

Spine SBRT with Halcyon™: Plan Quality, Delivery Accuracy, and Speed *

Heather Petroccia¹, Irina Malajovich¹, Chunhao Wang², Boon-Keng Kevin Teo¹, Dong Lei¹, and Taoran Li¹

¹University of Pennsylvania, Radiation Oncology, Philadelphia, USA.

²Duke University, Radiation Oncology, Durham, USA

* This work was accepted in *Front. Oncol.* (doi: 10.3389/fonc.2019.00319) after submission to ESTRO.

Introduction

Abstract: A new dual-layer staggered 1cm MLC in Halcyon™ treatment platform (Varian Medical, Palo Alto, CA) has improved speed, leakage, and DLG compared to 120-Millennium (0.5cm) and High Definition (0.25cm) MLCs in the TrueBeam platform. Halcyon 2.0 with SX2 MLC has the ability to modulate both upper and lower MLC banks; while previously in version 1.0 the SX1 MLC only uses the lower MLCs to modulate the fluence and the upper MLCs function as a back-up jaw by moving to the most distally extended lower leaf pair. It is not clear how this two newly designed MLCs performs for spine SBRT cases and compares to TrueBeam MLCs. In this study, we investigate the effects of 4 different MLC designs on spine SBRT treatments.

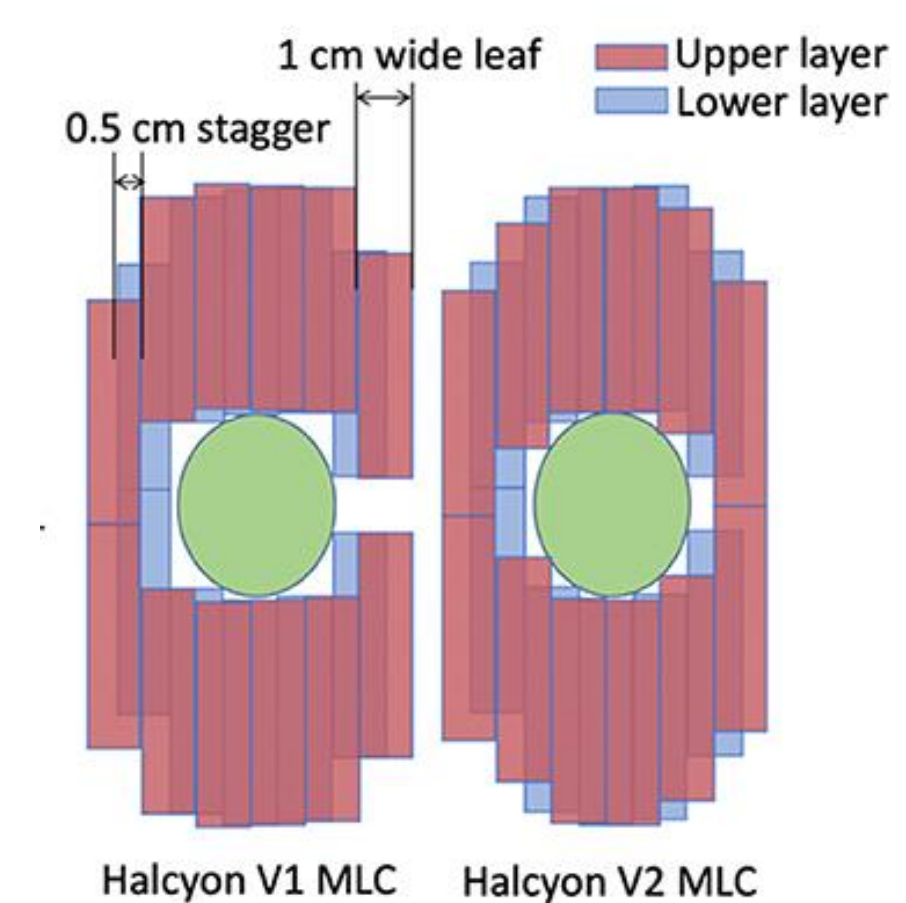
Materials & Methods

Study Cohort and Treatment Plan Parameters

- 15 patients previously treated with spine SBRT were re-planned according to NRG-BR002 guidelines
- Plan parameters were selected for a direct comparison between Halcyon and TrueBeam platforms:
 - 3000 cGy in 3 fractions
 - 800 cGy/MU dose rate
 - 6xFFF beam energy
 - 3-arc VMAT technique

