frontiers in Public Health

TYPE Perspective
PUBLISHED 18 November 2026
DOI 10.3389/fpubh.2026.2007800

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OPEN ACCESS

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RECEIVED 23 September 2026
REVISED 30 October 2026
ACCEPTED 04 November 2026
PUBLISHED 18 November 2026

CITATION
Goiana-da-Silva F, Tude-Graça D, Tamudjim-Fonseca P, Costa F, Correia FD, Renard R, Pereira J, Portas T, Silva P, Romano S, Rodrigues AT, Cardoso N, Paulino E and Ashrafian H (2026) Beyond access: the evolution of Portugal's pharmacy-based vaccination strategy and the future role of AI-driven outreach. *Front. Public Health* 14:2007800. doi: 10.3389/fpubh.2026.2007800

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Beyond access: the evolution of Portugal's pharmacy-based vaccination strategy and the future role of AI-driven outreach

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Vaccination programmes increasingly face a paradox: expanding access does not necessarily translate into coverage at policy targets. Portugal provides an instructive example. The integration of community pharmacies into seasonal influenza and COVID-19 vaccination created more than 3,500 vaccination points and approximately 70% of influenza doses were administered in pharmacies in 2023–2024. The pharmacy share then fell to under 46% by 2025–2026, while total influenza doses remained broadly stable (2.41 to 2.56 million per season). This indicates a redistribution of doses across settings rather than a loss of vaccination activity; changes in age eligibility, high-dose vaccination for adults aged ≥85 years in SNS units, and invitation and recall activity may all have contributed. Influenza coverage among adults aged ≥65 years remained below the World Health Organization target of 75%, at 70.5% in 2024–2025 and 73.0% in 2025–2026. This suggests that, residual under-vaccination reflects barriers beyond physical access. The authors use "activation gap" descriptively for potentially addressable interruptions between eligibility and vaccination. Portugal already uses registry-based invitations and reminders, the open question is what a conversational layer, scripted or based on generative AI, could add. Evidence is relatively strong for reminders, growing for scripted conversational interventions and preliminary for generative AI. The authors therefore propose a registry-based randomised comparison of existing recall, existing recall plus a scripted conversational intervention, and existing recall plus a generative-AI conversational intervention, with incremental vaccination, safety, equity, trust and cost per additional vaccinated person as outcomes.

KEYWORDS
artificial intelligence, behavioural and social drivers, community pharmacy, conversational AI, influenza, population health, Portugal, seasonal vaccination

Introduction

Vaccination is one of the most effective population-level interventions for preventing infectious disease, reducing severe illness and averting premature mortality (1). Seasonal influenza is particularly important because disease burden is concentrated among older adults and people with chronic conditions, while annual epidemics place recurrent pressure on health systems (2).

Despite longstanding recommendations and substantial vaccine availability, influenza vaccination coverage remains below policy targets in most European countries. The World Health Assembly established a target of at least 75% coverage among older adults in 2003, subsequently reinforced within European policy (3, 4). Yet in the 2024–2025 season, median influenza vaccination coverage among older adults across the 22 EU/EEA countries that reported coverage data in the ECDC survey was only 47%. Portugal, at 70.5%, was among the highest-performing countries but remained below the 75% target (5). The persistence of this gap suggests that vaccination uptake cannot be understood solely in terms of vaccine availability or formal recommendations.

Contemporary vaccination policy increasingly recognises the importance of behavioural and social determinants. The World Health Organization's Behavioural and Social Drivers of Influenza Vaccination framework distinguishes confidence, perceived risk and need, social processes and practical issues as interrelated determinants of uptake, and recommends measuring these drivers to design targeted interventions (6). Thus, the policy challenge is not simply to make vaccines available, but to ensure that availability translates into action.

Portugal provides a particularly informative case because it recently underwent a major transformation in seasonal vaccination delivery. Historically centred predominantly on National Health Service (SNS) primary care, the 2023–2024 campaign incorporated community pharmacies as vaccination sites for influenza and COVID-19 (7). The reform substantially expanded the vaccination network: more than 3,500 vaccination points became available nationally, approximately 88% of community pharmacies participated, and around 70% of influenza vaccinations were administered in pharmacies (7).

