

# Development and Deployment of Electronic Dispensing and Inventory Management system (eDIM) for a Rural Clinic in Honduras

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## Research article

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# Abstract

**Background:** Availability of complete, accurate, and timely information is essential for efficient planning and purchasing of medications. This is especially important in remote low-resource clinics that are often difficult to access, have limited health personnel, and receive supplies infrequently. Appropriate application of information technology can help address challenges in the availability and quality of data used for making decisions about purchasing medical supplies.

**Methods:** We used a phased deployment of electronic information systems to address challenges in quantification of the available medical supplies at the clinic in San José. First, we deployed a patient identification system to ensure that all medicines dispensed in the system were associated with a specific patient. This was followed by the deployment of an electronic dispensing and inventory management system that tracks available medicine and automatically deducts from these counts during electronic dispensation.

**Results:** Twenty months post-deployment of the patient identification application and electronic dispensing and inventory management system, 3,238 unique patients have been registered and 22,236 dispensations have been recorded. Of these dispensations, 226 unique drugs have been recorded with acetaminophen being the most prescribed medication followed by adult multivitamins.

**Conclusion:** Electronic interventions show significant promise for dispensaries in limited resource settings globally. However, strong user value propositions are needed to ensure continued usage.

## Background

Shortages of essential supplies continue to be a major challenge in the provision of healthcare in many low-resource settings. [1] Establishing reliable supply chains in these settings is often undermined by unavailability of timely, complete, and accurate information on the consumption and demand of supplies. [2] This information is essential for efficient planning and purchasing of supplies used in healthcare. Efficient planning is particularly important for remote low-resource clinics, which are often difficult to access, have limited health personnel, and receive infrequent medication supply shipments.

Medications are one of the fast-moving essential supplies used in healthcare. Drug therapy continues to be the most common form of treatment with 74% of all ambulatory hospital visits resulting in a minimum of one drug being prescribed. [3] Maintaining an optimal supply of frequently prescribed medications is therefore important to ensure continued provision of quality healthcare. Stock-outs of frequently prescribed medications can be disruptive in the delivery of healthcare and more importantly, critical drug shortages can lead to poor health outcomes. [4]

Critical drug shortages continue to pose a significant barrier to healthcare delivery in low- and middle-income countries (LMICs). [5] LMICs have to contend with the dual challenge of a disproportionately higher global disease burden and inadequate resources for health services. [6] To further compound the

situation, LMICs have a high prevalence of non-communicable diseases (NCDs) with 75% of all NCD-related deaths occurring in this setting. [7],[8] Maintaining an uninterrupted supply of medication in these settings will be crucial to reducing the global disease burden.

Several solutions have been proposed to reduce medication stock-outs. The World Health Organization (WHO) maintains a model list of essential medicines; these are medicines that cater to the priority healthcare needs of most populations. [9] The WHO recommends that health facilities globally should always have an adequate amount of these medications in stock. By prioritizing a limited number of medications, it is expected that a country can treat most of its health needs. However, low-resource settings often have competing demands for the limited financial resources available. Hospital administrators often need to make tough choices between various essential requirements to maintain their facilities, such as allocating resources toward additional staffing needs versus buying commodities. Furthermore, poor road networks, a common characteristic of most low-resource settings, makes transportation of medical supplies to these health facilities particularly difficult.

Appropriate application and use of information technology can play a role in addressing medication stock-outs. Electronic information systems may help improve decision making by increasing both the availability and quality of medication data. This could potentially be achieved through the use of an electronic system for dispensing medications and managing inventory. In a medicine dispensary, the system would be used to record receipt of new items into the inventory. The items can then be subsequently removed from the inventory individually as they are being dispensed to patients. If dispensed electronically, the dispensed amount can be subtracted from the stock levels to maintain an accurate count of items in stock. We refer to this concept as electronic dispensing and inventory management (eDIM). We hypothesize that a system with these capabilities can reduce time spent on reporting, improve dispensation workflows, streamline procurement processes, and increase the completeness and availability of data for pharmaceutical inventory management in an LMIC setting.

