GADSA: Persuasive Gamified Antimicrobial Stewardship Decision Support App for Antibiotics Prescribing Behaviour Change in Nigeria

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***Abstract*—Antimicrobial Resistance (AMR) is a prominent global threat. The spread of AMR is further accelerated by the inappropriate use of antibiotics. While misuse and overuse of antibiotics are particular global challenges regardless of resources and settings, there is evidence these are amplified in low-to-middle income countries (LMIC) such as Nigeria. While successful antimicrobial stewardship (AMS) programmes have been implemented in LMIC, more research is required to better understand how to overcome some of the underlying reasons and behaviour obstacles, such as lack of training, limited resources, culture and inadequate infection prevention and control practice. This is of particular importance for prophylactic antibiotic prescribing to prevent surgical site infections (SSI). Evidence-based guidelines published by the World Health Organization (WHO) and other public health agencies advise on best practice for prescribing and administering prophylactic surgical antibiotics. However, compliance with such guidelines amongst surgical teams is often limited. The development of engaging decision support tools, accessible at the point of care, at low cost for use in LMICs, is required to help surgeons apply AMS guidelines to their daily practice. Serious mobile games, developed with an educational or training purpose rather than for entertainment, are a powerful tool for persuasive behaviour change but little interest has been given to research for AMR to change prescription behaviour in LMIC. In this research we present the co-development of a decision support tool for the "Gamified Antimicrobial Stewardship Decision Support App" (GADSA) in Nigeria with surgeons from three participating hospital sites. GADSA is the first gamified decision support app using persuasive games techniques for prescribing behaviour change demonstrated to deliver a prescription behaviour change increasing compliance with SSI guidelines at the point of care. GADSA is also is novel at providing decision support for surgical antibiotic prescribing through gamified features such instruction of mentor, visual and textual immediate feedback system, persuasive messaging and positive and negative reinforcement.**

***Index Terms*—antibiotic resistance, awareness, games for health, healthcare, serious games.**

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I. Introduction

Antibiotics are the most widely prescribed antimicrobial agents to treat infections. Unlike other drugs the more they are used, the less effective they become [1]. Antimicrobial Resistance (AMR) is a prominent worldwide threat limiting ability to treat common infections and diseases. Without effective antimicrobials, medical and surgical procedures, such as cancer treatment, which rely on antibiotics, could become life-threatening.

It is estimated that by 2050 antimicrobial resistance will lead to 10 million deaths becoming the major cause of death [2]. Although this is a global problem indeed, the challenge is amplified in Low and Middle-Income Countries (LMIC) [3]. One of the contexts in which AMR is spreading is in hospital-acquired infection (HAI). There is evidence that this represents a significant challenge for low-income countries - in particular, where the incidence of contracting a Surgical Site Infection (SSI) is higher compared to that of similar procedures carried out in high income countries [4]. Reducing inappropriate antibiotic prescribing by improving compliance with guidelines can support efforts to slow the emergence of antimicrobial resistance. In this context, antimicrobial stewardship programmes aim to educate and empower prescribing clinicians to drive down cases of overuse and avoid misuse of antibiotics.

Surgery is one of the most dynamic and busy spaces in the hospital where prescribing decisions are often shared across the surgical team. In the fight against SSIs, the use of surgical antibiotic prophylaxis (SAP) (i.e. antibiotics administered shortly before, during or immediately after surgery to prevent infection) presents an effective option to prevent the spread of bacteria from surgical interventions. Good antibiotic stewardship practices to prevent infection include reducing the inappropriate and overuse of SAP [5] and improving compliance with evidence-based prescribing guidelines published by the World Health Organisation (WHO) and other public health authorities.

Despite compliance with such guidelines being widely advocated, inappropriate antibiotic prescribing in surgery is widely reported [3], [6]. Surgical compliance with guidelines for the use of SAP has been shown to be as low as 50% [5] with, for example, patients regularly receiving prolonged dosage for prophylaxis as a standard preventative against SSIs (despite the lack of scientific evidence supporting its benefits [7]) and in some cases, inappropriate prescription of SAP altogether [5]. Published guidance also includes advice on the appropriate administration of SAP. However it has been suggested this is still not sufficient to ensure full compliance [8].

