Normal and pathological MRI findings of the prostatic region after treatment for Prostate cancer.

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Learning objectives

To review the normal magnetic resonance imaging (MRI) findings of the prostatic region after different kinds of treatment for prostate cancer (PCa).

To illustrate the most frequent MRI patterns of residual and recurrence prostate cancer after different kinds of treatment for PCa.
Background

The primary treatments for PCa are: radical prostatectomy (RP), radiation therapy (RT) via either external beam RT (EBRT) or brachytherapy, cryotherapy, high-intensity focused ultrasound (HIFU) and laser interstitial thermal therapy.

Radical prostatectomy and radiation therapy are treatments with curative intent. The focal ablative techniques, such as cryotherapy, HIFU and laser interstitial thermal therapy, are minimally invasive procedures not completely established yet.

The first sign of recurrent PCa is a rising PSA, but biochemical failure is not synonymous with local recurrence; so, it is crucial to identify local recurrence because salvage treatments are associated with high morbidity.

All these treatments modify, in a greater or less way, the anatomy of the prostatic region. Indeed, it is essential to know normal post-treatment appearances and distinguish them from pathological findings of recurrent and residual disease.
Findings and procedure details

All multiparametric MRI (mpMRI) examinations are performed with a 1.5T scanner (Avanto, Siemens) using a phased array body coil and a dedicated endorectal coil. Our mp-MRI protocol includes: high spatial resolution T2-weighted sequences with small field of view in axial, sagittal, and coronal plane; wide field of view T2-weighted sequence from renal hilum to the pubic symphysis to detect nodal involvement; axial diffusion-weighted sequence with b-value 50-400-1200 and ADC map; axial dynamic T1 contrast-enhanced sequence with high temporal resolution (7 sec. per phase, 4 min. total scan time) during intravenous injection of 0.1mmol/kg of Gd-based contrast medium at a rate of 2ml/sec, following by intensity-time curves elaboration.

A) Radical prostatectomy

Background: RP remains the most common treatment of choice in patients with organ-confined PCa. A variety of surgical techniques are used, including perineal, retropubic, laparoscopic or robot-assisted approaches. Whatever is used, it involves the removal of the entire prostate gland, the seminal vesicles and the ampullary portion of the vasa deferentia, with creation of an anastomosis between the bladder and the membranous urethra. Whenever possible, the surgical procedure is tailored to preserve the neurovascular bundles responsible for erectile function as well as the external sphincter for continence. Pelvic lymphadenectomy may be performed in patients at mid to high risk.

Post treatment anatomy: the bladder and levator sling descend to occupy the space created by the absent prostate (Fig. 1 on page 7). The normal vesicourethral anastomosis shows a rather round or irregular morphology on axial plane (Fig. 2 on page 7) and a cone-like or V-shape morphology on sagittal and coronal plane (Fig. 3 on page 7), with a variable degree of low signal intensity in all sequences without focal enhancement indicating post-operative scarring. Rarely, it may be also be visualized residual prostate gland (Fig. 4 on page 8) that should not be confused with recurrence (PSA does not reach undetectable levels), although malignant cells can be present in residual tissue (Fig. 5 on page 8). In seminal vesicles bed, generally, a low signal intensity fibrotic tissue with linear morphology is visualized (Fig. 6 on page 9). Retained seminal vesicles are observed in approximately 20% of patients after RP and are usually easily recognizable on T2-weighted images, as they tend to maintain their normal convoluted tubular appearance with high signal intensity (Fig. 7 on page 10); alternatively low signal intensity, presumably as a result of fibrosis, may be seen in seminal vesicles remnants. Metallic clips are also visualized within the surgical field, particularly at level of vesicourethral anastomosis, as signal-void susceptibility artifacts depending on their number and distribution that may make
accurate evaluation of adjacent anatomic structures extremely difficult. Surgical clips are usually more conspicuous on DWI and gradient-echo T1 images than on fast spin-echo T2 images (Fig. 8 on page 11). Retropubic fat pad is reduced or absent following a retropubic approach; anterior rectal-wall scarring is more prominent following a transperineal approach.

