Revista de la Facultad de Medicina Humana

Volume 24 | Issue 1 Article 9

2024

Cold chain of the Peruvian National Immunization Program in the context of the COVID-19 pandemic

Alfonso Gutierrez-Aguado
Universidad Continental. Lima, Perú

Mariana Mendoza
Universidad Norbert Wiener. Lima, Perú.

Tatiana Sarazú
Sanofi. Lima, Perú

Paula Rodriguez-Ordoñez
Sanofi. Bogotá, Colombia

Rev. Fac. Med. Hum. 2024; 24(1):73-84.
DOI: 10.25176/RFMH.v24i1.6189
ORIGINAL PAPER
ISSN Versión Online: 2308-0531
Facultad de Medicina Humana URP
RFMH

COLD CHAIN OF THE PERUVIAN NATIONAL IMMUNIZATION PROGRAM IN THE CONTEXT OF THE COVID-19 PANDEMIC

CADENA DE FRÍO DEL PROGRAMA NACIONAL DE INMUNIZACIONES PERUANO EN EL CONTEXTO DE LA PANDEMIA COVID-19

Alfonso Gutiérrez-Aguado [1,a], Mariana Mendoza [2,b], Tatiana Sarazú [3,a], Paula Rodriguez-Ordoñez [4,a]

ORIGINAL PAPER

ABSTRACT

Objective: The aim of this study was to identify critical aspects of the Cold Chain in the immunization process in Peru. **Methods:** A descriptive study was conducted, analyzing data from the Ministry of Economy and Finance (MEF) and the Ministry of Health (MINSA) for the years 2020-2021, as well as administrative records from the MINSA's Regional Health Strategies for immunizations in 2020. Technical aspects established in the Health Technical Standard for Cold Chain Management, such as obsolescence, allocation, functionality, and storage capacity were taken into account. **Results:** In the year 2020, at the national level, 61.8% of the cold chain equipment showed obsolescence, with some regions exceeding 75%, with Lima's metropolitan region being the most affected at 88%. Concerning equipment allocation, 9% of the first-level health facilities lacked refrigeration equipment, with Loreto having the highest deficit (46%), followed by Huancavelica with a 21% gap. The overall equipment functionality nationwide was 84%, meaning that 16% of health facilities experienced technical failures, affecting vaccine's storage capacity and posing risks to their safety and immunogenicity. Significant gaps were identified when considering quarterly or monthly storage for COVID-19 vaccines or other health emergencies. **Conclusions:** This study highlights potential risks in the operability and storage capacity of the national immunization program's vaccines in Peru during contingencies such as the COVID-19 pandemic or other health emergencies.

Keywords: Cold chain; Immunization programs; Immunization; Vaccination coverage; vaccines. (Source: MeSH NLM).

RESUMEN

Objetivo: Identificar aspectos críticos de la Cadena de Frío en el Perú. **Métodos:** Estudio descriptivo. Se analizaron datos del Ministerio de Economía y Finanzas (MEF) y del Ministerio de Salud (MINSA) de los años 2020-2021, así como los registros administrativos de las Estrategias Sanitarias Regionales de inmunizaciones del MINSA en 2020. Se consideraron aspectos técnicos de la Norma Técnica de Manejo de cadena de frío, como es obsolescencia, dotación, funcionalidad y capacidad de almacenamiento. **Resultados:** En el año 2020, en términos de obsolescencia el 61.8% de los equipos de cadena de frío a nivel nacional presentaban obsolescencia, siendo regiones claves como Lima Metropolitana (capital del país) la más afectada con un 88%. En cuanto a la dotación de equipos, el 9% de los establecimientos de salud del primer nivel carecen de equipos de refrigeración, siendo Loreto la región con mayor déficit 46%, seguida de Huancavelica con un 21% de brecha. En términos de funcionamiento, se registra que el 84% de los equipos a nivel nacional funcionan, y el 16% reportan fallas técnicas, lo cual representa alto riesgo en la seguridad y potencia inmunogénica de las vacunas a prever. En términos de capacidad, al considerar el almacenamiento trimestral o mensual para las vacunas contra la COVID-19 u otras emergencias sanitarias se identificaron brechas significativas. **Conclusiones:** Existen riesgos en la operatividad, suministro y capacidad de almacenamiento de las vacunas del esquema nacional de inmunizaciones de Perú incluso ante emergencias sanitarias.

Palabras clave: Cadena de frío; Programa de Inmunizaciones; Inmunización, Vacunas. (Fuente: DeCS- BIREME)

[1] Universidad Continental. Lima, Peru.
[2] Universidad Norbert Wiener. Lima, Peru.
[3] Sanofi. Lima, Peru.
[4] Sanofi. Bogota, Colombia.
[a] Surgeon.
[b] Nurse.

Cite as: Gutiérrez-Aguado A, Mendoza M, Sarazú T, Rodriguez-Ordoñez P. Cold Chain of the Peruvian National Immunization Program in the context of the COVID-19 pandemic. Rev Fac Med Hum. 2024;24(1):73-84. doi 10.25176/RFMH.v24i1.6189

Journal home page: http://revistas.urp.edu.pe/index.php/RFMH

INTRODUCTION

Vaccination is a successful and cost-effective public health intervention that directly reduces medical costs [1]. In 1896, Peru's public health system took three significant steps in vaccination: 1) mandatory vaccination and revaccination were implemented nationwide, 2) the Instituto Vacunal de Lima (now known as the Instituto Nacional de Salud) was established, and 3) the Ministry of Promotion (now the Ministry of Health) commenced its activities[2]. In 1974, the Pan American Health Organization (PAHO) through Resolution CD25.R27 established the Expanded Program on Immunization (EPI), considering vaccination and epidemiological surveillance of preventable diseases as fundamental strategies in 1977 [3]. In 1979, EPI was implemented in Peru, and massive campaigns against poliomyelitis (National Vaccination Campaigns) were carried out successfully, leading to the eradication of wild poliovirus in Peru by 1991, as well as measles in 2000 and rubella in 2006[4].

