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A managerial approach to vaccine wastage rate reduction: a population-based cohort study from Istanbul, Türkiye

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Abstract

Aim: Vaccine wastage is considered an important parameter in the effective functioning of immunization programs. This study was conducted to evaluate the effectiveness of an implementation strategy introduced to reduce vaccine wastage.
Materials and Methods: This study was conducted using a retrospective cohort design based on data obtained from healthcare facilities across Istanbul. Educational programs aimed at reducing vaccine wastage were delivered to District Health Directorates in 2024, and District Health Directors were included in the managerial performance evaluation system as of January 2025. Vaccine wastage rates and reasons for wastage were compared between the six-month periods before (first) and after (second) the implementation of the strategy. The chi-square test was used for comparisons, and risk ratios (RR) with 95% confidence intervals (CI) were calculated.
Results: In the second period, a 14% reduction was observed in the overall vaccine wastage rate (RR: 0.86; 95% CI: 0.86–0.87). Significant reductions were observed for Pentavalent/Hexavalent (RR: 0.31; 95% CI: 0.27–0.35; p < 0.001), MMR (RR: 0.39; 95% CI: 0.34–0.45; p < 0.001), and HAV (RR: 0.40; 95% CI: 0.36–0.45; p < 0.001) vaccines. In contrast, increases in vaccine wastage rates were observed for HBV and Td vaccines, coinciding with the transition from single-dose to multi-dose vials in 2025. When the reasons for vaccine wastage were evaluated, the most pronounced reductions were observed in the categories of freezing/heat exposure, loss, and expiry.
Conclusions: A reduction in overall vaccine wastage was observed in Istanbul following the implementation strategy aimed at reducing wastage rates. Regular monitoring is recommended to determine whether these improvements can be sustained over time.
Keywords: Vaccine wastage; wastage reasons; expanded program on immunization; multi-dose vials; implementation strategy.

Yönetsel yaklaşımla aşı zayi-fire hızının azaltılması: İstanbul, Türkiye'den toplum temelli kohort çalışması
Öz

Amaç: Aşı zayi ve firesi, bağışıklama programlarının etkin işleyişinde önemli bir parametre olarak kabul edilmektedir. Bu çalışma, aşıların israfını azaltmak amacıyla hayata geçirilen bir uygulama stratejisinin etkilliğini değerlendirmek için yapılmıştır.
Gereç ve Yöntem: Bu çalışma, İstanbul genelindeki sağlık tesislerinden elde edilen veriler kullanılarak retrospektif kohort tasarımında gerçekleştirilmiştir. Aşı israfını azaltmayı amaçlayan eğitim programları 2024 yılında İlçe Sağlık Müdürlüklerine verilmiş ve İlçe Sağlık Müdürlerinin Ocak 2025 itibarıyla yönetimsel performans değerlendirme sistemine dahil edilmiştir. Stratejinin uygulanmasından önceki (birinci) ve sonraki (ikinci) altı aylık dönemler arasında toplam zayi-fire hızları karşılaştırılmıştır. Karşılaştırmalar için ki-kare testi kullanılmış ve %95 güven aralıkları (GA) ile risk ratio (RR) hesaplanmıştır.
Bulgular: Eğitim sonrası dönemde, toplam aşı zayi-fire hızında %14'lük bir azalma gözlemlenmiştir (RR: 0,86; %95 GA: 0,86–0,87). Karma (RR: 0,31; %95 GA: 0,27–0,35; p < 0,001), KKK (RR: 0,39; %95 GA: 0,34–0,45; p < 0,001) ve HAV (RR: 0,40; %95 GA: 0,36–0,45; p < 0,001) aşılarının israfında anlamlı azalmalar gözlemlenmiştir. Buna karşılık, HBV ve Td aşılarında 2025 yılında tek dozlu flakonlardan çok dozlu flakonlara geçişle eş zamanlı olarak aşı zayi-fire hızında artış gözlenmiştir. Aşı israf nedenleri değerlendirildiğinde, en belirgin azalmalar donma/sıcağa maruz kalma, kaybolma ve son kullanma tarihinin geçmesi kategorilerinde görülmüştür.
Sonuç: Zayi oranlarını düşürmeye yönelik uygulama stratejisinin ardından İstanbul'daki genel aşı zayi-fire hızında azalma gözlemlenmiştir. Elde edilen bu iyileşmelerin zaman içinde korunup korunamayacağını belirlemek amacıyla düzenli takip yapılması önerilmektedir.
Anahtar Kelimeler: Aşı zayi; zayi nedenleri; genişletilmiş bağışıklama programı; çoklu doz flakonlar; uygulama stratejisi.

