Possible dose reduction by dose-rate measurements using mobile phones/tablets combined with tabulated imaging procedure/radiation doses

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ABSTRACT

The purpose of our study is to demonstrate the effectiveness of using smartphones for measuring ionizing radiation and to combine the findings with radiation exposure from medical imaging procedures for recording individual annual/life-time radiation dose and provide improved radiation protection.

We developed an application for smartphones which can use the properties of the video camera chip in such smartphones together with highly sufficient statistical evaluation of the signals to detect ionizing radiation. We could show that this application can be used in a large range of dose rates from natural backgrounds to high dose rate pulsed radiation like in fluoroscopic radiation or CT investigations.

We could also show that these kinds of systems might help to provide better radiation protection by advising medical staff to use radiation protection material in best dose saving ways.

Keywords: optimization, minimal exposure, mobile phones, online dosemeters, radiation protection material

1. INTRODUCTION

Medical radiation imaging is one of the major sources of exposure to ionizing radiation to the population in many countries [1, 2]. Beside the exposure of the patients there is also a radiation exposure to the staff performing the investigations. This is especially true for medical doctors and nurses performing interventional procedures. Increasing the awareness of the impact of different behavior (short fluoroscopy times, more protected positions in the room, mounted radiation protection systems as well as radiation protection shieldings for staff and patients) will help to reduce the potential harm for the interventional radiologists. To do so, it is necessary to measure the exposure throughout the investigations. There is a system on the market providing such information, but it is an additional system to carry, it is quite expensive and gets inaccurate as soon that someone is working in the direct radiation beam by chance. We found that the camera chip of a smartphone can be used for dosimetry as well. The purpose of our study is to demonstrate the effectiveness of using smartphones for measuring ionizing radiation, to validate the effectiveness of radiation shielding and to combine the findings with radiation exposure from medical imaging procedures for recording individual annual/life-time radiation dose and provide improved radiation protection.

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Medical Imaging 2013: Physics of Medical Imaging, edited by Robert M. Nishikawa, Bruce R. Whiting, Christoph Hoeschen, Proc. of SPIE Vol. 8668, 866804 · © 2013 SPIE · CCC code: 1605-7422/13/$18 · doi: 10.1117/12.2008013

2. METHODS

Standard smartphones/tablets were configured with one camera chip blocked by either taping it with black adhesive tape or by shielding it with a plastic cover. The non-visible photons (gamma & beta radiation) are used for ionizing radiation level measurements. We do so by using a software application, which make use of the fact that ionizing radiation interacts with the silicon of the camera chip. The video signal of the camera chip is read out. Afterwards we separate the noise from any possible signal. In addition we use statistical methods to classify the signals of the different image pixels of the camera chip. The form of the single hit image depends on the energy and the kind of the radiation. The signal is the summed up signals over a certain time frame and all detector pixels (except possible failed pixels and some borderpixels due to shielding problems or pixels inhomogenities). We perform internal calibrations followed by the calculation of dose rates from the counts using smartphone depending calibration curves. 40 different devices were tested in the IAEA secondary dosimetry laboratory of our center using various dose rates ranging between 10 µG/h and 10 G/h. In addition, recordings were obtained in various settings including e.g. background, air travel, and during fluoroscopy procedures. We tested the devices using the smartphone video camera and the RadioactivityCounter application even in conditions where standard electronic dosemeters as used today have difficulties showing any reliable results like in the unshielded beam of a modern computed tomography system (in our case Philips iCT [3]).

To show the efficiency of our new measurement tool as well as its adequate performance under relevant conditions on the one hand side we performed measurements in an neuroimaging investigation center. We evaluated the effectiveness of additional radiation protection material during fluoroscopy procedures (RADPAD, Overland Park, KS [4]) using this measurement method.

A previously published list of tables of imaging procedures and radiation doses was reviewed [5]. Medical imaging procedure history using equipment calculations and the tabulated doses can be combined with the recordings to obtain annual/life-time individual radiation exposures.

