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Vaccine Cold Chain Management in Primary Health Care Centers: Literature Review

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Abstract

Vaccine cold chain management is an essential component in ensuring vaccine quality, safety, and effectiveness until administration in immunization services. Primary health care centers play a strategic role in cold chain implementation; however, various studies report persistent challenges related to storage, temperature monitoring, distribution, and human resource capacity. This article aims to comprehensively review vaccine cold chain management in primary health care centers by integrating national and international scientific evidence and pharmaceutical management perspectives. A narrative literature review was conducted using national and international databases, including articles published between 2020 and 2025 Of the 50 international and 25 national articles identified, screening based on titles, abstracts, and full-text assessment resulted in 14 relevant articles for analysis. The findings indicate that although most primary health care centers have implemented basic cold chain principles, significant gaps remain in temperature monitoring consistency, distribution documentation, utilization of supporting facilities, and pharmacist involvement in vaccine quality assurance systems. Strengthening the role of pharmacists, supported by temperature monitoring technology and adherence to national guidelines, is a key strategy to improve vaccine management quality in primary health care centers

Keywords: ***Vaccine Cold Chain, Primary Health Care, Pharmaceutical Management, Immunization.***

INTRODUCTION

Vaccines are biological products that are highly sensitive to temperature fluctuations and environmental exposure. Most vaccines must be stored and transported within a temperature range of 2–8 °C to maintain their stability and immunogenic potency. Exposure to temperatures outside this range, including excessive heat or freezing conditions, can result in irreversible loss of vaccine potency, thereby reducing the effectiveness of immunization programs (1–5,12–15).

As the primary healthcare providers in Indonesia, Community Health Centers (Puskesmas) play a pivotal role in the success of the national immunization program. One of their primary responsibilities is to ensure that vaccine cold chain management is implemented in accordance with established standards. However, numerous national and international studies have reported that cold chain implementation in primary healthcare facilities continues to face significant challenges, particularly regarding the availability of infrastructure, temperature monitoring, and compliance with standard operating procedures (16–20,21–27).

From a pharmaceutical perspective, pharmacists and pharmacy technicians possess the core competencies required for managing temperature-sensitive pharmaceutical products, including vaccines. Their responsibilities encompass logistics planning, storage, distribution, and quality assurance of vaccines. Nevertheless, existing literature indicates that the involvement of pharmacists in vaccine cold chain management at Community Health Centers remains limited and has not been extensively investigated (28–31,45–48).

Therefore, this literature review aims to provide a comprehensive overview of vaccine cold chain management in Community Health Centers, identify existing research gaps, and highlight the contribution of pharmaceutical management in maintaining vaccine quality and supporting the success of national immunization programs.

RESEARCH METHODS

Article Selection

Articles were identified using combinations of the following English keywords: "vaccine cold chain management," "primary health center," "vaccine storage," "vaccine management," and "knowledge attitude practice cold chain." For Indonesian-language literature, the keywords "manajemen rantai dingin vaksin" and "puskesmas" were used. The search was limited to publications published between 2020 and 2025.

The literature search was conducted using Mendeley, PubMed, Google Scholar, Scopus, and accredited Indonesian national journal repositories (SINTA). A total of 50 international and 25 national articles were initially identified. The articles were then screened based on their titles and abstracts, followed by a full-text assessment according to the predefined inclusion criteria. Ultimately, 14 articles met the eligibility criteria and were included in this review, comprising 5 international and 9 national studies.

RESULTS AND DISCUSSION

Research Synthesis

Based on the review of 14 primary articles analyzed in this study, the synthesis was conducted to identify common findings, contextual variations, and gaps in the implementation of vaccine cold chain management at the primary healthcare level. Most studies reported a relatively good level of compliance with vaccine cold chain management, particularly regarding the availability of storage facilities. However, consistent gaps were found in temperature monitoring and documentation, the readiness of supporting facilities, and the implementation of ongoing supervision and audits. This synthesis confirms that the active involvement of pharmacists in quality assurance, monitoring, and ongoing evaluation is a key element in improving the quality of vaccine management in community health centers.