International evidence supports the role of pharmacists as vaccination providers. Experimental and observational evidence indicates that pharmacist involvement, whether through direct administration or active recommendation, can improve immunisation uptake, although meta-analyses disagree on which of these two roles drives the larger effect (8–10).

Crucially, Portugal's experience illustrates that expanded access, although accompanied by higher coverage among adults aged ≥60 in the first season (7), did not by itself bring coverage among older adults to the 75% target (5). The expansion of pharmacy-based delivery produced a more distributed and convenient vaccination infrastructure.

The authors report influenza coverage for adults aged ≥60 years (the eligibility threshold since 2023–2024), ≥65 years (the EU and WHO target indicator) and ≥85 years (the group offered free high-dose vaccine) (11). Coverage describes vaccination in all settings, not only pharmacies.

The Portuguese experience therefore suggests an evolution in the nature of the policy problem. Where vaccination opportunities are scarce, interventions should primarily address access. Once access has been substantially expanded, however, additional gains may depend increasingly on identifying people who remain unvaccinated, understanding the barriers preventing action and engaging them at an appropriate time. The authors use "activation gap" descriptively to refer to potentially addressable interruptions between eligibility and vaccination. It is not a validated measure in this analysis and should not be confused with patient activation, which is a distinct construct.

This Perspective argues that Portugal's pharmacy-based seasonal vaccination reform should be seen not as the endpoint of vaccination-access policy but as the foundation for its next phase: improving the conversion of eligibility into vaccination across the combined delivery network. Building on the registry-based invitations and reminders already in use, we propose that conversational systems, scripted or based on generative AI, be evaluated comparatively as an additional layer. The sections that follow separate observed trends, possible explanations and the hypothesised benefits of conversational systems.

Portugal's pharmacy-based vaccination reform: from primary care delivery to proximity administration in community pharmacies

Portugal's incorporation of community pharmacies into seasonal vaccination distributed delivery across a large existing network of community-based health professionals, consistent with international evidence that pharmacist involvement, as administrator or advocate, increases immunisation uptake relative to usual care (7, 9, 10). Weekly influenza vaccination capacity rose from approximately 212,000 doses at the peak week in 2022–2023 to approximately 309,000 in 2023–2024, with the peak occurring about three weeks into the campaign rather than six, and 94.8% of respondents in the first-campaign evaluation supported the inclusion of pharmacies (7). The reform thus altered the architecture of access: vaccination was brought closer to citizens and a substantial share of seasonal activity moved into community pharmacies. Increased delivery capacity and convenience should not, however, be conflated with improved population coverage, as uptake is determined by behavioural, social, perceptual and practical factors (12). The two outcomes represent different stages of the vaccination pathway, and Portugal's experience allows us to examine what remains once the most visible structural barrier, where vaccination can occur, has been substantially addressed.

Post-reform vaccination trends: redistribution across delivery settings

Influenza vaccination coverage among adults aged ≥60 rose from 62.4% in 2022–2023 to 66.3% in the reform's first season, as pharmacies absorbed 69.8% of influenza doses and 69.1% of COVID-19 doses nationally (Figure 1, point A) (7). The pharmacy share of influenza

