Evaluation of Safety for Scanning Carbon-Ion Radiotherapy in Hemodialysis Patients with Prostate Cancer

Yosuke Takakusagi (✉ y-takakusagi@kcch.jp)

Kanagawa Cancer Center

Makito Suga

Kanagawa Cancer Center

Yohsuke Kusano

Kanagawa Cancer Center

Kio Kano

Kanagawa Cancer Center

Satoshi Shima

Kanagawa Cancer Center

Keisuke Tsuchida

Kanagawa Cancer Center

Nobutaka Mizoguchi

Kanagawa Cancer Center

Itsuko Serizawa

Kanagawa Cancer Center

Daisaku Yoshida

Kanagawa Cancer Center

Tadashi Kamada

Kanagawa Cancer Center

Shinichi Minohara

Kanagawa Cancer Center

Hiroyuki Katoh

Kanagawa Cancer Center

Research Article

Keywords: safety, carbon-ion radiotherapy, hemodialysis, prostate cancer, in-room CT

Posted Date: December 29th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-1153921/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at Cureus on February 14th, 2022. See the published version at <https://doi.org/10.7759/cureus.22214>.

Abstract

Background/Aim

The efficacy and safety of carbon-ion radiotherapy (CIRT) for prostate cancer have already been demonstrated. The number of hemodialysis (HD) patients is increasing. Although the toxicity of CIRT in HD patients may be more severe, it has been insufficiently investigated. Therefore, we retrospectively analyzed the safety of CIRT for HD patients with prostate cancer in the present study.

Materials and Methods

Five HD patients with prostate cancer who underwent CIRT at the Kanagawa Cancer Center during November 2015–2020 were included in this study. CIRT was delivered by the raster scanning method (sCIRT). Adverse events were assessed using the CTCAE v5.0. The dose-volume histogram (DVH) parameters of the target volume and normal organs were evaluated between initial planning computed tomography (CT) and in-room CT images.

Results

In the acute phase, Grade 1 genitourinary toxicity was recorded in 1 patient. In the late phase, Grade 1 genitourinary toxicity was recorded in 2 patients. No gastrointestinal toxicities were noted during the follow-up period. In-room CT analysis revealed no significant differences among all DVH parameters of the target volume and normal organs when compared with the treatment plan dose.

Conclusions

The safety of sCIRT for prostate cancer in HD patients was investigated in the present study. In-room CT analysis suggested the robustness of the treatment plan. According to the present results, sCIRT for prostate cancer can be safely performed in HD patients.

Introduction

Radiotherapy (RT) is one of the definitive treatments for prostate cancer (1). The advancement in treatment techniques has affected an increase in the dose to the target volume without increasing the dose to the surrounding normal organs (2). Especially, carbon-ion RT (CIRT) involves a sharp dose distribution, which is represented by the Bragg peak, and a high biological effect relative to that in with conventional X-rays (3–5). Owing to these characteristics of CIRT, CIRT has been expected to possess higher therapeutic efficacy and safety for prostate cancer. In fact, several past reports have demonstrated the usefulness of CIRT for prostate cancer (6–9).

The number of dialysis patients due to chronic kidney disease has been increasing across the world, exceeding 1 million count in the year 2010 (10). In Japan, the number of dialysis patients has also been increasing, with a report of >340,000 patients in 2018 (11). Approximately 98% of these patients were on hemodialysis (HD) (11). As reported earlier, the incidence of cancer is relatively higher in HD patients than in the general population (12, 13). Patients with HD tend to suffer from multiple comorbidities in addition to renal disease, and their general conditions tend to be poor. Therefore, the treatment options are limited for HD patients with cancer. RT is expected to be a promising treatment option for HD patients with cancer. However, there are limited reports on the safety of RT for HD patients (14). Moreover, the safety of CIRT in HD patients remains to be ascertained. Because HD patients have no or very poor urination, their bladder volume is small. As a result, CIRT for prostate cancer in HD patients may cause severe genitourinary (GU) toxicity due to irradiation of a large portion of the bladder (15). In addition, several studies have demonstrated that a small bladder volume requires a higher dose to the intestine in pelvic RT (16, 17). Thus, gastrointestinal (GI) toxicity is a concern in CIRT for prostate cancer in HD patients. Therefore, in the present study, we retrospectively investigated the toxicity in HD patients treated with CIRT for prostate cancer at our institution. We also evaluated the dose-volume histogram (DVH) to the target volume and normal organs by using computed tomography (CT) installed in the treatment room (in-room CT) images acquired during the treatment period of CIRT.

