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Comparison of Error Range of Delivery Quality Assurance by Type of Intensity Modulated Radiation Therapy

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Delivery Quality Assurance (DQA) is performed to evaluate the intensity modulated radiotherapy (IMRT). However, differences in the DQA results may be caused by factors such as the IMRT technique, treatment volume, etc. In this study, we compared five types of gamma index and four types of dose differences as IMRT technique, Treatment site, Volume of Planning Target Volume (PTV), Regularity Shape Index (RSI), indices of treatment planning evaluation. From January 1, 2016 to December 31, 2017, 32 patients who underwent IMRT plan were used to perform Step and Shoot (SNS) technique, Sliding Window (SW) technique, and Volumetric Modulated Arc radio-Therapy (VMAT) technique. After obtaining the Treatment Site, Volume of PTV, RSI, CI, HI, QOC according to each planning technique, nine factors of DQA were compared. As a result of the comparison, it was not possible to confirm the tendency of the items except the IMRT technique. The results of the IMRT technique showed the highest values for area gamma (< 1.0) and area dose difference (> 0.8) for SNS technique, and the lowest values for the other seven factors. For VMAT technique, the lowest value was obtained for area gamma (< 1.0) and area dose difference (> 0.8), and the highest value was obtained for the other seven factors. This study is limited to Electronic Portal Image Device(EPID). Therefore, it is necessary to study various equipment and program version in order to evaluate various DQA tools. In addition, there are limitations on the Treatment Site, Volume of PTV, and etc. necessary for evaluation. Therefore, it is considered that evaluation using various cases will be needed in the future. Nine factors, results of DQA, were a tendency by the IMRT techniques. The tolerance range of gamma index should be tightly in 80 % and 60 %, and the tolerance range of dose difference index should be tightly in 75 % and 25 %. Therefore, it can be concluded that accurate electromagnetic radiation therapy can be performed by applying the appropriate tolerance according to the IMRT technique in the future.

Keywords : radiotherapy, intensity modulated radiation therapy, delivery quality assurance

1. Introduction

In order to prevent electromagnetic radiation side effects in patients treated with radiotherapy, the optimal dose should be delivered to the tumor in the treatment plan and the minimum dose should be delivered to the protected normal organs [1, 2]. It is necessary to apply an intensity modulated radiotherapy (IMRT) technique, combining various field shape in various directions using Multi-Leaf Collimator (MLC), for achieve various dose distributions of tumors or adjacent normal organs [3]. Also, considering the applied dose, the direction, and the various field shape at IMRT, the inverse plan technique is used in a dedicated computer which can perform complicated operation in order to obtain an appropriate result [4, 5]. IMRT techniques are classified into various forms through various attempts and developments. And now, there exists a Modulated dose distribution technique using a Virtual Wedge filter (MVW), Field in Field (FiF) technique, Step and Shoot (SNS) technique, Sliding Window (SW) technique, Volumetric Modulated Arc radio-Therapy (VMAT) technique [6-9]. The virtual wedge filter is a wedge-shaped dose distribution changing system that realizes the physical wedge filter used for the dose distribution change in the conventional radiotherapy according to the movement of the MLC. The use of MLC to change the field of exposure may be included in the IMRT technique, but not all of them may be included [10]. The FiF technique is also referred to as simple IMRT technique. It is a method to acquire a dose distribution suitable for a purpose by

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summing multi fields through a digital reconstruction image of a dose distribution with respect to each direction. Recently, a modification method has been applied using the color wash tool through Dose Color Wash Change System of dose distribution in the exposure direction [11, 12]. Next, SW technique and SNS technique can be regarded as the difference according to the movement of the MLC. SW technique is method of continuously changing the movement of the MLC for acquisition of dose distribution by optimization. Then, SNS technique is method of stepwise changing of MLC [13, 14]. SW technique is a method in which the electromagnetic radiation is irradiated while the continuously movement of the MLC. On the other hand, SNS technique exposure electromagnetic radiation after stop moving MLC in each form. VMAT technique is considered to include a method in which the gantry angle is changed than conventional IMRT technique that only reflects the motion of MLC. In radiotherapy, it can be said that a suitable dose distribution in which the maximum dose of a normal organ is reduced and suitable dose distribution for the tumor while changing the shape of the MLC by the direction of the gantry while rotating the gantry around the patients [15, 16]. Thus, there are various types of IMRT, and it is expected that more various forms will be developed in the future. The IMRT technique is a very suitable method for implementing the dose distribution desired by the therapist, but the accuracy of the treatment is required due to various change factors. In the case of conventional radiotherapy, since there are no changes in the MLC and gantry, only the regular quality assurance by Task Group (TG) 142 recommended by the American Association of Physicists in Medicine (AAPM) can be implemented [17, 18]. However, in the IMRT technique, Delivery Quality Assurance (DQA) has been proposed since it is necessary to verifiable the reproducibility in each treatment plans. DQA is a method of demonstrating reproducibility by evaluating the dose distribution using a treatment plan computer while implementing plan of the IMRT technique with medical LINAC equipped with a dedicated evaluation tool [19]. DQA is divided into the method of comparing the gray scale at electromagnetic radiation film attached to the solid phantom, the method of comparing the integrated dose at the diode dot dosimeter mounted in a dedicated tool, and the method of comparing the dose distribution using arrayed detectors in Electronic Portal Image Device (EPID) installed opposite to the electromagnetic radiation source [20-22]. The tolerance range of DQA used in the evaluation of the IMRT technique is recommended in TG 219 by AAPM and is not distinguished by the type of IMRT. However, result value of DQA may be different from the type of IMRT, the movements of MLC, and the type of applied change factors, etc. Therefore, we will provide a reference for results of DQA from changing factors.