Table 1. Vaccine Cold Chain Management Research

No.	Author(s) and Year	Research Location	Research Design	Research Focus	Main Findings
1	Mohammed SA, Workneh BD, Kahissay MH (2021)	Oromia Special Zone, Ethiopia	Cross-sectional study	Knowledge, attitudes, and practices of vaccine handlers regarding cold chain management in public health facilities	53.5% had satisfactory knowledge, 45.7% had positive attitudes, and 48.8% demonstrated good practices. Cold chain training was significantly associated with knowledge (AOR = 3.04).
2	Ergetie FS, Kassaw AT, Sendekie AK (2023)	Bahir Dar, Northwest Ethiopia	Self-reported and actual practice observational cross-sectional study	Vaccine cold chain management practices in primary healthcare immunization centers	60% of EPI providers had good knowledge, 74% demonstrated good vaccine storage and transportation practices, and 50% of facilities had good cold chain management practices.
3	Erassa TE, Bachore BB, Faltamo WF, et al. (2023)	Wolaita Zone, Ethiopia	Facility-based cross-sectional study	Vaccine cold chain management and associated factors in public health facilities and district health offices	61% demonstrated good cold chain management practices. More than two years of experience, good knowledge, training, and supportive supervision were significantly associated with good

					practice (AOR = 2.80–3.02).
4	Komariah S, Hilmi IL, Ratnasari D, et al. (2022)	Karawang Regency, Indonesia	Descriptive observational study with a qualitative approach	Evaluation of cold chain product distribution (operations, personnel/training, and facilities) in community health centers	83.3% of health centers effectively distributed cold chain products. Fifty percent lacked dedicated cold chain storage buildings, while all equipment complied with performance standards.
5	Hillan A, Pung L, Ridderhof S, et al. (2024)	Western Australia	Electronic audit survey study	Audit of vaccine cold chain management in general practices and community pharmacies	89.6% of general practices (420/473) and 82% of pharmacies (276/345) participated. More than 70% had appropriate procedures and emergency storage practices, while 58% required follow-up regarding equipment.
6	Huriyati (2024)	Seribu Islands, Jakarta, Indonesia	Phenomenological qualitative research	Vaccine cold chain management for routine immunization in island community health centers	Among seven health centers, five conducted routine equipment maintenance, while one did not record storage temperatures. All vaccines were stored longer than the recommended duration. Equipment was adequate, but improvements in temperature monitoring and inventory management were required.
7	Pangalo et al. (2020)	Boalemo Regency, Gorontalo, Indonesia	Cross-sectional study	Relationship between knowledge, attitudes, and implementation of cold chain management	High levels of knowledge and positive attitudes (OR = 5.87) significantly improved the implementation of cold chain management (OR = 2.17–2.69).
8	Alfilia Lusita et al. (2021)	Surabaya, East Java, Indonesia	Descriptive cross-sectional study	Implementation of immunization cold chain management	98.42% of personnel had medical backgrounds, 100% received cold chain management training, 93.51% achieved complete reporting, and 12% of refrigerators were operating below optimal standards.
9	Emanuel Gerald Alan Rahmat et al. (2023)	Kupang, East Nusa Tenggara, Indonesia	Cross-sectional study	Profile of vaccine cold chain management in storage and distribution	Nineteen of 27 storage criteria and five of eight distribution criteria were implemented. Improvements were needed in standard operating procedures (SOPs) and thermometer calibration.
10	Rika Amanda Kesia et al. (2023)	West Kutai Regency, East Kalimantan, Indonesia	Descriptive observational qualitative study	Evaluation of vaccine storage and management based on the 2020 Good	Personnel performance was rated as Good (96.9%), buildings as Fair (65.2%), facilities as Fair (64.0%), operations as Good

