Single- versus Multi-computed Tomography Simulation for High-dose-rate Postoperative Gynecological Intracavitary Brachytherapy

Angeliki Douvara, Nikolaos Kollaros, Georgios Patatoukas, Marina Chalkia, Efrosini Kypraiou[1], Nikolaos Trogkanis[1], Vassileios Kouloulias[1], Kalliopi Platoni

Second Department of Radiology, Medical Physics Unit, Medical School, National and Kapodistrian University of Athens, Attikon University Hospital, Athens, Greece, [1]Second Department of Radiology, Radiation Oncology Unit, Medical School, National and Kapodistrian University of Athens, Attikon University Hospital, Athens, Greece

Abstract

Introduction: This study aimed to investigate whether there is a dosimetric difference of implementing single instead of multi-computed tomography (CT) simulation treatment planning for high-dose-rate postoperative gynecological intracavitary brachytherapy (BT). **Materials and Methods:** Eighty patients were registered in the study. They received three BT fractions of 7 Gy/week (three CTs, three original plans). The organs at risk (OAR), the rectal wall, and the clinical target volume (CTV) were delineated. The delivered doses for the 2cc of OARs (D_{2cc}), 1cc of rectal wall (D_{1cc}), as well as for the 90% and 100% of CTV volume ($D_{CTV90\%}$, $D_{CTV100\%}$) were evaluated. To evaluate the values of the above parameters if the single-CT-simulation method has been chosen, the time of the first treatment plan was corrected for the decay and applied as the second and third CT, retrospectively, creating the next fractions (two revised plans). **Results:** No statistically significant ($P > 0.05$) differences were found between the original and revised plans for the OARs and CTV. However, for the single-CT-simulation method, it was noted that the dose constraints for the total rectal dose were exceeded in some cases (36.3%). **Conclusion:** The fact that rectal dose constraints were exceeded in 1/3 of patients with the single-CT-simulation method is dosimetrically significant.

Keywords: High-dose rate, intracavitary brachytherapy, single- versus multi-computed tomography simulation

Received on: 03-10-2023 **Review completed on:** 27-01-2024 **Accepted on:** 29-01-2024 **Published on:** 30-03-2024

Introduction

Brachytherapy (BT) is a particularly powerful approach for the treatment of gynecological malignancies. BT is often combined with previous surgery to remove the target, with chemotherapy, and with external beam radiotherapy (EBRT), depending on the stage of the disease. Postoperative intracavitary BT (ICBT) may reduce the risk of local recurrence.[1] High-dose-rate (HDR) ICBT is widely used due to its logistical benefits against the low dose rate.[2] The rapid dose falloff with distance has a decisive role in BT treatment. Therefore, the proper applicator placement, the clinical target volume (CTV), and organs at risk (OAR) delineation are the most important steps to avoid target overdosing/underdosing.[3] The GEC-ESTRO[4,5] and ABS[6] proposed the concept of three-dimensional (3D) image-based BT for the improvement of the treatment plan. Dose constraints and recommendations by ABS/ GYN GEC-ESTRO were compiled in a way that total EQD_2 doses (including external beam radiotherapy and brachytherapy) remained below 75 Gy for the rectum and the sigmoid and 90 Gy for the bladder. The doses are in terms of a 2 Gy equivalent, EQD_2, using $\alpha/\beta = 10$ for the CTV and $\alpha/\beta = 3$ for the OARs. Computed tomography (CT) scan is the most common imaging modality used in BT worldwide due to the high availability of CT scanners in most of the radiation oncology centers.[7]

In a postoperative BT treatment, some dosimetric studies have shown little benefits using image-based planning before

Access this article online

Quick Response Code:

Website: www.jmp.org.in

DOI: 10.4103/jmp.jmp_130_23

Address for correspondence: Ms. Angeliki Douvara, Second Department of Radiology, Medical Physics Unit, Medical School, National and Kapodistrian University of Athens, Attikon University Hospital, Rimini 1, 124 62 Athens, Greece. E-mail: aggelikhdouv@hotmail.com

How to cite this article: Douvara A, Kollaros N, Patatoukas G, Chalkia M, Kypraiou E, Trogkanis N, *et al*. Single- versus multi-computed tomography simulation for high-dose-rate postoperative gynecological intracavitary brachytherapy. J Med Phys 2024;49:6-11.

