Prostate MRI Protocols

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Declaration of Financial Interests or Relationships

I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.

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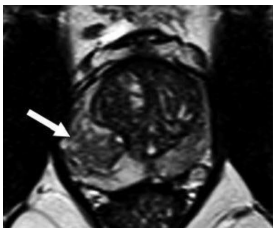
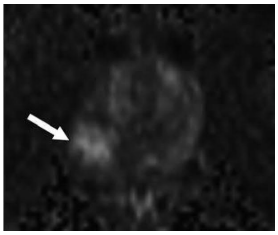
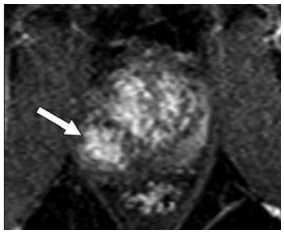
Introduction

- Multiparametric magnetic resonance imaging (mpMRI)

T2-weighted (T2W) Imaging | Diffusion-Weighted Imaging (DWI) | Dynamic Contrast-Enhanced (DCE)

- Prostate Imaging – Reporting And Data System (PI-RADS v.2.1)
  - Improves detection, localization, characterization, and risk stratification of prostate cancer (Pca)
  - Standardizes mpMRI acquisition, interpretation and reporting
  - Establishes minimum acceptable technical parameters

Purysko, AJR 216 (2021)

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Technical Specifications for mpMRI (PI-RADS v2.1)

- Tailored to specific patients, clinical questions, and MRI equipment
- Magnetic Field Strength
  - Both 3T and 1.5T – adequate and reliable
  - 3T – superior
    - Increased signal-to-noise ratio (SNR)
    - Increased spatial resolution, temporal resolution, or both
  - 1.5T – the choice for patients with implants (safety or image artifact)
  - Lower magnetic field strength (< 1.5T) not recommended

https://www.acr.org/Clinical-Resources/Reporting-and-Data-Systems/PI-RADS

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Technical Specifications for mpMRI (PI-RADS v2.1)

- Coils
  - Pelvic phased-array coils commonly used
  - Endorectal Coil (ERC)
    - Increased SNR, advantageous for larger patients
    - Increased exam time and cost, image artifacts, and patient discomfort
- Specialized post-processing software
  - Not required but may improve workflow
  - Provide quantitative measurements
  - Facilitate MR targeted biopsy

Specifications for Prostate mpMRI Protocol (PI-RADS v.2.1)

	T2-Weighted (T2W) Imaging	Diffusion-Weighted Imaging (DWI)	Dynamic Contrast-Enhanced (DCE)
Pulse sequence	2D RARE, fast-spin-echo (FSE) or turbo-spin-echo (TSE)	2D spin-echo echo-planar imaging (EPI) with spectral fat suppression	3D T1-Weighted (T1W) gradient echo (GRE)
Imaging planes	Axial (straight or oblique); Sagittal and/or Coronal	Axial (match T2W)	Axial (match T2W)
Slice thickness	3 mm, no gap	≤ 4 mm , no gap	3 mm, no gap
Field of View (FOV)	12–20 cm	16–22 cm	12–20 cm
Pixel size	≤ 0.7mm (phase) x ≤0.4 mm (frequency)	≤ 2.5mm (phase and frequency)	≤ 2mm (phase and frequency)
Specific Recommendation	3D axial acquisition as adjunct to 2D not a replacement	TE ≤ 90 msec; TR ≥ 3000 msec	TE < 5 msec; TR < 100 msec Temporal resolution ≤ 15 sec
	Appropriate echo train length to avoid T2 blurring	Apparent Diffusion Coefficient (ADC) maps: low b-value 0-100 sec/mm^2 (preferably 50-100 sec/mm^2); intermediate b-value 800-1000 sec/mm^2	Low molecular weight gadolinium-based contrast agent (GBCA) Dose: 0.1mmol/kg Injection rate: 2-3 cc/sec
		High b-value (≥ 1400 sec/mm^2): acquired or calculated	Total scan time ≥ 2 min (before, during, and after GBCA injection)
		Additional b-values (100-1000 sec/mm^2) for accurate ADC and high b-value calculations	