3. RESULTS

3.1 Calibration and dose rate range

Radiation levels recorded varied by model of the mobile devices; however with careful calibration most devices provided a reasonable estimate of confirmed radiation doses. The calibration curves of a number of units (to keep the single calibration curves separable) are shown in figure 1. Background radiation measurements varied depending upon the environment, for values below 10 µGy/h detection times of 15 minutes are necessary. This is due to various effects. On the one hand side there is a statistical fluctuation of the background signal especially important due to the small active detection area in the smartphone configuration. On the other hand, the performed statistical image evaluation might overestimate or underestimate the single event causing the signal in the detector. Each of the two main effects is averaging out after a certain while. We got very accurate results (within 10% deviation from a standard dosemeter for the environment for all tests).

For higher dose rates the needed integration time to gain reasonable accurate results drops with the dose rate. This is clear since both effects mentioned above are diminished linear with the dose rate. This means to measure an irradiation with a dose rate 10 times higher than the natural background would require a measurement time of less than 1 minute to achieve the same accuracy as above. For even higher doses and especially in quite uniform irradiation fields as in medical applications the needed measurement times will drop even further.

With all the irradiation equipment that was available to us either in the secondary standard dosimetry laboratory of the IAEA or its surrounding research irradiation facilities or in the clinical environment we could not reach a complete overflow of the signals. For the dose range given above (to 10 Gy/h) we did not measure any reduction in accuracy at all.

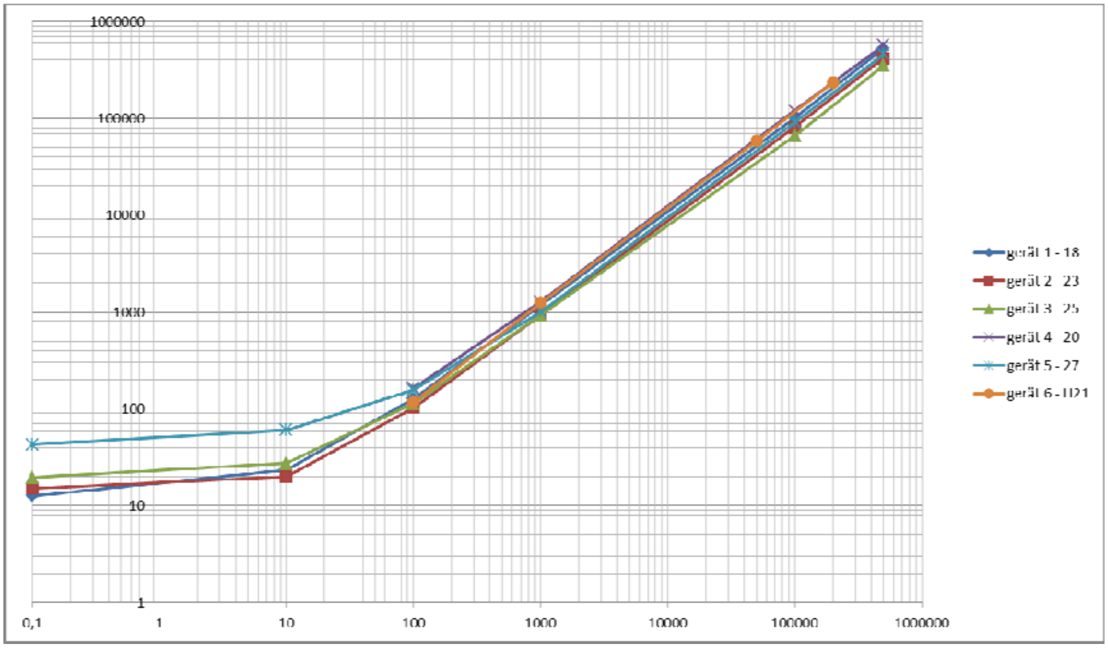


Fig. 1: 6 calibration curves measured for Cs-137 irradiation in various dose rates

