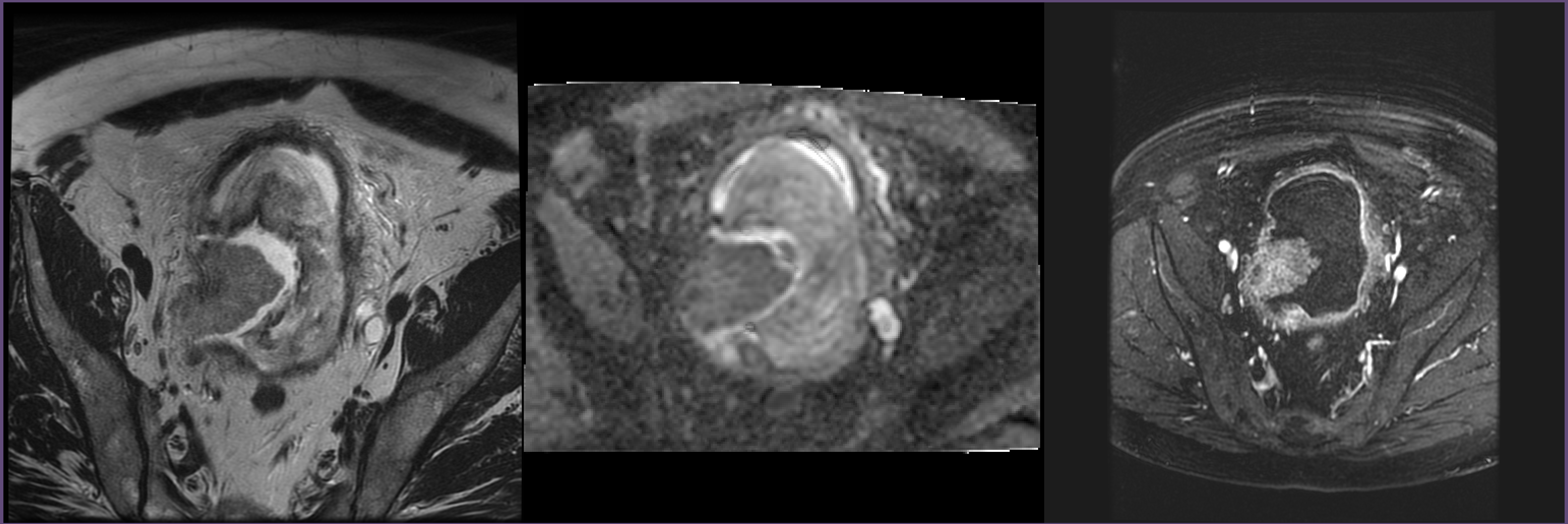

Development and Optimization of Multiparametric MRI for Bladder Cancer: Opportunities for Standardization and Quality Improvement

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Making Cancer History®

Bladder MR Imaging at MD Anderson Cancer Center

- **Unmet need for dedicated urinary bladder MR imaging & structured reporting for suspected high risk muscle invasive bladder cancer (MIBC)**
- **Additional, unmet need for dedicated bladder MR imaging for evaluation of patients following adjuvant/neoadjuvant systemic therapy**
  - Clinical need historically addressed with:
    - Routine pelvis MRI protocol
    - MR Urogram Protocol
    - Female pelvis MRI protocol
  - Bladder focused add on series, when added, limited to additional small FOV T2 series
  - Limitations:
    - Heterogenous FOVs & supplemental series depending upon base protocol
    - No multi-plane small FOV DWI
    - No bladder focused dynamic series

Implemented & optimized a dedicated bladder specific MRI protocol in keeping with the Vesical Imaging-Reporting and Data System (VI-RADS)

