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Introducing a Mobile Drug Formulary for Healthcare Professionals in Mauritius

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Background and Purpose: Prescribing errors and faults are common in medical practice and are more prevalent among young doctors. These are mainly due to erroneous medical decisions that can unfortunately cause much harm to the patients. This study aimed at exploring avenues of promoting medication safety by providing comprehensive details about the branded medications available in the Mauritius market through the development of a mobile Drug Formulary application for Mauritius.
Methods: Drug information were sought from pharmacies and wholesalers. The medications were categorized anatomically and relevant information about each medication was retrieved from established databases such as the British National Formulary and Vidal. A mobile framework was designed which allowed an administrator to upload a list of drugs on a cloud environment and the mobile devices to connect to this environment on start-up to download the updates, if any, to the local device.
Results: A database has been created with the existing medications provided by the participating wholesalers in Mauritius. An Android and iOS compatible mobile application was developed that linked to the database on the cloud and enabled loading of all information on demand. A user-friendly prototype with access to comprehensive information about drugs currently available on the Mauritian market was hence implemented.
Conclusions: This is the first initiative to develop an e-tool to facilitate the prescribing of medications in Mauritius. Further work is underway to improve the database as well as setting up of a reliable strategy for updating the database.

Keywords: Drug Formularies, E-health, medication safety, Mauritius, mobile application

1 Introduction

Drug safety is an important pillar in delivering quality healthcare and ensures that patients are prescribed and dispensed medications in the safest possible way. Stringent strategies such as Food and Administration regulators, pharmacovigilance and drug monitoring systems regulate all stages in drug development process including conception of a drug, marketing and monitoring of the adverse drug reactions. Despite rigid control, evidence shows that patients are increasingly facing the outcomes of poor prescribing practices. Mauritius, a developing nation is not spared from this precarious tendency.

Mauritius is a middle income, sub-Saharan country, situated on the East coast of Africa. With a population of 1.2 million and a yearly influx of around one million tourists, it has experienced major development in the economic and tourism sectors. The health system is an essentially free system where more than 80% of the population use the public sector [1]. The welfare state uses the principles of free

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health for all through the access of free medical services from primary care to secondary [2]. Health is delivered through a decentralized 5-zone system where each zone is guided by its respective Health Advisory Board, which acts under the umbrella of the Ministry of Health and Quality of Life (MoHQL), the main governing body for the health system in the country. The MoHQL is responsible for all health-related policies, regulations, and coordination both nationally and internationally [3].

An important aim of the MoHQL is to improve the quality of life and well-being of the population through the prevention of communicable and non-communicable diseases, the promotion of healthy lifestyles and an environment conducive to health. Mauritius has undertaken major leaps in the control of communicable diseases [4] and is at present tackling the rising trend of non-communicable diseases [5]. Capacity building has been the major priority for the MoHQL leading to the training of doctors and pharmacists locally. This has contributed to a boost in the number of doctors and pharmacists practicing in Mauritius, especially in the private sector. There has been an emphasis to further develop the private health system in Mauritius through the promotion of health insurance to meet the needs of the growing population. Private health care is delivered essentially through the 17 private clinics, which provide a high level of diverse medical services and up to date technologies. They are the biggest prescribers of branded medications in the country.

The MoHQL encompasses the pharmacy board and the pharmacovigilance committee, which ensure the proper drug registration and monitoring of drugs coming on the market. There is only one locally situated drug company, while most of the drugs used in Mauritius are imported from several countries across the globe. In 2019, Mauritius spent around 136 million USD on imports of drugs and the private sector accounted for 75% of the imports while the MoHQL accounted for essentially generic products [6]. Branded products came from India, South Africa, France, Germany, and the United Kingdom, where India had been the biggest supplier. There were 33 registered wholesale distributers in the country.

It is established that the private pharmaceutical company is an integral part of the health system. However, there is lack of guidance and information on the branded products that are currently available on the Mauritius market. With imports from different countries, one formulary is unlikely to meet the needs of the medical practitioner. There has been a demand for a tool that combines all the medications that are available in clinics and pharmacies in Mauritius. Hence, an innovative tool that offers a list of currently available branded medications through the use of smartphone applications has been proposed with a view to support safe prescribing in the country.