3.2 Dose rate measurements in clinical applications

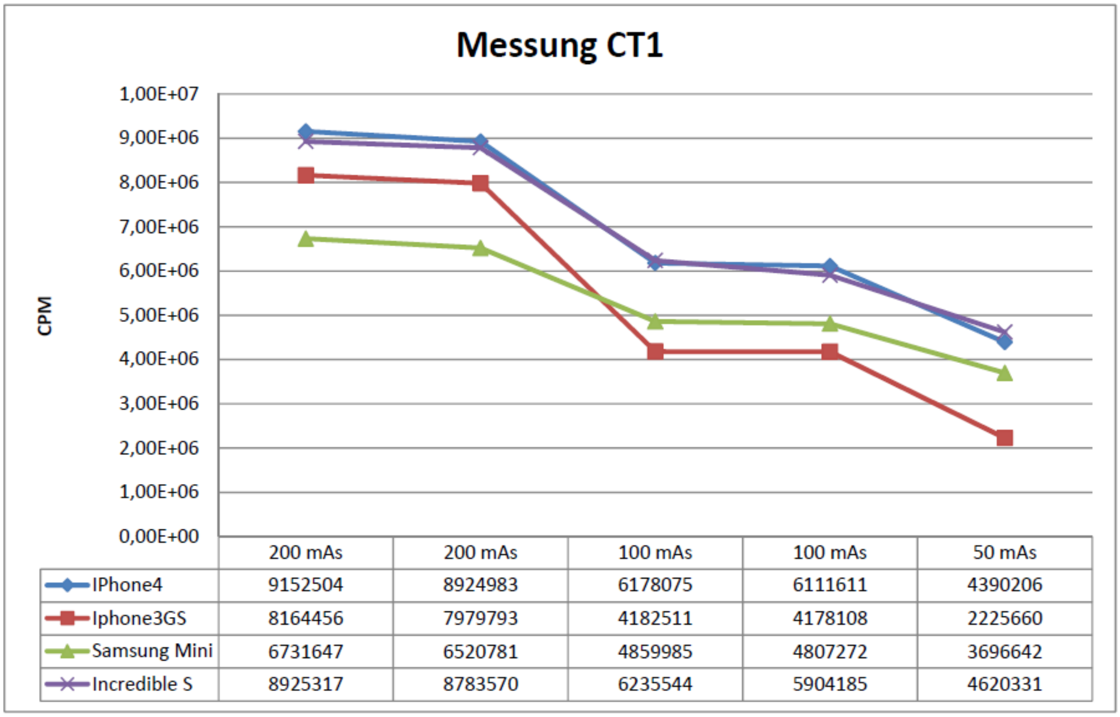
The result of the test of four different devices in the CT direct beam area is shown in figure 2. It proves the linear relationship between the applied dose and the output signal.

The RadioactivityCounter application provided evidence of increased radiation protection during fluoroscopy procedures using additional protective material. We show the resulting dose rates measured in a background condition (radiographic unit off) with the radiographic unit sending out irradiation but without protective clothing and the same source running with protective clothing in figure 3 a-c. We did the measurements with exact positioning of the smartphone-dosemeter on the body (head position) of the radiologists and we also recorded his position. These measurements are in good coherence with former results of the protective material. [6]

Annualized individual radiation dose estimates can be calculated by combining the actual radiation measurements, radiation equipment recordings and the tables of estimated imaging procedure doses.

4. DISCUSSION

Any smartphone can be converted to provide an estimate of ionizing radiation exposure. Appropriate calibration ensures accurate radiation measurements. This can be used for cost effective radiation protection training and confirm the effectiveness of additional radiation protection during fluoroscopic procedures. Combining background and occupational exposures with medical imaging doses can provide an estimate of individual radiation exposure. The solution of using the camera chip of a smartphone as a detector for ionizing radiation can also be used under certain circumstances to detect ionizing radiation caused by neutrons as e.g. in airplanes as it can be elaborated from figure 4. Thereby, also this elevated background could be implemented in the overall individual exposure data.



	200 mAs	200 mAs	100 mAs	100 mAs	50 mAs
IPhone4	9152504	8924983	6178075	6111611	4390206
Iphone3GS	8164456	7979793	4182511	4178108	2225660
Samsung Mini	6731647	6520781	4859985	4807272	3696642
Incredible S	8925317	8783570	6235544	5904185	4620331

Fig. 2: Signal response as detected by 4 different smartphone dosemeters in a standard clinical CT running with different mAs.

