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A Comprehensive Evaluation of an Emerging Technique of Low Dose Radiation Therapy(LDRT) of Osteoarthritis (OA)

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ABSTRACT

Purpose: Given the significant rise in patients receiving low dose radiation therapy (LDRT) of joint pains from osteoarthritis (OA), we evaluate this emerging treatment technique.

Methods: Since April of 2025, we accrued 132 patients (12 retreats) undertaking LDRT for a total of 169 Knees, 20 hips, 10 hands, 8 shoulders, and 1 ankle. We delineated joint deformed bones, articular cartilage, low-density effusion or lymphedema-lipedema-like tissues as the planning target volume (PTV). We used 3-mm thick skin as the common organs at risk (OAR). Other OARs are Lungs for shoulder, ganoids, GI/GU structures for the hip and fingernails for hands. Dose-volume histograms were exported for statistical analysis and doses from other joint fields and portal images were included for correlation with acute skin reactions and radiation-induced side effects.

Results: Standard AP/PA X-ray fields (PA-field only for hands with 0.5-cm bolus) provided acceptable target coverage but some knee joints had superior target missing by 1-4 cm; Most hips had medial marginal under dosing for edge-matching to the pelvic brim except two cases with inferior border missing; Two shoulders also has border missing. Five of ten hands had either partial ulna mass or distal interphalangeal (DIP) joint missing by blocking. Portal images of 1 MU open and 1 MU field had, average 5.6 MU per joint, added 5-cGy to the joint per image set. The hotspot dose to the skin, ganoids, bowel, rectum, bladder and lungs were 310, 30, 280, 30, 40, and 20-cGy, respectively.

Conclusion: We have identified that current AP/PA LDRT technique with some superior-border missing knees, occasional inferior-border missing for hips, shoulders and hands caused unacceptable low DVHs. Marginal underdosing occurred to the medial edge of hips. Knee PTV coverage could be significantly improved by superiorly shifting isocenter 1-2-cm; (2) CT based plan with defined PTVs and OARs could improve the coverage for all sites and not blocking nails if patients had DIP joint pains.

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INTRODUCTION

Chronic joint pains from osteoarthritis (OA) affects 32.5 millions of US adults which is more than 18.6 million cancer survivors. Some of them have chosen low dose radiation therapy (LDRT) after failure of other treatments for pain relief and improvement in mobility after treatment. However, so far, there is no cure from medications, physics therapy, LDRT, and surgery and future studies are required to unravel mechanisms and to explore the optimal dose and treatment technique of the "big" disease.

Current LDRT procedure uses AP/PA external beams with energy of 6X for small joints and 10X or higher for large joints, AP/PA fields (as shown in Fig.1), and immobilization techniques to deliver a dose of 3 Gy in 6 fractions (2-3 days per fraction) [1-2] to the target joint and its connective tissues. The planning target volume (PTV) and organs at risk (OARs) are not well defined for any OAs, and no actual dose and volume information to correlate with clinical outcomes.

Experiencing a sudden surge in patient volume and clinical interest, we are investigating factors such as age, side, PTV, OARs, and DVHs (dose-volume histograms) that may correlate with pain-response from LDRT of OAs among our patients.

METHODS AND MATERIALS

Based on recent discoveries of human periphery blood lymphocytes have higher radiosensitivity at low dose from 0.1 to 1 Gy and high cell killing rate with apoptosis at time of 2 to 3 days [3-4], as well as our knowledges of pains from inflammation, lymphedema and lipedema, we proposed to define the PTV to include the injured joint bones, articular cartilage and low-density effusion or lymphoedema-lipedema-like tissue connected to the joint. The PTV could extend >12 cm from the joint as shown in Fig. 2 for a left knee (PTV contours in Cyan) with low density tissue between the anterior muscles and the distal femoral shaft.
Skin of 3-mm-thick (5-mm is too thick for most joints) was defined as an OAR for the major concern of radiation-induced acute skin reaction and cancer. Bowel, rectum, bladder and ganoids were included for hips. Figure nails could be considered for the hands. Lungs was an OAR for shoulders. All contours of PTVs and OARs were shared for bilateral joint plans so that their plan sum would provide the total doses to the structures.

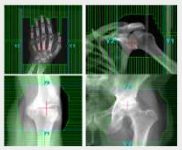

Figure 1 Fields for joints blocked nails, >2-cm margins, to the pelvis brim or lungs by MLC

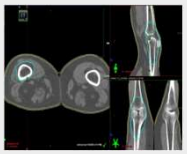

Figure 2. A left Knee with Lipedema-like tissue sup. extended 12 cm. 8 cm in the standard Knee AP/PA fields

RESULTS

1: Our patients underwent LDRT of OAs have ~2:1 ratio of females (85) to males (47) but balanced right and left joints and over 80% for the knees (Table 1). Almost all of patients had years-long, severe joint pains (in VAS of 10 before the treatment).