each fraction.[8-10] The International Commission on Radiation Units and Measurements in its report (ICRU Report 89) recommended replanning, based on 3D imaging, in each fraction of the BT process.[11] However, several factors, such as human resources availability, time restriction, CT scanner accessibility, and patients' specific needs, could lead to single-CT simulation only before the first fraction. The application of this single-CT method is adopted by several clinics around the world.[12]

This study was completed in a significantly higher number of patients (80 patients) than the studies of Yadav *et al*.,[8] Mobit *et al*.,[9] and Davidson *et al*.[10] with 38, 15, and 27 patients, respectively.

The purpose of the present study was to compare, analyze, and reach a conclusion about the use of single- versus multi-CT-based treatment plan for postoperative gynecological HDR ICBT. Through this analysis, the question of whether it is necessary to have a CT scan before each BT fraction is addressed.

Materials and Methods

Two treatment planning methods were compared:

- Multi-CT-simulation method: Treatment planning based on a CT simulation scan before each fraction of BT [Figure 1a]. Three original plans were created: Plan 1, Plan 2, and Plan 3 for three CTs, respectively
- Single-CT-simulation method: Treatment planning based on the CT simulation scan of the first fraction. Retrospectively and only for the purposes of the study, the first CT-simulation scan was implemented to the 2nd and 3rd fraction by simply correcting the decay time [Figure 1b]. Two revised plans were created, Plan2R and Plan3R.

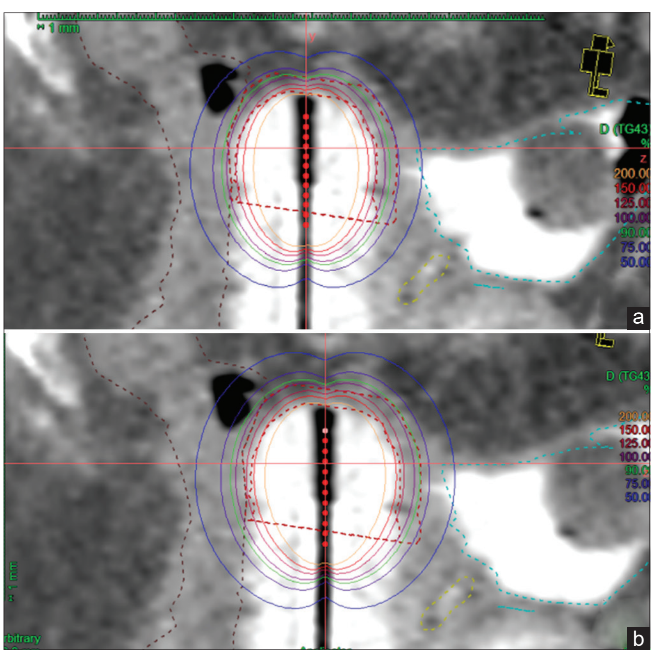

Figure 1: Isodose curves of a patient's plan. (a) Original plan, (b) Revised plan

Eighty patients were enrolled in the study; each of them received a total dose of 21 Gy (7 Gy/fraction × 3 fractions on weekly intervals), based on a CT simulation. Some of the patients had also received a dose of 46–50 Gy (2 Gy per fraction for 23–25 fractions over 5 weeks) by EBRT. The ages of the patients ranged from 45 to 84 years old. Before the BT treatment, patients were informed of the entire process of image-based BT and were asked to provide their consent. For all the CT simulations, OAR and the CTV were delineated.

Before the CT scan, the applicator was inserted into the patient's vagina under local anesthesia using all aseptic precautions. The diameters of the applicator (CT/MR Segmented Vaginal Applicator Set/SETM1406) were 20, 25, 30, and 35 mm, depending on the specific anatomic features of each patient. A gauge soaked in povidone-iodine was used on the vagina to hold and prevent the applicator assembly from slipping. A Foley catheter was inserted into the urinary bladder and a balloon was inflated with radio-opaque solution. Before the CT scan, a rectal tube was temporarily inserted into the rectum to remove any excess gas.