	Halcyon Dual Layer Staggered MLC [†]	TB Millennium MLC	TB High Definition MLC
MLC Leaf Width	1.0 cm	0.5 cm - central 20 cm	0.25 cm - central 8 cm
	0.5 cm effective width	1.0 cm - outer 20 cm	0.5 cm - outer 14 cm
Number of Leaves	114	120	120
Max. Field Size	28 x 28 cm ²	40 x 40 cm ²	40 x 22 cm ²
Transmission factor	0.5 %	1.5 %	1.0 %
Dosimetric Leaf Gap	0.01 cm	0.18 cm	0.0361 cm
Leaf Speed	5 cm/s	2.5 cm/s	2.5 cm/s
Gantry Speed	4 revolutions/min	1 revolution/min	1 revolution/min

Halcyon 1.0 modulates with distal MLC only, and Halcyon 2.0 modulates with both distal and proximal MLC

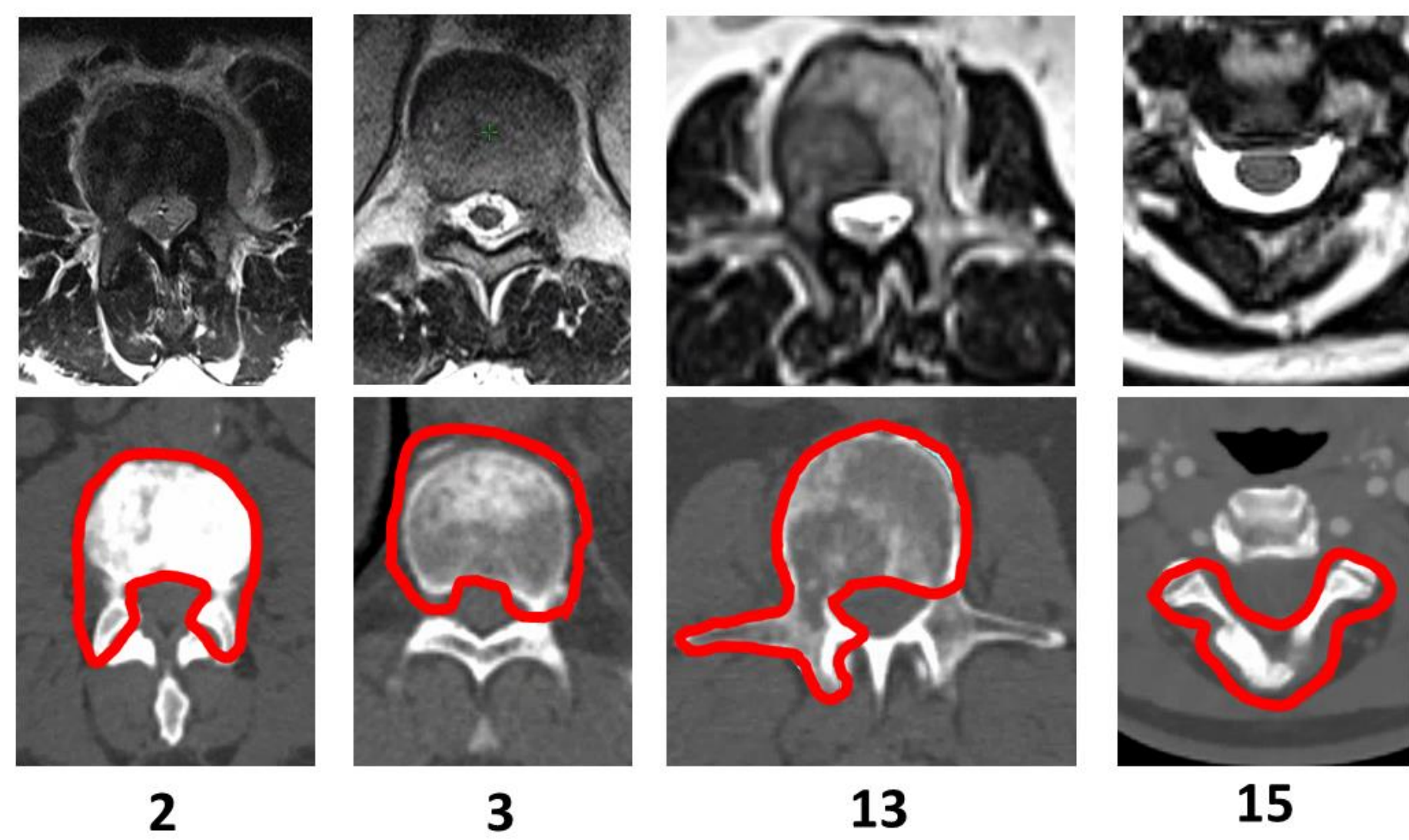


- Plans were normalized so 90% of the target is covered by the prescription dose.
- Physicians reviewed all contours including CTV and subsequent expansion, spinal cord, and thecal sac.
- Planning objectives were adjusted manually by experienced planers to generate optimal plans for each platform and consistent within each platform.

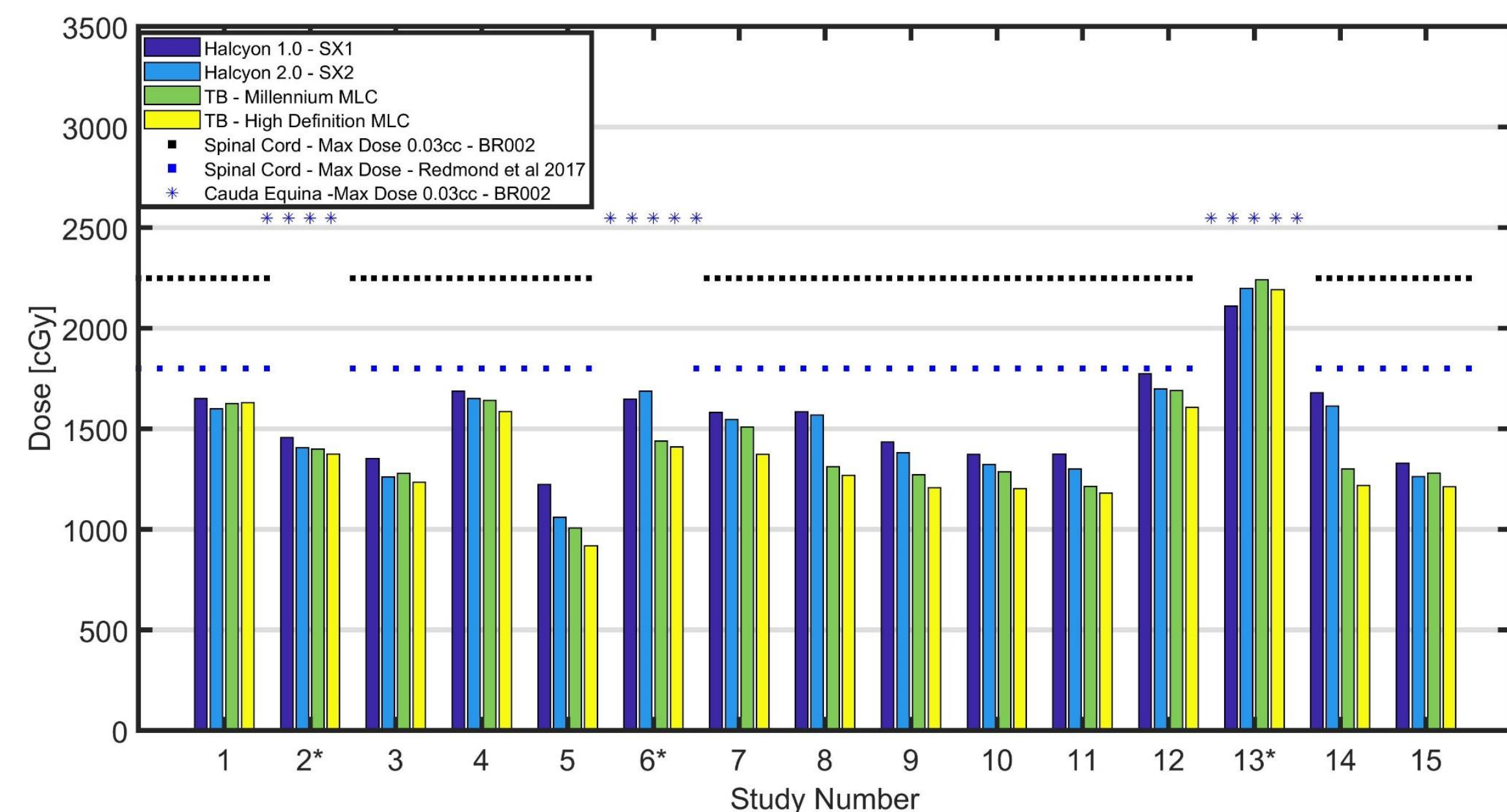
Above diagram is from Li et, al, Front. Oncol., 22 January 2019 | <https://doi.org/10.3389/fonc.2019.00007>, used under CC-BY license.