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Introduction

Vaccines are a fundamental component of immunization programs and prevent millions of deaths annually (1). In 2024, childhood vaccination coverage in Türkiye exceeded 94% for major routine vaccines, while coverage in Istanbul was approximately 92% for the third dose of pentavalent vaccine, Hepatitis B vaccine (HBV), and measles, mumps, and rubella MMR (2).

Maintaining high coverage requires not only effective service delivery but also efficient vaccine use. Vaccine wastage remains a major challenge, particularly in low- and middle-income countries, with reported rates reaching 84% for some vaccines, especially Bacille Calmette-Guérin (BCG) 3–5). Because vaccines represent a major cost component of immunization programs, minimizing wastage without compromising service delivery is essential (3–6).

World Health Organization (WHO) defines vaccine wastage as doses that are discarded, lost, damaged, or otherwise unused because of factors such as expiry, cold-chain failure, or physical damage (7). Wastage may occur in both unopened and opened vials and is influenced by inventory management, storage conditions, administration practices, vial size, and session planning (6).

Wastage related to unopened vials occurs due to breakage, expiration, inventory errors, theft, and cold chain breaks. Wastage related to opened vials includes failure to store remaining doses in the cold chain after a session, incorrect administration practices, contamination, inability to withdraw the specified number of doses from the vial, and dead space in syringes (6). Additionally, WHO defines vaccine wastage rate as "the percentage of doses that remain unused, damaged, or discarded out of the total number of doses distributed" (7).

Vaccine wastage is most commonly observed in multi-dose vials. Therefore, WHO developed the Multi-Dose Vial Policy (MDVP) in 2014, aiming to allow the use of opened vials for longer periods under specific conditions and to reduce wastage rates (8). WHO also reports average vaccine wastage rates according to vial type as follows: 5% for single-dose vials, 25% for 10- or 20-dose vials that can be used after opening, and 40% for 10- or 20-dose vials that must be used within 6 hours after opening (9). These rates may differ significantly depending on factors such as countries' health system capacity, stock management practices, and logistics infrastructure. In Türkiye, multi-dose vials are preferred for BCG, oral poliovirus vaccine (OPV), HBV, and tetanus-diphtheria (Td) vaccines (10). The WHO states that, provided vaccines are stored in accordance with cold-chain requirements, some liquid multidose vaccines can be used for up to 28 days after opening. In contrast, multidose lyophilized vaccines such as BCG and MMR must be used within 6 hours after reconstitution (8).

Studies from other upper-middle-income countries have also reported substantial wastage, including 45.8% across routine vaccines in Brazil and 46% for BCG in Mexico (11,12). However, evidence from Türkiye remains limited(3-5). Existing studies have mainly focused on cold-chain logistics, medical waste management, and operational processes rather than direct measurement of routine vaccine wastage (13,14). Therefore, real-world epidemiological data on vaccine wastage in Türkiye are scarce.

Although the vaccine wastage rate is one of the important indicators for evaluating the efficiency of resource utilization, it should not be interpreted as a performance indicator on its own and should be assessed together with outputs such as vaccination coverage. Nevertheless, high wastage rates generally indicate problems in management, planning, and logistics processes (15).

This study aims to evaluate the effectiveness of an implementation strategy applied to reduce wastage rates of vaccines administered within the scope of childhood vaccination in Istanbul.

Materials and Methods

The study was conducted in a retrospective cohort design. Istanbul (15,701,602 people) is the province where approximately one-fifth of Türkiye's population (85,664,944 people) resides and is the most cosmopolitan city (16). The research data belong to a total of 1,491 healthcare facilities located in Istanbul. The Vaccination Programs Unit of the Istanbul Provincial Health Directorate, Public Health Services Presidency, monitors all vaccination data across Istanbul through the Ministry of Health Vaccine Information System. Through this national system, cold chain monitoring, stock status, administration records, and wastage data for each vaccine and antiserum are recorded from the moment they are taken from the main warehouse until they reach the end user (10). This is a national system through which these data can be monitored electronically in real time and is actively used in all institutions where vaccines are stored (10). In addition, the data recorded in the Vaccine Information System are not based on individual self-reports by healthcare workers but are derived from inventory reconciliation of stock-in, stock-out, and administered

doses. Vaccines administered to individuals are recorded in the system in real time using personal identification information and vaccine vial/digital barcode numbers. As this was a retrospective study based exclusively on routinely collected administrative records, individual informed consent was not obtained.