VI-RADS

- **Vesical Imaging Reporting and Data System (VI-RADS)**
  - Standardized system for MR imaging and interpretation for urinary bladder cancer
- **Requirements:**
  - Delayed void and antispasmodic agent administration
  - Multi-planar T2w
    - At least 2 planes
    - High spatial resolution
  - DWI
    - At least 2 planes
    - Two b –values, low and high 800-1000 s/mm^2
- DCE-MRI
  - At least 30s temporal resolution
  - High spatial resolution
  - Fat saturation
- Larger FOV T1w

General Protocol

- **4 major sub-parts**
  - Large FOV Imaging
    - Assist is positioning
    - Evaluate nodes
  - Small FOV T2 Imagining
    - Focused on the bladder
    - All 3 planes
  - Small FOV DWI
    - Sagittal and Axial
  - Contrast Imaging
    - Dynamics and delayed
- **No more than 45 minutes active scanning**

Large FOV Imaging
- Localizer
- Coronal T2
- Axial T2
- Axial DWI

↓

Bladder T2
- Axial T2
- Coronal T2
- Sagittal T2

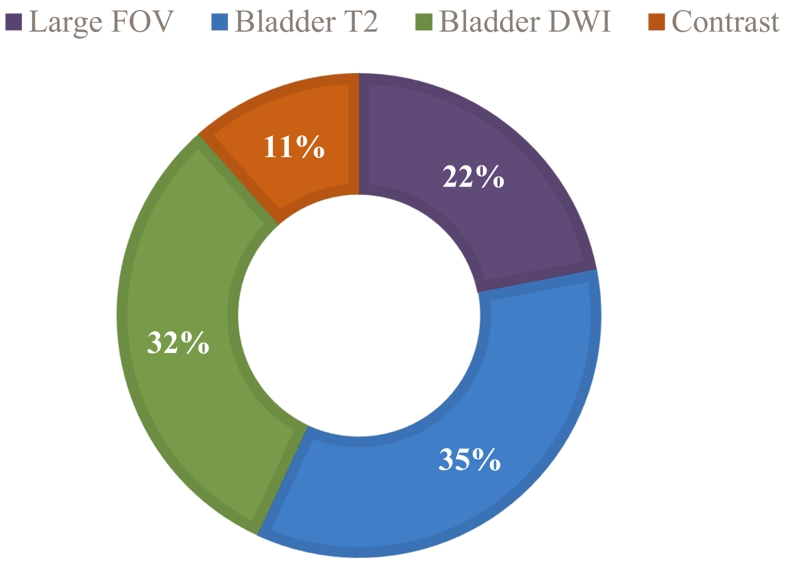
↓

Bladder DWI
- Sagittal DWI
- Axial DWI

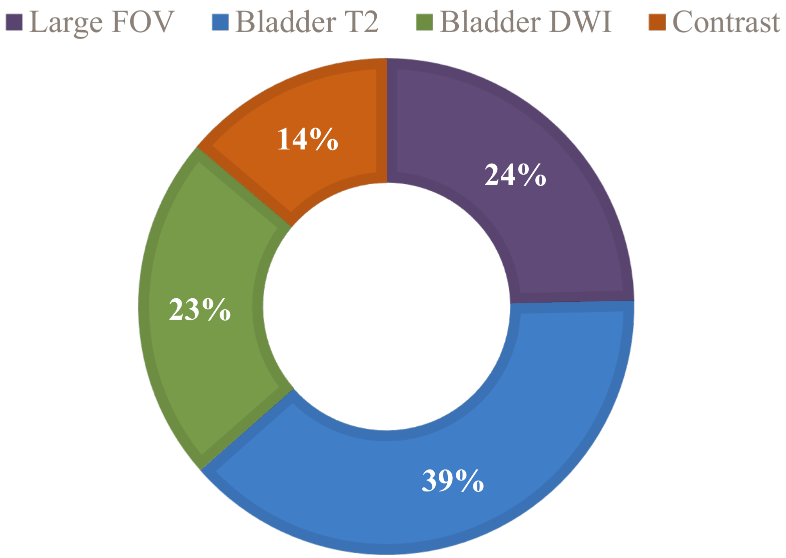
↓

Contrast Imaging
- Axial Pre
- Axial Dynamic
- Axial Post

Initial Protocol Time (Total 45 min)



