**Innovation**: The novelties of this study include: 1) we consider explicitly the delivery time budget and find an optimized treatment plan under this budget (first stage planning); 2) We further introduce a second stage planning which is based on the first stage planning. When the first stage planning does not find best treatment plan, the second stage planning can find one closer to the best treatment plan. When the first model finds the best treatment plan, the second stage model can serve as a double-checking role.

**Key Results**: The experiments are conducted on 5 patient cases. The tradeoff between delivery time reduction and plan quality is shown in Figure 1-2 for the case 2 and case 5 respectively. In Figure 3, we demonstrate the D90 improvements for each case with 5 different trials (the D90 obtained in second stage planning minus the D90 obtained in the first stage planning). We present the dose map and DVH dose escalation under different time budgets for case 1 using the first stage planning in Figure 4-7. We present the dose map and DVH dose escalation for case 2 using first stage planning and second stage planning in Figure 8-11. We present the quantitative results averaged over 5 cases in Table 1.

|  |  |  |
| --- | --- | --- |
|  |  |  |
| Figure 1: Dose variation and delivery time variation using first stage model. | Figure 2: Dose variation and delivery time variation using first stage model. | Figure 3: D90 improvement using second stage model. Compared with D90 obtained using first stage model. |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| Figure 4: Dose map of case 1 with delivery time 39.13 min, first stage model used. | Figure 6: Dose map of case 1 with delivery time 17.66 min, first stage model used. | Figure 8: Dose map of case 2, first stage model used. | Figure 9: Dose map of case 2, second stage model used. |
|  |  |  |  |
| Figure 5: DVH dose escalation of case 1 with delivery time 39.13 min, first stage model used | Figure 7: DVH dose escalation of case 1 with delivery time 17.66 min, first stage model used. | Figure 10: DVH dose escalation of case 2, first stage model used. | Figure 11: DVH dose escalation of case 2, second stage model used. |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatment time (min) | 45.85±13.49 | 37.10±10.66 | 28.14±7.91 | 19.02±4.99 | 10.16±2.00 |
| D90 (Gy) | 88.12±8.19 | 86.10±6.18 | 81.98±6.79 | 75.20±8.75 | 64.14±10.50 |
| D100 (Gy) | 67.13±7.14 | 64.46±6.04 | 60.52±5.39 | 56.58±5.99 | 52.41±6.41 |
| D2cc bladder (Gy) | 81.48±5.87 | 81.29±5.81 | 80.66±5.23 | 80.38±5.69 | 79.45±8.93 |
| D2cc rectum (Gy) | 70.28±6.69 | 71.67±5.86 | 72.90±4.69 | 73.91±2.44 | 73.27±3.86 |
| D2cc sigmoid (Gy) | 67.47±5.83 | 65.99±6.85 | 63.86±7.68 | 61.23±9.15 | 58.30±9.02 |
| Table 1: Average performance over 5 patient cases. Different trials have different delivery time budget. | | | | | |