

Improving Efficiency of Liver SBRT Planning using Eclipse Scripting

Authors: Zackary Morelli¹, Per H. Halvorsen¹, Ileana Iftimia^{1,2}

¹Radiation Oncology Department, Beth Israel-Lahey Health, Burlington, MA

²Tufts University School of Medicine, Boston, MA

Purpose

- Planning for liver SBRT cases following an Institutional Review Board (IRB) approved protocol can be time and labor intensive, so we embarked on a project to improve the efficiency of the planning process
- In addition to organs at risk DVH criteria, the protocol contains criteria for maximum liver effective volume (V_{eff}) and Normal Tissue Complication Probability (NTCP) for Radiation Induced Liver Disease (RILD). If these are not met, the Rx dose will be reduced per the Radiation Oncologist's decision (range per protocol: 27.5 – 50 Gy)
- To keep the Rx dose at 50 Gy we aim for liver $V_{eff} < 25\%$ of total volume and NTCP $< 10\%$
- A script was generated for this purpose to increase the efficiency of liver SBRT plan quality evaluation by computing V_{eff} and NTCP in real-time

Methods

- A plug-in script was written in C# using Microsoft Visual Studio Community Edition 2019, a popular Integrated Development Environment (IDE) for Windows-based software development
- The script is able to run in the Eclipse Treatment Planning System (Varian Medical Systems) by using Varian's Eclipse Scripting Application Interface (ESAPI). ESAPI enables the script to access all the information within a treatment plan in Eclipse
- Windows Forms is used for the script's Graphical User Interface (GUI) and the third-party open source Math.NET Numerics package is used for the mathematical functions needed to compute the NTCP
- The liver V_{eff} in a given liver SBRT plan is calculated using Equation 1 below:

$$V_{eff}(\%) = \sum_i \frac{V_i}{V_{liver}} * \left(\frac{D_i}{D_{reference}} \right)^{1/n} * 100 \quad (1)$$

- The v_{eff} (i.e., $V_{eff}(\%)/100$) is the fraction of an organ treated with a uniform dose ($D_{reference}$)
- For liver (parallel structure), $n=1$ and $D_{reference}$ per our protocol is equal to prescription dose
- The script extracts dose information directly from the liver DVH curve and performs the histogram-reduction technique to calculate the V_{eff}
- The NTCP for RILD is computed using the Lyman-Kutcher-Burman (LKB) model, with the volume-effect parameter $n = 1$ and slope-effect parameter $m = 0.12$
- The alpha/beta ratio of 3 for liver and the TD50(1) values for Hepatocellular Carcinoma and Liver metastases cases (39.8 and 45.8 Gy, respectively) used in the NTCP calculation are static values in the script
- The script obtains the max dose (at 0.03cc) and the number of fractions in the plan and then calculates the NTCP using the computed V_{eff} (see Equation 2):

$$NTCP = \frac{1}{2} \left(\text{Erf} \left(\frac{t}{\sqrt{2}} \right) + 1 \right) \quad (2), \quad \text{where} \quad t = \left(\frac{NTD2, max - TD50(v_{eff})}{TD50(v_{eff})} \right) \quad (3)$$

$$TD50(v_{eff}) = TD50(1) * v_{eff}^{-n} \quad (4) \quad NTD2, max = D_{max} * \left(\frac{D_{max}}{\#fractions} + \alpha/\beta \right) \quad (5)$$

- Equation 2 is a simplified form of the NTCP formula such that it can be expressed using an Error function, which is easy for the script to calculate using the Math.Net Numerics package
- Equations 3-5 break down the variable t , the argument of the Error function
- TD50(v_{eff}) is the liver tolerance dose at 2 Gy/Fx to a fraction v_{eff} of the whole organ leading to 50% complication probability in 5 years; TD50(1) is the same parameter but for the whole organ
- NTD2,max is the nominal standard dose in 2 Gy/Fx corresponding to D_{max}

Results

- The script is a binary plug-in script, meaning it can only be run from within Eclipse and with a specific patient open
- It runs on a per-patient basis, and can only access the information of one patient at a time
- The user interface prompts to select the specific plan for the patient, and if the plan is hepatocellular carcinoma or metastatic
- The NTCP Calculator script is easy to use and runs quickly, displaying in the user interface the V_{eff} and NTCP as percentages (see Figure 1)