There is also a lack of clarity around appropriate decision-making for prescribing in surgery [9]. Prescription guidelines are agreed to be necessary and beneficial yet often considered difficult to tailor to individual patient needs. Clinicians in LMIC are under increasing amounts of pressure to deliver quality care with limited time, capacity and resources and so prescribing in line with guidance should not be an overly difficult and time-consuming process. The high patient-doctor ratio and scarce training resources in Nigeria mean there is additional demand for meaningful education that can be easily digested and applied to practice. Decision support to improve evidence-based prescribing, accessible at the point of care to help clinicians easily adapt principles from guidelines into their everyday practice, is therefore urgently needed. This paper proposes a novel cross-platform, mobile decision support tool, integrating principles from behaviour change theory and gamification, to improve appropriate and compliant prescription of SAP for SSI at the point of care in clinical settings in Nigeria. Although using of serious games for antibiotic stewardship is not new, there is little research on their use in the context of LMIC countries in general and in this context in particular [10].

II. Antibiotic Prescription and Decision Support Tools

Computerised decision support tools for antibiotic prescribing are designed to aid clinicians making compliant prescription decisions. Such tools can simplify the process of understanding complex medical documents, alert clinicians to new data (e.g. resistance trends, patterns in patient data) and provide timely reminders and prompts at the point of care. Use of computerised decision support tools has been found to be associated with a lower rate of antibiotic utilisation and a higher adherence to antibiotic guidelines [11]–[13]

In the LMIC countries where access to mobile technology is more common than access to a computer, mobile technologies offer an opportunity to the future of appropriate prescribing. The healthcare domain is an area where mobile technology is expanding with smartphone apps have rapidly become part of the modern medical professional toolkit, radically transforming many aspects of clinical practice [14], supporting better decision making [15], [16], supporting doctors in LMIC [17], [18], and improving patient outcomes [19], [20]. Advantageously, app-based tools can be personalised, accessed at any point and easily updated to incorporate latest guidance and best practice for citizens and rural communities in LMIC [20].

To ensure that compliance with standards improves and changes in prescribing behaviours are maintained over time it is vitally important that decision support tools effectively engage, and continue to engage, clinicians. Serious games and simulations engage the user via a form of organised play and have a proven record of efficacy in helping healthcare workers translate theoretical knowledge and develop new skills into practice [21], [22]. There are a few gamified mobile apps that aim to improve antibiotic stewardship [23]. What makes GADSA app unique is the focus towards Nigeria and its integration of persuasive game techniques in the context of a decision support to encourage prescribing behaviour change [24].

III. GADSA Design and Development Process: Observations, Questionnaires and Focus Groups

The application design and development followed participatory research approaches [25]. Through this process, the stakeholders were actively involved in the process and vision of change through the technology [26].

In the case of GADSA, the **first phase** of the development focused on understanding the barriers surgeons face in prescribing antibiotics based on the existing guidelines in Nigeria [24], [27]. To do this a questionnaire was designed based on the behaviour change theory theoretical domains framework [28] followed by 3 focus groups. Among the findings of this study [24] include:

- participants awareness of WHO Guideless for Prevention of Site Surgical infections [29] and to a less extent of Sanford Guide [30] for antibiotic prescribing;
- the lack of clinicians access to copies of guidelines;
- the lack of time to read the guidelines in full and a large amount of information needed to remember means that information is not always remembered – just in time access to the information was needed;
- the need to improve the education of residents during training on the risks of AMR;
- importance of guidelines in protecting doctors against legal issues.

As a result of the study, a decision was made to focus on the two existing guidelines: WHO Guideless for Prevention of Site Surgical infections [29] and Stanford Guide [30]. As the lack of access to the guidelines and the need for just-in-time information was necessary it was decided to create a mobile application which would allow the surgeons just-in-time access to the data needed at that moment, literally at the point of care where they are making a prescription decision before surgery. The app will provide just the information required for the clinician based on the patient case being treated.