Final Protocol Time (Total 40 min)

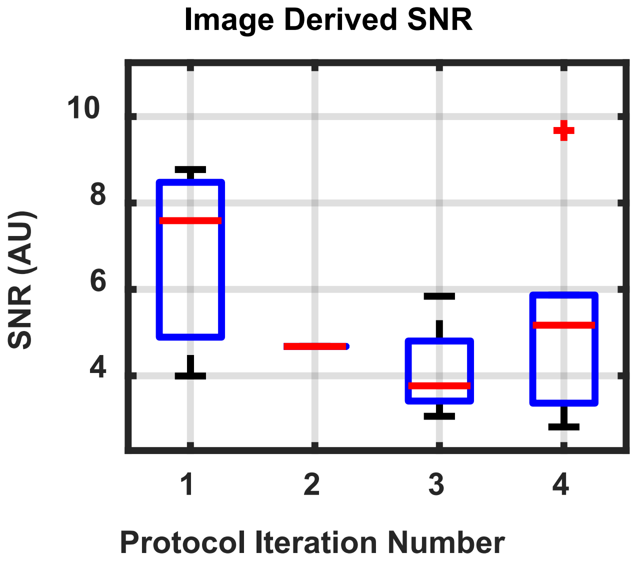


Protocol Specifics

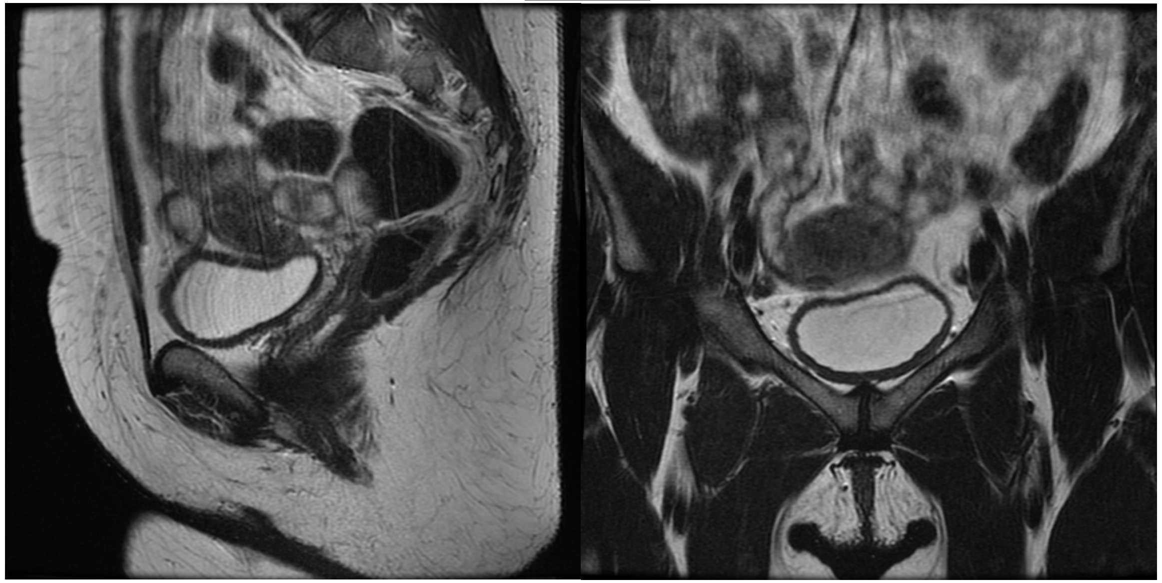
	T2 w				DWI			DCE			
Iteration #	1	2	3	4	1	2	3	1	2	3	4
Planes	Ax,Cor,Sag	Ax,Cor,Sag	Ax,Cor,Sag	Ax,Cor,Sag	Ax,Sag	Ax,Sag	Ax,Sag	Ax	Ax	Ax	Ax
TR (ms)	>6000	>6000	>6000	>6000	>6000	>6000	>6000	4.1	3.9	3.2	3.6
TE (ms)	140	116	119	119	62.2	53.2	51.1	1.71	1.6	1.4	1.6
Flip Angle (deg)	120	150	150	150	90	90	90	12	15	15	15
FOV (mm)	240	230	220	220	200	[320,160]	[220,176]	240	270	260	260
Matrix	[320,256]	[400,256]	[384,256]	[384,384]	[80,80]	[128,40]	[96,60] ↑	[224,160]	[192,192]	[192,192]	[192,192]
Resolution (mm)	[0.75,0.94]	[0.58,0.90]	[0.57,0.86]	[0.57,0.57]	[2.5,2.5]	[2.5,4]	[2.29,2.93]	[1.1,1.5]	[1.41,1.41]	[1.35,1.35]	[1.35,1.35]
Slice Thickness (mm)	3	3	3	3	3	4	4	4	2	2	2
Slice Gap (mm)	0	0	0	0	0	0.4	0.4	-2	-1	-1	-1 ↓
Acceleration	-	-	-	2	-	-	-	2	2	2.25	1.5
k-Space	Cart	Cart	Cart	Prop/Blade	EPI	EPI	EPI	partial	partial	partial	partial
NEX	3	1	1	2	2,14	4,10	2,10 ↓	0.72	0.74	0.73	0.71
b-value	-	-	-	-	50,800,1500s	50,1000	50,1000	-	-	-	-
Temporal Resolution	-	-	-	-	-	-	-	11	30	15	26 ↑
Scan Time per Slice (s)	9.40	6.30	6.00	7.10 ↓	6.20	5.70	5.00 ↓	0.66	1.30	1.83	2.34 ↑
Receive BW (Hz)	83.33	83.33	83.33	200	500	500	500	83.3	83.3	125	100