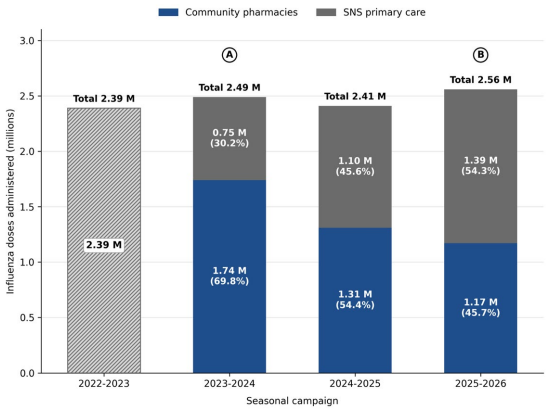


FIGURE 1
Influenza vaccine doses by setting, 2022–2023 to 2025–2026. Before the pharmacy reform, influenza vaccination was delivered almost exclusively through SNS primary care (2022–2023 reflects influenza doses administered within the SNS up to 30 April 2023, as reported by the DGS, and is shown hatched). **(A)** In the reform's first season, pharmacies became the dominant delivery channel. **(B)** SNS volume subsequently increased and exceeded pharmacy volume again by 2025–2026, while total doses remained broadly stable (2.49, 2.41, and 2.56 million in 2023–2024, 2024–2025, and 2025–2026). Pharmacy participation and the number of vaccination points remained essentially unchanged; pharmacy eligibility was limited to ages 50–84 in 2024–2025 and 60–84 in 2025–2026, and adults aged ≥85 years were vaccinated only in SNS units from 2024 to 2025 (7, 11, 13, 14).

doses then declined to 54.4% in 2024–2025 and 45.7% in 2025–2026, and in absolute terms SNS primary care overtook pharmacies as the dominant channel by 2025–2026 (Figure 1, point B) (7, 11, 13, 14). Total influenza doses, however, were broadly stable across the three post-reform seasons (approximately 2.49, 2.41 and 2.56 million), indicating a redistribution of doses between channels rather than a loss of vaccination activity.

This redistribution should not be interpreted as evidence of declining population engagement: the proportion administered in a particular setting is distinct from overall vaccination coverage and does not measure individual motivation or willingness to vaccinate. Influenza coverage among adults aged ≥60 was 66.3% in 2023–2024, 64.0% in 2024–2025 and 66.2% in 2025–2026, and in 2025–2026 it was higher than in 2024–2025 in every age group (7, 11, 13, 14). Several changes may have influenced the distribution of doses: pharmacy eligibility, which had no upper age limit in 2023–2024, was limited to ages 50–84 in 2024–2025 and 60–84 in 2025–2026; vaccination of adults aged ≥85 years took place only in SNS units from 2024–2025, when high-dose vaccine was first provided free of charge to this group; and invitation and recall activity increased, with SNS convocation SMS rising from approximately 2.3 million in 2024–2025 to 2.7 million in 2025–2026 (7, 11, 13, 14). The available aggregate data cannot quantify their separate contributions. Pharmacy participation and the number of vaccination points remained essentially unchanged, so the shift does not reflect reduced capacity. The policy question is therefore how to improve coverage across the combined delivery network, rather than how to restore a particular channel's share.

The pattern for COVID-19 was more pronounced: national coverage among adults aged ≥60 fell from 56.1% in 2023–2024 to 45.3% in 2024–2025 and 38.6% in 2025–2026, although the vaccine was offered through the same channels, often at the same visit, as influenza (11, 13, 14). This decline was already present in the reform's first season and also occurred among the chronic-disease population under 60 who continued to be vaccinated through SNS units, which suggests that it is not specific to the delivery channel (7). The decline probably has several causes that aggregate data cannot separate, such as lower perceived severity, previous infection, changing recommendations and attitudes to repeated boosters; in a Portuguese cohort, vaccine fatigue was reported only for COVID-19 and the associated factors differed between the two vaccines (12). For people who decline COVID-19 vaccination at a visit where they receive influenza vaccine, contact has already occurred, and the best-supported lever is the recommendation of the pharmacist or nurse (8–10) rather than remote outreach.

These findings are consistent with access being necessary but not sufficient for high coverage: the expanded network did not prevent the decline in COVID-19 uptake, and influenza coverage among older adults remained below the 75% target. The aggregate data cannot show which barriers account for this, and they are likely to differ between individuals, a question addressed in the next section.

