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Evaluation of Rectal Dose According to Body Mass Index (BMI) Using the Adjacent Organs and Belly Board

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Abstract: This study analyzed the set-up error by the difference in Body Mass Index (BMI) and applied the error to the existing treatment plan to compare the BMI determined dose for the small intestines and bladder in colorectal cancer to study the usability of belly board. Twelve patients received radiation therapy before or after surgery after being were diagnosed with colorectal cancer between August, 2014 and July, 2015. They were divided into two groups based on BMI (high BMI = 24 kg/m^2; low BMI or <24 kg/m^2) and each group was sub classified on the use/ non-use of belly board (Group 1, belly board and low BMI; Group 2, no belly board and low BMI; Group 3, belly board and high BMI; Group 4, no belly board and high BMI). For Group 1, the volume of bladder V10 did not change with V20 2.13±0.83, V30 3.66±2.99 and V40 4.53±3.45 cc. The volume of the small bowel V10 was 1.11±1.30 with V20 2.19±1.82, V30 2.55±2.25 cc and V40 2.75±2.55 cc (Group 2). In Group 3, V10 did not change with V20 11.73±14.94, V3015.08±19.78 and V40 19.40±23.92 cc while the volume of small bowel V10 was 1.19±1.82, V20 16.22±24.36, V30 17.67±25.30 and V40 18.49±26.37 cc. In Group 4, V10 did not change with V20 8.08±9.12, V30 15.45±7.63 and V40 19.53±9.61 cc while the volume of small bowel V10 was 0.73±0.86, V20 7.13±5.38, V30 15.26±14.97 and V40 10.77±7.92 cc. The volume of bladder V10 did not change with 0.39±0.68, V20 12.33±9.98, V30 18.03±8.79 and V40 21.55±8.12 cc while the volume of small bowel, V10 was 18.38±17.00, V20 11.45±1.69, V30 23.67±20.79 and V40 36.17±31.70 cc.

Key words: Radiotherapy, rectal Ca, BMI, voume, group

INTRODUCTION

According to the World Health Organization, 35% of adults are overweight with 10% of these obese individuals being men and 14% being women (WHO, 2009). Obesity increases the risks of breast, colorectal, endometrial, renal cell, esophageal and pancreatic cancer (Marmot *et al*., 2007).

Gastric cancer is the most common cancer for both men and women in Korea followed by Colorectal Cancer (CRC). In 2010, according to the Korean Cancer Prevalence Report, there were 7,645 CRC-related deaths in Korea. CRC is the fourth most lethal cancer related to obesity after lung, hepatic and gastric cancers (Jung *et al*., 2013). Else where it is the fourth most prevalent cancer globally with 800,000 people diagnosed annually(Jemal *et al*., 2008). The prevalence of CRC is likely related to the widespread adoption of a westernized diet and the consequent increase in the prevalence of obesity which has contributed to the increases in various metabolic syndromes, diabetes, cardiovascular diseases and cancer.

Body Mass Index (BMI) is one of the indices of obesity. BMI correlates height and weight and is used to evaluate the health-related risks of patients. It is related to body fat in adults. It is calculated by dividing weight in kg by the square of height in meters (kg/m^2). The standard of obesity varies from country to country; a BMI ≥25 kg/m^2 and ≥30 kg/m^2 is considered overweight and obese, respectively in Asia. The Korean Society for the Study of Obesity classifies BMI ≤18.5 kg/m^2 as underweight, 18.5-22.9 kg/m^2 as normal eight, 23 kg/m^2 as overweight, 24 kg/m^2 as risk of obesity, 25-30 kg/m^2 as minor obesity, 30-35 kg/m^2 as severe obesity and ≥35 kg/m^2 as extreme obesity. The number of Korean adults who are considered overweight has more than doubled in 6 years from 13.9% in to 30.6% in 2001, coincident with the rapid socioeconomic development of the country (Kim *et al*., 2005).