The **second phase** consisted of the development [31] and testing of the wireframe and the prototype followed by testing the flow and functionality of the prototype. This has informed the development of the application.

In the **third phase**, the application was tested through observations, focus groups and questionnaires. The **fourth phase** consisted of a pilot deployment study with 60 surgeons recording around 300 prescription decisions in three hospital settings (Lagos State College of Medicine, Lagos University Teaching Hospital, and Niger Delta University Teaching Hospital) over 6 months. The pilot showed changes in clinicians antibiotic prescribing as a result of using the app.

The co-design activity helped also with the artwork and imagery. Designing the appropriate artwork and imagery for end users in LMIC must follow culturally appropriate and sensitive design co-authored and co-developed with the end users [32]. As GADSA is a serious persuasive game the adoption of Mentor - a figure creating an advisory relationship with the user is essential [32].

A series of co-design [33] focus groups attended by surgeons informed selection of evidence-based behaviour change components and gamification features for inclusion in the GADSA app (e.g. a 'mentor' providing positive/negative feedback on user decisions to reinforce learning - red/green). An outcome of the co-design with Nigerian surgeons was the selection of a 'dog' as a mentor for the persuasive game, rather than (as expected) any human avatar/mentor. The participants required the mentor to wear a stethoscope to highlight his profession. The stethoscope, glasses and ward coat were suggested as signs to mark that the mentor was knowledgeable.

IV. The GADSA Decision Support System Architecture

The decision support system reflects the decision process of the surgeons and supports their two-stage decision when prescribing SAP before and after the surgery. Therefore, the GADSA app collects data from the user about their prescription decisions at two main points: (1) pre-operation - decisions made by the surgeon before the surgery takes place and, (2) post-operation- where surgeons either confirm SAP was administered as intended or report any changes that were made to their original decision. Surgeons are also asked to provide a reason why these changes were made, such as a complication during the procedure requiring a prolonged SAP prescription. This information helps to better understand the current barriers to complying with the guidelines.

The decision support system architecture is based on a decision recommendation 'tree' built by following the WHO and Sanford decision guidelines catering for two main decisions:

- `Decision A`: surgical risk level - whether the surgery is considered high or low risk (thus requiring SAP or not), and
- `Decision B`: prescription of SAP - if surgery is high risk (SAP is required) which SAP is administered and for how long

The main decision support framework, therefore, underpins both decision trees and is built by implementing the antibiotic prescribing guidelines published by WHO [29] and Sanford [30]. Key principles are taken from the guidelines and transposed into two separate decision trees: Decision Tree A (see Fig. 1) guides users in their selection of risk level for a specific surgery. Decision Tree B (see Fig. 2) guides users in their choice of SAP and how long to prescribe SAP (i.e. the duration of the prescription).

As users enter the patient case, type of surgery and patient allergy into the GADSA app, followed by their decision on high o low-risk surgery (A) and which SAP if needed (B) - the decision trees determine whether a positive (for a compliant decision) or a negative (for a non-compliant decision) or neutral (for decisions where no guidance is currently available) feedback is to be displayed. Receiving immediate feedback on their decisions provides the user with either confirmation that their prescription is in line with guidance (positive reinforcement) or negative reinforcement and the opportunity to change their non-compliant decision to a compliant one. GADSA is a decision-support tool only. Ultimately, the doctors have the final say on what to prescribe to their patients. However, to capture the reasons for non-compliance, surgeons provide a reason in case their decision does not comply with the guidelines after negative feedback was given [24].