In December 2024, all districts were contacted individually by the Istanbul Provincial Health Directorate. During these meetings, both the upcoming managerial performance evaluation system to be implemented as of January 2025 and the educational program were delivered simultaneously. Therefore, the July–December 2024 period represents a true pre-implementation baseline period, whereas the January–June 2025 period reflects the post-implementation phase. Within the scope of this educational program, a standardized curriculum was delivered uniformly across all districts and to all participants by the same team. The program covered topics such as vaccination session planning and appointment management, appropriate use of multi-dose vials and the principles of the WHO MDVP, proper storage of opened and unopened vials, compliance with cold chain requirements, stock and inventory management, vaccine administration techniques, and accurate recording of wastage reasons. Physicians working in the same primary care facilities were specifically trained to coordinate immunization activities when opening multi-dose vials and to manage vaccination sessions collaboratively, in order to minimize avoidable wastage while maintaining service accessibility. In addition to these topics, the program also included sessions aimed at addressing vaccine hesitancy and strengthening counseling and communication skills related to vaccination.

The educational program was delivered to healthcare personnel working in primary healthcare facilities through the District Health Directorates and was structured to include both theoretical instruction and practical field-oriented reminders. This educational program aimed to increase standardization in vaccination practices, reduce errors in planning and logistics processes, and minimize preventable causes of vaccine wastage.

In addition, wastage rates were examined by reason in each district, and district-level evaluations and briefings were conducted for each reason.

As of January 2025, the wastage rate was added to the managers' evaluation system. In this study, wastage rates and wastage reasons from the last six months of 2024 (July–December) and the first six months of 2025 (January–June), which represent the periods before (first) and after (second) the implementation of the wastage rate in the performance system, were compared. Childhood vaccines administered free of charge by the Ministry of Health as part of the Expanded Program on Immunization (EPI) were included in the evaluation (17, 18). Vaccines outside the scope of the EPI were not included in the study.

This study evaluated all vaccines included in the national childhood immunization schedule, namely: BCG, HAV, HBV, MMR, OPV, Pneumococcal Conjugate Vaccine (PCV13), Pentavalent/Hexavalent (DTaP-IPV-Hib/HBV), Quadrivalent (DTaP-IPV), Td, and Varicella. In Türkiye, the MMR vaccine was provided in single-dose vials in both 2024 and 2025. While OPV and BCG were used as multi-dose vaccines in both 2024 and 2025, HBV and Td were administered as single-dose vaccines in 2024 and as multi-dose vaccines in 2025.

The change in vial presentation for the HBV and Td vaccines from single-dose in 2024 to multi-dose in 2025 constitutes an important confounding factor in the pre–post comparison for these two vaccines. Therefore, the analyses for HBV and Td reflect not only the effect of the implementation strategy but also a comparison between two different vaccination systems (the transition from single-dose to multi-dose vials). This should be considered an important methodological limitation when interpreting the findings related to these two vaccines.

The sub-types of vaccine wastage were established in accordance with the United Nations Children's Fund (UNICEF) guideline on wastage in opened and unopened vials (6). In the study, wastage reasons were examined under the subheadings opened vials, broken or damaged vials, freezing/exposure to heat, loss, and expiry.

Opened vials refer to situations in which multidose vials cannot be fully used within the allowable period following vial opening. Wastage that occurs due to any form of physical damage to the vaccine vial is classified as broken or damaged vials. Wastage resulting from cold-chain breaches or suspected cold-chain failures is defined as freezing/exposure-to-heat. The condition in which vaccines are recorded as present in the inventory system but cannot be physically located due to loss. Additionally, vaccines that have passed their expiry date and are no longer usable are referred to as "expiry".