T2 Change

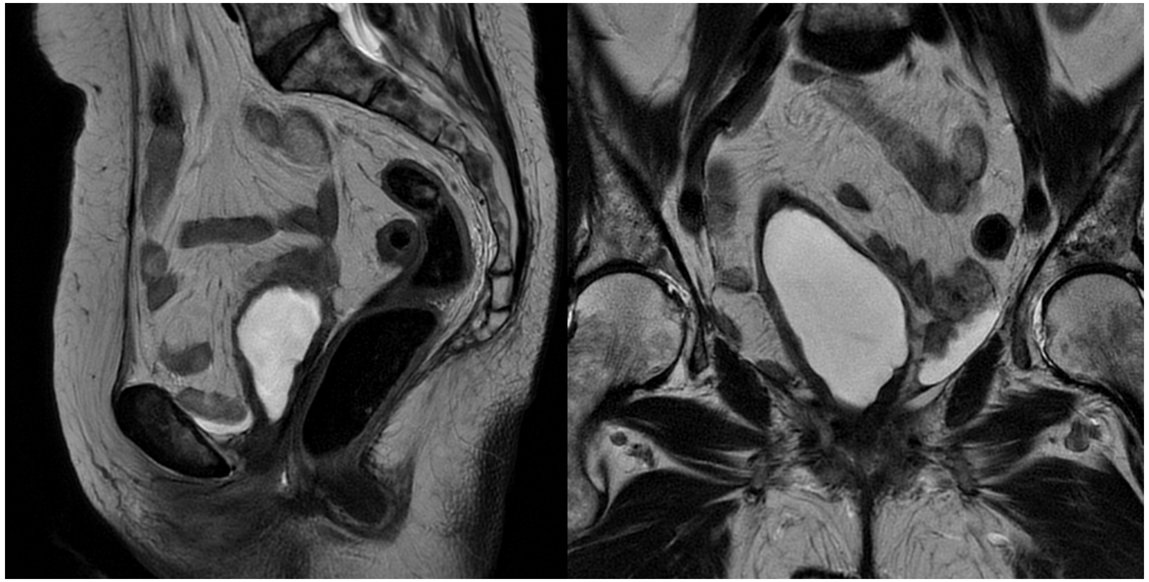
- **Initially focused on**
  - Reducing scan time
    - Protocol Iteration 3 had a 36% reduction in scan time
  - Improving resolution
    - [0.75x0.94] -> [0.57x0.86] mm
  - At the expense of SNR
- **Due to motion, non-Cartesian acquisitions (PROPELLER/BLADE) employed for final protocol**
  - Required modest scan time increase
    - 18% from protocol iteration 3 -> 4
  - Forced isotropic resolution 0.57 mm