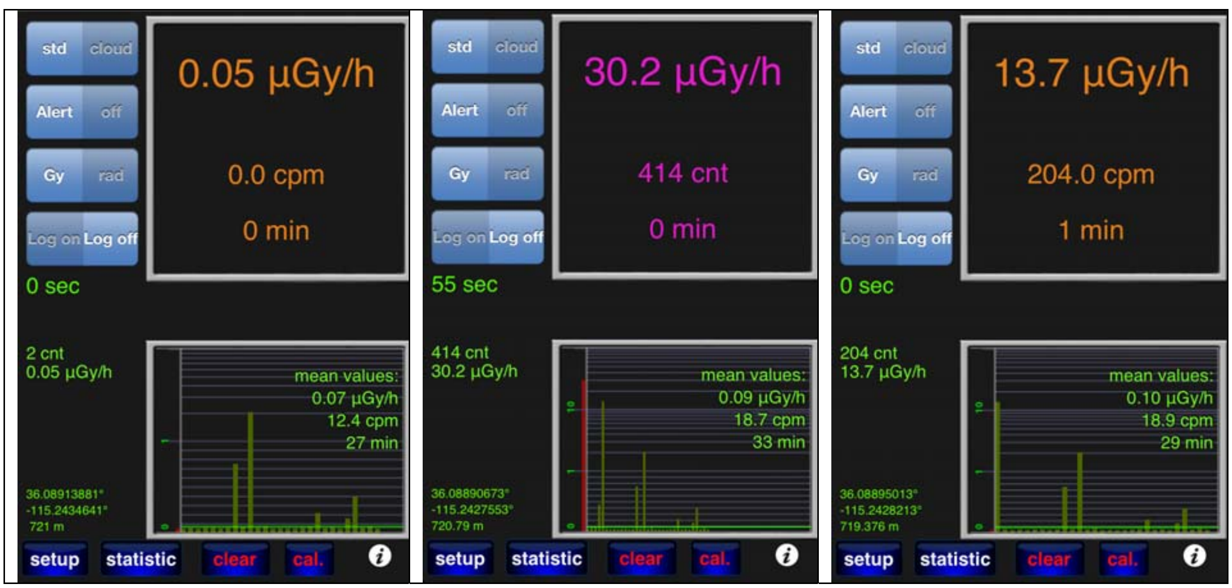


Fig. 3: Smartphone showing dose rate for a) background situation, b) with a running X-ray source on the radiologists body without wearing protective shielding and c) with the same position and for the same condition as in b) but with RadPad protective shielding.