2. Table 2 listed the mean PTVs of 530 ± 90, 316 ± 157, 204 ± 55, 102 ± 23 and 245 cc for the knee, hip, shoulder, hand and ankle, respectively. Prescribed dose of 300-cGy with SD <7% had been achieved for PTVs if there were no missing from the AP/PA fields. Skin D2cc were 290, 250, 310, 280, and 260 cGy at the knee, hip, hand, shoulder, and ankle joints, respectively. Hands had high skin dose due to usage of 5-mm bolus and PA field only.

3: Some joints particularly for the retreated joints with large lipedema-like tissue around the joints would cause portioned missing associating with the low DVHs of their PTVs (Fig.3a-d). The marginal missing often occurred at the medial border with field edge matching to the pelvis brim for the hip. Major hand missing occurred at DIP joints and partially at the ulna mass from MLC block. Shoulder joint had inferior portion missing due to low density tissue extension (Fig.4). Thus, the field adjustment from CT simulation images is another key finding here.

Table 1. Information of OA Patients under LDRT

# of patients	132
# of Retreated Cases	12
Age range	45-91
BMI range	16-35
# of Male/Female	47/85
# of Right/Left Side	105/103
# of Knees	169
# of Hip Joints	20
# of Hands	10
# of Shoulders	8
# of Ankles	1

Table 2. Doses and Vaolumes for PTVs & OARs

169 Knees	average PTV	530±90
	PTV Dose	298±30
	Skin D2cc	285±10
10 Hnads	Average PTV	102±23
	PTV Dose	272±62
	Skin D2cc	309±16
8 Shoulders	Average PTV	204±55
	PTV Dose	297±10
	10%Lung Dose	12±7
	Skin D2cc	280±20
20 hips	Average PTV	316±157
	PTV Dose	291±18
	Average Gonad V	104±22
	Gonad mean D	9±6
	Skin D2cc	250±20
	Bowel D2cc	280±120

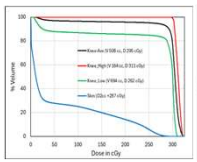

Figure 3a. DVHs of first 89 Knees

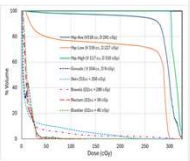

Fig. 3b. DVHs of 20 treated hips

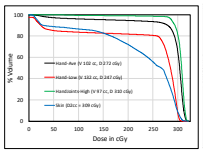

Figure 3c. DVHs of 0 treated hands

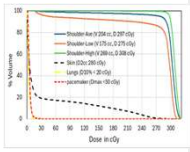

Figure 3d. DVHs of 8 Shoulders

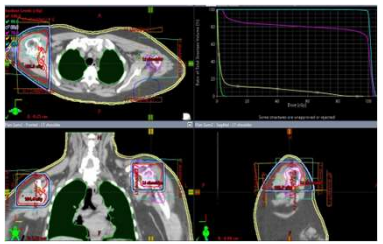

Figure 4. Example of inferior missing of a tissue-extended left shoulder vs 100% covered right shoulder in plan for 2nd Tx but Pt selected another Tx

DISCUSSION

Low-dose radiation therapy (LDRT) for osteoarthritis (OA) is a palliative treatment of chronic joint pain, aims to modulate joint inflammation rather than damage tissues. At recent ASTRO meetings, LDRT has emerged as a promising non-invasive option for medically inoperable patients or those seeking to delay joint replacement. However, people could not explain why up to 80% joint-pain response to very low dose of 50 cGy x 6 and some trials with inconsistent clinical results.

After abstract submission of our radiobiologic study (accepted by coming ASTRO annual meeting) and clinical investigations (presented here), we have just found a in-press and open assess article [5]. Which is an international expert consortium of 15 institutions with emphasizing of lacking PTV definition and provided practical guidance for the delineations of GTV, CTV and PTV in LDRT of OA. Coincidently, we have found similar results of more superior than inferior extension of PTV (and CTV) for the knee joint and possible interferer target extension of the shoulders (and hip) as presented from Figures 2, 3 and 4 of the article. Importantly, our study provided more detail information for the PTV, OARs and dose distribution (DVHs) information for over 132 patients and 206 joints.

CONCLUSIONS

1. This is the first detail dose-volume study of LDRT in OA for over 130 patients and 208 joints. All PTVs and OARs are retrospectively drawn on the standard plans using CT images. We have found significant missing of PTVs and high skin doses for some cases. Doses to other OARs are relatively low but varied with patients.
2. Out data strongly support the use of PTV for treatment planning to adjust current standard AP/PA fields with an isocenter at the midpoint of the joint space (or centrally within the pathological area) [5] and 2-cm margins beyond the bony structures since pathological tissues connected to the joint may extend more transversely and longer along the bone shaft than expected without checking CT and other diagnostic 3D images.
3. Technical improvement is possible if PTVs and OARs were defined. We have a systematic shift of isocenter superiorly by 1-2 cm for the knee joints in the late half of our patients for much better PTV coverage while using the standard AP/PA fields for knee joints.

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