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Original Article

Using a photographic image processing method as a part of the QA program in some radiotherapy departments where CTs are involved with COVID-19 patients

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Abstract

***Background & Aims*:** Owing to the significant role of CT images in diagnosis and follow up of patients affected with coronavirus, the imaging section of cancer centers in some countries engaged in providing services to COVID-19 patients. The aim of this study was to introduce a CT-independent photographic-based QA method in some radiotherapy departments where CTs are involved with COVID-19 patients.

***Materials & Methods*:** An anthropomorphic woman-like torso phantom was used in the first step of study for setup arrangement and preliminary data extractions. Then in the second step, four patients with early stage breast cancer were evaluated. In all steps, the key parameters extracted from photographic-based method were compared with the same parameters extracted from CT system, which was considered as the gold standard method. A home-made computer code developed in MATLAB was used to extract parameters in the new method. Finally, the corresponding parameters were compared using the non-parametric Wilcoxon method.

***Results*:** Our results showed that the newly introduced method can predict desired parameters equal to CT-based method. Using this method, a part of the QA program will be performed with no dependency on CT systems. Also, the image sections load work in some radiotherapy departments, which their CT systems are involved with COVID-19 patients, can reduce.

***Conclusion*:** The proposed method could help identify and remove important uncertainties and errors in radiotherapy courses, especially between fractions, without imposing ionizing radiation on patients in pandemic conditions.

***Keywords*:** Geometric uncertainty, Photographic based image processing, QA, Radiotherapy, Setup error

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Introduction

Radiotherapy is one of the main modalities of cancer treatment and is recommended as one of the effective treatments for patients with cancer. Along with the improvement of radiotherapy techniques during the last decade, assuring that the radiotherapy treatment chain is being performed correctly is very important (1). Geometrical uncertainties and setup errors are some important factors that cause dissatisfaction with radiotherapy treatment outcomes (2). The main sources of these uncertainties and errors are related to patient motion and changing of body contours during treatment courses and radiotherapy fractions (1, 2). By organizing a comprehensive quality assurance (QA) program and regular checking the radiotherapy treatment chain, especially between fractions, the source of uncertainties and errors can be discovered systematically and removed effectively (2, 3).

Nowadays, in advanced radiotherapy centers, using some modern systems and techniques such as EPID (electronic portal image device) and IGRT (image guided radiation therapy), the role of imaging becomes apparent more and more; however, the CT system alone still play a unique role in the advancement of QA programs (2, 3). Extraction of various features and numerous parameters from CTs and checking them during the execution of the QA program need to expend a long time with the involvement of imaging facilities and personals.

By prevalence of COVID-19 outbreak in the entire world, because of the unique role of the CT images in diagnosis and follow up of patients affected with Coronavirus, the workload of medical imaging departments has increased dramatically (4-8). In addition to the involvement of most hospitals, the imaging sections of radiotherapy departments in some countries are also under the burden of providing services to COVID-19 patients. This burden can affect the execution of QA tests, especially those that are closely associated with CT systems. This matter left the radiation oncology physicists with serious challenge regarding the QA tests execution. Thus, it is very important to find a method that can be used as an auxiliary method in some crowded departments whose CT systems are engaged in COVID-19 patients.

Introducing a CT independent method for quantitative evaluation of radiotherapy treatment chains for uncertainties and errors reduction was the aim of this study. To this end, we tried to introduce a novel method using photographic images to extract some essential parameters for the evaluation of patient setup and check body contours in order to reduce the above-mentioned errors in some radiotherapy departments with COVID-19 involvement. By application of this method, the load work of CT facilities can reduces and patients' setup will perform with the least possible errors. For this purpose, some key parameters were defined and extracted from the novel method and compared with the same parameters extracted from CT images. Application of our novel method without imposing extra ionizing radiation on patients can lead to the reduction of patient dose and radiation-induced side effects, especially in patients with early-stage cancers. In this study, patients with early-stage breast cancer on behalf of patients whose treatment heavily depended on QA tests were considered.

