Streamlining EPID-based IMRT quality assurance: auto-analysis and auto-report generation

Aitang XING[1], Sankar ARUMUGAM[1], Shrikant DESHPANDE[1,3], Armia, GEORGE, Lois HOLLOWAY[1, 2, 3,4], Gary GOOZEE[1, 4], Alison GRAY[1], Philip VIAL[1, 2]

[1]Liverpool and Macarthur cancer therapy centres and Ingham Institute, Liverpool Hospital, NSW, Sydney, Australia.
[2]Institute of Medical Physics, School of Physics, University of Sydney, Sydney, NSW, Australia.
[3]Centre for Medical Radiation Physics, University of Wollongong, Wollongong, NSW, Australia.
[4]South Western Sydney Clinical School, University of New South Wales, Sydney, NSW, Australia

aitang.xing@sswahs.nsw.gov.au

Abstract. Using an EPID for patient specific IMRT QA is an efficient way to verify patient plans prior to the treatment. Our centres' current EPID dosimetry method is based on a water equivalent depth approach, where EPID images of each IMRT field are converted to dose images and compared to Treatment planning system calculated dose images using a commercial software tool. Two physicists across two sites perform the analysis for an average of 12 new IMRT patients per week. To speed up this process, an in-house program called AutoEPIDIMRTQA was developed. The program automatically performs the following tasks sequentially: reading and converting raw EPID images acquired on either a Siemens Oncor or Elekta Synergy linear accelerator, registering them with planar dose images calculated by Pinnacle (Philips) or CMS XiO (Elekta) treatment planning systems, analyzing the profiles for registered images and calculating the Gamma map. Finally an IMRT QA report is automatically generated. AutoEPIDIMRTQA was validated against commercial software. The analysis time for a typical 9-beam IMRT head-neck patient decreases from 30 minutes to 4 minutes. The total QA time was reduced by 40% using AutoEPIDIMRTQA. Thus we have demonstrated a significant reduction in the time burden for physics staff performing IMRT QA.

1. Introduction

In modern radiotherapy, emerging new treatment techniques such as intensity-modulated radiotherapy (IMRT), intensity modulated arc therapy (IMAT) and Tomotherapy, provide more choices for oncologists and radiotherapist/dosimetrists to personalize patient treatment for the specific treatment situation. The resulting treatment plans are inherently more complex. To ensure the prescribed treatment dose is accurate, deliverable and within clinically acceptable error tolerance, medical physicists need to conduct quality assurance (QA) for each patient before treatment [1]. This presents a challenge for radiotherapy cancer centres with limited physics resources and a large number of new IMRT patients per week.

The clinical pressures to ensure QA is completed on time and the practical need for improving QA efficiency has resulted in many centres using electronic portal imaging devices (EPIDs) for patient specific quality assurance [2, 3]. EPIDs are a standard component of a large fraction of modern linear accelerators (Linacs). Compared with other dosimetry equipment used for IMRT QA such as 2D ion chambers, diode arrays or film, the use of EPIDs is expected to be more time efficient. High spatial resolution and relatively high sensitivity for detecting delivery errors are among the other advantages for adapting an EPID-based IMRT QA approach [4, 5]. EPID-based IMRT QA was implemented in our department in 2011 to replace the previous phantom and 2D ion chamber array approach. An in-house program was developed to convert the raw EPID images into water equivalent dose images based on a previously reported EPID dosimetry method [6]. In this work, a new software tool, AutoEPIDIMRTQA, was implemented to save physics time spent analyzing IMRT QA results by automating the procedure. The purpose of this report is to present the software implementation and evaluation of initial results.

2. Materials and Methods

2.1. Current IMRT QA system used for EPID-based IMRT QA

The EPID dosimetry method developed by Lee et al was originally tested for Varian aS500 EPID device from a Varian 21 EX Linear accelerator [6]. In our centres, two Elekta Synergy (Elekta Ltd, Crawley, UK) Linacs with EPID devices (iViewGT) and two Siemens Oncor Linacs equipped with EPID devices (OPTIVUE™ 500) are being used to deliver IMRT treatment to patients using 6MV photon beams. IMRT treatments are planned using either Pinnacle V9.0 (Philips) or XIO V 4.6 (Elekta). We implemented an IMRT QA system based on the approach developed by Lee et al [6] and adapted for our mix of equipment.

The IMRT QA system is based on flood-field corrected integrated EPID images acquired either on Elekta or Siemens Linacs as input and outputs DICOM-RT image files. The EPID image is converted to a ‘dose image’ calibrated to the dose at a reference depth in water, in our case 5.4 cm depth in water at the isocenter plane. The planar dose is calculated at the same depth in a virtual water phantom by the TPS (Pinnacle or XIO). This methodology was validated against a two dimensional (2D) ion chamber array [7] and has been used clinically for more than two years in our centre. In current routine QA practice, radiation therapists (RTs) acquire the EPID images and physicists use an in-house developed software program to convert the EPID image to dose image. The EPID and TPS calculated dose images for each field are manually loaded into OmniPro-I'mRT for profile and gamma map analysis and to enable generation of an IMRT QA report.