Fig. 1. (Color online) Medical LINAC (RapidArc) with EPID.

2. Materials and Method

2.1. Materials

(1) Medical Linear Accelerator as shown in Fig. 1 : CLINAC-iX(Ci) (VARIAN, USA) with EPID

(2) Electromagnetic radiation Treatment Planning System : ECLIPSE ver. 10.1 (VARIAN, USA)

(3) Treatment Planning Images : 32 images of complete treatment planning in IMRT at January 1, 2016 to December 31, 2017

(4) Delivery Quality Assurance System as shown in Fig. 2 : Portal Dosimetry (VARIAN, USA)

2.2. Method

2.2.1. Plan by IMRT technique

There is a difference in selection of beam direction, optimization, and applied dosimetric calculation according to the type of IMRT technique as shown in Fig. 3. Therefore, we would like to compare the treatment planning criteria of each technique. In the case of SNS technique, the selection of the direction of beam and the number of beam were set using the gantry geometry optimization tool. Gantry geometry optimization conditions

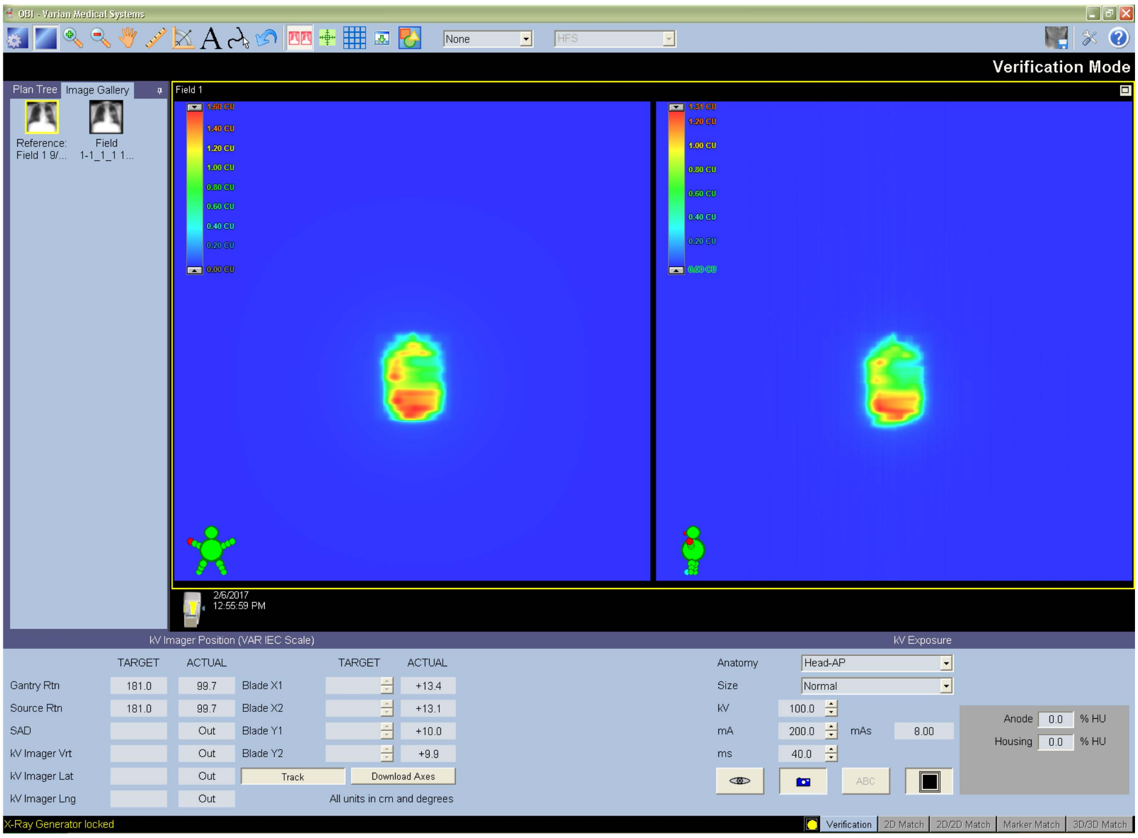

Fig. 2. (Color online) DQA implementation scene.

applied for actual treatment condition and optimized calculation time for 10 minutes with a number of beams between 8 and 14. For the treatment plan optimization after setting the direction of gantry, the recalculation was carried out three times after the optimization calculation time for 10 minutes under the same conditions, and the results were obtained by selecting MLC setting of SNS technique for the dose calculation. In the case of SW technique, the same method as SNS technique was used. Just, MLC setting is applied to SW technique instead of SNS technique. Finally, in the case of VMAT technique, the clock wise has a collimator angle of 330 degree with gantry angle is start angle of 178 degree and stop angle of 182 degree. The cross clock wise has a collimator angle of 30 degree with start angle of 182 degree and stop angle of 178 degree. In the case of the optimization process, optimization work and dose calculation time are set automatically as compared with SNS technique and SW technique.

