Verification of Treatment Planning System Using IMSure QA Software in Non-reference Condition

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ABSTRACT

Objectives: The aim of this study was to verify the treatment planning systems (TPSs). The next aim was to validate IMSure QA software for patient-specific QA in radiotherapy clinics.

Material and Methods: We used IMSure QA software (standard Imaging, v 3.5) for verification of 92 non-IMRT plans (540 fields) in 10 radiotherapy clinics. To validate the IMSure, dose measurement was performed in CIRS phantom. Then, IMSure Calculations were compared with dose measurements. Finally, 92 patient plans (540 fields) were re-calculated including abdomen-pelvic, head & neck, breast & chest treatment sites.

Results: IMSure shows good agreement with dose measurements in the phantom. In the analysis of 540 fields, the mean difference of dose between IMSure and TPS was 0.62% (~3% SD) and for MU calculation was 1.5% (5.5% SD). Per site-treatment analysis shows mean differences of MU for abdomen-pelvic, head & neck, breast & chest treatments 1.3%(5.35% SD), 0.52%(5.22% SD) and 2.5% (7.13%SD), respectively. In addition, it was found that among different treatment planning systems, AAA algorithm has the best agreement with IMSure in mean difference of 0.68% for MU and 1.33% for total dose.

Conclusion: Our results show that IMSure can be a suitable tool for routine and patient-specific QA, especially when a treatment plan is complex. Based on our results, we suggest re-assessment of agreement criteria for chest site treatment.

Keywords

IMSure QA software, MU verification, TPS verification

Introduction

In recent years, the development of volumetric imaging, CT/PET/MRI simulation and advancement of computation algorithms and clinical treatment planning systems (TPS) have significantly increased the complexity of the patient treatment [1-4].

'Monitor Unit Verification'(MUV) is the most important step in a comprehensive QA program that avoids incorrect dose delivery to the patient and ensures patient safety [1,5,6]. In this light, different reasons may result in MU uncertainty including patient setup, mechanical errors, human mistakes, machine characteristics and TPS calculations. The reports show that TPS calculations are main reasons [7,8].

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MUV process has also been recommended by many international organizations and bodies [9,10]. Based on IAEA documents, independent MUV can significantly reduce major errors and cause patient safety. In addition, the complexity of current TPS is a main source of error. Also according to ICRP, "a simple secondary MU calculation, independent from TPS, has proven for many years to be an efficient tool for the prevention of major errors in dose delivery"[5]. AAPM Task Group 40 has been recommended MUV for conventional radiation oncology [6].

The most routine method for dose verification is the use of homogenous or heterogeneous phantoms. In this process, the treatment plan created by TPS will be applied; phantom and irradiation are done by linac machine. Then, dose will be measured (using ion chamber and electrometer) in phantom to verify the calculated dose. This process is time consuming [1-4].

and also, patient geometry is more complex than phantom geometry. Therefore, in phantom study tissue heterogeneities in the patient are underestimated and some errors such as mistakes in external contour of the patient may not be identified, so using a homogenous phantom for entire QA process is not sufficient [6].

Previously, an MUV procedure based on the hand-calculation was performed independently by a second person. This method could lead to many major errors such as: underestimation of heterogeneities of tissue and scatter photons. Today, because of complexity of calculation algorithm and clinical treatment planning, it is not recommended to perform the double check procedure by hand calculation except for very simple reference conditions [5].

Recently, most MUV calculations are done by independent computer programs and dose calculation algorithms [5,6]. This type of verifying algorithm is simpler than primary calculation algorithm (TPS). Therefore, it has been considered to develop a standard guideline for checking the agreement/difference level between verification calculation and primary calculation [1,5]. However, it should be noted that verification using software is not a replacement for precise measurement using either film dosimetry or ion chamber in phantom during QA process. But, it provides medical physicists an additional degree of security and safety against any major error before the plan is accepted for treatment [13].

One instance of treatment plan QA software is IMSure (Standard Imaging, Middleton, WI) that is available commercially, and calculates the dose and MU of both IMRT and non-IMRT plans. Also, this software can check Cyberknife and RapidArc plans. Its calculation engine is a patented "3-Source Model" algorithm developed at Stanford University that considers dose from three scattered photon sources in addition to dose of primary photons [14].