Structural changes occurred in the Peruvian government from the year 2000 onwards, including decentralization and regionalization [5]. In health, "vertical" programs like EPI were phased out, leading to the creation of the National Immunization Health Strategy (ESNI, by its Spanish acronym) in 2004, with an Advisory Committee and a Permanent Committee as advisors [6]. The General Vaccines Law No. 28010 was enacted in June 2003, making vaccination activities mandatory and securing dedicated funds for vaccination activities. An international evaluation in 2014 [7] led to the integration of EPI into the Ministry of Health (MINSA) structure[8], enhancing its significance.

The development of the cold chain has faced a series of challenges and solutions, propelling the immunization process globally. In 1976, Professor David Morley of the Institute of Child Health in London proposed that WHO establish a team within EPI to address three critical issues: the absence of systems to monitor the temperature of heat-sensitive vaccines, lack of appropriate equipment for storing and transporting vaccines, and insufficient adequately trained personnel to handle vaccines[9]. Morley emphasized the importance of proper cold chain management, while PAHO-UNICEF warned that transportation issues, staff or vaccine shortages, or cold chain interruptions could lead to decreased confidence and reduced demand for immunization services[10]. This underscores the need for robust infrastructure and logistics to manage an efficient national immunization program.

In Peru's history, the Cold Chain has undergone several inventories. The first was conducted in 1989, the second between 1993 and 1994, and the third in 2004 with UNICEF support, coinciding with the establishment of the National Immunization Strategy and Vaccines Law. The latter inventory revealed the need to revitalize immunization components, prioritizing the incorporation of new vaccines and upgrading the Cold Chain with cutting-edge technology to ensure vaccine preservation and quality[11].

According to Shibeshi et al[12], vaccine supply within the cold chain can be affected by geographical inaccessibility to services, vaccine shortages, and/or cold chain issues, representing missed opportunities for vaccinating children in many countries. Pambudi et al [13] state that the success of a vaccination program relies not only on vaccine effectiveness but also on cold chain supply management. Functionality, according to Ogboghodo et al[14], is a significant determinant of cold chain management practice, and Hatchett et al [15] describe that vaccine refrigerator operation is crucial for ensuring safe storage and maintaining efficacy.

Internationally, it is recommended that all three levels of the cold chain have appropriate management and planning considering efficient vaccine supply management. According to WHO, for the introduction of the COVID-19 vaccine[16], the cold chain is one of the operational components that must be ensured for planning, organizing, and executing a national vaccination against SARS-CoV-2, ensuring fair, equitable, and safe vaccine access.

ORIGINAL PAPER

https://imicb.upp.edu.pe/rfmh/vol24/iss1/9
DOI: https://doi.org/10.25176/RFMH.v24i1.6189

ORIGINAL PAPER

Tao et al[17] suggest exploring methods to calculate cold chain capacity needs using immunization product databases, considering that cold chain capacity needs for immunization programs can be accurately measured with the volume of immunization product doses, as established in the Technical Health Standard (NTS, by its Spanish acronym) for Cold Chain Management in Immunizations[18], whose methodology has been employed for this study.

In the context of the COVID-19 pandemic, Peru aimed to vaccinate 24 million people[19], for which MINSA secured procurement agreements under the COVAX Facility or bilateral agreements to ensure vaccine access for the population, including migrants[20]. During this period, technical and operational guidelines were established to implement vaccination, which were modified based on vaccine availability and scientific evidence. Currently, Peru has four different vaccines against SARS-CoV-2[21], which have been distributed and administered nationwide.

The objective of this study is to identify critical aspects of the cold chain, using a structured information database tool, whose analysis shows the situational reality in vital aspects of its management and performance. This data, in the context of the COVID-19 pandemic and similar future situations, will be crucial for timely and appropriate decision-making in national and subnational immunization management by the Ministry of Health.

METHODS

Location and Execution Period

This study included information on cold chain equipment obtained nationwide from all MINSA health service providers (IPRESS) that provided vaccination services during the period from December 2020 to December 2021.

Study Type and Research Design

Descriptive study analyzing databases from the Ministry of Economy and Finance (Integrated Administrative Management System Asset Module and Integrated Financial Management System)[23] of MINSA IPRESS, vaccine dose and distribution records (SISMED)[24] for the years 2020 and 2021, and administrative records from MINSA's Regional Health Strategies for immunizations in 2020.

STUDY VARIABLES

Inclusion Criteria

Data on cold chain equipment from MINSA IPRESS providing vaccination services in 2020 and 2021, registered in MEF's SIGA Asset Module.

Data on cold chain equipment from all MINSA IPRESS Management Units – UGIPRESS[25] registered in MEF's SIGA Asset Module for the years 2020 and 2021.

Data Collection Instruments

This study established four evaluation criteria, aligned with the current Peruvian cold chain technical standard [18]. These were described based on data recorded in Regional Health Directorates or Management Entities (DIRESAs and GERESAs, by their Spanish acronyms), Integrated Health Network Directorates (DIRIS, by its Spanish acronym), and provided by the SIGA Asset Module of the Ministry of Economy and Finance.

Review of national and international technical information allowed for assessing the operability and functionality of the Cold Chain for immunization in Peru in the context of the COVID-19 Pandemic:

Criterion 1: Obsolescence. Based on installation or usage time of equipment, this criterion establishes the adequacy of equipment for use. According to the Peruvian technical standard, all equipment should be less than 10 years old to ensure proper functioning; otherwise, its usage relevance must be evaluated or it should be withdrawn from service.

Criterion 2: Supply. This criterion identifies the number of Health Establishments equipped with cold chain equipment, highlighting the need for 100% equipment coverage nationwide. Each region vaccinates 100% of its first-level IPRESS, hence any establishment lacking this equipment poses a risk to vaccine preservation.

