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CASE REPORT

High-Frequency Micro-Ultrasound Transrectal Imaging Enhances Staging and Preoperative Planning of Prostate Radiation Induced Rectal Cancer: A Case Report

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ABSTRACT

High-frequency ultrasound, known as micro-ultrasound (microUS), is a sonographic imaging modality capable of acquiring high-resolution, microscopically detailed images. This technology has been increasingly utilized for prostate cancer biopsy and diagnosis. Its utility outside of prostate cancer is under-described. A 76-year-old male with a past medical history of brachytherapy 25 years prior developed rectal cancer. Before undergoing resection, transrectal microUS was utilized to determine the relation of the rectal mass to the urogenital organs, which better established the planned surgical approach. To our knowledge, using transrectal microUS for evaluation of rectal masses invading the prostate has not yet been reported.

1 | Introduction

Transrectal microUS is a novel sonographic imaging modality that has been added to the repertoire of tools for prostate-related diagnoses (Basso Dias and Ghai 2023). The microUS technology was initially introduced into the urological field as a novel way to perform targeted biopsies for prostate cancer. At a frequency of 29 MHz, microUS improves resolution by 300%—though at reduced penetration depth—when compared to the traditional 9–12 MHz ultrasound (Ghai et al. 2016). Images acquired by microUS achieve a remarkable resolution of 70 μm, enabling detailed visualization of the glandular ducts and acini of the prostate, which typically measure 150–300 μm (Eure et al. 2019; McNeal 1988). In patients with a prior prostate biopsy, needle biopsy tracks can even be visualized on microUS—a capability never seen with standard frequency transrectal ultrasound (TRUS) (Harland and Stenzl 2021).

Historically, limited resolution has complicated the evaluation and biopsy of prostate cancer. Standard frequency TRUS has long been the standard of care, despite missing clinically significant disease in approximately 30% of patients (Rouviere et al. 2019). Over the past decade, multiparametric magnetic resonance imaging (mpMRI) revolutionized imaging of prostate cancer relative to traditional TRUS. Images obtained via mpMRI provide accurate estimates of prostate cancer locations, enabling targeted biopsy of detected lesions (Stabile et al. 2020). However, with improved resolution came increased expense due to the higher cost MRI technology and the mandatory second office visit for fusion overlay.

As a result, microUS was introduced in the urological field to perform targeted biopsies for prostate cancer at lower costs and in real-time in a single office visit (Pedraza et al. 2024). Research has shown that microUS maintains similar sensitivity, specificity, positive predictive value, and negative predictive value in comparison to mpMRI for the detection of prostate cancer (Eure et al. 2019; Pedraza et al. 2024; Chessa et al. 2021; Ditonno et al. 2023; Dias et al. 2022; García Rojo et al. 2024). Other studies even reveal improved detection rates of clinically significant prostate cancer through the use of microUS over mpMRI (Claros et al. 2020; Sountoulides et al. 2021).

Despite its established utility in prostate cancer, microUS has rarely been described for other uses in urological studies. A 2020 study assessed the feasibility and accuracy of microUS for bladder cancer diagnostics. Researchers used a linear 29 MHz probe via a transrectal approach in males and transvaginally in females to obtain bladder images with patients under sedation. It was shown that microUS could accurately differentiate bladder wall layers as well as identify the stage of bladder cancer (Saita et al. 2020). Outside of the urological system, microUS has been used for skin cancer and cardiology, as well as diseases of the hepatobiliary system, thyroid, and pancreas (Bezugly and Rembielak 2021; Potkin et al. 1990; Enea and Horrow 2023; Guth et al. 2009; Xu et al. 2022).