				Distribution Practice (CDOB) guidelines	(80.7%), and the overall assessment was categorized as Good.
11	Rahmat EGA, Yunita Nita, Yuni Priyandani (2023)	Kupang, East Nusa Tenggara, Indonesia	Cross-sectional study	Profile of vaccine cold chain management in storage and distribution across 11 community health centers in Kupang	Nineteen vaccine storage criteria had been implemented in all health centers, while eight criteria had not been adequately implemented (including inadequate air circulation, suboptimal thermometer calibration, unavailable SOPs, and unvalidated distribution equipment). Five of eight distribution criteria had been implemented. Improvements were needed in thermometer calibration, availability of storage and distribution SOPs, validation of transport equipment, and installation of air circulation systems in storage rooms.
12	Lusita, Syahrul, Ponconugroho (2020)	70 Community Health Centers, Surabaya, Indonesia	Descriptive cross-sectional study	Cold chain management (human resources, equipment, and reporting)	Cold chain management was generally well implemented; however, challenges remained in reporting systems and equipment quality.
13	Prosser, Spisak, Hatch, McCord, Tien, Roche (2021)	Four countries: Sierra Leone, Madagascar, Niger, and Guinea	System design analysis using modeling tools (Supply Chain Guru and AnyLogistix)	Analysis of vaccine cold chain system design to reduce bottlenecks and improve efficiency	An optimized cold chain design improved vaccination coverage and system reliability. Six key lessons were identified for applying a system design approach.
14	Zahra, Tetuko, Rosita, Fajri (2024)	Petapahan Community Health Center, Kampar Regency, Riau, Indonesia	Descriptive observational study	Efficiency of vaccine management (refrigerators, cold chain, and distribution)	Vaccine management performance ranged from 76% to 100%. Increased staff knowledge of cold chain procedures was recommended to further improve performance.

Vaccine Cold Chain Management Concept

Vaccine cold chain management is an integrated system aimed at maintaining the quality, safety, and potency of vaccines from production to administration to immunization targets. The cold chain encompasses a series of processes, including storage, distribution, temperature monitoring, recording, and handling of temperature excursions. International literature consistently reports that failure in any link in the chain can lead to irreversible reductions in vaccine potency and ultimately lead to immunization program failure (1–5, 12–15).

Within the Effective Vaccine Management (EVM) framework, cold chain management focuses not only on the technical aspects of storage but also encompasses logistical governance, human resource competency, monitoring and evaluation systems, and policy support. This approach has become a global standard and is used as a reference in various national and international studies to

assess the performance of vaccine management in primary healthcare facilities, including community health centers (24, 25, 33).

Vaccine Storage and Temperature Monitoring at Community Health Centers

Vaccine storage at community health centers must meet the temperature requirement of 2–8°C using a dedicated vaccine refrigerator equipped with a minimum–maximum temperature monitor or data logger. International literature indicates that the use of non-standard refrigerators, inconsistent temperature recording, and the lack of temperature monitoring calibration increase the risk of exposure to extreme temperatures, particularly freezing, which often goes undetected (6–10, 33–35).

Studies at various community health centers in Indonesia indicate that although most community health centers have vaccine refrigerators, there are still discrepancies in daily temperature recording, the availability of calibrated temperature monitors, and the implementation of temperature excursion procedures (16–20, 28–31). These findings align with international studies confirming that discontinuous temperature monitoring is a major cause of cold chain failure at the primary healthcare level (7, 8, 36).

Vaccine Distribution and Transportation Management

Vaccine distribution is a critical stage in the cold chain with a high risk of temperature deviation. International literature emphasizes the importance of using cold boxes or insulated vaccine carriers, properly conditioned ice packs, and managing distribution time to maintain temperature stability during transport (29,33,45).

In Indonesia, vaccine distribution from district/city pharmacy warehouses to community health centers and then to immunization service posts still faces challenges such as limited refrigerated transportation, varying travel distances, and limited documentation of temperature monitoring during transport. Several national studies have shown that although the distribution system is considered quite effective, temperature monitoring during transport is not fully documented (4,41,43).

Human Resources and Training Factors

National and international literature confirms that staff knowledge and training are key determinants of successful vaccine cold chain management. Staff who have received immunization or cold chain management training tend to have better storage, temperature monitoring, and record-keeping practices than staff who have not received training (21–27). This is consistent with findings from Indonesian community health centers (Puskesmas) showing a positive relationship between staff knowledge levels and compliance with operational standards (28–31).

However, several international studies have shown a gap between knowledge and actual practice in the field. This situation indicates that training alone is insufficient without regular supervision, internal audits, and ongoing managerial support (24,25,32).