Results

PTV Shapes- Selection of patients previously treated for spine tumors were retrospectively selected under IRB approval.



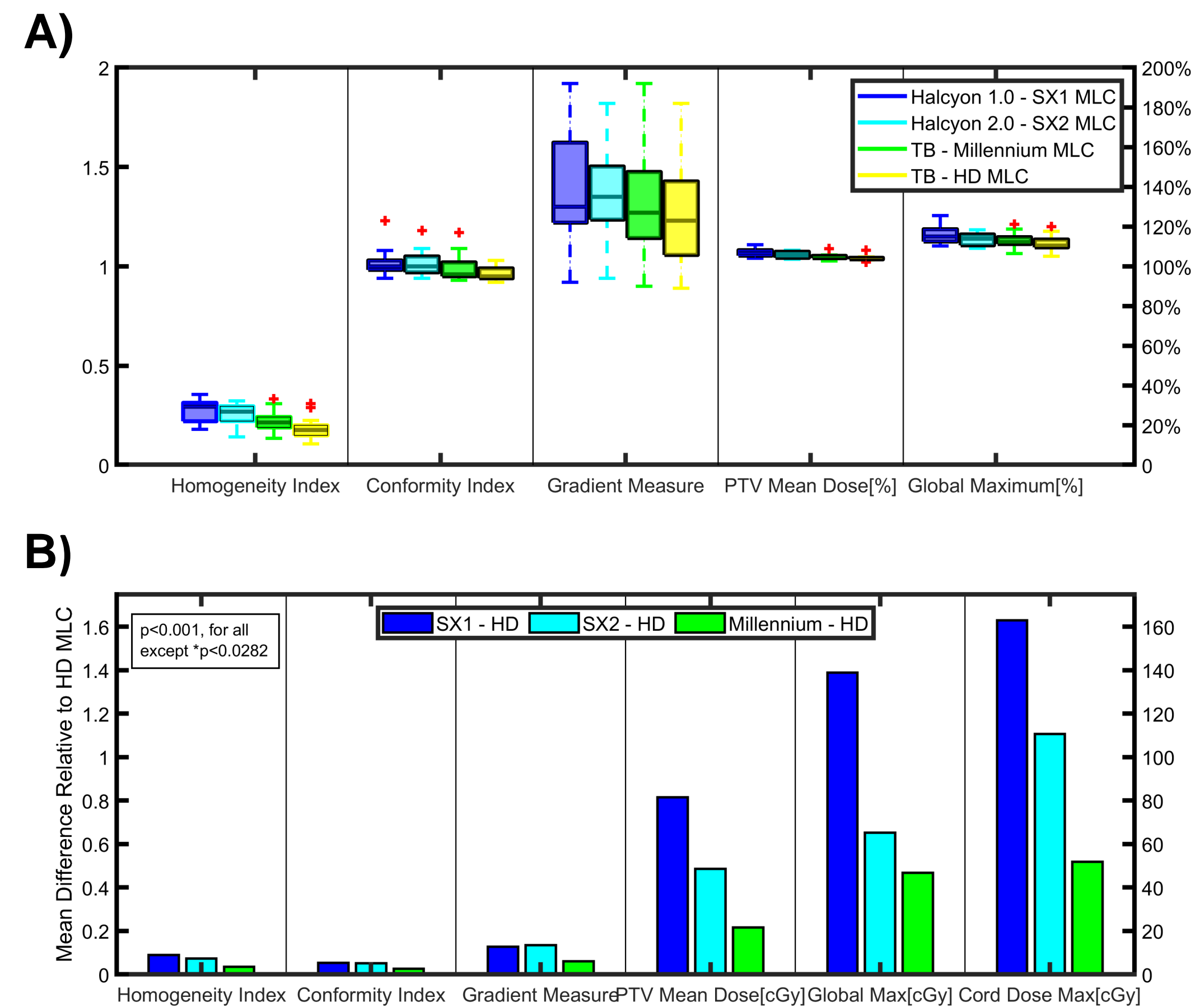
Cord Max Dose Comparison- Comparison of cord max dose or cauda equina (D0.03cc) across all patients. Cauda equina is indicated by an asterisks.