2.2. Implementation of AutoEPIDIMRTQA

The new software tool, AutoEPIDIMRTQA, was designed not only to convert the raw EPID images into dose images but also to automate the process of analyzing the EPID QA results and generating a QA report. The software was implemented in Matlab (2010a). Figure 1 shows a flow chart of the program structure. The program reads the EPID and TPS data and processes the dose images as per the current program described above. AutoEPIDIMRTQA automatically aligns and registers EPID and TPS dose images using a sub-pixel image registration algorithm [8]. The profiles passing through the center of the registered images along x and y axis are analyzed and a 2D gamma map is also calculated using user-specified criteria. This procedure is repeated automatically for each IMRT beam. Finally, the program saves the dose image into DICOM-RT files and compiles an IMRT QA report that contains the dose profile results and calculated gamma maps.

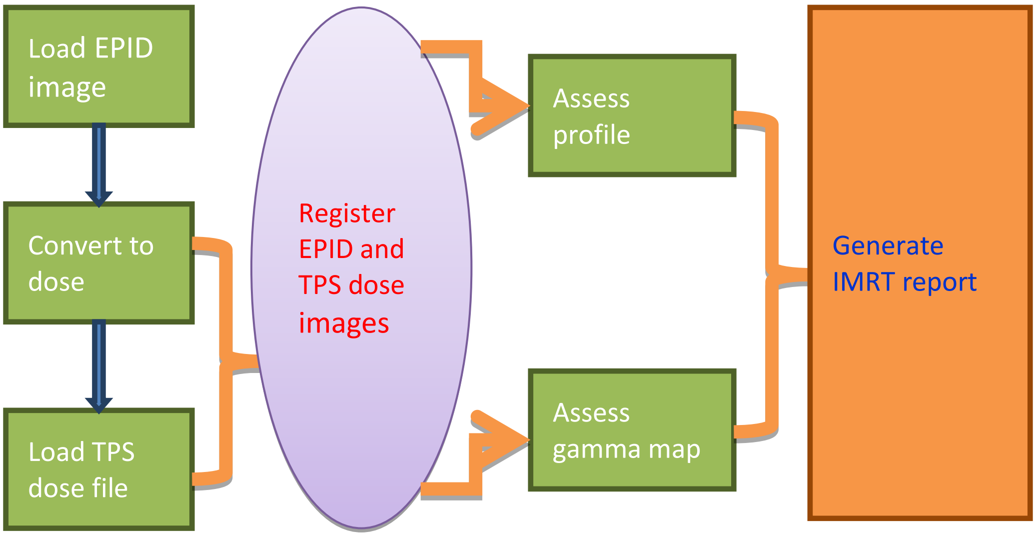


Figure 1. The internal flow chart implemented in AutoEPIDIMRTQA.

2.3. Software validation

There are four sub functions implemented in AutoEPIDIMRTQA: i) conversion of EPID images to dose images, ii) registration of converted EPID dose images and TPS-calculated dose images, iii) the calculation of the gamma map and profiles and iv) report generation. The EPID images are converted to dose using the same pixel-to-dose conversion algorithm used in the current clinical program. This code was validated against a 2D ion chamber array [7] and also by patient-specific QA results of over 100 patients clinically using 2%/3mm gamma criteria (global), 10% low dose threshold with acceptable gamma pass rates of over 95% for each IMRT beam. The image registration algorithm used in the program was verified by comparing the introduced image shifts and algorithm-calculated shifts for given EPID images. The accuracy of the gamma function was verified by comparing it with a commercial software tool. Once the first three sub functions are verified, the sub function of report generation just inserts the automatically generated profile and Gamma image into a word document with customizable format. The efficiency improvement as a result of using AutoEPIDIMRTQA was compared among different IMRT QA schemes used in our centres.

3. Results and Discussion

3.1. The unique features of AutoEPIDIMRTQA

The AutoEPIDIMRTQA program has incorporated several features to address clinical needs for our IMRT QA program: (1) Ease of use. As shown in figure 2, the only user interaction is to select i) the folder containing the raw EPID images and exported TPS dose images, ii) select the TPS system utilised and ii) if reference EPID images for a 10x10cm field was taken for this patient. (2) Real-time animation of gamma map and profile analysis. The program will analyze profiles and calculate the gamma map while compiling the results into a word document report. During this process, two pop-up windows containing the profile images and gamma images are displayed providing a convenient way for the physicist to quickly review results for all beams before the final QA report. (3) Backward compatibility to the program currently being used. Except for generating a QA report, the program also automatically outputs a DICOM-RT image file containing an EPID dose image for each beam. The EPID dose image can be loaded into other software tools for further analysis if necessary.