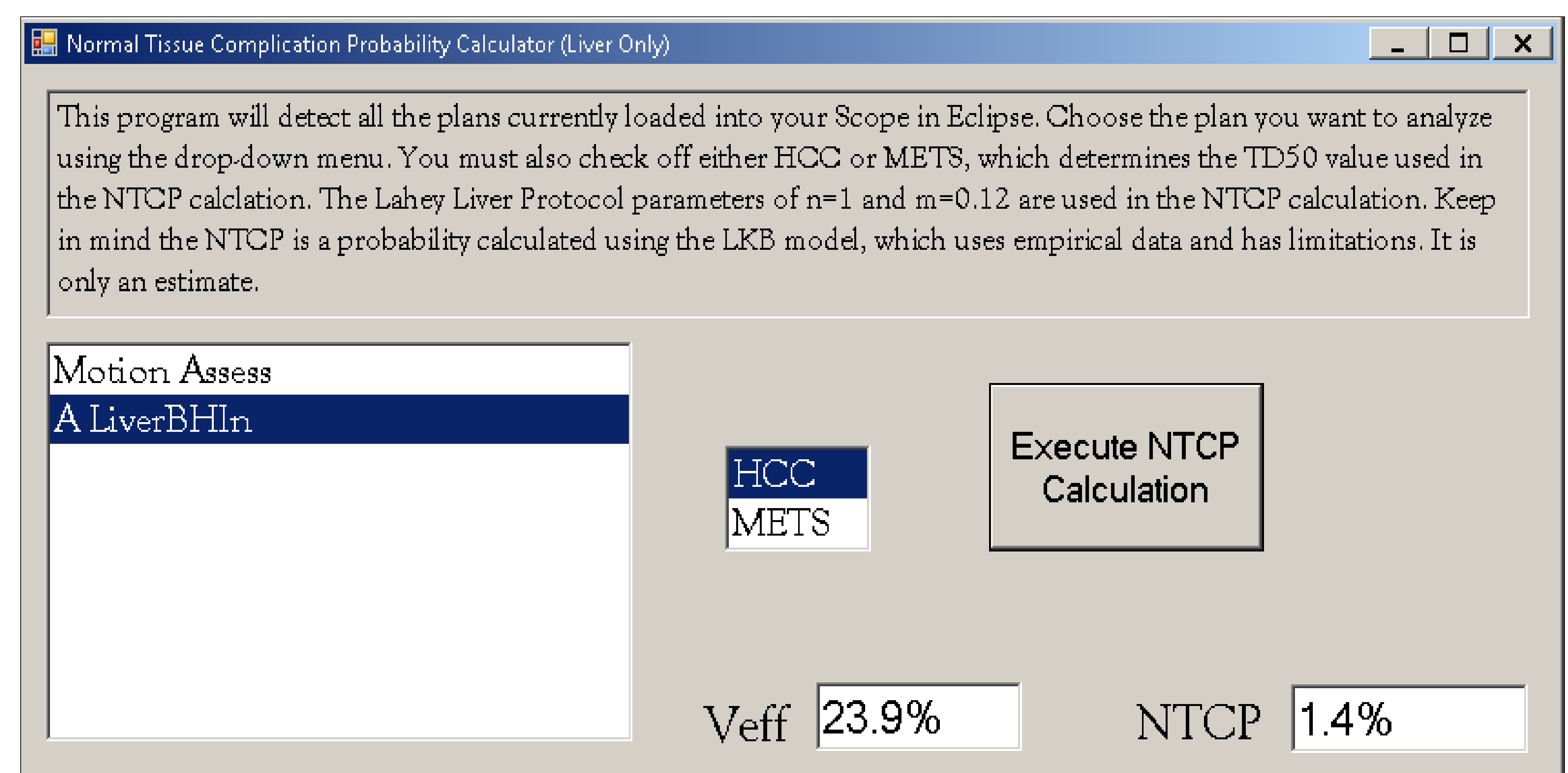


Figure 1 – The NTCP Calculator script, as it appears in Eclipse

- The V_{eff} and NTCP values generated by the script were compared with the values obtained by hand calculation for 10 mixed cases of Hepatocellular Carcinoma and Liver metastases and with different prescribed doses in order to evaluate the accuracy of the script's calculations, showing excellent agreement
- Based on these results the script was released for clinical use

Conclusion

- The NTCP Calculator has proven to be useful in expediting the liver SBRT planning process
- Prior to having the script, the dosimetrists had to wait for a medical physicist to manually calculate the V_{eff} and NTCP outside of Eclipse
- Using the script, the dosimetrists can assess the V_{eff} and NTCP of a plan themselves in real-time, providing crucial information for the plan optimization process
- Because the script runs quickly, the dosimetrists can use it iteratively to evaluate V_{eff} /NTCP at various stages of plan optimization

References

1. Kutcher GJ BC, Brewster L, et al. *Histogram reduction method for calculating complication probability for three-dimensional treatment planning evaluations*, International Journal of Radiation Oncology · Biology · Physics 1991; 21:137-146.
2. Dawson, LA, Eccles, C, and Craig, T. *Individualized image guided iso-NTCP based liver cancer SBRT*, Acta Oncologica 2006;45:856-864.

Corresponding author: Zackary Morelli; Lahey Hospital & Medical Center, 41 Mall Road, Burlington MA 01805;

E-mail address: zackary.t.morelli@lahey.org