Understanding the remaining coverage shortfall

Remaining unvaccinated does not identify a single barrier or establish that physical access is adequate for every individual. Non-vaccination may reflect concerns about safety, low perceived need, practical constraints, or failure to translate an intention to vaccinate into action. The intention-behaviour gap (15), the WHO Behavioural and Social Drivers framework (6) and the 5C model (16) provide complementary ways to investigate these mechanisms, and being unvaccinated should not automatically be read as vaccine hesitancy (6, 12). Identifying the relevant barrier is essential: professional counselling, practical assistance and reminders are not interchangeable responses.

Coverage also varies across the eligible population. In 2025–2026, influenza coverage was 87.91% among adults aged ≥85 years, 73.00% among those aged ≥65 and 66.23% among those aged ≥60 (11). These are cumulative groups, which mask the pattern by age band: coverage was 50.09% among adults aged 60–69, 75.24% among those aged 70–79, 78.84% among those aged 80–84 and 87.91% among those aged ≥85 (11), so the residual gap lies mainly in the youngest eligible band. The oldest group was vaccinated only in SNS units, which convoked eligible users by SMS and telephone, and received free high-dose vaccine (11, 13), a combination compatible with a contribution of proactive contact, although it cannot be separated from age-related differences in perceived risk and contact with health services.

Coverage also differs markedly between regions (among adults aged ≥65 in 2025–2026: 83.0% in the North and 54.8% in the Algarve) (11), which may reflect differences in access and local organisation as well as behaviour. Pharmacy distribution, transport, stock at individual sites and the circumstances of disadvantaged groups are not captured by counts of vaccination points, so residual practical barriers cannot be excluded.

In a national cohort of adults aged ≥60 years followed through the 2023–2024 campaign, lack of trust in vaccine safety was the most frequently self-reported reason for non-uptake among people who had intended to be vaccinated (69.4% for influenza, 72.4% for COVID-19), while lack of personal availability was cited by only 9.4% of initially undecided people who did not receive the influenza vaccine (12). Confidence and perceived need therefore weighed more than practical barriers. This interpretation is consistent with the broader European

evidence. ECDC reported a median influenza vaccination coverage of only 47% among older adults in 2024–2025, despite all EU/EEA countries maintaining recommendations for this group (5). The WHO similarly notes that achieving high influenza vaccination uptake requires attention to behavioural and social drivers in addition to programme accessibility (6).

These differences point to a role for recall that adapts to each person's position in the vaccination pathway, rather than communicating once with the entire eligible population. Portugal already conducts registry-based recall, described below (11, 13), the open question is how far its content and mode of contact can be adapted.

From reminders to behavioural activation: lessons from international evidence

The case for active outreach does not depend on artificial intelligence. Considerable evidence already demonstrates that reminders can increase vaccination uptake (17, 18).

Cochrane reviews of reminder and recall interventions (17) and of interventions to increase influenza vaccination in adults aged ≥60 (18), together with the first NUDGE-FLU trial in Denmark (17), provide the benchmark against which any conversational intervention should be compared. Reminders and recalls raised adult influenza vaccination by about 9 percentage points in the first review (17), whereas in a Danish trial of almost 965,000 older adults only two of nine electronic letters increased uptake, by less than 1 percentage point over usual care (19).

In a randomised study involving 689,693 customers of Walmart pharmacies, text-message reminders increased influenza vaccination by an average of 2.0 percentage points compared with usual care; the most effective messages communicated that a flu vaccination was "waiting" for the recipient, and repeated reminders outperformed single contacts (20). The effect was modest, but the study shows that simple, inexpensive interventions can alter behaviour at very large scale.

In a randomised trial involving 396 adults aged ≥65 years in Hong Kong, a chatbot-delivered intervention tailored to participants' stage of behavioural change outperformed a non-tailored equivalent (21). In Argentina, a preregistered trial involving 249,705 participants found that a behaviourally informed, two-way WhatsApp chatbot increased COVID-19 vaccination by 1.6 percentage points compared with no message and by roughly 1 percentage point compared with a conventional one-way reminder (22). Both trials used scripted chatbots rather than generative AI, and the effects were modest, but they suggest that interactive, tailored delivery may add value to simple reminders.

