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Original Article

Application of 4G wireless network-based system for remote diagnosis and nursing of stomal complications

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Abstract: Background: This study aims to apply 4G wireless network in the remote diagnosis of stoma complications for the first time. Background: Remote diagnosis and nursing care for a variety of illnesses are urgently needed in clinical settings. Objectives: Combining with relevant clinical manifestations, an Android phone-based intelligent diagnosis system was designed to construct a universe, easy access to exploitation and human-computer interaction database and exploitation environment for applications and programs. Methods: "Production rule" and forward reasoning method were utilized to design arborescence structures and logic reasoner associated with stoma complications. Stoma physicians were responsible for delivering evaluation scores on patients' health status using analytic hierarchy process. The emphasis of this study is to exploit an "Android phone-based system for remote diagnosis of stoma", which is of certain universe usage. Results: Such system was tested in the Medicine Information Center of Qilu Hospital of Shandong University and initially applied in the city of De Zhou, Shandong province, China. Conclusions: These results collectively demonstrated that the system is easy to carry, of high utility and free from the limitations of wire network environment, *etc*. It provides clinical evidence for establishing a novel type model for the exchange between patients and physicians.

Keywords: Stomal complications, remote diagnosis, mobile phone, nursing

Introduction

Albeit the quality of life has been enhanced, the incidence of digestive and urinary system diseases, such as rectal cancer, bladder carcinoma and ileus is gradually increasing year after year. Enterostomy is the most commonly used surgical technique for the purpose of saving patients' lives with a population of more than 100,000 around the globe each year, especially for cases of ileum terminal or colon stoma. It is estimated that approximately 100,000 new cases developing permanent intestine stoma each year in China and the total count adds up to approximately one million [1]. More importantly, the incidence of rectal cancer keeps ever rising in China. Consequently, the number of cases with stoma is likely to have an elevating trend [2]. Postoperative nursing, complication treatment and continuing nursing play an extremely important role in the quality of life of stoma patients [3, 4]. Previous studies indicated that a percentage range of 16.35% and 53.8% of intestinal stoma patients presented with one type of complications or above [5]. Common postoperative complications included skin inflammation surrounding stoma, parastomal hernia, hyperplastic granulation tissue and stoma prolapse, *etc*., which result in worsened quality of life and even threaten patients' lives. Based upon previous findings, main problems and characteristics during the diagnosis and nursing of stoma complications are stated as follows [6-9].

1. High nursing standards: professional, continuing and systemic nursing care is urgently needed from the special department because of multiple and common postoperative complications. However, continuous postoperative nursing service is still lacking in most hospitals.

2. High costs: a large proportion of patients are located in a site with a long distance from the

hospitals. Hence, the transportation fee is high, which may even prevent the patients from admitting to hospitals in a timely manner.

3. Visualized display: the physicians can merely instruct the patients how to nurse themselves aided by telephone consultation or non real-time network platform. Additionally, 85% of cases with stoma complications can be finally diagnosed and properly delivering nursing care by means of image consultation.

4. Lack of professional stoma physicians: up to December, 2012, a total of 514 stoma physicians have been registered in China, merely 23 of whom from Shandong province. Among the cities in Shandong province, no stroma nurses have been registered in five cities including De Zhou, Lai Wu, Tai An, Wei Fang and He Ze.

Remote medical treatment integrates a variety of disciplines, which utilizes remote communication, computer and multimedia and information technologies into the remote transmission of medical and clinical data of patients, thereby realizing the goal of implementing remote nursing and consultation. At present, relevant attempts have been made both at home and abroad. A home user can capture an ECG waveform by using ECG@ home device, invented by Health Frontier from the United States, and transmitted the measured data to the service provider [10]. IST from European Union and King's College of London from the United Kingdom cooperated to exploit and develop medical devices for home users [11]. Chinese researchers Guangya Chen and Junbo Chen hosted a project of a collection and wireless transmission system for multiple life signs [12]. The staff from Shenzhen Eten Technology is working on a project regarding a wireless ECG monitor [13]. To sum up, along with the progress of communication techniques, especially the invention of 4G technologies, remote systems designed for medical purposes have evolved from wire era to wireless connection, which provides novel clues for the diagnosis of stoma complications and new evidence for establishing a new generation of patient-physician exchange model.