Criterion 3: Functionality. This assesses the current condition or operating level of cold chain equipment, which determines the operational status of the cold chain across all three levels of healthcare. Non-functioning or repair-needing equipment does not ensure storage capacity.

Criterion 4: Storage Capacity by Levels. This describes the actual storage capacity of an IPRESS to cover routine vaccination needs and additional activities like COVID-19 vaccination. The standard specifies that all vaccines must be stored between +2°C and +8°C at the local level, so all IPRESS must have equipment for 100% of routine vaccines and vaccines for supplementary activities (campaigns, emergencies, sweeps, among others).

Data Processing and Analysis Plan

For data analysis and evaluation, information from the SIGA Asset database on cold chain equipment was used, collected and reported for the years 2020 and 2021, alongside a comparative analysis based on the description and location of these equipment types, functionalities, and lifespan per cost center (IPRESS, UGIPRESS, Warehouse).

Processing and Analysis

Data on electric and solar refrigerators and freezers were reviewed based on information obtained from the MEF's SIGA Asset Module, chosen for consistency and possessing more evaluation and identification variables than unofficial information available in most IPRESS vaccination service. The SIGA Asset Module data was extracted from the cubes in the Cognos Power Play application[26]. Subsequently, information pertaining to evaluation criteria was exported to Microsoft Office Excel, and report tables were processed using pivot tables. The final processing involved consolidating evaluated variables by region (DIRESAs, GERESAs, DIRIS), by cost center (IPRESS, UGIPRESS), by category level, and considering only variables identifying cold chain equipment used in immunizations. The analysis was conducted based on the criteria established in the technical standard for cold chain management in immunizations[18].

Ethical Considerations

This research was conducted using freely accessible secondary databases from official state portals, presenting no individual patient data. Therefore, approval from an ethics committee was not required.

RESULTS

Obsolescence:

Using data from the SIGA Asset Module, the number and type of equipment older than 10 years were identified. Table 1 reflects nationwide cold chain equipment that is obsolete; approximately 61.8% of health facilities responsible for vaccination processes have obsolete cold chain equipment. In some regions, this value exceeds 75%, notably Lima Metropolitan Area (88%), Ayacucho (81%), Cusco (79%), and Huancavelica (77%), which are key regions in the country.

The SIGA Asset data reports all active cold chain equipment in health facilities nationwide up to December 2021, where 7,643 pieces of equipment (38.2%) are less than 10 years old, and 12,370 pieces of equipment (61.8%) are over 10 years old. This finding is crucial in terms of risk management for cold chain management in Peru.

Supply

The supply of cold chain equipment in Peru has steadily increased since 2008. In 2021, during the COVID-19 Pandemic, Peru strengthened its cold chain with an investment of 145 million soles[27], increasing regional and local vaccine storage capacity. At a regional level, routine and COVID-19 vaccines can be stored globally; however, at the local level where vaccines are applied and must be available, there are 727 first-level health facilities (9%) lacking this equipment as of December 2021, representing an ongoing supply gap.

ORIGINAL PAPER

https://imicb.upp.edu.pe/rfmh/vol24/iss1/9
DOI: https://doi.org/10.25176/RFMH.v24i1.6189

ORIGINAL PAPER

Table 1. Obsolescence of refrigeration and freezing equipment at national level, January 2022.

REGIONS	Under 10 years old	%	Over 10 years old	%	Total cold chain equipment
LIMA METROPOLITANA[1]	243	12	1757	88	2000
AYACUCHO	182	19	788	81	970
CUSCO	192	21	724	79	916
HUANCAVELICA	226	23	768	77	994
CALLAO	60	26	172	74	232
PASCO	132	27	353	73	485
AREQUIPA	116	27	308	73	424
CAJAMARCA	321	28	809	72	1130
ANCASH	413	29	990	71	1403
PUNO	200	31	443	69	643
JUNIN	330	33	667	67	997
TUMBES	57	34	109	66	166
ICA	177	39	282	61	459
LIMA REGION	409	42	554	58	963
APURIMAC	413	44	535	56	948
TACNA	85	47	97	53	182
LAMBAYEQUE	340	48	366	52	706
LORETO	278	49	286	51	564
PIURA	729	51	697	49	1426
LA LIBERTAD	539	55	447	45	986
MADRE DE DIOS	156	56	123	44	279
AMAZONAS	531	59	371	41	902
SAN MARTIN	407	60	267	40	674
MOQUEGUA	101	62	62	38	163
UCAYALI	389	67	191	33	580
HUANUCO	617	75.2	204	25	821
TOTALS	**7643**	**38.2**	**12370**	**61.8**	**20013**

Source: SIGA Asset Module – MEF

Table 2 shows that 91% of first-level health facilities have refrigeration equipment, while 727 (9%) do not, with Loreto (46%) and Huancavelica (21%) regions having the largest gaps. These regions should be prioritized for strengthening as they have dispersed and inaccessible populations, lower routine and COVID-19[28,29] vaccination coverage rates, and report more outbreaks of vaccine-preventable diseases. Additionally, it is concerning that Lima, the capital, has one of the lowest supplies of cold chain equipment despite being the most densely populated region. The lack of cold chain equipment leads to inadequate capacity, potentially interrupting vaccination services and public health emergency responses[30].

Table 2. Provision of refrigeration equipment in IPRESS (health facilities) at the primary care level, December 2021.

