Developing a Mobile Application for Estimating Patient's Radiation Dose

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ABSTRACT

In diagnostic radiology, entrance surface air kerma (ESAK) is one of the patient radiation dose quantities, and the effective dose is used as an estimator of possible risk for radiation exposure level. Calculation of the ESAK and effective dose requires both X-ray machine parameters and patient exposure parameters. Due to the high performance of smartphones and the increase in mobile applications, this study aimed to develop a mobile application to estimate the ESAK and effective dose in general radiography. The ESAK calculator was then developed using Android studio software, which is a standalone application operating on Android operating system version 5.0 or higher. X-ray machine parameters are initially required for calculating X-ray output. For the ESAK and effective dose calculation, exposure parameters for each examination are needed. The results showed that the average score of satisfaction was 4.64±0.13, which was very satisfactory. In conclusion, the ESAK calculator could be used for estimating ESAK and effective dose for individual radiographic examination.

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Keywords

Smartphones; Mobile Applications; Radiography; Radiation Dosage

Introduction

Global system for Mobile Communications Association (GSMA) reported that the number of mobile users reached 5.2 billion (67% of the world population) by the end of 2020 in the world, reaching 70% of the population by 2025 [1]. This report indicates that mobile devices provide a greater impact on daily life. At the same time, various purposes of mobile applications have also been developed to support the mobile user requirements. Mobile applications are generally used daily for an easier life, such as banking, shopping, entertainment, and education [2, 3]. Applications are used not only for general purposes but also for special purposes, such as medical/health-related applications [4-7]. The number of health-related applications in 2017 was estimated greater than 165,000 [8] for radiological diagnosis purposes.

Advancement in radiological diagnostic technology provides reliable and expeditious ways of diagnosis. On the other hand, the number of patients who require a radiological diagnosis is increasing. However, the radiation dose delivered to the patient is relatively low in diagnostic imaging, it is considered the risk of stochastic effects, especially for the pediatric and young patients. As low as reasonably achievable (ALARA) is the principle of radiation doses for patients and personnel recommended by the International Commission Radiological Protection

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(ICRP). The patient dose is difficult to measure directly during examinations. According to a technical report series (TRS), no.457 of the International Atomic Energy Agency (IAEA), incident air kerma (IAK), entrance surface air kerma (ESAK), and air kerma-area product (KAP) are recommended as the principal quantities for measuring patient radiation dose [9]. Furthermore, the effective dose is a radiation quantity related to the possibility of radiation-induced stochastic effect [10]. Therefore, the effective dose is used as an approximate indicator of possible risk for diagnostic radiation exposure level [11].

To the best of our knowledge, the mobile application for estimating the ESAK and effective dose in general diagnostic radiology has not been developed and released by application providers. This study aimed to develop a mobile-based application operated on the Android operating system to estimate the ESAK and effective dose in general diagnostic radiology.

Material and Methods

This study was approved by Naresuan University Institutional Review Board with the number of COA No. 534/2018. The proposed application was classified into two phases and designed for an Android operation system. The user interface (UI) and flowchart of the application were designed in the first phase. The application was developed using the Android Studio software.

The calculation and definition of the ESAK in this application followed the technical report series (TRS) no.457 [9]. In addition, the ESAK is incident air kerma with backscattered radiation included and is calculated by IAK, which is the kerma to air measured on the central beam axis at the patient or phantom surface and multiplied by the back-scatter factor as follows (1).

$$K_e = K_i \times B \quad (1)$$

Where K_e is entrance surface air kerma (mGy); K_i is incident air kerma (mGy), and B is the back-scatter factor. In clinical calculation, if the radiation tube output is known, equation (1) can be derived as (2).

$$K_e = Y_{(d)} \times mAs \left(\frac{d_{SDD}}{d_{SID} - t_p - t_b} \right)^2 \times B \quad (2)$$

Where $Y_{(d)}$ is X-ray tube output (mGy/mAs); mAs is milli-ampere second; d_{SDD} is the source to detector distance; d_{SID} is the source of image receptor distance. Additionally, t_p is patient's thickness at the central beam axis, and t_b is tabletop/ wall bucky to image receptor distance (if bucky radiography is used).

For the application design, basic X-ray machine information is required, such as a source to detector distance (d_{SDD}), tabletop-to-image receptor distance (t_b), and half-value layer (HVL) for a specific kVp, total tube filtration, added filtration, and radiation output equation. The output equation for each X-ray machine can be manually added in terms of (3).

$$output\left(Y_{(d)}\right) = ax^2 + bx + c \quad (3)$$

Where x is kVp.

Otherwise, the application was designed to create the output equation by radiation output for various kVps that all basic information is stored in the database of the application. Further, kVp, mAs, filed size (FS_W*FS_L), and patient thickness (t_b) is also required for the ESAK calculation. Backscatter factor (BSF) is calculated based on water material for a specific HVL according to the technical report series (TRS) no.457 [9].