In this manuscript, we describe the development of an electronic information system designed to minimize interruptions in the availability of pharmaceutical supplies by improving the quantification of demand and use of medicine at a rural clinic in San José del Negrito, Honduras. While the system described here was optimized for this particular clinic, our approach and the lessons learned from this implementation are applicable in other LMIC health facilities.

## Methods

### *Setting*

The system described in this manuscript was implemented at a rural clinic in the town of San José del Negrito, a roughly 45-minute drive outside the city of San Pedro Sula, Honduras. This clinic is wholly supported by the Shoulder to Shoulder Pittsburgh-San José Organization, which has been working with the community since 2000. In that time, the clinic has grown to employ two full-time Honduran staff - a physician and a nurse, and a part-time dentist. The clinic operates during weekdays and serves as the

primary healthcare facility for a catchment area of roughly 5,000 people. The doctor is available outside regular clinic hours to deal with emergencies. In addition to providing primary care services, the clinic also runs a non-communicable diseases (NCD) clinic every two months. To meet the pharmaceutical needs of the clinic, large medication orders are placed twice annually with international generic wholesalers. This covers a majority of the pharmaceutical requirements. Local pharmaceutical purchases are used to fill any gaps in the formulary, including covering stockouts that may happen between the two international orders and access to medications not available through international generic wholesalers. The cost of medications procured from the local retailers is often higher than those from the international wholesalers. Furthermore, due to the remote location of the clinic, local pharmaceutical purchases are undesirable to the clinic staff as it compromises their personal safety. Therefore, reducing the number of local purchases makes more resources available for the clinic and simplifies purchasing for the Honduran staff.

This research was reviewed by the University of Pittsburgh Institutional Review Board and classified as exempt.

### *System design and development*

The system was designed to facilitate an uninterrupted supply of medication at the clinic in San José. To achieve this, we had to uniquely identify medications to keep track of available items in the inventory and dispensed medications. Best practice in medication dispensation and administration also requires that all dispensed medications be labeled with patient name, directions for use, and medication name. We therefore decided to uniquely identify all patients that were receiving services at the clinic. This enabled us to add value for the user by printing the patient's name on the medication label. Additionally, this allowed us to maintain an electronic medication history for all patients and provide an audit trail for the medications as all dispensations can be linked back to specific patients. Maintaining accurate medication histories can help reduce the chance of medication errors, improve medication reconciliation, and assist in the case of medication recalls. [10] Furthermore, the printing of medication dosage and directions on the label ensures legibility of the prescription and addresses a common source of medication errors: poor or illegible handwriting. [11]

### Designing the Patient Identification Module

While Honduras has a national policy of issuing identity cards to its citizens, we did not know the prevalence of this identifier in our catchment area. Furthermore, only citizens above the age of 18 are issued an identity card, leaving children without any means of unique identification. [12] With this understanding, we decided to implement a patient identification system as the first module of the electronic interventions so that all patients of the clinic receive a unique identifier. In addition, as the patient registration process was relatively straightforward, it afforded us the opportunity to assess the feasibility of running an electronic system in this setting. We utilized our previous work in Malawi to develop and customize the patient identification system for the clinic. [13]

## Designing the Electronic Dispensing and Inventory Module

We based our approach to inventory management on concepts from the Prescription Management And General Inventory Control (RxMAGIC) system we had previously developed for an underserved clinic in Pittsburgh. [12-14] This approach is grounded in the use of electronic dispensing to quantify medication consumption, reducing the need to do frequent periodic counts of inventory on hand, and allowing for alerts and reminders for medications with low stock. The approach further involves pre-labeling all medicines such that every item that can be dispensed has a unique identification number in the stock management system. The unique identifier is printed on an adhesive label that is attached to the medication packaging. This pre-work allows the time-sensitive dispensing process to move more quickly, reducing the length of the queue for people waiting to have prescriptions filled.

## Leveraging scientific concepts from RxMAGIC

To accommodate for both environmental and cultural differences in the San José clinic, we made four major modifications to our underlying model for the RxMAGIC system.