REGIONS	HEALTH FACILITIES WITH EQUIPMENT	HEALTH FACILITIES WITHOUT EQUIPMENT	TOTAL HEALTH FACILITIES	%
PASCO	252	2	254	99
ANCASH	398	7	405	98
LAMBAYEQUE	178	4	182	98
CUSCO	334	8	342	98

MADRE DE DIOS	90	3	93	97
JUNIN	485	18	503	96
LIMA	319	12	331	96
CAJAMARCA	823	32	855	96
SAN MARTIN	352	14	366	96
LA LIBERTAD	289	12	301	96
ICA	137	6	143	96
PIURA	397	18	415	96
PUNO	438	26	464	94
AYACUCHO	377	26	403	94
LIMA NORTE	100	8	108	93
AMAZONAS	437	42	479	91
TACNA	69	7	76	91
HUANUCO	297	32	329	90
AREQUIPA	230	26	256	90
MOQUEGUA	56	7	63	89
CALLAO	45	6	51	88
LIMA SUR	115	16	131	88
LIMA ESTE	70	10	80	88
UCAYALI	188	29	217	87
LIMA CENTRO	63	10	73	86
APURIMAC	336	54	390	86
TUMBES	37	7	44	84
HUANCAVELICA	321	86	407	79
LORETO	233	199	432	54
TOTALS	**7466**	**727**	**8193**	**91**

Source: SIGA Asset Module-MEF Data

ORIGINAL PAPER

Functionality

The functionality of national cold chain equipment (Table 3) is at 84%, meaning that despite 16% of health facilities having refrigeration and freezing equipment, these have technical failures or deterioration. As a result, the vaccine storage capacity is nonexistent in these health facilities, posing a risk to the safety and immunogenic potency of the vaccines. In the context of COVID-19 vaccination or similar contingency situations, these establishments would struggle to store vaccines due to the inability to guarantee proper temperature maintenance, which would affect the immunogenic capacity of the vaccines. This situation jeopardizes the availability of routine vaccines [31] and consequently leads to incomplete vaccination schedules or unvaccinated populations. Table 3 shows that five regions have over 95% functionality of cold chain equipment (Lambayeque, East Lima, Tacna, Cajamarca, and Tumbes), while five have less than 80% functionality (Ucayali, Loreto, Arequipa, Lima Center, and North Lima), posing challenges in vaccine storage and vaccination operations.

Table 3. Operation of cold chain equipment (cooling and freezing), December 2021.

REGION	D	NFRE	NFRR	NI	F	Total equipment	% in F
LAMBAYEQUE					363	363	100
LIMA ESTE			3		190	193	98
TACNA			3		190	193	98
CAJAMARCA		3	26		1759	1788	98
TUMBES		4		1	119	124	96
JUNIN		35	27	3	1185	1250	95

https://incib.unp.edu.pe/rfmh/vol24/iss1/9
DOI: https://doi.org/10.25176/RFMH.v24i1.6189

LA LIBERTAD		23	20		706	749	94
HUANCAVELICA		14	60		853	927	92
PIURA		1	100		871	972	90
LIMA PROVINCIAS	3	18	74		811	906	90
SAN MARTIN		46	49	4	784	883	89
HUANUCO		21	83		665	769	86
MADRE DE DIOS		2	26		172	200	86
AMAZONAS			129		765	894	86
CALLAO		10	12		125	147	85
ICA			42		219	261	84
LIMA SUR		43	28	4	371	446	83
AYACUCHO			155	1	743	899	83
ANCASH		53	164		931	1148	81
PASCO		67	29	44	595	735	81
APURIMAC			169		711	880	81
CUSCO			161		670	831	81
MOQUEGUA			36		144	180	80
PUNO		57	197	3	1007	1264	80
UCAYALI		30	86		412	528	78
LORETO		115	64	1	392	572	69
AREQUIPA			239		348	587	59
LIMA CENTER			119		127	246	52
NORTH LIMA			260		160	420	38
Total	**3**	**542**	**2,361**	**61**	**16,388**	**19,548**	**84**

Source: SIGA Module Asset-MEF Data/Cold chain stock DMUNI, 2021

Legend: F = Operational NI = Not installed D = Deteriorated NFRE = Not functioning, requires evaluation

NFRR = Not functioning, requires repair

Storage Capacity

The National Technical Standard (NTS) for cold chain management in immunizations stipulates the need for properly trained and qualified personnel to measure the volume of each vaccine in the National Vaccination Scheme according to the methodology established in said standard[18]. Table 4 shows that while there is overall coverage for the storage capacity needed for regular schedule vaccines on a quarterly and monthly distribution basis, when contrasted with the requirements for COVID-19 vaccine storage, it is observed that 15 (58%) out of 26 regions can cover the quarterly and monthly storage capacity needs for these vaccines. This analysis was conducted using information available as of December 2021, without considering vaccines that require ultra-freezing storage, as these are only stored at the national and regional levels[21]. Additionally, the gap of 582,579 and 56,809 cubic meters of quarterly and monthly storage capacity respectively for COVID-19 vaccines implies increased rotation in the distribution of routine vaccines as well as COVID-19 vaccines in the 11 regions (42%) that lack capacity for quarterly and monthly storage.

Published by INICIB-URP, 2024

https://doi.org/10.25176/RFMH.v24i1.6189
DOI: https://doi.org/10.25176/RFMH.v24i1.6189

Tabla 4. Estimation of annual, quarterly, and monthly storage capacity needs for routine vaccines and gaps for COVID-19 vaccine storage based on available capacity with routine vaccines, December 2021.