The estimation of the effective dose per examination was obtained using the ESAK to effective dose conversion factors as follows:

$$K_e = K_e \times CF \quad (4)$$

Where CF is ESAK to effective dose conversion factors.

The effective dose was estimated from the ESAK using the appropriate conversion factors for posteroanterior and lateral chest, anteroposterior and lateral cervical-thoracic-lumbar spine, and anteroposterior abdomen as 0.130, 0.090, 0.035, 0.023, 0.094, 0.031, 0.120, 0.027, and 0.130, respectively [12]. The flowchart of the calculation is shown in Figure 1.

The second phase was validation and user evaluation. The correctness of the calculation of this application was tested and validated by comparing results with those of Microsoft Excel. User satisfaction was then performed and divided into two aspects: application usability, accessibility, and design. The satisfaction was assessed by five radiographers using a 5-point Likert scale 5, in which 5,4,3,2,1 are very satisfied, satisfied, neither, dissatisfied, and very dissatisfied, respectively.

Technical Presentation

The ESAK application, named ESAK calculator, can calculate the ESAK for individual examinations and the effective dose (optional) for 9 examinations. The application can be installed on Android operating system version 5 and above with 31.12 MB of mobile phone storage. Figure 2 shows the icon of the application with a screenshot of the main menus which are machine-information addition, calculation, and guidebook. The basic information of the X-ray machine is initially required and saved to the database of the application as shown in Figure 3 (left). The X-ray machines can be added as many as required. Figure 3 (right) is the calculation page by entering exposure parameters requesting to calculate the ESAK with an option to calculate the effective dose. The calculation results are rounded into 4 decimal places.

The calculation results were validated by comparing with the calculation on Microsoft Excel 2013 on the PCs. As the calculation method was the same for the application and Microsoft Excel, the results were the same.

The user satisfaction assessment showed that the average scores were 4.63±0.15, 4.67±0.12, and 4.64±0.13 for application usability, accessibility, design, and overall aspect, respectively (Table 1), showing that users were very satisfied with the application. Regarding the application usability and accessibility aspect, the usefulness in diagnostic radiology and the accessibility of the application was the highest score. A total of 4 of 5 radiographers were very satisfied with the usefulness in diagnostic radiology and the accessibility of the application, and one was satisfied. The satisfaction of the user manually received the lowest score in this aspect. For application design, the size,

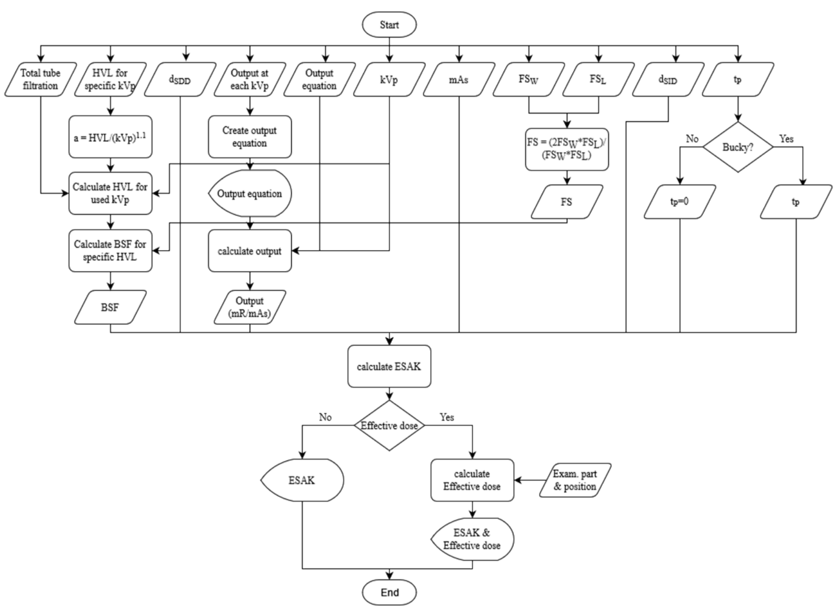

Figure 1: Entrance surface air kerma (ESAK) and effective dose calculation flowchart

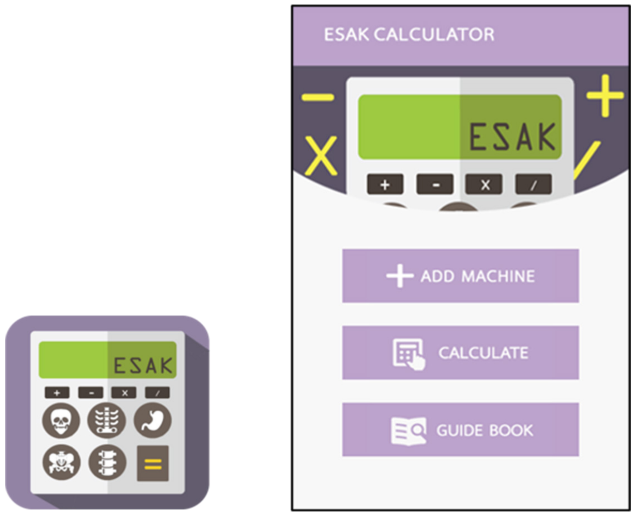

Figure 2: Application's icon (left) and a screenshot of the main menu (right).