"Everyday" Clinical Prostate mpMRI at UTSW

- Magnetic Field Strength
  - 3T preferred
  - 1.5T for patients with implants not safe for 3T, or bilateral hip replacements
- Pelvic phased-array coils and Endorectal coil (ERC)
  - Protocol for without ERC: more signal averages, compromised spatial resolution
- DynaCAD (Invivo) and syngo.via (Siemens)
  - Segmentation of the prostate and the lesion for biopsy targeting
  - DCE analysis

Costa, Urol Oncol: Seminars and Orig Investig 34 (2016)

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Clinical Prostate mpMRI Examination

- Philips: 3T and 1.5T Ingenia, 3T and 1.5T Achieva
- Siemens: 3T Skyra; 1.5T Avanto, Aera, and Sola

3T Ingenia Scan	Imaging Plane	TE/TR (msec)	FOV (cm)	Pixel size (mm)	Slice thickness /Gap (mm)	Accel. factor	Phase encoding	NSA	Scan Time (min:sec)
T2W SSTSE	3-Plane	80/1000	44 x 44	2 x 4	20/10	0	--	1	0:15
T2W TSE	SAG	120/3800	25 x 25	1 x 1	3/0.3	2	FH	1	2:26
T2W TSE	Obl AX	110/3938	18 x 18	0.45 x 0.6	2.5/0	2	RL	1	3:33
DWI SS-EPI	Obl AX	87/2425	16 x 16	1.25 x 1.32	3/0.3	4	RL	2	6:50
T2W TSE	Obl COR	110/2500	16 x 16	0.38 x 0.42	2.5/0	1.6	RL	1	4:50
T1W DCE	Obl AX	2.3/4.6	25 x 25	0.9 x 1	3/0	4	RL	1	5:46
T1W Post	AX	1.3/2.3/3.6	40 x 35	1.6 x 1.7	4/0	2.8	AP	1	0:21

Obl = oblique

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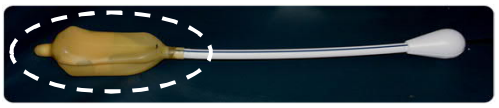
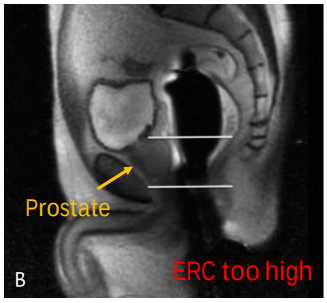
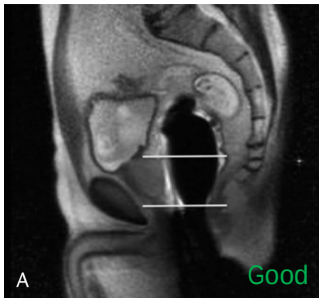
Verify Endorectal Coil (ERC) Position

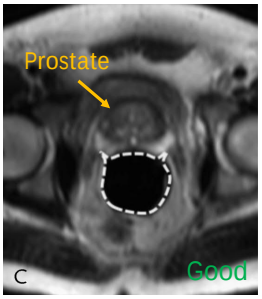
3T Ingenia Scan	Imaging Plane	TE/TR (msec)	FOV (cm)	Pixel size (mm)	Slice thickness /Gap (mm)	Accel. factor	Phase encoding	NSA	Scan Time (min:sec)
T2W SSTSE	3-Plane	80/1000	44 x 44	2 x 4	20/10	0	--	1	0:15

SSTSE = Single-shot turbo spin-echo









- ERC placed by technologist
- Inflated with barium

Costa, Top Magn Reson Imaging 23 (2014)