Evidence involving generative AI is newer and less mature. In a 2025 quasi-experimental study of 100 adults aged ≥65 years, a retrieval-augmented ChatGPT intervention was associated with higher influenza vaccination uptake than a comparison group that received no intervention (33.3% vs. 14.3%) (23). The study was small and non-randomised, and its authors call for a full-powered randomised controlled trial, so its findings should be read as preliminary.

The evidence is therefore hierarchical: relatively strong for reminders, growing for scripted conversational interventions, and preliminary for generative AI specifically. Findings from other health behaviours do not establish effectiveness for influenza vaccination in older adults. Current evidence supports evaluating conversational approaches, but does not establish generative AI as superior to existing recall or to simpler conversational systems.

A conversational extension to existing recall

Portugal already uses eligibility-based communication, invitations and reminders to people who remain unvaccinated. In 2025–2026, the DGS reports an informative SMS to all eligible people (approximately 4.3 million), convocation by SMS and telephone through SNS units (approximately 2.7 million SMS, up from 2.3 million in 2024–2025) and large-scale reminders to eligible people not yet vaccinated (more than 2 million in November 2025, compared with more than 1.7 million in 2024–2025) (11, 13). Vaccination administrations are recorded in the national vaccination information infrastructure, and community pharmacies and SNS facilities provide a dense network through which vaccination can be delivered (7, 11). The identify-engage-facilitate-verify pathway therefore builds on existing programme functions, it should not be presented as an entirely new recall infrastructure.

The component requiring evaluation is an additional conversational layer that could clarify questions, identify practical difficulties and support access to vaccination. Scripted systems may be sufficient for many of these functions. Relevant comparators include automated SMS reminders, scripted chatbots, structured telephone outreach and pharmacist-led counselling; telephone reminders were the most effective in the Cochrane review (17), but they cost more per contact, so the question is incremental effect per unit of cost, not effectiveness alone.

Generative AI could potentially interpret a wider range of questions and adapt explanations while drawing on an approved knowledge base, but its incremental benefits, costs and risks relative to scripted interaction remain uncertain. Grounding responses in approved sources is a safeguard, not evidence that errors have been eliminated.

The pathway comprises four stages: identify, engage, facilitate, verify (Figure 2).

First, vaccination information can be used to identify eligible individuals who remain unvaccinated during an active campaign, a function already performed in Portugal (11, 13). Previous vaccination behaviour may be particularly informative in determining who is most likely to benefit from additional outreach. In Denmark's nationwide NUDGE-FLU-2 trial, which randomised 881,373 adults aged ≥65 years, electronic letters delivered before the vaccination period, irrespective of vaccination history, produced a small overall increase in influenza vaccination (pooled effect of about 0.3 percentage points), with greater effects among individuals who had not been vaccinated during the previous season (24). Because the letters were not targeted at people still unvaccinated during the campaign, the trial provides limited evidence on targeted recall; it shows that registry-based randomisation is feasible at national scale and that the effects of low-intensity contact are modest.

Second, the system can engage the individual through an appropriate channel. Low-intensity digital reminders may be appropriate as the first step because their marginal cost is low and large-scale evidence supports their effectiveness (20). Non-responders could then be offered a more interactive conversation through text or voice. In Portugal, this step corresponds to the SMS invitations and reminders already in use (11, 13).