Diagnostic imaging of rectal masses involves some combination of magnetic resonance imaging (MRI), computed tomography (CT), and endorectal ultrasound (EUS). MRI has become increasingly valuable in staging rectal cancer by providing information on both the depth of invasion—T staging—as well as nodal metastasis—N staging—to a high degree of specificity (Fernandes et al. 2022; Horvat et al. 2019; Wang et al. 2020). CT scans may be used to uncover metastases and to stage disease (Feeney et al. 2019). EUS offers an adjunct to these techniques to provide information on the localized rectal wall and adjacent structures, offering the advantage of lower cost and ease of performance (Edelman and Weiser 2008). In the setting of high-resolution rectal protocol MRI, however, EUS has been reserved to differentiate between T1- and T2-staged tumors (Surace et al. 2014; Siddiqui et al. 2006). When determining the treatment approach, the depth of tumor invasion through the rectal wall is the single most important factor (Reginelli et al. 2021). Successful and complete resection can only occur if the mesorectal fascia—the connective tissue overlying the perirectal fat—is not involved (Oronsky et al. 2020). Thus, imaging and thorough understanding of the anatomy surrounding rectal lesions are critical. A multimodal approach may therefore represent the ideal diagnostic method for assessing rectal masses, particularly in cases of advanced disease (Reginelli et al. 2021).

To our knowledge, the use of microUS for evaluation of a rectal mass has not yet been reported. This case report demonstrates the utility of microUS for preoperative evaluation of a rectal mass infiltrating the urogenital organs.

2 | Case Report

2.1 | Patient History

A 76-year-old male was evaluated for new-onset bowel complaints, flatulence, and incontinence. The patient had a history of prostate cancer managed with brachytherapy 25 years prior. Sigmoidoscopy revealed a rectal mass abutting the anal complex and measuring 2.5 cm in diameter with an area of central necrosis. On digital rectal exam, the mass was palpable 2 cm from the anal verge, extending to 7 cm deep with 50% circumferential coverage and involving the anal sphincter complex. Biopsy of the mass confirmed rectal adenocarcinoma. Initial MRI of the rectum and CT of the abdomen/pelvis demonstrated a T3/possible T4, 2.5 cm mass with invasion into the mesorectal fascia.

The patient underwent 12 cycles of neoadjuvant chemotherapy to shrink the mass prior to surgical excision. Neoadjuvant chemoradiotherapy was excluded due to prior pelvic radiation. An abdominoperineal resection of the remaining mass was planned, and a final set of preoperative images was obtained.

2.2 | Preoperative Imaging

2.2.1 | CT

A preoperative staging CT scan of the chest, abdomen, and pelvis was performed to assess for metastasis. No suspicious distant lymphadenopathy was identified. A clear distinction between prostatic parenchyma and rectal mass could not be perceived, suggesting local tumor infiltration (Figure 1).

2.2.2 | MRI

An MRI of the rectum was performed to stage the cancer. This showed a mass on the anterior rectal wall with invasion through the mesorectal fat and into the mesorectal fascia (Figure 2). Invasion depth measured 5 mm, which was consistent with T3 disease. The peripheral tumor margin was inseparable from the posterior prostate mid-gland and apex. However, MRI could not definitively distinguish tumor invasion from post-radiation changes or inflammation.

The patient was then referred to urology to better understand the relation of the rectal mass to the prostate and receive a preoperative urogenital assessment.

2.2.3 | High-Frequency Micro-Ultrasound

An in-office transrectal microUS was performed to evaluate the rectal mass and its relation to the urogenital organs. Images were obtained using the ExactVu system with a high-frequency 29 MHz linear transducer. The ultrasound showed a heterogeneous mass that extended from the rectal mucosa to 1.7 cm anterior to the rectal wall. The mass was measured at 2.7 cm in length. It appeared to be in contact with the posterior surface of the prostate (Figure 3). The prostate was elevated 3 cm over the mass and predominantly hypoechoic with hyperechoic foci consistent with prior brachytherapy seeds. Additionally, microUS revealed several of these seeds to be directly contained within the rectal mass, helping confirm direct extension from the prostate. The overlap between the rectal mass and prostate was no greater than 4 mm in depth. It also appeared to directly invade into the left seminal vesicle and midline vasa, without abutting the bladder neck (Figure 4). No well-defined plane existed between the prostate gland and rectal mass.

