The prostate treated for prostatic carcinoma: Magnetic resonance (MR) patterns

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Learning objectives

To illustrate the most frequent MR imaging appearance of the prostate treated for prostate cancer, after surgical and ablative treatments.
To review the most common recurrence patterns after prostate surgical and ablative treatments.
To evaluate the most effective MR imaging examination techniques.
Background

Surgical and ablative treatments for prostate carcinoma are: (a) Radical prostatectomy; (b) Radiotherapy; (c) Brachytherapy; (d) Cryoablation; (e) High Focused UltraSound (HIFU) ablation (1).

MR is an effective imaging technique in the follow-up of treated prostate (1).

We reviewed 149 cases of MR examinations of patients with prostate cancer, treated with radical prostatectomy, radiotherapy, brachytherapy, cryoablation and HIFU ablation, to illustrate MR imaging patterns of the treated prostate and most frequent recurrence patterns.
MATERIALS AND METHODS
149 patients treated with radical prostatectomy, radiotherapy, brachytherapy, cryoablation and HIFU ablation performed MR follow-up between July 2005 and February 2009.
All MR examinations were performed with a 1.5T MR system (Philips Gyroscan Intera Power), using a dedicated endorectal coil. Pts treated with cryotherapy were examinated using the body phased-array coil.
All the patients underwent MR conventional multiplanar Turbo Spin-Echo (TSE) T2w sequences, followed from dynamic axial contrast enhanced (ce) Gradient-Echo (GRE) T1w sequence. In some patients we also performed MR spectroscopic acquisitions.

IMAGING FINDINGS
A) RADICAL PROSTATECTOMY
Background
Radical prostatectomy with a retropubic or perineal approach is the most frequently used treatment for prostate carcinoma confined to the gland. Prostate and seminal vesicles are removed and is created an anastomosis between the bladder and the membranous urethra. One or both of the neurovascular bundles surrounding the prostate are spared to preserve potency in patients with clinically localized disease. Pelvic lymphadenectomy may precede both retropubic and perineal prostatectomy in patients with a prostate-specific antigen (PSA) level of more than 10 ng/mL and a Gleason score of at least 7 (1,2).
Postoperative anatomy
The normal vesicourethral anastomosis showed a smooth, conelike morphology, without plication abnormalities (Fig. 1 on page 8). A non-enhancing low signal nodule was frequently seen at the anastomosis and usually represents fibrosis. Retropubic fat pad was reduced or absent following a retropubic approach. Anterior rectal-wall scarring was present following a transperineal approach (1,2,3).
Patterns of recurrence
After Radical Prostatectomy, recurrent prostate carcinoma appeared as an enhancing mass in the surgical site. Local recurrences were located around the area of the urethrovessel anastomosis, at the bladder neck or in the retrovesical space. On conventional T2w MR images local recurrences resulted slightly hyperintense compared to the perianastomotic tissue. On dynamic ce-GRE T1w MR images local recurrences showed focal early enhancement compared to the perianastomotic tissue (4,5,6) (Fig. 2 on page 8, Fig. 3 on page 9, Fig. 4 on page 10).
B) RADIOTHERAPY
Background
17% of newly diagnosed patients undergo external-beam radiation therapy as definitive treatment for clinically localized disease (7).
Post treatment anatomy
Morphologic MR evaluation showed (a) parenchymal fibrosis and atrophy, (b) reduction in size of the gland, (c) postirradiation zonal indistinctness on T2w images due to a diffuse reduction in secretion volume and T2w signal intensity. Dynamic ce MR evaluation showed a reduction of the vascularization of the gland. MR spectroscopy showed metabolic alterations, with decrease of metabolites, in particular of citrate (1,7,8) (Fig. 5 on page 11).

Patterns of recurrence
After radiation therapy, recurrent prostate carcinoma appeared as focal nodular region of reduced signal intensity at morphologic T2w MR images. On dynamic ce MR images local recurrences showed greater enhancement compared to the perilesional prostatic tissue. The pattern of the Time/Intensity curves of the lesions resulted similar to the patterns of the pathologic curves before the treatment. MR spectroscopic evaluation showed increased (Cho + Cr)/Cit ratios and/or the presence of Cho voxels in regions with metabolic atrophy (6,7) (Fig. 6 on page 12, Fig. 7 on page 13).

