INTERNATIONAL JOURNAL OF MEDICAL INFORMATICS 84 (2015) 334–340

journal homepage: www.ijmijournal.com

Electronic diagnostic algorithms to assist mid-level health care workers in Nepal: A mixed-method exploratory study

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ARTICLE INFO

Article history:
Received in revised form
16 January 2015
Accepted 17 January 2015

Keywords:
Algorithm
Mobile apps
Diagnosis
PDA
Rural health
Community health worker
Decision support

ABSTRACT

Introduction: The use of mobile health applications for data collection and disease management by rural health care workers in developing countries has been shown to be accepted by patients and health care workers. However, the acceptances of diagnostic decision applications have not been studied. Moreover, verbal acceptance of these tools has not been shown to equate with actual usage by the health care workers when use is not compulsory.

Objective: To measure the acceptance, usage and reasons for use or non-use of electronic diagnostic applications by health care workers to aid in clinical diagnosis.

Methods: Eleven health care workers (HCW) from rural facilities were asked to use the e-algo application on an electronic tablet with patients over the age of five presenting with acute complaints. Use was compulsory for the first 30 working days and after that optional. Patients were asked by questionnaire about their preference and confidence between the traditional approach and that of the e-algo. HCW acceptance was measured by focus group discussions after the compulsory period. The HCW was then told to use the application as they desired. After two months of non-compulsory usage, reasons were explored for use or non-use through a focus group discussion and interviews.

Results: A total of 1410 out-patient encounters occurred in the first phase. Of this, the e-algo was used with 1177 encounters (83%). 496 patients were asked about their preference and confidence in the use of the e-algo. 325 preferred the e-algo over the traditional visit 65.8–25.1%. Patient confidence was higher in the e-algo 72.2–17.4%.

In the second phase, three of the nine HCWs did not use the e-algo at all, the remaining six HCWs reported e-algo use dropped to approximately 15% of total OPD visits. E-algos were reported to be used primarily with more complicated or confusing cases. Reasons for non-use was primarily time related.

Conclusions: We concluded that patients had confidence in and preferred the HCW using the e-algo in their patient care. The HCW users were also positive about the e-algo application, seeing its primary benefit as assisting them in more difficult cases through the use of a differential diagnosis and focused questions. HCWs also reported that the e-algo functioned as a learning tool as well as a diagnostic tool. However, actual usage of the application dropped off significantly when its use was not mandatory. The primary reason was that they

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http://dx.doi.org/10.1016/j.ijmedinf.2015.01.011

did not feel the time required to use the application was warranted in the vast majority of their cases which they perceived as being simple and easily diagnose without the assistance of the application. Unless the HCW perceives the decision-support application to be valid, time-saving and easy to use, they will not use them.

1. Introduction

Mid-level health care workers (MLHCW) compose the backbone of the rural health care system in Nepal, often taking the place of a doctor due to a lack of doctors in rural areas. This author showed significant performance gaps of these health care workers (HCW) in diagnostic and clinical decision-making skills [1]. Studies in India found gaps in quality of care by non-physician providers [2]. In response to these findings, NSI developed diagnostic algorithms which were used in a problem and skill-based training called the Mid-Level Practicum (MLP). These diagnostic algorithms have been shown to be effective in improving the HCW clinical decision making in a classroom setting [3]. However, training follow-up revealed a reluctance by HCWs to use the paper algorithms in front of patients for fear of being seen as less than competent.

NSI funded and this author developed an electronic mobile version of its paper-based diagnostic algorithms for use in rural health posts by rural HCW's. The electronic algorithm ("e-algo") is an Android OS application that operates on any Android OS mobile platform, including smart phones and tablets. These diagnostic algorithms cover more than 35 acute complaints. The decision trees lead to more than 260 different diseases endpoints, which also provide diagnostic criteria, management and patient education. This open-source application can be used or modified for use in other countries.