Initial

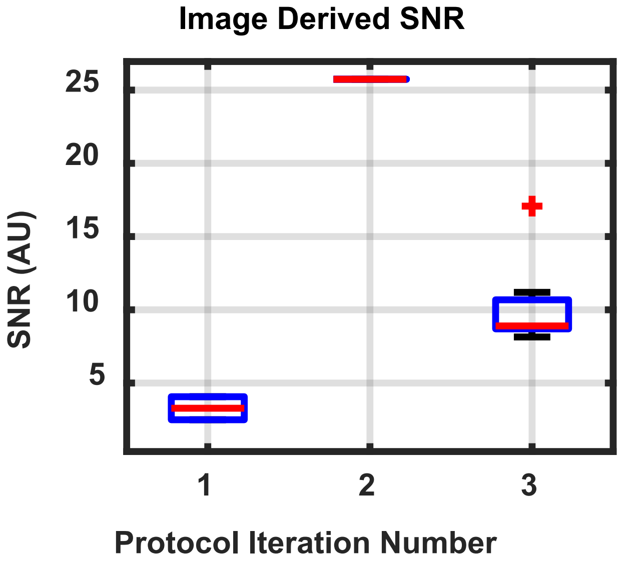


Final

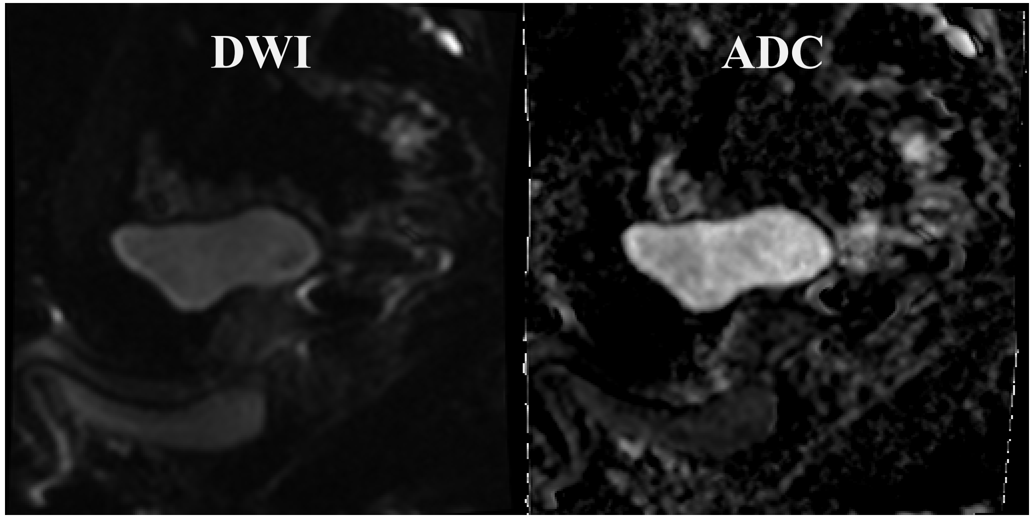


DWI Change

- **Initially acquiring DWI at higher spatial resolution and SNR than needed**
- **Reduced time by ~25%**
  - Increased slice thickness 3-> 4
  - Reduced NEX 14 ->10
- **Saved time then used on other sequences**
- **SNR Impacts mitigated by Slice thickness change**



