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Case reports and case series

# Case report: Clinical workflow considerations for treating soft-tissue sarcoma on a 1.5-T MR-Linac

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ABSTRACT

We present specific issues that arose when using a 1.5-Tesla MR-Linac to treat a series of 4 soft-tissue sarcoma (STS) patients. These issues arose from the combination of typical STS attributes (long, off-axis target) and MR-Linac design-specific limitations on field size and patient positioning. Despite the availability of on-line plan adaptation, STS patients were more efficiently treated after workflow changes to improve patient selection and immobilization. Other issues arising from off-axis STS target locations: geometric distortion of MR images and patient-specific QA, are discussed.

## Introduction

Soft tissue sarcoma (STS) patients could benefit from adaptive magnetic resonance-guided radiation therapy (MRgRT). Substantial volume change has been reported for STS during treatment, which could be addressed with plan adaptation [1–3]. Online adaptation could be a potential solution to the setup challenges of STS, which have been addressed with a range of immobilization and image-guidance strategies [4].

When treating STS on the Unity (Elekta AB, Stockholm, Sweden) MR-linac (MRL), specific challenges may arise because of the device's design and the typical size and location of STS targets. STS patients often present with large lesions—one study of 1460 sarcoma patients found a mean lesion size at time of diagnosis of 10 cm [5]. With a CTV margin of up to 4 cm longitudinally [6], the radiation target volume for STS is often long and, because STS is most commonly found in the extremities, lateral [7]. We present four cases of STS treated on the Unity illustrating challenges and discuss strategies to mitigate them.

## Materials and Methods

### *Original workflow*

Prior to this patient series, eligibility to be treated on the MRL included consideration of the superior-inferior (SI) length of the planning target volume (PTV) with a 20-cm upper limit chosen, because the Unity's maximum field size in the SI direction is 22 cm at isocenter. During simulation, patients were given one anterior tattoo and no devices except for patient comfort (e.g., knee wedge, footrest, or pillow) with the expectation of correcting setup deviation with plan adaptation. The adapt-to-position (ATP) workflow was expected and preferred for online use because of shorter time-on-table, while the longer adapt-to-shape (ATS) workflow was expected mostly for off-line adaptation to volume changes. Patient-specific QA (PSQA) was delivered for all initial reference plans and ATS plans using ArcCheck-MR (Sun Nuclear, Melbourne, FL) in the Elekta-provided QA platform, which centers and fixes the location of the device at isocenter.

### *STS patients*

When treating STS, four characteristics of the Unity MRL (Table 1) were expected to pose challenges when using the original workflow. Characteristics of the four treated STS patients are given in Table 2, with boldface characteristics causing challenges when using the original workflow.

For each patient, the following data was retrospectively collected:

1. number of fractions requiring repeated setup attempts to position the target within the 22-cm longitudinal field size limit and where the ATP workflow could produce an acceptable plan

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**Table 1**

| Unity MRL Characteristic | Challenge for STS |
|---|---|
| Longitudinal field size limit of 22 cm at isocenter | If a long target is not initially positioned completely within the field size limit, this cannot be corrected with adaptive planning. Patient must be re-positioned and imaging repeated. |
| Closed bore;<br>No lateral couch motion | It may not be possible to position a lateral target at isocenter. Target imaging may suffer from geometric distortion, which increases with radial distance from isocenter. |
| Single sagittal setup laser;<br>No lateral setup lasers | No laser localization for lateral targets, which, without immobilization, may have rotational setup errors. The Unity's faster adaptive workflow (adapt-to-position) cannot correct rotations. |
| Patient-specific QA (PSQA) device can only be placed in one fixed, central position | For a lateral target, beams may not intersect the PSQA device and thus are not being validated. (Fig. 1) |

**Table 2**

| **Patient** | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Treatment Site** | Left calf | Right buttock | Left posterior thigh | Left calf |
| **Histology** | undifferentiated pleomorphic sarcoma | high grade myxofibrosarcoma | dedifferentiated liposarcoma | pleomorphic spindle cell carcinoma |
| **Target (PTV) length in SI direction** | **18.7 cm** | 17.2 cm | 10.2 cm | 16.5 cm |
| **Radial distance from PTV center to Isocenter** | **15.5 cm** | **12.7 cm** | 7.3 cm | **16.8 cm** |
| **Immobilization devices used** | **vendor-supplied footrest and towels under contralateral leg** | **vendor-supplied knee wedge** | VacQfix™ vacuum cushion (QFix®, Avondale, PA) | vacuum cushion |