In this paper, we review the currently available mobile drug formulary applications and report on the development of a digital formulary in the form of a mobile application for the Mauritian market, where safe prescribing has become a national priority requiring immediate attention. We document the different stages in the development of the application and discuss the implications of such a tool in the Mauritian healthcare industry.

1.1 Literature review

A drug formulary contains a list of medicines that are usually approved for prescription throughout the country [7]. It typically includes data on the indication, caution, contra-indication, dosage, side effects and composition of the drugs. There are several national formularies available, for example, the British National Formulary, the Australian Pharmaceutical Formulary, the National Formulary of India and the Jordan National Formulary amongst others. The World Health Organization has also published a WHO Model Formulary which is deemed helpful for countries who wish to develop their own National Drug Formulary [8].

A unique situation prevails in Mauritius whereby the formularies commonly used by doctors and pharmacists are the Vidal, the British National Formulary and the Martindale. In December 2016, the Ministry of Health and Quality of Life implemented General Guidelines for antibiotics prescription with the aim of promoting judicious use of antibiotics and to minimize the spread of resistant organisms [9]. The MoHQL has also recently developed a list of essential drugs but it contained only the names of the generic drugs available on the Mauritian market. Therefore, the need of a comprehensive drug formulary for the country is of utmost importance [10]. Table 1 highlights the primary aim and features of some common mobile drug formulary applications.

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Table 1: Features of some common drug applications

App Name	Aim	Features
Drug Formulary [11]	To provide evidence-based knowledge and tools to help prevent cancer and deliver high-quality care	Access to evidence-informed regimen information for healthcare professionals and patients. Information about public funding and reimbursement programs and forms for prescribing take-home chemotherapy.
Formulary Search [12]	Aims at being the single source of reliable and current drug coverage and restriction information for prescribing doctors	Updated nightly, ensuring that doctors have the data points needed to guide prescribing decisions for patients. It includes over 6,500 health plans, drug access across location and channel, search coverage information by various forms of a drug and alternative drug coverage information.
Mosby's Drug Reference for Health Profession [14]	Advertised as a must-have item for every current or aspiring health professional in the field today	Concise, reliable information that is easy to navigate and simple to follow. Key details are presented in short monographs for 1,000 generic drugs (including 4,500 trade-name drugs) that are listed alphabetically and that include drug name, pronunciation, trade name(s), category and schedule, classification, mechanism of action, pharmacokinetics, availability, indications and dosages, contraindications, interactions (drug, herbal, and food), diagnostic test effects, side effects, serious reactions, and precautions and considerations. It also features information about chemotherapy, ophthalmic, and other pertinent drugs.
The Medscape mobile application [15]	Features a drug reference tool with the current prescribing and safety information	A drug interaction checker, medical calculators, procedure reference and formulary information are also found in the app. Moreover, healthcare professionals can interact with a community of physicians over the world to ask questions, share cases and gain from their knowledge and experiences

Haffey et al. [16] conducted a search on the six main smartphone application stores and provided a list of applications designed for healthcare professionals. These applications provided drug reference and prescribing materials. They reported that some applications included drug calculation capabilities, drug dose or infusion calculator functions, drug interactions, support for e-prescribing apps and drug formularies. Some applications included a drug reference resource for logging clinical events and medications while others allowed the pharmacists to monitor their patients-controlled drug usage

Based on the overview of drug formulary mobile applications, a critical analysis has been performed highlighting the main features and weaknesses of these mobile applications. It was observed that many drug formulary mobile applications offer a comprehensive drug database with detailed drug information such as name, dosage, pregnancy, drug reactions amongst others. Many of the applications are quite established and are regularly updated to cater for new or discontinued drugs. Offline support is also an important functionality where the application can be used without any internet connection. Some mobile applications include other functionalities such as price comparator, reminders and disease dictionary among others.