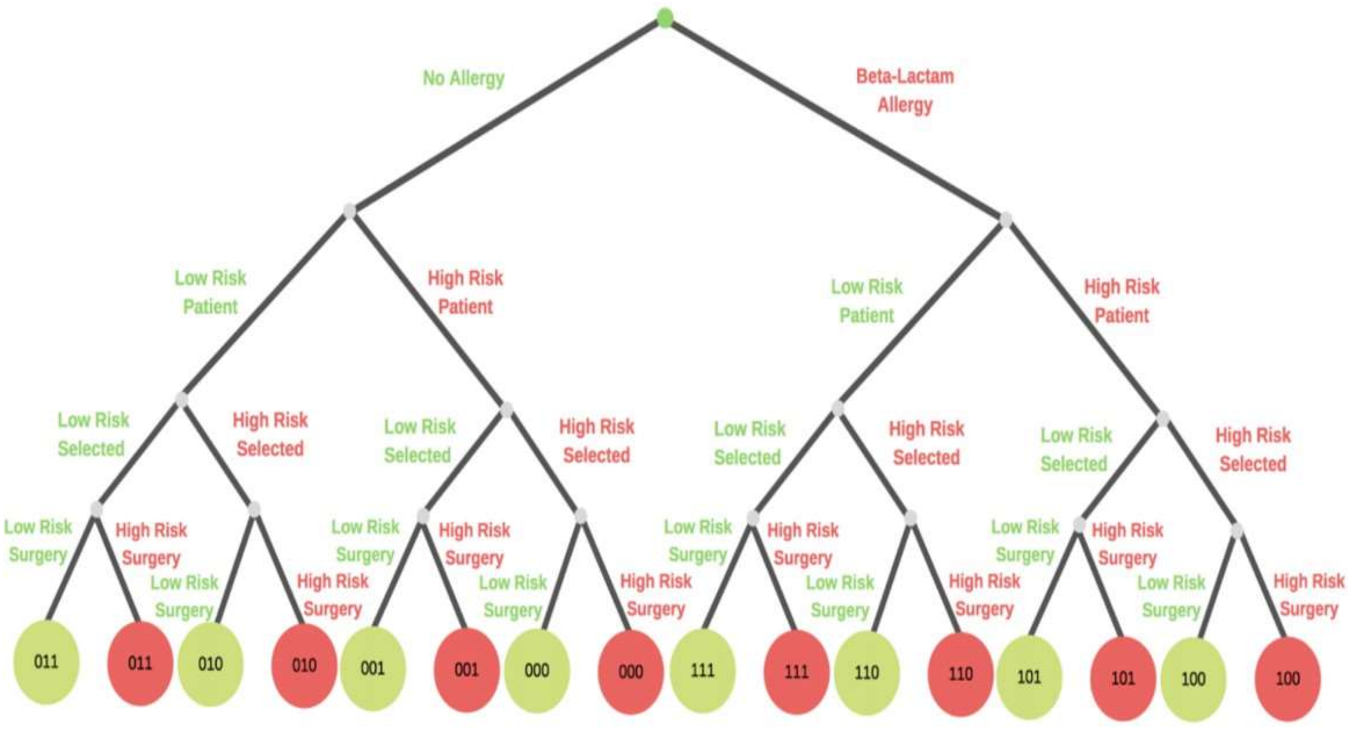

Fig. 1. SAP Decision Tree A

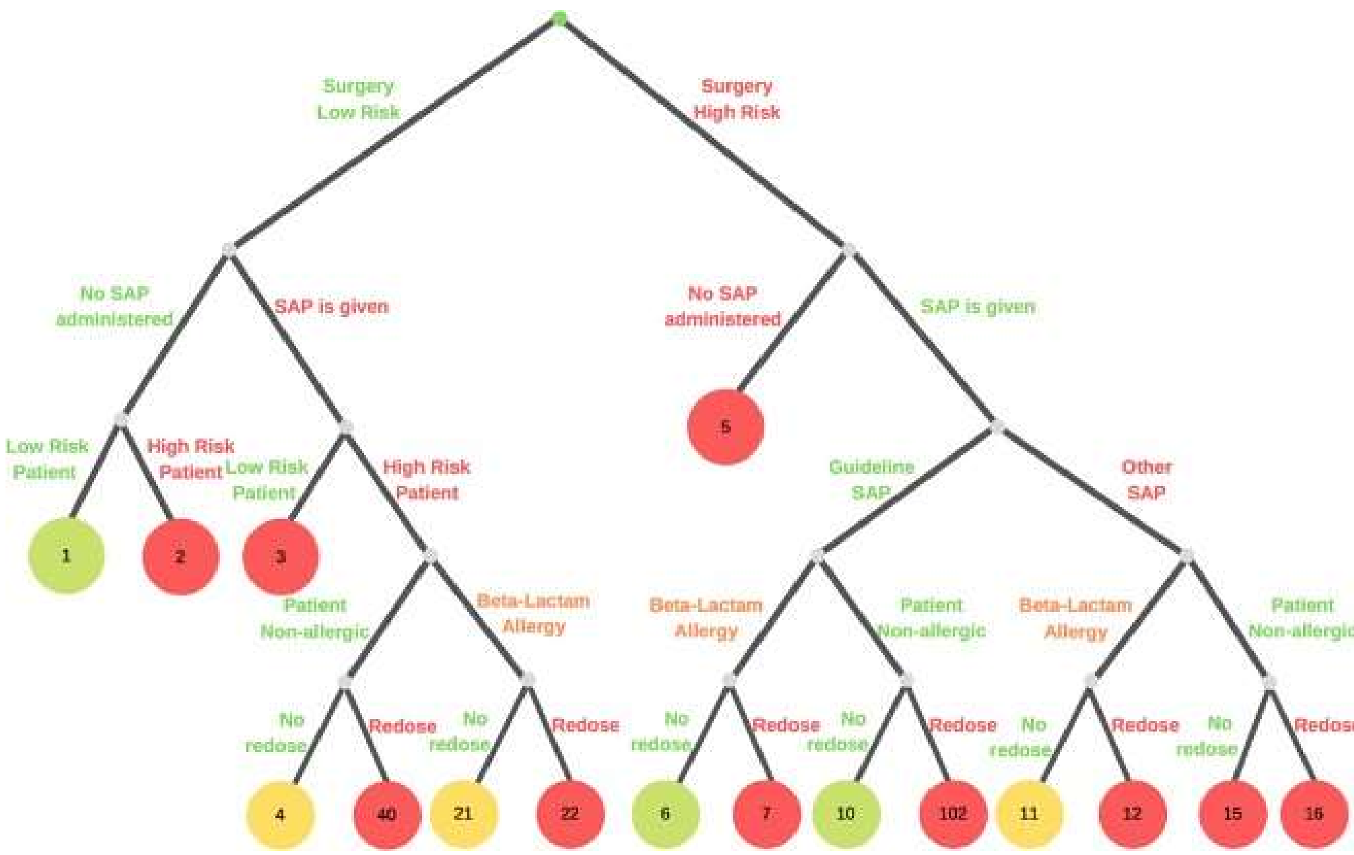

Fig. 2. SAP Decision Tree B

A. Decision Tree A - Surgery Risk Level

During pre-surgery appointments, the surgeon decides whether the surgery is a high or low risk. This determines whether prescribing SAP is needed. Using GADSA, the surgeon enter about their patients, such as the patient's allergies to beta-lactam (ruling out penicillin SAP), patient risk level (either low or high risk of developing a surgical site infection), surgery type and surgery risk level. This answer is assessed by the decision support tree system A and feedback is provided whether the indicated level of surgery is correct (according to the guidelines). This feedback is important as the risk level of the surgery directly determines whether a patient needs to be prescribed antibiotics. The risk level of surgery can be either low for "clean operations not involving implantation of foreign materials" or high for "non-clean and implant surgeries" [29]. Usually, low-risk surgeries do not require surgical antibiotic prophylaxis [30].

As displayed in Figure 1, there are 16 possible responses returned by the decision support system reflecting all combinations of the input variables. These responses take into account the patient's allergies, and patient risk and verify whether the surgery risk indicated by the doctor matches the risk mentioned in the guidelines. Two types of responses are available: positive (green) and negative (red).