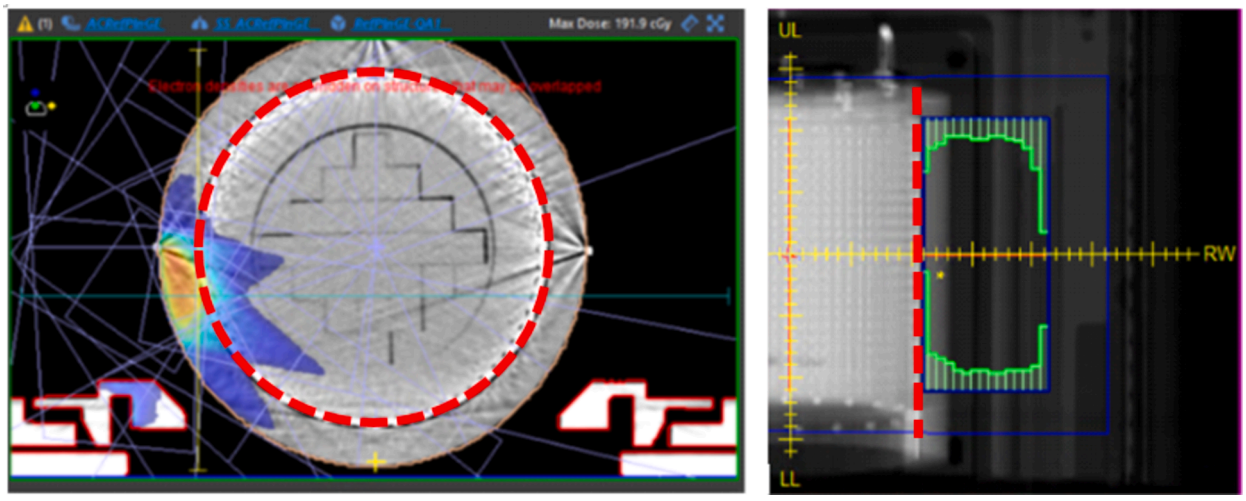


**Fig. 1.** An example of how the PSQA device's fixed position may result in a large portion of the high dose region not being captured by the PSQA device. (Left) The reference plan for Patient 4 calculated on the ArcCheck-MR device. Violet lines represent the beams, and the colorwash represents the delivered dose volume. The majority of the high dose area misses the detectors (red dashes). (Right) Beams-eye view from one of the beams incident on the edge of the device, completely missing the detector plane (red dashes).

2. maximum number of setup attempts in any session
3. session time measured from the completion of first setup of the day to the end of treatment delivery
4. number of off-line adaptive plans for target volume change
5. MRI geometric distortion, estimated using QA data and the radial distance of the PTV to isocenter
6. the percentage of V50 (50 % of maximum dose) captured by the PSQA device

## Results

The data collected from the four patients are shown in Table 3. Although Patient 1 passed the initial eligibility criteria of 20 cm for target length, it was observed during planning that the PTV measured as large as 20.8 cm in some beams-eye views due to magnification. The target grew between planning and treatment, and the radiation therapists (RTTs) had to repeat patient setup as many as five times in a single session partly due to the difficulty of fitting the target within the longitudinal field size limit.

For Patients 1 and 2, who were simulated without immobilization, RTTs repeated setup in six of 29 fractions–two of four fractions for Patient 1 and four of 25 fractions for Patient 2. The maximum number of setup attempts in a day was six for Patient 1 and four for Patient 2. On these days, session times were 62.6 and 49.9 min, respectively. RTTs identified lack of reproducibility, exacerbated by lack of axial lasers and robust setup devices, as the main reason for setup difficulty.

Patients 3 and 4 were treated with vacuum immobilization. Out of 56 sessions, two required repeated setup, and at most two attempts were required to proceed to treatment. The session times for both patients did not exceed 31 min.

Out of ten PSQA plans, eight delivered less than half of the planned V50% to the PSQA device. Because of this, an in-house method was implemented that instead compared the PSQA delivery in the record-and-verify system's database to the planned delivery. This was performed for all ten plans, and no plans were reported to have an in-field MLC positioning error of 1 mm or larger.

## Discussion

To our knowledge, this is the first report on the experience of treating STS patients on the Unity. Blitzer et al. [8] published a review article that provides a general overview of the role of MRgRT in the treatment of STS. Dunkerley et al. [9] discussed treatment of extremities on the Unity. Their description shows some common experiences with our own, for example, in their use of immobilization devices such as vacuum cushions. They also mention in-house guidance for simulation to position the target as close as possible to the isocenter to maximize the usable field size, which is supported by our experience with Patient 1 where the lesion appeared magnified due to the off-axis position of the target.

