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# Modular vaccine packaging increases packing efficiency

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ABSTRACT

*Background:* Within a typical vaccine supply chain, vaccines are packaged into individual cylindrical vials (each containing one or more doses) that are bundled together in rectangular "inner packs" for transport via even larger groupings such as cold boxes and vaccine carriers. The variability of vaccine inner pack and vial size may hinder efficient vaccine distribution because it constrains packing of cold boxes and vaccine carriers to quantities that are often inappropriate or suboptimal in the context of country-specific vaccination guidelines.
*Methods:* We developed in Microsoft Excel (Microsoft Corp., Redmond, WA) a spreadsheet model that evaluated the impact of different packing schemes for the Benin routine regimen plus the introduction of the Rotarix vaccine. Specifically, we used the model to compare the current packing scheme to that of a proposed modular packing scheme.
*Results:* Conventional packing of a Dometic RCW25 that aims to maximize fully-immunized children (FICs) results in 123 FICs and a packing efficiency of 81.93% compared to a maximum of 155 FICs and 94.1% efficiency for an alternative modular packaging system.
*Conclusions:* Our analysis suggests that modular packaging systems could offer significant advantages over conventional vaccine packaging systems with respect to space efficiency and potential FICs, when they are stored in standard vaccine carrying devices. This allows for more vaccines to be stored within the same volume while also simplifying the procedures used by field workers to pack storage devices. Ultimately, modular packaging systems could be a simple way to help increase vaccine coverage worldwide.


## 1. Introduction

Currently, individual vaccines vials and their component packaging vary significantly in overall length, width, and height. This is because the vaccine packaging size is determined by the dimensions of both individual cylindrical vials (each containing one or more doses of vaccine) and rectangular inner packs that typically contain 10, 20, 50 or 100 vials of a particular vaccine. The variability of inner pack and vial dimensions may hinder efficient vaccine distribution because it constrains packing of cold boxes and vaccine carriers to quantities that are often inappropriate or suboptimal in the context of country-specific vaccination guidelines. In particular, estimating storage space requirements is more difficult with non-standard sizes and in a resource constrained system it may not be possible to take all the vaccines needed in a carrier because of the inefficient packaging. Modularized packaging is one way to address this because the consequent increase in packing efficiency has the potential to reduce storage space requirements and replenishment frequencies. The standardization of packaging also has the benefit of making operations much simpler for personnel since vaccines can be more easily packed and space requirements can be more easily estimated. While vaccine vial size has been a recent topic of academic and policymaker interest, explorations of alternative packing configurations have not yet addressed inner packs [1–10]. The packing analysis in this paper proposes that a solution to inefficient packing caused by inner pack and vial size variability is a modular packing system (where vial and inner pack dimensions are more consistent between different vaccines) that allows for more effective packing into cold boxes and vaccine carriers.

## 2. Methods

We developed in Microsoft Excel (Microsoft Corp.) a spreadsheet model that evaluated the impact of different packing schemes

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for the Benin routine regimen plus the introduction of the Rotarix vaccine. The Benin routine vaccine regimen includes Bacillus Calmette-Guerin (BCG), Tetanus, Measles, Oral Polio, Yellow Fever, Diphtheria–Tetanus–Pertussis–Hepatitis B–Haemophilus influenzae type B (DTC–HepB–Hib), Pneumococcal Conjugate (PCV13), and Rotavirus (Rota) vaccines. Specifically, we used the model to compare the current packing scheme to that of a proposed modular packaging system. The storage device considered is the Dometic RCW25, which is prequalified by the WHO, is used in over 100 countries and was noted as a commonly used storage device in a recent study of in-country vaccine transport devices [11–13].

The RCW25 has a vaccine storage volume with length 40.5 cm, width 26.5 cm and height 19 cm after it is packed with conditioned ice. In Benin, workers at a "Health Post" (the lowest level of the vaccine distribution chain where vaccines are administered) typically travel to a "Commune Store" once per month to pick up vaccines; the amount of vaccines picked up depends on the population characteristics of the catchment area served by the Health Post and is determined by workers at the Health Post based on prior months' demand. The vaccines are transported back to the Health Post in a vaccine carrier using a motorcycle. In determining packing efficiency, analyses of both current inner pack/vial sizes and the proposed modular system considered the number of fully immunized children (FIC) possible and packing efficiency (% space occupied) per fully packed device. The FIC metric ensures that our evaluations are with vaccine carriers that transport the suite of vaccines required for an FIC (as opposed to simply filling the carrier with just one or two types of vaccines).