The application requires the HCW to input patient data and answer specific questions. The steps in the application of a patient encounter are as follows:

1. Patient age and gender is entered.
2. A list of common chief complaints is displayed of which the HCW chooses one (Fig. 1).
3. Vital signs are required to be entered.
4. A list of Warning Signs are displayed to which the HCW enters "Yes" or "No". A positive response results in direction to emergency management (Fig. 2).
5. If there are no warning signs, a series of questions based on the chief complaint are asked. The HCW answers based on his history and examination (Fig. 3).
6. A provisional diagnosis is given and the HCW is asked whether they agree with this. If yes, they are referred to the disease management section. If they disagree, they are referred to a differential diagnosis list from which they can pick.

Mobile electronic devices have been used in various developing countries to improve data collection and improve treatment. DeRenzi [4] and Bogan [5] found both patients and HCWs were accepting electronic decision making tools in the

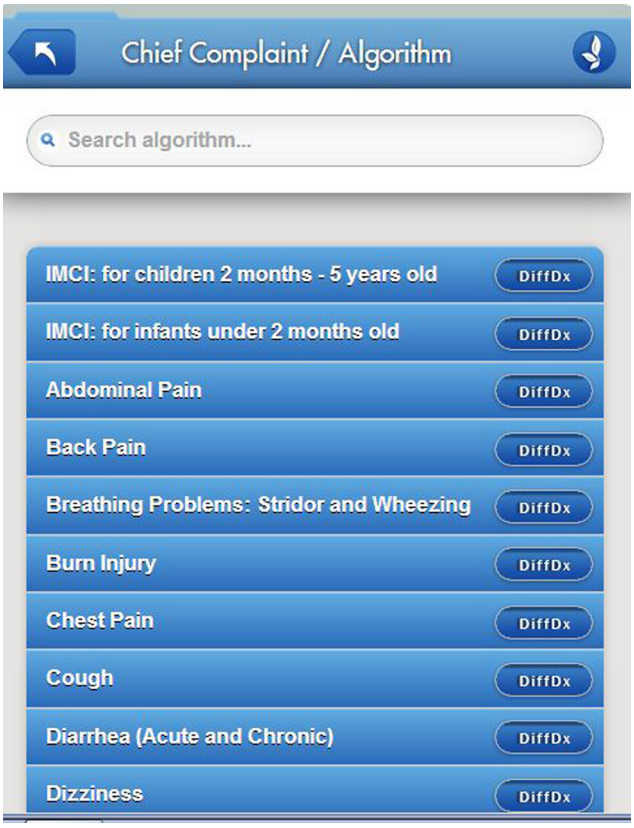

Fig. 1 – Screenshot of algorithms.

care of pediatric patients using the Integrated Management of Childhood Illnesses (IMCI). Using electronic applications to guide HCWs in treatment protocols showed that their use improved the adherence to accepted protocols and was then assumed to improve treatment and patient outcomes [6].

Curry and Reed found that the use of electronic clinical decision support in ordering diagnostic tests did improve the quality of the physicians' clinical care, however, physicians were reluctant to change their clinical habits because they believed that it interrupted their routine work flow [7]. A study of Ghanian midwives showed an acceptance of the mobile application's usefulness but a lack of usability resulted in reduced usage [8].

The vast majority of studies looking at electronic devices however are for the purpose of improving data collection, patient record keeping or specific disease management. Electronic applications that assist the HCW in primary clinical diagnosis have not been studied [9].

In studies exploring patients' attitudes, they generally have been positive about HCWs using mobile devices in their care. Cheng, however, found that HIV patients were reluctant to give

Fig. 2 – Screenshot of warning signs.