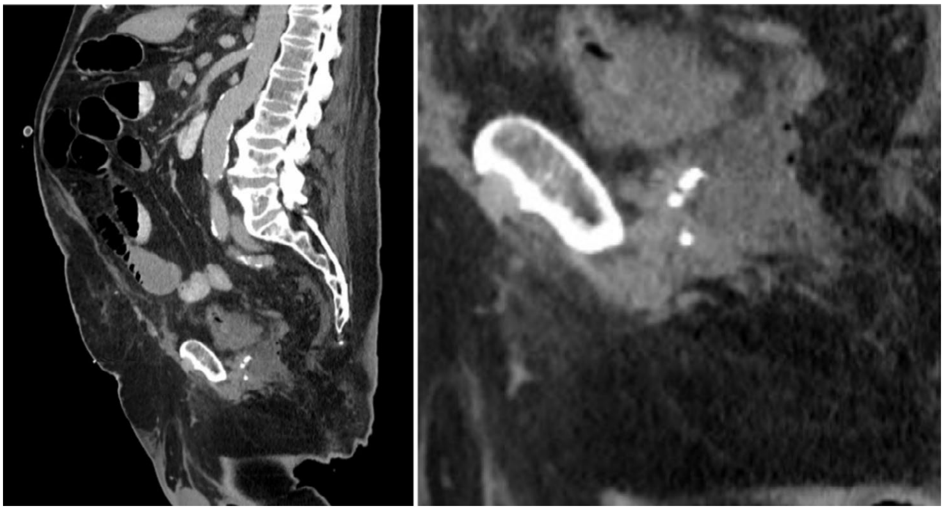

FIGURE 1 | CT scan of the chest, abdomen, and pelvis with contrast performed primarily to look for metastatic disease. Brachytherapy seeds can be seen in a zoomed view of the prostate with enhancement of signal posterior to the pubic symphysis.

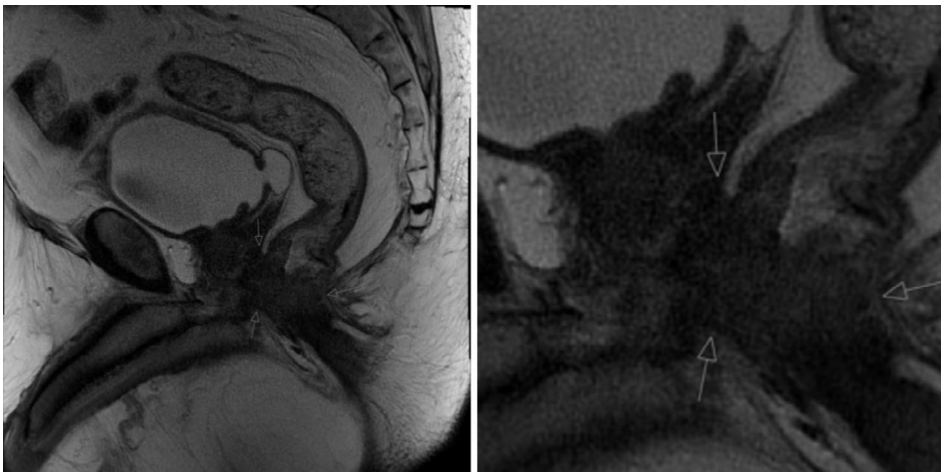

FIGURE 2 | MRI T2 Rectal, sagittal view of the pelvis. Rectal mass indicated within arrows. Mass can be seen in proximity to the prostate. It is difficult to distinguish infiltrative disease from the inflammatory process.

Images from microUS confirmed that the mass infiltrated the prostate and seminal vesicles, guiding the abdominoperineal resection of both the rectal cancer and infiltrated tissue. The images also confirmed that the bladder and bladder neck were spared from infiltration by the mass. An *en bloc* radical perineal prostatectomy in conjunction with the abdominoperineal resection was planned with the open placement of a suprapubic cystostomy tube. The approach would preserve the bladder neck, as there was no evidence of mass infiltration into the bladder.