Materials And Methods

Patients

The present study was approved by the institutional review board of the Kanagawa Cancer Center (approval number: 2021-85). HD patients with prostate cancer who were treated with CIRT at the Kanagawa Cancer Center during December 2015–2020 were enrolled in the present study. The relevant clinical records were collected in October 2021. The eligibility criteria for this study were as follows: (i) HD performed at the time of CIRT initiation, (ii) histological diagnosis of prostate adenocarcinoma, (iii) cT1bN0M0 to T3bN0M0 according to the 7th UICC classification, and (iv) no previous treatment for prostate cancer excluding androgen deprivation therapy (ADT). Patients with peritoneal dialysis were excluded from the study. The D'Amico classification was applied to determine the risk groups (18).

CIRT

The detailed method of CIRT is as described in our previous study (9). Briefly, the clinical target volume (CTV) was defined as the entire prostate and proximal seminal vesicle, while the planning target volume (PTV) was expanded 5-mm superoinferior and posterior to the CTV and 10-mm anterior and lateral to the CTV. The total dose was set to 51.6 Gy (relative biological effectiveness; RBE) in 12 fractions and the PTV was covered by $\geq 95\%$ of the prescribed dose. CIRT was delivered by the raster scanning method (sCIRT). The bladder, rectum, and intestine were identified as organs at risk (OAR). The rectum was defined as the rectum that existed in the area where the PTV was enlarged by 1 cm in the superoinferior direction. The small intestine and sigmoid colon together were defined as the intestine. The dose constraint for the

rectum was aimed at the volume irradiated with 80% of the prescribed dose ($V_{80\%}$) <10 cc, while, for intestine, the maximum dose (D_{max}) was <70% dose of the prescribed dose. In cases where the PTV and intestine were extremely close, the PTV was modified to meet the dose constraints of the intestine. Patients without urinary function were not subjected to any pre-treatment restrictions on drinking or urination for the treatment. Patients with preserved urinary function were instructed not to urinate before treatment as much as possible. The rectum was emptied as much as possible using a laxative and an anti-flatulent before each session, and enema was performed if the patient did not defecate within 24 h of the treatment.

In-room CT was performed at the 1st, 5th, and 9th treatment sessions. The acquired in-room CT images were transferred to the MIM maestro software version 7.0 (MIM Software Inc., Cleveland, OH, USA), and rigid image fusion was performed by bone matching with the initial planning CT. On each in-room CT image, an experienced radiation oncologist delineated the CTV, bladder, rectum, and intestine. Dose distribution was accordingly calculated on the in-room CT images without changing the irradiation conditions as determined in the initial treatment planning. The calculation results were confirmed by two or more radiation oncologists. The dose of each structure was evaluated using DVH. The dose covering 98% of the target volume ($D_{98\%}$), $D_{95\%}$, $D_{50\%}$, $D_{2\%}$, and the homogeneity index (HI) were estimated for CTV. HI was calculated using the following formula: $D_2 - D_{98}/D_{50}$ (19). The percentage of the structure volume receiving at least 10 Gy (RBE) [$V_{10_{Gy(RBE)}}$], $V_{20_{Gy(RBE)}}$, $V_{30_{Gy(RBE)}}$, $V_{40_{Gy(RBE)}}$, $V_{50_{Gy(RBE)}}$, and the mean dose (D_{mean}) for the bladder and rectum as well as the D_{max} for the intestine were estimated as the DVH parameters for OARs. $V_{80\%}$ for the rectum was also calculated. DVH parameters were compared between the treatment planning CT and in-room CT.

ADT

Patients with high-risk prostate cancer were treated by urologists with ADT, which consisted of a combined androgen blockade (CAB) with anti-androgen therapy and medical castration. The high-risk group patients received neoadjuvant ADT for 4–8 months, followed by adjuvant ADT for a total of 2 years.