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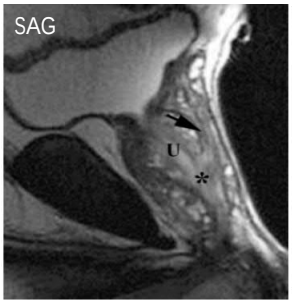
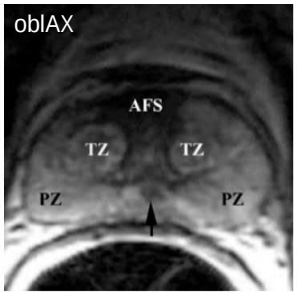
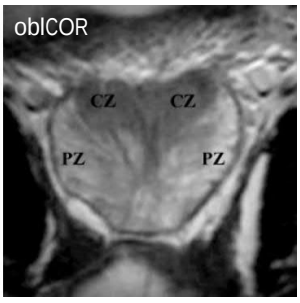
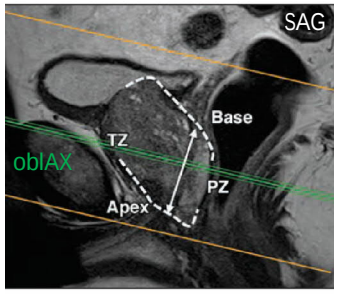
Prostate Zonal Anatomy on T2-Weighted Images

3T Ingenia Scan	Imaging Plane	TE/TR (msec)	FOV (cm)	Pixel size (mm)	Slice thickness /Gap (mm)	Accel. factor	Phase encoding	NSA	Scan Time (min:sec)
T2W TSE	SAG	120/3800	25 x 25	1 x 1	3/0.3	2	FH	1	2:26
T2W TSE	Obl AX	110/3938	18 x 18	0.45 x 0.6	2.5/0	2	RL	1	3:33
T2W TSE	Obl COR	110/2500	16 x 16	0.38 x 0.42	2.5/0	1.6	RL	1	4:50









https://www.acr.org/Clinical-Resources/Reporting-and-Data-Systems/PI-RADS; Purysko, AJR 216 (2021)

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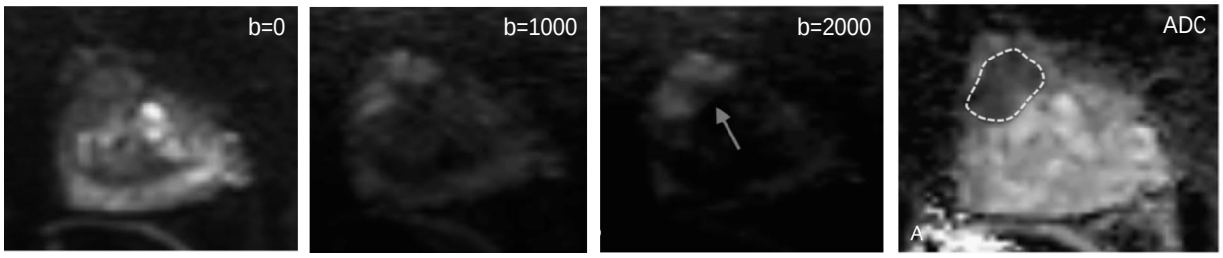
Diffusion-Weighted Imaging (DWI)

3T Ingenia Scan	Imaging Plane	TE/TR (msec)	FOV (cm)	Pixel size (mm)	Slice thickness /Gap (mm)	Accel. factor	Phase encoding	NSA	Scan Time (min:sec)
SS SE-EPI	Obl AX	87/2425	16 x 16	1.25 x 1.32	3/0.3	4	RL	2	6:50

- Single-shot SE-EPI with b-values of 0, 100, 1000, 1500, 2000 (3T) s^2/mm, with corresponding NSA of 2, 2, 4, 6, 6
- ADC maps: monoexponential model



Costa, Top Magn Reson Imaging 23 (2014)

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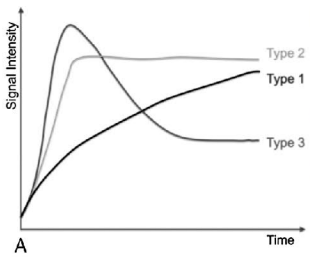
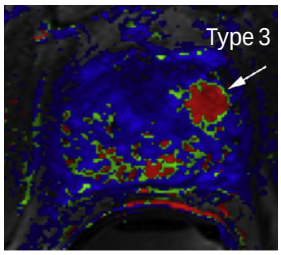
T1-Weighted Dynamic Contrast-Enhanced (DCE) Imaging