3D images from the bladder to mid-thigh were acquired on a CT simulator (General Electric Medical Systems Hellas CT HI SPEED/I) with a slice thickness of 2 mm. After the completion of the CT procedure, the patient's dataset was transferred to the BT treatment planning system (Elekta Oncentra Brachy Image-guided 3D Treatment Planning system, Elekta AB, Stockholm, Sweden, version 4.5.3). Volumetric delineation of the CTV and OARs (bladder, rectum, and sigmoid) was performed by a radiation oncologist. The applicator was then reconstructed, and the dose was calculated by a medical physicist according to the guidelines of ABS/GYN GEC–ESTRO.[4-6] Using dose-volume histograms, the medical physicist calculated the position and dwell time that the source will remain in each position using the Oncentra software (Elekta Oncentra Brachy Image-guided 3D Treatment Planning system, version 4.5.3).[13] The doses for the 2cc volume of the OARs were evaluated as well as the CTV that received 100% and 90% of the prescribed dose. The dose constraints and the relevant recommendations by ABS/GYN GEC–ESTRO were compiled in a way that the total equivalent dose at 2 Gy (EQD_2) remained below 75 Gy for the rectum and the sigmoid and below 90 Gy for the bladder (including EBRT and BT).[14] The calculated doses from TPS were delivered to the patient using a remote afterloading machine (Elekta Nucletron MicroSelectron HDR BT Afterloader Treatment Delivery, afterloader ^{192}Ir).

For both methods, single- and multi-CT scan simulation, the OARs and CTV doses of the three fractions were compared. For the bladder, sigmoid, and rectum, the doses at 2cc volume for the original and the revised plans were calculated (D_{bla2cc}, $D_{sigm2cc}$, D_{rec2cc}). The same procedure was performed for the CTV of 100% and 90% dose values ($D_{CTV100\%}$, $D_{CTV90\%}$).

Furthermore, for bladder, sigmoid, and rectum volume of 2cc, the total absorbed doses of the fractions for the original and for the revised plans were summarized and compared to the dose constraints, which for this type of BT treatment, are: for the bladder 2010 cGy (670 cGy ×3 fractions) and for the rectum and sigmoid 1590 cGy (530 cGy ×3 fractions), according to EQD_2 using $\alpha/\beta = 3$.[4-6]

In this study, the dose absorbed by the rectal wall was evaluated. The volume of interest of the rectal wall was considered to be 1cc since such volumetric estimation offers a sufficient targeted and precise dose calculation. Two new structures were contoured using a 1 mm margin inner and outer from the initial rectum volume, and the rectal wall was considered the structure resulting from the subtraction of these new volumes. The estimation was performed for all of the 80 patients of the study. The rectal wall estimation was carried out for both single- and multi-CT simulation. The doses of 1cc volume for the rectal wall ($D_{wrec1cc}$) among the fractions were estimated and compared.

The statistical software package SPSS (SPSS Statistics, version 28.0 software, IBM, Armonk, NY, USA) and, more specifically, the paired samples *t*-test were used to examine whether there are statistically significant differences of the doses evaluated for the bladder, rectum, rectal wall, sigmoid, and CTV for the two different methodologies.

Results

Revised treatment plans compared with original plans for all fractions. The statistical significance of the dosimetric differences between related fractions for the OARs and the target. The dose differences of none of the dose parameters have been found significant ($P > 0.05$).

Dosimetric analysis for the estimated rectal wall dose of 1cc volume (Dwrec1cc), indicates no statistically significant dose differences ($P > 0.05$) between the original and revised plans. These results are shown in Table 1. Furthermore, the dose received by the 1cc of the rectal wall was systematically higher than that of the 1cc rectum volume for all plans (original and revised) [Table 1].

Table 1: The *P* values for 2cc volumes of rectum, bladder, sigmoid, clinical target volume, and rectal wall between the fractions of the original and revised plans

Parameter	**P* (fr2–2R)	**P* (fr3–3R)
D_{rec2cc}	0.085	0.150
D_{bla2cc}	0.373	0.140
$D_{sigm2cc}$	0.616	0.560
$D_{CTV90\%}$	0.401	0.535
$D_{CTV100\%}$	0.554	0.849
$D_{wrec1cc}$	0.094	0.069

**P* (fr2–2R): *P* value related to fraction 2 for the original and revised plans, **P* (fr3–3R): *P* value related to fraction 3 for the original and revised plans. $D_{wrec1cc}$: Rectal wall dose of 1cc volume