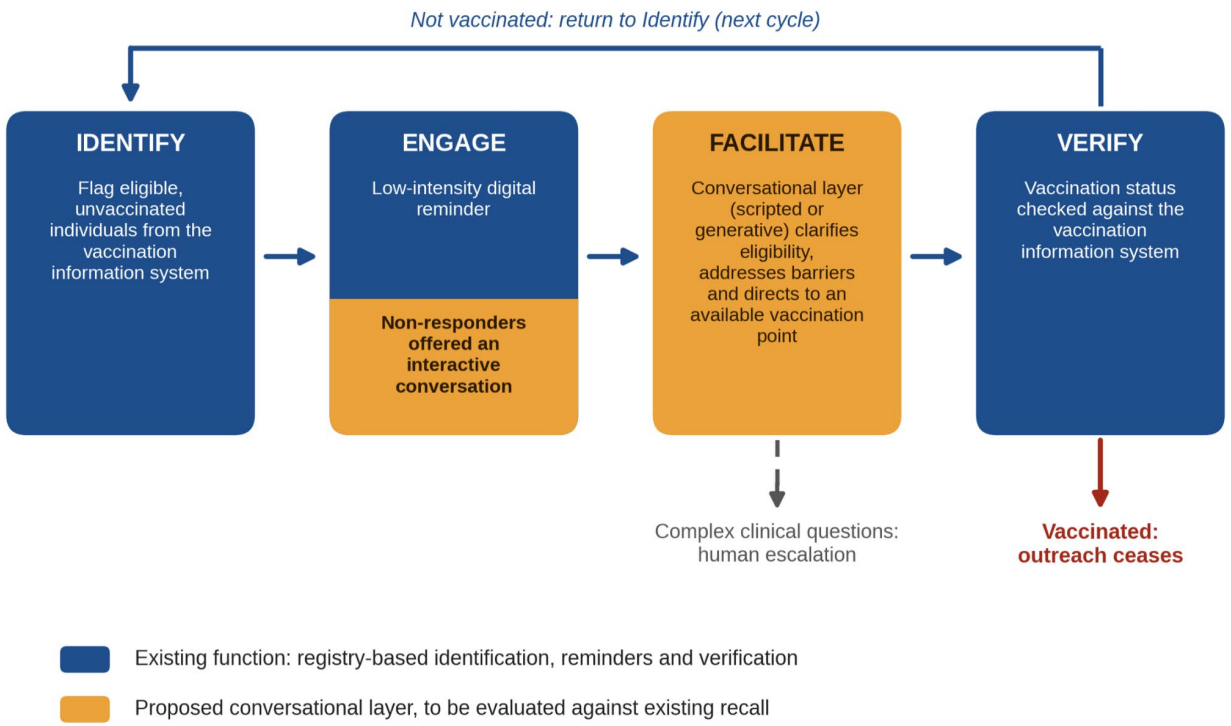


FIGURE 2
Four-stage closed-loop pathway for registry-based recall. Identification, reminder-based engagement and verification correspond to functions already in use in Portugal (11, 13); the conversational layer (shown in amber) is the component proposed for comparative evaluation. Eligible, unvaccinated individuals are identified, engaged through a reminder or a conversational interaction, and directed to vaccination; status is then verified against the vaccination information system. Vaccinated individuals exit the process; those still unvaccinated return to the identification stage.

Third, a conversational layer, scripted or generative, could support the transition from intention to action. Rather than providing generic vaccine information, it could clarify eligibility, answer predefined questions using an auditable knowledge base, identify practical barriers and direct the person to an available vaccination point. More complex clinical questions should trigger human escalation.

Fourth, vaccination status should be verified through the vaccination information system. Once vaccination is recorded, outreach should cease. This creates a closed-loop intervention (Figure 2) in which communication responds dynamically to the actual state of the population rather than operating as a fixed campaign independent of outcomes.

Implementation requires a lawful basis and data-access agreement for individualised outreach, accurate contact details and communication preferences (including opt-out), and a single vaccination record across pharmacies and SNS units, which already report administrations to the national platform (11, 13). Because unsolicited AI-generated calls or messages may raise fraud and authenticity concerns, contact should use channels people already receive from the SNS, identify the sender and the use of AI, and never request personal or payment data. The system should provide information and behavioural support only, clinical advice belongs to a health professional.

The scientific question is therefore whether a conversational layer generates incremental vaccination coverage beyond existing recall, at acceptable cost and without compromising safety, equity or trust, and whether generative interaction adds anything to scripted interaction.

