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Evaluation the effect of inhomogeneity correction algorithms on stereotactic body radiotherapy of lung tumors

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Abbreviations:
SBRT: stereotactic body radiation therapy, GTV: gross target volume, CTV: clinical target volume, PTV: planning target volume, RTOG: Radiation Therapy Oncology Group, NSCLC: non-small cell lung cancer, CT: computed tomography, MLC: multi leaf collimator, CI: Conformity Index, CN: Conformation Number, TPS: Treatment Planning System, Fast TMR (hetro.): Fast TMR algorithm with heterogeneity correction, Fast TMR (homo.)- Fast TMR algorithm with homogeneity, P+S (hetro.): Primary + Scatter algorithm with heterogeneity corrections, P+S (hom.): Primary + Scatter algorithm with homogeneity, DVH: Dose Volume Histogram, SSD: source surface distance, MU: monitor unit, ICF: Inhomogeneity correction factor

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Abstract
Purpose: The study was aimed to evaluate the impacts of different heterogeneity correction algorithms on dose distributions of SBRT for lung. *Materials and Methods:* twenty one patients with non-small cell lung cancer (NSCLC) included in the study. Plans were generated with nine beams (noncoplanar, non-opposing beams) with 6 MV X-ray optimized to deliver 95% of prescribed dose (60 Gy in three fractions) to100% of the volume of planning target volume, keeping the risk organs dose at tolerance limits. Two algorithms Fast TMR and Primary +Scatter with & without heterogeneity corrections were used. All factors, such as target volumes and beam arrangements identical in all plans for four groups were taken. *Results:* Our results have been showed that the superiority of the Fast TMR algorithm with heterogeneity correction in conformity, dose homogeneity, the lowest doses to healthy tissue and risk organs. Primary + Scatter algorithm with heterogeneity corrections has the superiority in lower treatment delivery and deviation between measurements and calculations dose than Fast TMR algorithm with heterogeneity correction. Two algorithms without heterogeneity correction are constituted a “major” protocol violation. *Conclusion:* Inhomogeneity corrections have a large influence on the dose delivered to the PTV and OARs for SBRT of lung tumors.

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1. Introduction

1.1 Inhomogeneity correction factor

The human body consists of a variety of tissues and cavities with various physical and radiological properties. Most significant between these, from a radiation dosimetry particular, are tissues and cavities that are radiologically various from water, including lungs, oral cavities, teeth, nasal cavities, sinuses and bones. The dose distribution is affected by these tissue inhomogeneities and since treatments are becoming increasingly conformal, the opportunity for geographic misses of the target due to incorrect isodose coverage increases. In view of the inconsistent use of inhomogeneity corrections is defined as dose in heterogeneus

medium/dose at same point in homogeneous medium, the recent advances in the dose calculation algorithms, the improved 3D image acquisition and display capabilities, and the trend towards dose escalation in smaller target volumes (Nikos Papanikolaou et al., 2004).

1.2 Lung cancer

Lung cancer is the second most common of cancer death in man and woman in United States. There were 221,200 new cases of lung cancer cases were expected to be diagnosed in the year 2015 with an estimated 158,040 Americans are expected to die from lung cancer, accounting for approximately 27 % of all cancer deaths(American Cancer Society, 2015). Seventy-five percent of patients with bronchogenic carcinoma will be diagnosed with non-small cell lung cancer (NSCLC). Approximately 15-20% of NSCLC patients present with early or localized disease. (RTOG 0236, 2009)

1.3 Stereotactic body radiation therapy (SBRT)

Stereotactic body radiation therapy (SBRT) usually used to NSCLC patients for peripheral tumors < 5 cm, delivered in few fractions (20 Gy /3 fractions) over 1.5-2 weeks with 2-8 days between fractions (Fakiris A.J. , 2009) .

1.4 Justification of Research

The lungs are histologically heterogeneous organs composed of large amounts of air and soft tissues. Therefore, different heterogeneity corrections can cause changes in the dose distributions in treatment planning systems. All previous studies did not address the impact of heterogeneity corrections on radiological depth and thus the effect on change of the total doses which deliver to the tumor, healthy tissues and the risk organs. This work aimed to study the impact of heterogeneity corrections on radiological depth and prescribed dose to lung tumor and also, the impact of different algorithms have different accuracies in dose calculations with heterogeneity corrections in lung treatments.