Obesity is a risk factor of colorectal cancer. However, little is known concerning dose assessment of the small intestines and bladder which are the internal organs adjacent to the rectum, according to BMI when CRC patients receive radio therapy (Meyerhardt *et al*., 2006;

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Simkens *et al*., 2011). Most colorectal cancer patients receive radiotherapy positioned stomach-down so radiation may not target the tumor and interfere with the treatment when geometric consistency is not achieved due to improper position of patients by body weight or breathing. Therefore, rectal cancer patients receiving radiotherapy are required to minimize movement using a belly board for accurate positioning according to the use of ostomy. Many studies have already discussed the use of the belly board while CRC patients lie stomach-down to expand the bladder during radio therapy (Yoon, 2005). The belly board is used only for patients who are wearing an ostomy. Obese patients who are not wearing an ostomy may not maintain the right position as their lower belly moves due to breathing during radiotherapy. Prior studies have discussed positioning of CRC patients during radiotherapy according to BMI and the use of belly board; obese patients can adopt improper positions regardless of the use of an ostomy and the use of belly board can reduce the error (Shim *et al*., 2013).

However, the is no information regarding the difference in dosage on the surrounding small intestines and bladder during radiotherapy for CRC in case of positioning errors due to differences in BMI.

This study analyzed the setup error according to different BMI values and applied the error to the existing treatment plan to compare the dose on the small bowel and bladder during radiotherapy for CRC according to BMI. The aim was to study the usability of the belly board.

MATERIALS AND METHODS

The study involved 12 patients who received radiotherapy before or after surgery after they were diagnosed with CRC at a general hospital in Seoul between August 2014 and July 2015. The patients were divided into two groups based on BMI ($\geq$24 and <24 kg/m^2). Each groups was comprised of two subgroups based on the use or non-use of the belly board. In total, there were four groups with three individuals per group: Group 1, belly board and BMI <24 kg/m^2; Group 2, no belly board and BMI <24 kg/m^2; Group 3, belly board and BMI $\geq$24 kg/m^2 and Group 4, no belly board and BMI $\geq$24 kg/m^2).

To evaluate patient position-related errors during simulated therapy, 58 images were taken after the patient was positioned in the therapy room. The bladder was expanded by withholding urination for 2 h before the position simulation for radiotherapy. Patients maintained a prone position during examination using a High Advantage Computed Tomography (CT) device 16 channel (GE, USA) to obtain three-dimensional information needed for a treatment plan. The CT scans had a sectional thickness of 5 mm and pitch of 1.35 degrees. Sixty images were acquired for each patient. The scan range for the simulation was 5 mm from the lumbar spine level 4 to the perineum. To establish an accurate treatment plan and for dosage analysis, Pinnacle Ver. 9.0 software (Phillips, Andover, MA, USA) was used to examine the images transmitted using Digital Imaging and Communications in Medicine (DICOM).

The target volume of the transmitted image or the gross tumor volume included all tumors observed in the radiological view according to the international commission on radiation units report 50. It included the pelvic lymph node, except for the external iliac lymph node. The planning target volume was applied with a 1.5 cm margin to the clinical target volume and the prescription dose was set at 97-103%. The upper boundary of each irradiation was the joint between lumbar spine level 4 and the pelvis and the lower boundary was the bottom of the obturator foramen or over 3 cm to the bottom of the tumor. The left and right boundaries of the irradiation were 1.5 cm from the sides of pelvic cavity.

The treatment was planned by applying a Planning Target Volume (PTV) to the transmitted images and the radiotherapy equipment applied multicollimators using a LINAC 21EX (Varian, USA) that consisted of a total of 120 leaves including forthy 5 mm leaves and twenty 10 mm leaves. When needed for an even distribution of dosage, the optimized radiotherapy plan was established using the universal wedge or Enhanced Dynamic Wedge (EDW). The energy applied was one 10 MV ray for each of the left and right beam and the 4 MV ray for the rear irradiation zone. Total dosage was 44 Gy for 22 sessions of 2 Gy a day with 40% weight on the rear beam and 30% weight on each of the side beams.