With RxMAGIC, we utilized RxNorm, a standardized medication nomenclature developed by the United States National Library of Medicine, to uniquely identify the medications. [16] However, because the RxNorm vocabulary does not provide full coverage for medications and other supplies used outside of the United States, we opted to use a custom drug list for the clinic in San José. We used the medications purchased in previous drug orders to develop this list.

To facilitate medication dispensing, the RxMAGIC system receives electronic prescription orders via outbound Health Level 7 messages from EPICARE, an ambulatory EMR. As the clinic in San José does not have an EMR to generate electronic prescriptions, we customized the user interface to support a dispensing-only workflow.

The patient identification, electronic dispensing, and inventory management modules were designed to require minimal training, even for novice users without prior computer literacy. We therefore decided to implement touchscreen clinical workstations, which have demonstrated high learnability in these settings, for capturing all patient demographics and dispensations. [17], [18]

To further serve the local setting, all prompts and messages in the system are in Spanish, the official language in Honduras. All software development and customization were done in Pittsburgh by the Center for Health Informatics for the Underserved, part of the University of Pittsburgh Department of Biomedical Informatics.

## *System Implementation and Ongoing Support*

We utilized a phased deployment of electronic interventions to address challenges in pharmaceutical inventory management at the clinic in San José. In phase 1, we deployed a patient identification module. Our goal was to allow sufficient time for the clinic staff to integrate the relatively straightforward patient

registration process into their standard workflow and ensure that the system was stable and working as intended prior to introducing the more complex electronic dispensing module. In phase 2, we deployed the electronic dispensing and inventory management modules, which maintain stock counts of all items in the electronic inventory and automatically deducts from these counts when a particular medicine has been dispensed.

Due to the operating model of the clinic, pharmaceutical procurement is done once every six months. Consequently, any under-estimation of demand can result in a prolonged stock-out. A core requirement for this system was to provide the US-based medication procurement team with accurate medication consumption data that could inform new medication orders. To enable access and use of consumption data in this way, it was critical that system downtime and hardware defects be minimal. Further, it required that the users consistently use the system to maintain accurate inventory counts. This could best be achieved by building-in a significant value proposition for the users.

To minimize system downtime, we designed the system to have a small but robust footprint in terms of hardware. A server was deployed onsite to host the patient identification, electronic dispensing, and inventory management modules. Remote data backup was configured to ensure that no information was lost in case of complete server damage. Furthermore, to reduce the amount of work needed to set up the modules at the clinic, we used the existing wireless network to connect the touchscreen workstations to the server. This decision eliminated the need for network cabling and additional networking devices that could increase the potential points of failure in the systems architecture. All of these decisions were based on the understanding that the clinic does not employ any information technology specialists.

## Results

The patient identification system was deployed in September 2016. The nurse was trained on the system and started registering patients attending the clinic. This was followed by the deployment of the pharmacy system in April 2017. The eight months between these deployments allowed the nurse to become proficient with using the identification system before adding additional modules.

In the 20 months following the deployment of the patient identification module, 3,238 of patients have been registered and 22,236 dispensations have been recorded. A breakdown of patient demographics as captured in the identification system is shown in Figure 1. Of the total dispensations, 226 unique drugs have been recorded. Acetaminophen followed by adult multivitamins were the most prescribed medications overall. A summary of the five most frequently prescribed medications broken down by product and therapeutic class is provided in Table 1.

Table 1: Five most frequently prescribed medications by formulation and therapeutic class

| Prescriptions by product                 | Prescriptions by therapeutic class |
|--|------------------------------------|
| Acetaminophen 500mg tablets (6.7%)       | Infectious Diseases (22.7%)        |
| Adult Multivitamins (6.0%)               | Pulmonology/Allergic (18.3%)       |
| Albendazole 400mg tablet (4.0%)          | Analgesic (18.1%)                  |
| Diphenhydramine 12.5mg/5ml liquid (3.5%) | Cardiology (15.7%)                 |
| Aspirin 81mg tablets (3.4%)              | Nutrition (13.7%)                  |

### *Patient Identification Implementation: Benefits and Challenges*

To account for a lack of technical expertise in the remote area where the clinic is located, all configuration of the hardware required for the implementation of the patient identification system was done and tested in Pittsburgh where the system was developed. When the hardware was transferred to the clinic, the local staff simply had to connect the different pieces of hardware to electricity outlets to start using the system.