**Patterns of recurrence**: the typical appearance of recurrence is an asymmetric thickening of anastomosis or a nodular soft-tissue in the prostatectomy bed that is slightly hyperintense on T2 weighted images, shows increasing signal intensity on high b-value diffusion weighted images with restriction on ADC map, and tends to enhance avidly in the arterial phase with wash-out in the venous phase on dynamic contrast-enhanced sequence (Fig. 9 on page 11, Fig. 10 on page 12); on the contrary post-operative changes tend to show either no enhancement or mild enhancement in later phase. Sometimes, small foci of cancer recurrence can show restricted diffusion and early focal enhancement without T2-weighted imaging appearance (Fig. 11 on page 12). Granulation tissue may occasionally be present in the perianastomotic region, where it can mimic the appearance of tumor recurrence showing marked enhancement, particularly during the early post-operative period. The most common sites of local recurrence after RP are the vesicourethral anastomosis, retrovesical fat, seminal vesicles bed (Fig. 12 on page 13) and the anterior or lateral surgical margins of the prostatectomy bed.

**B) Radiation therapy**

**Background**: about 25% of patients with PCa undergo RT with a curative intent. EBRT involves the use of ionizing radiation directed at the prostate and surrounding tissues through multiple portals. In brachytherapy, radioactive sources are implanted directly into the prostate gland to deliver a permanent dose of radiation to the tumor while sparing the bladder and the rectum.

**Post treatment anatomy**: morphologic changes after RT are decreased volume and diffusely decreased signal intensity on T2 weighted images of the entire prostate and seminal vesicles (Fig. 13 on page 14); so, the peripheral, central and transitional zones appear less distinct from each other. These changes are due to RT-induced glandular atrophy and fibrosis. Prostate tumor also shows morphologic changes, which may include decreased size, reduced capsular bulging, capsular irregularity or decreased extracapsular extension. In addition, diffusion weighted sequence shows a reduced restriction on high b-value images and ADC map, while dynamic contrast-enhancement sequence shows a reduction of the vascularization (Fig. 14 on page 15). The effects of RT on adjacent structures include high T2 signal intensity and thickening of bladder wall, rectal wall, perirectal fascia and pelvic sidewall muscles (Fig. 15 on page 15), as well as hyperintense bone marrow on T1 weighted images owing to fatty replacement.
In brachytherapy, the seeds are seen on T1 or T2 images as small foci of focal signal intensity void inside the prostate gland.

**Patterns of recurrence:** recurrent tumor after RT typically appears on T2 weighted images as a nodular lesion of lower signal intensity than the adjacent normal prostate, in the same location as the pre-RT tumor. However, focal regions of hypointensity in the prostate on T2 images may represent treated tumor and not necessarily cancer recurrence, as well as recurrent tumors may not be apparent on T2 weighted images. So, restricted diffusion on high b-value diffusion weighted images and ADC map, as well as a rapid enhancement with wash-out on dynamic contrast-enhanced images are much more sensitive and specific for the presence of recurrence (Fig. 16 on page 16). Other identifying features of recurrence include growth of the lesion and progressive bulging of the prostatic capsule over time.

**C) Focal therapies**

**Background:** focal therapies are valuable emerging forms of treatment for low- and intermediate-risk localized PCa. Cryotherapy consists of the ablation of tissue by extremely cold temperature. HIFU technique converts mechanical energy into heat generating a cavitation process. Laser interstitial thermal therapy enables destruction of targeted tissues by using a laser light of a specific wavelength in the presence of oxygen. The results of these techniques are inflammatory reaction, coagulative necrosis and finally fibrosis and scarring. Their major limitation is the difficulty in ablating the entire prostate, especially in a large gland.