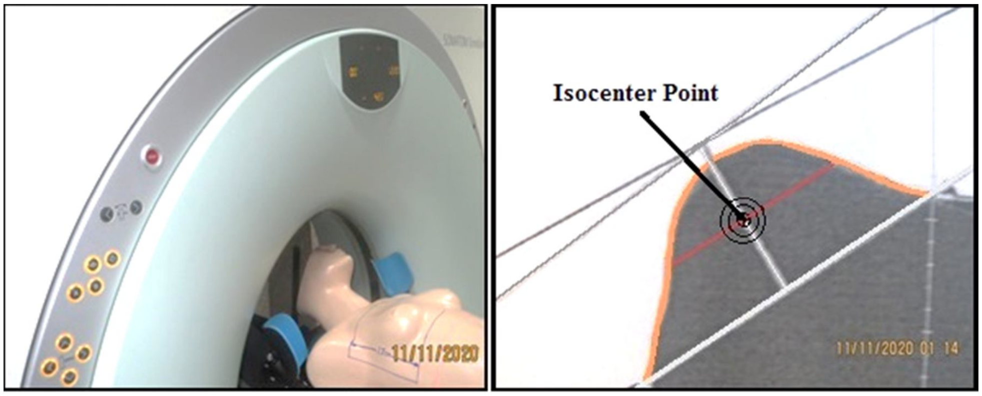
Materials & Methods

First Step: Phantom Study

Extraction of essential parameters using CT system:

CT-based contouring is considered as a gold standard method for the extraction of desired parameters in this research. In the first step, an anthropomorphic epoxy resin-based woman-like phantom with a density of 1.20 ± 0.04 g/cm^3 was used. From the researcher's point of view, using an anthropomorphic phantom in terms of shapes with uniform density to achieve the desire geometric parameters and the external contour extraction was an essential step for our research set up preparation. The region of interest for irradiation in tangential fields was specified on the breast region of the phantom with 17 cm length by a radiation oncologist. Then the phantom was positioned supine on the couch of a CT simulator (Computed Tomography, 2-slice Somatom Sensation Open, Siemens, Germany) using an inclined breast board, and the CT images of the phantom were taken with slice thicknesses of 4 mm (Figure 1a and 1b). The CT images from the thorax region including intact breasts were imported to the commercial treatment planning system (TPS; Core PLAN-Seoul C & J, Seoul, Korea). The TPS by using beam's data of the

Siemens linear accelerator machine the PRIMUS model was commissioned. Source to axes distance (SAD) was set to 100 cm. Then CT-based treatment plan was simulated by application of two tangential fields, and then the geometric plan parameters were derived (Table 1).



a b

Fig. 1. (a) Scanning of the phantom with CT system and (b) the main central CT slice used for extracting desired parameters

Extracted parameters included field width (FW), gantry angle from the medial side of phantom (GA-m), gantry angle from the lateral side of phantom (GA-l), source to skin distance from the medial side of phantom (SSD-m), source to skin distance to the lateral side of phantom (SSD-l) (Table 1).

Table 1. CT image based parameters obtained for phantom

CT image-based parameters	FW	GA-m (α)	GA-l (β)	SSD-m (SAD-X2)	SSD-l (SAD-X1)
Values	7.9 cm ± 0.00	58° ± 0.00	122° ± 0.00	95.6 cm ± 0.00	94.7 cm ± 0.00

Special inclined breast board with accessories and holders fabricated for taking photographic images:

In this research, we designed and fabricated an unique setup equipment composed of an inclined breast board with some accessories and holders in which the phantom and then the patients were settled on it in a supine position similar to that explained in the previous method (Figure 2). Two plastic stand bases for the holding of a high resolution 10 Mega Pixels Full HD camera were designed and embedded on two sides of the breast board. An aluminum-based smooth plate with three horizontal lines used to determine the gantry angle was designed and placed in a standing posture on the breast board. This plate can be displaced and moved in the longitudinal direction of the breast board during photographic imaging. After positioning the phantom on the breast board, we turned the laser lights to adjust plate horizontal lines with the actual horizon. Subsequently, two parallel opposed photographic images were taken in two cranio-caudal and caudo-cranial directions. Provided images of the phantom must be such that the horizontal line is observed.

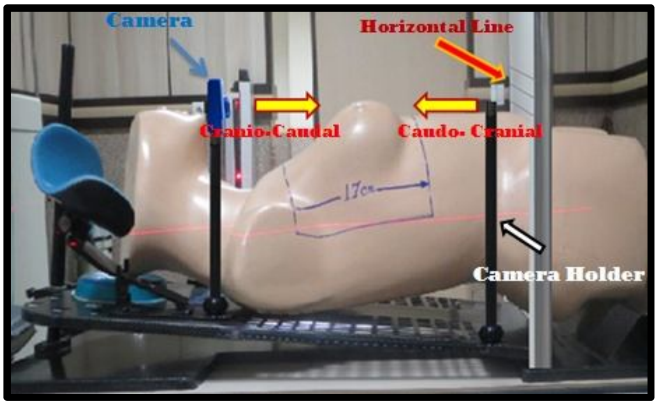


Fig. 2. Fabricated Set up system composed of an incline breast board, camera holders, and Aluminum plate used for photographic imaging

Developing a homemade computer code in MATLAB for image processing and parameters extracting:

A homemade computer code was developed in MATLAB (Mathworks-Rb2018) to perform some image processing operations such as image smoothing, de-noising, and edge detection on photographic images. For this purpose, each image was segmented using the thresholding method, and the edge of the breast in each photographic image was detected and dilated. To eliminate the effect of distance changes between camera, breast, and plate on calculated results, an aluminum rectangular test object with dimensions 2 cm^2 was used in all photographic images as a pixel size calibrator. Subsequently, image edges were resized using a calibrator and matched with real size, and then two calibrated edges were combined. Figure 3 shows the processing executed on photographic images and final images of the whole breast contour.

