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Human Vaccines Cold Supply Chain Practices In Public Health Facilities At Kilimanjaro Region Tanzania

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Abstract

Background

Vaccines are important products in the prevention of illnesses, but failure to ensure the requirements in the vaccine cold supply chain during storage, transportation, and distribution might result in an increased risk of vaccine-preventable diseases. Therefore, this study was conducted to assess the vaccine cold supply chain practices in public health facilities in Kilimanjaro region.

Methods

A descriptive cross-sectional design using a quantitative approach was conducted in 32 health facilities in the Kilimanjaro region, Tanzania. A structured questionnaire was used to collect data. The collected data was cleaned, coded and analyzed by using STATA 18.

Results

There were 32 public health facilities and majority located in rural areas (78.1%). Nurses predominantly operated the cold vaccine chain (93.8%). Compliance to storage protocols was high, notably in maintaining cleanliness (96.9%) and ensuring dry floors (100%). However, significant gaps were observed. Compliance to the vaccine cold chain during distribution was high across all facilities in using special containers and loading ice packs. Disparities were observed in the use of functional car/motorbike in case of refrigerator failure and utilization of transportation resources. At least (90.6%) health facilities complied with vaccine cold supply chain requirements.

Conclusion

The study highlights high compliance with vaccine cold supply chain practices in Kilimanjaro's public health facilities, particularly in cleanliness and temperature maintenance. However, while healthcare workers demonstrated good knowledge, gaps remain that indicate opportunities for improvement in various vaccine handling aspects.

Introduction

Cold chain involves keeping temperature sensitive goods in cold environment in every step of the way from the factory to beneficiary[1, 2]. Vaccine is very sensitive product towards the degree of hotness or coldness of its surrounding environment[3, 4]. To ensure the quality of vaccine is preserved, the cold chain is applied in management of vaccine(5), from the area where they are manufactured, stored and the way they are transported until they reach to the targeted individual [6, 7]. The World Health

Organization (WHO) has reported that about 67% of global vaccines are likely to be defective due to poor quality management and handling policies[8].

In African countries several factors such as low level of knowledge, peripheral location of the healthcare facility, logistics issues and poor cold chain infrastructure have been reported to be the contributing factors towards the loss of the vaccine potency[9–11]. In Tanzania, the Immunization and Vaccination Development (IVD) program it collaborates with the Medical Store Department in order to ensure the potency of the vaccine is maintained throughout the cold supply chain[12]. The study reported that government of Tanzania invests between $3.2 million and $7.9 million every year in order to get a standard vaccines and pay for newer global health partnership vaccines[13].

Despite the invested efforts in maintaining the cold chain in Tanzania, but still there is a high wastage rate of vaccine due to defect at some stages in the cold chain system of the some healthcare facilities[14]. Therefore, this study aimed to assess the vaccine cold supply chain practices in public health facilities in Kilimanjaro region and identified the underlying factors that influence the performance of the system.

Materials and Methods

Study design and setting

The study used a cross-sectional design and a quantitative approach to collect data from 35 health facilities that offer immunisation services in the Kilimanjaro region, Tanzania. The study was conducted from December 2023 to January 2024 in public health facilities in the Kilimanjaro region, Tanzania, covering 13,250 square kilometres and inhabited by 1,861,934 [9]. The research was conducted in four out of seven randomly selected district councils, which comprised 35 public health facilities that offered immunisation services.

Study population

The study population comprised 32 health facilities spread across the four districts. These facilities were categorised according to the level of care offered.

Sample size calculations

The determination of the sample size in this study comprises a two-stage process. In the initial stage, the study adhered to the World Health Organization's (WHO) guidelines for calculating the sample size when evaluating lower-level health facilities such as dispensaries and health centers. The WHO guidelines recommend that when facing resource constraints and dealing with over 100 health facilities in the study area, a minimum of 30% of the health facilities should be included [2]. Sample size calculation for this study employed the WHO assumptions for assessing health facilities, considering the resource limitations in the study area. Therefore, given the presence of more than 100 health facilities, at least 30% of them were incorporated into the study. Considering the 101 immunization centers in the

selected study sites, the calculated sample size, following WHO assumptions, is determined as N = 30/100 × 101 = 31. However, with the addition of one specialized hospital for TB and other infectious diseases (Kibong'oto Hospital, which is located in Siha district), a total of 32 public health facilities is included in this study.