Analysis: A total of 58 anteroposterior and lateral images taken during the simulated positioning and the electronic portal imaging device for accurate positioning before radiotherapy were utilized to analyze the mean and standard deviation values of the X, Y and Z axes of each patient. Error analysis of the axes of each patient was done at least twice to evaluate the position of the image taken before the first therapy and after >10 sessions of radiotherapy using the images saved on the patient information system. When the error on the position was large, standard deviations were calculated for the images including those taken until the position matched the initial position. The center point was moved as much as the

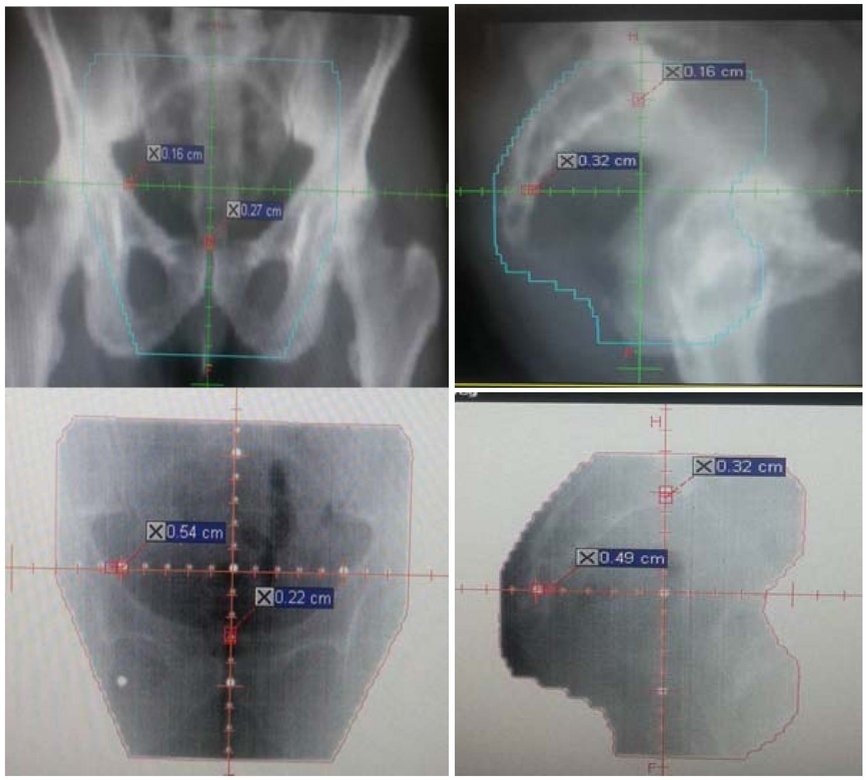

Fig. 1: Set-up errors (X, Y, Z axis) of AP and LAT (EPID)

error and a new treatment was planned by moving the previous CT image as much as the error using full term for RTP. Based on this, the minimum dosage, maximum dosage, mean dosage and standard deviation of Groups 1-4 were compared to analyze the difference in dosage on normal tissues and tumors and to classify the critical organs of small intestines and bladder into 10-30 and 40 V in case of errors.

The difference compared to the previous treatment plan was comparatively analyzed by measuring volume and dosage (Fig. 1).

RESULTS

The mean and standard deviation of the X, Y and Z axes of the 12 patients are summarized in Table 1. The mean and standard deviation of the 12 patient's X, Y and Z axes were 1.5±0.5, 1.8±0.2 and 1.3±0.2 mm for (Group 1) 2.0±0.5, 1.0±0.5 and 2.2±0.2 mm for (Group 2) 2.0±0.1, 1.0±0.5 and 2.5±0.5 mm for (Group 3) and 1.5±0.5, 2.5±1.0 for 3.0±1.0 mm (Group 4). As a result of this, colorectal cancer patients with high BMI showed higher mean and standard deviation for the error of position of patients. The volume of bladder V10 did not change with V20 2.13±0.83, V30 3.66±2.99 and V40 4.53±3.45 cc (Group 1).