3T Ingenia Scan	Imaging Plane	TE/TR (msec)	FOV (cm)	Pixel size (mm)	Slice thickness /Gap (mm)	Accel. factor	Phase encoding	NSA	Scan Time (min:sec)
T1W DCE	Obl AX	2.3/4.6	25 x 25	0.9 x 1	3/0	4	RL	1	5:46
T1W Post	AX	1.3/2.3/3.6	40 x 35	1.6 x 1.7	4/0	2.8	AP	1	0:21

- T1W DCE
  - 3D spoiled gradient echo sequence (11 s/dyn)
  - Variable flip angle T1 mapping (optional)
- T1W post-contrast
  - 3D two-point DIXON gradient echo sequence
  - Evaluation of lymph nodes and bone lesions

Tissue Contrast Enhancement





Diaz de leon, Magn Reson Imaging Clin N Am 24 (2016)

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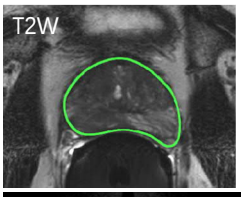
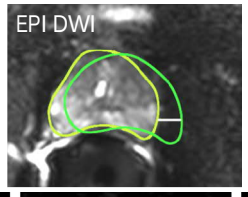
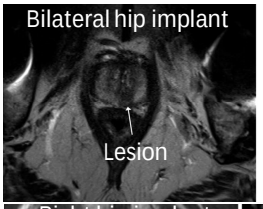
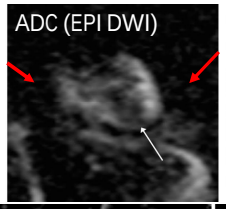
Susceptibility Artifacts of EPI DWI

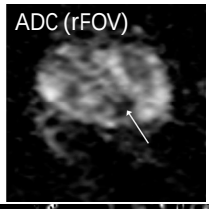




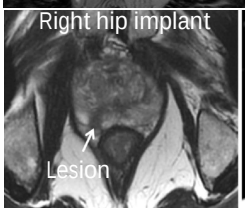
- Geometric distortion reduced by parallel imaging and high receiver bandwidth[1]

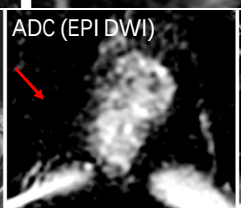


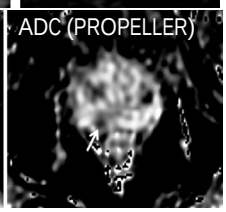




- Reduced FOV DWI with 2D focused excitation and parallel transmission[2]
- Siemens 3T Skyra







- PROPELLER DWI[3]
- GE 1.5T MR450

[1]Donato, Acad Radiol 21 (2014); [2]Rosenkratntz, Curr Prob Diag Radiol 47 (2018); [3]Czarniecki, Eur J Radiol 102 (2018)

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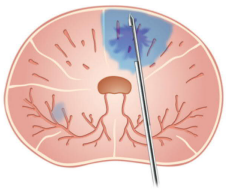
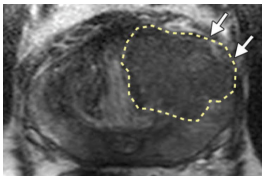
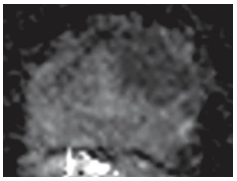
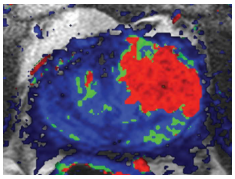
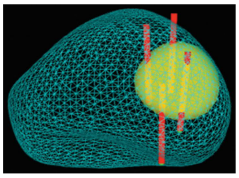
MRI Targeted Biopsy




T2W


ADC


DCE


MRI-TRUS

- MRI-transrectal ultrasound fusion biopsy
  - Improves lesion targeting
- MRI-guided in-bore biopsy
  - Target the center of a small lesion or the lowest ADC area of a heterogeneous lesion

DynaTRIM (Invivo)

Adjustments
S/I, A/P, L/R

Costa, RadioGraph 35 (2015)