Sampling procedures

This study employed a multistage cluster sampling technique wherein the first stage was the selection of four district councils out of seven district councils in the Kilimanjaro region. The names of the seven councils were written on small pieces of paper, and only four out of seven were selected using the lottery method. The second stage. The second stage is the selection of the health facilities. The health facilities were listed in the sampling frame from each district council and sampled using a lottery method based on the proportional size of the respective health facilities in the councils by mixing dispensaries, health centers and hospitals. The third stage is the selection of health care providers, whereby the health care providers who were working at immunization units at the health facilities were listed, and only one health care provider was selected randomly using the lottery method after giving the lottery paper to all eligible health care providers in the immunization unit. This was done repetitively in all 32 health facilities until the 32 health care providers were reached

Data collection

With regards to data collection tool; this study used a researcher-administered questionnaire with close-ended questions. The questionnaire had five sections. These were participants' information/facilities information, compliance with the vaccines' cold supply chain during distribution, knowledge of healthcare workers in handling the vaccines' cold supply chain and the magnitude of compliance with cold supply chain requirements.

In term of data collection procedures, the research assistants were trained to collect data before data collection began, followed by pretesting of the data collection tool, which was conducted in five facilities that were not included in the main study to ensure accuracy, clarity, and efficiency. Before visiting the selected public health facilities, we obtained permission from the management, explained the research's purpose, and asked participants to consent. They observed the vaccines' cold storage area and asked respondents who work in immunisation services at respective health facilities to provide relevant data. The researcher and the assistants filled out the questionnaire based on the responses provided by the respondents. The questionnaire and consent form were collected and kept in a secure computer to ensure confidentiality.

Data analysis

Quantitative data were entered, cleaned, and coded using Microsoft Excel 2013 before the analysis; it was then imported to STATA 18 for analysis. The analysis was done using descriptive statistic presented by percentages and frequencies, and results were presented in tables.

Results

Social demographic characteristics

This study was conducted in 35 public health facilities (PHFs), of which half (50.0%) were dispensaries. Most of the facilities were situated in rural areas (71.8%), and nurses comprised the majority (93.7%) of participants. Notably, the majority of facilities (90.6%) had trained personnel in cold vaccine chain logistic management, as shown in Table 1.

Table 1
Social demographic characteristics of health facilities in Kilimanjaro region (N = 32)

Variable	Frequency(n)	Percentage(%)
Level of the facility		
Dispensary	16	50.0
Health centre	12	37.6
District hospital	2	6.2
Regional referral hospital	1	3.1
Specialized hospital	1	3.1
Location of the facility		
Urban	9	28.2
Rural	23	71.8
Cold vaccine operating cadre		
Nurse	30	93.7
Medical attendant	1	3.1
Medical doctor	1	3.1
Having trained personnel on cold vaccine chain logistic management		
No	3	9.4
Yes	29	90.6

Public health facilities' compliance with the vaccine cold supply chain requirements during storage practices

At least (100%) health facilities complied with most of the practices recommended. The practices that had poor compliance included vaccine cold room requirements having windows and external room security maintained (9.7%) and vaccine packing area being protected from direct sunlight and also only 7

(21.9%) and having a functional backup generator with fuel available or an alternative power source in case of electricity cut-off (7, 21.9%), as shown in Table 2.

Table 2
Public health facilities' compliance with the vaccine cold supply chain storage practices (N = 32).