Table 1: Difference of BMI each group and the error and SD unit: mm

Variables	Group 1 (mm)	Group 2 (mm)	Group 3 (mm)	Group 4 (mm)
X	1.5±0.5	2.0±0.6	2.0±0.2	1.5±0.5
Y	1.8±0.2	1.0±0.4	1.0±0.5	2.5±1.0
Z	1.3±0.2	1.0±0.5	2.5±0.5	3.0±1.0

Group 1 = using belly board and under BMI 24; Group 2 = not using belly board and under BMI 24; Group 3 = using belly board and BMI 24 or over; Group 4 = not using belly board and BMI 24 or over

Also, the volume of small intestines V10 was 1.11±1.30 with V20 2.19±1.82, V30 2.55±2.25 cc and V40 2.75±2.55 cc (Group 2). The volume of bladder V10 didn't change with V20 11.73±14.94, V30 15.08±19.78 and V40 19.40±23.92 cc while the volume of small intestines V10 was 1.19±1.82, V20 16.22±24.36, V30 17.67±25.30 and V40 18.49±26.37 cc (Group 3). The volume of bladder V10 did not change with V20 8.08±9.12, V30 15.45±7.63 and V40 19.53±9.61 cc while the volume of small intestines V10 was 0.73±0.86, V20 7.13±5.38, V30 15.26±14.97 and V40 10.77±7.92 cc (Group 4) (Table 2). The volume of bladder V10 did not change with 0.39±0.68, V20 12.33±9.98, V30 18.03±8.79 and V40 21.55±8.12 cc while the volume of small intestines V10 was 18.38±17.00, V20 11.45±1.69, V30 23.67±20.79 cc and V40 36.17±31.70 (Table 3). As a result the patients who had high BMI and did not use the belly board showed high dosage on the bladder and small intestines which are the normal organs close to the rectum.

Table 2: Comparison of bladder volume according to difference of each group unit: cc

OARs volume (group)	Bladder V_{10}	V_{20}	V_{30}	V_{40}
1	0	2.13±0.830	3.66±2.990	4.53±3.450
2	0	11.73±14.94	15.08±19.78	19.40±23.92
3	0	8.08±9.120	15.45±7.630	19.53±9.610
4	0.39±0.68	12.33±9.980	18.03±8.790	21.55±8.120

Table 3: Comparison of small bowel volume according to difference of each group unit: cc

OARs volume (group)	Bladder V_{10}	V_{20}	V_{30}	V_{40}
1	1.11±1.30	2.19±1.820	2.55±2.250	2.75±2.550
2	1.19±1.82	16.22±24.36	17.67±25.30	18.49±26.37
3	0.73±0.86	7.13±5.380	15.26±14.97	10.77±7.920
4	18.38±17.0	11.45±1.690	23.67±20.79	36.17±31.70

DISCUSSION

This study investigated the correlation between the error in the position of CRC patients during radiotherapy and BMI. The control group of patients with high BMI showed high position error. Another study also showed that the error in position increased by the difference in BMI in case of the radiotherapy of prostatic cancer patients using CT (Wong *et al*., 2009). Several other studies mentioned that the only way to reduce the position error in relation to BMI in the case of radiotherapy of head and neck cancer patients and lung cancer patients is to use an appropriate fixture (Johansen *et al*., 2008; Santanam *et al*., 2008).

A recent study on the correlation between position during radiotherapy and BMI showed that higher BMI increased the error in the position of endometrial cancer patients during radiotherapy and the error in the X, Y and Z axes more than doubled for the patients with high BMI compared to the patients with normal BMI (Lingareddy *et al*., 1997). As a way to reduce positioning error, the authors suggested the use of alpha cradle and Vac-loc bags to fix the patients in place. It was considered that only the use of such fixtures can reduce the error. This study discussed the error that occurs during radiotherapy of CRC patients.

