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Automated Erythema Quantification in Radiation Therapy - a Java Based Tool

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Abstract

Introduction: In radiotherapy, erythema is a common side-effect, especially during radiotherapy treatment regimes that last several weeks. The measurement of erythema might be of clinical relevance, especially when standardized interpretation is possible. *Aim*: The aim of this article is to present a tool that can be implemented for automatized and time efficient quantification of erythema from digital images taken during radiotherapy treatment. M*ethod*: Instead of relying on commercially available graphic editors and performing manual operations on the images within these programs we developed a java based tool that can automatically evaluate the "redness" of images. These erythema values receive a score number, are connected with the date and time the pictures were taken and are exported into a comma separated values (CSV) file. *Results*: The Erythema values of images could be quickly evaluated with the developed tool. With spreadsheet software the exported file could be easily manipulated to produce graphical representations of erythema rise. *Conclusion*: Erythema quantification from digital images can be easily performed by custom developed java tools. An automated quantification provides a method of detecting an increase in erythema that may not be visible to the naked eye.

Keywords: Erythema; Radiotherapy; Imaging; Breast Cancer; Radiation Oncology; Java; Software tool.

Introduction

In radiotherapy of malignant disease, erythema presents a common side effect of treatment. In breast cancer postoperative breast irradiation represents a typical treatment where erythema occurs [1]. The typical treatment duration is around 7 weeks [2,3]. During this time, mostly towards the second half of the treatment, erythema may arise in the involved skin regions [4-9]. This not only represents a common side-effect but can also be very unpleasant and distressing to the patient. Erythema is often associated with tenderness, epitheliolysis as well as itching [1,5,7]. Our policy at the Department of Radiation Oncology of the Kantonsspital St. Gallen is to give soothing lotions only when a visible change on the skin appears, though several approaches exist [1,10,11]. The main problem we face is that the redness of skin is a subjective criterion. Interobserver variability represents the main obstacle to a standardized approach [12,13]. Another factor, which complicates the situation, as expected, is the inter-patient variability [14,15]. The aim of our investigation was to find an automated software solution for the evaluation of erythema from digital images. A search of literature was performed in order to find possible methods of analysis. Methods found relied on

commercially available graphic editors [12]. While these were user-friendly, they did not allow sufficient customization and automatization. One problem that had to be dealt with was different picture angles as well as different light conditions.

An option as described in other reports is to have a room for photography. This can be fit with light sources and a fix camera position. The exact positioning of the patient remains a problem. We are proposing a different approach; Due to radiation protection, daylight plays no role in the treatment room of most radiation oncology departments, furthermore the angles of irradiation are constant during the whole radiotherapy treatment. The camera can be mounted on the linear accelerator and thereby solve the angle and daylight problem. To objectively quantify the extent of erythema during radiation therapy, colour analysis of digital images during radiotherapy may be helpful. An objective quantification of erythema during radiotherapy can improve our understanding of side-effects; in several situations, quantification of skin lesions based on different methods has been implemented [16-19]. It is possible that this objective quantification may even serve as a predictive factor for side-effects.

The goal of this work was to describe a feasible and simple IT solution for quantifying erythema from digital images taken under standardized conditions.

Material and Method

Java Program

Instead of using commercially available graphic editors our proposal was to create a Java based application that would perform this task automatically. With basic knowledge of informatics we could easily create a java tool that was capable of performing this task. For the development of the Java application [20] the Eclipse IDE was used [21].

With the help of standard Java libraries for file and image handling a simple program was developed. This retrieves a list of all files with a JPG ending in the same directory. The files are opened and the pixel colour values of all images retrieved. The numerical values of all pixels for red, green and blue were extracted. The red value alone, has no significance, as black for example, contains a maximum red value. As a basis for red factor evaluation the ratio [2xRedValue: (GreenValue+BlueValue)] was used.

Test series

For initial tests a series of images was created, clearly containing increasing red values.

Figure 1. Images used as a basis for testing the software

Procedure

Within 1 day the core java program was developed and operational. The small application (.jar file) was copied into the folder containing the JPG images that were to be analysed. After execution the program sequentially opened all JPG files, this is the format of the pictures as they are saved by the digital camera. The Application also extracted the last modified date of the file, which represents the date when the picture was taken. Before closing, the program creates a report file in CSV format containing the names of the images, their dates and times as well as the red value. This format allows simple exportation to tools for statistical analysis.

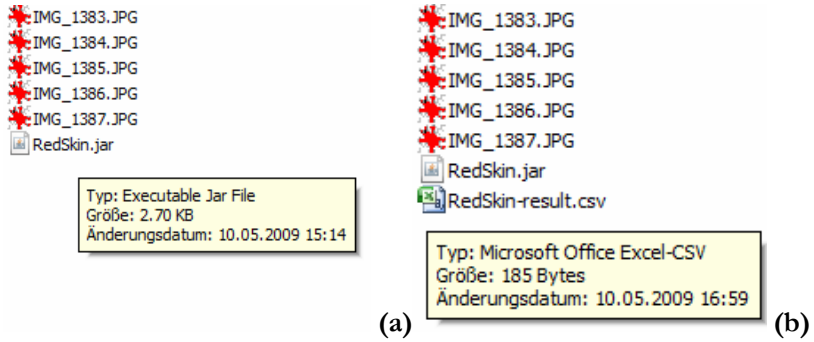

Figure 2. (a) The file list as well as the Java application. **(b)** Within a seconds a CSV file is produced

Results

We demonstrated the principal functioning of the software on the test series. After testing several output formats, the CSV file format proved to provide easy handling.