A pragmatic registry-based randomised trial could compare existing seasonal recall, existing recall plus a scripted conversational intervention, and existing recall plus a generative-AI conversational intervention. Randomisation of individuals or households from the vaccination registry, as in NUDGE-FLU (19), avoids contamination between service-level clusters. The conversational arms should offer comparable contact opportunities and navigation support, allowing the contribution of generative interaction to be assessed.

The primary endpoint should be registry-confirmed influenza vaccination within a prespecified period, analysed by intention to treat. Secondary outcomes should include time to vaccination, additional vaccinations per 1,000 eligible individuals, cost per additional vaccinated person, response accuracy, human escalation, trust and differential effects by age, socioeconomic circumstances and digital access. Allocation and analysis should account for plausible household-level spillover. Cost analysis should include set-up, integration with the vaccination register, maintenance and human supervision, compared with the cost per additional vaccinated person achieved by existing SMS recall.

Potential harms include inaccurate or misleading answers (25), inappropriate reassurance, unequal reach, privacy breaches and loss of trust. Evaluation should include independent testing of response accuracy, monitoring across languages and population groups, accessible human alternatives, clear escalation pathways and predefined criteria for pausing the intervention. To avoid benefiting mainly people who are easier to reach, the pathway should offer voice and telephone options, plain-language and large-print formats, involvement of carers, a one-step route to a person, and non-digital recall for those who cannot or do not wish to use automated systems.

Deployment requires assessment of the applicable legal framework, including AI-interaction transparency under Article 50 of the EU AI Act (26) and GDPR requirements concerning lawful processing, health data, purpose limitation, data minimisation and security (27). A data protection impact assessment should precede any

deployment likely to entail high risks to individuals. Citizens should understand when they are interacting with AI and be able to access human support. AI should function as an activation mechanism, not an autonomous clinical decision-maker.

Conclusion

Portugal's seasonal vaccination programme illustrates the value of combining community pharmacies and SNS services within a broad delivery network. Changes in the distribution of doses between settings do not, by themselves, demonstrate disengagement or identify the causes of remaining under-vaccination, and they do not suggest that the pharmacy model failed: it expanded the density of vaccination points and was strongly supported by the public (7).

An independently conducted repetition of the survey on public satisfaction with pharmacy involvement in seasonal vaccination would help determine whether this initially high level of support has been sustained across subsequent campaigns.

The next policy question is how to improve coverage through this combined infrastructure, building on existing invitations and recall while determining the relative contribution of confidence, motivation, and practical and residual access barriers, and testing interventions accordingly. Conversational systems, including generative AI, merit comparative evaluation as possible additions to these approaches. Their value should be established through incremental vaccination uptake, safety, equity, trust and cost-effectiveness, rather than assumed from technological capability.

These conclusions rest on ecological, aggregate data that cannot establish individual-level causality, and the mechanisms discussed will require confirmation through prospective, patient-level research. Such evaluation should be conducted independently of any specific commercial provider, using transparent and predefined criteria.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

FG-d-S: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. DT-G: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. PT-F: Investigation, Methodology, Writing – original draft, Writing – review & editing. FaC: Writing – original draft, Writing – review & editing. FeC: Writing – original draft, Writing – review & editing. RR: Writing – original draft, Writing – review & editing. JP: Writing – original draft, Writing – review & editing. TP: Writing – original draft, Writing – review & editing. PS: Writing – original draft, Writing – review & editing. SR: Writing – original draft, Writing – review & editing. AR: Writing – original draft, Writing – review & editing. NC: Writing – original draft, Writing – review & editing. EP: Writing – original draft, Writing – review & editing. HA: Writing – original draft, Writing – review & editing.

Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Conflict of interest

FG-d-S, DT-G, FaC, FeC, RR, JP, and TP are employees of Sword Health, Inc. PS, SR, AR, NC, and EP are affiliated with the Associação Nacional das Farmácias (ANF). EP is the President of ANF. ANF represents the community pharmacies that deliver seasonal vaccination in Portugal.

The remaining author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that Generative AI was not used in the creation of this manuscript.

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