CASE REPORT
RADIOLOGY

Diseases & Research

Positron Emission Tomography Enables Accurate Targeting and Documents Sustained Efficacy for Low Dose Radiotherapy in Plantar Fasciitis: A Case Study

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Abstract: Plantar Fasciitis (PF) is a degenerative condition of the plantar fascia and is considered the leading cause of foot pain among adults aged ≥ 50 years in Australia. A 53-year-old male with a one-year history of PF was treated with low dose radiotherapy (LDRT) incidentally detected on a diagnostic staging 18F-Fluorodeoxyglucose Positron Emission Tomography/Computed Tomography (PET/CT) done for other reasons. Symptom control and return to running continues at six months. A further PET/CT scan, done for other reasons, showed resolution of PF Standardized Uptake Value (SUV) from 4.1 to 2.6. This paper includes a literature search of LDRT in PF and describes our department's technique of planning and treating PF with LDRT using megavoltage photons. To our knowledge this is the first published evidence of the resolution of plantar fasciitis on PET/CT following LDRT.

Keywords: Fasciitis; Plantar; Volumetric modulated arc therapy (VMAT); Positron emission tomography; Radiotherapy; Australia.

Introduction

Plantar fasciitis (PF) is a degenerative condition of the plantar fascia and is a result of repetitive mechanical overload associated with prolonged weight-bearing, running or standing[1–3]. PF is reported to be the most prevalent cause of heel pain among adults aged ≥ 50 years in Australia[1,4,5]. Diagnosis is primarily clinical. Diagnostic imaging can assist in confirming the diagnosis, guiding treatment options and advising prognosis. Modalities commonly employed include plain radiography, ultrasound and magnetic resonance imaging[4,6]. Nuclear medicine scanning is not widely used due to limited access and associated cost[7].

Traditional PF treatment ranges from conservative approaches including non-steroidal anti-inflammatory drugs, targeted stretching, physiotherapy, orthotic support and low dye taping to more advanced interventions, such as corticosteroid injections, platelet-rich plasma therapy, botulinum toxin injections, extracorporeal shock wave therapy and surgical fasciotomy[5]. These methods are associated with lengthy recovery times and can fail[6]. An emerging treatment is low-dose radiotherapy (LDRT). The most used regime is 6 Gray (Gy) in 12 fractions, delivered in two phases of 0.5 Gy per fraction two to three days a week, with a six to eight-week break between phases. Mild dose escalation and a third phase can be added depending on response[8–10].

We present a case study where Positron Emission Tomography/Computed Tomography (PET/CT) supported the diagnosis of PF, enabling accurate target delineation and documented sustained efficacy at six months following LDRT.

Case presentation

The patient has given explicit permission for the use of their de-identified information for this case study. A 53-year-old male was referred with an initial diagnosis of a poorly differentiated cutaneous squamous cell carcinoma (PDcSCC) of the left preauricular region. A PET/CT was performed to evaluate potential nodal involvement. The imaging protocol followed the administration of 248.6 megabecquerels (MBq) of F-18 FDG intravenously via the left cubital fossa, followed by a 60-minute uptake period prior to image acquisition. The findings indicated no evid-

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ence of hypermetabolic locoregional disease in the preauricular area. Additionally, there was no evidence of hypermetabolic regional nodal involvement or distant metastatic disease. However, an incidental focal area of increased FDG uptake was noted in the central band of the left plantar fascia as shown in Fig. 1. This had a maximum standardized uptake value (SUV max) of 4.1 and was reported to be consistent with PF. Upon discussion, the patient confirmed a prior symptomatic diagnosis of PF. The patient had disclosed he was unable to run for the past 14 months, and the standard treatments of physiotherapy and corticosteroid injections had failed. A physical examination confirmed tenderness at the calcaneal - plantar fascia junction. LDRT was offered and consent attained.