With the Unity being a relatively new radiation therapy system, it is crucial for users to share their efforts in addressing challenges on the system to achieve the best user and patient experience. We describe challenges over the entire clinical workflow of treating STS patients on the Unity, from pre-simulation to PSQA. These challenges stem from a combination of the attributes of STS lesions and the design of the Unity system. Contrary to the notion that adaptation can take care of any variation, patient selection criteria and achieving reproducible setup were shown still to be important. Adaptation cannot correct for target SI dimensions exceeding the physical field size limit, and multiple setup attempts were sometimes required to position a long target within this limit. An appropriate size selection criterion is needed that leaves room for tumor growth. While tumor growth in Patients 1 and 2 were initially addressed with adaptation, Patient 1 had to be switched to a conventional linac after four fractions because of target growth beyond the limit, and our target length limit for MRL eligibility was subsequently reduced to 18 cm.

The importance of reproducible setup despite the availability of online adaptation is demonstrated by our experience with Patient 2. The ATP workflow corrects positioning errors through a virtual isocenter shift. Target rotation can only be addressed by the longer ATS workflow. No immobilization devices were used for Patient 2 and, in multiple fractions, target rotation was observed in initial imaging. The RTTs

**Table 3**

| **Patient** | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **# of fractions that required multiple setup attempts** | 2/4 | 4/25 | 0/23 | 2/33 |
| **Maximum # of setup attempts in a session** | 6 | 4 | 1 | 2 |
| **Mean session time ± std. deviation** (minutes) (Min - Max) | 36.5 ± 22.6 (22.8 - 62.6) | 31.5 ± 7.8 (13.3 - 49.9) | 23.8 ± 1.0 (22.7 - 26.5) | 21.3 ± 2.9 (16.4 - 30.8) |
| **Estimated MR distortion at target position** | 0.6 mm | 0.4 mm | <0.4 mm | 0.8 mm |
| **Percentage of V50% captured by PSQA** | 3 plans 0.3%, 2.2%, 26.2% | 4 plans 29.7%, 38.8%, 42.5%, 61.2% | 1 plan 75.0% | 2 plans 9.1%, 0.2% |

chose to re-position the patient rather than switch to online ATS, because they judged it would take less time, even without lateral setup lasers. Table 2 shows the resulting longer table time relative to Patients 3 and 4 who were rigidly immobilized.

Investigation showed an anticipated issue with MRI distortion was clinically unimportant. The magnitudes of distortion, even for our most off-axis targets, were all under 1 mm, and no changes (e.g., PTV margin increase) were adopted.

We identified a problem in the PSQA of off-axis STS targets, which we addressed by implementing an additional in-house PSQA utilizing delivery data stored in the Elekta Mosaiq SQL database. This resembles log-file-based PSQA and is thus faced with the same concern of PSQA based on delivery information from the machine rather than independent measurement [10]. Ferris et al. recently demonstrated that, without the platform, an ArcCheck-MR can be positioned 12.9 cm lateral to isocenter with acceptable accuracy and reproducibility [11]. We are further working to develop a measurement-based PSQA solution using custom 3D-printed PSQA device holders that allow off-axis placement.

A limitation of this work is that it is a case study with a limited number of patients and not a prospective investigation to prove the effects of workflow changes. However, our cases clearly identify concerns that future users will run into while treating this subgroup of patients. Longer and more challenging treatment sessions could be considered a justified cost of MRgRT's ability to adapt to STS target changes. But this is all the more reason to address potential issues and seek workflow improvements, such as described here, in order to reduce unnecessary time expenditures and make MRgRT a feasible and attractive modality for more STS patients.

## Conclusion

The treatment of soft-tissue sarcoma on the Unity faces unique challenges due to the attributes of the disease and the Unity's design. This paper reports how our clinic modified our workflow to address these challenges. The modifications include limiting the superior-inferior length of the PTV to under 18 cm, utilizing MR-safe immobilization devices, assessing geometric distortion during target definition, and implementing a new patient-specific QA method. Continuous effort to share the identification and resolution of new issues using new technology are crucial in realizing the technology's potential to improve patient care.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### *Waiver of Patient Consent*

This is a retrospective case study. Patient consent has been waived by Ethic committee.

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