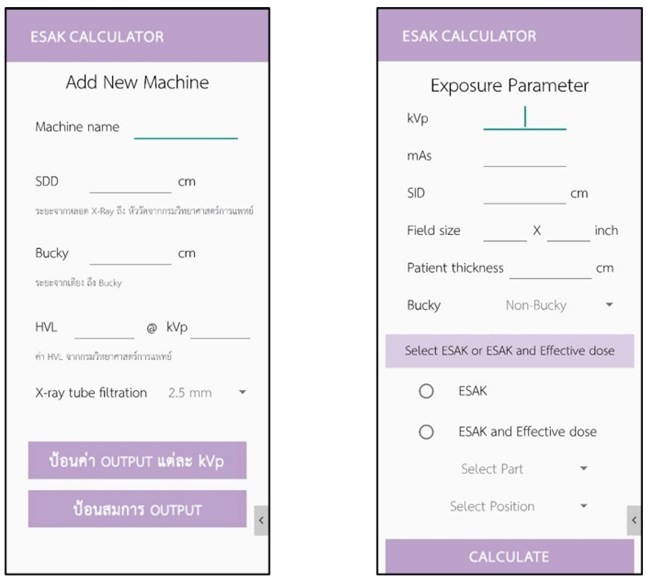

Figure 3: Application screenshots of inputting the X-ray machine information (left) and the exposure parameter (right)

style, and color of text were considered suitable for the application with the highest score while the screen design and button, and UI were also very satisfactory.

Discussion

Mobile phones have become a very important device due to a vast number of mobile applications available on the market, changing very commonly used options because of their simplicity, user-friendliness, speed, and portability [2]. They have been introduced into a medical/healthcare-related field since the early 2000s including disease diagnosis, drug reference, medical calculators, clinical communication, and medical training [4]. In radiology, several mobile applications are available such as mobile Picture Archiving and Communication System (PACS) workstations, mobile Digital Imaging and Communications in Medicine (DICOM) viewers, image interpretation, radiology education/training,

Table 1: User evaluation scores from radiographers (n=5)

Aspects	Mean±SD	Meaning
Application usability and accessibility		
1 Usefulness in diagnostic radiology.	4.80±0.45	very satisfied
2 Easy to access the application	4.80±0.45	very satisfied
3 The application can be used continuously, smoothly, and without interruption.	4.60±0.55	very satisfied
4 Calculation time.	4.60±0.55	very satisfied
5 The text is readable and understandable.	4.60±0.55	very satisfied
6 The user manual is easy to understand	4.40±0.55	satisfied
Average	4.63±0.15	very satisfied
Application design		
1 Screen design	4.60±0.55	very satisfied
2 Size, style, and color of the text	4.80±0.45	very satisfied
3 Button and UI	4.60±0.55	very satisfied
Average	4.67±0.12	very satisfied
Overall average	4.64±0.13	very satisfied

SD: Standard deviation, UI: User Interface

and radiotherapy calculation [13-16].

The ESAK calculator is a standalone application without any need for an internet connection or any other service. The installation requirements are an Android mobile operating system version 5 or higher with at least 31.12 MB of free space that this application has an option to estimate the effective dose for 9 examinations.

Moreover, the ESAK is a radiation dose quantity recommended by ICRP for setting diagnostic reference levels (DRLs), which is an effective tool in the optimization of patient radiation doses for diagnostic procedures [17]. Therefore, if the local or national DRLs are establishing or revising, this application could help to calculate the ESAK for individual examination. Additionally, this application could help the radiological technologist to calculate the patient doses for comparing to the DRLs for reviewing the exposure technique setting. However, there is no recommendation to calculate the patient radiation dose individually. Therefore, this application was developed for radiographers, not for patients.

This study has some limitations as follows: 1) the ESAK calculator provides only the Thai language restriction for Thai users, 2) there is no data backup and data storage for individual examination options which could be further developed, and the application was only developed for the Android operating system.

Conclusion

In this study, an android-based application, named ESAK calculator, was developed and validated for estimating the ESAK in general radiography. This application has an option to estimate the effective dose for 9 examinations. The application can be used to estimate the patient dose for individual examination and help to establish or revise the local or national DRLs as ESAK is one of the radiation dose quantities recommended for setting the DRLs. User evaluation results showed that users were very satisfied with the application.

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Authors' Contribution

T. Pengpan was involved in the writing, research planning, and development of the methodology, and was responsible for the funding acquisition and supervision. N. Nulnukul, T. Kongthai, and S. Boonrueng contributed to application design, development, validation, and the application's user satisfaction analysis. All the authors read and approved the final version of the manuscript.

Ethical Approval

This research was approved by Naresuan University institutional review board (COA No. 534/2018).

Informed Consent

Written informed consent to be a part of the user satisfaction evaluation was obtained from all participants.

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Conflict of Interest

None

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