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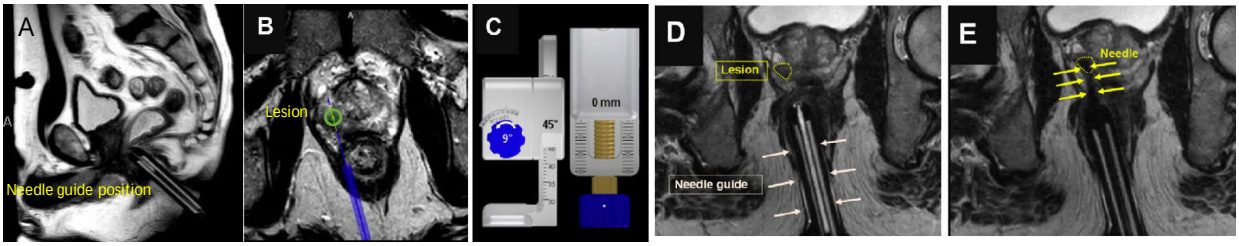
MRI Protocol for In-bore Biopsy

Procedure	Scan	Sequence	TE/TR (ms)	FOV (cm)	Acq Voxel (mm)	Scan time
Device gross position	3-plane localizer	2D bFFE	2/4	30 x 30	1.3 x 2.1 x 10(20)	30sec
Needle guide position	SAG T2	2D SSTSE	80/1300	26 x 26	0.9 x 1.1 x 3/0.3	19sec
Prebiopsy planning	SAG T2	2D TSE	110/3400	23 x 21	0.7 x 0.8 x 3/0.3	3min 30sec
	Straight AX T2	2D TSE	110/2500	20 x 20	0.6 x 0.8 x 3/0.3	2min 45sec
Needle guide verification	SAG T2	2D SSTSE	80/1300	26 x 26	0.9 x 1.1 x 3/0.3	19sec
Needle placement	AX T2	2D TSE	110/2300	20 x 20	0.8 x 0.9 x 3/0.3	1min 38sec



Costa, Eur Urol Onc 2 (2019)

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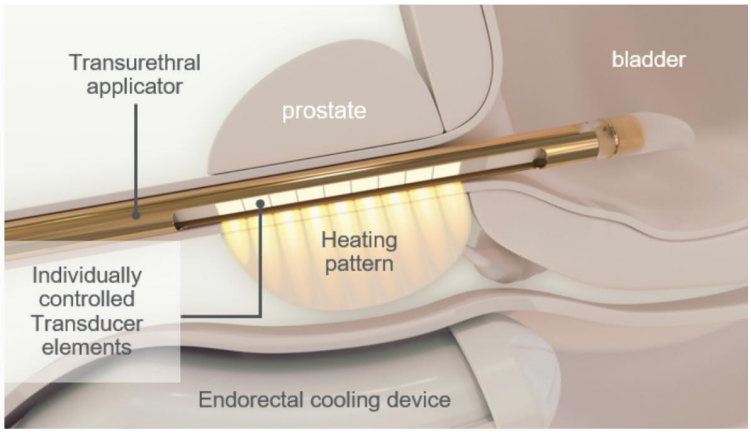
MR-guided Transurethral Ultrasound Ablation



- Linear array of 10 transducer elements
- Continuous sweeping ultrasound beam
- Real-time MRI thermometry feedback control
- Cooling of urethra and rectum

TULSA-PRO® (Profound)

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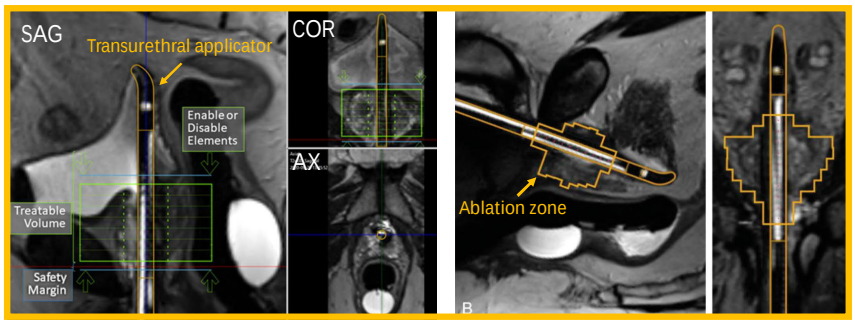
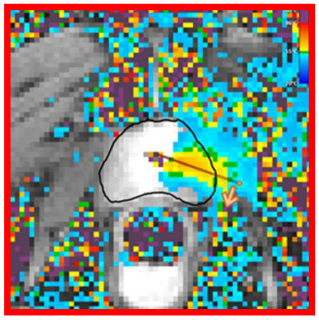
MRI Protocol for TULSA Therapy