Initial



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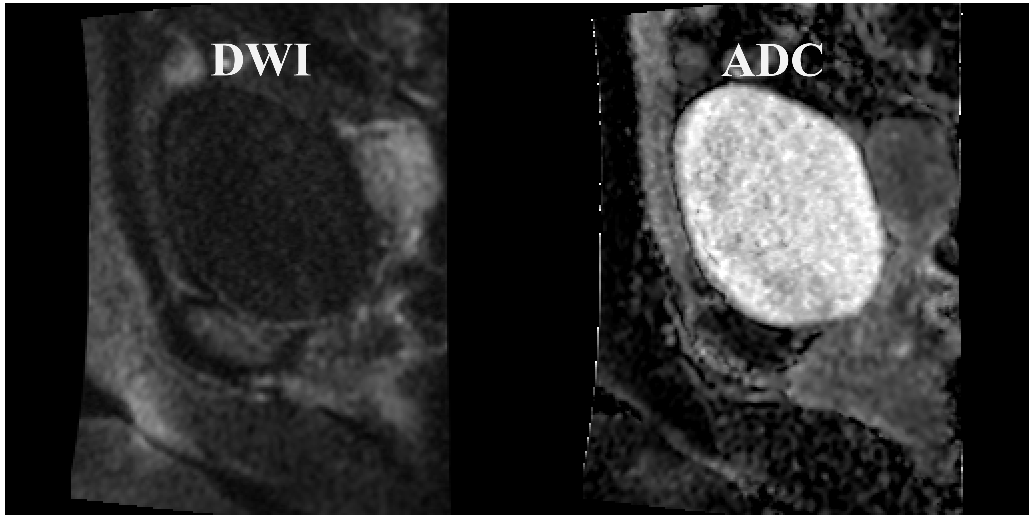
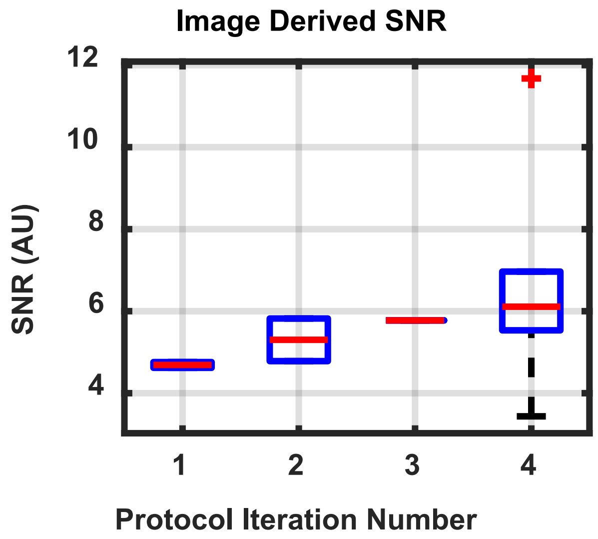


DCE Change

- **Dynamic Image Quality was improved by increasing scan time at the expanse of temporal resolution**
- **Scan Efficiency reduced by a factor of ~2.5**
    - Temporal Resolution ~10s -> 25s
    - Still met VIRADs suggested temporal resolution of 30s
- **Done to improve SNR and resolution**
    - Lower acceleration 2 -> 1.5
    - Better slice resolution 2 -> 1 mm