2.3 | Surgery

The patient underwent a multidisciplinary abdominoperineal resection for the malignancy. Once the perineal incision had been developed and the anterior rectal wall was dissected to the pelvic floor, the *en bloc* radical perineal prostatectomy commenced. Digital and visual inspection revealed the malignancy to be adherent to the prostate but not the bladder. First, the prostate was separated from the bladder neck. The seminal vesicles and prostate were then dissected away from the surrounding tissue. Once the prostate was removed, the bladder appeared small in caliber but intact. The bladder neck was then oversewn, and a suprapubic cystostomy tube was placed. Ultimately, the prostate and seminal vesicles were removed *en bloc* with the rectum, rectal mass, and anus (Figure 5). Lower urinary tract reconstruction was considered, but in the setting of invasive rectal cancer and prior radiation, it was determined that the risk of subsequent toxicity was too high, and the patient preferred being left with an intact bladder and suprapubic tube.

Gross examination of the specimen revealed that the prostate and rectal mass were inseparable. Histopathological examination confirmed that the rectal adenocarcinoma invaded directly into the prostatic parenchyma. All surgical margins were confirmed clear of remaining adenocarcinoma on histopathology.

At six-month follow-up, the patient remained tumor free.

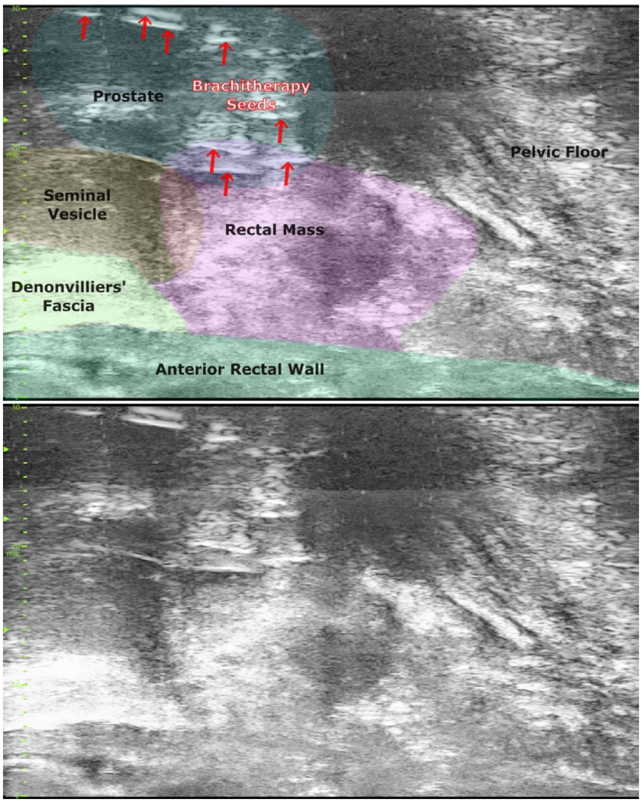

FIGURE 3 | Micro-ultrasound image highlighting the invasion by rectal mass into the prostate and seminal vesicles.

