Automated Biological Dose Conversion with Predictive OAR Tolerances

B. MORRIS [1], S. PETRO [1], K. LAI [1], L. RIGSBY [1], V. COFFMAN [1], and S. HEDRICK [1]

[1]Provision Cares Proton Therapy Center - Knoxville

INTRODUCTION

Due to the push towards hypofractionation and the prevalence of retreatment in radiation oncology, biological dose conversion has become necessary and more frequent. Performing these conversions needs to be accurate and efficient to facilitate safe treatment and prevent delays. We developed a set of tools to perform automated biological dose conversion for planning and intercomparison of dose schemes.

AIM

The work increases the reliability and efficiency of creating biological dose conversions. Biological dose conversion is often required due to the prevalence of hypofractionated dose schemes, combined with the increased frequency of re-irradiation treatments. Re-irradiation requires knowledge of the previously delivered dose so that composite dose distributions can be evaluated. Biologically equivalent dose (BED) and equivalent dose in 2 Gy fractions (EQD2) are relatively straight-forward to produce yet combining multiple courses with multiple phases can be time consuming and error prone. Additional utility of BED and EQD2 comes from the ability to use these calculations to compare dose fractionation schemes and to predict the dose tolerances of tissues previously irradiated. We developed a set of tools that help in the creation of biological dose conversions and can speed the planning process and reduce potential errors. The tools have been clinically implemented in our physics department, and we believe could benefit other departments.

METHODS

A spreadsheet was designed that automatically calculates BED and EQD2 for multiple dose schemes and phases. These calculations can be used to compare dose schemes and/or convert dose distributions to the desired regimen. One tool also estimates the adjusted dose tolerances with a given fractionation scheme that correspond to the conventional fractionation tolerances. The estimates allow the planner to create hypo- or hyper-fractionation objectives that will result in conventional tolerances being met after the final plan dose is converted to EQD2. If prior dose has been delivered, the user is provided an estimate of the remaining dose tolerance under the specified fractionation scheme.

RESULTS

Tool #1

SCHEME 1

	Physical Dose		BED		EQD2		# Fractions for EQD2 Scaling	
	Dose (Gy)/Fxn	#Fxns	a/b=10	a/b=3	a/b=10	a/b=3	a/b=10	a/b=3
Phase 1	2.0	25.0	2.4	3.3	2.0	2.0		
Total Dose (Gy)	50.0		60.0	83.3	50.0	50.0	25.0	25.0
Phase 2	2.0	5.0	2.4	3.3	2.0	2.0		
Total Dose (Gy)	10.0		12.0	16.7	10.0	10.0	5.0	5.0
Phase 3	2.0	5.0	2.4	3.3	2.0	2.0		
Total Dose (Gy)	10.0		12.0	16.7	10.0	10.0	5.0	5.0
Composite (Gy)	70.0		84.0	116.7	70.0	70.0		

SCHEME 2

	Physical Dose		BED		EQD2		# Fractions for EQD2 Scaling		# Fractions for Scheme1 Scaling	
	Dose (Gy)/Fxn	#Fxns	a/b=10	a/b=3	a/b=10	a/b=3	a/b=10	a/b=3	a/b=10	a/b=3
Phase 1	2.5	18.0	3.1	4.6	2.6	2.8				
Total Dose (Gy)	45.0		56.3	82.5	46.9	49.5	18.8	19.8	23.4	24.8
Phase 2	2.5	4.0	3.1	4.6	2.6	2.8				
Total Dose (Gy)	10.0		12.5	18.3	10.4	11.0	4.2	4.4	5.2	5.5
Phase 3	2.5	4.0	3.1	4.6	2.6	2.8				
Total Dose (Gy)	10.0		12.5	18.3	10.4	11.0	4.2	4.4	5.2	5.5
Composite (Gy)	65.0		81.3	119.2	67.7	71.5				

Tool #2

EQD2 for Normal Tissues

Rx	Physical Dose		BED		EQD2	
	Dose (Gy)/Fxn	#Fxns	a/b=10	a/b=3	a/b=10	a/b=3
Previous Scheme	2.0	25.0	2.4	3.3	2.0	2.0
Total Dose (Gy)	50.0		60.0	83.3	50.0	50.0
Current Scheme	2.5	15.0	3.1	4.6	2.6	2.8
Total Dose (Gy)	37.5		46.9	68.8	39.1	41.3

EQD2 for Normal Tissues

Tissue	Previous Max Dose (Gy)	α/β	BED of Previous Dose	EQD2 of Prior Dose	Current Max Dose (Gy)	BED of Current Dose	EQD2 of Current Dose*	Total EQD2 Dose
Spinal Cord	35	2	59.5	29.8	18	28.8	14.4	44.2
Brainstem	30	3	42.0	25.2	23	34.8	20.9	46.1
		3	0.0	0.0		0.0	0.0	0.0
		3	0.0	0.0		0.0	0.0	0.0
		3	0.0	0.0		0.0	0.0	0.0
		3	0.0	0.0		0.0	0.0	0.0
		3	0.0	0.0		0.0	0.0	0.0
		3	0.0	0.0		0.0	0.0	0.0
		3	0.0	0.0		0.0	0.0	0.0
		3	0.0	0.0		0.0	0.0	0.0