2. Material and Methods

2.1 Objective of research

In SBRT were used high-dose confirms that this highly focused, rigidly delivered, and tightly controlled radiation approach results in excellent local control and minimal toxicity in most patients with medically inoperable. We decided early on to stick with one form of delivery and be very conservative in order to understand how SBRT worked, not only from a cancer point of view but also from a safety point of view, because these patients are relatively fragile, therefore the purpose of this study is to assess the real target dose coverage when radiation treatments were delivered to lung cancer patients based on treatment planning according to the RTOG Protocol. Calculated dosimetric results between the two algorithms for stereotactic body radiation therapy treatment planning in lung cancer were compared.

This work is divided into two main parts, patients study and phantom study.

2.2 Patients study

Twenty one patients with early stage I / II NSCLC were planned with SBRT at the department of radiation oncology at "Ayadi-Almostakbal Center" in Alexandria. The study indicated 15 male and 6 female and the group average age 66 years (range 55 to 83 years). The target volumes ranged from 2.25 to 61.25 CC**.** Patients were simulated using computed tomography (CT) (Siemens SOMATOME) while fixed in vacuum matters to be comfortable, secure and reproducible. Scan was made with 2-mm slice thickness. The data of the patients with primary lung tumors who underwent SBRT between March 2013 and February 2014 were used.

2.3 Planning System

Once the imaging is complete, data is transferred to the Xknife Treatment Planning System (TPS).gross target volume(GTV) were created where GTV is typically assumed to be the clinical target volume (CTV), PTV were created by adding 5-mm margins to the GTVs in all directions. A 5-mm margin was uniformly added to the PTVs to create the shape of the multi leaf collimator (MLC) for each port. Organs at risk were delineated on an average-density CT reconstruction. Plans were generated with nine beams (noncoplanar, non-opposing beams) with 6 MV X-ray optimized to deliver 95% of prescribed dose (60 Gy in three fractions) to100% of the volume of planning target volume (PTV), organ tolerance dose limits in Table 1 (RTOG 0236, 2009).

Table 1: Organ tolerance dose limits according to the Radiation Therapy Oncology Group (RTOG) 0236

Organ	**Volume**	**Total Dose**
Spinal cord	Any point	18 Gy maximum
Esophagus	Any point	27 Gy maximum
Heart	Any point	30 Gy maximum
Trachea	Any point	30 Gy maximum
Whole lung (Right& Left)	<10% of volume	20 Gy

Exceeding organ limits by more than 2.5% constituted a "minor" protocol violation. Exceeding these organ limits by more than 5% constituted a "major" protocol violation.

Start Calculate the dose distributions with Fast TMR (hetro.) algorithm then recalculated this plan with the same algorithm but without heterogeneity correction. The same with done using the P+S algorithm by recalculating previously optimized treatment plans with and without heterogeneity correction. Keeping all factors such as target volumes (GTV and PTV) and beam arrangements (e.g. coordinates of the isocenter , gantry and couch angles, field size, field fluencies, prescription dose etc.) were comparable.

Our study showed that Conformity has been described using both:

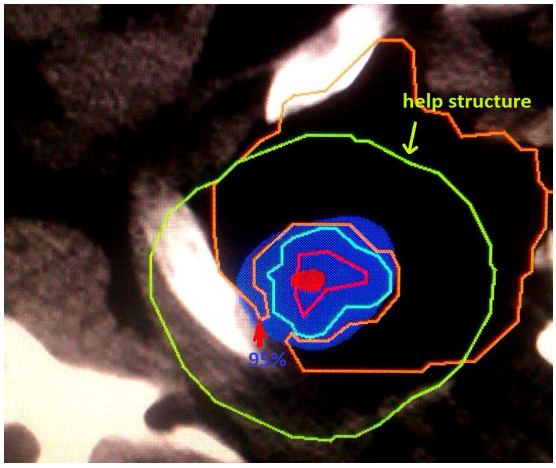
1. Conformity $Index_{RTOG}$ (CI) has been reported to describe the conformity of the prescription isodose to the target volume as shown in equation: CI = V_{RI} / TV
2. Conformation Number (CN) takes into account irradiation of the target volume and irradiation of healthy tissues as shown in equation CN= TV_{RI} / TV X TV_{RI} /V_{RI}

Where: RI: Reference isodose, TV: Target volume, TV_{RI}: Target volume covered by the reference isodose and V_{RI}: Volume of the reference isodose.