Figure 3 displays the two types of responses (immediate feedback) with further recommendations for surgeons. In the first screen, the surgeon correctly specifies the risk level for the "Head and Neck, Maxillofacial - Cleft lip" surgery as High Risk. In the second screen, the surgeon receives negative feedback' when indicating "High Risk" for the "Gastric, Billary and Colonic - Laparoscopic" surgery, since the procedure is identified as Low Risk in guidelines. Each response contains a first message stating the risk mentioned in the guidelines and a more comprehensive text including the medical reasons specified in the guidelines for a surgery to be high or low risk to incorporate persuasive techniques.

B. Decision Tree B - Prescription of Surgical Antibiotic Prophylaxis (SAP)

Once the risk of surgery is decided, the decision support system for decision B is based on five main factors affecting a surgeon's decision regarding the correct SAP prescription and duration of prescription: surgery risk level, patient allergies and patient risk level, and type of surgery. The first factor is the surgery risk level (low or high) and as a result, SAP is not prescribed. Patient allergies (Beta-Lactam/Penicillin or no allergy) affect the SAP type prescription, as well as the patient risk level (low or high, e.g. patients with diabetes or other comorbidities require SAP even for a low-risk surgery). Next, one of the main factors is the type and subtype of surgery. For each kind of surgery, the guidelines specify the appropriate types of antibiotics and their dosage. The type of SAP introduced by the doctor in the mobile app is checked against the medications indicated by guidelines. Finally, the duration for which antibiotics are prescribed is also checked (24 hours or more).

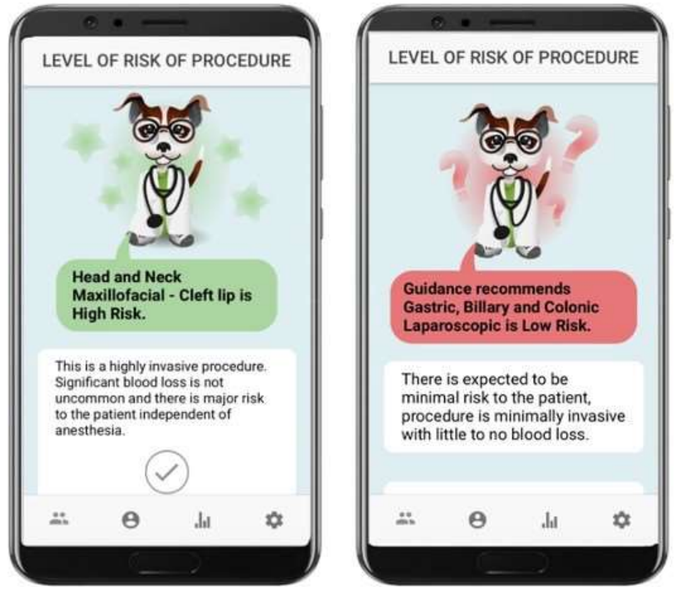

Fig. 3. Feedback provided by the mentor

Fig. 2 depicts the decision tree B for the SAP prescription. The SAP decision tree includes 16 different cases. Based on the user input, the feedback can be either positive (green), neutral (yellow) or negative (red), as displayed in Figure 2. A positive response indicates that the surgent prescription choices were in line with the guidelines. Oppositely, a negative response signals that some choices are against the guidelines' recommendation and clearly states what elements are not in line - either the type of SAP or the duration of the SAP prescription. Yet, the neutral response (yellow) is indicating that guidelines do not currently recommend a specific antibiotic for that instance. Therefore, misleading feedback is avoided by clearly stating there is no guidance for that case thus the app cannot confirm the compliance level. This case is not uncommon for allergic or high-risk patients and highlights the need to complete the recommendations to improve the local AMR and prescription practice.

For each of the final nodes of the decision tree, a different response is created. The response will provide two messages, a "mentor response" (displayed in the mentor's speech container, Fig. 3), indicating whether the choice is in line with the guidelines, and a "detailed response" (displayed in the white box below the mentor, Fig. 3), containing further recommendations.

C. Setting Correctness of Surgeon's Decisions

Throughout the app, immediate feedback is given to surgeons to reinforce learning - reiterating the SAP decision made, the guidelines recommendation and the advice. To keep track of the correctness of a surgeon's decision, the following encoding is used to set the outcome of the Decision Trees A and B and summarize the case in a final 'summary Page' to further reiterate learning. All user's decisions and their compliance with the guidelines) that are dynamically generated. further these 'correctness' values were used in the analysis, assessing compliance and behaviour change using the app.