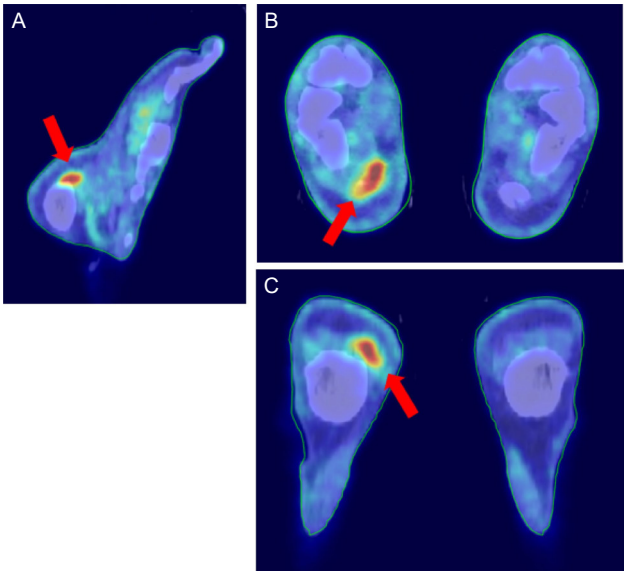

Fig. 1. Pre-Radiotherapy PET/CT demonstrates the focal uptake in the central band of the left plantar fascia with an SUV of 4.1 supporting a diagnosis of PF.
A. Sagittal.
B. Coronal.
C. Transverse planes.
The uptake is shown by the red arrows.

Technique of planning and treating with LDRT using megavoltage photons

Simulation

The patient was simulated in the supine position on top of a Type S-Overlay (CQ Medical, Orange City, Iowa, USA), with their left foot extended and immobilized using a Klarity Green® S-Type Thermoplastic Head Mask AccuPerfTM (Klarity Medical, Health, Ohio, USA) and ALCARE Moldcare RI II (ALCare, Tokyo, Japan). The untreated right leg was flexed away from the treatment site to not be included in the CT scan, see Fig. 2.

Computed-Tomography (CT) scan

The patient was positioned feet-first for the planning CT. The scan was completed on a Canon Aquilian CT scanner, using a tube voltage of 120 kV, a slice thickness of 2.0 mm and a field of view (FOV) of 500 mm. The scan limit was from mid-tibia to the end of the Type S-Overlay to ensure the entire treatment area was covered and to include any immobilisation devices used. The scan was subsequently exported to the treatment planning system.

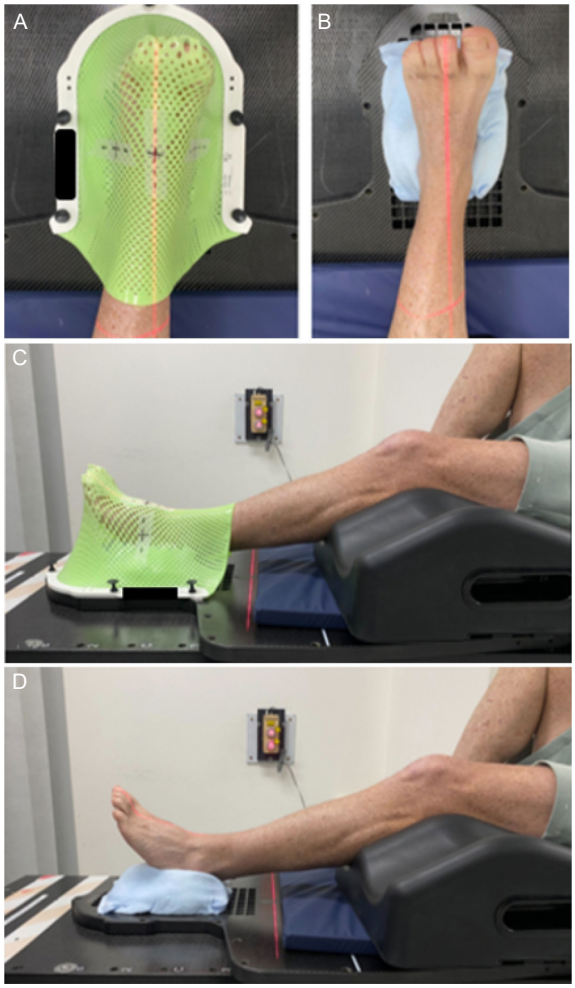

Fig. 2. Patient immobilisation equipment used and patient set up.
A. Shows the Klarity Green S-Type Thermoplastic Head Mask AccuPerf™ of the patient's left foot.
B. Shows the ALCARE Moldcare RI II mould holding the the patient's foot.
C. Shows a lateral view of the patient positioning with the thermoplastic mask.
D. Shows a lateral view of the patient positioning without the thermoplastic mask.

RO contouring

Contouring of the clinical target volume (CTV)[11] was enhanced by the fusion of the PET with the planning CT. The whole compartment of the foot inferior to the bones was included. This could be done as the dose was so low, and the absence of organs at risk (OARs). The expansion of the CTV to planning target volume (PTV)[11] was only three millimeters (mm) as there was excellent reproducible daily set up due to the Mold care and thermoplastic mask, with daily cone beam verification.