The goal of this study is to validate IMSure software for routine and patient-specific QA programs. The next goal is verification of TPS algorithms and then determining the agreement difference level between verification calculation and TPS calculation for some treatments at non-reference and non-IMRT conditions.

Methods

Commissioning IMSure QA Software

In the present study, version 3.5 of IMSure verification software was used. This software needs to be commissioned for the linac properties such as linac type, nominal energy, maximum depth (dmax)for each energy, reference depth, calibration field size, calibration dose rate (cGy/MU), source-to-phantom distance, beam type (photon/electron/SRS/FFF), tray factor, wedge type, wedge transition factor, MLC type, dosimetric MLC leaf offset, mean dose leaf leakage and mean fluence map leaf

leakage.

In addition, IMSure for both open and wedged fields needs tissue-maximum-ratio (TMR), off-Central-ratio (OCR), output factor (OF) and scatter factor (Sc) tables. All data tables have to be imported into the software in '.csv' format of Excel Microsoft Office (Figure 1).

Validation of IMSure QA Software

For validation of IMSure, we measured point doses in different setups of the phantom and then compared dose measurements with dose calculated by IMSure software.

For dose measurement, we used CIRS-like thoracic phantom (made by Sepahan Parto Esfahan Company) and calibrated ion chamber (0.6 cc Farmer, PTW). The CIRS-phantom consists of lungs, mediastinun space and spinal cord (Figure 2).

Initially, a computed tomography (CT) scan was obtained from CIRS-Phantom with 2mm thickness. Then, DICOM file of the CT was exported to TPS for treatment planning. Four simple plans from audit tests were chosen and treatment planning was performed by four different types of TPS including ISOgray (DOSIsoft SA, v), Eclipse (Varian medical system, Palo Alo, CA, v.13), TiGRT (lina tech Co.) and CorePlan (Seoul C&J, Inc): plan1 has one simple antero-posterior (AP) field, plan2 has one lateral field with 60-wedge, plan3 has one oblique field with 6×12cm2 block (or MLC) and plan4 has two oblique and one vertex field (Figure 3).

Then, CIRS phantom set up on linac machine and exposure were done. We also used three various types of linacs: Varian Clinac 600/c, Siemens primus/oncor and Electa compact.

The measured doses have been determined according to IAEA-TRS 398 dosimetry protocol formulism:

$$Dose\ (cGy) = Readings\ average \times K_{T,P} \times K_{Q,Q0} \times K_{pol} \times K_{Sat} \times N_{D,W} \quad (1)$$

The chamber reading in (nC), KT,P is temperature and pressure correction factor, KQ,Q0 is coefficient correction for beam quality, ND,W is chamber calibration factor (mGy/nC), Kpol is for polarity and KSat for saturation correction factors.

The differences between dose measurements with calculation of TPS and IMSure have been determined by the following formulism:

$$\text{diff}\,\% = \frac{\text{IMSure dose-Meaurment}}{\text{Meaurment}} \times 100 \quad (2)$$

$$\text{diff}\,\% = \frac{\text{IMSure dose-TPS dose}}{\text{TPS dose}} \times 100$$

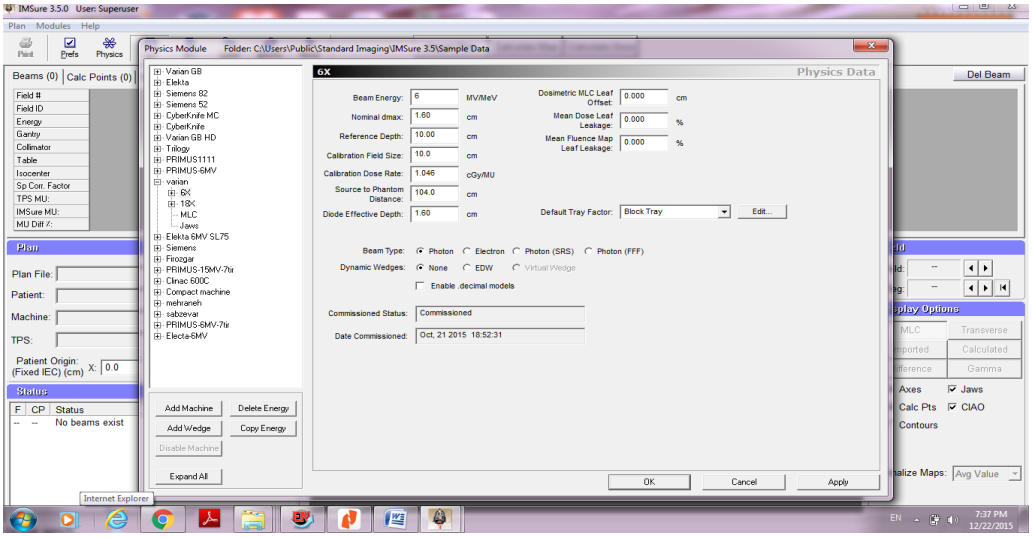
Verification of Patient Plans (non-standard condition)