Fig. 3. Photographic-based image processing and whole breast contouring stages

After deriving the intact breast contour, a complimentary computer code in MATLAB was developed and used to obtain the mentioned parameters. Although the extraction method of parameters was similar to the usual method used for two-dimensional (2D) breast planning in past years, the mathematical relations employed in this method had enough precision for the extraction of our study desired parameters. By executing this computed code, the contour of the breast with desired parameters was derived and depicted (Figure 4). These parameters are the same parameters that were obtained in the CT-based method. In our novel method, the horizontal lines were used for the calculation of gantry angles in two tangential fields, which were seen in processed images in Figure 4.

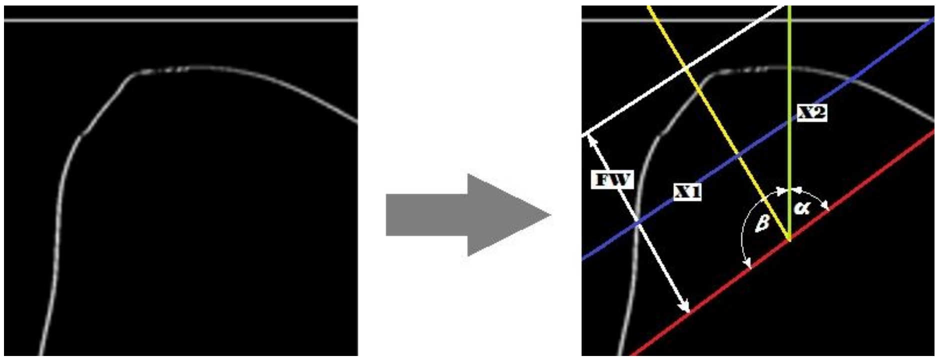


Fig. 4. Desired parameters extracted from intact breast image contour.

All the steps, including photographic imaging, image processing, and parameters extracting, were repeated three times, and the mean values of obtained quantities with standard errors (SD) were derived and tabulated (Table 2).

Table 2. Photographic image processing-based parameters.

Photographic image-based parameters	FW	GA-m (α)	GA-l (β)	SSD-m (SAD-X2)	SSD-l (SAD-X1)
Values	8.1 cm ± 0.23	56° ± 0.35	124° ± 0.9	95.5 cm ± 0.1	95.1 cm ± 0.11

Second Step: patient Study

Essential parameters extraction using CT system:

In the second part of this study, four female patients with the average age of 40 ± 2 years were chosen from those who were referred to the Radiation Oncology Department of Omid Hospital in Urmia, Iran. All the patients had the early-stage left-sided breast cancer and referred to radiotherapy department for conservative breast radiation therapy. The Research Ethics Committee of Urmia University of Medical Sciences approved the study protocol, and the research team considered the confidentiality of patient information. According to previous explanations, the CT images were obtained via standard protocols, and the essential parameters were selected (Table 3).

Table 3. CT image-based parameters obtained for four patients

CT image-based parameters	FW	GA-m (α)	GA-l (β)	SSD-m (SAD-X2)	SSD-l (SAD-X1)
Values	8.88 cm ± 0.87	64.3° ± 0.92	116.69°± 1.57	93.08 cm ± 1.54	93.92 cm ± 1.16

Photographic images and extraction of photographic image-based parameters:

In this step of study, each patient lay down on a especial fabricated incline breast board in the same positions explained before, and photographic images were taken according to protocol explained. The image processing was then performed on photographic images as explained before, and finally the mentioned parameters were derived (Table 4).

Table 4. Photographic image-based parameters obtained for four patients

Photographic image-based parameters	FW	GA-m (α)	GA-l (β)	SSD-m (SAD-X2)	SSD-l (SAD-X1)
Values	9.43 cm ± 0.77	62.63° ± 1.65	119.05° ± 2.16	91.03 cm ± 1.18	95.10 cm ± 0.84

Figure 4 shows the comparative values of parameters derived from CT versus photographic-based parameters for patients.