In 29 of 80 patients, it was observed that the total rectal dose of 2cc volume (from 3 fractions) with the single-CT method (revised plans) was higher from the dose constraints [Table 2]. The rectum constraint for the whole BT procedure is 1590 cGy (530 cGy ×3 fractions). The excess dose range was from 0.86% to 18.75% with a mean dose difference of 4.9%. The bladder and sigmoid did not present overdose. The percentage of patients who exceeded the theoretical limit of 75 Gy for rectal dose was 36.3%. This dosimetric theoretical limit resulted from the BT treatment, as well as from the assumption that all patients had also received a dose of EBRT.[4-6] The results are shown in Table 3.

Discussion

In the present study, the question of replanning before each fraction for ICBT based on 3D CT-simulation images was addressed. The multi-CT-simulation method has been implemented for a group of 80 patients based on the protocol of our hospital. No relevant studies with a higher number of patients have been reported. The results of the single-CT-simulation method have been assessed by retrospectively implementing the first CT simulation plan and revising it for the second and third fractions by correcting only the decay time.

The analysis on treatment planning comparison of doses for the OARs and CTV between the original and revised plans showed no statistically significant differences for the majority of the parameters studied.

Moreover, regarding the dose received by the 1cc of the rectal wall, this was systematically higher than that of the 1cc rectum volume for all plans (original and revised). This could be justified by the fact that the rectal wall is at a closer distance from the source. No statistically significant dose differences ($P > 0.05$) between the original and revised plans were found.

Regarding the total rectal dose of 2cc volume, it was calculated that for the single CT-simulation method in the 3 fractions, the dose constraint of 75 Gy was exceeded. The excess dose received ranges from 0.86% to 18.75% with a mean value of 4.9% in 36.3% of patients. The lower value of 0.86% (0.1 Gy) for the rectum is related to a patient who has not received EBRT previously, and thus, this dose excess may be considered insignificant. Furthermore, the upper dose excess of 18.75% (3 Gy) is related with a patient who had not undergone EBRT. In this study, not all patients who exceeded the dose constraints had undergone EBRT. The mean value of 4.9% (0.8 Gy) with or without EBRT is a clinical decision whether it is considered important. A dose excess of 5% is considered acceptable, according to the study of Yadav *et al*.[8] In this study, only five patients with preceded EBRT had rectal overdose >5% which corresponds to approximately 2 Gy dose. Yadav *et al*.[8] analyzed the plans of 38 patients using CT image-based BT. They found that the dosimetric deviation for the OARs and target due to the use of

Table 2: Total actual absorbed doses of 3 brachytherapy fractions for 2cc volumes of rectum, bladder, sigmoid, clinical target volume, and rectal wall for multi-computed tomography method (Method 1) and for single-computed tomography method (Method 2)