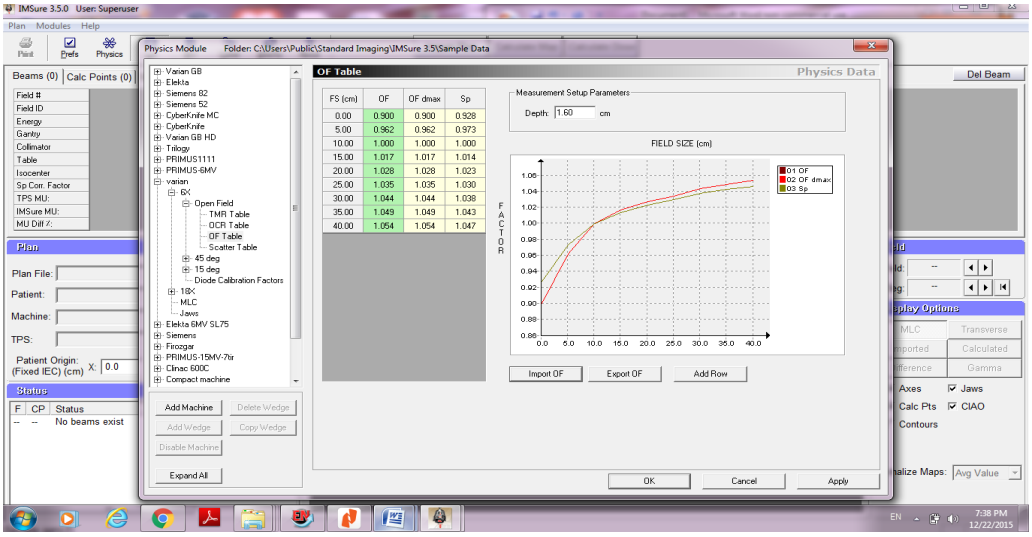
Different patient plans were randomly selected in each clinic. Totally, we verified 92 patient plans (540 fields) by IMSure in all 10 radiotherapy clinics. Three plan groups were considered including pelvic & abdomen, head & neck, breast & chest. To perform plans QA using IMSure, DICOM file of the plan consisting of RT file, RT structure, RT images and CT were exported to IMSure software for patient specific calculation. IMSure QA software calculates the number of MUs required for treatment delivery and then results were compared with the MUs obtained by TPS which provides a difference in MUs as a percentage value. We analyzed the results based on both the anatomical treatment site and TPS algorithm.

Results

Validation of IMSure QA Software

Absorbed doses of 48 points were calculated in four radiotherapy clinics. Overall, IMSure showed good agreement with doses measured by CIRS phantom. The mean difference between dose measurements and dose calculated by IMSure was 2% (4.84% SD) (Figure 4). The mean difference between MU calculation