Standard Vaccines Cold supply chain storage practices	**n (%)**
Assured cold room clean, and free of dust	31(96.9)
Cold room floor dry at an acceptable level	32(100)
Cold room roof free of leaks	31(96.9)
Windows and external room security maintained	3(9.7)
Vaccine room has sufficient storage capacity	8(25.0)
Only vaccines stored in the refrigerator	14(43.8)
Vaccines properly arranged in the refrigerator	19(59.4)
Vaccine management following the FEFO principle	30(93.8)
No expired vaccines present in the refrigerator	29(90.6)
No frozen vaccines present in the refrigerator	28(87.5)
The refrigerator temperature maintained at 2–8˚C	32(100)
Presence of a functional thermometer for the refrigerator	32(100)
Refrigerator temperature recorded twice daily	20(62.5)
Packing area protected from direct sunlight	3(9.4)
All vaccine transactions recorded	22(68.8)
Vial monitor status recorded for each vaccine	22(68.8)
Vaccine logistic management information system reporting and requisition form done in the last month	24(75.0)
Presence of functional power backup	7(21.9)
Fuel for the generator or alternative power source available	7(21.9)
Designated person responsible for cold room cleanliness	31(96.9)
Regular inspections are performed for potential contaminants in the cold room	32(100)

The reasons for public health facilities not to comply with the vaccine cold supply chain during distribution practices

The practices that had poor compliance included having a functional car/motorbike to use in case of refrigerator failure, having available fuel for a car/motorbike, and having regular documentation of the process for handling vaccines during transportation, among others, as shown in Table 3.

Table 3
Public health facilities' compliance with the vaccine cold supply chain distribution practices (N = 32).

Standard Vaccines Cold supply chain storage practices	**n (%)**
Use special containers used during vaccine transport	32(100)
Use cold box and/or vaccine carrier at the facility	32(100)
The cold box and/or vaccine carrier correctly loaded with ice packs/cool water packs	32(100)
The ice packs placed at the sides of the cold chain	32(100)
The thermometer in the box and/or vaccine carrier is placed according to the guideline	8(25.8)
Have functional car/motorbike to use in case of refrigerator failure	13(40.6)
Available fuel for a car/motorbike	12(37.5)
Regular documentation of process for handling vaccines during transportation	8(25.0)
The transportation vehicles equipped with temperature monitoring systems	3(9.4)

Knowledge of healthcare workers (HCWs) in handling vaccines in public health facilities

About 71.9% of healthcare workers showed overall good knowledge of handling vaccines. Specific areas of knowledge that had poor compliance included demonstrating the correct placement of a thermometer (43.8%) and interpreting the "shake test" (40.6%), as shown in Table 4.

Table 4
Knowledge of Healthcare workers in handling vaccines in public health Facilities (N = 32).

Knowledge area	**n(%)**
Managing Heat, light, and freezing-sensitive vaccines	28(87.5)
The recommended temperature range for vaccine storage (2–8˚)	24(75.0)
Demonstrating the correct practice of placing a thermometer	14(43.8)
Reading and interpreting the vaccine vial monitor (VVM)	29(90.6)
The correct interpretation of the "Shake test"	13(40.6)
The conditioning of ice packs, vaccine arrangement in a cold box, and vaccine carrier	31(96.9)
The storage codes for cold chain products storage	29(90.6)
Personnel best practices for handling vaccines	30(93.8)
The protocol for handling vaccines in case of power outages	27(84.4)

The magnitude of compliance with vaccine cold supply chain requirements

Twenty-nine (90.6%) health facilities complied with vaccine cold supply chain requirements, Specific health facility requirements that had poor compliance included lacking a system to address deviations from storage temperature (78.1%), standard operating procedures for vaccine storage and distribution (46.9%), and dedicated storage rooms for vaccines (34.4%) respectively as shown in Table 5.