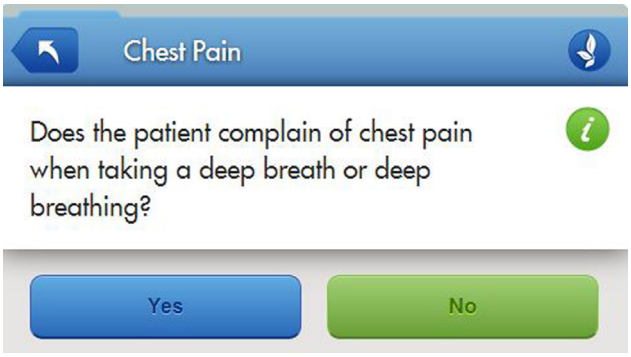

Fig. 3 – Screenshot of an algorithm question.

accurate data to workers using an electronic device due to fear of how the data would be stored or used leading to questions about the accuracy of the collected data [10,11]. However, there are no studies that have looked at the problem of inaccurate patient answers in a diagnostic context.

Literature review indicates the acceptance of usefulness of electronic decision-support applications by health care workers. However, some studies indicate that HCWs will choose not to use it when given the option of practicing as they had previously.

2. Objectives of the study

1. Determine patient acceptance to health care worker use of the e-algo application in their clinical care for disease diagnosis.
2. Determine health care worker acceptance to using a diagnostic assistance application.
3. Determine if mobile application usage drops off when usage is not compulsory and the reasons for that occurring.

3. Methods

3.1. *Sample*

A mixed method, exploratory design was used. Eleven rural healthcare facilities with HCWs were chosen. Selection of the facilities was based on the HCW having previously taken the MLP training and a moderate patient flow of 15–25 patients per day. To provide diversity, we included one faith-based mission hospital, one community-based primary health care center, one government district hospital, one government Primary Health Care Center and seven government health posts. There was only one HCW in the health posts. The other facilities had more than one HCW seeing patients. Approval was obtained from the Nepal Health Research Council and from the directors of each of the health institutions.

3.2. *Design*

Each user was supplied with an electronic tablet and a paper patient-encounter log. All HCWs were oriented to the e-algo application and to recording of study data in the paper log. Each HCW also practiced using the application with simulated patient encounters. The e-algo and paper log were pre-tested in the field prior to the beginning of the study.

Phase one involved the HCW's compulsory use of the e-algo application for 30 days with all patients over the age of five years who presented with complaints (excluding trauma) of less than one month. Patients were registered, informed about the study, and asked to give informed-consent. The HCW took chief complaints and, using their traditional method of history taking and examination, determined a provisional diagnosis. The HCW logged the patient's demographic data, vital signs, chief complaint and their provisional diagnosis on the paper patient log. The HCW then used the e-algo application to arrive at a diagnosis which was also logged on the paper record. If the HCW's own provisional diagnosis and the e-algo diagnosis were different, they recorded perceived reasons for disagreement. If they were unsure, the HCW was to treat the patient according to their own provisional diagnosis and not to defer to the e-algo diagnosis. Finally, the HCW asked the patient to fill out a questionnaire about their confidence and preference of the e-algo in comparison to a traditional visit. At the end of the 30 working days, the HCWs turned in their paper logs and participated in a focus group discussion or interview about acceptance of the application by the patients and themselves.

Upon completion of phase one, each HCW was told to use the tablet and e-algo application as they desired. Phase two (non-compulsory use) lasted for two months, after which the HCWs participated in a focus group or were interviewed regarding their use of the tablet. HCWs provided estimates of the total number of patients they saw and for how many patients per week they used the e-algo with. All electronic patient data was uploaded at the end of the second phase. The paper data was entered into an Excel format for analysis.

Table 1 – Patient encounters.

Description	Number	Percentage
Phase 1 (compulsory use)		
Total outpatient encounters	1410	–
Outpatient encounters with e-algo use	1177	83.5%
Phase 2 (optional use)		
Average reported weekly outpatient encounters	128	–
Average reported weekly e-algo use	16	14.8%

4. Results

4.1. Patient encounters

HCWs logged a total of 1410 patient encounters in phase one from nine sites. Two sites, PHCRC and Tansen Mission Hospital were not included in the data sample because their use of the e-algo application and paper logging was not consistent and did not follow the study design requirements. Reasons for non-use were that they were too busy and the study logging and questionnaires took too much time.