This wireless connection-based remote technique, invented in this study, overcomes the disadvantages of geographic locations and wire cables in the wire connection mode. However, this technology is still in premature stage and remains to be applied in a broader range. Currently, it mainly applies to the PC and PDA terminals [14, 15]. In terms of the actual effects, the application of such terminal into remote medical settings is highly expensive and has limited functions for ordinary users. It equally depends upon network environment, which reduces the range of application. In addition, current remote system is mainly based on windows operation system, which negative affects the open resources, free of charge and human-computer interaction. Consequently, in this study, we attempt to exploit a user-friendly remote system for diagnosing stoma complications by using a popular application terminal, which is free of charge and of open resources. The exploitation is of clinical significance for providing a novel and timely technology to deliver nursing care for stoma patients.

Recently, along with the popularity of smart mobile phones, Android operation system and the wide coverage of 4G network, more and more Chinese users chose to utilize 3G smart phones, especially the Android-powered handsets priced below 1 000 yuan [16-18]. The popularity of these phones attributes to the following aspects. First, 3G Android phone is an intelligent terminal which integrates phone chatting, multimedia, and internet-surfing into one device. Second, the price is low and accepted by a large population. Third, it is free of charge and open resources, which provides more flexible designs for software designers. Fourth, it supports the functions of audio chat and screen touch, which enhances the human-machine interaction. All these advantages demonstrate 3G Android phone as a proper platform for exploiting remote diagnosis system for stoma complications.

In this study, a 4G wireless network-based remote diagnosis system was designed, facing the users of Android phone terminals. First of all, a remote diagnosis system for stoma complications and a system for health guidance were simultaneously invented. Then, the "production rule" and forward reasoning method were adopted during the design process. Subsequently, the stoma physicians began to evaluate on the health status of patients and deliver corresponding scores via this remote system. Finally, the remote system was widely

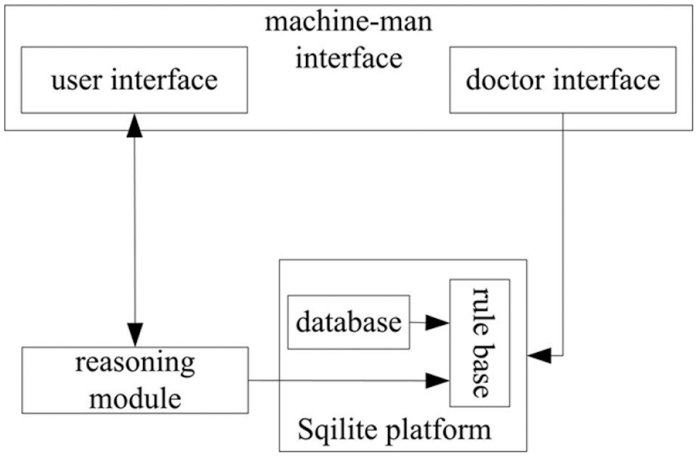

Figure 1. Structure chart of intelligent system.

applied in hospitals from the city of De Zhou, based on the hardware and software technologies provided by Qilu Hospital of Shandong University.

Methods

System function and structure

The measuring and monitoring software is embedded in Android-based 3G mobile phones, which integrates a variety of functions, such as nursing knowledge of stoma complications, remote registration, stoma imaging, remote consultation center with instant exchange, recording and managing patients' information, *etc*. After image gathering, the obtained images of stoma patients and users can be transmitted to the 4G network-based adjuvant diagnosis system as image files based on the signaling protocol of SIP. The stoma physicians are able to simply login on the system and download and unzip the files containing patients' clinical data (medical record and stoma images) using mobile phones, make a diagnosis using the adjuvant system, deliver evaluations of patients' health status and nursing suggestions and issue new updates of the field progress on a regular basis. The information managers are responsible for managing the information of all users, patients' data and the dispatch of stoma physicians, *etc*. All these data are restored in the database of the information center. The system consists of four different modules: image processing module, alarming module, instant exchange module and diagnosis information management module.

Image processing module: this module connects remote server, produces a remote-working list of all stoma clinicians by identity validation, receives and decodes the data package transmitted from the data port of wireless transmission equipments, adds the new data into the data queue and allows the clinicians to observe the stroma status and make a prop er diagnosis using this module.

Alarming module: the system is defaulted to set an alarm of one of the three parameters exceeds the defaulted threshold limits.