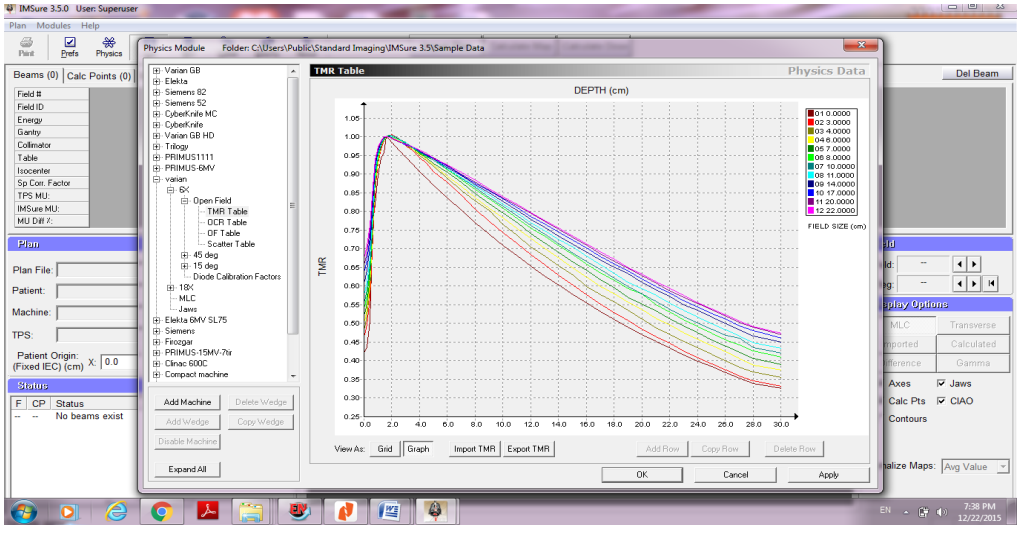


Figure 1: commissioning of IMSure QA software. a) Characteristics of linac machine b) OF and c) TMR graph

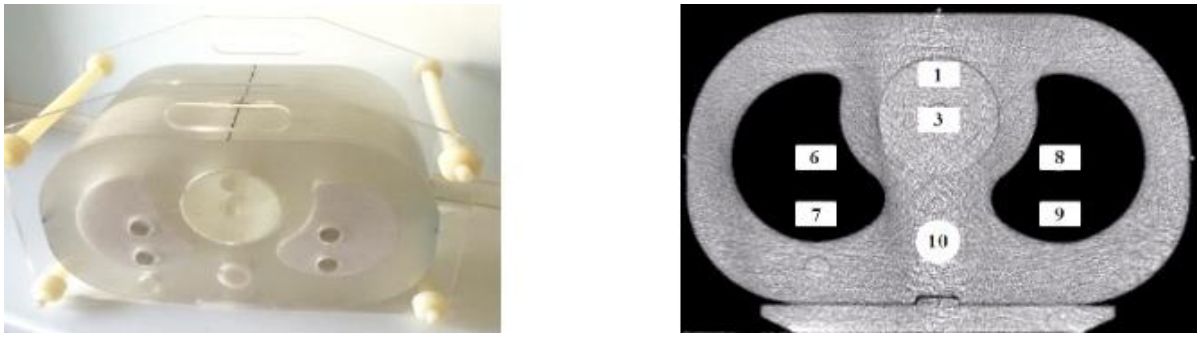


Figure 2: Cirs-like phantom properties: soft-tissue: PMMA
bone: tetraflouroethylenteflon lung: Cork
Long: 21cm width: 35cm height: 20cm slice thickness: 9mm