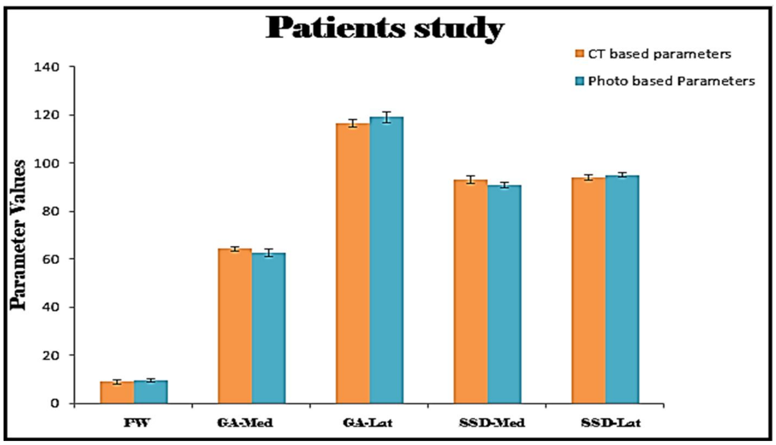


Fig. 4. CT-based parameters versus photographic-based parameters derived from study patient

Statistical analysis:

All parameters derived from our novel method were compared with those derived from CT-based method by the non-parametric Wilcoxon method with a 0.05 level of confidence (Table 5).

Table 5. Results of non-parametric Wilcoxon method with a 0.05 level of confidence

Study parameters	Study groups		Confidence level P value
	CT-Based parameters	Photographic-based parameters	
FW-CT	8.88 ± 0.867	9.43 ± 0.769	0.068
GA-m-CT	64.3 ± 0.92	62.63 ± 1.648	0.141
GA-l-CT	116.69 ± 1.571	119.05 ± 2.163	0.14
SSD-m-CT	93.08 ± 1.544	91.03 ± 1.181	0.068
SSD-l-CT	93.92 ± 1.159	95.1 ± 0.841	0.144

Results

Table 1 shows that all parameters were derived from CT-based method, which assumed to be the gold standard method in this research. Photographic-based parameters are represented in Table 2. To attain a high level of confidence, each method (CT based and photographic image based) repeated three times, and the mean values with SDs are depicted in Tables 1-4. Based on Table 5, there was no significant differences between photographic- and CT-based parameters derived for four patients (confidence level: $p < 0.05$).

Discussion

Due to the unique role of CT images in diagnosis and follow up of COVID-19 patients, the workload and use of CT systems have increased meaningfully (4-8). At the same time, the imaging section of radiotherapy departments in some countries is involved with COVID-19 patients. According to AAPM-TG reports, a comprehensive QA program using CT systems must regularly be performed in radiotherapy departments; therefore, engaging CTs with COVID-19 patients can alter these activities strongly (2, 3). Considering this critical condition, an intelligent radiation physicist must create an appropriate QA program depending on their circumstances and possibilities. Application of a novel method as a part of the QA program with CT independently will be useful and cause the reduction of the extra load work of imaging sections in departments with CT engaged.

In this research, a photographic-based method was developed and used as a rapid method for evaluating radiotherapy treatment chains to discover geometric uncertainties and setup errors as a part of the QA program. For this purpose, some key parameters were defined for checking external body contours and setup accuracy and extracted from the new method. The extracted parameters were then compared with the same parameters obtained from CT images, which are considered as the gold standard method. By applying our introduced method, no ionizing radiation imposed on patients; thus, the risk of radiation-induced side effects via new photographic-based method will be zero (9, 11-17). Our results confirmed that the novel method introduced in this study can reduce setup errors and geometric uncertainties efficiently. The Wilcoxon non-parametric test showed that the newly introduced method in this study can predict desired parameters equal with CT-based method with no significant differences ($P < 0.05$; Table5).

Recent studies have demonstrated that in some cases such as patients with small breast size, CT-based 2D planning acts the same as CT-based three-dimensional (3D) planning in breast contouring and extraction of parameters. Therefore, the newly introduced method with no imposing radiation to patients, simplicity in execution, accurate performance, and rapid performance has a high priority than CT-based 2D and 3D methods, especially in crowded radiotherapy departments, which CT-based QA programs cannot implement properly (14-17). However, due to our small sample size, we could not draw general conclusions in the level of clinical application till performing comprehensive research on a large number of patients using this new method.

Conclusion

It is generally concluded that using the introduced novel method as a part of the QA program in some crowded radiotherapy departments with no imposing of radiation on patients will be performed with no need for CT systems.

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Conflict of interest

The authors have no conflict of interest in this study.

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No

Data availability

The raw data supporting the conclusions of this article are available from the authors upon reasonable request.

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