Instant exchange module: both pa-tients and physicians can perform instant communication via this module, which makes the mutual exchange easier and simpler.

Diagnosis information management module: it mainly functions to record diagnosis outcomes including three sub-modules: patients' information, physicians' advice and patients' implementation sub-modules.

Structural design of intelligent system

To resolve the disadvantages of Android phones in terms of database support and hardware resources, the remote diagnosis system for stoma complications mainly comprises human-machine interaction interface, reasoning structure, rule base and database, *etc*., as illustrated in **Figure 1**.

As shown in **Figure 1**, visualization interface is adopted for the convenience of users. The physicians' interface functions to update rule base and use database. The reasoning module is achieved by means of JAVA. Both database and rule base are equally exploited aided by the Sqlite3 platform.

Both the database and rules are independent of the exploitation of application programs. Hence, the users can simultaneously update the database using 4G network when the physicians make updates regarding rule base and data.

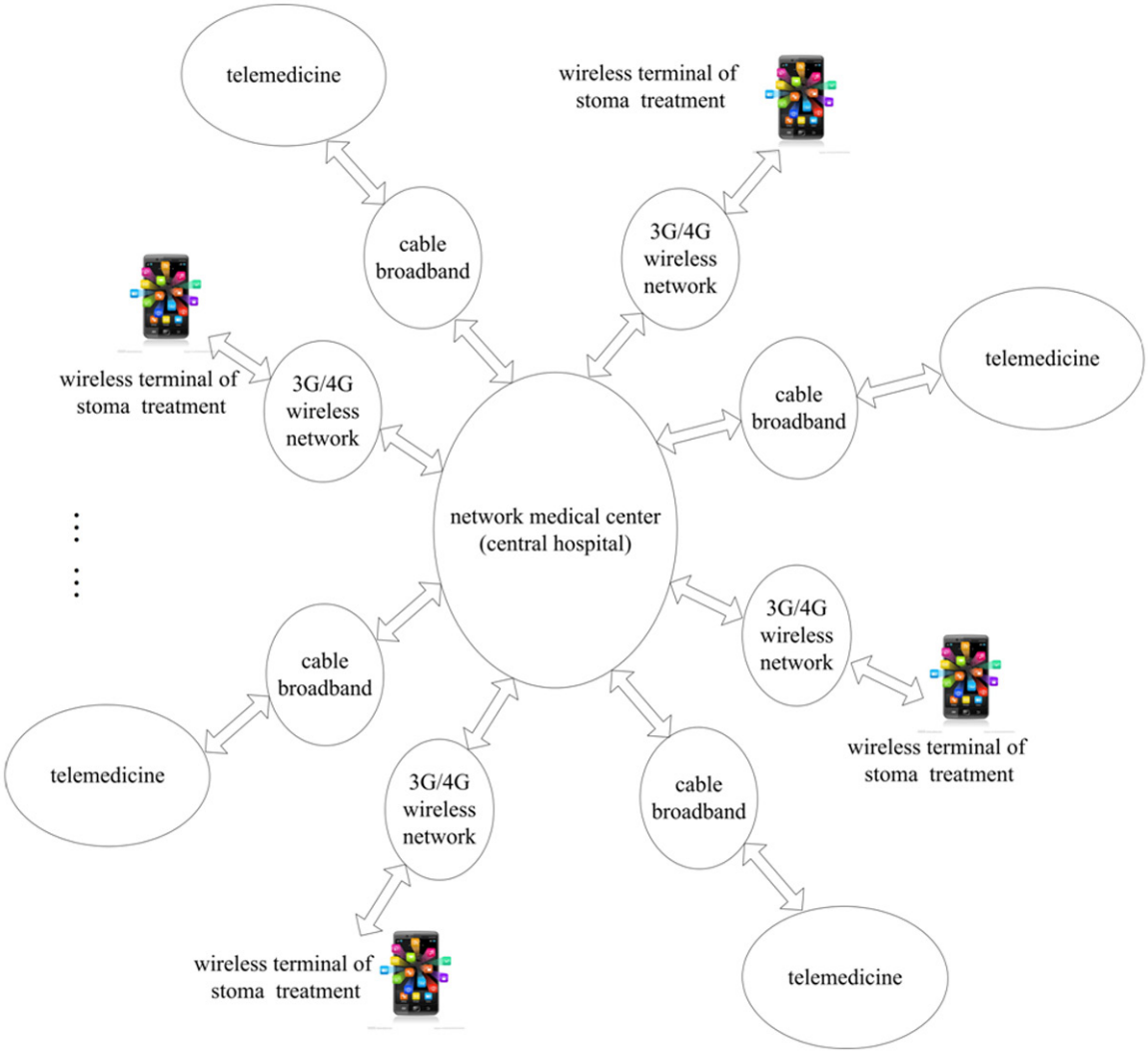

Figure 2. Structural sketch of remote diagnosis system for stoma complications.