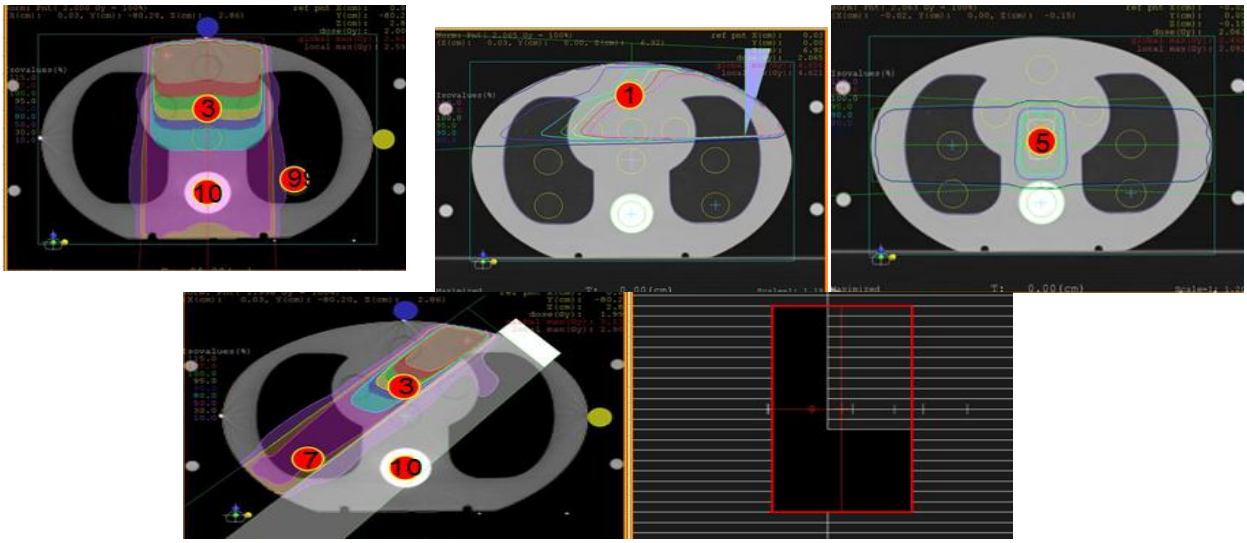


Figure 3: a,b,c) the four tests using this study for validation of IMSure

of TPS and IMSure was 4% (6.95% SD) for simple tests. There was greater dose difference in out-field points. The mean difference was 8% in these points and one case was 14.8%. In addition, there was a great difference of approximately 28% in MU calculation between TPS and IMSure in oblique field of plan 4.

Verification of Patient Plans (non-standard condition)

The summary of the clinics characteristic is shown in Table 1. We verified 540 fields from 92 patient plans by IMSure software. Overall, the mean difference of doses between IMSure and TPS was 0.62% (~3% SD) with P-value=0.113. For MU calculation, the mean

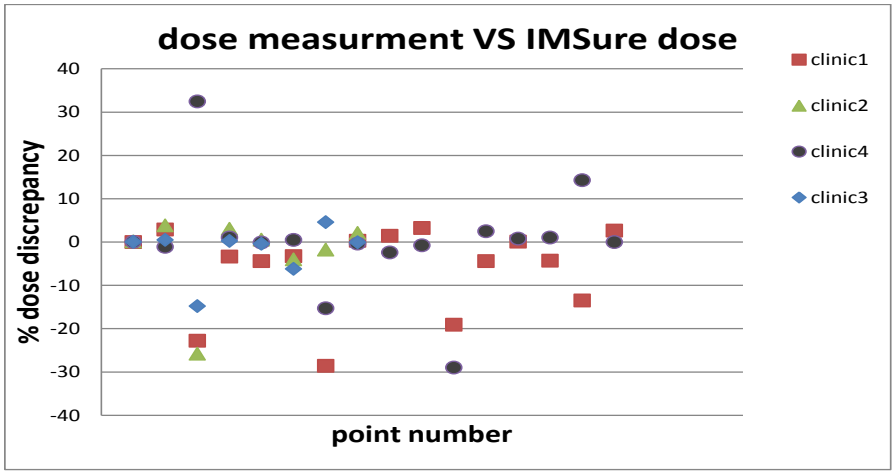


Figure 4: Comparison between dose measurements with dose calculations of TPS and IMSure for four radiotherapy clinics.

difference was obtained 1.5% (5.5% SD) with P-value=0.45 (Figure 5).

Site-specific Comparison

Dose variation results were also analyzed for different treatment sites. The summary of the results is shown in Table 2. P-values of dosimetric variations for three groups of pelvis & abdomen, head & neck and breast & chest were 0.673,0.916 and 0.589, respectively. The site-specific differences of MUs calculation between both IMSure and TPS were shown in Figure 6.

Comparison based on TPS Algorithm

This study verified four TPSs with different algorithms. Eclipse TPS has AAA (analytical anisotropic algorithm) algorithm, ISOgray TPS has CCC (collapse con convolution) algorithm, TiGRT and the CorePlan with convolution /superposition (CS) and ETAR (equivalent-tissue-air ratio) algorithms, respectively.