**Post treatment anatomy:** focal therapies may be used to treat the entire prostate, only one lobe or a specific prostate region. After treatment, the treated areas show iso-hypointense signal intensity on T1 images and hypo- or hyperintense signal on T2 images due to coagulative necrosis; on dynamic contrast-enhanced images they appear as unenhanced hypointense regions with a thick peripheral rim enhancement that resolve within 6 months. Later, the most significant MR patterns of focal therapies, depending on the extent of the treatment, are the decrease in size of the prostate gland, loss of zonal differentiation, absent focal restriction, complete ischemia, thickening of the prostate capsule and periprostatic fibrosis and scarring (Fig. 17 on page 16).

**Patterns of recurrence:** local recurrence after focal therapy appears as a focal nodular soft-tissue enhancing area with intermediate signal intensity on T2 weighted images and restricted diffusion on high b-value images and ADC map (Fig. 18 on page 17). Sometimes, it may be difficult to differentiate viable tumor from reactive enhancing prostate tissue, particularly at the margin of the treated areas (Fig. 19 on page 18).
Fig. 1: Normal pre (a) and post-operative anatomy (b): after radical prostatectomy the bladder (yellow line) and levator sling descend (blu line and arrow) to occupy the space created by the absent prostate (red line).

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Fig. 2: Normal post-operative vesicourethral anastomosis on axial plane: the normal vesicourethral anastomosis shows a rather round (a) or triangular (b) or irregular morphology (c) on axial plane with low T2-signal intensity.

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**Fig. 3:** Normal post-operative vesicourethral anastomosis on sagittal and coronal plane: the normal vesicourethral anastomosis shows a cone-like or V-shape morphology on sagittal (a, c) and coronal plane (b); thin short blind-end fistula is sometimes seen at vesicourethral anastomosis (arrow in c).

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**Fig. 4:** Residual prostate gland after radical prostatectomy on sagittal (a) and coronal plane (b).

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Fig. 5: Residual prostate gland after radical prostatectomy with a small focus of residual cancer: on axial T2 image it is shown residual prostatic tissue (a) in which is present a small nodular focus of hypointensity on ADC map (arrow in b) demonstrating early enhancement on DCE (arrow in c) suggestive for residual prostate cancer.

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Fig. 6: Normal finding of seminal vesicles bed after radical prostatectomy: low signal intensity fibrotic tissue with linear morphology (arrows).

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**Fig. 7:** Retained seminal vesicles after radical prostatectomy: on T2-weighted sagittal (a) and axial images (b), retained seminal vesicles tend to maintain their normal convoluted tubular appearance with high signal intensity (arrows).

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**Fig. 8:** Metallic clips at vesicourethral anastomosis: metallic clips are visualized as signal-void susceptibility artifacts, depending on their number and distribution; surgical clips are usually more conspicuous on DWI (c) and gradient-echo T1 images (d) than on fast spin-echo T2 images (a, b).

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**Fig. 9:** Cancer recurrence after radical prostatectomy: T2 axial image (a) shows an asymmetric thickening on the left posterolateral aspect of vesicourethral anastomosis (arrow) that demonstrates focal intense enhancement in the early arterial phase on dynamic contrast-enhanced image (b), confirmed by the time intensity-curve (c, d) of the lesion (red ROI and curve) compared to time-intensity curve of perianastomotic tissue (yellow and green ROIs and curves).

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**Fig. 10:** Cancer recurrence after radical prostatectomy: T2 sagittal (a) and axial images (b) shows a nodular soft-tissue mass in anterior perianastomotic fat (arrow) that is markedly hyperintense on high b-value DWI (c) with intense restriction on ADC map (d) and demonstrates early wash-in with wash-out on dynamic contrast-enhanced image (e), confirmed by the time-intensity curve of the lesion (f, red curve).