However, it was also noticed that many mobile applications were specific to countries. Some examples include the specially designed application for the Philippines, EMDEX 2017 for Nigeria and Medical Guide App Pakistan with an authentic list of brands of all pharmaceutical companies of Pakistan. Many medical schools also had mobile applications for their students. Examples include UBC Med Formulary for University of British Columbia (UBC) medical school and Personal Formulary for University of Liverpool

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medical students. Therefore, since the brand names are specific to one country, the existing mobile drug formulary applications do not reflect the list of brands available on the Mauritian market.

2 Aims

The uses of a drug formulary have evolved with time and technology, from a simple list of medications to be used by a specific institution to a specialized mobile application providing accessible information about complex and new medications within a simple click. The fast pace of development in this sector has pushed for applications and formularies with refined features to adapt to the growing needs of a varied population. The aim of this study is to provide a tool that assists in prescribing and dispensing as well as reduce medication errors in Mauritius. At present, there are limited guides to prescribing especially in private practices. The prototype has been tailored to the Mauritian market and therefore contains a database of medications available locally. The primary aims of the study are to:

- Develop the prototype of a formulary that suits the Mauritian context,
- Assess the opinions of the different stakeholders during and after the development of the prototype, and,
- Reflect on the feasibility of the implementation of such a system for Mauritius.

We anticipate that the provision of such a tool will definitely enhance the safety of medication prescribing.

3 Materials and methods

This section of the paper reports on the methods used to design and develop the drug formulary application. The main steps of our methodology include the building of the mobile application and validating the mobile application through stakeholder workshops.

3.1 Developing the application

The application was developed based on a classical client-server architecture comprising of a client mobile application and a server with data storage capabilities, as illustrated in Figure 1. The client mobile application was also connected to an offline database for local data storage.

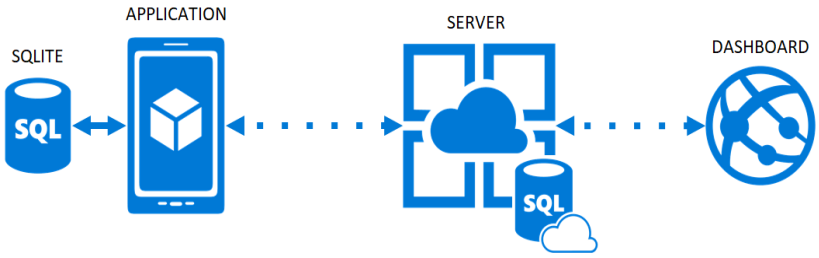

Figure 1: Overall Architecture

The application process consisted of the client initially connecting to the server, a cloud service, to check for new drug formulary records. The cloud service in turn connects to the database to fetch any newly added records and returns the data to the client. Finally, the client saves the data locally (on the phone itself) so that it may be accessed even in the absence of an internet connection.

The mobile application was developed using Xamarin Forms – a development platform that allows the creation of a single application catering for all major systems (Android, iOS and Windows). It was also supported by SQLite for local data storage. The cloud service was developed in ASP.NET Core and hosted on Microsoft Azure. It was designed as a mobile service, hence allowing the mobile application to connect to it and fetch data with ease. The cloud service can be accessed and managed for administrative purposes from a custom web application, also developed in ASP.NET Core. The data storage was enabled through

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Microsoft Azure SQL that allows persistent saving of data and also provides the necessary infrastructure for external entities (such as the mobile application or the cloud service) to access the data. The dashboard is a password protected admin website that will be used by the administrator(s) to update the list of drugs on the system.

3.2 Acceptability of the application

Three focus groups were organized to discuss the importance and acceptability of the project as well as provide feedback on ways to improve the application. Stakeholders invited included policymakers and representatives from the Ministry of Health and Quality of Life, members from the different committees such as the pharmacy board, the pharmacovigilance committee, the medical council and the pharmacy council. Doctors and pharmacists working both in the private and public sector as well as academics and scientists were also invited.

