Varian RapidArc Treatment Plan Verification using Gafchromic EBT3 Film

1. Purpose

Radiochromic film provides dose measurement at high spatial resolution, but often is not selected for routine evaluation of patient-specific treatment plans owing to ease-of-use factors. In this work we use an efficient film dosimetry protocol[1] combining calibration and measurement of Gafchromic EBT3 film in a single scan and enabling a Rapid Arc treatment plan to be measured at high spatial resolution and verified in less than 30 minutes. The protocol avoids complications due to post-exposure changes in radiochromic film that delay the completion of a measurement, often for up to 24 hours, in commonly used methods. In addition the protocol addresses the accuracy and integrity of the measurement by eliminating environmental and inter-scan variability issues that can affect the process when calibration and application films are scanned at different times often weeks apart.

2. Method and Materials

The application film, a 20.3 cm x 25.4 cm sheet of Gafchromic EBT3 dosimetry film (Lot A101711-02), was irradiated at the center of a cylindrical acrylic phantom 20 cm diameter x 40 cm length. A Varian RapidArc treatment plan developed with Varian's Eclipse planning system was selected and applied to the film using a 6MV photon beam delivered in a single arc by a Varian TrueBeam linear accelerator and using variable dose rate, gantry speed and dynamic MLC shaping.

The cylindrical phantom was replaced with one consisting of 25 cm x 25 cm acrylic plates. A 4 cm x 20.3 cm strip of EBT3 film (Lot A101711-02) was placed between 5 cm layers of the phantom material and a calibration exposure of 280.9 cGy of 6MV photons was delivered with the TrueBeam linac using a 10 cm x 10 cm open field. The application and calibration films were exposed within a 5-minute time window.

After allowing twenty minutes, or more, time to elapse after the exposures the application film, the exposed calibration film and an unexposed film strip were scanned together in 48-bit *rgb* transmission mode on an Epson 10000XL at a resolution of 72 dpi. All color correction features of the scanner were turned off during acquisition of the digital image.

The scanned image of the films was measured and analyzed using triple channel dosimetry[2] and FilmQA Pro software[3]. The film dosimetry protocol used in this example takes dose-response measurements from the exposed and unexposed calibration films and applies that data to re-scale pre-determined and lot-specific calibration response data.

The re-scaled calibration was then used to convert the application film image to a dose image which was subsequently compared to the RapidArc treatment plan in the film plane. Comparison between measurement and plan was made through the FilmQA Pro software using iso-dose contour plots, dose profiles, and gamma index analysis with test criteria of 2% dose agreement within 2mm.

3. Results

Figure 1 is the scan image of the application film and the exposed and unexposed calibration films. In this image a region of interest has been defined in each calibration film and the exposure doses of 280.9 cGy and zero have been defined. Using these measurements, the previously determined calibration data was rescaled and the scanned image was converted to dose space (Figure 2). Measurements of the exposed and unexposed calibration films in the dose image provided assurance that the dose values were correctly rescaled to 280.9 cGy and zero respectively.

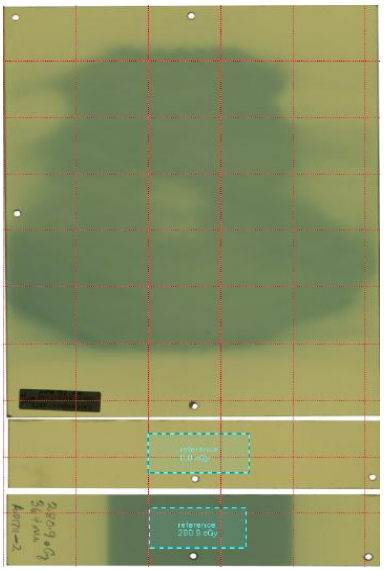

Figure 1: Scanned Image: Application film with exposed and unexposed calibration films

Figure 2: Dose Image: Application film with exposed and unexposed calibration films

Figure 3a shows the measured dose map superimposed on a map of the treatment plan. In this view both dose maps as positives, i.e. brighter areas are higher in dose than dark areas. In Figure 3b a feature of FilmQA Pro software has been used to display the measured dose maps in opposing contrast, e.g. as a negative of the measurement image superimposed on the treatment plan as a positive. When the two dose maps have a similar dose scale this tool is very useful in aligning the maps with one another since the display will show a uniform grey color when the images are aligned.