The paper log recorded the e-algo application was used on 1177 (83.5%) patient encounters. The e-algo was not used on the remaining 233 (16.5%) encounters due to a lack of algorithm, non-acute nature of the visit or the patient was presenting only for a procedure.

E-algo use dropped significantly once the compulsory phase ended. Data was recorded differently in each phase: during phase 1 (compulsory), each encounter was recorded on the paper log; during phase 2 (optional use) this information was extracted by focus group discussion or phone interviews with the HCWs (Table 1).

4.2. Patient acceptance and satisfaction

Among 883 recorded e-algo encounters, 496 patients (56.2%) from eight sites filled out the patient acceptance survey. Not all patients were surveyed. This was due to a number of HCWs who either stopped midway or did not use the forms claiming they took too much time. Of these patients, 36.3% were male, 63.7% were female. The average age was 37.7 and 34.0 for males and females respectively (Tables 2 and 3).

When patients were asked to compare the experience of being cared for by a HCW using the e-algo/tablet with a traditional history and physical exam, they clearly expressed confidence in the electronic device and stated that that was their preference. One quarter (25.1%) of patients stated a preference for the traditional examination. This study did not explore the reasons for this any further.

Table 2 – Patient confidence.

Most confident in	Number	Percentage
Tablet/e-algo	358	72.2
Traditional examination	85	17.4
Same confidence	51	10.3
No answer	2	0.4
Total	496	100.0

Table 3 – Patient preference.

Preferred	Number	Percentage
Tablet/e-algo	325	65.8
Traditional examination	124	25.1
No preference	44	8.9
No answer	1	0.2
Total	494	100.0

4.3. Phase 1: focus group discussion on HCW acceptance

Upon the completion of the compulsory phase one, six HCW users were gathered for a focused group discussion and the other three HCWs were interviewed individually due to geographical constraints. The objective of the first discussion group was to get their feedback on the application and as to how the patients viewed their use of it in an encounter. The HCW e-algo users overwhelmingly reported that their patients' views of the application were positive. They reported that the patients appeared quite comfortable and positive with them using the tablet because it required more time than a traditional visit. HCWs stated that patients had confidence that the "computer" would give the correct diagnosis.

The HCWs were also generally positive about the e-algo application. They stated that it improved their decision-making and enabled them to view a full differential diagnosis for a specific complaint. They saw the tablet having a dual purpose: learning as well as diagnosis. One HCW said that the application made it unnecessary for him to refer to books when dealing with patients.

Initially, they stated some difficulty in learning how to navigate the application but after a few days of practice, the HCWs found the device easy to use. The application separated cases that could be handled locally from those needing referral. The algorithm questions helped refresh their memory of things they had missed in their history and examination. They also valued the disease management section which standardized and helped them focus their treatment rather than their traditional broad treatment approach. Finally, the "Warning Signs" list at the beginning of each chief complaint made them think about these issues in advance.

HCWs mentioned some negative aspects of the e-algo/tablet, such as certain common chief complaints missing from the application. The headache and skin complaint algorithms were not available but were mentioned as needed. Chronic diseases such as hypertension, COPD and diabetes were also not covered. The tablet lacked a feature that allows for saving patient information to access for follow-up visits. The use of combination questions and some English terminology was also difficult causing misunderstanding and resulting in wrong decision-making pathways. Technological complaints included the small size (7 inch) of the tablet, the insensitivity of the touch-screen and the lack of reliable electricity impacting use due to the less than optimal battery life.

4.4. Phase 2: focus group discussion and phone interview

After phase one, the HCWs were given the tablets and told to use them as they desired. After two months, six HCWs

participated in the focus group and the other three were contacted through the phone and interviewed about their usage. Each was followed up with another phone interview. The primary objective was to determine if and why usage of the e-algo went down during the non-compulsory phase of the study.

