV were found to be more inclined to opt for LAIV over IIV. This preference for LAIV was attributed to the perception that it was less invasive to children's immune systems, caused less pain and discomfort, and was more acceptable for children. Future risk communication should leverage the acceptability of LAIV in hesitant parents to increase childhood vaccination uptake.

Data availability

Data used in the quantitative analyses of our study, including the specific numerical data underlying Figs. 2, 3 (source data), are publicly available in an OSF repository³⁰. Data of qualitative interviews for this study is not publicly available for privacy reasons but may be made available to qualified researchers on reasonable request from the corresponding author.

Code availability

Codes for main analyses in the quantitative section of our study are publicly available in an OSF repository³⁰.

Received: 25 January 2024; Accepted: 31 July 2024;

Published online: 16 August 2024

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Acknowledgements

This study received funding from the Health and Medical Research Fund of the Food and Health Bureau of the Hong Kong SAR Government (DKMI, grant number: INF-HKU-2).

Author contributions

Q.L. conceptualized, designed, and supervised the study, contributed to data interpretation, and revised the manuscript critically for important intellectual content. J.Y. and L.L. contributed equally to data analysis, data interpretation, and manuscript drafting. M.D. contributed to data collection and analysis of the qualitative data. H.C.S. provided administrative, technical, and material support. D.K.M.I. and B.J.C. contributed to the study design and data interpretation. D.K.M.I., B.J.C., and Q.L. obtained funding. All authors approved the submitted version and have contributed to the final version of the manuscript.

Competing interests

B.J.C. reports honoraria from AstraZeneca, Fosun Pharma, GlaxoSmithKline, Moderna, Pfizer, Roche, and Sanofi Pasteur. All other authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1038/s43856-024-00585-w>.

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Peer review information *Communications Medicine* thanks the anonymous reviewers for their contribution to the peer review of this work. A peer review file is available.

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