Overall framework

The overall framework of this system is illustrated in **Figure 2**. The major links include conventional remote medical station, remote wireless terminal and diagnosis and treatment center located at the medical information center. Patients have multiple options and make a choice based on individual preferences. They can simply stay at home and receive diagnosis, treatment and health guidance via the wireless terminal (mainly mobile phones), go to the nearby remote medical station or choose to face-to-face inquiry with the stroma physicians in large comprehensive hospitals. This study was approved by the Ethics Committee of Qilu Hospital of Shandong University (QL876542).

Results

In this remote adjuvant diagnosis system for stoma complication, Android phone is utilized as the receiver terminal. Besides the professional knowledge and experience from the experts, the remote consultation center also requires the expert system to conduct adjuvant assistance. This remote intelligent diagnosis system for stoma complications satisfies the requirement of adjuvant assistance. The intelligent phone client is developed based on the android 2.3 platform, running test on a smart mobile phone. On the basis of Android platform, the system directly utilizes the function ports of blue tooth and wireless modules and controls the functions of these two modules.

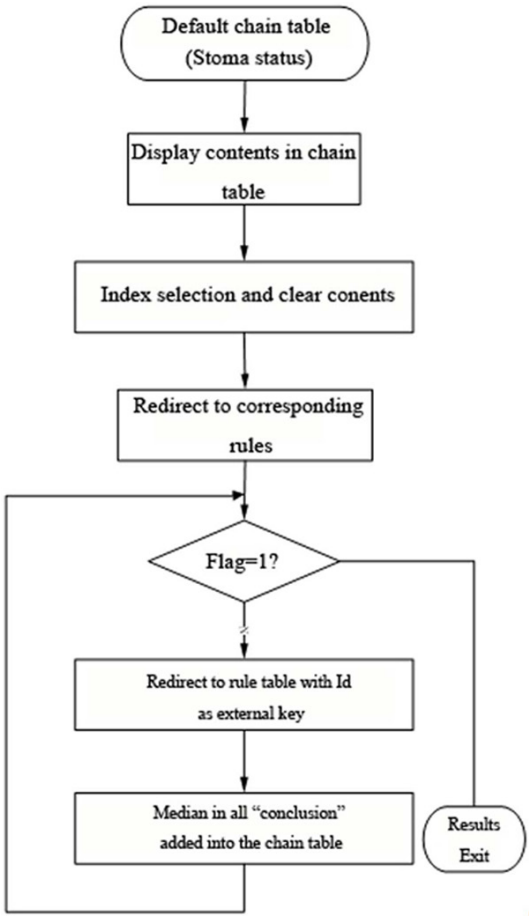

Figure 3. Flow chart of logic reasoner program.

Construction of knowledge table

According to the physicians' experience and the findings reported by relevant literatures, the clinical characteristics are summarized and classified. A knowledge table for stoma complications is designed according to the classification of color changes displayed in images, ulcer and tissue hyperplasia, which provides a foundation for rule base establishment.

Construction of rule base and data structural table

Combining with knowledge table of stoma complication diagnosis and the diagnostic search logics, the knowledge table is described in a straight manner. Knowledge table was adopted to express the "production rule" and the knowledge rules of this intelligent diagnosis system, which transformed into the expression form of "production rule" in all pathways from the root nodes to leaf nodes. Accordingly, we designed