Follow-up

Urologists and radiation oncologists followed-up the patients every 3 months after the completion of sCIRT. Prostate-specific antigen (PSA) was measured at each follow-up. According to the Phoenix definition, PSA recurrence was defined as the nadir PSA level plus 2 ng/mL (20). The observation period and the time to the events were calculated since the initiation of sCIRT. Toxicity was assessed using the Common Terminology Criteria for Adverse Events version 5.0. Toxicity <3 months after the initiation of sCIRT was defined as acute toxicity, while toxicity after 3 months was defined as late toxicity. The worst grade of toxicity was evaluated as the final grade of toxicity.

Statistical Analysis

The DVH parameters between the initial plan and in-room CT were compared using the Mann–Whitney U-test. $p < 0.05$ was considered to indicate statistical significance. Statistical analysis was performed using the STATA software (version 13.1, College Station, TX, USA).

Results

Patient Characteristics

Five patients were enrolled in this study. The patient characteristics are summarized in Table 1. The median age of the subjects was 68 (range: 66–75) years. All patients were classified as high-risk groups according to the D'Amico classification parameters. The median duration of HD at the initiation of sCIRT was 22 (range: 6–33) years. The recorded primary diseases included diabetic nephropathy, polycystic kidney disease, chronic glomerulonephritis, and congenital renal atrophy in 2, 1, 1, and 1 patient, respectively. Two of the 5 patients recorded a residual urinary function. ADT was performed in all patients with neoadjuvant and adjuvant CAB. The median follow-up duration was 21 (range: 12–24) months. No death or PSA recurrence was recorded during the observation period.

Toxicity

The cases of toxicities are summarized in Table 2. Grade 1 GU toxicity was recorded as acute toxicity (patient no. 3). No other acute toxicity was noted. Two cases of Grade 1 GU were noted as late toxicity (patients no. 3 and 4). Patient no. 3 had acute cystitis, which continued for 3 months after sCIRT, and hence judged as late toxicity. This patient's toxicity resolved spontaneously at the next visit. Patient no. 4 complained of gross hematuria at 5 months after sCIRT. The patient did not visit any hospital at the onset of hematuria, and no urinalysis or cystoscopy was performed. He experienced only one episode of gross hematuria, which subsequently disappeared. No Grade 2 or higher toxicity were recorded in either acute or late phase.

In-room CT Analysis

The DVH parameters of CTV in the initial plan CT and in-room CT are summarized in Table 3. The DVH parameters of CTV were not significantly different between the two groups. The DVH parameters of OARs in the initial plan CT and in-room CT are summarized in Table 4. The DVH parameters of all OARs were not significantly different between the two groups. There were 3 cases in which the dose distribution in the in-room CT did not meet the dose constraints. The dose distributions of these 3 cases are indicated in Figure 1. All these cases were recorded only once in different patients. In patient no. 3, the V80% of the rectum exceeded the constraint of 10 cc because the rectal volume was enlarged as a result of gas filling in the rectum; the V80% was 2.6 cc in the treatment plan, but 11.8 cc in the in-room CT. In patients no. 2 and 4, the Dmax of the intestine exceeded the constraint of 36.12 Gy (RBE) because the intestine was closer to the target volume than that in planning CT. The Dmax of the intestine in patients no. 2 and 4 was 20.6 Gy (RBE) and 27.2 Gy (RBE) in the initial treatment plan and 49.4 Gy (RBE) and 42.1 Gy (RBE) in

the in-room CT, respectively. In all but these 3 cases, the doses for the rectum and intestine met the constraints.

Discussion

In this study, we investigated the safety of sCIRT for prostate cancer in HD patients. The analysis of dose distribution using in-room CT demonstrated comparable dose distribution to the initial plan. To the best of our knowledge, there have been no reports on the safety of CIRT in HD patients; the present study is the first report of its kind.

The dialysis tubing, dialysis membranes, and other equipment used for HD patients can cause inflammation (20). In addition, several factors including cytokines from uremia can cause chronic inflammation (21). Such inflammation has been reported to increase the cardiovascular risk in HD patients (22). The acute toxicity of RT is related to inflammation. Moreover, tissue damage based on vascular injury is one of the causes of late toxicity from RT. It has also been reported that patients with diabetes, which is the most common underlying cause of HD, have higher toxicity after RT for prostate cancer (23). Therefore, both acute and late toxicities may occur more frequently in HD patients treated with RT.