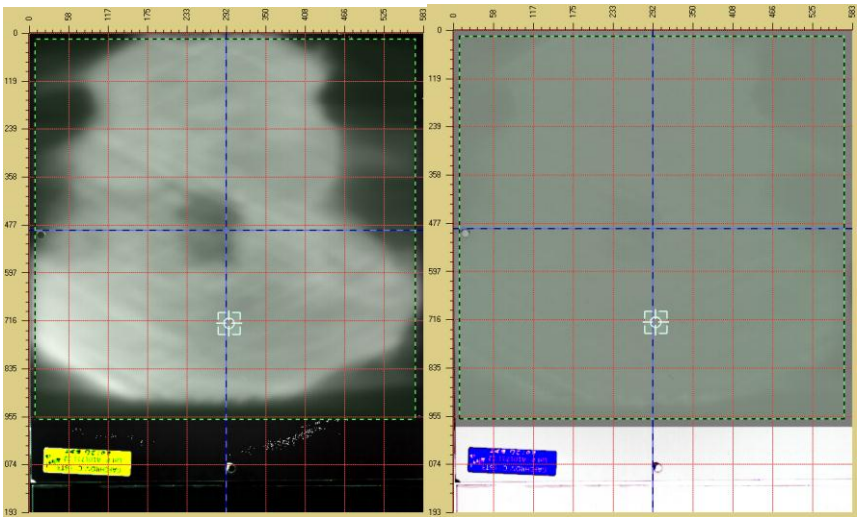

Figure 3: Measurement and plan superimposed: a) both as positive images; b) in opposing contrast

Figure 4 shows iso-dose profiles comparing the dose measurements (thin lines) to the RapidArc treatment plan (thick lines). On the right side of the FilmQA Pro screen shot in Figure 5 is an example of the dose profile comparing measurement (thin line) to plan (thick line). The position of the profile is indicated on the superimposed dose maps shown in the center of the figure.

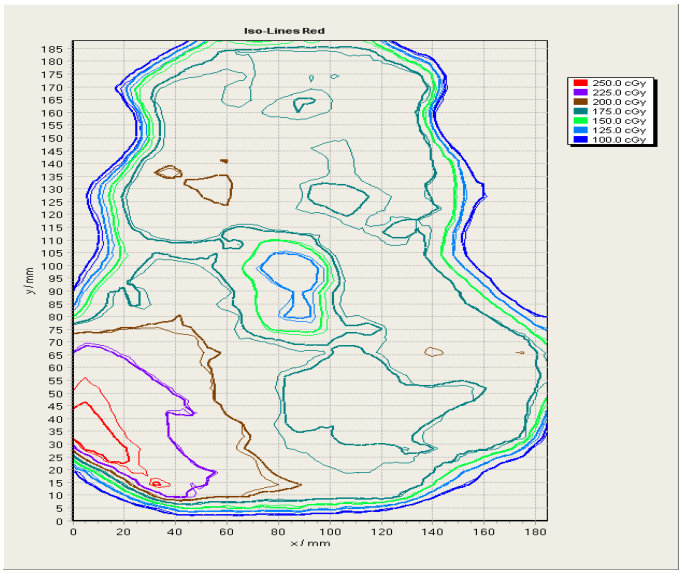

Figure 4: Isodose Plots of Measurement (thin lines) vs. Treatment Plan (thick lines)