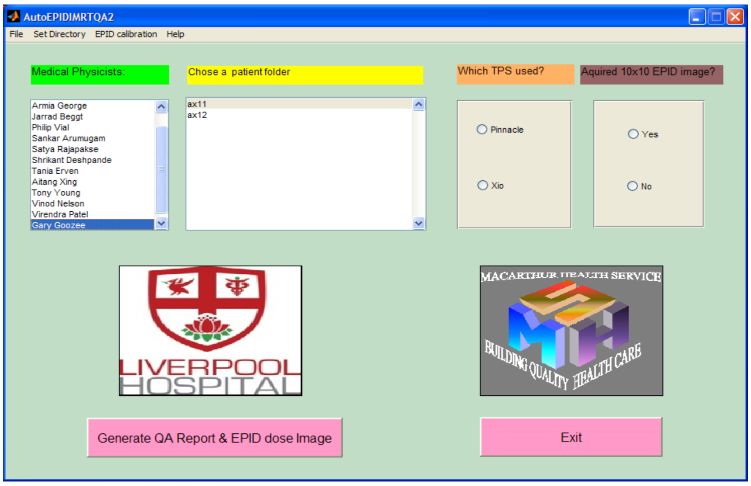


Figure 2. The simple graphic user interface designed for AutoEPIDIMRTQA.

3.2. Image alignment and Gamma function evaluation

The image registration algorithm implemented in the program can achieve sub-pixel accuracy for image alignment [8]. The implementation of this registration algorithm in the AutoEPIDIMRTQA program was validated by introducing known shifts to images along X and Y directions and then registering the offset image with original one. The calculated and introduced shifts in the units of pixels are presented in Table 1.

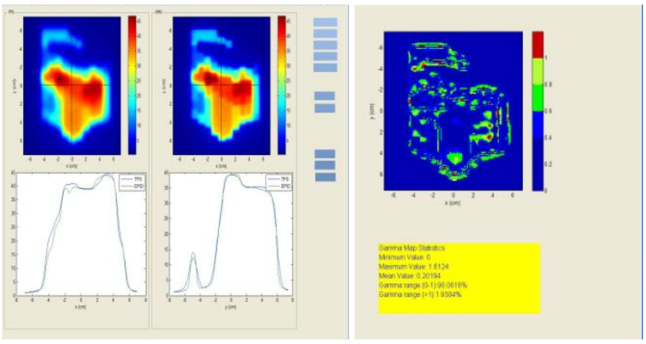
Table1. Comparison of introduced and registration algorithm calculated shifts

	Shifts (pixels) along X and Y directions (X,Y)					
Introduced shifts (pixels)	(-1, 2)	(1,2)	(2,3)	(4,1)	(3,0)	(6,-9)
Calculated shifts (pixels)	(-0.17,1.86)	(1.2,2.03)	(1.45,2.89)	(3.48,0.16)	(2.72,0)	(5.34,-8.5)
Differences (pixels)	(-0.83,0.14)	(0.2,-0.03)	(0.55,0.11)	(0.52, 0.84)	(0.28,0)	(0.64,-0.5)

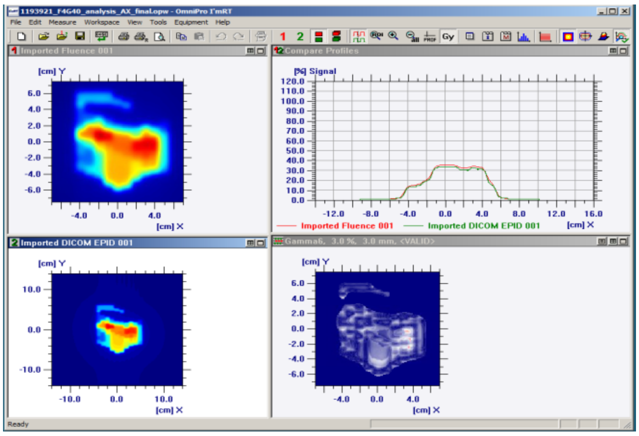
Table 2. Comparison of the Gamma pass rate calculated by AutoEPIDIMRTQA and OminiPro for a seven-beam prostate patient.