Table 5
The magnitude of compliance with vaccine cold supply chain requirements (N = 32)

Requirement	Frequency(n)	Percentage(%)
Having dedicated room for the vaccine cold chain	11	34.4
Having a special person dedicated for vaccine cold chain activities	29	90.6
Having a person involved in the handling of the cold chain trained in vaccine cold chain management	28	87.5
Has a refrigerator special for the vaccines	29	90.6
Availability of the refrigerator functional	30	93.8
Having correctly placed thermometer	32	100.0
Having the thermometer functional	31	96.9
Presence of the National guidelines for immunization	24	75.0
The standard operational procedures (SOP) utilized	15	46.9
Regular audit for vaccine cold supply chain practices	32	100.0
A system in place to address deviations from vaccine storage guidelines	25	78.1

Discussion

Compliance of healthcare facilities with vaccine cold supply chain storage practices

The findings of this study showed that most healthcare facilities adhered to the storage practices required for the vaccine cold supply chain, in which about 32 (100%) facilities had kept their refrigerator at the correct temperature of 2–8°C, 32 (100%) facilities had a good working thermometer for the vaccine refrigerator, 31 (96.9%) facilities kept the cold room clean and free of dust and most of the facilities to about 30(93.8%) facilities had followed the first-expiry-first-out(FEFO) principle for vaccine management. This observed adherence and availability of cold chain equipment was a contributing factor towards preventing vaccine damage in the cold chain in which about 29(90.6%) facilities were found to had no expired vaccine in the vaccine refrigerator. This finding aligns with the study conducted in Ethiopia which explained that the effective cold chain depends on the reliable cold chain equipment and temperature monitoring devices[15]

On the other hand, this study found that healthcare facilities had challenges in keeping windows and external room security in place, with only 3 (9.7%) facilities that were found to meet this standard, some healthcare facility about 18(56.2%) facility were found to keep vaccine with other item in the refrigerator, also the majority of healthcare facility about 29(90.6%) facility didn’t protect the packing area from direct sunlight, in addition only 7 (21.9%) facilities had a functional backup generator with fuel available or an

alternative power source in case of an electricity cut-off. This was contributing factor towards loss of vaccine potency in the cold supply chain. This finding is consistent with a study conducted in Ethiopia and Tanzania, which highlighted improper refrigerator use and inadequate backup systems as the challenges that face the cold supply chain[16–19].

Reasons for Health facilities not to comply with the vaccine cold supply chain Distribution practices

Despite the fact majority of the healthcare facilities had struggled in the adherence towards the needed requirements in the distribution practices of vaccine cold supply chain as recommended by WHO. This study found a crucial gap that is needed to be addressed in which most healthcare facilities to about 24(75%) facility, didn't have a regular documentation of vaccine handling processes during transportation, and only 3(9.4%) facility had temperature monitoring systems in transportation vehicles. This suggests that there is a need for improving documentation and monitoring practices in order to ensure the vaccine potency is preserved in the cold chain during distribution, as emphasized by WHO guidelines. This finding aligns with WHO and Tanzania IVD recommendations in which they had emphasized the importance of proper storage and transportation of vaccines to maintain their efficacy[20].

Knowledge of healthcare workers (HCW's) in handling vaccines in public health Facilities

This study found out that most healthcare workers had overall good knowledge in various aspects of vaccine handling in the cold chain such as being able to read and interpret the vaccine vial monitor (VVM), ability to manage heat and freezing sensitive vaccines, and good understanding towards the conditioning of ice packs, proper vaccine arrangement in a cold box and vaccine carrier, this finding is consistent with study conducted in Malaysia were about 78.7% of the healthcare workers were found to had sufficient knowledge[21], on the other hand it contradict with cross-sectional study conducted in Nigeria which recruited 78 participants, with only 3.8% of the respondents were reported to had good knowledge[22].

The magnitude of Compliance with vaccine cold supply chain requirements

The finding of this study, revealed that most healthcare facilities adhered to cold supply chain requirement, in which about 29(90.6%) facility had a special person allocated for vaccine cold chain activities, 29(90.6%) facility had a special refrigerator for the vaccine activities, 30(93.6%) facility had a functional refrigerator special for vaccines, and about 32(100%) facility had a regular audit for vaccine cold supply chain practices; however, there was significant gaps that were observed in the availability of functional backup fuel power or an alternative power source in case of electricity cut off. This finding is consistent with a study conducted in Ethiopia, which highlighted the inadequate backup systems as the challenge facing the cold supply chain[16].