C) BRACHYTHERAPY
Background
Permanent low dose-rate brachytherapy is an alternative therapeutic option to radical prostatectomy as well as to conformal radiotherapy in patients with clinically localized carcinoma (9) (Fig. 8 on page 14).

Post treatment anatomy
Morphologic MR evaluation showed (a) reduction in size of the gland, (b) diffuse reduction of signal intensity on T2w images due to parenchymal fibrosis and atrophy. Dynamic ce MR evaluation showed a reduction of the vascularization of the gland. Radiation therapy seeds were seen on T1w images as small foci of focal signal intensity void inside the prostate gland parenchima. On T2w images prostate anatomy was better visualised due to the high contrast naturally available between the gland and the surrounding tissues (9) (Fig. 9 on page 15).

Post-implant dosimetry
MR imaging is also used for post-implant dosimetry. The post-plan dosimetries were based on GRE T1w (to locate the radioactive sources) and TSE T2w (to visualise the prostate) imaging. Post-implant dosimetry was performed on fused transverse T1w and T2w MR images, using dedicated image fusion softwares (10) (Fig. 10 on page 16).

Patterns of recurrence
Recurrent prostate carcinoma after brachytherapy appeared as focal nodular region of intermediate signal intensity on T2w MR images, with greater enhancement compared to the perilesional prostatic tissue on dynamic ce MR images (9) (Fig. 11 on page 16).

D) CRYOTHERAPY
Background
Cryosurgery is the term used to describe tissue destruction using extreme cold temperature (Fig. 12 on page 17). The histologic sequelae of this process are inflammatory reaction, coagulative necrosis and finally fibrosis and scarring. Cryosurgical ablation is a safe, well tolerated and minimally invasive alternative therapy for localized prostatic carcinoma.
As it is not possible to document hystopathologically the complete tissue necrosis after cryoablation and PSA level results variable during the follow-up, a radiological follow-up can be helpful. MR can be an effective imaging technique in the follow-up of prostate tumors treated with cryosurgical ablation, in particular in the early evaluation of the efficacy of the treatment (immediate feedback about size and geometry of the cryoinsult) and in the evaluation of patients with clinical or laboratory suspect of recurrence (11,12).

_Post treatment anatomy_

Cryolesions typically appeared to be isointense on T1w images and hypo- or hyperintense on T2w images due to the coagulative or colliquative necrosis induced by cryotherapy. All cryolesions showed an increase in size 24 hours after treatment, due to postcryosurgery prostate edema, and a progressive decrease in size (more than 80% at 36 months) due to fibrotic evolution of cryolesions. Treated prostate showed no significant vascularization of the peripheral zone, with periurethral zone sparing, on ce-MR images, due to vasocostriction and thrombosis of distal arterioles and venules induced by cryotherapy (11,12) (Fig. 13 on page 17).

The most significant MR patterns in the follow-up of prostatic carcinoma treated with cryosurgical ablation were the decrease in size of the gland with the passing of time and the complete ischemia of the prostate, with periurethral zone sparing.

The most effective MR techniques for lesions size and enhancement evaluation were TSE T2w and subtracted ce-GRE-FS T1w sequences (12).

_Patterns of recurrence_

On MR images local recurrences after prostate cryoablation showed focal nodular areas with intermediate signal intensity on T2w images and contrast enhancement on ce GRE T1w images (Fig. 14 on page 18).

**E) HIFU ABLATION**

_Background_

HIFU ablation is an alternative treatment for localized prostate carcinoma, that has the potential to treat the tumor minimizing the sexual and urinary morbidity that accompany radical therapies.

The treatment is performed using an endorectal probe capable of provide real-time diagnostic imaging or high energy for therapeutic ablation. The treatment induces a coagulative necrosis of the gland (13) (Fig. 15 on page 18).

MR can be an effective imaging technique in the follow-up of prostate tumors treated with HIFU ablation, in particular in the early evaluation of the efficacy of the treatment and in the evaluation of patients with clinical or laboratory suspect of recurrence (13).