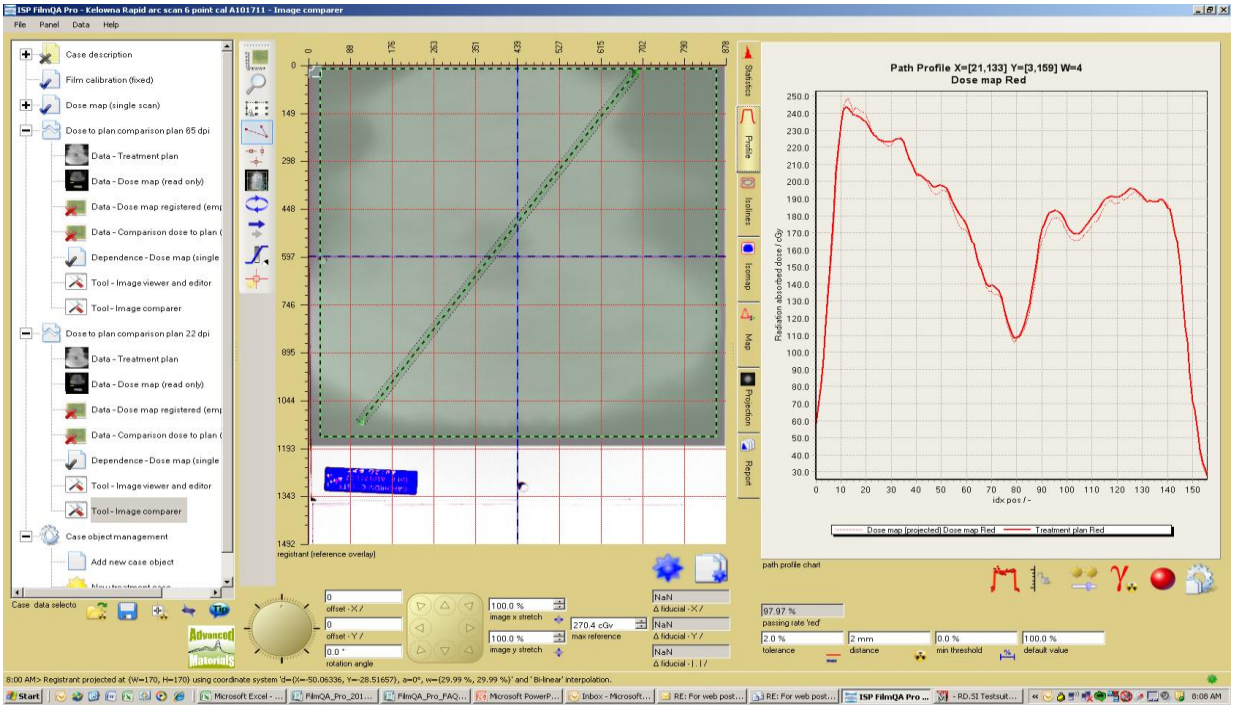

Figure 5: Dose Profile of Measurement (thin lines) vs. Treatment Plan (thick lines)

Figure 6 shows a FilmQA Pro screenshot with results of the gamma analysis. Using test criteria of 2% at 2mm the passing rates in the red, green and blue channels were 98.0%, 93.9% and 98.2% respectively. The areas where the agreement was outside the test limits are shown in color in the map on the right side of the screen shot.