As shown in Fig. 3, the clinical target volume (CTV)[11] is shown by the pink structure. The blue structure is the PTV, following a 0.3 cm expansion from the CTV. The planning structures used to control the low dose include the intermediate ring (green structure), the middle ring (orange structure) and the outer ring (red structure).

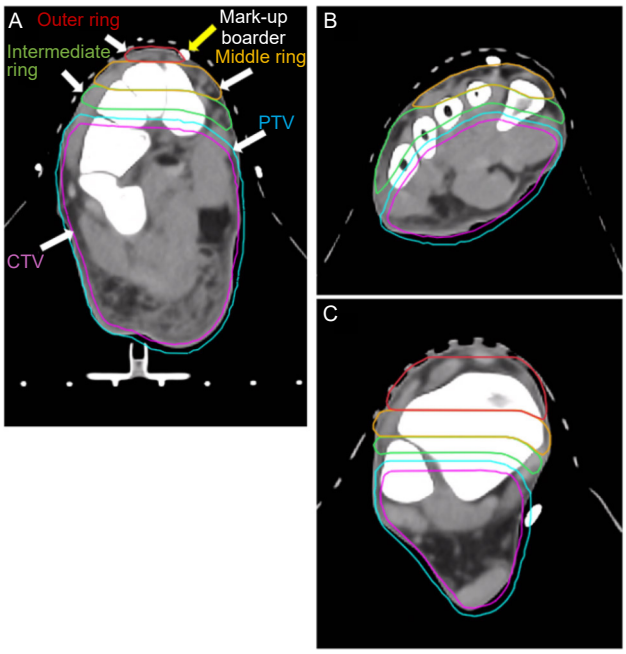

Fig. 3. The planning volumes.
A. At the center of the planning target volume (PTV)[11].
B. 1 cm inferior from the most superior level of the PTV.
C. 1 cm superior from the most inferior level of the PTV.

RT planning

The prescribed dose was 6 Gray (Gy) in 12 fractions to the PTV with a frequency of 3 fractions per week. The prescription was divided into two phases of 3 Gy in 6 fractions with an 8-week break between phases. The planning technique used was volumetric modulated arc therapy (VMAT) generated in the Eclipse treatment planning system v18.0 (Varian Medical Systems, Palo Alto, California, USA). The dose algorithm used AcurosXB, version 16.1 due to its improved dosimetry calculations in heterogeneous densities. This is advantageous in planning PF plans due to the amount of bone to soft tissue interfaces within the foot. The plan is generated for a Halcyon linear accelerator (Varian Medical Systems, Palo Alto, California, USA), which has a single energy of a 6 MV flattening filter free (FFF) photon beam with a depth of maximum dose (Dmax) of 1.2 cm.

To improve the conformity of the plan, additional optimization structures were used. Three ring structures - intermediate, middle and outer - were created from the PTV with the intention of reducing the 5 Gy dose wash, improving target dose uniformity, and enhancing dorsal skin sparing. As the PTV includes the plantar skin, a bolus effect is typically required. However, for this patient, the application of a traditional bolus was deemed unnecessary. This is because the treatment area lies directly against the Moldcare® cushion, which has a density of approximately 0.15 g/cm^3 and a thickness of 5.5 cm, which converts to a water-equivalent depth of 0.8 cm. This build-up depth is usually sufficient to achieve the prescribed dose at the surface of the sole, particularly with the use of VMAT as the planning technique and as described in our previous publication[9].

Due to the location of the PTV, there were no organs at risk, and the as low as reasonably achievable (ALARA) principle was instead applied. The 95% TD and 50% TD isodose wash distribution are shown in Fig. 4 and Fig. 5.

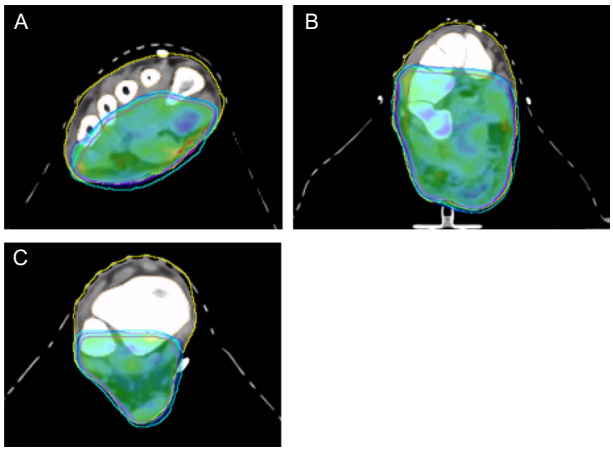

Fig. 4. The 95% TD dose coverage of the PTV.
A. 1 cm inferior from the most superior slice of the PTV.
B. At the center of the PTV.
C. 1 cm superior from the most inferior slice of the PTV.