There have been a very few studies on RT for HD patients, for instance, a past study on RT for various primary sites in 56 HD patients revealed that both acute and late toxicities were clinically acceptable (14). However, severe Grade 5 infections were recorded in 4 of these 56 patients. In this past study, patients who received chemotherapy were also included. Infections accounted for >20% of all deaths among HD patients (11). In addition to the immune system abnormalities inherent in HD patients, treatment-induced leukopenia was presumed to be the cause of these severe infections. There have been several case reports on chemoradiation therapy (CRT) for HD patients. In a report on CRT with low-dose cisplatin for recurrent cervical cancer, no adverse events were observed during a 6-month follow-up period (24). In a case report of lung cancer treated with CRT using oral etoposide, adverse events during the treatment period were found to be within acceptable limits; however, post-treatment follow-up was not performed and late toxicity was unknown (25). A case report on the long-term outcomes of >4 years after CRT for esophageal cancer revealed a good local control and a few adverse events (26). In the present study, no serious adverse events were recorded after sCIRT. These reports may suggest that adverse events of RT are acceptable even in HD patients. However, past reports on the clinical outcomes after RT in HD patients are scarce, warranting further studies.

The risk of GU and GI toxicity due to low bladder volume and reduced rectal reproducibility owing to unstable voiding are concerns in RT for prostate cancer in HD patients. In a study on intensity-modulated RT (IMRT) for prostate cancer, an association between V70_{Gy} and GU toxicity has been demonstrated (15). On the other hand, in another study, empty bladder was associated with non-inferiority in GU toxicity after RT when compared to full bladder (27). Another study reported that the hotspots in the bladder served as a risk factor for GU toxicity (28). Although the association between bladder irradiated volume

and GU toxicity remains controversial, GU toxicity may require attention if high doses are administered to a large area of the bladder. In addition, RT in the empty bladder can induce increased intestinal doses. In a study of RT for prostate cancer using the 4-field box technique, a higher frequency of higher dose in the intestine was recorded during irradiation with an empty bladder rather than with a full bladder (16). A study of IMRT for cervical cancer suggested that the volume irradiated with 45 Gy in an empty bladder was larger than that in a full bladder (17). In the present study, the analysis of dose distribution of in-room CT revealed cases wherein the intestine dose exceeded the dose constraint. Although no GI toxicity was observed clinically in the present study, careful observations are warranted for the possibility of unexpectedly high intestine doses. Moreover, in patient no. 3, the increased volume due to gas accumulation in the rectum increased the rectal V80%. Patients with HD were found to be prone to defecation disorders such as constipation and diarrhea (29). The enlargement of the rectal volume due to constipation and gas retention may increase the rectal dose more than expected.

There are several limitations to this study, including the small number of patients, the short observation period, inclusion of a single-center, and the retrospective nature of the study. In addition, based on a study of the robustness of prostate cancer from our institution, a total of 3 in-room CTs were performed during sCIRT (30). Therefore, the dose distribution in each treatment session could not be accurately evaluated. The safety of CIRT in HD patients remains unclear, requiring further investigation.

Conclusion

Our results validated that sCIRT for prostate cancer was safely performed in the HD patients. The DVH analysis using in-room CT generally reproduced the initial treatment plan. However, attention should be paid to the possibility of unexpectedly high doses in the intestine and rectum in such cases.

Declarations

Ethics Approval and Consent to Participate

The current study was designed and conducted according to the principles outlined in the Declaration of Helsinki and within the guidelines of Good Clinical Practices and was approved by the Institutional Review Board of the Kanagawa Cancer Center (approval number: 2021-85). Written informed consent was obtained from all patients.

Conflicts of Interest

Dr. Hiroyuki Katoh, Dr. Daisaku Yoshida and Dr. Shinichi Minohara receive research funding from Toshiba Energy Systems and Solutions Corporation. All the other authors have no competing interests.

Authors' Contributions

YT collected and analyzed the data and drafted the manuscript. DY, TK, SM, and HK analyzed the data and contributed to the final draft of the manuscript. MS, YK, KK, SS, and KT collected and analyzed the data of the dose distribution in initial plan and in-room CT. NM and IS aided in writing the manuscript and contributed to the final draft of the manuscript. All Authors read and approved the final manuscript.

Availability of data and material

The datasets generated and/or analyzed during the current study are not publicly available due to its large amount of the data such as the parameters of dose volume histogram but are available from the corresponding author on reasonable request.