The patient identification system is designed to provide a way of uniquely identifying all patients that come to the clinic. On the first visit to the clinic, a patient's demographic details are entered in the system and a unique identification number is assigned to the patient. This identification number is printed on a 3-inch by 2-inch adhesive label in both human readable form and as a barcode together with the patient name, gender, and date of birth. The label is affixed to a plastic credit-card sized card which the patient keeps and uses to identify themselves on all future clinic visits. A sample ID card is shown in Figure 2. Scanning the barcode label on the patient identification card displays the patient demographic record in the system.

While it is possible to print the patient demographic details directly on the plastic card, we decided against that approach as the overall cost of such an implementation would be high and potentially unsustainable. Specialized card printers require ink cartridges that can be expensive and a clean, dust-free environment for sustained use.

Our approach of printing on adhesive labels was further justified by a potential use case of the patient identification system that we had not anticipated in our initial planning. The nurse at the clinic used the labels printed after patient registration to improve her paper filing system by printing a second label to affix to the corresponding patient record. This was used to double-check the correct patient and further eased the dispensation of medication even when the patient forgot to bring their card to the clinic. This unanticipated benefit could not be realized if we had used card printers instead of label printers.

## *Electronic Dispensing and Inventory Management Implementation: Benefits and Challenges*

While the introduction of the patient identification system required minimal training and pre-work, preparing eDIM for use was more labor-intensive. All medication stock-on-hand had to be entered into the system and receive an inventory label prior to electronic dispensation. A sample label is shown in Figure 4. We were fortunate that the deployment coincided with a visit for roughly fifteen medical and pharmacy students and residents from the United States, including a pharmacy resident and a senior pharmacist, who were able to assist in this process. The nurse was trained on how to use the system through the use of an interpreter (See Figure 3).

To quantify consumption, eDIM deducts items that have been dispensed from the current stocks of that item. Only items that have been previously recorded in inventory can be dispensed. To initiate a dispensation, the user first scans a patient identifier to display the patient demographics and medication history before selecting to dispense an item. The user selects the medication to be dispensed, its dose, and the duration for which the medication should be taken. This information is used to define the instructions that are printed together with the patient's name and medication on an adhesive label. The label is then affixed to the medication bag and given to the patient (see figure 4). At the completion of this process, the system deducts the dispensed amounts from the existing stock levels to maintain an accurate inventory.

### *System Costs*

Implementing electronic health systems requires several resources that come at a cost. These resources include hardware on which the information system will run and supplies such as ribbons and labels. All hardware used to implement the eDIM and patient identification system at the clinic in Honduras and their costs are summarized in Table 2. These costs represent one-off capital investments to setup the electronic interventions at the clinic. There are few ongoing costs to maintain the system, such as purchasing the adhesive labels used for patient identification cards, labeling inventory, and printing prescription/dispensation labels. Each label costs roughly \$0.02 USD. We estimate that 31,000 labels have been used since system implementation at a cost of \$620 USD, or roughly \$300 annually. Use of the system did not noticeably increase the electricity utility bills for the clinic. Therefore, electricity is not included as part of ongoing system maintenance.

Table 2: A summary of the equipment required to implement the patient identification and eDIM systems in the San José clinic.

| Item  | Quantity | Cost   | Total  |
|---|----------|--------|--------|
| 19-inch Touchscreen computer (Acer eeeTop, used)              | 1        | \$ 200 | \$ 200 |
| 15-inch Point-of-Sale terminal (J2 Retail Systems, Model 615) | 1        | \$ 600 | \$ 600 |
| 10-inch Touchscreen Clinical Workstation (Raspberry Pi)       | 2        | \$ 140 | \$ 280 |
| Custom Low-power Server (Mini-ITX, Intel i7, 4GB RAM)         | 1        | \$1000 | \$1000 |
| Wireless router (MikroTik Rb751)                              | 1        | \$ 85  | \$ 85  |
| Thermal label printers (Zebra TLP-2844, used)                 | 4        | \$ 100 | \$ 400 |
| Barcode scanner (Symbol LS2208, used)                         | 4        | \$ 25  | \$ 100 |
| <b>Total</b>  |          |        | \$2665 |