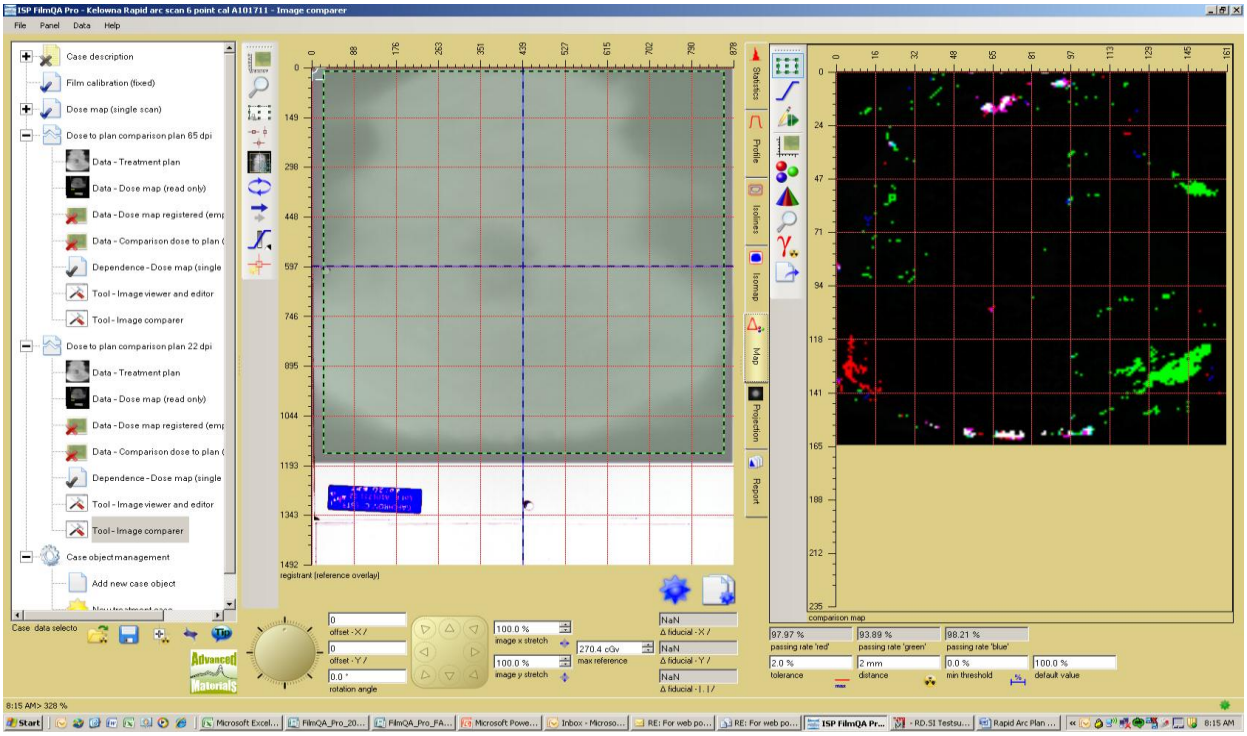

Figure 6: Gamma analysis of measurement-to-plan agreement within 2% at 2mm

Figure 7 shows another FilmQA Pro screenshot with results of the gamma analysis depicted in a different way. In this view the map on the right of the figure shows dose differences measurement-to-plan that fall within the 2mm radius of comparison.

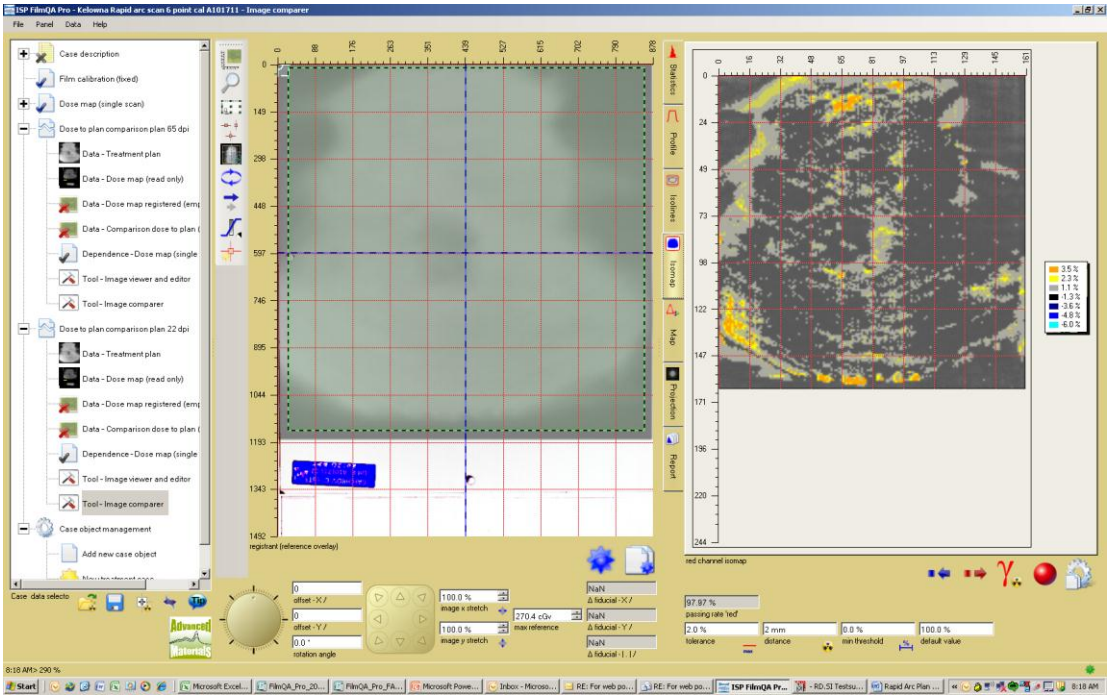

Figure 7: Gamma analysis showing dose differences measurement-to-plan within 2mm radius

4. Conclusion

This work demonstrates an efficient protocol for measuring doses delivered by a RapidArc therapy treatment plan using the patient film, one calibration film and one unexposed film and applying a single scan to acquire a digital image for calculation and analysis. The process of acquiring application film and calibration data in a single scan eliminates inter-scan variability as an error source and provides an efficient, timesaving and practical solution for using radiochromic film for routine RapidArc plan verification at high spatial resolution not attainable with other available methods. .

References

1. An Efficient Dosimetry Protocol for Radiochromic Film Dosimetry. The protocol is available at www.filmqapro.com

2. Micke, A., Lewis, D.F., Yu, X. “Multichannel film dosimetry with non-uniformity correction,” *Med Phys*, 38(5), 2523-2534 (2011).

3. FilmQA Pro™ radiochromic film dosimetry software is a product of Ashland Specialty Ingredients, Advanced Materials Group, Wayne, NJ. Tel: 866-218-0594. The application is available for download and trial at www.filmqapro.com