References

1. Scherr D, Swindle PW, Scardino PT. National Comprehensive Cancer Network. National Comprehensive Cancer Network guidelines for the management of prostate cancer. *Urology*. 2003; 61(2 Suppl 1):14–24.
2. Sanguineti G, Cavey ML, Endres EJ, Brandon GG, Bayouth JE. Is IMRT needed to spare the rectum when pelvic lymph nodes are part of the initial treatment volume for prostate cancer? *Int J Radiat Oncol Biol Phys*. 2006;64:151–160.
3. Schulz-Ertner D, Tsujii H. Particle radiation therapy using proton and heavier ion beams. *J Clin Oncol*. 2007;25(8):953–64.
4. Kanai T, Matsufuji N, Miyamoto T, Mizoe J, Kamada T, Tsuji H, et al. Examination of GyE system for HIMAC carbon therapy. *Int J Radiat Oncol Biol Phys*. 2005;64(2):650–6.
5. Kanai T, Endo M, Minohara S, Miyahara N, Koyama-ito H, Tomura H, et al. Biophysical characteristics of HIMAC clinical irradiation system for heavy-ion radiation therapy. *Int J Radiat Oncol Biol Phys*. 1999;1;44(1):201–10.
6. Ishikawa H, Tsuji H, Kamada T, Akakura K, Suzuki H, Shimazaki J, et al. Working Group for Genitourinary Tumors. Carbon-ion radiation therapy for prostate cancer. *Int J Urol*. 2012;19(4):296–305.
7. Nomiya T, Tsuji H, Kawamura H, Ohno T, Toyama S, Shioyama Y, et al. A multi-institutional analysis of prospective studies of carbon ion radiotherapy for prostate cancer: A report from the Japan Carbon ion Radiation Oncology Study Group (J-CROS). *Radiother Oncol*. 2016;121(2):288–293.
8. Kawamura H, Kubo N, Sato H, Mizukami T, Katoh H, Ishikawa H, et al. Group for Genitourinary Tumors at Gunma University Heavy Ion Medical Center. Moderately hypofractionated carbon ion radiotherapy for prostate cancer; a prospective observational study "GUNMA0702". *BMC Cancer* 2020;30;20(1):75.
9. Takakusagi Y, Katoh H, Kano K, Anno W, Tsuchida K, Mizoguchi N, et al. Preliminary result of carbon-ion radiotherapy using the spot scanning method for prostate cancer. *Radiat Oncol*. 2020;27;15(1):127.

10. Bello AK, Levin A, Tonelli M, Okpechi IG, Feehally J, Harris D, et al. Assessment of Global Kidney Health Care Status. *JAMA*. 2017;9;317(18):1864–1881.
11. Nitta K, Goto S, Masakane I, Hanafusa N, Taniguchi M, Hasegawa T, et al. Japanese Society for Dialysis Therapy Renal Data Registry Committee. Annual dialysis data report for 2018, JSDT Renal Data Registry: survey methods, facility data, incidence, prevalence, and mortality. *Ren Replace Ther*. 2020;6, 41.
12. Cheung CY, Chan GC, Chan SK, Ng F, Lam MF, Wong SS, et al. Cancer Incidence and Mortality in Chronic Dialysis Population: A Multicenter Cohort Study. *Am J Nephrol*. 2016;43(3):153–9.
13. Butler AM, Olshan AF, Kshirsagar AV, Edwards JK, Nielsen ME, Wheeler SB, et al. Cancer incidence among US Medicare ESRD patients receiving hemodialysis, 1996-2009. *Am J Kidney*. 2015;Dis 65(5):763-72.
14. Hirota H, Ito K, Kageyama SI, Tamamoto F, Karasawa K, Yoshimura R. Safety of radiotherapy for hemodialysis patients with cancer. *Int J Clin Oncol*. 2020;25(5):978–983.
15. Inokuchi H, Mizowaki T, Norihisa Y, Takayama K, Ikeda I, Nakamura K, et al. Correlation between urinary dose and delayed radiation cystitis after 78 Gy intensity-modulated radiotherapy for high-risk prostate cancer: A 10-year follow-up study of genitourinary toxicity in clinical practice. *Clin Transl Radiat Oncol*. 2017;6:31–36.
16. Moiseenko V, Liu M, Kristensen S, Gelowitz G, Berthelet E. Effect of bladder filling on doses to prostate and organs at risk: a treatment planning study. *J Appl Clin Med Phys*. 2006;12;8(1):55–68.
17. Chen VE, Gillespie EF, Manger RP, Skeritt LA, Tran JH, Proudfoot JA, et al. The impact of daily bladder filling on small bowel dose for intensity modulated radiation therapy for cervical cancer. *Med Dosim*. 2019;44(2):102–106.
18. D'Amico AV, Whittington R, Malkowicz SB, Schultz D, Blank K, Broderick GA, et al. Biochemical outcome after radical prostatectomy, external beam radiation therapy, or interstitial radiation therapy for clinically localized prostate cancer. *JAMA*. 1998;280(11):969–74.
19. Hodapp N. Der ICRU-Report 83. Verordnung, Dokumentation und Kommunikation der fluenzmodulierten Photonenstrahlentherapie (IMRT) [The ICRU Report 83: prescribing, recording and reporting photon-beam intensity-modulated radiation therapy (IMRT)]. *Strahlenther Onkol*. 2012;188(1):97–9.
20. Dukkipati R, Molnar MZ, Park J, Jing J, Kovesdy CP, Kajani R, et al. Association of vascular access type with inflammatory marker levels in maintenance hemodialysis patients. *Semin Dial*. 2014;27(4):415–23.
21. Stenvinkel P, Alvestrand A. Inflammation in end-stage renal disease: sources, consequences, and therapy. *Semin Dial*. 2002;15(5):329–37.
22. Zimmermann J, Herrlinger S, Pruy A, Metzger T, Wanner C. Inflammation enhances cardiovascular risk and mortality in hemodialysis patients. *Kidney Int*. 1999;55(2):648–58.
23. Herold DM, Hanlon AL, Hanks GE. Diabetes mellitus: a predictor for late radiation morbidity. *Int J Radiat Oncol Biol Phys*. 1999;43(3):475–9.