All admitted that they had not used the algorithms as before. Three of the nine did not use it at all, the other six reported reduced usage. The primary reason given was the time the application took for routine patient encounters. Of those that used the application, they reported use of the e-algo only when they were confused or had more difficult cases. They did not feel the time required to use the e-algo warranted its use in the cases they perceived as routine or simple. Their feelings were that the vast majority of their cases are routine; they stated the need for the e-algo was minimal and just wasted their time. Their estimate of usage ranged from 5 to 20 patients per week or about 15% of all acute problem visits.

When asked if they would use it more if they could by-pass some of the mandatory steps to save time such as patient demographic data and vital signs, they indicated this would encourage them to use it more. Directly accessible features such as emergency management, chronic disease management and differential diagnoses were listed as reasons they would consider using it more often.

The HCWs or their health facilities did not receive any financial support for their participation in this study. However, the HCWs were given the tablet at the end of the study. This may have biased their answers in the focus group discussion, making them more positive than they would have been otherwise.

5. Discussion

We introduced the use of paper algorithms to facilitate decision making based on the observation that mid-level workers tend to be 'reflexive' in making diagnoses and utilize narrow differentials. We also saw the need for 'red flagging' of dangerous cases and those calling for referral to larger medical centers. Although we did not test these algorithms against a diagnostic gold standard, we have observed improved performance in graduates from the Mid-level Practicum. [3] The primary problem with the paper algorithms however was lack of usage: HCWs reported that they were hesitant to use the algorithm chart-book that we gave them because patients might interpret this as their incompetence. This led to the development of the e-algo application. In addition, we identified other ways that the e-algo application could be used by adding helpful features beyond the paper algorithm.

6. Acceptance and usage

We found that over two thirds of patients preferred the e-algo to a traditional clinical encounter and that they were confident in it being used for their care. Some health care workers felt that patients liked the idea of a computer diagnosing them. This is in line with the findings of DeRenzi [4] and Bogan [5]. Perhaps related to the patient acceptance, they saw the health care workers were also generally quite positive about the e-algo. The fact that patients generally accept electronic devices used by HCWs in their care is not surprising. The issue studied by Cheng [10] of patients giving false answers in HIV care due to fear of how the data may be used did not seem to apply to general medical diagnosis. No HCW reported the feeling that the patients were not reporting accurately.

The HCWs in phase one also verbally acknowledged the value of the tool and stated that they found it helpful in terms of diagnosis as well as standardizing their care. However, the second phase also showed that HCWs did not use it consistently with all the patients that they encountered. Use reduced considerably after the initial compulsory phase – from 83% to an estimated 15% of patients. They only used it on patients when they were confused or as a reference source for treatment and management of diseases that they did not see on a regular basis. Perception of time-taking was the primary factor that impacted its use. They requested short-cuts to key features such as the differential diagnosis, emergency treatments and management options without going through the whole patient encounter process. This issue may be specific to the Nepal context where government HCWs generally work from 10 am to 2 pm. Most have their own private medical practice which they use to supplement their income. Thus, they do not have an incentive to spend the necessary time with patients in the government clinic. This contributes to cutting corners in their traditional patient encounters. The e-algo required that they complete all the traditional steps in a quality patient encounter. This variable could be a barrier to HCW usage despite their acceptance of the tool.

Thus, as has been shown in other studies, the primary barrier to the successful implementation of mobile health applications is convincing the HCWs to use them on a regular basis. This study shows that the barrier also applies to diagnostic decision support applications as it has applied to data collection or disease treatment protocol tools.

For any mobile application to be successful it must meet three basic criteria. It must be perceived to be accurate and valid, time saving and it must present features that a HCW deems necessary for patient care. If these three aspects cannot be delivered in a comprehensive application that is easy to use, the HCW will not use it consistently. This presents the main challenge to all that are seeking to use this type of technology to improve the quality of health delivery in the developing world.