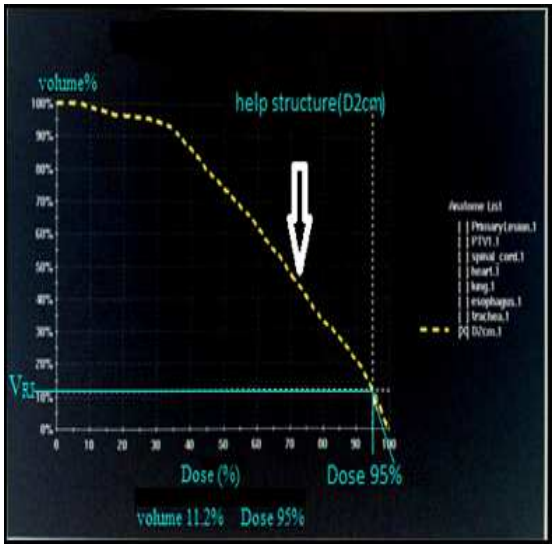
In our study we faced a major problem in the calculation of the CN because the soft ware don't support all the parameters required to calculate the CN where V_{RI} (Volume of the reference isodose). This problem has been overcome manually by calculation of the V_{RI} from help structure delineated with 2 cm around of the volume of PTV. As example to calculate V_{RI} (assume 95% isodose line is the reference isodose) represented in figure (1.a) and from DVH (Dose Volume Histogram) in Figure (1.b). The intersection of the help structure with 95% dose represents the V_{RI} as illustrated in Figure 1 (Loïc feuvret et al., 2006. Shaw E. et al.,1993. Van't R. iet A. et al., 1997).

Figure 1: (a) and (b) Graphs illustrate the method of calculation of the V_{RI}.

(a) An example for relative isodose 95% and help structure.



(b) Extraction the V_{RI} Using the DVH of the help structure (D2cm)



In addition, recorded of the monitor units (Mu) of each treatment plan gave us a reasonable data to estimate the treatment delivery time.

2.4 Phantom study

Finaly, EasyBody Phantom used to measured absolute doses for different plans by used Farmer-type ionization chamber PTW30013 which was positioned in the middle of the phantom with air cavity(as lung) as illustrated in Figure 2. It was scanned with CT simulator (SOMATOM, Siemens). CT images of the phantom were transferred to TPS. The chamber was connected with UNIDOS electrometer (PTW, Freiburg) and it was employed for the phantom measurements of the types of algorithms by the linear accelerator (Artiste, Siemens) .The chamber and electrometer have a calibration from Egypt National Institute of calibration. Pressure and temperature were measured for each measurement.

Figure 2: The EasyBody phantom measurements by the linear accelerator (Artiste,Siemens)

2.4 Statistical analysis

For normally distributed data, comparison between more than two independent population were done using F-test (ANOVA) to be used and Post Hoc test (LSD), while for abnormally distributed data Kruskal Wallis test was used to compare between different groups and Mann-Whitney Test was assessed for pair-wise comparisons. The level of statistical significance was considered $p < 0.05$ for all calculation; therefore, a 95% confidence interval was applied (Kotz S., 2006. Kirkpatrick L.A., 2013).

3. Results

3.1 Comparison for PTV

The mean ± SD of PTV was 38.55±26.935 (range 6.62 cc to 102.5 cc). Table 2 are shown the minimum doses, doses inhomogeneity(the difference between the maximum and minimum dose) , maximum doses and average doses of PTV for all patients derived from four treatment plans used two algorithms with and without heterogeneity corrections. Fast TMR (hetro.) is the lowest to the dose inhomogeneity, P + S (hetro.) the next and after that P + S (homo.) followed by Fast TMR (homo.) they were (5.63%± 1.58%, 5.7%±1.78%, 8.23%±2.04% and10.24%±2.99%) respectively.