REGIONS (MINSA)	Total capacity	Routine Vaccine Cold Chain Need (Regular vac.)			Available Capacity		COVID-19 Vaccine Cold Chain Nee			Cold chain gap for COVID-19 Vaccines	
		Annual	Quarterly	Monthly	(A) - (C)	(A) - (D)	Annual	Quarterly	Monthly	Quarterly	Monthly
	(A)	(B)	(C)	(D)	Quarterly (E)	Monthly (F)	(G)	(H)	(I)	(E) - (H)	(F) - (I)
AMAZONAS	87,817.50	9,665.00	2,416.25	805.42	85,401.25	87,012.08	76,726.00	19,181.50	6,393.83	66,219.75	80,618.25
ANCASH	78,401.50	22,902.00	5,725.50	1,908.50	72,676.00	76,493.00	219,466.00	54,866.50	18,288.83	17,809.50	58,204.17
APURIMAC	57,143.50	8,425.00	2,106.25	702.08	55,037.25	56,441.42	79,404.00	19,851.00	6,617.00	35,186.25	49,824.42
AREQUIPA	52,669.00	27,269.00	6,817.25	2,272.42	45,851.75	50,396.58	283,608.00	70,902.00	23,634.00	-25,050.25	26,762.58
AYACUCHO	21,775.50	12,972.00	3,243.00	1,081.00	18,532.50	20,694.50	118,092.00	29,523.00	9,841.00	-10,990.50	10,853.50
CAJAMARCA	129,941.50	27,158.00	6,789.50	2,263.17	123,152.00	127,678.33	274,326.00	68,581.50	22,860.50	54,570.50	104,817.83
CALLAO	24,150.00	19,846.00	4,961.50	1,653.83	19,188.50	22,496.17	203,333.00	50,833.25	16,944.42	-31,644.75	5,551.75
CUSCO	54,286.80	25,079.00	6,269.75	2,089.92	48,017.05	52,196.88	255,151.00	63,787.75	21,262.58	-15,770.70	30,934.30
HUANCAVELICA	48,732.00	7,772.00	1,943.00	647.67	46,789.00	48,084.33	74,906.00	18,726.50	6,242.17	28,062.50	41,842.17
HUANUCO	48,029.50	14,477.00	3,619.25	1,206.42	44,410.25	46,823.08	146,289.00	36,572.25	12,190.75	7,838.00	34,632.33
ICA	29,621.50	17,019.00	4,254.75	1,418.25	25,366.75	28,203.25	161,213.00	40,303.25	13,434.42	-14,936.50	14,768.83
JUNIN	68,573.50	25,599.00	6,399.75	2,133.25	62,173.75	66,440.25	243,997.00	60,999.25	20,333.08	1,174.50	46,107.17
LA LIBERTAD	80,596.00	36,019.00	9,004.75	3,001.58	71,591.25	77,594.42	354,679.00	88,669.75	29,556.58	-17,078.50	48,037.83
LAMBAYEQUE	56,103.50	23,744.00	5,936.00	1,978.67	50,167.50	54,124.83	242,125.00	60,531.25	20,177.08	-10,363.75	33,947.75
LIMA METROPOLITANA	113,808.00	164,459.00	41,114.75	13,704.92	72,693.25	100,103.08	1,862,744.00	465,686.00	155,228.67	-392,992.75	-55,125.58
LIMA REGION	37,690.00	18,735.00	4,683.75	1,561.25	33,006.25	36,128.75	188,162.00	47,040.50	15,680.17	-14,034.25	20,448.58
LORETO	57,016.50	19,573.00	4,893.25	1,631.08	52,123.25	55,385.42	174,239.00	43,559.75	14,519.92	8,563.50	40,865.50
MADRE DE DIOS	25,514.00	3,219.00	804.75	268.25	24,709.25	25,245.75	29,341.00	7,335.25	2,445.08	17,374.00	22,800.67
MOQUEGUA	25,691.50	3,190.00	797.50	265.83	24,894.00	25,425.67	36,816.00	9,204.00	3,068.00	15,690.00	22,357.67
PASCO	16,855.00	5,027.00	1,256.75	418.92	15,598.25	16,436.08	50,193.00	12,548.25	4,182.75	3,050.00	12,253.33
PIURA	65,810.00	36,555.00	9,138.75	3,046.25	56,671.25	62,763.75	346,606.00	86,651.50	28,883.83	-29,980.25	33,879.92
PUNO	68,123.50	21,897.00	5,474.25	1,824.75	62,649.25	66,298.75	228,670.00	57,167.50	19,055.83	5,481.75	47,242.92
SAN MARTIN	57,586.00	15,823.00	3,955.75	1,318.58	53,630.25	56,267.42	159,276.00	39,819.00	13,273.00	13,811.25	42,994.42
TACNA	25,085.50	5,954.00	1,488.50	496.17	23,597.00	24,589.33	70,031.00	17,507.75	5,835.92	6,089.25	18,753.42
TUMBES	22,648.00	4,343.00	1,085.75	361.92	21,562.25	22,286.08	41,535.00	10,383.75	3,461.25	11,178.50	18,824.83
UCAYALI	7,431.50	11,361.00	2,840.25	946.75	4,591.25	6,484.75	98,020.00	24,505.00	8,168.33	-19,913.75	-1,683.58
TOTALS	**1,361,100.8**	**588,082.0**	**147,020.5**	**49,006.8**	**1,214,080.3**	**1,312,094.0**	**6,018,948.0**	**1,504,579.0**	**501,579.0**	**-582,756.0**	**-56,809.2**

Source: SIGA Asset Module-MEF Data. Source MINSA: Estimation of COVID-19 vaccine needs - DMUNI / CENARES

ORIGINAL PAPER

ORIGINAL PAPER

DISCUSSION

Currently, validation of timely specialized preventive maintenance control at the regional level of the cold chain has not been achieved, resulting in equipment over 10 years old becoming planned obsolescence, causing difficulties in storage capacity not only for regular schedule vaccines but also for COVID-19 vaccines, as only 38.2% of equipment is less than 10 years old. Additionally, it is noteworthy that around 80% of equipment in the top 5 regions of Peru is obsolete. Cold chain interruption leads to avoidable vaccine wastage, and the COVID-19 pandemic demonstrated the need for vaccines to be stored at different temperatures (between 0°C and 10°C, at -20°C and -70°C), increasing the complexity of vaccine supply chains and emphasizing their importance. The current study highlights the urgency and importance of promoting intervention strategies in refrigeration and biological systems to enhance storage capacity, supply, and adequate vaccine management during future contingencies similar to the COVID-19 pandemic.