Supporting Facilities and Cold Chain Technology

Supporting facilities are a critical component of successful vaccine cold chain management in Puskesmas. International and national literature highlight the importance of stable electricity availability, calibrated temperature monitoring devices, backup generators, and contingency procedures for emergencies (33,36,38,49). Limited supporting facilities have been shown to contribute to vaccine temperature deviations, particularly in healthcare facilities with limited resources.

As technology advances, several studies recommend the implementation of remote temperature monitoring systems and the use of solar-powered refrigerators in areas with limited electricity supply. International evidence shows that this technology can improve compliance with temperature standards and reduce the risk of vaccine damage (39–44).

Pharmacy Management Perspective and the Role of Pharmacists

Confirmed discussions from national and international literature indicate that vaccine cold chain management cannot be separated from pharmaceutical management principles. Pharmacists are competent in managing temperature-sensitive pharmaceutical preparations, including logistics planning, storage supervision, distribution, and vaccine quality assurance (45–47). Studies in primary

care and community pharmacies in developed countries indicate that the active involvement of pharmacy personnel contributes to high compliance with cold chain standards (36,37).

In Indonesia, although the role of pharmacists in community health centers is increasingly recognized, their involvement in vaccine management remains suboptimal and is often limited to administrative aspects. The integration of national and international findings in this review confirms that strengthening the role of pharmacists has the potential to be a key strategy in improving the quality of vaccine cold chain management in community health centers (28, 31, 48).

National Guidelines for Vaccine Cold Chain Management in Indonesia

Vaccine cold chain management in Indonesia refers to guidelines and regulations issued by the Ministry of Health of the Republic of Indonesia. The Guidelines for Vaccine Management in Healthcare Facilities emphasize that all stages of the cold chain, from receipt, storage, distribution, and use of vaccines, must be carried out according to standards to ensure vaccine quality and safety. These guidelines also emphasize the division of roles and responsibilities of healthcare workers, including pharmacists and pharmacy technicians.

The Minister of Health's Regulation on Immunization Administration serves as the legal basis for implementing vaccine cold chain management in community health centers. This regulation requires each community health center to have written standard operating procedures (SOPs) regarding storage, temperature monitoring, distribution, and handling of vaccine temperature deviations.

To strengthen the implementation of these guidelines, the Ministry of Health has developed the Immunization Monitoring and Electronic Logistics System (SMILE), which enables integrated monitoring of vaccine temperature and stock levels from the central level to community health centers. Although implementation has shown significant improvements, various evaluations still find variations in compliance levels across community health centers, particularly related to the availability of supporting facilities and staff understanding of technical guidelines.

Policy Implications and Research Gaps

The integration of findings from the core article, supporting literature, and national guidelines demonstrates the need for a systemic approach to strengthening vaccine cold chain management in community health centers. While numerous studies have assessed compliance with standards, studies specifically evaluating the impact of pharmaceutical interventions and pharmacists' contributions to vaccine quality are limited, particularly in Indonesia. This gap opens up opportunities for further research and the development of evidence-based policies to strengthen the national immunization system.

CONCLUSION

This literature review demonstrates that vaccine cold chain management in community health centers (Puskesmas) is a complex and crucial system for ensuring vaccine quality, safety, and effectiveness, all the way through to the immunization service stage. Integration of national and international scientific evidence reveals that although most Puskesmas have implemented basic cold chain principles, consistent challenges remain, particularly in the areas of continuous temperature monitoring, distribution documentation, the readiness of supporting facilities, and the capacity and consistency of human resources. Pharmacy management literature confirms that pharmacists play a strategic role in vaccine cold chain management, encompassing logistics planning, storage and distribution oversight, and vaccine quality assurance. However, pharmacist involvement in Puskesmas remains suboptimal and has not been systematically integrated into vaccine management, particularly in quality assurance and ongoing evaluation. Strengthening vaccine cold chain management in Puskesmas requires an integrated approach that combines adherence to national guidelines, the use of temperature monitoring technology, staff competency enhancement, and the optimization of pharmacists' roles within the pharmacy management system. This approach is expected to sustainably

improve the quality of vaccine management and support the success of the national immunization program.

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