The vaccine wastage rate was calculated using the formula "(total doses – administered doses) / total doses × 100". In the wastage rate formula, "total doses" refers to all vaccine doses consumed at healthcare facilities during the relevant period, including both administered doses and doses wasted for any reason, rather than doses issued to facilities or doses entering the supply system. The chi-square test was used to compare vaccine wastage between the last six months of 2024 and the first six months of 2025. In addition, wastage rate values and sub-causes were compared, (Risk Ratio) RR was calculated and presented with 95% CI. Analyses were performed using the OpenEpi Version 3.01 (Open Source Epidemiologic Statistics for Public Health, Atlanta, GA, USA).

Results

Wastage rate comparisons by vaccine type are presented in Table 1. The largest reductions were observed for Pentavalent/Hexavalent (RR: 0.31; 95% CI: 0.27–0.35), MMR (RR: 0.39; 95% CI: 0.34–0.45), and HAV (RR: 0.40; 95% CI: 0.36–0.45) vaccines (all p<0.001). Wastage also decreased for BCG (RR: 0.94; 95% CI: 0.93–0.94) and OPV (RR: 0.92; 95% CI: 0.91–0.93)(both p<0.001).

In contrast, wastage increased for HBV (RR: 3.45; 95% CI: 3.23–3.70) and Td (RR: 1.63; 95% CI: 1.48–1.78)(both p<0.001), coinciding with the 2025 transition from single-dose to 10-dose vials. However, 2025 wastage rates remained low (HBV: 1.38%; Td: 0.37%) relative to BCG and OPV. BCG had the highest wastage rate.

Overall vaccine wastage decreased in 2025 (RR: 0.86; 95% CI: 0.86–0.87; p<0.001).

Wastage decreased across all reason categories, particularly freezing/heat exposure, loss, and expiry (Table 2).

Opened-vial wastage increased for HBV (RR: 2.07; 95% CI: 2.04–2.09) and Td (RR: 1.82; 95% CI: 1.77–1.87), while expiry-related wastage increased for HBV (RR: 1.82; 95% CI: 1.73–1.90) and broken/damaged-vial wastage for Td (RR: 1.13; 95% CI: 1.02–1.26) (all p<0.001). The increase in opened-vial wastage likely reflects the transition to multidose vials (Figure 1).

Table 1. Comparison of vaccine wastage rates by vaccine type, Istanbul, 2024–2025

Vaccine	2025 Wastage Rate	2024 Wastage Rate	RR (95% CI)	p-value
BCG	65.92%	69.91%	0.94 (0.93-0.94)	**<0.001**
HAV	0.21%	0.53%	0.40 (0.36-0.45)	**<0.001**
HBV	1.38%	0.40%	3.45 (3.23-3.70)	**<0.001**
MMR	0.12%	0.31%	0.39 (0.34-0.45)	**<0.001**
OPV	23.04%	24.90%	0.92 (0.91-0.93)	**<0.001**
PCV13	0.19%	0.39%	0.48 (0.42-0.53)	**<0.001**
Pentavalent/ Hexavalent (DTaP-IPV-Hib/ HBV)	0.11%	0.37%	0.31 (0.27-0.35)	**<0.001**
Quadrivalent (DTaP-IPV)	0.36%	0.83%	0.43 (0.37-0.49)	**<0.001**
Td	0.37%	0.23%	1.63 (1.48-1.78)	**<0.001**
Varicella	0.59%	0.76%	0.77 (0.69-0.87)	**<0.001**
Total	9.39%	10.80%	0.86 (0.86-0.87)	**<0.001**

Table 2. Vaccine wastage by different reasons

	2025	2024	RR (95% CI)	p-value
Opened vials	9.15%	10.24%	0.89 (0.88-0.89)	**<0.001**
Broken or damaged vials	0.06%	0.08%	0.81 (0.75-0.86)	**<0.001**
Freezing/ exposure-to-heat	0.13%	0.32%	0.41 (0.40-0.43)	**<0.001**
Loss	0.001%	0.002%	0.11 (0.05-0.26)	**<0.001**
Expiry	0.03%	0.14%	0.21 (0.19-0.23)	**<0.001**