Table 1: Radiotherapy clinics and their details

Radiotherapy clinic/hospital	TPS/algorithm	Linac type	Energy(MV)
Omid Pars	TiGRT/convolution&superposition	Siemens	6/15
Asia hospital(Tehran)	TiGRT/convolution&superposition	Electa compact	6
Pars hospital(Tehran)	Corplan/ETAR	Varian	6/18
Fieoozgar hospital(Tehran)	Corplan/ETAR	Electa compact	6
Shohada Tajrish(Tehran)	Isogray(CCC)/Eclipse(AAA)	Electa compact	6/18
Fajr(Tehran)	Isogray/CCC	Varian	6
Shohada 7tir(Tehran)	Isogray/CCC	Electa compact	6/15
Mehrane(Zanjan)	Isogray/CCC	Siemens	6/18
Parsian(Shahrekord)	TiGRT/convolution&superposition	Siemens	6/15
Total	10 clinic		

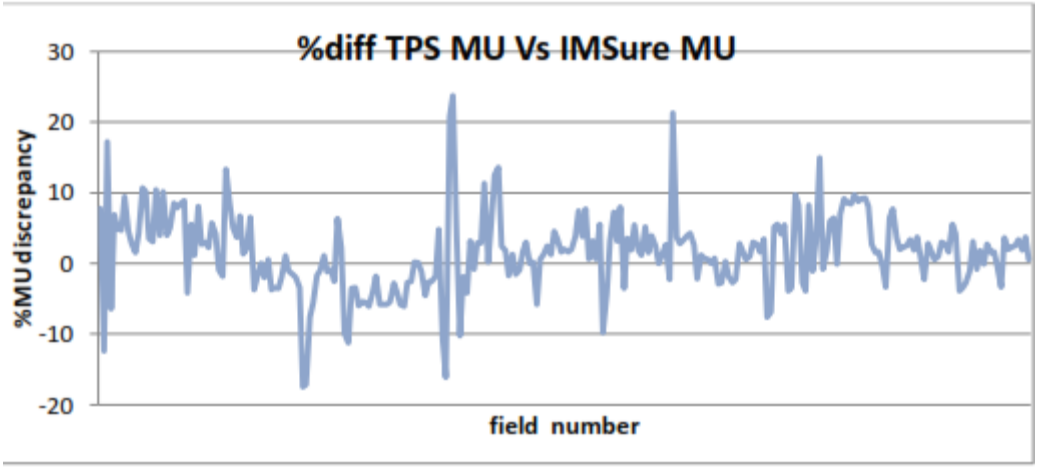


Figure 5: % differences between MU calculation of TPS and IMSure for 92 patient plans with 540 fields in ten radiotherapy clinics

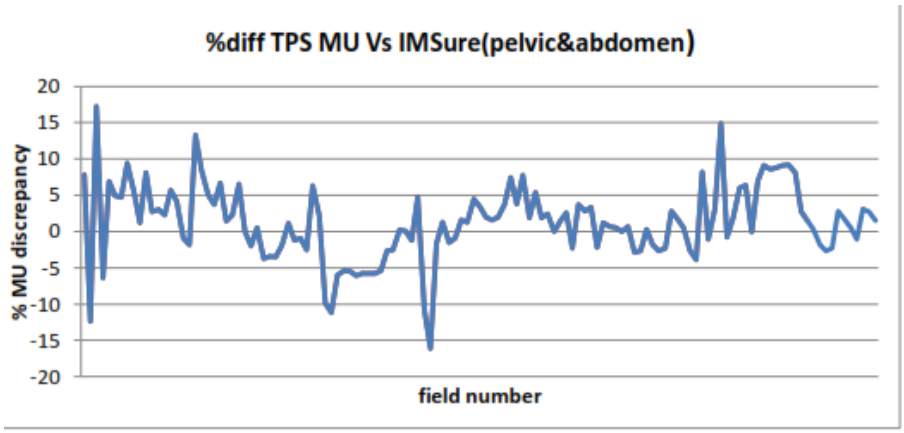
Table 2: Summary of results for different anatomical sites, for comparison between TPS and IMSure