Procedure	Scan	Sequence	TE/TR (ms)	FOV (cm)	Acq Voxel (mm)	Scan time
Device gross position	3-plane localizer	2D bFFE	2/4	30 x 30	1.3 x 2.1 x 5.0	30sec
Device alignment	SAG T2 (straight)	3D TSE	370/1800	30 x 30	1 x 1 x 2 (→1)	3min
Treatment planning	AX T2	2D TSE	110/2500	26 x 26	0.8 x 0.8 x 3/2	3min
Temperature mapping	AX Thermometry	2D GRE-EPI FS	12/25	26 x 26	2 x 2 x 5/0.4	5 sec/dyn
Post-treatment evaluation	AX T1 pre/post Gd	3D DIXON	1.5/2.7/4.3	35 x 30	1.1 x 1.3 x 3	1min 23sec





Klotz, JURO 205 (2021)

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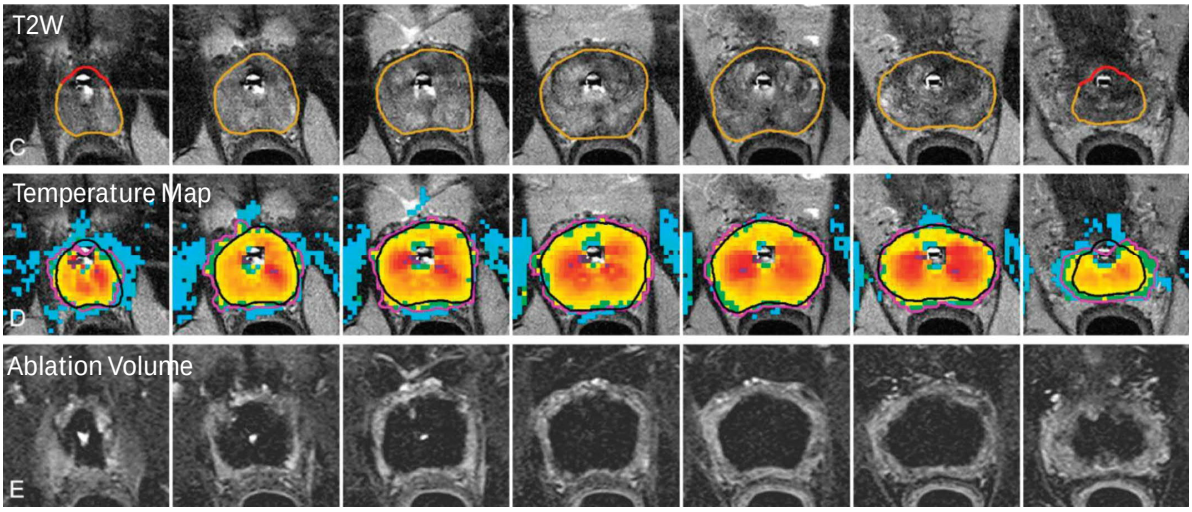
TULSA Procedure



Klotz, JURO 205 (2021)

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Summary

- High-quality prostate mpMRI depends on
  - Hardware, software, scanning parameters, and patient-related factors
- Implementation of prostate MRI protocols
  - PI-RADS technical specifications as guidelines
  - Preloaded sequences by MR vendors
- Optimization of prostate mpMRI protocols
  - Tailored to each scanner and institution
  - High image quality at a patient level
  - Development of novel and advanced MRI technology

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Thank You!

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  - Dr. Daniel Costa, Dr. Taemee Pak (Radiologists)
  - Adrian Gaspar, Heather Shelley, Orlando Morales (MRI Technologists)
  - Debbie Travalini (PA-C)
- Profound Medical Inc.
  - Dipti Joshi (Lead Clinical Product Expert)
- UT MD Anderson Cancer Center
  - Dr. Ho-Ling Anthony Liu
  - Dr. Jingfei Ma

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