Tool #3

Tissue Tolerance Estimator

	Physical Dose		BED		EQD2	
	Dose (Gy)/Fxn	#Fxns	a/b=10	a/b=3	a/b=10	a/b=3
Phase 1	10.0	5.0	20.0	43.3	16.7	26.0
Total Dose (Gy)	50.0		100.0	216.7	83.3	130.0

Normal Tissue BED Adjusted Tolerances   a/b= 3

(Calculation is conservative assuming 2Gy per fraction delivered in the conventional dose tolerance)	Conv Tolerance	BED	Adjusted Dose Tolerance*	Prior Physical Dose	BED of Difference	Adjusted Remaining Dose Tolerance*
Small Bowel	55	91.7	21.2	20	58.3	13.5
Small Bowel (D30%)	45	75.0	17.3			
Large Bowel	55	91.7	21.2			
Large Bowel (D30%)	45	75.0	17.3			
Stomach	55	91.7	21.2			
Stomach (D30%)	45	75.0	17.3			
Liver (mean)	30	50.0	11.5			
Kidneys (mean)	18	30.0	6.9			
Spinal Cord	45	75.0	17.3			

$$\text{Tolerance Dose} = \frac{BED}{\left(1 + \frac{d}{a/b}\right)}$$

d= Rx dose per fraction

*These dose tolerances are calculated estimates only and not designed to replace standardized Quantec, RTOG, or other published tolerances

Tool #1: Allows the user to compare two fractionation schemes with up to 3 phases each. The user can also instantly identify the BED and EQD2 for each scheme with a chosen a/b ratio. Finally, the fractionation from Scheme 2 can be used to scale a dose distribution to EQD2 (figure 1) or the fractionation of Scheme 1.

Tool #2: The user can combine previous EQD2 converted doses with current EQD2 converted doses with selectable a/b ratio to find the maximum potential total max dose for all treatments.

Tool #3: The Tissue Tolerance Estimator can aid the planning team in predicting the dose limitations of certain tissues when delivering a non-conventional fractionation. The tool can also be used if prior dose has been delivered.
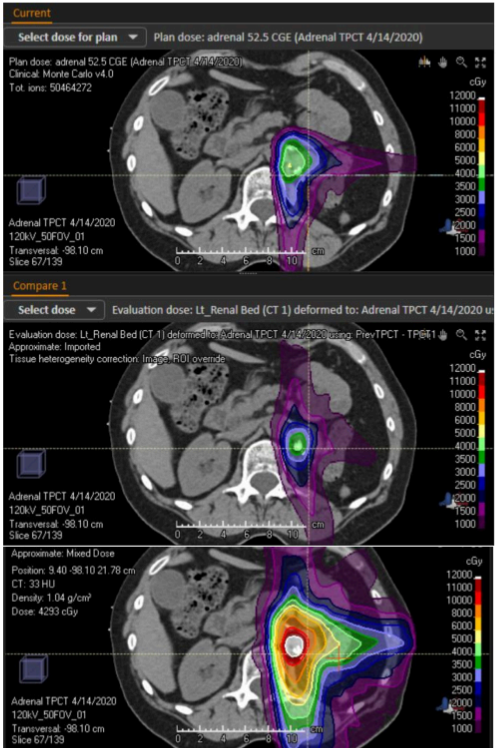

Figure 1. Example dose distributions for current tx plan (above), previous tx plan (middle), and scaled and converted composite EQD2 dose, generated from Tool #1 (below).

RESULT (cont)

On average, the time required for biological dose conversions was reduced by 38%. No mistakes were found upon review of the calculations generated by the spreadsheet, compared with one mistake found in the manually calculated dose conversions.

Table 1. Preliminary comparison results for dose conversion work done with and without the automated conversion tools.

	Manual	Automated
Calculations Performed	20	8
Average Time for Conversion (min)	15.9	9.9
Number of Mistakes	1	0

CONCLUSIONS

The biological dose conversion tools are offer efficient and reliable methods for calculating a wide range of doses. They were implemented as the standard dose conversion modality for our clinic. The tools decreased the average time required to derive converted doses and empowered the dosimetry team to confidently plan with accurate optimization objectives across various dose regimens. In the future, we will build a GUI interface which will also allow the user to convert dose distributions to BED or EQD2 on a voxel-by-voxel basis.

ACKNOWLEDGEMENTS

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CONTACT INFORMATION

Bart Morris, bart.morris@provisionproton.com