Table 2: The mean ± SD of doses (%) delivered to different volumes of PTV to comparison between the types of algorithms

	Fast TMR		Primary + Scatter	
	Homo. (n = 21)	Hetro. (n = 21)	Homo. (n = 21)	Hetro. (n = 21)
Min. Dose	92.07%±1.13%	93.74%±0.87%	92.79%±0.89%	93.72%±0.77%
Max. Dose	102.33%±2.32%	99.4%±1.07%	101.02%±1.74%	99.41%±1.52%
Dose Inhomo.	10.24%±2.99%	5.63%±1.58%	8.23%±2.04%	5.7%±1.78%
Average Dose	97.49%±1.22%	96.91%±0.71%	97.26%±1.11%	96.89%±0.9%

With regards to the Table 3 of PTV the differences were significant higher in two algorithms with than without heterogeneity corrections *(P <0.001).*

Table 3: Comparison between the different types of algorithms according to PTV

	Fast TMR		Primary + Scatter		F	p
PTV	Homo (n = 21)	Hetro (n = 21)	Homo (n = 21)	Hetro (n = 21)		
Min. – Max.	91.0 – 94.50	95.0 – 96.60	92.20– 95.40	94.80– 97.30		
Mean ± SD.	93.30 ± 1.07	95.39 ± 0.39	93.99 ± 0.85	95.46 ± 0.58	40.325*	<0.001*
Median	93.50	95.30	94.0	95.30		
p_1		<0.001*	0.005*	<0.001*		
p_2			<0.001*	0.764		
p_3				<0.001*		

F: F test (ANOVA), P1: p value for Post Hoc test (LSD) for comparing between Fast TMR (homo.) and each other group

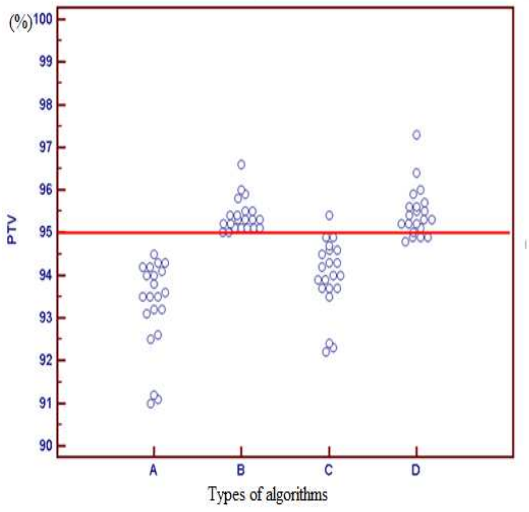
p_2: p value for Post Hoc test (LSD) for comparing between Fast TMR (hetro.) and P + S (homo. and hetro.)

p_3: p value for Post Hoc test (LSD) for comparing between P + S (homo. and hetro.)

*: Statistically significant at $p \leq 0.05$

In Figure 3 the results were showed all cases were optimized such that 100% of the volume of the PTV received > 95% of the prescribed dose when used algorithm of Fast TMR (hetro.) but when used the same algorithm without heterogeneity correction all cases not covered with 95%.In addition to this, when used algorithm of P + S (hetro.) all cases covered with > 95% excepted four cases and when used the same algorithm without heterogeneity correction all cases not covered with 95% excepted one case.

Figure 3: Comparison between the types of algorithms according to PTV (100% of the volume covered with 95% of the prescribed dose) in 21 patients



3.2 Conformity Indices

With regards to the results in tables 4 and 5 of CI and CN the differences were significant in Fast TMR algorithm with and without heterogeneity corrections *(P =0.002, P <0.001)* respectively and in Primary + Scatter algorithm with and without heterogeneity corrections (P =0.03, P =0.001,).Also, the differences were not significant between two algorithms with and without heterogeneity. Figure 4 shows in the Fast TMR (hetro.) all cases of the conformity index is situated between 1 and 2, treatment is considered to comply with the treatment plan and in the P+ S (hetro.) all cases of the conformity index is situated between 1 and 2 excepted 1 case the index between 2 and 2.5, the protocol violation is considered to be minor but when used two algorithms without heterogeneity corrections all cases of the conformity index is situated between 1 and 2 excepted 6 cases,four cases the index between 2 and 2.5, the protocol violation is considered to be minor and two cases the index exceeds 2.5, the protocol violation is considered to be major (loïc feuvret et al.,2006.). The CN ranges from 0 to 1, where 1 is the ideal value and value 0 indicates either total absence of conformation. From the Table 4 the mean value of Fast TMR (hetro.) is the nearest value of one (ideal value) then the Fast TMR(hetro.) is the highest Conformation Number, (P+S(hetro.)) is the next and after P + S (homo.) , followed by Fast TMR (homo.) 0.71 ± 0.09, 0.70 ± 0.11, 0.60 ± 0.10, 0.58 ± 0.10 respectively.