CONCLUSION

Generally, obesity is denoted by a BMI of 23 kg/m^2. However, the present results of analysis of position error of CRC patients, repositioning by altering the method of positioning according to the patients BMI. For patients whose BMI is higher than 24 kg/m^2, the belly board should not be used just for patients with an ostomy. This is based on results with rectal cancer patients with ostomy for whom the belly board minimizes movement, allowing optimum position without unnecessary dose on normal tissues during radiotherapy. This is important, since patients with a BMI $\geq$24 kg/m^2 can move their bodies significantly when breathing.

LIMITATIONS

One limitation of this study is that the images from the treatment could not be checked daily and that the number of images taken and the number of target group were limited. The other limitation is the small number of subjects which obviated statistical analysis. The significance of this study is that it observed the position of rectal cancer patients and assessed the dose on the normal organs of small intestines and bladder in regard to BMI.

REFERENCES

Jemal, A., R. Siegel, E. Ward, Y. Hao, J. Xu, T. Murray and M.J. Thun, 2008. Cancer statistics, 2008. CA: Cancer J. Clin., 58: 71-96.

Johansen, J., A. Bertelsen, C.R. Hansen, J. Westberg and O. Hansen *et al*., 2008. Set-up errors in patients undergoing image guided radiation treatment: Relationship to body mass index and weight loss. Acta Oncologica, 47: 1454-1458.

Jung, K.W., Y.J. Won, H.J. Kong, C.M. Oh and H.G. Seo *et al*., 2013. Cancer statistics in Korea: Incidence, mortality, survival and prevalence in 2010. Cancer Res. Treat. Off. J. Korean Cancer Assoc., 45: 1-14.

Kim, D.M., C.W. Ahn and S.Y. Nam, 2005. Prevalence of obesity in Korea. Obesity Rev., 6: 117-121.

Lingareddy, V., N.R. Ahmad and M. Mohiuddin, 1997. Palliative reirradiation for recurrent rectal cancer. Intl. J. Radiat. Oncol. Biol. Phys., 38: 785-790.

Marmot, M., T. Atinmo, T. Byers, J. Chen and T. Hirohata *et al*., 2007. Food, Nutrition, Physical Activity and the Prevention of Cancer: A Global perspective. American Institute for Cancer Research, Washington, DC., ISBN-13: 9780972252225.

Meyerhardt, J.A., E.L. Giovannucci, M.D. Holmes, A.T. Chan and J.A. Chan *et al*., 2006. Physical activity and survival after colorectal cancer diagnosis. J. Clin. Oncol., 24: 3527-3534.

Santanam, L., J. Esthappan, S. Mutic, E.E. Klein and S.M. Goddu *et al*., 2008. Estimation of setup uncertainty using planar and MVCT imaging for gynecologic malignancies. Intl. J. Radiat. Oncol. Biol. Phys., 71: 1511-1517.

Shim, J.G., H.R. Jung, J.M. Seo, B.S. Park and J.Y. Jang *et al*., 2013. Analysis of body mass index on set up errors rectal cancer in radiotherapy. J. Korea Contents Assoc., 13: 412-418.

Simkens, L.H., M. Koopman, L . Mol, G.J. Veldhuis and D.T.B. SHuinink *et al*., 2011. Influence of body mass index on outcome in advanced colorectal cancer patients receiving chemotherapy with or without targeted therapy. Eur. J. Cancer, 47: 2560-2567.

WHO., 2009. Global health risks: Mortality and burden of disease attributable to selected major risks. World Health Organization, Geneva, Switzerland.

Wong, J.R., Z. Gao, S. Merrick, P. Wilson and M. Uematsu *et al*., 2009. Potential for higher treatment failure in obese patients: Correlation of elevated body mass index and increased daily prostate deviations from the radiation beam isocenters in an analysis of 1,465 computed tomographic images. Intl. J. Radiat. Oncol. Biol. Phys., 75: 49-55.

Yoon, S.M., 2005. Postoperative adjuvant fluorouracil based chemotherapy combined with RT for rectal cancer. J. Korean Soc. Ther. Radiol. Oncol., 23: S150-150.