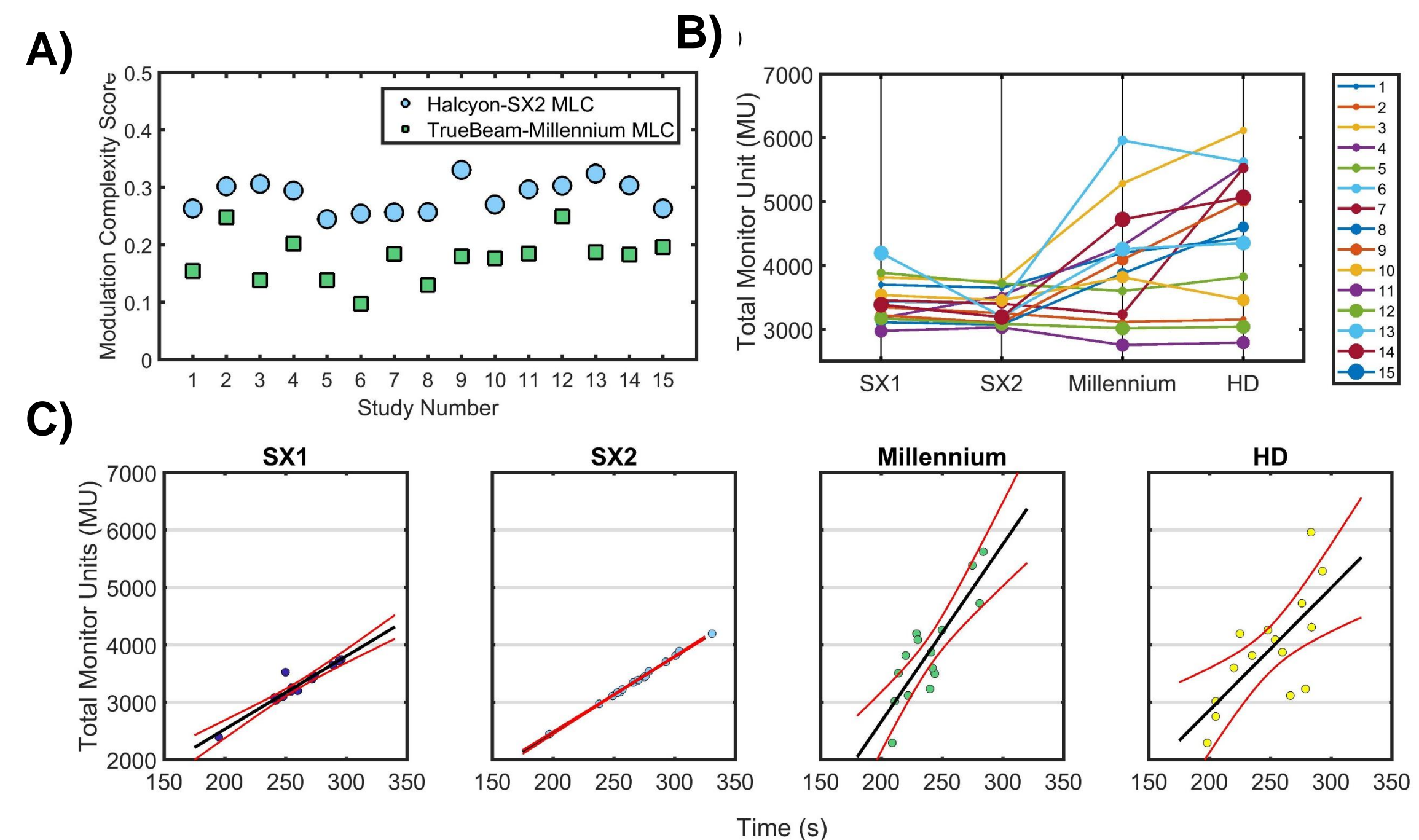
Maximum dose to spinal cord was found to have a range of [1060–1698] cGy for the Halcyon™ 2.0 with SX2, while the TrueBeams with Millennium MLC and HD MLC were found to have comparable maximum doses ranges of [1006-1688] cGy and [919 – 1631] cGy, respectively.