## Discussion

This manuscript describes our experience developing and implementing electronic interventions in a clinic in rural Honduras. This was the first electronic system to be implemented in this setting. The first intervention, a patient identification system, was aimed at uniquely identifying all patients of the clinic by producing a label with the patients identifying details. The second intervention, the eDIM system, enabled electronic dispensing and automated stock maintenance to inform US-based medication ordering.

The value to be gained from an information system depends on how the user interacts with it, the outcome of which cannot be fully predicted in advance. [19] We had not anticipated that the patient identification system would be used to improve patient record filing and organization. While not the intended use of the system, we were pleased to see the added value that label printing was providing to this workflow.

The second intervention introduced the notion of electronic dispensing to quantify demand and consumption of medications. In addition to streamlining dispensing practices at the clinic, the primary goal of this intervention was to enable the US-based procurement team access to real-time consumption data to facilitate medication ordering. This should minimize inventory gaps at the clinic between bi-annual orders and reduce the need to purchase local supplies, ultimately saving clinic resources that can be allocated elsewhere.

While its use case is generalizable across LMIC settings, the implementation of this eDIM differed from our previous work (RxMAGIC) in the underserved clinic in Pittsburgh to accommodate for both cultural and environmental differences. Most notably, the clinic in San José did not have existing electronic prescribing capabilities, which was a driving factor behind our implementation efforts in Pittsburgh. While an electronic prescribing module could have been developed for the clinic in San José, this would have

introduced the first and only clinician-facing application at this site, thus altering the clinical consultation experience for both the physician and patient. An argument can be made that such an intervention could provide significant value, such as providing prescription guidelines as a digital job aid and informing the physician of available medication at the point of care. However, introducing all of these electronic changes at once could have overwhelmed the clinic staff and hindered the success of any individual module. The risk of failure with so-called “big-bang” implementations where multiple interventions are deployed concurrently is significantly higher than with incremental changes. [20]

Justifying the implementation of electronic information systems in low-resource settings is not easy. To begin with, it is not always clear whether this is the best use of the limited resources. Furthermore, implementations such as those described here may incur significant costs that are not immediately apparent. It is therefore important to be able to articulate the nature and magnitude of the problem that the electronic information system is meant to address. Furthermore, the electronic information system must be implemented in a way that minimizes ongoing support and maintenance cost.

Through our experiences with implementing electronic interventions in LMIC settings since 2001, we have converged on the use of touchscreen appliances and thermal printers as our standard hardware platform. Not only do these devices reduce upfront implementation costs, they also require little maintenance thereby reducing the total cost of ownership. Further, as computer literacy may be lower in these settings, touchscreen appliances reduce the learning curve for the users resulting in an earlier adoption of the intervention. [17]

For the implementation in San José, we repurposed an eeeTop computer and a J2-615 Point-of-Sale terminal. However, both of these computers developed calibration issues on the touchscreen that made them difficult to use over time. We resolved this by replacing them with Raspberry Pi touchscreen clinical workstation, which has proven to be more reliable. While the smaller screen on the Raspberry Pi touchscreen clinical workstation reduced the amount of information that could be displayed, the significantly lower cost and power consumption were very compelling. Furthermore, the software was designed with a “low information density” user interface such that the smaller screen had no apparent impact on performance or user satisfaction.

Another significant differentiator of this eDIM implementation was our departure from RxNorm as the medication vocabulary, which was required to facilitate integration with the existing electronic prescribing system in our prior implementation. While a standard vocabulary enables system sustainability and interoperability, RxNorm has incomplete coverage of non-drug items such as supplies, equipment, and multivitamins, all of which are routinely dispensed in this setting. Further, as a controlled vocabulary intended for use in the United States, RxNorm does not sufficiently represent medications prescribed in other countries. To this end, we chose to develop a custom drug list for use in the San José clinic. We recognize that use of a non-standard vocabulary can affect system generalizability, maintenance, and the potential to integrate with other applications. However, these implications may not be as relevant in this setting given a lack of other health information systems that require data sharing and an incredibly

limited yet specialized formulary. Thus, there are limited benefits to using a vocabulary such as RxNorm in this setting.