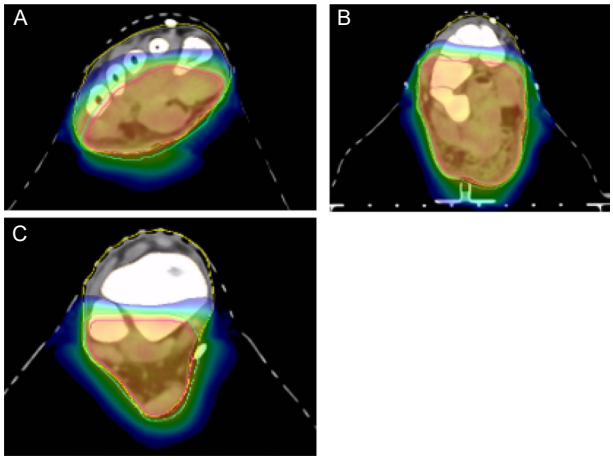

Fig. 5. The 50% TD dose coverage of the PTV.
A.1 cm inferior from the most superior slice of the PTV.
B. At the center of the PTV.
C. 1 cm superior from the most inferior slice of the PTV.

Radiotherapy treatment

Treatment was delivered on the department's Varian Halcyon Linear Accelerator (Varian Medical Systems, Inc, Palo Alto, California, USA). A maximum dose rate of 800 monitor units per minute (MU/min) was applied. The plan delivered 181.3MU per fraction, with an average beam on time of approximately 90 seconds. Prior to each treatment delivery, a cone-beam computed tomography (CBCT) was acquired to ensure correct patient positioning and target accuracy.

In-vivo Dosimetry (IVD)

IVD was performed on the first fraction of treatment to confirm the surface dose of the treated area. Specifically, a piece of Gafchromic™ external beam therapy (EBT3) film (Ashland, New Jersey, USA), a tissue-equivalent planar dosimeter, was placed in the middle of the PTV to measure the surface dose, as shown in Fig. 6. Upon completion of that fraction of treatment, the film was removed and scanned on a film scanner (Epson, Suwa,

Nagano, Japan), and the dose reading was determined from the pre-established calibration curve.

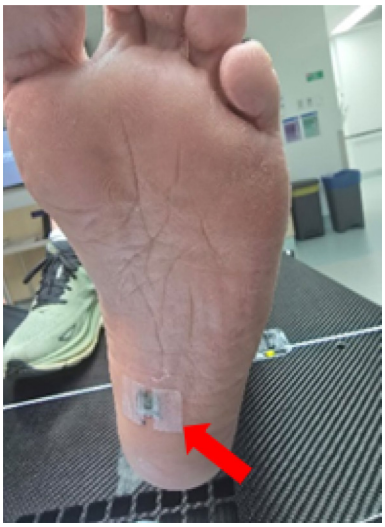

Fig. 6. EBT3 film placement on the left foot which is the equivalent of the middle of the PTV to measure the surface dose.
This was on the skin surface directly the most tender spot on examination. The film is indicated by the red arrow.

The uncertainty associated with the IVD measurement process using EBT3 was estimated to be ± 5.0% within the authors' department. For the patient in this study, the fractional dose acquired by the EBT3 film was 0.5 Gy, which agrees with the calculated dose of 0.5 Gy. This result highlights the accuracy of surface dose calculations in the Eclipse treatment planning system. The prescribed dose was delivered.

Follow up

After completion of the first phase, the patient had reported that his pain had reduced and he was able to return to running after not being able to for 14 months.