Regarding supply, the study by Shibeshi, Masresha, and Daniel [12] demonstrated that cold chain issues accounted for the majority of missed vaccination opportunities for children in many countries, with 25% of countries lacking sufficient cold chain equipment to execute extension services. Similarly, Piché-Renaud [32], concerning vaccine supply, noted substantial modifications to pediatric immunization services in Canada due to COVID-19, necessitating strategies to mitigate immunization barriers during the pandemic to prevent immunity gaps that could lead to an eventual increase in vaccine-preventable diseases. Both situations described align with findings in Peru, where lack of equipment (9%) at the primary care level jeopardizes supply of routine vaccines and COVID-19 vaccines to the population in these areas. It also highlights that regions like Loreto, which have a high rate of morbidity and mortality due to preventable infectious diseases, have a very low percentage of refrigeration equipment supply (54%), exposing the population to higher risk.

The present study reveals a 16% malfunction rate in equipment, proving to be a critical factor in Peru's cold chain management. According to Ogboghodo et al.[14], the presence of functional refrigerators (p=0.016) was the most significant determinant for cold chain management practices, and Hatchett[15] demonstrated that proper functioning of vaccine refrigerators and required health professional controls ensures safe storage, maintaining efficacy. Therefore, as Feyisa [33] identified, concerted efforts are needed to provide proper vaccine cold chain management at immunization delivery points. Functionality directly correlates with obsolescence, considering that a higher number of obsolete equipment at the national level leads to greater dysfunctionality of these systems. Considering this criterion, the results of this analysis are valuable, as the level of obsolescence of cold chain equipment in health facilities responsible for vaccination exceeds 61%.

Regarding the storage capacity gap for COVID-19 vaccines, urgent measures are needed to avoid additional costs due to high vaccine turnover that risks their safety and timeliness, as described by Ortiz et al.[34] and Bulula et al.[35], who mention that immediate attention to strengthening immunization systems is essential to support pandemic responses, particularly enhancing vaccine storage capacity, which could even reduce costs in vaccine supply chains. This study demonstrates the current collapse in monthly and quarterly vaccine storage in Lima and Ucayali.

CONCLUSIONS

The analysis allows us to identify risks in storage capacity to safeguard vaccines in the national scheme and to respond adequately to contingencies like the COVID-19 pandemic, which require timely intervention.

Considering that not all strategies and practices are suitable for every country and circumstance [36], it is proposed to integrate approaches that comprehensively address the current cold chain issue for vaccines. The cold chain is crucial in the vaccine supply system; the introduction of new vaccines challenges storage capacity in the cold chain, necessitating innovations tailored to community needs, particularly those of underserved populations [37]. Patients expect to be treated with the best products, and providers need technologies that facilitate their work. In this context, the use of combination vaccines minimizes the need for increased storage capacity and reduces vaccination operational costs[38]. Thus, the alternative of using a fully liquid hexavalent acellular combined vaccine in the current Peruvian vaccination schedule could enhance cold chain performance nationwide, with a stronger focus on the country's most inaccessible areas [39]. Peru's cold chain has made significant strides, but there are gaps that must be addressed effectively, emphasizing the importance of up-to-date, integrated information enabling appropriate management that positively impacts the introduction of new vaccines, vaccination during pandemics or other contingency situations, and health emergencies.

ORIGINAL PAPER

Authorship Contribution: Authors A. Gutiérrez, MA Mendoza, PA. Rodríguez, and T. Sarazu contributed to the study's conception. Data collection was performed by MA Mendoza, and data analysis was carried out by A. Gutiérrez and MA. Mendoza. The manuscript was prepared by A. Gutiérrez and MA. Mendoza. All authors have read and approved the final manuscript: PA. Rodríguez, T. Sarazu, A. Gutiérrez, and MA. Mendoza.

Conflict of Interest: PA. Rodríguez and T. Sarazu are employees of Sanofi Vaccines; the other authors declare no conflicts of interest.

Ethics Committee Approval: This article does not involve human or animal participants before, during, or after the study.

Acknowledgments: To the healthcare personnel responsible for vaccination services at the IPRESS of all DIRIS/DIRESA/GERESA MINSA and to the Ministry of Economy and Finance (MEF) for the SIGA Asset data.

Funding: Financial support was provided by Sanofi Vaccines.

Received: December 19, 2023.
Accepted: April 11, 2024.

Correspondence: *Dra. Silvina Mastaglia.*
Address: *Av. Córdoba 2351; Piso 8 (CP: 1120).*
Telephone: *(+54) 1159508972*
Email: *silvinamastaglia@hotmail.com*

ORIGINAL PAPER

REFERENCES

1. Armstrong, P. Economic Benefits and Costs Associated With Target Vaccinations. Supplement to Journal of Managed Care Pharmacy JMCP September 2007 Vol. 13, No. 7, S-b www.amcp.org

2. Rabi, M; Las campañas de vacunación y las acciones inmunopreventivas contra la viruela. Proceso Histórico y social, Ed. Conmemorativa del septuagésimo aniversario del Ministerio de Salud del Perú (1935-2005). ISBN. N°9972-678-08-03. Lima – Perú, 2005. Disponible en: http://bvs.minsa.gob.pe/local/MINSA/1149_HIST115-1.pdf

3. Andrus, JK. , Bandyopadhyay, AS. , Danovaro-Holliday, MC. , Dietz, V., Domingues, C., Figueroa, P. Pasado, presente y futuro de la inmunización en las Americas. Rev. Panam. Vol. 41, Número 8. Organizacion Panamericana de la Salud, Dic. 2017. Disponible en: https://go.gale.com/ps/i.do?p=AONE&u=googlescholar&id=GALE|A626505147&v=2.1&it=r&sid=googleScholar&asid=d7096985