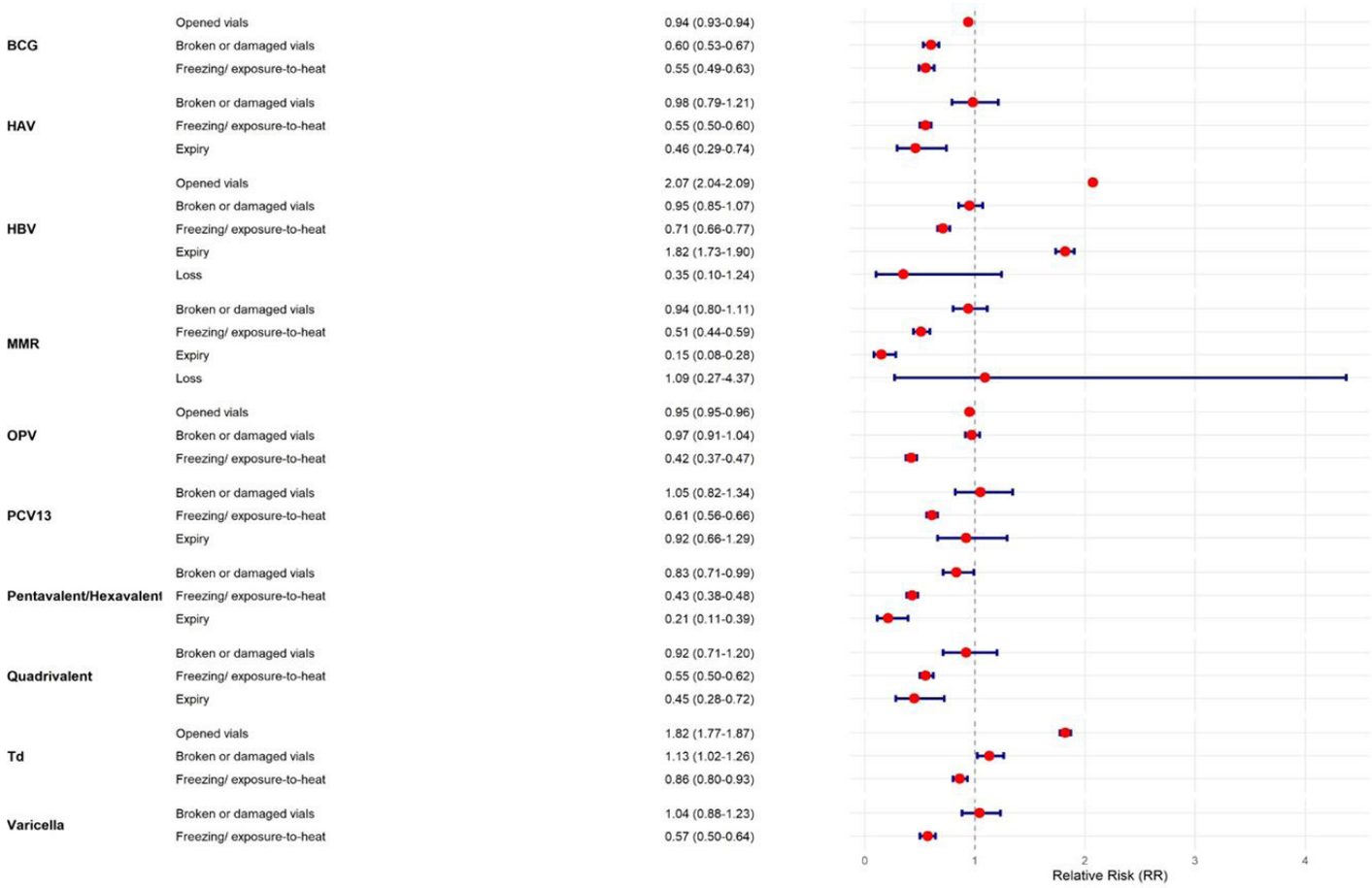


Figure 1. Rate ratios of vaccine wastage by vaccine type and wastage reason after versus before the implementation strategy.

Discussion

This study evaluated vaccine wastage within the EPI in Istanbul during the second half of 2024 and the first half of 2025 following an administrative intervention. It is one of the few large-scale studies in Türkiye to investigate vaccine wastage and assess the longitudinal outcomes of a managerial implementation.

Following integration of vaccine wastage into the managerial performance evaluation system, total vaccine wastage decreased significantly (RR: 0.86; p<0.001). Previous studies have shown that feedback and monitoring-based approaches can reduce wastage, whereas high wastage rates often reflect shortcomings in management, planning, or logistics (15,19). The overall improvement observed here may therefore reflect increased attention to planning, inventory management, and cold chain monitoring.