Results

Key Dosimetric Parameters- **A)** Planning parameters are compared between the Halcyon™ and TrueBeam platforms to evaluate plan quality **B)** Matched paired analysis was performed comparing the difference between SX1, SX2, Millennium-120 MLC to the High Definition-120 (HD) MLC for plan parameters to evaluate statistically significant trends.



Treatment Delivery Parameters - Delivery parameter including total MU, modulation complexity score, and delivery time is compared for the Halcyon™ platform with SX1 and SX2 and TrueBeam platform with High Definition (HD) 120 MLC and Millennium 120 MLC



A) The modulation complexity score is shown for Halcyon™ 2.0 - SX2 MLC is compared to TrueBeam Millennium-120 MLC. **B)** Shows the total MU delivered for each of the different treatment modalities. **C)** All TrueBeam plans were adjusted to be 1400 MU/min as compared to the 800 MU/min available in the Halcyon™ platform to utilize optimal delivery characteristics per treatment unit. Linear fits with the 95% confidence interval for delivery time compared to the total MU for all patients with the exception of case 3 due to exceptionally high MU.

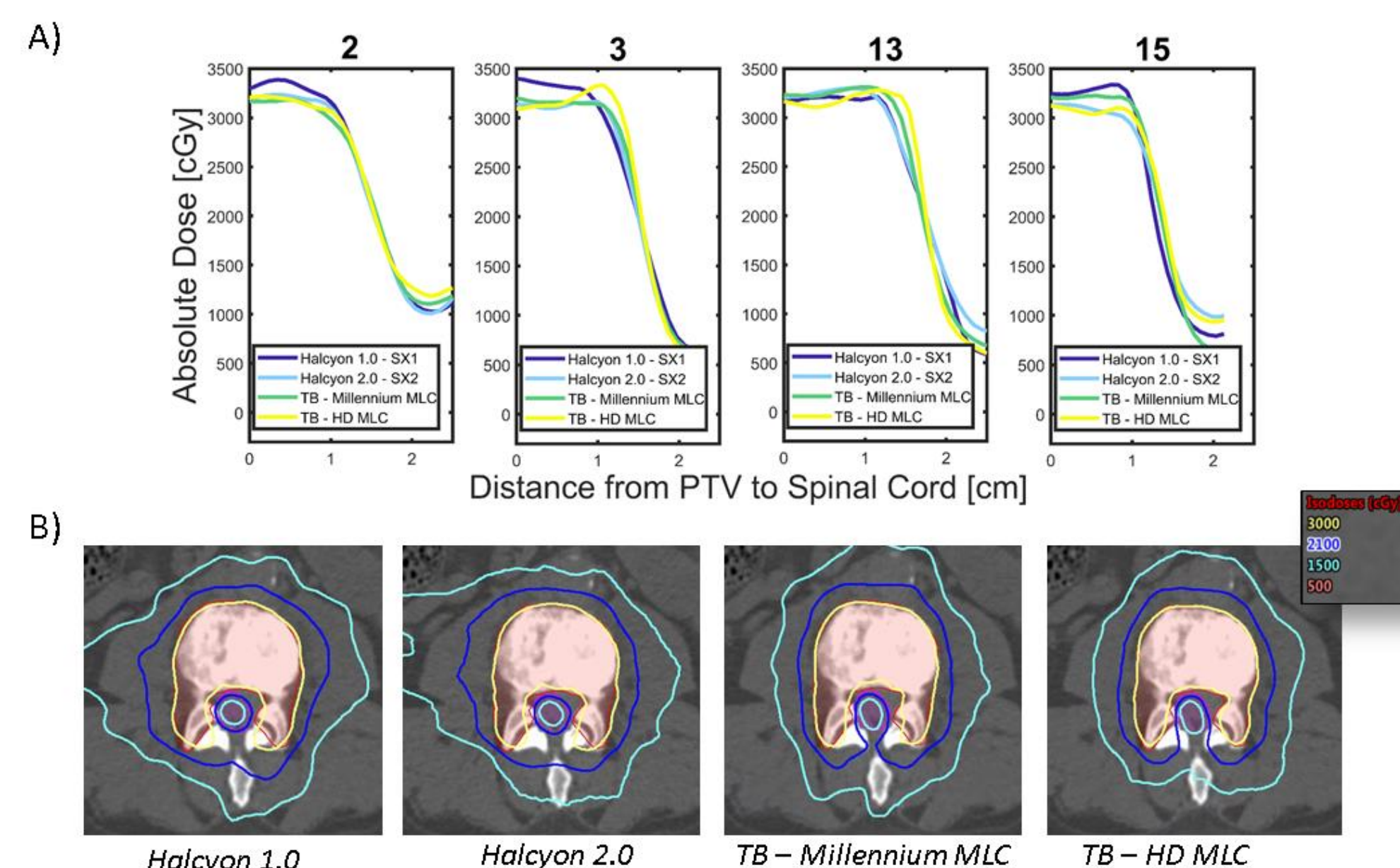
IMRT QA Results- Delivery accuracy for the 4 treatment modalities were measured using ArcCheck (SunNuclear, Melbourne, Florida) and a gamma index metric with a criterion of 2%/2mm.

Summary of Gamma Passing Rates Between Planned and Measured Dose Distributions