2.2.2. Acquisition of factors by planning

The compared factors in the treatment plan were

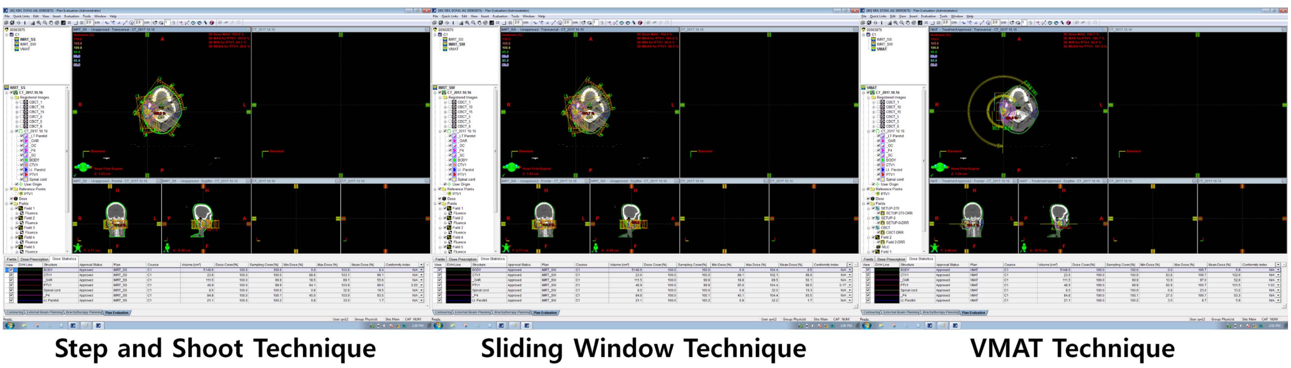

Fig. 3. (Color online) Sample plan images of SNS window, SW, and VMAT.

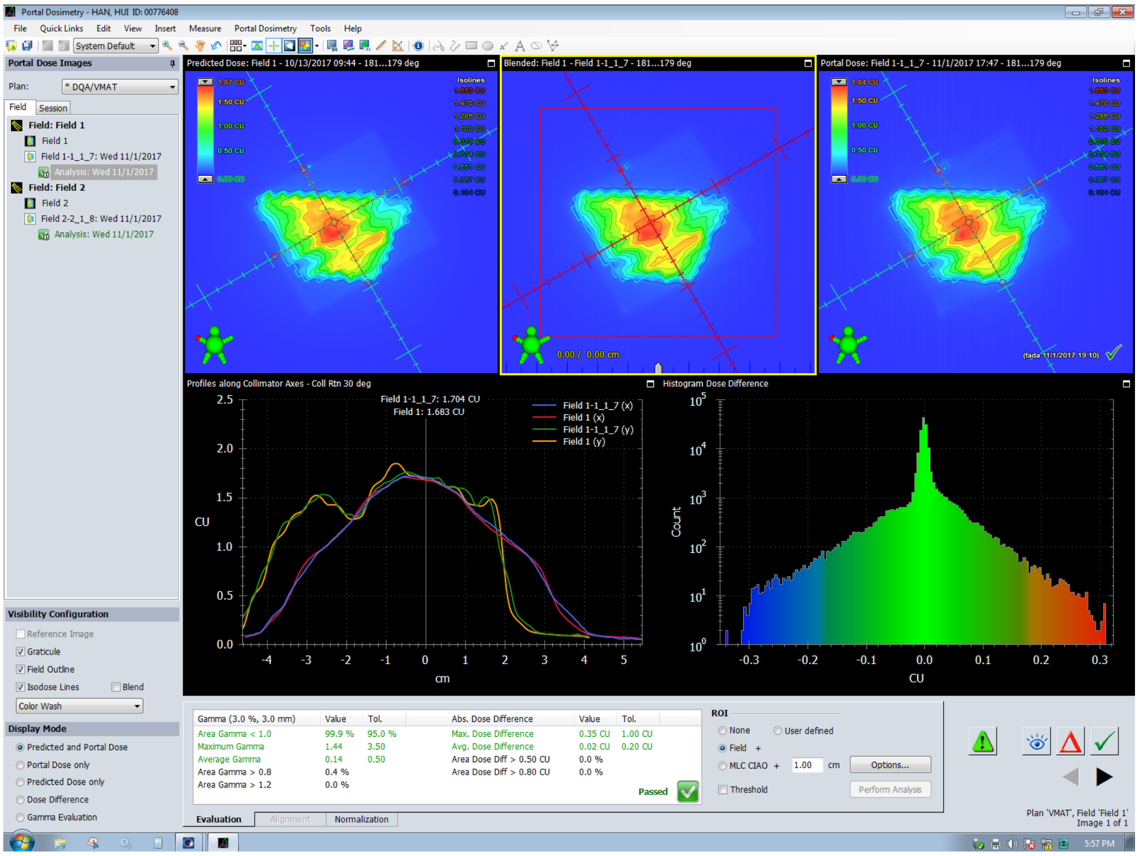

Fig. 4. (Color online) DQA result sample image.