A presentation was made to introduce the application and the main features of the application. Post presentation, a discussion was initiated inviting stakeholders to comment on the importance of the application and suggestions for features. Notes were taken by the different investigators and were reviewed and discussed by the team members.

A second meeting was organized with the members of the Ministry of Health and Quality of Life to discuss the project, where the emphasis was essentially on the feasibility and importance of such a project for the country and for the MoHQL.

The third and final focus group was essentially gathered to review the final version of the application and discuss the implementation of such a system in Mauritius and the potential barriers and solutions. The team members then analyzed all the data qualitatively using a thematic approach.

4 Results

The Drug Formulary Application consisting of two main components: the mobile application and the drug formulary website, is presented in this section, which also outlines the main feedback obtained during the stakeholders' meetings.

4.1 The Mobile Application

The splash screen (Figure 3) appears at the start of the application. In the background, an attempt is made to connect to the Azure website to check for any updates. If there are updated records, these are downloaded automatically on the mobile phone. If there is no internet connection, the previously downloaded data is made available to the user.

The main screen of the application (Figure 4) consists of the logo and three buttons that shall direct the user to the following sections:

- Browse All – Here the user can browse all the drugs sorted in alphabetical order.
- Categories – The section groups the drugs as per the different categories. There are 15 categories altogether.
- Search – The responsive search of the mobile application.

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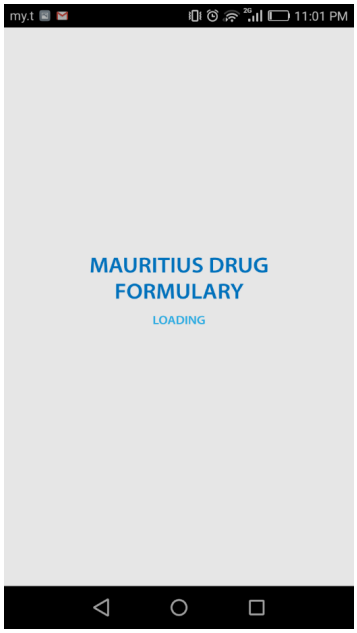

Figure 3: Splash Screen

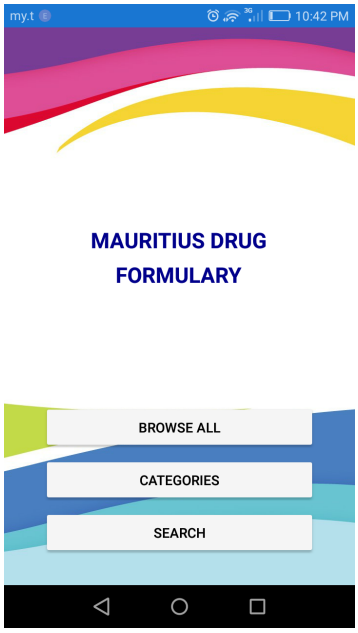

Figure 4: Main Screen

The mobile application has been implemented in such a way that it provides a list of drugs tailored for the Mauritian market. The following details, as shown in Figures 5 and 6, are retrieved for each drug: *indications, class, category, preparations, dosage, cautions, contra-indications, side effects, pregnancy warnings, breastfeeding warnings* and *interactions*. The intuitive user interface easily alerts the user if a drug is classified as high risk.