4. Reid, M., Fleck, F. The inmunization programme that saved millions of lives. Organizacion Mundial de la Salud. 2014 [Internet] [citado 2020, Dic 10]. 92(5), 314–315Disponible en: https://doi:10.2471/blt.14.020514

5. Rühling, M. Proceso de descentralización en el Perú: análisis, retos y perspectivas 2002. Aportes al Debate No. 2, Lima, febrero 2002. [Internet] [citado Dic 10] Disponible en: https://library.fes.de/pdf-files/bueros/peru/02148.pdf

6. Ministerio de Salud. Resolución Ministerial N°771-2004/MINSA. Establece las Estrategias Sanitarias Nacionales del Ministerio de Salud, y sus respectivos órganos responsables. Disponible en: https://www.gob.pe/institucion/minsa/normas-legales/253112-771-2004-minsa

7. Ministerio de Salud y Organización Panamericana de la Salud (OPS). Informe: Evaluación Internacional de la Estrategia Sanitaria Nacional de Inmunizaciones del Perú. 1era ed. Junio 2015. [Internet] [citado Dic 5] Disponible en: http://bvs.minsa.gob.pe/local/MINSA/3996.pdf

8. Ministerio de Salud. Decreto Supremo N°008-2017-SA. Decreto supremo que aprueba el Reglamento de Organización y Funciones del MINSA. Artículo 72°. Disponible en: https://cdn.www.gob.pe/uploads/document/file/190604/reglamento-de-organizacion-y-funciones-del-ministerio-de-salud-ds-n-008-2017-sa.pdf?v=1596557232

9. Lloyd, J; Cheyne, J (2017). The origins of the vaccine cold chain and a glimpse of the future. Vaccine, 35(17), [Internet] 2022 [citado Abr 10] 2115–2120. doi:10.1016/j.vaccine.2016.11.097. Disponible en: https://www.sciencedirect.com/science/article/pii/S0264410X17300476

10. Maurice, J., Davey, S. Vacunas e inmunización: Situación mundial, UNICEF, Banco Mundial. tercera edición. Ginebra, Organización Mundial de la Salud, 2010.

11. UNICEF. Resumen Evaluación Cadena de Frío: Informe Final – Inventario Cadena de Frio 2004. Lima – Perú, 2004 [Internet] [citado Mar 20]. Disponible en: https://es.scribd.com/document/244635487/resumen-eval-cadena-de-frio-unicef-pdf

12. Shibeshi ME, Masresha BG, Daniel F. Immunisation program reviews in East and Southern Africa: 2012-2018; key lessons. Pan Afr Med J. 2020 Dec 30;37:385. doi: 10.11604/pamj.2020.37.385.27140.

13. Pambudi NA, Sarifudin A, Gandidi IM, Romadhon R. Vaccine cold chain management and cold storage technology to address the challenges of vaccination programs. Energy Reports. 2022 Nov;8:955–72. doi: 10.1016/j.egyr.2021.12.039.

14. Ogboghodo EO, Omuemu VO, Odijie O, Odaman OJ. Cold chain management practices of health care workers in primary health care facilities in Southern Nigeria. Pan Afr Med J. 2017 May 11;27:34. doi: 10.11604/pamj.2017.27.34.11946.

15. Hatchett R. The medicines refrigerator and the importance of the cold chain in the safe storage of medicines. Nurs Stand. 2017 Oct 4;32(6):53-63. doi: 10.7748/ns.2017.e10960.

16. Organización Mundial de la Salud/ Organización Panamericana de la Salud. Introducción de la vacuna contra la COVID-19: Orientaciones para determinar los grupos prioritarios y elaborar la microplanificación. Versión 1, 18 enero 2021. [citado el 13 marzo 2021]. Disponible en: https://iris.paho.org/bitstream/handle/10665.2/53250/OPSFPLIMCOVID-19210008_por.pdf?sequence=5&isAllowed=y

17. Tao LN, Wang YC, Bai QR. [Application of immunization products database in calculation of cold chain capacity needs]. Zhongguo Yi Miao He Mian Yi. 2009 Jun;15(3):270-3. Chinese.

18. Ministerio de Salud. Norma Técnica de Salud para el Manejo de la Cadena de Frio en las Inmunizaciones. NTS N°136-MINSA/2017/DGIESP. Lima – Perú, junio 2017. [citado abril 2022]. Disponible en: https://www.gob.pe/institucion/minsa/normas-legales/189291-497-2017-minsa

19. Ministerio de Salud. Actualización del Plan Nacional de Vacunación contra la COVID 19, Resolución Ministerial N°488-2021-MINSA, Perú abril 2021. [citado el 27 marzo 2022]. Disponible en: https://cdn.www.gob.pe/uploads/document/file/2961118/RM%20N%C2%B0239-2022-MINSA.pdf.pdf

20. Organización Mundial de la Salud/ Organización Panamericana de la Salud. Actualización sobre la pandemia de covid-19 en la Región de las Américas, preparación para el COVAX y acceso equitativo a las vacunas contra la COVID-19. Resolución CDSS1.R1, Sesión especial del Consejo Directivo. Ginebra, diciembre 2020.