6.1. *The e-algo as a learning tool*

Another aspect of the application not foreseen by the developers was that the users saw it as an educational tool for themselves within the context of a clinical encounter. The decision-making flow, the questions that needed answers and the attention to warning signs also functioned as an educational refresher for the HCW. Thus, although the e-algo may not be used for every patient, their decision-making process may be reinforced, resulting in more accurate diagnoses, treatment and outcomes. This could be an area of further research.

6.2. *Technology and software challenges*

The e-algo interposes relatively high level of technology into an undeveloped setting. More software bugs than anticipated were discovered after the phase one data was collected. There were 126 e-algo encounters that ended in an application error (10.7%). These errors occurred randomly in many of the algorithms, but were primarily concentrated in the fever and joint pain algorithms. These have been revised and errors have been reduced in the upgraded version.

There were technical limitations of the study including the quality of the tablets used for the study. A Chinese-made Mitashi "Play B100" 7-inch tablet was used in all but one of the study sites. These tablets cost approximately $150 each in the local market. The quality, especially the touch-screen sensitivity, was not optimal. This resulted in multiple tries to finger-click on items.

The e-algo application relies on a well-functioning electric infrastructure for tablet battery recharging. Nepal, depending on the season, can be without 10–20 h of electricity a day. This makes the use of a tablet on a consistent basis problematic. That said, lack of reliable electricity and battery life does not seem to be a major factor in non-use. Almost all HCWs own a mobile phone which requires electricity and they seem to use them without any problem.

HCW usage of a mobile device must include easy usability. This study supports previous findings that HCW input into the development of these mobile applications is critical. Communication and feedback from the end-users is a crucial step to ensuring a user-friendly application that is not only accepted by HCWs, but also actually used.

7. Future direction

Based on the feedback from the HCW users, the developers have made significant changes in the application. Version 2.4 includes the addition of chronic patient encounters, a shortcut to disease references, emergency treatment protocols and the differential diagnosis based on the chief complaint. Other algorithms have also been added that were not in the original application. The HCW users continue to use version 2.4 and NSI is continuing to collect feedback and monitor long-term usage by HCW's.

Authors contributions

Stephen J. Knoble, the lead author was the primary designer of the study methodology, tools and data analysis. He was involved in the pre-study testing of the tools and conducted one of the phase two focus group discussion. He also was the primary writer of the draft study manuscript.

Madhab Bhusal, the co-author, had substantial input into the design of the study and tool preparation. The co-author also conducted and coordinated the initial field work and conducted the phase one focus group discussions. He also conducted the majority of the follow-up phone interviews. The co-author also had some input into the draft study manuscript.

Summary points

What was already known:

- Disease management and data collection electronic applications have been used in studies with some success in developing countries.
- Health care workers do not like to use paper in front of patients as they believe patients see it as a sign of incompetence.
- Patients generally accept the use of electronic mobile health applications by health care workers in their care.

What has been added with this research:

- This study shows that diagnostic decision making applications are also accepted by patients and health care workers.
- Even if mobile applications are "accepted" by health care workers. They will only occasionally use them if it is not compulsory. Reasons for non-use primarily are time related but also include validity and ease of use.
- Mobile clinical decision making applications can serve as learning tools for health care workers and not just improve patient care.

Conflict of interest

The lead author and co-author are both employees of the Nick Simons Institute. The Nick Simons Institute is a non-profit, health development organization which funded the development of the e-algo mobile application and this research.

The lead author is a developer of the paper algorithms and the primary developer of the e-algo application of which this research seeks to evaluate. The e-algo application is not a commercial product and neither the Nick Simons Institute nor the author seek or expect to get any financial benefit from the success or failure of this product.

Acknowledgements

The authors would like to thank the mid-level health care workers for their assistance with this study. Additionally, the Gulmi District Health Officer and the administrators of the Primary Health Care Research Center and Tansen Mission Hospital for their support. Special thanks to Dr. Barry Farkas whose input was invaluable in the overall development of the algorithms. Thanks also to Drs. Mark Zimmerman and Daniel Munday who also added their input and editing skills to this project. This study was funded by the Nick Simons Institute.

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