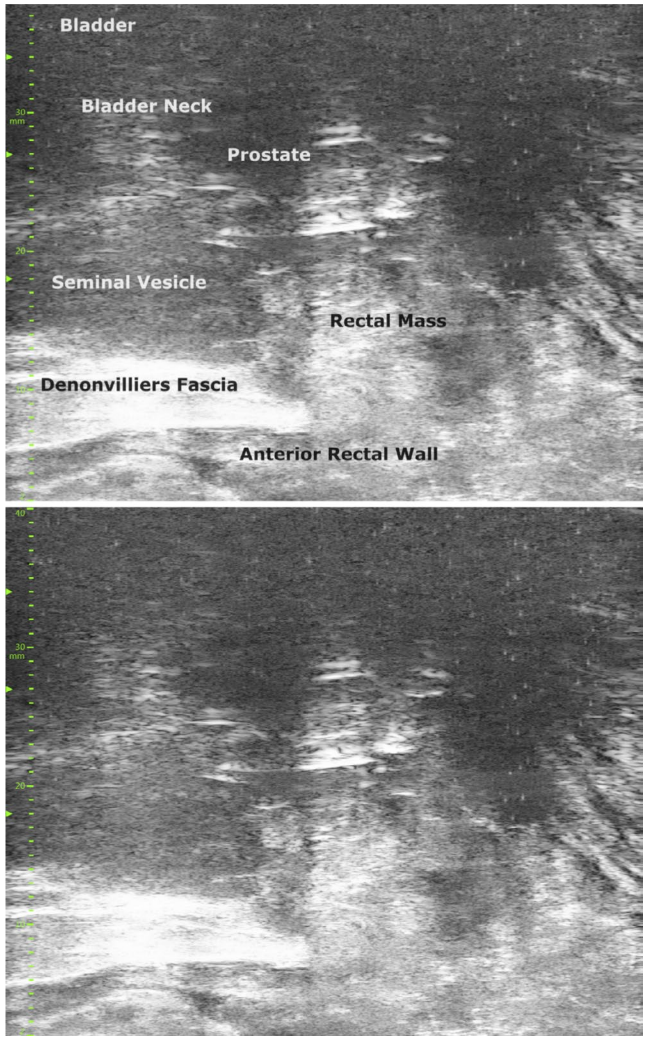

FIGURE 4 | Micro-ultrasound demonstrating the bladder and bladder neck without invasion by rectal mass.

3 | Discussion

This case demonstrates the clinical efficacy, potential value, and utility of microUS for the evaluation of rectal masses invading the prostate.

Micro-ultrasound provided critical information for preoperative planning in this patient. The high frequency, high-resolution images clearly demonstrated that no plane existed between the prostate gland and rectal mass, and that the bladder neck was spared. Easily recognizable brachytherapy seeds further confirmed that the mass infiltrated the prostate. These critical pieces of information favored an *en bloc* radical prostatectomy and suprapubic cystostomy in conjunction with abdominoperineal resection. Histopathological analysis of the removed specimen confirmed our microUS imaging findings, suggesting invasion of the rectal malignancy into the prostate. The theoretical tumor margins identified on microUS were substantiated by negative margins on histopathology.

Standard imaging sequences of both MRI and CT insufficiently demonstrated the degree of urogenital organ infiltration by the rectal mass and would have led to excessive resection. Routine MRI could not adequately rule out prostate, seminal vesicle, or bladder base involvement such that a cystoprostatectomy is the standard surgical approach in this clinical setting. This approach would have added to the surgical difficulty of an already challenging case and—more importantly—subjected the patient to even greater lifelong health management related to this operation. With invasion of the urogenital tract by rectal cancers at a rate of 3%–10% (Carne et al. 2004; Eldar et al. 1985; Kobayashi et al. 2003; Stief et al. 2002), these locally invasive masses typically undergo aggressive surgery involving abdominoperineal resection with total pelvic exenteration (Fernández-Martínez et al. 2014). MicroUS clearly identified prostatic involvement without infiltration in the bladder base, allowing for a more limited resection in this medically co-morbid patient.

A similar case reported in 2016 described a 67-year-old patient with rectal cancer suspected to have invaded the prostate. Preoperative MRI demonstrated broad contact between the anterior portion of the rectal mass and the posterior edge of the prostate, which was presumed to be fibrosis. On the assumption that the mass had infiltrated beyond the anterior rectal wall, this patient underwent abdominoperineal resection with *en bloc* cystoprostatectomy. Histopathological examination of the gross specimen revealed there was no invasion of the mass into the prostate (Guy et al. 2016). Standard workup of MRI failed to absolve the prostate and bladder from malignant infiltration. Use of microUS in such a case may have led to preservation of the prostate and bladder entirely. Given the extensiveness of a cystoprostatectomy and lifelong implications of this surgery, the value that may have come from evaluation of this rectal mass via microUS can hardly be overstated. In the case we report here,