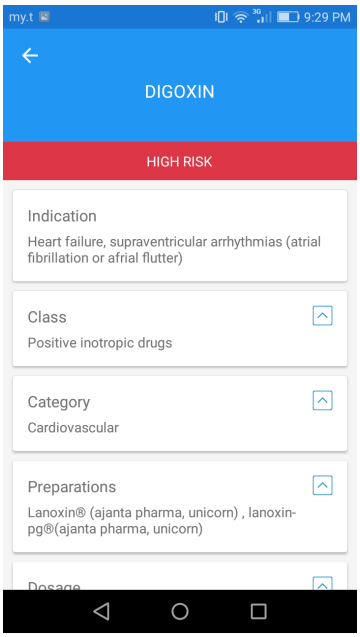

Figure 5: Drug Details

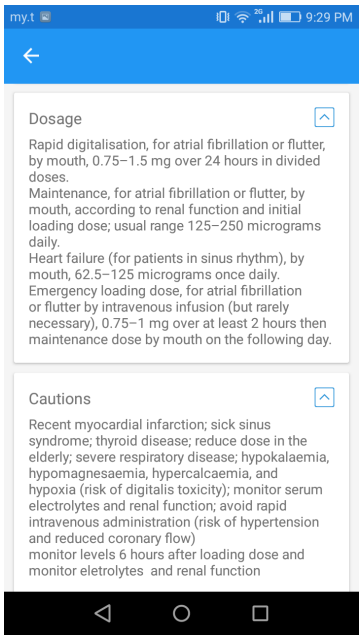

Figure 6: Drug Details

The list of drugs has been classified according to the human anatomical system and therefore the application contains 15 categories (Figure 7), namely: *anaesthesia; cardiovascular; central nervous system; ear, nose and oropharynx; endocrine; eye; gastro-intestinal system; immunological products and vaccines; immunosuppressants and cancer; infections; musculoskeletal and joint diseases; nutrition and*

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blood; obstetrics, gynecology and genito-urinary; respiratory and *skin*. The mobile application also provides a responsive search, shown in Figure 8, that can locate drugs containing a particular keyword. As the user types in the search text, the application refines its list of results. An advanced search feature has also been implemented for more precise queries that could be filtered by each of the different fields. For convenience, a list of recently opened items is also displayed to the user whenever the search page is loaded.

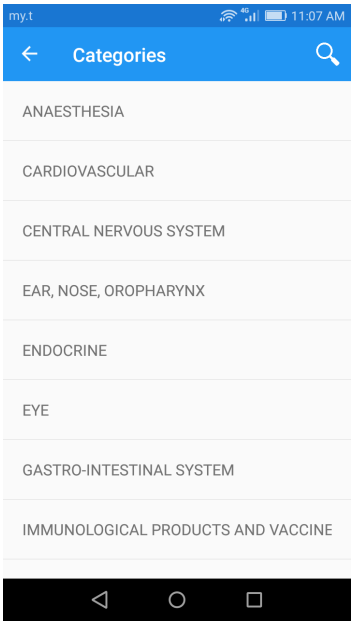

Figure 7: Categories

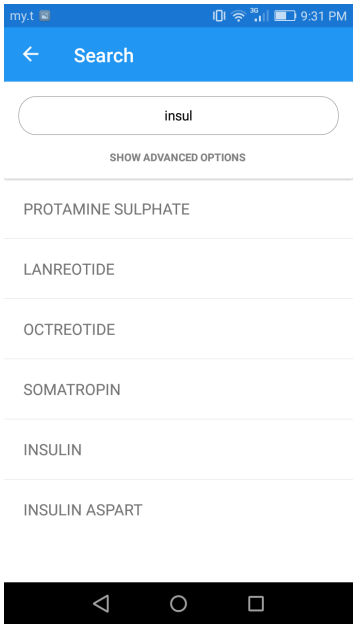

Figure 8: Responsive Search

4.2 The Drug Formulary Website

The Drug Formulary website consists of two main sections:

- A section providing information on the mobile application, its features and other general information accessible to the public.
- A password-protected administration section that is used by the administrator(s) to update the list of drugs on the system.

4.3 Stakeholder feedback

Several themes evolved during the group discussions, namely the importance of such a database for Mauritius and its application in the country, barriers to the implementation of such a system and the need for multi-stakeholder collaboration.

- **Promoting Medication Safety**

The stakeholders present were very enthusiastic about the project since such an application was missing for the Mauritian market. There has been a growing demand for a database or formulary that enlists all medications and brands available in Mauritius. They immediately realized the need and importance of the application as an essential safety tool and more specifically, how the application would be beneficial in the day-to-day execution of their duties.