Wastage for single-dose vaccines remained below 2% before and after the intervention. This was lower than the 5% threshold accepted by WHO (9) and comparable to the 1–5% range reported in the United States (20). In contrast, higher rates of 18–35% reported in developing countries such as Nigeria highlight the importance of robust vaccine logistics infrastructure (21).

BCG and OPV wastage also declined, from 69.91% to 65.92% and from 24.90% to 23.04%, respectively (RR: 0.94 and 0.92). High BCG wastage is partly attributable to the requirement that this lyophilized vaccine be discarded within 6 hours of reconstitution, consistent with the high rates reported for reconstituted vaccines (3,8,22–24). The BCG wastage rate remained above the WHO 50% limit for lyophilized multi-dose vaccines, indicating persistent operational constraints (9). Smaller vial sizes, dedicated vaccination sessions, and improved appointment coordination may help reduce open-vial wastage without restricting access to immunization services.

For OPV, which can be used for up to four weeks after opening, wastage remained within acceptable limits. The greatest reduction was observed in freezing/heat-related wastage, while open-vial wastage decreased by approximately 5%. These findings suggest that multi-dose vaccine wastage depends not only on vaccine characteristics but also on session planning and service organization.

Preventable wastage categories showed marked improvement. Wastage attributed to "loss" was almost eliminated (RR: 0.11; 95% CI: 0.05–0.26), while "freezing/heat exposure" decreased by approximately half (RR: 0.41; 95% CI: 0.40–0.43). These improvements may reflect more effective inventory tracking, stricter expiry checks, and more standardized responses to potential cold chain breaches, consistent with previous findings from Türkiye (25).

The transition of HBV and Td from single-dose to 10-dose vials in 2025 increased open-vial wastage (RR: 2.07 for HBV; RR: 1.82 for Td). This suggests that multi-dose formats introduce additional wastage related to session scheduling and patient throughput, independent of cold chain or inventory management. Higher wastage for multi-dose formulations has been documented previously (8,22). Therefore, the increased wastage observed for HBV and Td likely reflects, at least partly, the new vial presentation rather than an administrative shortcoming. The concurrent decline in freezing-related wastage for both vaccines supports an improvement in logistical processes.

Several limitations should be considered. First, reliance on retrospective data from the national immunization information system prevented detailed analysis of human factors and specific session-scheduling practices. Second, the comparison periods covered different seasons (July–December 2024 versus January–June 2025), introducing potential seasonal confounding. Seasonal variations in ambient temperature may have particularly influenced vaccine wastage related to freezing or heat exposure, independently of the managerial implementation strategy. In addition, changes in vaccine demand may have affected patient flow and the feasibility of clustering patients for multi-dose vials. As corresponding calendar-month data from previous years were not included in the analysis, the potential influence of seasonality could not be directly controlled. Third, the impact of the performance evaluation system cannot be fully separated from the accumulation of healthcare provider experience over time. Although a substantial reduction was observed in wastage attributed to loss, this finding alone does not establish a causal effect of the implementation.

Qualitative studies exploring healthcare workers' perspectives on these performance metrics are warranted. Because immunization coverage was not directly assessed, future studies should also determine whether stringent wastage-reduction strategies affect vaccine coverage and equitable access to immunization services.

The administrative performance strategy implemented in Istanbul was associated with a significant reduction in overall vaccine wastage, particularly preventable losses. However, the transition from single- to multi-dose vials for HBV and Td increased open-vial wastage, partially masking the broader gains achieved by the intervention.

Conclusions

Healthcare administrators should combine performance monitoring with operational measures tailored to multi-dose formulations, including coordinated session scheduling, clustering of eligible patients, inter-provider communication before vial opening, and standardized vial-tracking protocols. Future prospective and mixed-methods research should identify optimal vaccination session sizes and frequencies and assess the long-term sustainability of these improvements. Sustainable reduction of vaccine wastage requires flexible logistics systems that can adapt to changes in vial presentation without compromising managerial accountability or equitable access to immunization services.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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Statement of ethical approval

Ethical approval for this study was obtained from the Non-Interventional Clinical Research Ethics Committee of Istanbul Medipol University (Decision No. 699, dated June 19, 2025). All procedures were performed in accordance with the principles of the Declaration of Helsinki. In addition, authorization for the use of institutional data was obtained from the Istanbul Provincial Health Directorate.

Statement of generative AI technologies

During the preparation of this work the authors used ChatGPT 5.3 in order to make language corrections. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the published article.

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