	A	B	C	D
1	.\IMG_1416.JPG	16:50:02	27.04.2009	87
2	.\IMG_1417.JPG	16:50:08	28.04.2009	106
3	.\IMG_1418.JPG	16:50:16	29.04.2009	110
4	.\IMG_1419.JPG	16:50:20	30.04.2009	108
5	.\IMG_1420.JPG	16:50:26	01.05.2009	131
6	.\IMG_1421.JPG	16:50:34	04.05.2009	169
7	.\IMG_1422.JPG	16:50:40	05.05.2009	154
8	.\IMG_1423.JPG	16:50:50	06.05.2009	318
9	.\IMG_1424.JPG	16:50:56	07.05.2009	603

(a)

(b)

Figure 3. (a) The CSV file containing the dates and times as well as the calculated red values. **(b)** With the help of spreadsheet (22) software it was easy to create a graphical representation

To demonstrate that the software is capable of detecting a rise in erythema on actual skin, we performed a simple experiment. A volunteer was positioned on a couch for 5 minutes and a warming lotion was applied to the skin on the left thigh. Pictures of the region were taken every 15 seconds after application. The pictures were very similar to the naked eye.

The application was copied into the directory and after execution the tool created a CSV file in the same directory.

Figure 4. A gradual increase in erythema within the same region of interest (no significant difference detectable by the human eye)

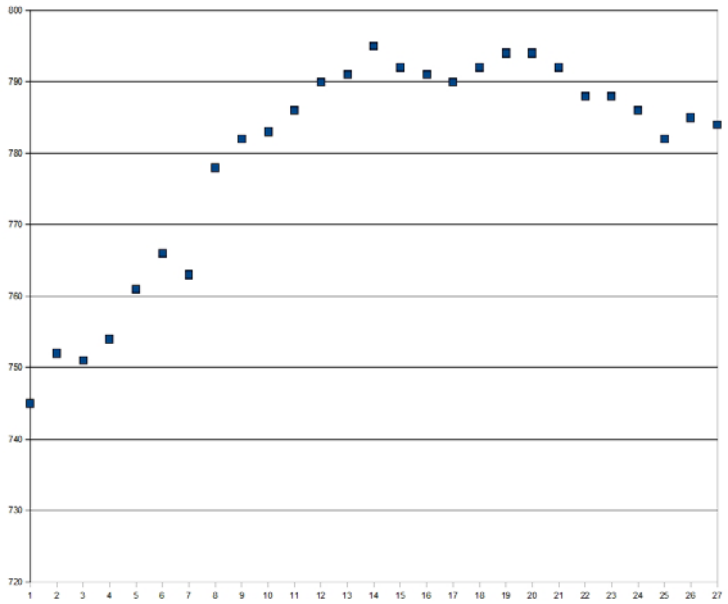

Figure 5. The automatic analysis of the images above demonstrates a significant rise in redness values; at the middle of the measurement (after approx. 3 minutes, 15 seconds interval) the erythema stabilizes, slowly reducing thereafter

Discussion

In comparison to comparable published data [12], we demonstrate a fully automated method. The proposed procedure and our first experience with the software demonstrate a detection of erythema increase, which is not quantifiable with the naked eye. The form of the graph demonstrates a clear rise, although minor variations occur, the rise in erythema values could be clearly demonstrated. Within the first 3 minutes, the seventh measurement seems to deviate from the trend. The reason for this cannot be explained by visual review of the images. The high customizability of the java application will provide flexibility for further improvements. At this point we have demonstrated the basic functionality and the principle. The question whether this procedure, as described, will work as designed in clinical practice still remains unanswered. A possible problem that might be encountered is that electronic devices seem to „age" faster when exposed to ionizing irradiation, this is an experience that we have made with other cameras within the treatment room. To which extent this can influence the proper functioning of the digital camera is unclear at this point. A Solution for this problem is to remove the camera from its position at the linear accelerator before irradiation starts.

A relevant point which is not dealt with in this paper is that in certain situations skin markings that are used for the positioning of the patient during radiotherapy might be within the image field. These markings use different colours and might have an impact on the calculated redness score. Furthermore, the markings are redrawn and fade as the treatment progresses. In order to eliminate the impact of these markings, an option would be defining regions that are to be ignored in the first image; the same blind fields are then applied to all pictures of a series of a single patient treatment.

Another disadvantage was the high sensibility of minimal movement if non-skin areas were included in the region of interest. If for example a piece of textile was in the corner of the image and the size of this corner differed among images, the impact on the total red value of the image was strongly influenced, disabling a meaningful analysis.

Conclusions

The Java Virtual Machine, which is installed on all the computers within the clinic, provides an ideal platform for small customized applications. The Java tool makes the analysis of the red values of JPG images very time effective and time sparing. The time used to develop this tool is saved with the analysis of 25 pictures of a single patient. This example shows how the effectiveness of clinical research can be dramatically improved by simple time-effective solutions. We could demonstrate that our software tool could detect an erythema increase of the skin, which could not be quantified visually.

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