Total absorbed doses in 3BT fractions											
D_{rec2cc}		D_{bla2cc}		$D_{sigm2cc}$		$D_{CTV90\%}$		$D_{CTV100\%}$		$D_{wrec1cc}$	
Method 1	Method 2	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
1589.89	1518.13	1160.95	1083.21	290.3	306.87	1751.08	1670.35	1300.35	1265.18	1866	1897.7
1497.56	1606.58	1174.81	1251.06	338.05	320.26	1832.94	1947.65	1409.4	1476.3	1883.7	1858.9
1588.42	1652.33	1368.77	1429.42	298.57	289.34	1885.12	1943.74	1421.97	1371.44	1918.4	2080.1
1534.13	1741.49	1165.99	1294.84	309.44	296.65	2013.54	2219.45	1582.99	1804.66	2012.1	1844.3
1583.83	1511.82	1013.12	924.8	363.01	396.44	1726.38	1634.34	1256.35	1233.74	1882.1	1815.4
1605.91	1537.93	1070.89	1019.16	651.89	682.08	1765.07	1684.57	1272.42	1219.48	1775.8	1889.6
1515.72	1403.78	902.21	878.94	182.74	188.5	1876.44	1765.24	1394.42	1280.22	1821.6	1707.2
1586.68	1636.13	1389.96	1465.27	346.35	336.76	1884.23	1969.07	1398.34	1427.16	1974.7	1898.1
1588.97	1707.95	509.61	532.11	176.22	172.2	1696.84	1740.71	1324.86	1285.87	1990.5	2001.4
1565.45	1671.02	1507.81	1655.61	657.57	581.84	1945.19	2096.04	1466.55	1503.71	1916.5	1900.2
1556.88	1439.46	1612.02	1496.2	892.71	921.92	2039.04	1894.36	1552.13	1390.18	1823.9	1724.2
1470.06	1611.87	983.93	1137.43	190.51	174.14	2130.65	2307.11	1593.45	1594.68	1974	1697.9
874.34	921.3	346.87	362.34	104.72	95.62	2098.41	2156.31	1588.3	1550.61	1038.6	988.67
1421.99	1327.29	392.36	380.42	138.85	141.17	2604.66	2612.75	2023.65	2075.94	1510.4	1652.1
1602.38	1646.16	1431.24	1449.33	690.78	702.41	1849.35	1899.51	1306.84	1399.19	1912.8	1912.1
1309.71	1319.37	1452.86	1491.2	376.79	386.78	2041.9	2079.27	1514.99	1506.68	1578.9	1383
1589.65	1477.26	1308.99	1263.97	245.17	245.35	1869.06	1734.62	1379.46	1208.83	1803	1845.3
1589.12	1533.66	959.23	953.82	316.89	298.15	1737.74	1695.11	1227.15	1124.72	1931.8	1908.5
1591.84	1715.02	695.64	745.47	483.62	468.29	1774.09	1883.07	1176.26	1241.01	2000.9	1974
1556.81	1603.66	1735.64	1804.22	639.94	629.66	2054.59	2133.54	1605.64	1639.62	1845.1	1862.8
1583.05	1576.9	829.97	839.35	337.86	329.76	1801.01	1814.89	1424.55	1414.12	1850.5	1923.4
1587.73	1603.61	1322.16	1338.94	147.2	147.84	2038.37	2070.54	1651.71	1643.37	1819.3	1874.6
1582.1	1651.81	1215.82	1255.9	335.52	341.31	1922.27	2005.68	1452.25	1514.78	1912.3	1898.9
1578.3	1557.01	932.9	926.18	298.39	317.82	1735.43	1702.07	1287.59	1259.51	1870.1	1809.4
1588.03	1557.96	1096.13	1070.84	133.62	132.24	1874.24	1834.28	1456.31	1500.97	1973.4	1841.4
1564.8	1454.85	889.4	813.71	399.12	410.65	1789.21	1658.4	1386.94	1325.09	1820.2	1765.1
1072.81	1129.39	341.67	358.43	1176.56	1074.4	1992.37	2129.39	1529.3	1643.03	1261.6	1253.3
1563.36	1471.45	1441.38	1342.68	756.17	839.68	1855.85	1714.56	1492.53	1379.61	1816.2	1906.1
1530.36	1637.17	1444.08	1567.87	217.49	208.75	1839.81	1944.99	1356.16	1408.85	1881.5	1891.3
1590.02	1514.67	1337.8	1249.14	646.31	684.7	1763.27	1618.07	1419.48	1240.68	1829.6	1845.1
1588.99	1675.11	1064.09	1142.67	429.81	460.63	1840.59	1915.24	1357.42	1425.88	2046.9	1865.2
1503.23	1538.75	1627.6	1596.32	531.04	518.03	1983.47	1932.53	1476	1458.57	1686.3	1829.6
1561.37	1491.99	1745.52	1661.12	514.75	528	2261.75	2212.97	1560.84	1533.32	1842.2	1789.5
1591.82	1686.97	1057.63	1114.36	366.6	361.05	1847.09	1953.99	1421.63	1476.75	1992.2	2011.4
1571.04	1495.94	1232.69	1194.96	788.16	686.06	1913.76	1802.82	1485.5	1358.48	1759.3	1829.1
1584.1	1510.69	1751.21	1959.9	147.99	157.42	2110.47	1993.87	1659.15	1517.32	1812.8	1819
1584.81	1662.02	1480.98	1579.34	742.19	738.32	1938.22	2060.32	1482.5	1545.76	1957.3	1913.6
1589.15	1435.32	1060.97	927.32	245.91	244.52	1920.41	1734.69	1533.02	1361.34	1775.7	1749.9
1575.97	1663.76	1567.74	1589.21	334.86	345.13	2056.2	2125.96	1552.69	1669.62	1921.1	1848.3
1527.92	1540.96	822.84	823.48	403.78	402.43	2008.75	2048.63	1499.6	1558.68	1811.5	1817
1470.98	1455.98	1456.02	1431.79	172.62	173.93	1812.43	1756.21	1406.31	1325.89	1480.3	1996
1519.49	1560.46	1383.06	1395.16	826.56	846.64	1935.56	1984.71	1397.54	1434.31	1819.1	1778.2
1589.33	1653.01	922.27	912.53	243.36	249.2	1895.83	1957.45	1505	1617.1	1869.3	1971
1494.27	1376.35	1298.47	1228.98	169.44	162.56	1983.09	1844.93	1458.13	1242.96	1573.6	1796.7
1589.66	1513.91	655.21	630.43	771.43	783.07	1714.17	1659.27	1278.34	1291.68	1845.6	1817
1463.69	1549.54	670.91	691.89	210.33	218.91	1874.79	1979.15	1444.56	1534.18	1701.1	1907.5
1587.05	1536.84	1048.88	942.72	399.49	268.76	1655.6	1594.17	1280.75	1250.88	1841.1	1556.2
1350.13	1320.83	1436.03	1429.17	195.65	190.96	2076.78	2065.46	1704.8	1669.89	1529	1495.8
1587	1548.25	1059.65	1028.41	460.05	451.27	1791.69	1754.02	1298.45	1279.79	1869.7	1877.3