_Post treatment anatomy_

After the treatment, the prostate showed predominantly low signal intensity on both T1w and T2w MR images, with poor definition to the capsule and with heterogeneous signal intensity of the surrounding fat. Treated glands showed an increase in size 24 hours after treatment and a progressive decrease in size (more than 45%), due to fibrotic evolution. On ce-dynamic MR images the treated gland showed nonenhancing, low signal intensity within the prostate, extended outside the gland and involved the periprostatic fat and the levator ani muscle (Fig. 16 on page 19).
The most significant MR patterns in the follow up of prostatic carcinoma treated with HIFU ablation were the decrease in size of the gland with the passing of time and the complete ischemia of the prostate, with periurethral zone sparing. The most effective MR techniques for lesions size and enhancement evaluation were TSE T2w and subtracted ce-GRE-FS T1w sequences (13).

*Patterns of recurrence*

On MR images local recurrences after prostate HIFU ablation showed focal nodular areas with intermediate signal on T2w images and contrast enhancement on ce GRE T1w images (Fig. 17 on page 20).
Fig. 0: Fig. 1 RADICAL PROSTATECTOMY NORMAL ANATOMY Normal vesicourethral anastomosis shows conelike morphology on MR images, with low signal intensity on T2w images (A,B,C) and non enhancing pattern on post contrast GRE T1w images due to fibrosis (D).

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Fig. 0: FIG. 2 RADICAL PROSTATECTOMY RECURRENCE 4 YEARS AFTER TREATMENT Transverse (A) and sagittal (B) TSE T2w MR images show a solid tissue with signal intensity slightly higher than that of the adjacent pelvic muscles in the posterior wall of vesico-urethral anastomosis (arrow), isointense on GRE T1w image (C). After injection of contrast material, ce GRE T1w image showed fast enhancement of the lesion (D, arrow), better evaluated on subtracted ce GRE T1w image (E, arrow). The time/intensity curve from the lesion shows more intense enhancement compared to the time/intensity curve of the perianastomotic tissue (F)

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Fig. 0: FIG. 3 RADICAL PROSTATECTOMY RECURRENCE 6 YEARS AFTER TREATMENT Transverse (A) and sagittal (B) TSE T2w MR images show high signal intensity tissue in the left retrovesical region (arrow), isointense on GRE T1w image (C). After injection of contrast material, ce GRE T1w image shows fast enhancement of the lesion (D, arrow). Better evaluation of the lesion on subtracted ce GRE T1w image (E, arrow. The time/intensity curve from the lesion shows more intense enhancement compared to the time/intensity curve of the normal right retrovesical region (F).

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Fig. 0: FIG. 4 RADICAL PROSTATECTOMY RECURRENCE 3 YEARS AFTER TREATMENT Transverse (A) and sagittal (B) TSE T2w and unenhanced GRE T1w (C) MR images show no lesion in the perianastomotic zone. Focal early enhancement in the left perianastomotic tissue on subtracted dynamic ce GRE T1w image (E, arrow). The time/intensity curve from the lesion shows more intense enhancement compared to the time/intensity curve of the normal right perianastomotic tissue (F).

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**Fig. 0:** Fig. 5 RADIOTHERAPY NORMAL ANATOMY
Transverse (A) and sagittal (B) TSE T2w MR images show reduction in size and signal intensity of the gland due to parenchimal fibrosis and atrophy, with diffuse reduction in secretion volume. On MR spectroscopic images (C,D) the gland shows decrease of metabolite levels, in particular of citrate, due to parenchimal atrophy.

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Fig. 0: FIG. 6 RADIOTHERAPY RECURRENCE 4 YEARS AFTER TREATMENT
Transverse (A) TSE T2w MR image shows a hypointense lesion of the right anterolateral zone of the prostate (arrow). After injection of contrast material, dynamic ce GRE T1w image shows fast enhancement of the lesion (B). MR spectroscopic evaluation (C,D) shows increased (Cho + Cr)/Cit ratio (2.06).

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**Fig. 0: FIG. 7 RADIOTHERAPY RECURRENCE 6 YEARS AFTER TREATMENT**

Transverse (A) TSE T2w MR image shows reduction in size of the prostate, with small area of intermediate signal intensity in the right peripheral zone (arrow). Subtracted ce-dynamic MR images (B,C) show marked enhancement of the lesion (red circles). MR spectroscopic evaluation (D) shows the presence of Cho voxels.