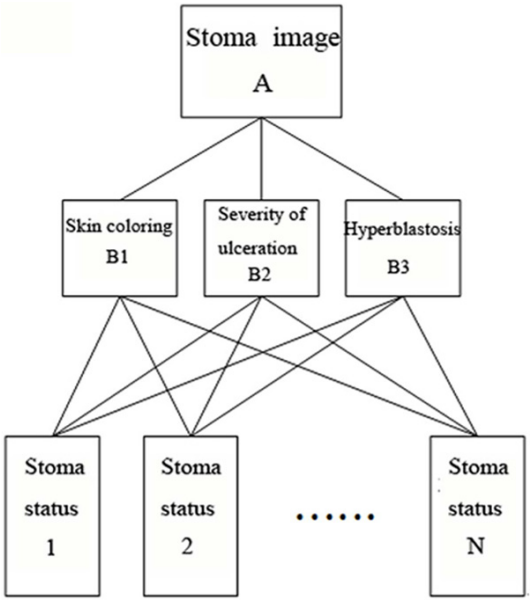

Figure 4. Hierarchy chart of diagnosis images of stoma.

a structural table for this intelligent diagnosis system using rule base and the fields and meanings were stated as follows:

Realization of system logic reasoner

By means of rule base designs and forward reasoning method, the logic reasoner of this intelligent diagnosis system is achieved using Java programming language, as illustrated in **Figure 3**. The realization of logic reasoner involves database processing and SQLite database is required (android. database. sqlite. SQLite database). SQLite database static method is utilized to create or modify the database.

Adjuvant decision-making by physicians

Analytic hierarchy process was adopted to evaluate the images of stoma patients: the doctors delivered scores for each parameter according to stoma images and patients' self-complaints, the system automatically produced the comprehensive evaluation results and the evaluation details and doctors' advice were input into the database for subsequent use. The detailed process method was stated as below.

The weighted influence of each factor upon the stoma complications was quantitatively analyzed and the correlation between various influential factors was analyzed to construct hierar-

Table 1. Analytic hierarchy process-based judgment matrix on the health status of stoma patients

A	B1	B2	B3
B1	1	a/b	a/c
B2	b/a	1	b/c
B3	c/a	c/b	1

chical network of various factors. The influence of each factor of the lower layer on those of the upper level was subject to paired comparison to construct a judgment matrix. The relative weight of the lower level factor to the upper level factor was validated by the judgment matrix. The synthetic weight of each layer factors on the stoma complications was evaluated. The factors were arranged in sequence according to the synthetic weight. The relative weight for each factor was illustrated as follows.

$$\omega_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}$$

n=1, 2...n; I and n are natural numbers, a, I and j denotes value at the line i and row j (**Figure 4**).

In **Table 1**, a, b, and c denote skin color, degree of ulcer and the effect of tissue hyperplasia on stoma severity; the data denote the relative severity of paired factors. a, b and c values were determined after expert discussion (range: 1-9), the defaulted a was 1, 2 for b and c; B1, B2 and B3 denote the relative severity of paired factors.

System completion and update

After completing the exploitation of each system module, the order of "Run As Android Application" was implemented to produce the installation files (APK files) and uploaded the documents to the server. The installation files can be downloaded to the users' smart Android phones, PC or the SD card.

Data update is conducted both at the physician and patient terminals. For the physician terminal, the system database and rule base can be modified on the smart phone and uploaded the updated system database files to the server. For the patient terminal, the users select whether update or not after noticing the update notification.

Discussion

System implementation and integration

Utilizing a simple and user-friendly interaction interface and assisting the users to exploit ideal strategy rules are the vital premises of widespread application of this adjuvant diagnosis system. The human-machine interaction interface is designed based on the Android SDK.

System test

The system mainly comprises common user and physician functions. Common user functions include remote registration, uploading images, analyzing the disease severity assisted by remote system and instant communication with physicians, *etc*. Physician functions include viewing images, medical records and modifying the rule base at the background. In this study, Samsung I5700 mobile phones were used as testing devices and the remote system was tested in the city of De Zhou based on the remote network laboratory of Qilu Hospital of Shandong University.

1. Testing images as illustrated in **Figure 5**.

2. Testing procedures: typical images revealing stoma complications were uploaded. The remote system ran testing for 100 times and the diagnosis outcomes were statistically analyzed. The results revealed that the accuracy rate of diagnosis achieved up to 93.1% and the mean time of uploading data was 40 seconds, suggesting a relatively high accuracy rate and efficiency.