Contd...

Table 2: Contd...

Total absorbed doses in 3BT fractions											
D_{rec2cc}		D_{bla2cc}		$D_{sigm2cc}$		$D_{CTV90\%}$		$D_{CTV100\%}$		$D_{wrec1cc}$	
Method 1	Method 2	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
1430.27	1888.13	1170.2	1858.89	805.41	849.33	1923.91	2086.32	1407.4	1190.61	2034.6	1986
1528.47	1574.43	567.19	593.77	482.63	566.99	2020.62	2071.37	1487.4	1483.38	1815.5	1806.4
1597.95	1642.79	1424.32	1468	925.85	841.03	1962.96	2014.03	1496.55	1533.27	1856.4	1963.3
1258.59	1308.81	1402.81	1335.05	729.9	691.75	2006.62	1928.5	1567.8	1546.83	1515.2	1432.3
1591.24	1537.22	1049.52	982.79	409.91	379.97	1849.96	1720	1452.56	1408.6	1839.8	1926.6
1538.36	1680.65	1189.41	1271.89	196.92	198.14	1811.89	1981.12	1351.13	1453.17	2058.5	1800.1
1589.14	1751.28	1036.46	1128.3	756.57	731.61	1887.82	2080.83	1460.09	1558.73	1946.9	1930.7
1590.77	1625.95	1060.93	1136.21	830.86	807.68	1826.91	1883.8	1405.77	1423.48	1970.2	1906.9
1386.33	1386.89	1498.33	1482.84	166.18	163.22	2099.7	2100.46	1601.84	1606.92	1701.7	1478.6
1610.86	1720.2	1321.72	1404.09	367.15	362.26	1808.01	1938.8	1483.17	1591.33	2010.1	1986.8
1438.18	1494.79	1612.88	1673.26	336.15	361.11	2013.82	2088.83	1546.33	1636.3	1736.5	1566.9
1588.01	1651.22	587.12	604.86	337.82	349.1	1747.04	1841.95	1184.86	1284.57	1963.4	1957.2
1565.82	1567.64	1538.04	1624.23	284.58	294.97	2037.29	2036.46	1560.59	1573.26	1884	1869.8
1584.88	1655.67	857.72	848.13	148.76	146.25	1755.76	1589.9	1247.26	1103.58	1956.6	1972.5
1546.29	1479.36	1725.11	1634.02	360.69	357.9	2037.25	1941.55	1554.24	1469.51	1722.3	1877.9
1397.05	1317.49	1172.18	1133.5	646.75	683.13	2050.85	1955.62	1534.81	1402.11	1564	1599.4
1558.16	1630.65	996.65	1021.07	178.97	175.6	2002.52	2091.75	1539.53	1523.33	1871.3	1921.2
1579.51	1728.82	1412.93	1502.78	165.69	166.49	1874.2	2023.65	1387.31	1553.78	1934.9	2001.3
1418.2	1426.54	1097.69	1077.43	590.23	631.59	1949.59	1910.05	1491.92	1555.55	1690.7	1582.8
1528.47	1546	410.32	421.41	413.48	416.16	1829.43	1842.84	1259.72	1296.84	1876.8	1753.3
1476.93	1488.88	483.7	493.66	230.64	234.31	2053.08	1993.12	1666.41	1471.49	1718.2	1708.8
1447.73	1441.2	1471.07	1404.93	1170.45	1132.41	1941.73	1850.14	1444.47	1409.64	1570.8	1799.8
1375.73	1357.77	1235.33	1212.02	140.03	144.74	1974.2	1942.35	1487.31	1526.09	1638.5	1540.4
1266.39	1259.22	815.94	791.46	394.74	400.58	2043.46	2028.71	1594.29	1623.19	1403.3	1467.8
1298.32	1478.37	1425.29	1522.18	305.74	293.43	2094.35	2273.88	1540.01	1763.33	1406.7	1747.9
1591.78	1480.43	1052.28	957.08	253.85	249.43	1800.3	1717.09	1380.04	1379.46	1801.2	1807.7
1560.44	1567.73	1489.42	1425.49	431.92	444.29	1944.66	1970.87	1493.18	1593.35	1798.7	1874.9
1580.51	1642.67	599.22	620.39			1971.58	2037.25	1553.9	1587.06	1984.7	1858.2
1551.39	1570.22	1446.63	1473.37	*	*	2013.79	2038.2	1460.72	1491.27	1888.2	1922.6
1586.54	1537.91	1121.74	1077.49	*	*	1933.68	1868.01	1561.37	1541.45	1862.6	1867.8
1294.51	1275.46	1219.63	1234.51	*	*	1923.26	1956.91	1520.52	1510.63	1388.1	1602.5