Figure 4: Comparison between the different studied groups according to CI

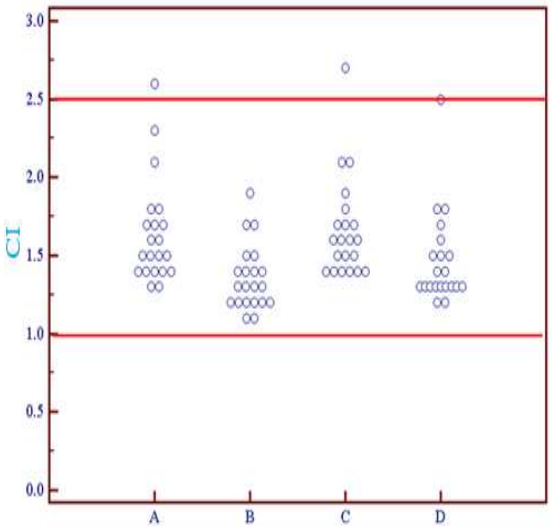


Table 4: Comparison between the types of algorithms according to CI:

CI	Fast TMR		Primary + Scatter		F	p
	Homo (n = 21)	Hetro (n = 21)	Homo (n = 21)	Hetro (n = 21)		
Min. – Max.	1.30 – 2.60	1.10 – 1.90	1.40 – 2.70	1.20 – 2.50		
Mean ± SD.	1.64 ± 0.33	1.36 ± 0.21	1.67 ± 0.32	1.47 ± 0.30	5.284*	<0.002*
Median	1.50	1.30	1.60	1.30		
p_1		<0.002*	0.794	0.056		
p_2			0.001*	0.231		
p_3				0.030*		

Table 5: Comparison between the types of algorithms according to C.N:

CN	Fast TMR		Primary + Scatter		F	p
	Homo (n = 21)	Hetro (n = 21)	Homo (n = 21)	Hetro (n = 21)		
Min. – Max.	0.37 – 0.76	0.52 – 0.82	0.37 – 0.75	0.40 – 0.83		
Mean ± SD.	0.58 ± 0.10	0.71 ± 0.09	0.60 ± 0.10	0.70 ± 0.11	9.384*	<0.001*
Median	0.60	0.74	0.61	0.73		
p_1		<0.001*	0.597	<0.001*		
p_2			0.001*	0.767		
p_3				0.001*		

F: F test (ANOVA)

p_1: p value for Post Hoc test (LSD) for comparing between Fast TMR Homo and each other group

p_2: p value for Post Hoc test (LSD) for comparing between Fast TMR Hetro and Primary + Scatter

p_3: p value for Post Hoc test (LSD) for comparing between Primary + Scatter Homo and Hetro

*: Statistically significant at $p \leq 0.05$

3.3 Comparisons for the OAR

Figures 5, 6, 7 shows the doses comparison between the types of algorithms to the organs at risk (spinal cord, esophagus and heart) all the values not significant but these differences between there types clinically significant because the Fast TMR (hetero.) is the only one which organs not exceeding the limits but another types there are

cases take over doses based on RTOG 0236.In Fast TMR (homo.) there are 4 cases exceeding the spinal cord limits 2 cases more than 2.5% and 2 cases more than 5%. In heart there are 4 cases one case more than 2.5% and 3 cases more than 5%. In esophagus there is one case more than 5%. In the P + S (hetero.) there are one case exceeding in spinal cord limits more than 5%. In heart there are one case more than 5%. In esophagus there isn't any case exceeding in organ limits. In the P + S (homo.) there are four cases exceeding in spinal cord limits more than 5%. In heart there are three cases one case more than 2.5% and 2 cases more than 5%. In esophagus there is one case exceeding in organ limits more than 5%.

Figure 5: Comparison between the types of algorithms according to Spinal cord (maximum limit dose 18Gy)