classified into factors for comparing and evaluating the treatment plan and factors for evaluating the form of tumor. Factors for evaluating the treatment plan were the Conformity Index (CI), Homogeneity Index (HI), and Quality of Coverage (QOC) by quantified indicators of Radiation Therapy Oncology Group (RTOG). In order to evaluate the form of the tumor applied the Regularity Shape Index (RSI) to compare the usefulness of IMRT planning for heteromorphic tumor.

CI=Vri/TV
HI=Imax/RI
QOC=Imin/RI
RSI=PTV/CCV
Vri : Volume of the reference isodose
TV : Target volume
Imax : Maximum isodose in the target
Imin : Minimal isodose surrounding the target
RI : Reference isodose
PTV : Volume of PTV (Planning Target Volume)
CCV : Volume of circumscribed cubic

2.2.3. Comparison of DQA by IMRT technique

The portal dose of DQA was measured by each IMRT technique as shown in Fig. 4. Then, the results of the measurement were evaluated by the dedicated computer. The comparison factors were divided into gamma index and dose difference index according to results of evaluation. Gamma index are divided into area gamma, maximum gamma, and average gamma. Area gamma index are classified into three types: 1.0 or less, 0.8 or more, and 1.2 or more. Next, the dose difference index is divided into maximum dose difference, average dose difference, and area dose difference. Area dose index is classified into more than 0.5 CU and more than 0.8 CU. At this time, the criteria that can be applied to the treatment with the electromagnetic radiation treatment plan should be area gamma of 95 % or more, maximum gamma of 3.5 or more, and average gamma value of 0.5 or more. For dose difference index, maximum dose difference shall be not less than 1 CU and average dose difference shall not be less than 0.2 CU.

2.2.4. Tendency evaluation of each index

The results were compared and evaluated using indices obtained for each plan. The nine indices of DQA results compared with treatment site (part), IMRT technique, volume of PTV, RSI, and evaluation indices of treatment planning. Treatment sites were classified as Head and Neck, Chest, Abdomen, and Pelvis. IMRT was classified into SNS technique, SW technique, and VMAT technique. The volume of the treatment target was the volume of Planning Target Volume (PTV). Tumor heteromorphy was applied by RSI. Evaluative indices of treatment plan were classified as CI, HI, and QOC.

3. Result

3.1. Part of treatment

The results of DQA according to the treatment site were as shown in Fig. 5.

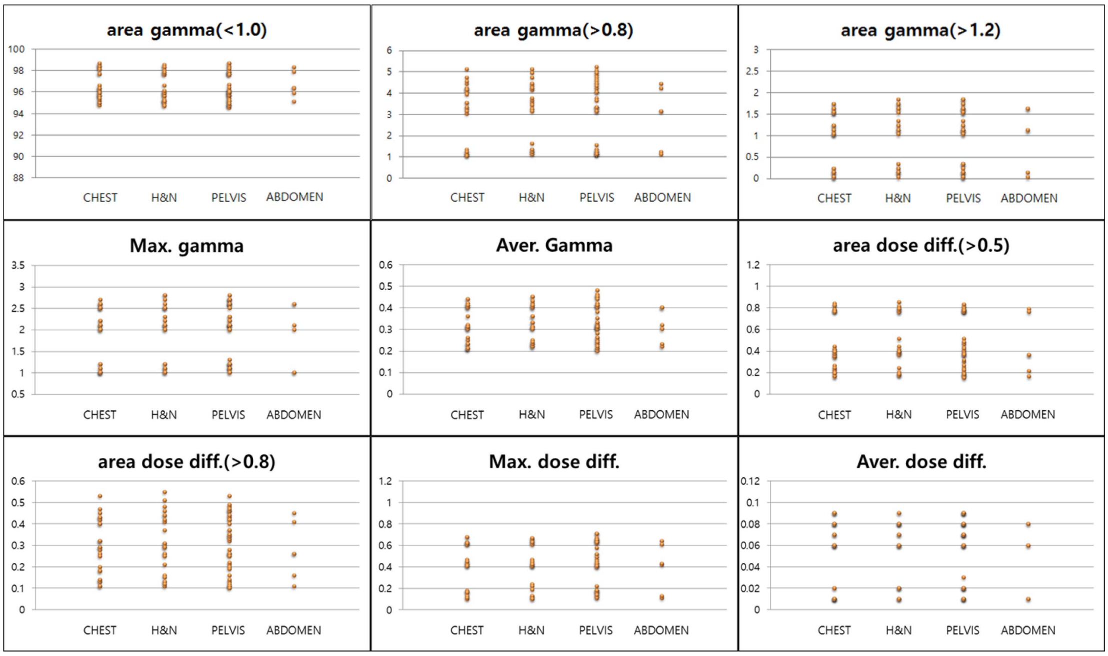

Fig. 5. (Color online) Graph of DQA result by treatment site.