V. GADSA App Structure and Navigation Flow

Fig. 4 contains the wireframe of the mobile application, based on the requirements gathered and the gamification features set for the application. In the case of GADSA, the requirements are the result of a close collaboration of various stakeholders, such as the three partner hospitals in Nigeria. Both the functional and non-functional requirements were gathered and refined based on the feedback gathered during various focus groups that took place in Lagos.

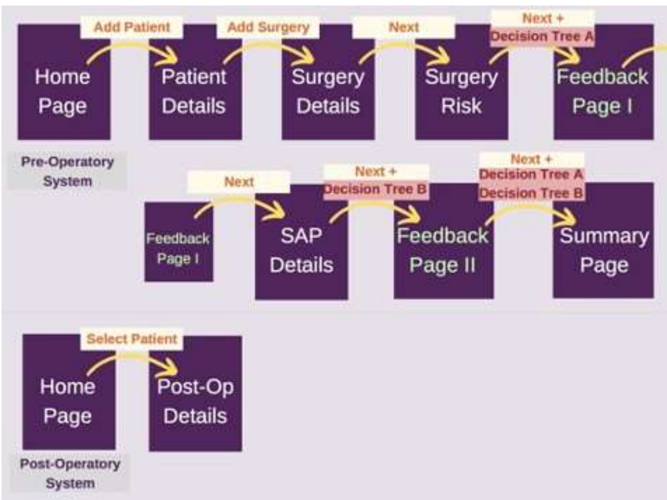

Fig. 4. Wireframe of the GADSA app. Decision Trees A and B are run before the summary page to update the correct values.

The app launches with the "Home page", where a list of patients is available. For the pre-operatory process, the user will choose the "Add Patient" option. At this point, the navigation controller in Ionic is used to define the order of various pages. The user will then be able to complete the patient's details, add a new surgery and specify the surgery risk.

Once the surgery risk page is completed, the user's decision will be assessed. The decision of the surgeon will be verified by running the Decision Tree A. Next, the user is directed to the first feedback page. Next, the user completes the surgical antibiotic prophylaxis (SAP) details. After inputting the treatment choices, the user is directed to the second feedback page. Before the page is rendered, the Decision Tree B algorithm is run. This way, the second feedback page contains the responses from the decision tree. The feedback page can be either positive, negative or neutral. Users have the option to change their prescription based on the feedback response. Finally, a summary page is created, where the user can review the patient information, surgery details and prescription choices, along with further recommendations. Since user's current prescription might have changed after the two feedback responses, the prescription choices are again verified in the Decision Trees A and B algorithms before the "Summary page" is loaded. Back to the home page (Fig. 5), the user can start the post-operatory process, by selecting one of the added patients from the patient list. Here, the post-operatory page is launched, where users are able to update patient prescriptions or to confirm that no change occurred, based on the outcome of the surgery.