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Fig. 0: FIG. 8 BRACHITHERAPY TREATMENT TECHNIQUE Iodine-125 seeds (A). Needles containing radioactive sources (B) are placed throughout the prostate under transversal ultrasound control, with the aid of a needle-spacing template (C)

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**Fig. 0:** FIG. 9 BRACHITHERAPY NORMAL ANATOMY Transverse GRE T1w (A), TSE T2w (B) and fused transverse GRE T1w and TSE T2w (C) MR images. Diffuse reduction of signal intensity on T2w image (B) due to parenchimal fibrosis and atrophy. Radiation therapy seeds are seen on GRE T1w image (as small focal signal intensity voids) while the anatomy is well visualised on TSE T2w image. Fused MR images are obtained for 3D reconstruction of the performed implant.

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**Fig. 0:** FIG. 10 BRACHITHERAPY MR POST IMPLANT DOSIMETRY Post-implant dosimetry based on fused transverse GRE T1w and TSE T2w MR images. The yellow line represents the isodose line of the reference dose.

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**Fig. 0:** FIG. 11 BRACHITHERAPY RECURRENCE 4 YEARS AFTER TREATMENT
Transverse (A) TSE T2w MR image shows reduction in size of the prostate, with small area of intermediate signal intensity in the left peripheral zone (arrow). After injection of contrast material, subtracted ce GRE T1w image shows fast enhancement of the lesion (B, arrow). Better evaluation of the lesion on fused TSE T2w and ce GRE T1w image (C, arrow).

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**Fig. 0:** FIG. 12 CRYOTHERAPY TREATMENT TECHNIQUE (A) 17G cryoneedle. (B) scheme of cryoprobes placement into the prostate gland (C) 17G cryoneedles inserted through the perineum to outline the shape of the prostate

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**Fig. 0:** FIG. 13 CRYOTHERAPY NORMAL ANATOMY 24 hrs after treatment, cryolesion was more than 6 mm larger than the original gland; progressive decrease in size at 12 and 36 months after surgery. Subtracted ce-T1w MR images showed ischemia of the peripheral gland and enhancement of the central portion of the prostate, due to the sparing of the periurethral zone.

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**Fig. 0:** FIG. 14 CRYOTHERAPY RECURRENCE 3 YEARS AFTER TREATMENT Increase in size of the periurethral spared zone (red arrows) on MR images at 36 months from treatment, in patient with increase of PSA level. Biopsy findings suggested a local recurrence.

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**Fig. 0:** FIG. 15 HIFU ABLATION TREATMENT TECHNIQUE Scheme of position of the HIFU endorectal probe, capable of provide real-time diagnostic imaging or high energy for therapeutic ablation.

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**Fig. 0:** FIG. 16 HIFU ABLATION NORMAL ANATOMY After the treatment, the prostate shows predominantly low signal intensity on both T2w (A) and T1w (B) MR images. Subtracted ce-dynamic MR image (C) shows lack of enhancement of the treated gland.

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**Fig. 0:** FIG. 17 HIFU ABLATION RECURRENCE 2 YEARS AFTER TREATMENT

Transverse (A) and sagittal (B) TSE T2w MR images show low signal intensity of the peripheral gland, with an area of intermediate signal intensity in central zone (arrow). After injection of contrast material, conventional (C) and subtracted (D) ce GRE T1w images show fast enhancement of the lesion (arrow).

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Conclusion

DISCUSSION
The most effective examination techniques in the MR evaluation of pts treated with surgical or ablative therapies for prostate carcinoma were multiplanar TSE T2w and dynamic GRE T1w sequences. A useful additional technique was MR spectroscopy. The most important parameter in the MR imaging evaluation of patients treated with radical prostatectomy for prostate carcinomas was the absence of enhancing nodules, at the excision site and at the perianastomotic space. The most important parameters in the evaluation of conservative treatments were the lack of increase in size and the hypovascularization of the treated areas. The most important parameters in the evaluation of recurrences were the presence of nodular patterns of enhancement on dynamic MR study in the treated areas, associated to the increase of (Cho + Cr)/Cit ratio on spectroscopic images evaluation.

CONCLUSION
MR was a effective imaging technique in the immediate, short and long-term follow-up of the prostate following various prostate-directed surgical and ablative therapies.
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