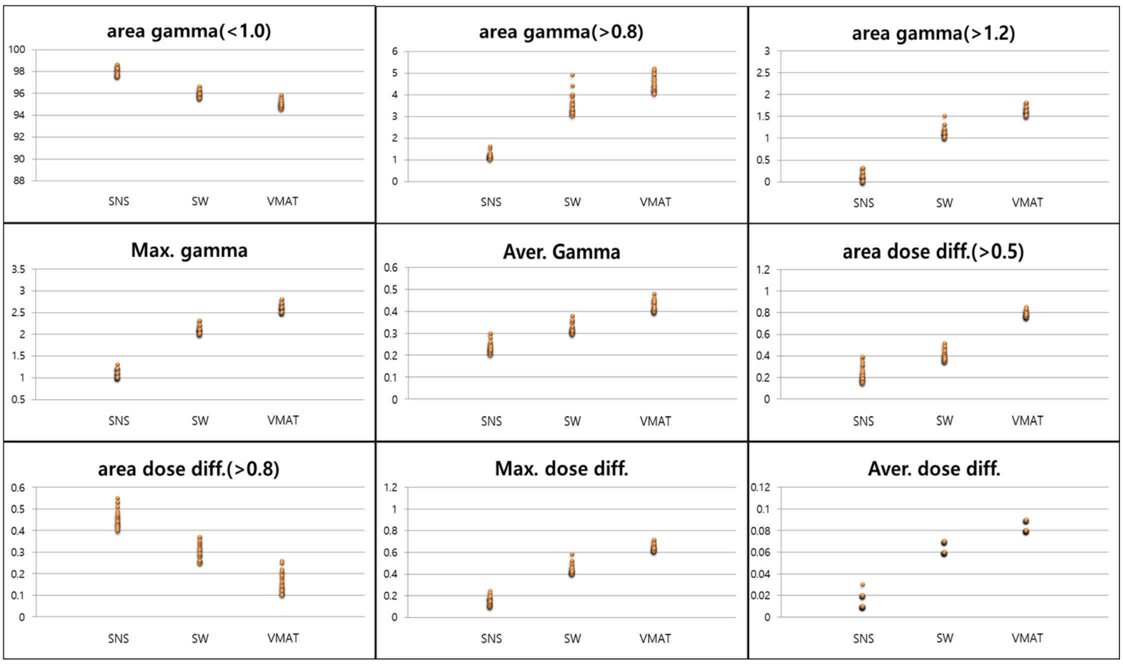

Fig. 6. (Color online) Graph of DQA result by each IMRT technique.

3.2. Planning technique of IMRT

The results of DQA according to types of IMRT technique, SNS technique, SW technique, and VMAT technique, were shown in Fig. 6.

3.3. Volume of PTV

The results of DQA according to the volume of PTV were as shown in Fig. 7.

3.4. RSI

The results of DQA according to RSI, which is the heteromorphic tumor, were shown in Fig. 8.