	Gamma pass rate						
Beam Number	1	2	3	4	5	6	7
AutoEPIDIMRTQA (%)	98.1993	99.6652	98.8681	99.4242	99.2272	98.6741	98.9585
OminiPro-I'mRT (%)	98.66	97.97	99.14	99.47	99.13	99.13	98.76
Difference	-0.4607	1.6952	-0.2719	-0.0458	0.0972	-0.4559	0.1985

The Gamma pass rate calculated by AutoEPIDIMRTQA and OminiPro-I'mRT was compared for 90 IMRT beams using a Gamma criteria of 3%/3mm. The maximum and average difference in gamma pass rate was 2.1 % and 1.3 % respectively. Table 2 shows the Gamma results for one typical seven-beam prostate patient. The differences may be explained by the fact that the manual alignment is not exactly the same as automatic alignment and the different implementation of the Gamma functions in the two programs. Figure 3 shows manual and automatic alignment for one IMRT beam from one head-neck patient. The collimator angle for this beam was 40 degrees. In order to manually achieve a good alignment of these two images shown here in OmniPro-I'mRT, one image had to be rotated by 40 degree clockwise and then translated in both horizontal and vertical directions. The gamma pass rate for this IMRT beam by AutoEPIDIMRTQA and OminiPro was 98.06% and 97.91%, respectively.



(a)



(b)

Figure 3. The profiles analysis and Gamma map calculated by (a) AutoEPIDIMRTQA and (b) by physicist in OmniPro-I'mRT.

3.3. Clinical benefits and future development

The benefit from the implementation of AutoEPIDIMRTQA is that it will further improve the efficiency of our EPID-based IMRT QA. Although the EPID images are acquired by radiation therapists at a scheduled machine time for each patient in our centres, a dedicated physicist was still assigned to perform the following tasks: converting the EPID raw images into dose images, loading them and TPS dose image into OminiPro IMRT, manually aligning them, analysing the profile, calculating Gamma map and compiling a QA report. Figure 4 shows the total time for performing IMRT QA measurement and analysis using different QA devices and software tools. The time shown here for each step was averaged over 8 patients. The times in figure 4 also reflects the evolution of IMRT QA methodology in our clinic. The time for Radiation Therapists to acquire and export EPID image is the same for methods B and C (figure 4). The QA analysis time decreases from an average of 30 minutes for a typical 9-beam head-neck IMRT patient to 4 minutes with AutoEPIDIMRTQA. The physics QA time and the total QA time was reduced by 86% and 40% respectively when changing from method B to method C (figure 4). In comparison with the Matrix-only QA method (method A), IMRT QA with EPID plus AutoEPIDIMRTQA decreased the total QA time by 57%.

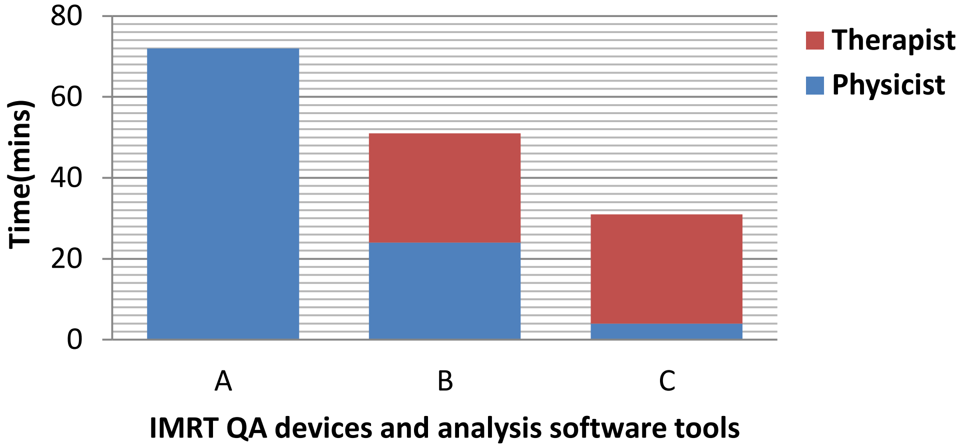


Figure 4. The total time taken to perform IMRT QA and analysis using (A) ion chamber array and commercial software (B) EPID and commercial software (C) EPID and AutoEPIDIMRTQA. The red and blue parts of the columns indicate the time spent by therapists and physicist respectively. For matrix-based QA (A) physicists perform measurement and analysis. For EPID based QA (B and C) therapists perform measurements and physicists analyze the results.

AutoEPIDIMRTQA is still being actively developed. A full automation is planned to be achieved by implementing it as a daemon or a server. In this manner it will be always running in the background and reviewing a folder in a network driver where patient raw EPID image and TPS dose images are stored as a subfolder. The QA report will then be automatically sent to physicists. A database is also going to be included to record the QA results for further statistical analysis.

4. Conclusion

An in-house software tool was developed and validated to aid the analysis of QA results for EPID IMRT QA. This program achieves significant efficiency gains streamlining clinical practice.

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