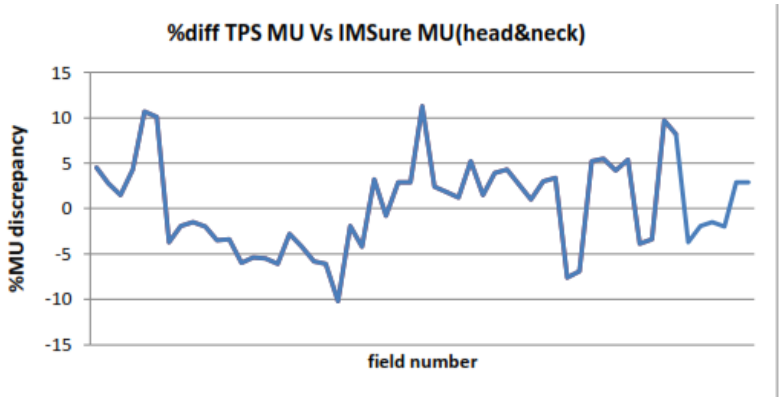
Site treatment	Number of plan	Minimum(%)	maximum(%)	Mean difference(%)	Standard deviation(%)
pelvic & abdomen	38	-16.1	17.2	1.3	5.32
Head & neck	22	-10.2	11.3	.52	5.22
Breast& chest	32	-17.5	23.7	2.49	7.33
total	92				

All of these algorithms are model-based except for ETAR that is correction-based. Analyses show that the mean difference between AAA algorithm and IMSure algorithm is 0.68% for MU calculations and 1.3% for overall dose. The difference between ETAR algorithm and IMSure is ~4% for MU and 2% for dose. This value for CS algorithm is obtained to be 0.15% for MU calculation and approximately zero for point dose. Finally, for CCC algorithm, the mean difference is 3% for MU calculation and 0.6% for point dose. It has to be mentioned that the number of cases for AAA and CCC algorithms were less than others.

Discussion

The aim of the present study was to verify TPS algorithms by using the capability of IMSure QA software. IMSure results showed good agreement with dose calculation in 48 points of interests. The minimum and maximum differences were both out of main radiation field. The maximum difference between TPS and IMSure was 28% that is related to oblique field of the test 4 in lung site. Pawlicki et al. used Monte Carlo simulations to verify





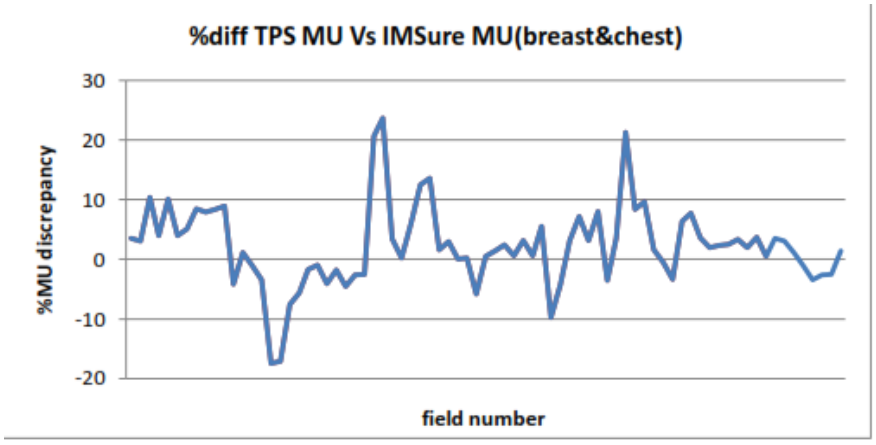


Figure 6: Difference of MU between TPS and IMSure calculation for a) 38 pelvic and abdomen plans b) 22 head and neck plans c) 32 breast and chest plans

dose calculation from a Corvus TPS for IMRT treatments. They found that the difference between Monte Carlo algorithm and TPS was 20% in the edge of the field in lung of a cancer patient [15]. Mata Colodro et al. validated 59 VMAT plans using Diamond software. All differences were located within a 2%. Only two cases showed deviations outside the range 3.5%. They found that incorrect selection of the reference point led to this result. So, the reference point was changed to a dose homogenous region inside PTV and deviation reach 2.5% [16]. Watanabe reported that the difference between TPS and MUV was within +/- 2% when calculation points were in a dose homogenous region. When calculation points are located in a region of high dose gradient; however, the difference could be greater than 5% [17]. Based on our analyses, differences are considerable when beam passed through a gross heterogeneity region such as air-soft tissue or air-bone interfaces. High density of tissues and absence of electron equilibrium cause these differences. AAPM has recommended that the reference point was selected in a homogenous region.