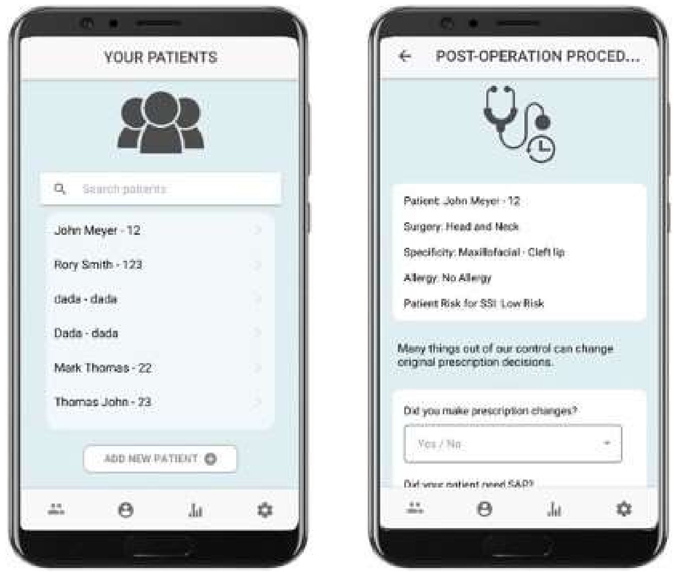

Fig. 5. Application Screenshot

To encourage continuous engagement with the app several gamification features were developed and piloted in the app during the pilot study. These include badges for interacting within the app, the star of the week award and inter-hospital competitions. A separate screen showing the awards received was implemented within the app (see Fig. 6). On this screen, the user can see all their achievements. When selecting an award more information about the badge is provided. As gamification with online applications is not always successful [34] further interactions outside the app were implemented such as participation certificates for the doctors taking part in the study.

VI. Implementation, Discussion and Future Work

Antimicrobial Resistance represents one of the most worrying threats to global public health [35]. Creating an engaging, gamified antimicrobial decision support app used at the point of care represents an important step towards addressing the problem of antibiotic misuse and overuse in surgical hospital settings, and contributes to AntiMicrobial Stewardship (AMS). The application is useful for clinicians but also for national public health agencies who can further understand the prescription trends in hospitals from the data collected by the app. The app can be used to complement existing approaches to promote responsible antibiotic use such as those aimed at other clinicians [36], [37], and other segments of the population such as children [38], students [39], [40] or the public at large [41].

Fig. 6. Example of Awards Received Within the App

GASDA was piloted by three hospitals in Nigeria over a period of 6 months collecting over 300 prescription decisions having demonstrated a behaviour change at the point of care around the risk of surgery, prescription and the length of prescription. The evaluation of the app in a six months pilot study showed that 11% of surgeons updated their decision to meet the standard guidelines for surgical risk decisions and 3% changed their decision regarding the SAP requirement [42]. Furthermore, surgeons also change their decision when it comes to the duration and type of antibiotic prescribed (16% and 7% respectively) [42]. This shows the potential of the application in refreshing surgeons' knowledge on antibiotic prescription and following antibiotic prescription guidelines.

Going forward, one of the main challenges of the project consists of motivating surgeons (who are busy professionals who volunteered their time participating in the project) to continue engaging with the app to track their medical decisions and provide feedback according to the health guidelines. Due to the busy schedule of clinicians, a support system giving recommendations at the point of care might seem hard to use [24]. To solve this issue, several user engagement strategies were successfully integrated into the app. Several components are integrated into GADSA, such as creating challenges with clear goals for the surgeons and offering badges to track their performance. Finally, long-term support requires close collaboration with clinicians and public health agencies.

The app provides valuable feedback to clinicians, guiding them towards compliant prescription decisions, having evaluated the main barriers and enables for antibiotic use [24]. Our future work will consist of exploring the use of the application in other countries to determine whether the same approach can be applied across different contexts. Currently, the GADSA app is being piloted in the NHS in the UK.

The project was also highly regarded by industry - the PI of the project won the Innovator of the Year 2019 Award by Computing Women in IT Excellence, and was the runner up in the prestigious UK IT Awards 2020 competition in a category Healthcare Project of the Year.

VII. Conclusions

Many deaths caused by infectious diseases in lower-income countries could be avoided by better infection prevention and appropriate prescribing of antibiotics. Antimicrobial Stewardship (AMS) means the effective use of antibiotics including compliance with published guidance. The challenge of the GADSA innovation was to improve antibiotic stewardship amongst surgeons in Nigeria through sustained behaviour change by developing a persuasive mobile gamified decision support app integrating the latest evidence on best-practice localised to Nigerian settings and evaluating it at the point of care in three hospital settings. GADSA is the first gamified decision support app for AMR successfully evaluated at the point of care [24] - combing cutting-edge novel persuasive game technology with behaviour change methods localised to the African settings - awarded the Innovator of the Year 2019 and UK IT Healthcare Project of year 2020 - runner Up, this is one of the most innovative digital solution tackling the global challenge of antibiotic resistance in the world at the moment

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