Some stakeholders described it as 'an easily accessible tool for quick information retrieval' and if geared to the local context, might be highly beneficial as it can promote safer prescribing and dispensing among healthcare professionals. The areas where the tool can be important included highlighting the high-risk

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groups of medications and precautionary advice. They also stated that the application could be a vital tool for new doctors starting their private practice.

- **Improving the Application**

A number of relevant feedback was obtained which the project team did not initially think about. The most recurring and important features were given a higher priority and were implemented accordingly. The workshops proved to be very beneficial as a lot of interesting feedback was received, some of which have been listed below:

- Inclusion of a Drug Interaction section to highlight possible interactions between drugs.
- Incorporation of high-risk medications to visually notify the healthcare professionals of drugs that can pose significant danger to the patient's safety.
- Hepatic and renal impairment, i.e. to inform the health care professionals about the possible effects of drugs in the case of dysfunctions of the liver and the kidney.
- Inclusion of memory of drugs recently visited
- Inclusion of drugs by brand names and wholesalers on the Mauritian market
- Development of an iOS-compatible version
- Regular updates (ideally 6 months) that can be catered through a membership fee
- Collaboration with the Ministry of Health and Quality of Life

- **Barriers to Implementation**

Although the application has been welcomed by several stakeholders, some barriers to the use of the application have been identified including the cost of the application. There are a number of free resources that are currently available and are being used by most healthcare professionals. Therefore, the usage of mobile drug formulary application will depend on the benefits conferred as well as accessibility and the cost of the application.

Additionally, fierce competition with Android applications might make it look less attractive. Another important feedback received has been to regularly update the application which might eventually have an implication on human resources and costs. All stakeholders unanimously agreed that the leading health agency that regulates drug licensing and sales in Mauritius need to collaborate to ensure regular update of such an application.

Local and international wholesalers can also collaborate to update researchers/administration about medication alerts and changes.

5 Discussion

The formulary has been shown to be an established tool worldwide to assist in the prescribing and dispensing practice. The absence of a thorough and up-to-date list of medications in the Mauritius market necessitates the introduction of an affordable, user-friendly and reliable tool that caters for patients and healthcare professionals' unmet educational needs. This project is an attempt to develop such a tool that can foster a healthy prescribing and dispensing practice. The first phase of the study enabled the shortlisting of specific features required for the application, development of a drug database and the design of a prototype for the mobile application.

The prototype was demonstrated in workshops facilitating the validation of the features and the tool. This initiative has been welcomed by members of the medical and pharmaceutical professions.

The choice of medications included in this formulary relies on the participation of the interested stakeholders. However, with the evolution of drug formularies worldwide, new criteria have been stipulated to facilitate the inclusion of medications that are cost-effective in specific formularies. For example, in the US, the approval of specialty medications by the FDA leads to the coverage of the medication by Medicare [17]. The authors reviewed the monograph prepared by a clinical pharmacist which was reviewed by a physician to decide on its suitability for the formulary. The Drug Formulary is currently at its conception phase. The prototype provides a model to be used during the consolidation phase of the formulary. The conventional choice of medications to go on a formulary depends on the needs of the health system. The safest and cost-effective medications are given priority as the role of a formulary is

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to promote cost-effective prescription of medications. However, the absence of a comprehensive list of essential medications in Mauritius calls for a list of medications that can guide new practitioners on prescribing, which can eventually lead to reduced prescribing errors. The Drug Formulary serves the purpose of bringing together the list of branded medications that will cater for the needs of practitioners joining the health system as well as experienced practitioners wanting to try something new safely.

- **Implications of the project**

Several countries are in a similar situation as Mauritius, where there is a need for a comprehensive list and guidance on branded medications. However, resource-limited countries struggle to put such a system in place due to economic and political barriers. Although a very interesting concept, maintaining the quality of the output can be challenging as it demands human and financial resources. Similar Applications are already available such as the Drugs.com [18] which is a database of more than 20 000 drugs and provide general drug related advice. Although it can be used across the world, the information provided can be less useful in different countries due the complexity of the drug import system. While an affordable and cost-effective tool is highly desirable, the systems in several countries might not support the development of such a tool due to poor health system [19]. With the advocacy on E-health, global internet coverage and easy access to smartphones, several countries might consider the formulation of such a digital, safety-enhancing tool. However, this project is in its infancy stage and there are needs for further trials and evidence to facilitate its implementation.