The patient was reviewed at six-week post-radiotherapy to evaluate for any persistent treatment-related toxicities and to monitor general recovery. At six months post-radiotherapy, a repeat PET/CT scan was acquired to assess for residual disease associated with the original diagnosis of PDcSCC of the left preauricular region. The imaging protocol replicated the original scan and included full body coverage. The administration followed 241.6 megabecquerels (MBq) of F-18 FDG injected intravenously via the cubital fossa, with a 61-minute uptake period prior to image acquisition. A specific request was made to evaluate and comment on the findings related to the PF of the left foot. The subsequent PET/CT reported a significant decrease in metabolic activity along the central band of the plantar fascia with an SUVmax of 2.6. This had decreased from the original scan which reported an SUVmax of 4.1, see Fig. 7. The central band in the plantar fascia no longer showed the earlier hypermetabolism activity, consistent with interval resolution. Following LDRT treatment, the patient reported no pain and was able to resume his preferred activities, including running. The patient reported that the LDRT had significantly enhanced his overall QOL.

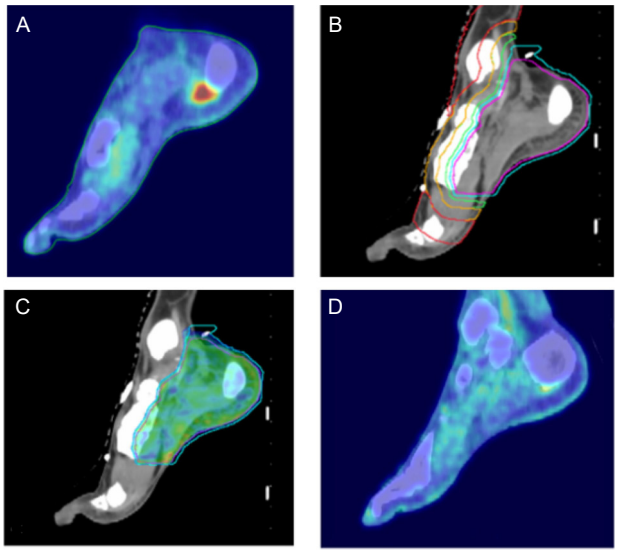

Fig. 7. The left foot in the sagittal plane.
A. Pre-Radiotherapy PET/CT demonstrating the focal uptake of an SUV of 4.1 in the central band of the left plantar fascia.
B. The planning clinical target volumes at approximately the same level on the PET/CT scan.
C. The planned 95% TD dose-wash at approximately the same level on the PET/CT scan.
D. The Post-Radiotherapy PET/CT demonstrates the focal uptake of an SUV of 2.6 indicating an interval resolution.

Discussion

We present a case of symptomatic PF incidentally diagnosed on a PET/CT that maintained a complete symptomatic and reported interval resolution at six months following LDRT planned with assistance of PET/CT fusion to a total dose of 6 Gy in 12 fractions delivered via six MV photons. To our knowledge, this case is the first to report on the use of post-radiotherapy PET/CT imaging to assess the therapeutic efficacy of LDRT in PF.

Radiation therapy emerges as a promising treatment due to its anti-inflammatory effect. While many studies have reported on symptomatic relief, research to assess treatment response through objective imaging biomarkers remains limited. This case study presents the novel application of a PET/CT to help diagnose and evaluate metabolic changes post-radiation therapy in PF.

The diagnosis of PF can be supported by imaging modalities such as ultrasound, plain radiography, conventional scintigraphy and magnetic resonance imaging[4,6]. While conventional imaging remains the standard, PET/CT offers a functional insight into disease activity, which in turn can confirm clinical outcomes for benign conditions[12]. Ahmed[12] reported incidental findings within lower extremities, including PF, during oncologic PET/CT scans, highlighting its potential diagnostic value in non-oncologic conditions. This is particularly relevant in cases where clinical symptoms persist despite conservative management, as metabolic activity may indicate ongoing inflammation even when structural changes are subtle or stable. In our case, the PET/CT not only confirmed active PF but also provided a baseline for evaluating therapeutic response following radiotherapy. Although cost and accessibility are limitations, the incidental detection of PF sug-

gests an opportunity for broader clinical application and warrants further investigation into its diagnostic, prognostic and therapeutic applications in benign conditions.

In the management of PF, Clinical Practice Guidelines (CPG) recommends a variety of interventions including manual therapy, stretching, taping, foot orthoses, night splints, low-level laser therapy, education and weight loss, resistance training, and dry needling[13]. Recent expert consensus recommends that, as a first-line treatment, clinicians provide education, taping and stretching, then shockwave therapy, and custom orthoses for those who don't improve[13,14]. Despite these treatments, it is common for people experiencing plantar heel pain to experience symptoms that can last over a year, with some people's pain never resolving[13,15].