## **Limitations**

Due to the semi-annual procurement schedule of medications for the clinic, we have not yet had enough opportunities to fully measure the impact of the eDIM system on stock maintenance and turnover. We intend to use these data in the next procurement cycle of pharmaceuticals for the clinic.

## **Conclusion**

Electronic interventions show significant promise for dispensaries in limited resource settings globally. However, to achieve the desired outcome of uninterrupted supply chain of pharmaceuticals, interventions like the eDIM must be incorporated into the daily workflow in dispensaries to enable complete and accurate consumption data. Strong value propositions such as the reduction in workload, streamlined processes, and improved communication with both patients and suppliers increase the likelihood of continued use of these interventions in clinical practice.

## **Future Work**

In the future, we plan to conduct a more comprehensive assessment of the impact of the eDIM system on the clinic's supply chain and supporting processes. We hypothesize that the information gleaned from the eDIM can inform and improve the semi-annual ordering process of pharmaceutical supplies at the clinic. Specifically, we would like to evaluate the quality and completeness of stock levels and consumption rates from the eDIM with the aim of utilizing this information for the modeling of pharmaceutical demand at the clinic.

## **Abbreviations**

LMICs, low- and middle-income countries; NCDs, Non-communicable diseases; WHO, World Health Organization; eDIM, electronic dispensing and inventory management; RxMAGIC, Prescription Management and General Inventory Control;

## **Declarations**

*Ethics approval and consent to participate*

This research was reviewed by the University of Pittsburgh Institutional Review Board and classified as exempt.

*Consent for Publication*

Not Applicable

### *Availability of Data and Materials*

Not applicable

### *Competing Interests*

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

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### *Authors' Contributions*

TMM drafted the manuscript and developed all the required software components. AMF conceived the original idea of the eDIM and managed the software development. AMF and LJJ conducted on-site workflow assessment at the San José clinic. LJJ and SEC were the pharmacy domain experts and provided guidance on best practices and workflows for pharmacies and dispensaries. MWM was responsible for coordinating activities in the San José Clinic and the deployment of the patient registration module. GPD was responsible for coordinating the overall development of the system, customized all hardware for the implementation, designed the network architecture, and deployment of the eDispensing module. All authors critically read and revised the manuscript before approving it.

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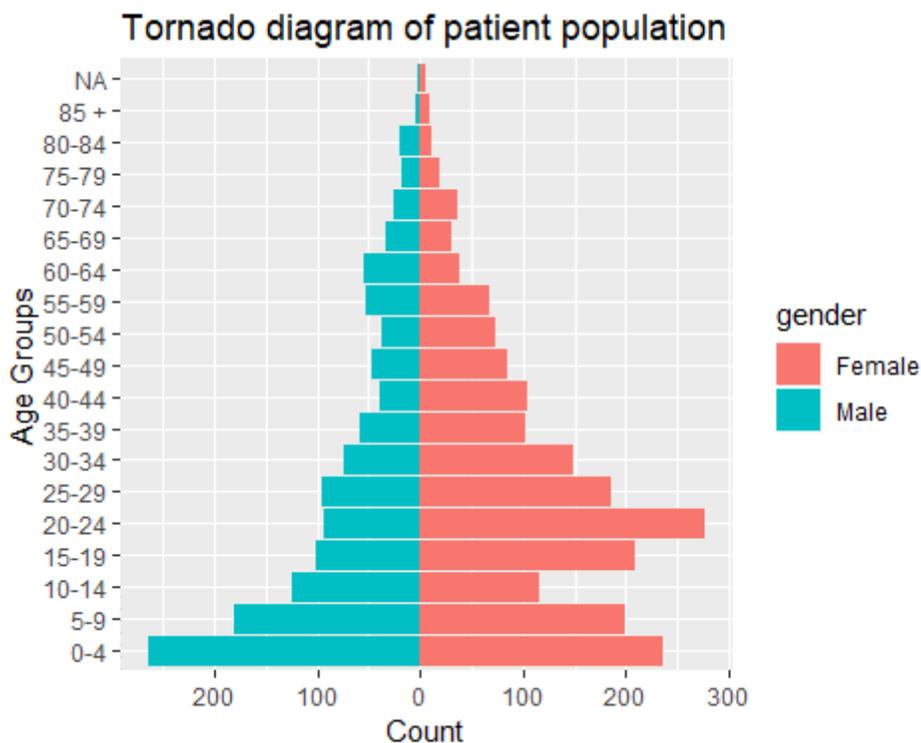
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## Figures