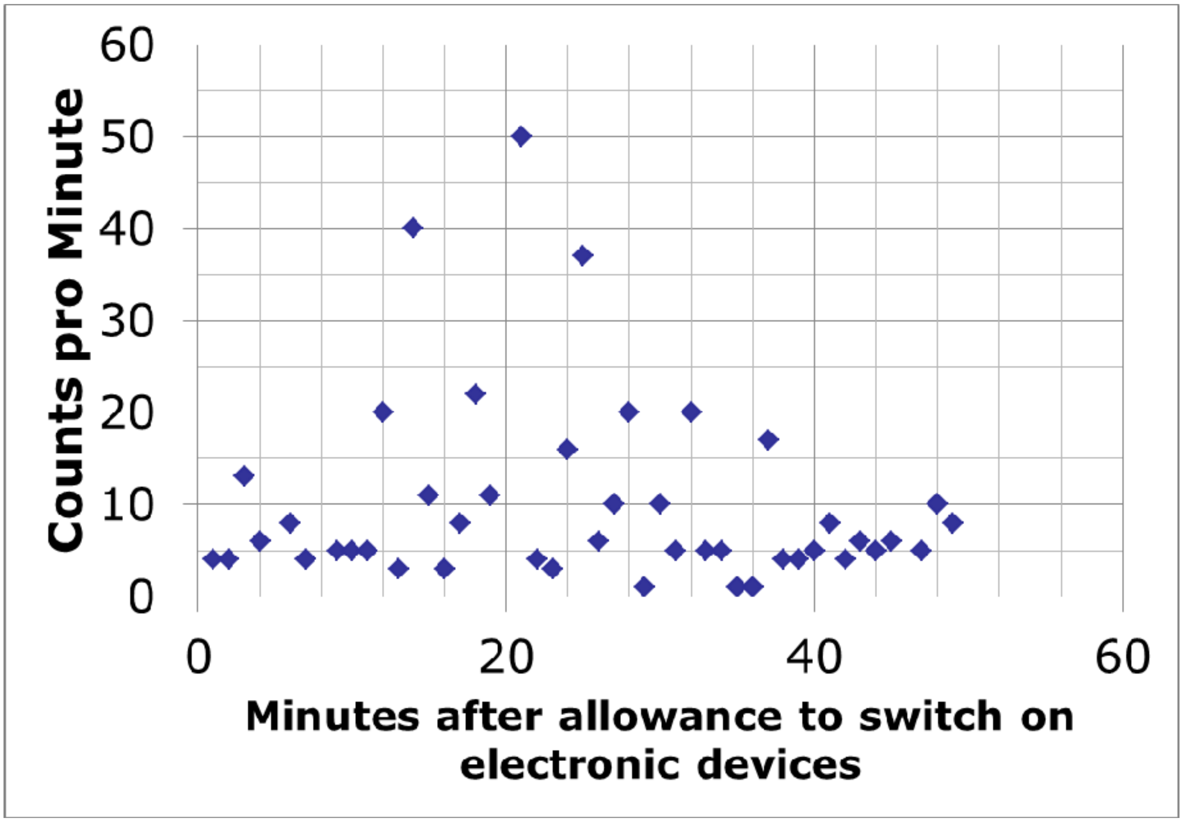


Fig. 4: Signal from a measurement during a flight from cologne to munich. The average signal over a few minutes correlates with the dose rate dependence of the irradiation in different altitudes.

5. OUTLOOK

The dosimetry method is working quite well, however there are some drawbacks, which need to be mentioned. First of all, for low dose rates it might be a problem, that there are some changes in detection efficiency and electronical noise of the camera chip depending on its temperature. This is not important for higher dose rates but might have an effect in lower dose rate ranges close to background signal. The effect can partly be corrected by gaining information about the smartphone temperature and correcting the corresponding effects. However this will be for the cost of some accuracy still and some sensitivity as well.

In addition, smartphone vendors might change their onboard software by updates from time to time. These new software updates might cause differences in camera chip read-out which would be a problem for the accuracy of the system again. Especially problematic is the fact that a number of improvements of the updates often are connected with improved noise cancellation techniques for the camera. However the noise in the visible images is to a large amount the signal we are evaluating. This results in reduced sensitivity and the need for a new calibration.

A further aspect is, that most smartphones are neither water resistant nor resistant against dropping down or other implications on the glass. This means they are not ideal for the clinical environment, since a dropping cannot be avoided always during clinical procedures. It is even more difficult to avoid blood or other fluids on the smartphone.

Therefore a system is needed, which is able to detect and measure correctly ionizing radiation in the clinical environment for all possible conditions and in general surrounding. It has to be cheap and reliable. The system needs to be usable in the clinical environment and it would be helpful if it could function also as a standard dosemeter e.g. for legal purposes as required in many countries. To obtain the best radiological protection it is necessary that it is combined with guidelines describing standard procedures and corresponding exposures to patients and staff like [5, 7]. It is necessary to train radiologists and other medical doctors using ionizing radiation during their procedures using such devices and in optimizing their procedures in terms of exposures for their patients and themselves. It is necessary to increase the awareness of radiologists for using radioprotective shielding material.

Dosimetry systems based on the smartphone-camera technology are currently under development. These newly developed systems will be connected also to the clinical information systems providing standard procedures, its expected outcome and the corresponding exposures. These values will be crosschecked with the measured dose values.

Assuming the size of the used detectors it should be possible to also provide very small patient dosemeters to measure doses at various positions of the patient during an investigation. This will give the possibility for various new studies for optimal procedures relating outcome and exposure.

In addition to these medical applications one could also think of using the dosimetry technology presented here for other purposes like for in flight dosimetry or for homeland security purposes. In this case one would use the broad distribution of smartphones for an online evaluation of the radiological situation throughout the country for detecting problems very fast. To do so, one would combine the results from many smartphones using e.g. reconstruction algorithms as used in medical three dimensional imaging.

6. ACKNOWLEDGEMENTS

The authors would like to thank Dr. Mathias Greiter and Florian Wagner for help with the measurements in the IAEA-SSDL. We are grateful for the possibility to use the clinical Philips brilliance iCT computed tomography scanner in the Klinikum rechts der Isar and the team there, namely Dr. Peter Noel as well as Bernhard Renger. In addition, we would like to thank Worldwide Innovations & Technologies for providing the RadPAd shieldings for that part of the measurements.

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