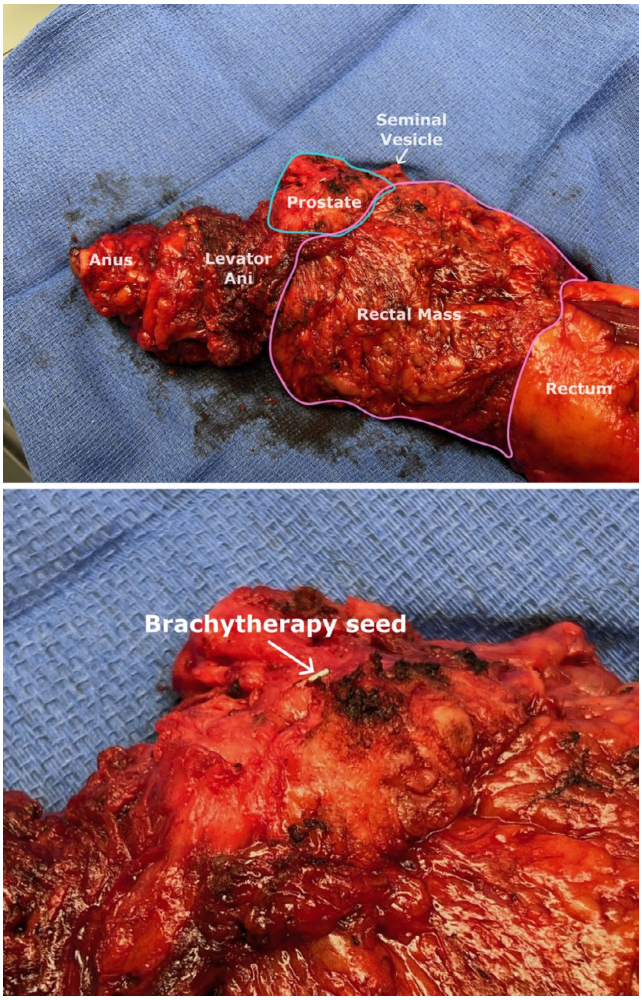

FIGURE 5 | Gross specimen involving anus, levator ani, prostate, seminal vesicle, rectal mass, prostate, and rectum. Brachytherapy seed can be seen within prostate on zoomed view.

a simple in-office microUS ultimately spared the patient from bladder resection and a life of urostomy management.

The approach for abdominoperineal resection of masses involving the prostate and seminal vesicles varies, with laparoscopic, robotic, trans-sacral, and retropubic approaches reported (Raghavan et al. 2023; Sugita et al. 2007; Takahashi et al. 2022; Tashiro et al. 2017). The decision should be made based on the unique patient anatomy to optimize safety, efficacy of mass removal, and patient recovery. The present case supports the addition of microUS into the repertoire of useful assessment tools for rectal masses, particularly those with prostate invasion.

However, several limitations must be acknowledged. First, this report is a single case, and the findings may not be generalizable. In this case, microUS was an adjunct in a comprehensive multimodality workup of an advanced rectal mass, useful in preoperative planning and staging, but it was not a replacement for all other imaging strategies. Staging of rectal cancer is crucial for treatment and prognosis. The mainstays of CT and MRI should always be used in assessing for metastasis or depth of invasion, particularly beyond T2 when rectal cancer depth extends to the mesorectum and mesorectal fascia. This study is not designed to be a prospective comparison, but a case to demonstrate the unique contribution of each imaging modality. Further investigations may be of use for such comparisons. MicroUS is best considered a complementary tool, particularly in cases where standard imaging cannot determine local organ invasion. Successful imaging in microUS requires extensive experience and anatomic familiarity and may not be as readily implemented for less experienced ultrasound users. In this case, microUS was implemented by a long-time user adept at this technique. Regardless, standard ultrasound experience does provide foundational experience that translates to microUS.

4 | Conclusion

Transrectal microUS is a valuable tool for evaluation of anatomy in the rectal and pelvic region. The diagnostic capabilities described in this case show that microUS is a useful technology for surgical evaluation of rectal masses invading the prostate. Micro-ultrasound continues to prove its utility in the diagnostic evaluation of prostate cancer as a comparable alternative to mpMRI. However, few studies have elucidated its potential beyond prostate pathology. With a short educational learning curve, no secondary appointment for fusion overlay, and 300% improved resolution from TRUS, further investigation is needed of this real-time imaging modality to determine if clinicians can consistently improve patient care and outcomes through the incorporation of this new technology into their practice.

Ethics Statement

This study was exempt from institutional review board approval by the Carilion Clinic Institutional Review Board Standard Operating Guidelines Title: 3.5: Reviews Requiring Special Consideration: Case Reports. All procedures in Carilion Clinic IRB Title 3.5 outlining ethical publication of case reports were followed in the creation of this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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