Conclusion

In this study, we invented a design method of a novel type of "Android mobile phone-based remote diagnosis system for stoma complications", successfully constructed the system exploitation environment by using "JDK + Eclipse + AndroidSDK + ADT" and sqlite3, and implemented adjuvant decision-making by employing "production rule", forward reasoning and analytic hierarchy process. The invented remote system utilizes the human-machine interaction provided by the Android operation system, offers new methods for updating the system database files, achieves multiple functions of remote registration (selecting specialty

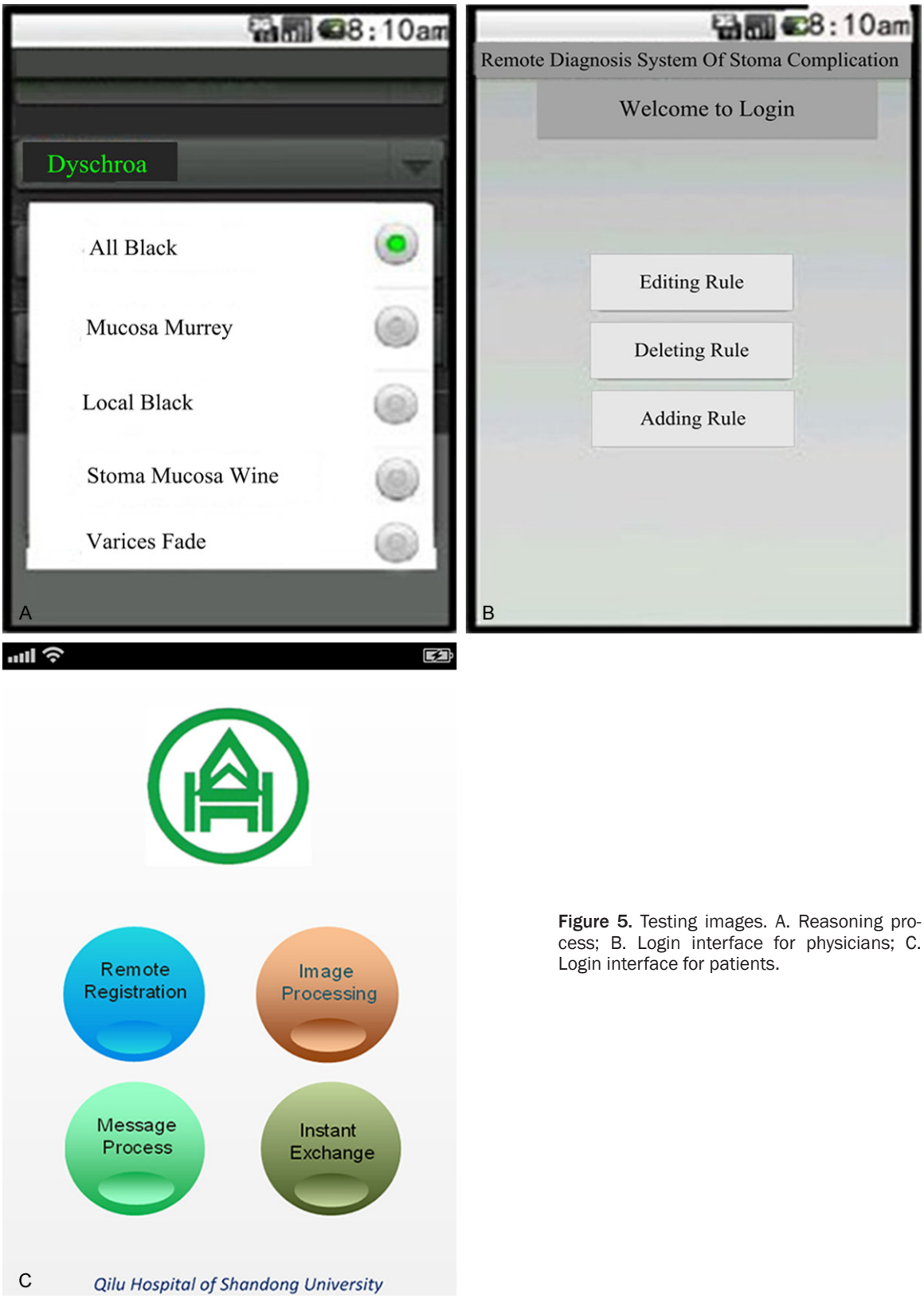

Figure 5. Testing images. A. Reasoning process; B. Login interface for physicians; C. Login interface for patients.

or ordinary registration), uploading stoma images, instant communication between patients and physicians and provides rational nursing advice.

Disclosure of conflict of interest

None.

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