Radiotherapy for PF has an increasing evidence base. Studies by Hajtmanová[16] and Badakhshi & Budach[8] report pain relief rates of 61–75% and improvements in health-related QOL following LDRT[8,16]. Our regime of delivering 6 Gy in two phases using VMAT, aligns with standard protocols for inflammatory benign disease[10] and demonstrates the feasibility of advanced planning techniques for benign conditions. The lack of OARs and the application of ALARA principles allowed for highly conformal dose distribution with minimal toxicity, consistent with findings from Miszczyk[17] who emphasized the safety of low-dose radiotherapy in PF[17]. As such unlike these studies, which relied primarily on clinical outcomes, our case incorporated PET/CT imaging as an objective measure of metabolic activity before and after treatment. Having an interval resolution on PET/CT suggests that the relief offered by LDRT may be more than just placebo.

A concern of PF, if left untreated, is that it can evolve into plantar fasciosis. PF is represented by its acute inflammatory process characterized by microtears, oedema and inflammatory-cell infiltration at the calcaneal attachment. These features are what make PF PET avid and potentially responsive to LDRT. However, if not adequately managed, PF can evolve into plantar fasciosis which is a degenerative disorder, characterized by collagen breakdowns, fibroblast abnormalities, mucoid degeneration and poor vascularity[18,19]. Therefore, plantar fasciosis may lack PET avidity and potentially may not respond as well to LDRT. In our case, despite over a year of symptoms, the patients' findings remained PET avid and responded well to treatment. This highlights the potential for PET avidity as a marker for distinguishing inflammatory PF from degenerative fasciosis, potentially helping clinicians to better identify candidates who would most likely benefit from LDRT, however more research is needed.

When considering radiotherapy for benign conditions such as PF, it is important to acknowledge the potential risk of radiation induced malignancy (RIM). Contemporary reports have emphasized that the risk of RIM is rare, affecting 1 in 1000 patients at 10 years, depending on the age when irradiated[20,21]. Given that RIM typically only presents after long latency of time, it is important to consider a patient's age and expected lifespan when considering the benefit-to-risk ratio. As the patient is 53 years old and the prescribed dose of 6 Gy is relatively small, it can decrease but does not completely exclude the possibility of RIM.

Limitations of this study include being only a single case, the retrospective nature of the report and a relatively short follow-up. Additionally, access to a PET/CT was only available due to the patient's primary diagnosis of PDcSCC of the left preauricular region. It is also important to acknowledge that despite the observed improvement following treatment, it is possible that the findings could alternatively reflect natural resolution, placebo effect or regression to the mean. Such factors cannot be excluded in a single case study. Further research with a larger cohort is warranted.

Conclusion

The comparative analysis of the pre- and post-radiotherapy PET/CT demonstrated a resolution of the patients' PF, highlighting the therapeutic efficacy of LDRT in treating PF. While the short-term outcomes are promising, ongoing follow up is essential to monitor any late toxicities. This case study not only reinforces the clinical benefit for radiotherapy in PF but also indicates the potential use of PET/CT to quantify treatment response in benign inflammatory conditions. To our knowledge this is the first published evidence of the resolution of a case of PF on PET/CT following LDRT.

Abbreviations

ALARA, As Low As Reasonably Achievable; CBCT, Cone-Beam Computed Tomography; CTV, Clinical Target Volume; Dmax, Depth of Maximum Dose; EBT3, External Beam Therapy Gafchromic Film; FFF, Flattening Filter Free; Gy, Gray; IVD, In-Vivo Dosimetry; LDRT, Low-Dose Radiotherapy; MU, Monitor Units; PET/CT, Positron Emission Tomography/Computed Tomography; PF, Plantar Fasciitis; PTV, Planning Target Volume; QOL, Quality of Life; RIM, Radiation Induced Malignancy; SUVmax, Maximum Standardized Uptake Value; VMAT, Volumetric Modulated Arc Therapy.

Ethical approval and consent to participate

The patient has given explicit permission to use their information for the purpose of this case study.

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Conflicts of Interest

There are no relevant conflicts to declare.

Authors' contributions

KB: wrote the MS and managed the process; GBF: had the idea, gathered the team and supervised the MS, YH: reviewed the MS and contributed to the planning and treatment technique from a physics point of view, DB: reviewed the MS and contributed to the use of physical therapies, MS: reviewed the MS, organized

the PETs and contributed to the nuclear medicine involvement, EJP: reviewed the MS and assisted in formatting and idea progression, DL: reviewed the MS and contributed to the understanding of plantar fasciosis.

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