24. Marnitz S, Kettritz R, Kahl A, Lehenbauer-Dehm S, Förster L, Budach V, et al. Simultaneous chemoradiation with cisplatin in a patient with recurrent cervical cancer undergoing hemodialysis: analysis of cisplatin concentrations in serum and dialysate and therapy-related acute toxicity. *Strahlenther Onkol.* 2011;187(12):831–4.
25. Gao F, Cong X, Liu Z. Successful treatment of a patient with small cell lung cancer receiving hemodialysis, with concurrent oral etoposide and radiotherapy: A case report. *Medicine (Baltimore).* 2020;99(40):e22637.
26. Rebibou JM, Chauffert B, Dumas M, Mousson C, Bone MC, Tanter Y, et al. Combined chemotherapy and radiotherapy for esophageal carcinoma in a hemodialyzed patient. Long-term survival. *Nephron.* 1996;74(3):611–2.
27. Tsang YM, Hoskin P. The impact of bladder preparation protocols on post treatment toxicity in radiotherapy for localised prostate cancer patients. *Tech Innov Patient Support Radiat Oncol.* 2017;3-4:37–40.
28. Cheung MR, Tucker SL, Dong L, de Crevoisier R, Lee AK, Frank S, et al. Investigation of bladder dose and volume factors influencing late urinary toxicity after external beam radiotherapy for prostate cancer. *Int J Radiat Oncol Biol Phys.* 2007;67(4):1059–65.
29. Yasuda G, Shibata K, Takizawa T, Ikeda Y, Tokita Y, Umemura S, et al. Prevalence of constipation in continuous ambulatory peritoneal dialysis patients and comparison with hemodialysis patients. *Am J Kidney Dis.* 2002;39(6):1292–9.
30. Tsuchida K, Minohara S, Kusano Y, Kano K, Anno W, Takakusagi Y, et al. Interfractional robustness of scanning carbon ion radiotherapy for prostate cancer: An analysis based on dose distribution from daily in-room CT images. *J Appl Clin Med Phys.* 2021;22(6):130–138.

Tables

Due to technical limitations, table 1,2,3 is only available as a download in the Supplemental Files section.

Figures

Fig 1

Figure 1

Dose distribution in cases wherein the dose constraint exceeded.

Patients no. 2 and 4 received high doses to the nearby intestine (white arrows). In patient no. 3, the rectum enlarged because the rectal gas was irradiated with a high dose (red arrows).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table1.xlsx](#)
- [Table2.xlsx](#)
- [Table3.xlsx](#)
- [Table4.xlsx](#)