The study revealed that most healthcare facility didn't have the dedicated room for vaccine cold chain activities in which only 11(34.4%) facility were found to have specified room that was allocated for the

vaccine cold chain activities, along with that only 15(46.9%) of the healthcare facility ensured the utilization of the standard operational procedures (SOP) for vaccine cold supply chain, this observed defects in the cold chain had led to inadequate vaccine storage facilities and mismanagement of vaccine in the cold chain hence leading to loss of vaccine potency. This was consistence with the study conducted in Tanzania and Ghana [17, 19].

Conclusion and recommendations

Conclusion and recommendations

Conclusion

The study highlighted high compliance with vaccine cold supply chain practices in Kilimanjaro's public health facilities, particularly in cleanliness and temperature maintenance. However, while healthcare workers demonstrated good knowledge, gaps remain that indicate opportunities for improvement in various vaccine handling aspects.

Recommendations

- Healthcare facilities should have a reliable backup power in order to keep refrigerators running even during power cuts to ensure the vaccine is preserved.
- Healthcare facility should ensure the vaccine transportation vehicles are equipped with a reliable temperature monitoring system and checklist for documentation process during the moving of vaccines.
- Healthcare facility should allocate a separate room and refrigerator for cold chain activities.

Limitations

The cross-sectional study design used in this study for assessing human vaccine cold supply chain practices and equipment status in public healthcare facilities cannot be used as a general conclusion because of its inability to establish a causal relationship over time.

Declarations

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Author contributions

All authors had full access to the study data and they all took responsibility for the integrity of the data. Study conceptualization and design: S.M.N, R.M, M.M, P.N.K and E.R. Analysis and or interpretation of the data: S.M.N and P.J.A. Data cross-checking and drafting the final version of the results: S.M.N, R.M, G.G, D.O, Y.S, J.C, E,J, J.M, A. E.S, M.M, P.N.K, E.R and J.M. Drafting of the original manuscript: S.M.N and R.M. All authors read, revised, and approved the final manuscript.

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Data availability

Due to the privacy, ethical and institutional restrictions, the datasets used in this study are not publicly accessible. However, they are available from the corresponding author upon reasonable request.

Ethical Approval and accordance

The proposal for this study was reviewed and approved scientifically by the Research and Ethical Committee Unit of the East Africa Community (EAC) Regional Centre of Excellence for Vaccines, Immunization and Health Supply Chain Management with reference number EAC RCE-VIHSCM-2023. Also the permission to conduct the study was granted by the Office of the Regional Administrative Secretary, Kilimanjaro (Ref. No. DC.109/228/01J) and by the Moshi Municipal Council (Ref. No. MMC/M.20/45/VOL.33/111). The study was conducted in accordance with the relevant guidelines and the principles of the Declaration of Helsinki.”

Consent to participate

The written informed consent was obtained from all individual participants included in the study before data collection. All participants were adults (aged 18 years or above), so parental or legal guardian consent was not required. Participation was voluntary, and participants were informed of the purpose of the study and of their right to withdraw at any time was repected. Strict measures were taken to safeguard the confidentiality of the collected data. All personal and sensitive information was anonymised and stored securely, the access to the data was restricted to the research team, and no identifying information is disclosed in this publication. Confidentiality clauses were included in the informed consent forms signed by participants to ensure their understanding of and agreement to the privacy measures

Consent to publish

Not applicable.

AI disclosure

The authors used OpenAI's ChatGPT (GPT-5, chat.openai.com) to assist in improving the language, grammar, and readability of this manuscript. The authors take full responsibility for the content and interpretation presented

Competing interests

The authors declare no competing interests.

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