21. Ministerio de Salud. Modifica la Directiva Sanitaria N°137-MINSA/DGIESP-2021, "Directiva Sanitaria para la vacunación contra la COVID-19". Resolución Ministerial N°239-2022-MINSA, Perú marzo 2021. [citado el 15 abril 2022]. Disponible en: https://www.gob.pe/institucion/minsa/normas-legales/2866885-239-2022-minsa

22. Ministerio de Salud – SUSALUD. Reglamento para el Registro Nacional de Instituciones Prestadoras de Servicios de Salud. Resolución de Superintendencia N°004-2021-SUSALUD/S. Lima – Perú, enero 2021. Disponible en: https://busquedas.elperuano.pe/normaslegales/aprueban-el-reglamento-para-el-registro-nacional-de-institu-resolucion-no-004-2021-susaluds-1921675-1/

23. Ministerio de Economía y Finanzas. Manual de Usuario Módulo de Patrimonio Sistema Integrado de Gestión Administrativa del SIGA – MEF. Oficina General de Tecnologias de la Información, Versión del aplicativo 20.06.01. Lima - Perú, marzo 2021. Disponible en: https://www.mef.gob.pe/contenidos/doc_siga/manuales/modulo_patr imonio/MU_modulo_patrimonio_siga.pdf

24. Ministerio de Salud. Sistema Integrado de Suministro de Productos Farmacéuticos, Dispositivos Médicos y Productos Sanitarios – SISMED. Lima, Perú. Disponible en: https://appsalud.minsa.gob.pe/portal_sismed/

25. Ministerio de Salud – SUSALUD. Registro de Unidades de Gestión de Instituciones prestadoras de servicios de salud y aprueban el Reglamento para el Registro de Unidades de Gestión de Instituciones Prestadoras de Servicios de Salud. Resolución de Superintendencia N°114-2014-SUSALUD/S. Lima – Perú, diciembre 2014. Disponible en: https://busquedas.elperuano.pe/normaslegales/crean-el-registro-de-unidades-de-gestion-de-instituciones-p-resolucion-n-114-2014-susaluds-1191084-1/

26. IBM, Cognos Analytics. Cognos PowerPlay 11.0. Disponible en: https://www.ibm.com/docs/es/cognos-analytics/11.0.0?topic=configuration-cognos-powerplay-110

27. Presidencia del Consejo de Ministros (PCM), Decreto de Urgencia N°131-2020, que dicta medidas extraordinarias que permitan el almacenamiento, conservación, distribución y aplicación de la vacuna contra la COVID-19. Disponible en: https://busquedas.elperuano.pe/download/url/decreto-de-urgencia-que-dicta-medidas-extraordinarias-que-pe-decreto-de-urgencia-n-131-2020-1908696-1

28. Ministerio de Salud (MINSA). Repositorio Único Nacional de Información en Salud (REUNIS). Coberturas de Vacunación Regular. Disponible en https://www.minsa.gob.pe/reunis/data/Inmunizaciones.asp

29. Ministerio de Salud (MINSA). Repositorio Único Nacional de Información en Salud (REUNIS). Coberturas de vacunación contra la COVID-19 Disponible en: https://www.minsa.gob.pe/reunis/data/vacunas-covid19.asp

30 . Ashok A, Brison M, LeTallec Y. Improving cold chain systems: Challenges and solutions. Vaccine. 2017 Apr 19;35(17):2217-2223. https://doi.org/10.1016/j.vaccine.2016.08.045.

31. TechNet-21. Gestión de equipos de cadena de frío – Recursos Técnicos. Disponible en: https://www.technet-21.org/en/hot-topics-items/428-supply-chain-and-logistics/5314-cold-chain-equipment-management-technical-resources

32. Piché-Renaud PP, Ji C, Farrar DS, Friedman JN, Science M, Kitai I, Burey S, Feldman M, Morris SK. Impact of the COVID-19 pandemic on the provision of routine childhood immunizations in Ontario, Canada. Vaccine. 2021 Jul 13;39(31):4373-4382. doi: 10.1016/j.vaccine.2021.05.094.

33. Feyisa D. Cold Chain Maintenance and Vaccine Stock Management Practices at Public Health Centers Providing Child Immunization Services in Jimma Zone, Oromia Regional State, Ethiopia: Multi-Centered, Mixed Method Approach. Pediatric Health Med Ther. 2021 Jul 22;12:359-372. doi: 10.2147/PHMT.S312039.

34. Ortiz JR, Robertson J, Hsu JS, Yu SL, Driscoll AJ, Williams SR, Chen WH, Fitzpatrick MC, Sow S, Biellik RJ, Neuzil KM. The potential effects of deploying SARS-Cov-2 vaccines on cold storage capacity and immunization workload in countries of the WHO African Region. Vaccine. 2021 Apr 8;39(15):2165-2176. doi: 10.1016/j.vaccine.2021.02.037.

35. Bulula N, Mwiru DP, Swalehe O, Thomas Mori A. Vaccine storage and distribution between expanded program on immunization and medical store department in Tanzania: a cost-minimization analysis. Vaccine. 2020 Dec 3;38(51):8130-8135. doi: 10.1016/j.vaccine.2020.10.088.

36. Organización Mundial de la Salud (OMS). Estrategias y prácticas mundiales de inmunización sistemática (GRISP): documento complementario al Plan de Acción Mundial sobre Vacunas (GVAP). Marco integral de estrategias y prácticas para la inmunización sistemática. ISBN 978-92-4-351010-1. Disponible en: https://apps.who.int/iris/rest/bitstreams/1087182/retrieve

37. Organización Mundial de la Salud (OMS). Agenda de Inmunización 2030. Una estrategia mundial para no dejar a nadie atrás. IA2030. Disponible en: https://cdn.who.int/media/docs/default-source/immunization/strategy/ia2030/ia2030-document---spanish.pdf?sfvrsn=5389656e_69&download=true

38. Seinfeld J, Rosales ML, Sobrevilla A, López Yescas JG. Economic assessment of incorporating the hexavalent vaccine as part of the National Immunization Program of Peru. BMC Health Serv Res. 2022 May 16;22(1):651. doi: 10.1186/s12913-022-08006-1.

39. DAR Mathijssen;M. Heisen;JF Clark-Wright;LJ Wolfson;X. Lu;S. Carrol;BCP van Dijk;SL Klijn;B. Alemayehú; (2020). Análisis del impacto presupuestario de la introducción de una vacuna hexavalente no reconstituida para la inmunización pediátrica en el Reino Unido. Revisión de Expertos de Vacunas – doi: 10.1080/14760584.2020.1873770.

ORIGINAL PAPER