3.5. Factors of plan

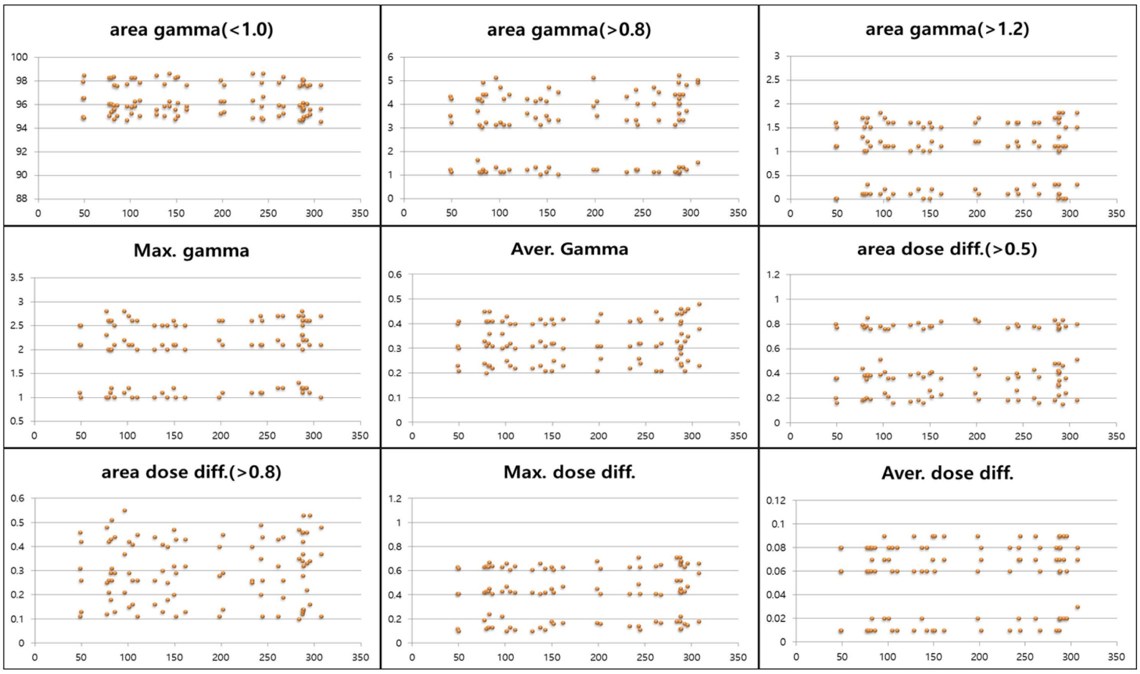

Fig. 7. (Color online) Graph of DQA result by volume of PTV.

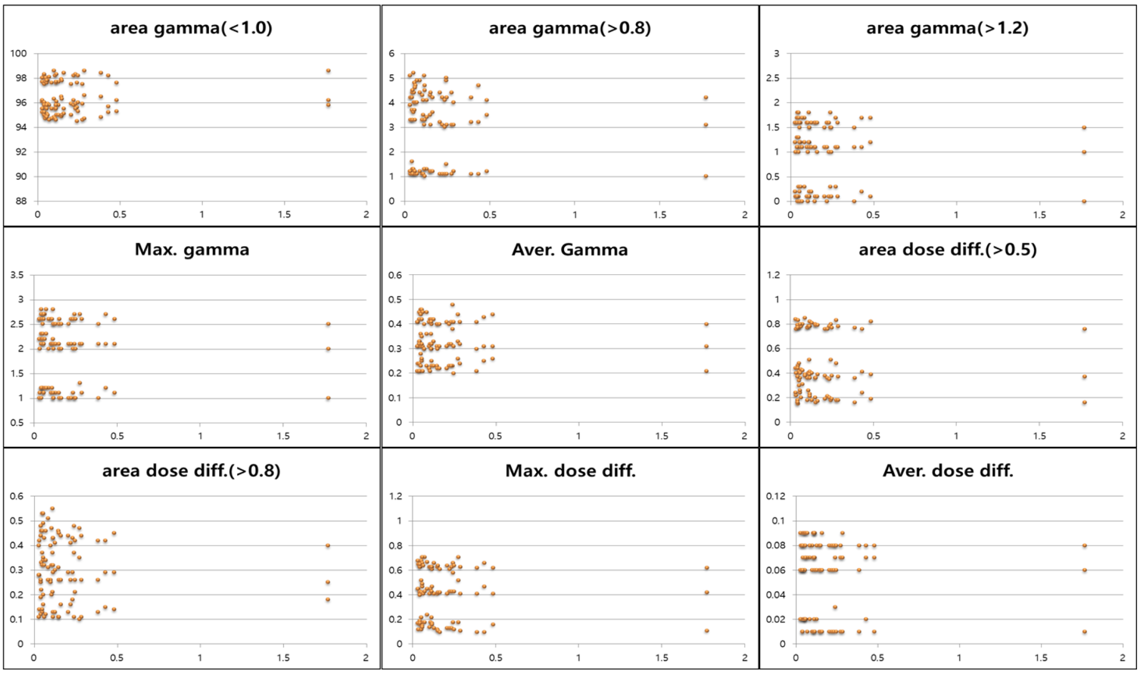

Fig. 8. (Color online) Graph of DQA result by RSI.