- **Limitations of the Design and Methodology**

The mobile application has been compiled as an Android APK and tested on several Android mobile phones. Although a cross-platform technology was used, the application could not be tested on iOS and Windows devices due to lack of appropriate devices.

The Android mobile application was found to be responsive once the data has been downloaded on the device. However, the initial fetching of drugs takes some time depending on the internet connection. In terms of the functionalities, the stakeholders suggested some cosmetic changes in the third workshop such as personalizing the colors, zooming on the different parts of the application and change the font and its size.

Stakeholders further requested additional options such as personalizing the high risk of medications to the local market based on current practices and malpractices as well as integrating certain features such as a pill check. The next phase of the project aims at reviewing the practicality as well as the importance of additional features in the tool, hence will provide an opportunity to consider the feedback provided.

Although the stakeholders have welcomed the application as a tool to improve prescribing safety, its efficacy needs to be assessed and addressed in the next phase. The practicalities of using such a tool in real life will enable further adaptation of the application.

- **Challenges and Future Directions**

A number of challenges were encountered in the development of a Mauritian Mobile Drug Formulary and are listed below.

  - List of Medications from the Ministry of Health and Quality of Life were not readily available.

A complete list of medications registered on the local market is found at the Ministry of Health and Quality of Life. Negotiations are underway to gain access to the list for consolidating the database and regular updating of the currently available medication list. However, as we had expected, we have to seek appropriate approval from higher authorities for the use of the information which are generally not available to the general public.

  - Reluctance of pharmacies and wholesalers to share the list of drugs

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Most of the Mauritian pharmacies and local and international wholesalers were contacted requesting information pertaining to their individual list of medications in Mauritius. However, only two wholesalers shared their list to be used in the mobile application.

- Reluctance of Wholesalers to share their price list

Wholesalers were not willing to give access to their price drug list. Consequently, it was difficult to include the price of the medications in the application. We were of the opinion that, may be, the wholesalers might fear the fact that their competitors would know the price of similar drugs and hence they might lose a competitive advantage over the others.

- Human power for the development and maintenance of a mobile drug formulary

Human resource was limited due to restricted funds. Ideally, a full-time research assistant had to be recruited for the collection, filtering and verification of the data. The collection of data was also time consuming since the data was manually verified and inputted on the system.

- Dynamic nature requiring regular updates

Such a drug formulary in Mauritius will need regular updating once it is officially launched. Therefore, a mechanism must be thought carefully before embarking on the marketing of the mobile application.

- Efficacy of such a tool in promoting medication safety

Although the main aim of this tool has been to promote safety of medication prescribing, we currently lack objective and quantitative data to show the efficacy of the formulary as a safety enhancing tool. While all the stakeholders agree that it is an essential tool in improving safe prescribing, there is nevertheless the need to do a further investigation to demonstrate the efficiency of the mobile Drug Formulary application in the prescribing process in Mauritius.

6 Conclusion

The medical errors related to prescribing and dispensing of medications can lead to life threatening incidents as recently experienced in Mauritius. This calls for urgent strategies to promote safer prescribing and drug administration practices. A user friendly and affordable tool such as the Mobile Drug Formulary Application in Mauritius can definitely help to improve the current prescribing standards. However, before envisaging a potential marketing of the product, the refinement and improvement of the prototype will be of utmost necessity. Trialing of the application among prescribers in Mauritius will also be important so as to test its efficacy. Furthermore, there will be a need to update the database and peer review the medications on a regular basis. Continuous collaboration with important stakeholders will be essential for the consolidation and implementation of the tool.

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Statement on Conflict of interest

The authors declare that there is no conflict of interest.

Author Contributions

All authors have contributed equally to the work and have read and approved the final manuscript.

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