Our results are almost similar to the results of Xing et al. They verified five IMRT plans created by Corvus TPS using MUV program. The results show that differences were 4% and one case was more than 7% [18]. In a similar study, Haslam et al. have used RadCalc software to verify IMRT plans. They suggested criteria of 3% for accepting the verification of IMRT plans using RadCalc [6].

Anatomically based results show the greatest difference. The maximum difference between IMSure and TPS for MU calculation was 23.7% in the lung region. Air-soft tissue interfaces led to it. Haslem et al. suggested that the site-specific offset value might be essential for audit of the treatment planning systems due to electronic non-equilibrium condition in this and/or other similar conditions [6].

Elith et al. checked VMAT plans using two tools; namely, ArcCHECK phantom and IMSure QA software. VMAT plans had been created by Eclipse TPS using AAA algorithms. All cases were within 3% difference level between IMSure and Eclipse but three cases were out of this range. They also found that the VMAT verification took 3.5 min using IMSure plan QA software, and 31.5 min using ArcCHECK phantom [12]. Shahine B. et al had the research at British Columbia Cancer Agency (BCCA). They verified five-field IMRT treatment of prostate cancer by IMSure software. The difference of point dose calculations between IMSure and Eclipse (Varian Medical Systems, Palo Alto, CA) TPS was 1%. Therefore, they had been using IMSure software for routine QA of prostate IMRT treatment [15]. In other study, John Fan examined RapidArc plans with IMSure software. These plans consisted of abdomen and pelvic treatment sites. The results show that dose difference between Eclipse TPS and IMSure software was 2.5% on average [13]. Yoo et al. also verified 3D conformal breast cancer with use of IMSure. In this research, these plans were created by AAA and PBC algorithm (Eclipse TPS). The mean difference of dose calculations between IMSure and PBC algorithm was 3%. They obtained 5% dose difference between IMSure and AAA algorithm [16].

We also found that these differences depend on the calculation algorithm of TPS. Yoo et al. attained the same results when using IMSure QA software. Similarly, they suggested 3% difference criterion when TPS utilizes PBC algorithm. However, this difference criterion is about 5% in TPS using AAA algorithm [19]. In another study, Rana et al. verified VMAT plans that were created by Acuros XB algorithm by using IMSure software. They attained 5% difference level for verification of VMAT plans [20]. In the previous research at FVC, IMRT plans pencil beam convolution (PBC) algorithms were verified by IMSure software. The results showed that agreement between two

algorithms was 1% [21]. In current study, we checked 6 plans (20 fields) created by Eclipse TPS using AAA algorithms. The dose difference between IMSure and AAA algorithms was also about 1.3% and only for one case, it was 4.3%. From the point of MU calculation, this value was only 0.68%. IMSure calculated less MU than the AAA algorithm in 14 fields. Dunn et al. compared AAA algorithm calculations and measured audit doses. They reported that AAA algorithm calculated higher dose up to 3% than measured dose in CIRS phantom, when the measured point dose was located in heterogeneities such as lung [22]. In the same study, Kry SF et al. compared TPS algorithm calculations and measured dose in the thorax phantom. They concluded that AAA and CS algorithms overestimated the dose in heterogeneities such as lung [23].

Also in most fields, IMSure software calculated less MU than ETAR algorithm. ETAR algorithm is a correction-based algorithm but IMSure has a model-based algorithm. To explain this result, IMSure software considers three source scatterings to calculate MU/dose while ETAR algorithm uses correction coefficient for this. So, IMSure software obtains less MU/dose. Adversely, IMSure calculated more MU than CCC algorithm for half points. As to CS algorithm, we are not sure because the results were very various in all clinics, but, it could be said that in most clinics, IMSure calculated less MU than this algorithm.

In addition to the anatomical site and TPS algorithm, some errors could affect our results such as setup error, error in the commissioning process of the IMSure, calculation errors, etc.

Conclusion

The introduction of QA software provides a new option for improving accuracy and efficiency in the clinical practice of radiation therapy. Several international organizations have recommended using second algorithm for the verification of these plans. Our results also show that IMSure could be a suitable tool for patient-specific QA in modern radiotherapy clinics as a second check point. We also suggest a bigger criterion level for treatment plans with a more complicated condition and the criteria would depend on the calculation algorithm of TPS; however, the clinical judgment can be as effective as available equipment for delivering a precise treatment in clinics.

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Conflict of Interest

None

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