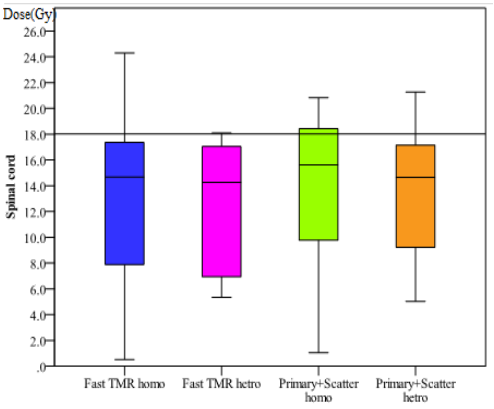
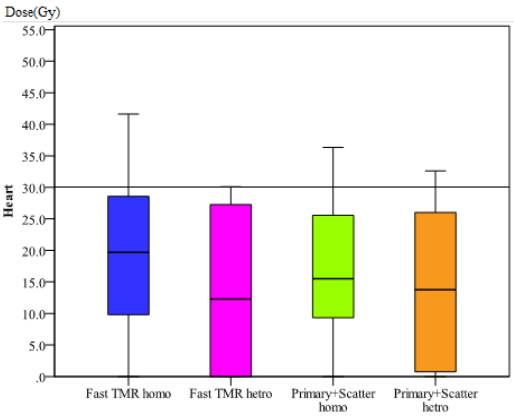


Figure 6: Comparison between the types of algorithms according to Esophagus (maximum limit dose 27Gy)



died
Gy)

Figure 8 shows all types not exceeding the limit and the values not significant of trachea. In particular, the results of the lung the differences were significant lower in Fast TMR algorithm with than without heterogeneity corrections (P <0.004) and in P + S algorithm with than without heterogeneity corrections (P =0.028).Also, the differences were not significant between two algorithms with and without heterogeneity corrections.

Figure 7: Comparison between the types of algorithms according to Trachea (maximum limits dose 30Gy)

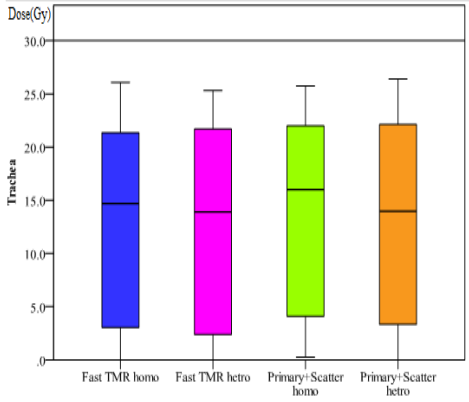


Figure 8: shows the Fast TMR (hetro.) not exceeding limits in lung and the same algorithm without heterogeneity there are 7 cases exceeding in lung limits one cases more than 2.5% and 6 cases more than 5%. The P + S (hetro.) not exceeding in lung limits and the same algorithm without heterogeneity corrections there are 6 cases exceeding more than 5 %.

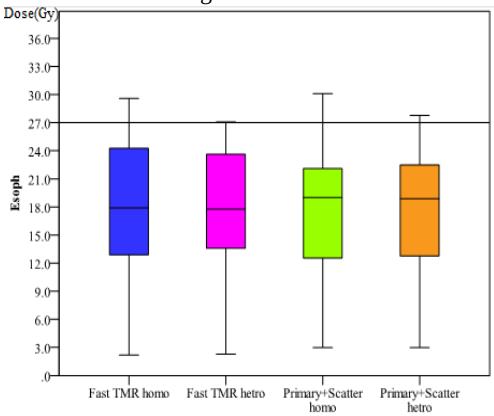
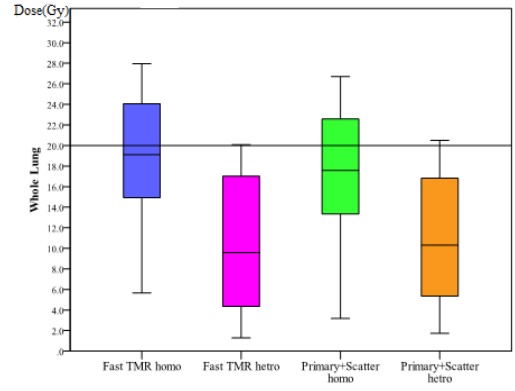


Figure 9: Comparison between the types of algorithms according to Whole Lung (10% of the volume not exceeds



3.4 Estimation of treatment delivery time

The results in Table (6) showed the differences were significant lower between the Fast TMR algorithm with than without heterogeneity corrections (P<0.001) and in Primary + Scatter algorithm with than without heterogeneity corrections (P = 0.001).Also, the differences were

not significant between two algorithms with heterogeneity corrections (P=0.18) and significant between two algorithms without heterogeneity corrections (P<0.001). In addition, from table 5 the P+S (hetero.) algorithm is the lowest estimated time, the next Fast TMR (hetero.) algorithm and after that P + S (homo.) algorithm followed by Fast TMR (homo.) algorithm (31.05 ± 2.17, 32.79 ± 5.51, 35.60 ± 2.88, 40.99 ± 5.12).