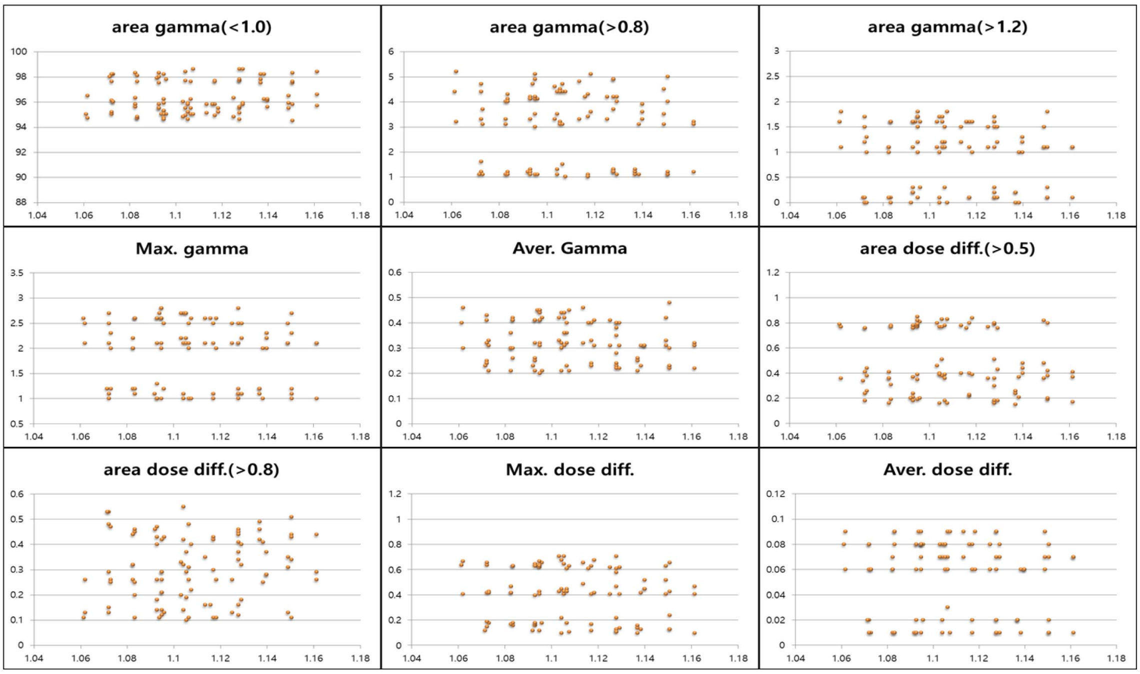

Fig. 9. (Color online) Graph of DQA result by CI.

The results of DQA according to evaluation factors of treatment plan, CI, HI, and QOC, were as shown in Fig. 9 to Fig. 11.

4. Discussion

Preliminary studies on DQA consisted of studying the usefulness of the making or application of phantom for evaluation, evaluation of DQA at tomotherapy or cyber-knife, and studying the evaluation factors of DQA. However, there is a need for research to evaluate the factors that may cause errors in DQA analysis in clinical practice as the applied DQA becomes popular. Therefore, in this study, we analyzed the factors affecting the result of DQA

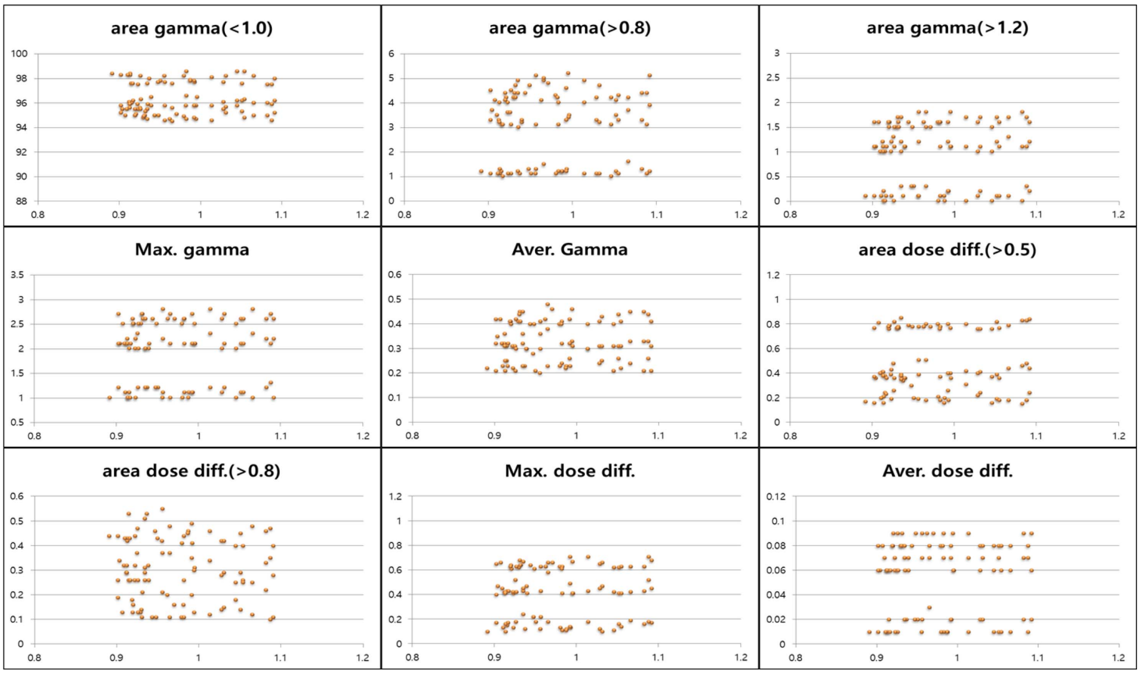

Fig. 10. (Color online) Graph of DQA result by HI.