### 2.1. Conventional packaging configuration

The dimensions in Supplementary Table 1 were used for analyses of existing, conventional inner packs and their constituent vials; the volume of the inner pack is simply the product of its length, width, and height as described by the vaccine manufacturer. These dimensions were used to determine the number of conventional inner packs for each vaccine type that could be placed in the RCW25 in order to maximize the FIC per device. To pack the device, we used a combination of algorithms and manual modifications. Note that each inner pack could be positioned in any orientation and that inner packs of the same type could have multiple orientations (see PCV13 in Fig. 2). For each inner pack combination we placed the inner packs into the storage device until its dimensions prohibited the addition of any more.

In our simulation of storage device packing, the device is filled with the objective of maximizing the number of children that could be fully immunized as per the Benin routine vaccination schedule. This involved two steps. In step 1 we considered the vaccine schedule required for each FIC—for each vaccine we determined the average number of children that can be fully vaccinated per inner pack, based on the scheduled number of doses, the wastage rate, the number of doses per vial and the number of vials per

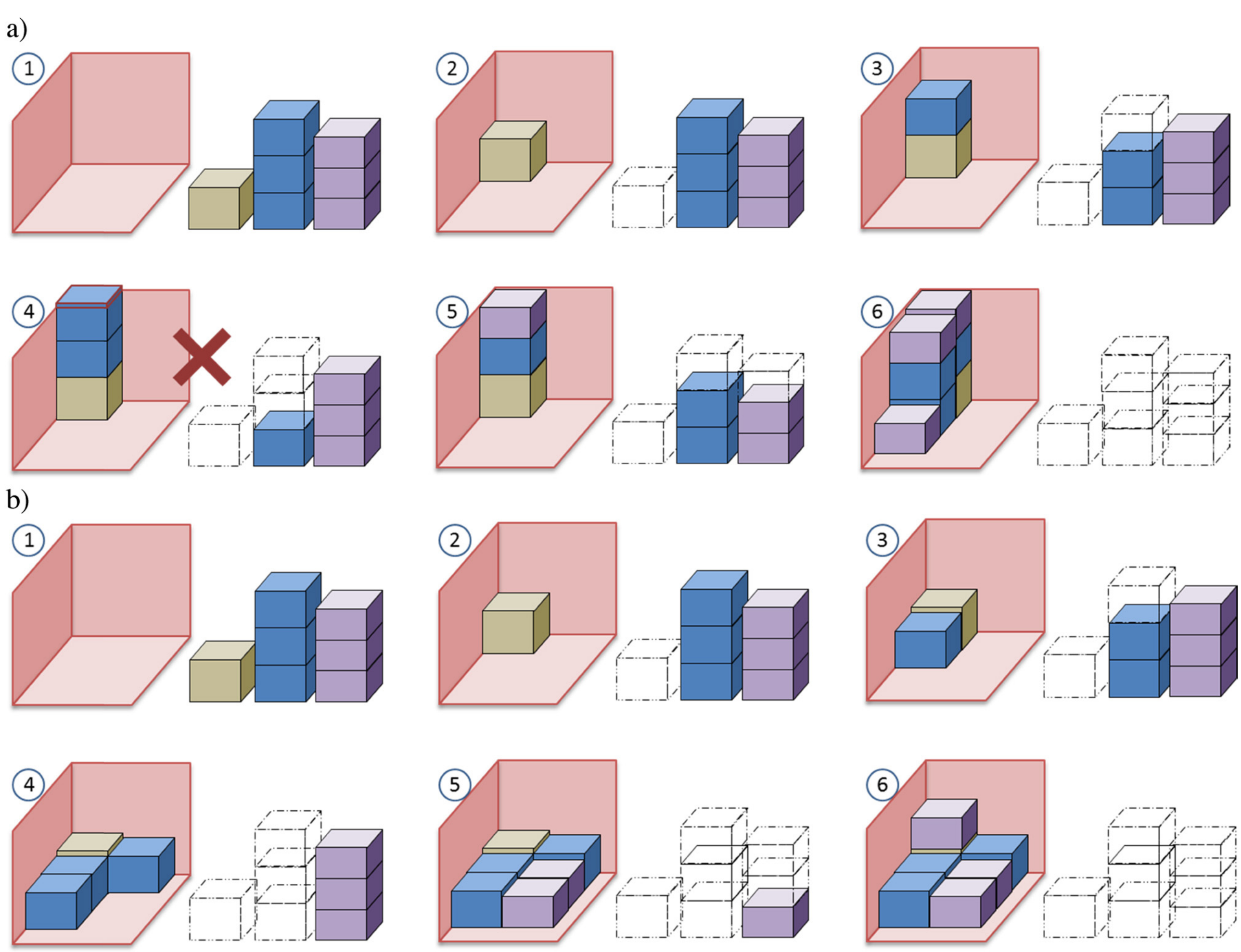


**Fig. 1.** Tower (a) and layer (b) packing methods.