Table 6: Comparison between the types of algorithms according to Mu's

	Fast TMR		Primary + Scatter		F	p
Mu's required ($\times 10^2$)	Homo (n = 21)	Hetro (n = 21)	Homo (n = 21)	Hetro (n = 21)		
Min. – Max.	34.31– 56.0	18.73 – 39.33	31.23 – 43.38	26.55 – 34.20		
Mean ± SD.	40.99 ± 5.12	32.79 ± 5.51	35.60 ± 2.88	31.05 ± 2.17	22.734*	<0.001*
Median	40.17	34.29	35.22	31.27		
p_1		<0.001*	<0.001*	<0.001*		
p_2			0.032*	0.180		
p_3				0.001*		

F: F test (ANOVA), P1: p value for Post Hoc test (LSD) for comparing between Fast TMR (homo.) and each other group

p_2: p value for Post Hoc test (LSD) for comparing between Fast TMR (hetro.) and P + S (homo. and hetro.)

p_3: p value for Post Hoc test (LSD) for comparing between P + S (homo. and hetro.)

*: Statistically significant at $p \leq 0.05$

3.5 Phantom Study

The maximum errors between measured and calculated doses for different plans are presented in Table 7. the Primary + Scatter algorithm with heterogeneity corrections is the lowest deviation between measurements and calculations, the next Fast TMR algorithm with heterogeneity corrections and after that Primary + Scatter algorithm without heterogeneity corrections followed by Fast TMR algorithm without heterogeneity corrections (1.3%, 2.3%, 14.45%, and 20.9%) respectively.

Table 7: Comparison between the types of algorithms according to maximum errors between measured and calculation

Comparison between two algorithms	Fast TMR		Primary + Scatter	
	Homo.	Hetro.	Homo.	Hetro.
Max. Error between measured and calculation in air cavity (lung) when it is in field.	20.9%	2.3%	14.45%	1.3%

4. Discussion

The goal of SBRT planning is to deliver the maximum dose to the tumor and the minimum dose to the healthy tissues and the risk organs. With regards to the results of PTV the differences were significant higher in two algorithms with than without heterogeneity corrections (P <0.001) in addition to this, there are all cases under doses (<95%) to PTV when used Fast TMR and P + S algorithms without heterogeneity corrections except one case and this means that isodose not cover all of the clinical and pathologic target volume, it is considered to be major (RTOG 0236, 2009.). As clear that, Fast TMR (hetro.) algorithm is the highest to the cover of PTV with 95% of the doses, P+ S (hetro.) algorithm the next and after that P + S (homo.) algorithm followed by Fast TMR (homo.) algorithm. These results are in compliance with (Tania et al., 2010.). The results of CI and C.N refer to the differences were significant in two algorithms with than without heterogeneity corrections only and Fast TMR (hetro.) is the best in Conformity $Index_{RTOG}$ and the Conformation Number this mean it is the more coverage to the target volume and the lowest doses to healthy tissues and this is the important aspects of plan quality(Van't R iet A, et al., 1997), P+S(hetro.) with the next and after that P+S(homo.) followed by Fast TMR(homo.).

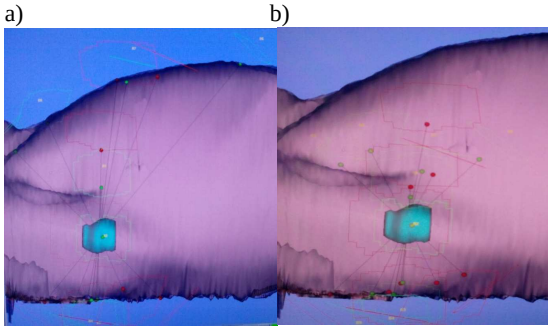
Based on RTOG 0236 the exceeding limits of organs by more than 2.5% constituted a "minor" protocol violation and exceeding these organ limits by more than 5% constituted a "major" protocol violation are shown in table(1). In our study, Fast TMR (hetro.) not exceeding limits in spinal cord, heart, trachea, esophagus and whole lung but the same algorithm without heterogeneity corrections all organs at risk (spinal cord 2cases minor and 2 cases major protocol violation, heart one case minor and three major protocol violation, esophagus one case major protocol violations, whole lung one case minor and 6 cases major protocol violation) exceeding the limit excepted in trachea(not exceeding the limit) . In P+ S (hetro.) not exceeding limits in trachea, esophagus and whole lung but in spinal cord and heart there are