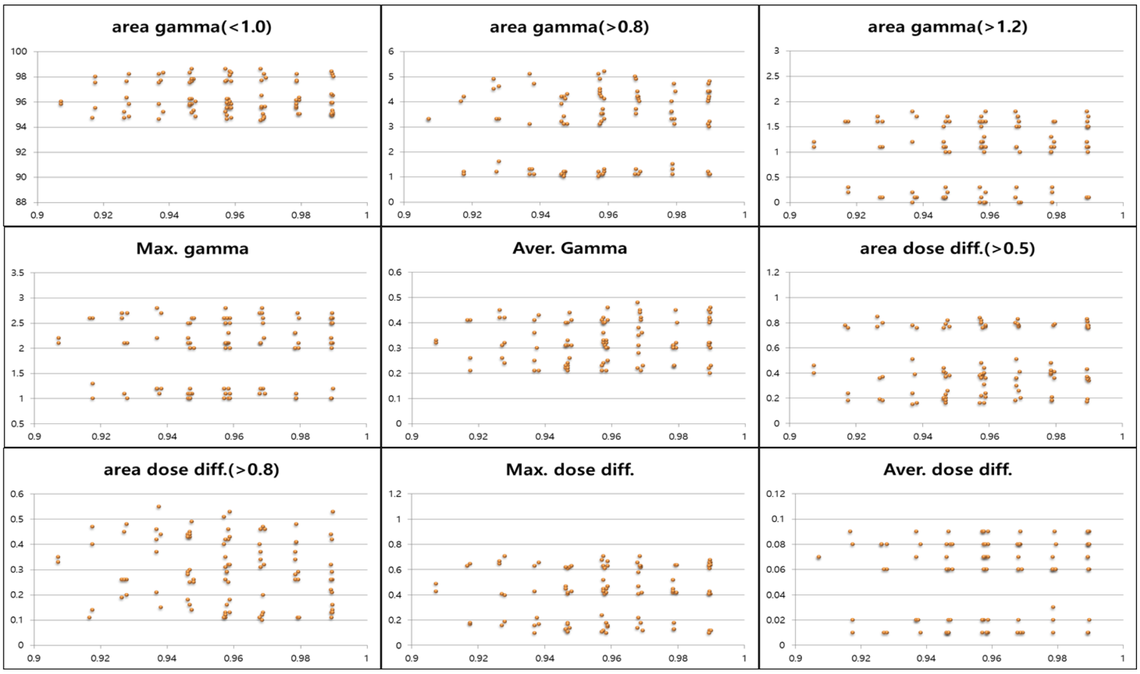

Fig. 11. (Color online) Graph of DQA result by QOC.

by using various factors in the radiotherapy plan which was not presented in the previous study. Since there is a limit to the application of all currently applied IMRT techniques, only SW technique, SNS technique, and VMAT technique, which can produce similar results through the optimization process, were applied. In the future, the development of various evaluation methods will require the evaluation of the tendency of DQA including the application of the MVW and FiF technique. In addition, considering various factors such as the distribution of major normal organs, the number and interval of tumors, and the field size, it can be used as a basic data for improvement of DQA evaluation method.

5. Conclusion

In this study, we tried to compare the results of DQA considering the characteristics of the IMRT technique. Then, the difference in the dependence of DQA results were examined through classifying the treatment site, the treatment volume, indices applied to the treatment plan, and the tumor heteromorphy. Treatment sites were classified as Head and Neck, Chest, Abdomen, and Pelvis. Results of DQA did not confirm the dependence on all nine factors according to treatment site. However, in the case of the abdomen, there are not many cases and further research is needed. In the case of the volume of PTV, the dependence was not confirmed as in the case of the treatment site, and the volume of 200 cc was not much. The evaluative indices of treatment plan tended to slightly increase in the area dose difference (> 0.5) with increasing HI, but it was not significant. Area gamma (> 1.2) and maximum gamma were slightly decreased with increasing CI, but not with HI. In QOC, it is confirmed that there is no tendency. In the case of RSI, as the index of heteromorphy increased, all evaluative indices of DQA showed a tendency to decrease, but not significant. Just, declining trends in area gamma (> 0.8), average gamma, and area dose difference (> 0.8) were perceived to be of relatively interest. Finally, the results of IMRT technique showed a very significant trend. In the area gamma (< 1.0) and area dose difference (> 0.8), the SNS was the highest and the VMAT technique was the lowest. For the remaining 7 factors, SNS were the lowest and VMAT technique was the highest. Therefore, the tendency according to the IMRT technique was compared. The acceptable range of area gamma (< 1.0) is more than 95 %, maximum gamma is less than 3.5, average gamma is less than 0.5, maximum dose difference is less than 1.0 and average dose difference is less than 0.2. As a result of comparing the mean value of each factor with the percentage based on the acceptable range and the percentage based on the largest value of the measurement result, the percentage based on the largest value of the measurement result showed similar change. Therefore, as a result of determining the tolerance of each factor based on the percentage based on the largest value of the measurement result, VMAT technique will have to apply existing clinical acceptable range. In the case of the

SW technique, it can be judged that it is appropriate to tighten the gamma index to 80 % of the conventional acceptable range and to 75 % of the dose difference index. In the case of SNS technique, it can be judged that it is appropriate to tighten the gamma index to 60 % of the conventional acceptable range and to 25 % of the dose difference index. Therefore, in the case of applying the IMRT technique in the clinic, considering the fact that the error of the SNS technique and SW technique are less than VMAT technique, strengthening the criterion of tolerance and applying the DQA, electromagnetic radiation therapy may be performed.

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