*$D_{sigm2cc}$: No results for four patients due to lack of volumetric delineation by radiation oncologist. CTV: Clinical target volume, BT: Brachytherapy

Table 3: Analysis of D_{rec2cc} for single computed tomography-simulation method

Percentage of patients with absorbed dose >75 Gy (BT + EBRT)	Percentage of dose excess range (actual dose–theoretical dose)	Mean percentage of dose excess (actual dose–theoretical dose)
36.3	0.86–18.75	4.9

BT: Brachytherapy, EBRT: External beam radiotherapy

the original plan instead of revised plans for each fraction is within the acceptable limits required for clinical radiotherapy. They recommended the replanning method for each fraction, and the use of a revised plan should be attempted only when there are limited resources. Mobit *et al*.[9] using revised plans for HDR tandem and ovoid leads to reduced doses of the OARs, except for the bladder dose which was almost always higher. They suggested using the multi-CT method reducing any geometric miss of the target volume. Davidson *et al*.[10] recommended that a CT simulation should be tailored for each fraction. They found that a single-CT method can result in a significant increase to OAR doses for tandem and ring applicators and unpredictable OAR doses for tandem and ovoid applicators. Zhou *et al*.[15] analyzed data of the replanning method before each fraction, against the single method, answering that the treatment replanning should not be utilized on a routine basis. The findings of the present study are in accordance with the above publications, except the study of Zhou *et al*.,[15] concerning dosimetric differences in OARs and CTV between original and revised plans. Although the dosimetric differences for this study for OARs and CTV between the two methods were not statistically significant, the increased rectal dose in 36.3% of patients raises concerns about adopting single-CT method. Furthermore, the use of single- or multi-CT method depends on several factors such as lack of staff, time restriction, CT scanner availability, and patients' specific needs. Therefore, the choice of method could be a medical/clinical decision.

The present study refers to the specifications and the equipment of the particular department (University General Hospital "Attikon"). Thus, a general conclusion is not possible.

The perspectives of this study are the urethra dose estimation and the optimal CTV coverage: dose homogeneity index, dose nonuniformity ratio, coverage index, overdose volume index, and conformity index.