one case major protocol violation. In the same algorithm without heterogeneity corrections all organs at risk (spinal cord 4 cases major protocol violation, heart one case minor and 2 major protocol violation, esophagus one case major protocol violations, whole lung 6 cases major protocol violation) exceeding the limit excepted in trachea (not exceeding the limit) .it is clear, the two algorithms with heterogeneity corrections keep the organs at risk save from the over doses. These results are in compliance with (Chang D.T. et al., 2006 and Ding M., 2005).

In addition, the results showed the percentage differences in the mean of monitor units between the Fast TMR algorithm with and without heterogeneity corrections 25%, Primary + Scatter algorithm with and without heterogeneity corrections 14.7%, two algorithms with heterogeneity corrections 5.6% and two algorithms without heterogeneity corrections 15.1%. This results refer to high difference in monitor units when use algorithm with and without heterogeneity corrections and also between two algorithms without heterogeneity corrections.
In phantom study, the deviation between two algorithms with heterogeneity correction is 1% and the deviation between two algorithms without heterogeneity correction is 6.45 %. The deviation between the algorithm Fast TMR with and without heterogeneity correction is 18.6%.Also; the deviation between the P + S algorithm with and without heterogeneity correction is 13.15%.These results are in compliance with (Chang et al., 2007 and Kong et al., 2006.*)*.
In addition, there are different in source surface distance (SSD) in algorithm with and without heterogeneity (7.5%) and this explains the large difference in monitor units and deviation between measurements and calculations whereas In homogeneous depth mode was calculates geometric depth and does not consider variations in tissue density. In this mode, XKnife considers all pixels to have the same density as water and all the tissue is assumed to have a water equivalent depth (density = 1.0). In heterogeneous depth mode (also called radiological depth), the tissue density is considered along each step of the ray-trace and considers the variations in tissue density. In this mode, XKnife scales each pixel along the line by its density and sums the results. For beams which traverse bony tissue (density ~1.6 g/cm3), this can increase the depth. For beams which traverse lung tissue (density ~0.3 g/cm3), this can decrease the depth. Since the dose is a function of depth, this can have a significant effect on the MU and therefore the treatment delivery time.

Figure 9: The effect of heterogeneity correction on SDD of fields

a) b)



a) Arrangement of fields without corrections

b) Arrangement of fields with heterogeneity Heterogeneity corrections

The results of the present study indicate that different between algorithm with and without heterogeneity corrections have a marked impact on the dose distributions around the targets, dose homogeneity, conformity index, conformation number (target and healthy tissue), risk organs, estimation of treatment delivery and deviation between measurements and calculations dose.

Conclusion

Heterogeneity correction of algorithm is important aspects on dose distributions and plan quality of SBRT for lung tumors. Our results showed the superiority of the Fast TMR algorithm with heterogeneity correction in conformity, dose homogeneity, the lowest doses to healthy tissue and risk organs. Primary + Scatter algorithm with heterogeneity corrections has the superiority in lower treatment delivery and deviation between measurements and calculations dose than Fast TMR algorithm with heterogeneity correction. Two algorithms without heterogeneity correction are constituted a “major” protocol violation.

Research Highlights

This study highlights the importance of using heterogeneity correction algorithms on SBRT of lung tumors. In case of non-use of heterogeneity correction leads to increased radiation dose to the tumor about the prescribed dose by up to 25 % and thus increase total doses which deliver to healthy tissues and the risk organs and this is because when beams which traverse lung tissue (density ~0.3 g/cm3), this can decrease the depth by up to 7.5%. Since the dose is a function of depth, this can have a significant effect on the MU and therefore the treatment delivery time and prescribed dose. In addition, the present study was performed in order to evaluate the impacts of different heterogeneity correction algorithms on dose distributions of SBRT for lung tumors. Ideally, treatment plans with heterogeneity corrections would predict more accurate dose distributions, compared to those

without heterogeneity corrections. However, the prediction relies on the accuracy of dose calculation algorithms. Studies have shown that different algorithms have different accuracies in dose calculations with heterogeneity corrections in lung treatments.

Authors' Contribution and Competing Interests

The authors declare that they have no competing interests.

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