**Figure 1**

Breakdown of patient demographics at the clinic since the system was implemented.



Figure 2

Sample patient identification label.

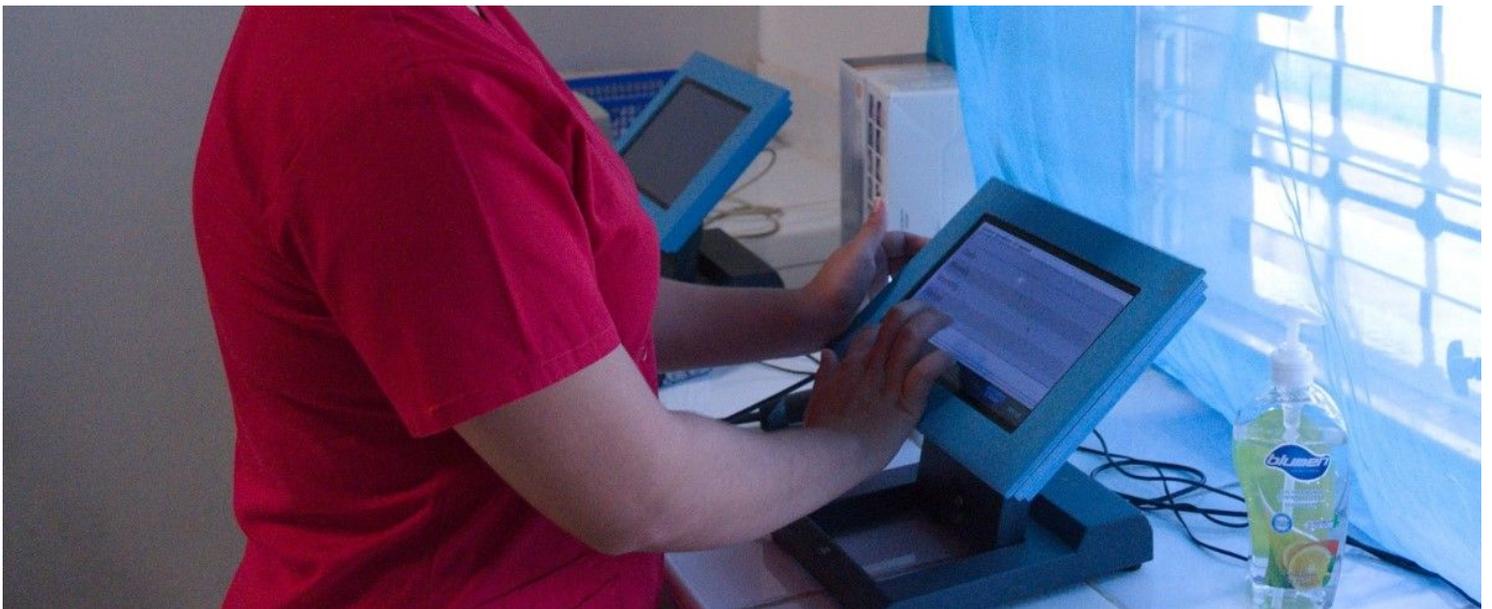


Figure 3

Nurse using the eDIM system to dispense medications.



**Figure 4**

Sample of dispensation label generated after electronic dispensation.