Halcyon 1.0 –SX1	Halcyon 2.0 – SX2	TB Millennium-120 MLC	TB High Definition MLC
98.8 ± 0.2%	96.9 ± 2.0%	94.1 ± 2.5%	95.5 ± 2.3%

Conclusions

The results in this study indicated Halcyon™ platform is capable of generating treatment plans that met clinically accepted constraints and pass routine patient-specific quality assurance for delivery accuracy verification.



- Halcyon™ treatment plans generated with SX1 and SX2 were shown to have a similar CI and HI as compared to the TrueBeam platform.
- Gradient measure indicates that TB plans have steeper dose fall-off than the Halcyon™ platform and an increase in modulation as indicated by MCS for the TB Millennium MLC as compared to the Halcyon™ 2.0 plans.

- For clinics that only have Halcyon™ as the sole treatment delivery option, administering spine SBRT is feasible & safe. However, caution should be taken on rigorous IGRT and patient repositioning, as the current system cannot provide automatic yaw correction for patient positioning.
- For clinics that have access to TrueBeam platforms, our data supports that Truebeam platforms are still preferred over Halcyon™ both for superior cord sparing and simpler IGRT workflow.
 - Treatment time for both Halcyon™ and TrueBeam are comparable, as the former is limited by 800 MU/min dose rate.
- Future development on Halcyon™ to incorporate higher dose rate and 6-degrees-of-freedom couch will likely make it a more attractive option for spine SBRTs.