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**Fig. 11:** Cancer recurrence after radical prostatectomy: T2 axial image (a) shows neither asymmetric thickening nor soft-tissue mass; high b-value DWI (b) and ADC map (c) show, however, a small focal area of restricted diffusion on the right posterolateral aspect of vesicourethral anastomosis (arrows) with intense enhancement in the early arterial phase on dynamic contrast-enhanced image (d, arrow), confirmed by the time-intensity curve (e, f) of the lesion (red ROI and curve).

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Fig. 12: Cancer recurrence after radical prostatectomy: T2 axial image (a) shows a small nodular soft-tissue in the left seminal vesicle bed (arrow) that is hyperintense on high b-value DWI image (b) with restricted diffusion on ADC map (c) and shows focal early enhancement better seen on dynamic contrast-enhanced subtracted image (d), confirmed by time-intensity curve (e, f).

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Fig. 13: Post-radiation therapy normal changes: T2 coronal (a) and axial images (b, c) show decreased volume and diffuse decreased signal intensity of the entire prostate and seminal vesicles; high b-value DWI image (d) and ADC map (e) show restricted diffusion
while dynamic contrast-enhanced images show diffuse reduction of the vascularization (f).

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Fig. 14: Post-radiation therapy normal changes: pre-treatment mpMRI shows two low signal intensity nodules in peripheral zone (arrows) on T2 axial image (a) that are hypointenses on ADC map (b) and show focal early enhancement on dynamic contrast-enhanced image (c); after radiation therapy, the whole peripheral zone shows reduction of T2 signal intensity with lesser conspicuity of the nodules (d) that are less hypointenses on ADC map (e) and less vascularized on dynamic contrast-enhanced image (f).

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**Fig. 15:** Effects of radiation therapy on adjacent structures: T2 axial image (a) and high b-value DWI image (b) show high signal intensity of obturator internus muscles (arrows) consistent with post-radiation edema.

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**Fig. 16:** Cancer recurrence after radiation therapy: T2 axial image (a) shows diffuse reduction of signal intensity without nodular appearance; high b-value DWI image (b) and ADC map (c) show a focal area of restricted diffusion (arrows) with early enhancement on dynamic contrast-enhanced image (d), confirmed by time-intensity curve (e, f) of the lesion (red ROI and curve) compared to normal gland (yellow and green ROIs and curves).

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Fig. 17: Normal anatomy after focal therapy (HIFU): T2 sagittal (a), coronal (b) and axial images (c) show diffuse reduction in size and signal intensity of the prostate gland without focal appearance; ADC map (d) shows diffuse hypointensity without focal restriction; dynamic contrast-enhanced image shows no focal enhancement (e), confirmed by time-intensity curve (f).

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**Fig. 18:** Cancer recurrence after focal therapy (cryotherapy): T2 axial (a) and coronal images (b) show diffuse reduction in size and signal intensity of the prostate gland with a slightly hyperintense nodule in the left lobe (arrows) that is markedly hyperintense on high b-value DWI image (c) and hypointense on ADC map (d), and shows early wash-in and wash-out on dynamic contrast-enhanced image (e), confirmed by time-intensity curve (red curve in f).

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**Fig. 19:** Recurrence vs reactive tissue after focal therapy (HIFU): T2 axial image (a) shows diffuse reduction in size and signal intensity of the prostate gland without focal appearance; high b-value DWI image (b) and ADC map (c) show restricted diffusion without focal appearance; dynamic contrast-enhanced image (d) shows diffuse enhancement with an irregular area of early wash-in and wash-out on the left side (arrow), confirmed by time-intensity curve (red curve in e); however, biochemical failure was due to bone metastasis (arrow in f).

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Conclusion

MRI can play an important role when there is clinical or biochemical suspicion of residual or recurrent disease after treatment. In particular, MRI allows the differentiation between residual glandular healthy tissue, scar/fibrotic tissue, granulation tissue and tumor recurrence.

It is mandatory for a radiologist to distinguish normal and pathological findings of the prostatic region to allow patients to be correctly worked up.
Personal information

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