Conclusions

The results of the present study have shown no statistically significant difference for the dose levels at OAR and CTV between the single- and multi-CT simulation methods used for BT. However, in 36.3% of the patients, the total rectum doses exceeded the dose constraints in the case of the single-CT simulation. This overdosage of the rectum was considered dosimetrically significant.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Griffith T, Nwachukwu C, Albuquerque K, Gaffney D. The role for vaginal cuff brachytherapy boost after external beam radiation therapy in endometrial cancer. Brachytherapy 2022;21:177-85.
2. Small W Jr., Erickson B, Kwakwa F. American brachytherapy society survey regarding practice patterns of postoperative irradiation for endometrial cancer: Current status of vaginal brachytherapy. Int J Radiat Oncol Biol Phys 2005;63:1502-7.
3. Kim RY, Meyer JT, Spencer SA, Meredith RF, Jennelle RL, Salter MM. Major geometric variations between intracavitary applications in carcinoma of the cervix: High dose rate versus. Low dose rate. Int J Radiat Oncol Biol Phys 1996;35:1035-8.
4. Haie-Meder C, Pötter R, Van Limbergen E, Briot E, De Brabandere M, Dimopoulos J, *et al*. Recommendations from gynaecological (GYN) GEC-ESTRO working Group (I): Concepts and terms in 3D image based 3D treatment planning in cervix cancer brachytherapy with emphasis on MRI assessment of GTV and CTV. Radiother Oncol 2005;74:235-45.
5. Pötter R, Haie-Meder C, Van Limbergen E, Barillot I, De Brabandere M, Dimopoulos J, *et al*. Recommendations from gynaecological (GYN) GEC ESTRO working group (II): Concepts and terms in 3D image-based treatment planning in cervix cancer brachytherapy-3D dose volume parameters and aspects of 3D image-based anatomy, radiation physics, radiobiology. Radiother Oncol 2006;78:67-77.
6. Nag S, Cardenes H, Chang S, Das IJ, Erickson B, Ibbott GS, *et al*. Proposed guidelines for image-based intracavitary brachytherapy for cervical carcinoma: Report from image-guided brachytherapy working group. Int J Radiat Oncol Biol Phys 2004;60:1160-72.
7. Viswanathan AN, Creutzberg CL, Craighead P, McCormack M, Toita T, Narayan K, *et al*. International brachytherapy practice patterns: A survey of the gynecologic cancer intergroup (GCIG). Int J Radiat Oncol Biol Phys 2012;82:250-5.
8. Yadav S, Singh OP, Choudhary S, Saroj DK, Maurya AK, Yogi V. Interfraction physical dose variations in high-dose-rate brachytherapy for carcinoma cervix based on computed tomography image dataset to find the compatibility of the first fraction plan to treat successive fractions. J Cancer Res Ther 2019;15:1304-8.
9. Mobit P, Baird MC, Kanakamedala MR, Mourad WF, Vijayakumar S, Yang CC. 3D image-based customized treatment planning versus standard plans for cervix cancer HDR brachytherapy. Int J Radiat Oncol Biol Phys 2010;78:S408.
10. Davidson MT, Yuen J, D'Souza DP, Batchelar DL. Image-guided cervix high-dose-rate brachytherapy treatment planning: Does custom computed tomography planning for each insertion provide better conformal avoidance of organs at risk? Brachytherapy 2008;7:37-42.
11. ICRU Report 89, Prescribing, recording, and reporting brachytherapy for cancer of the cervix. J ICRU 2013;13:NP.
12. International Atomic Energy Agency (IAEA). Setting up a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects; 2008.
13. Yang J. Oncentra brachytherapy planning system. Med Dosim 2018;43:141-9.
14. Dumane VA, Yuan Y, Sheu RD, Gupta V. Computed tomography-based treatment planning for high-dose-rate brachytherapy using the tandem and ring applicator: Influence of applicator choice on organ dose and inter-fraction adaptive planning. J Contemp Brachytherapy 2017;9:279-86.
15. Zhou J, Prisciandaro J, Lee C, Schipper M, Eisbruch A, Jolly S. Single or multi-channel vaginal cuff high-dose-rate brachytherapy: Is replanning necessary prior to each fraction? Pract Radiat Oncol 2014;4:20-6.