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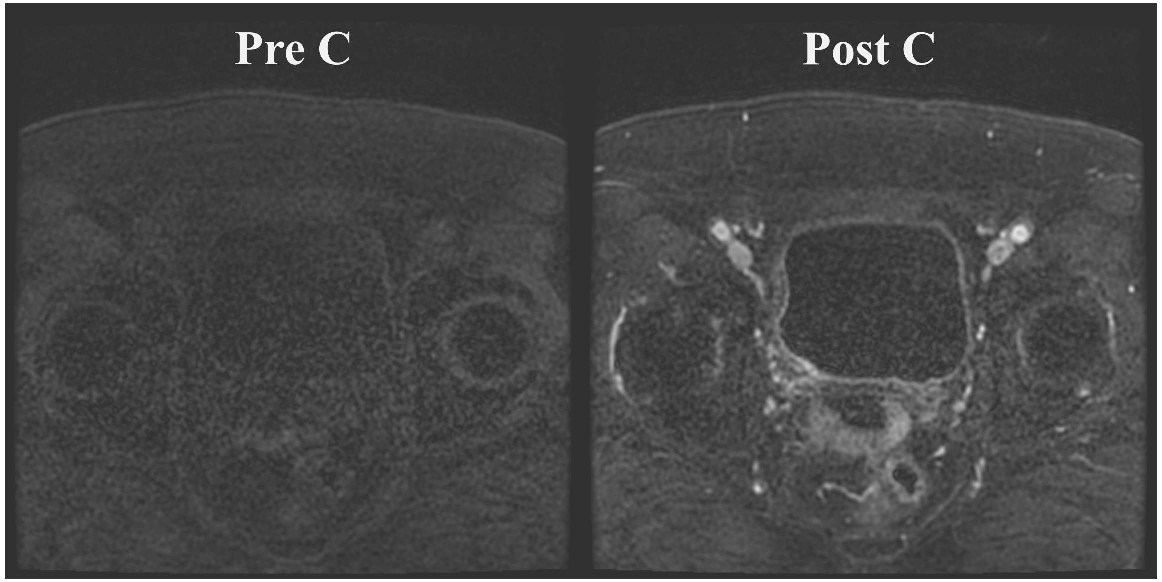
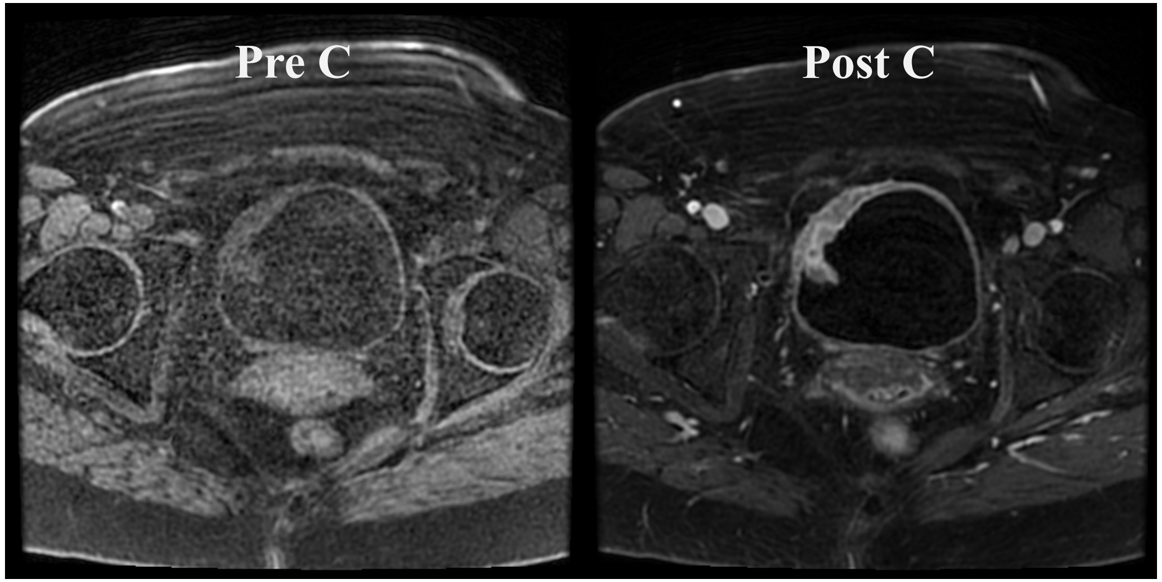
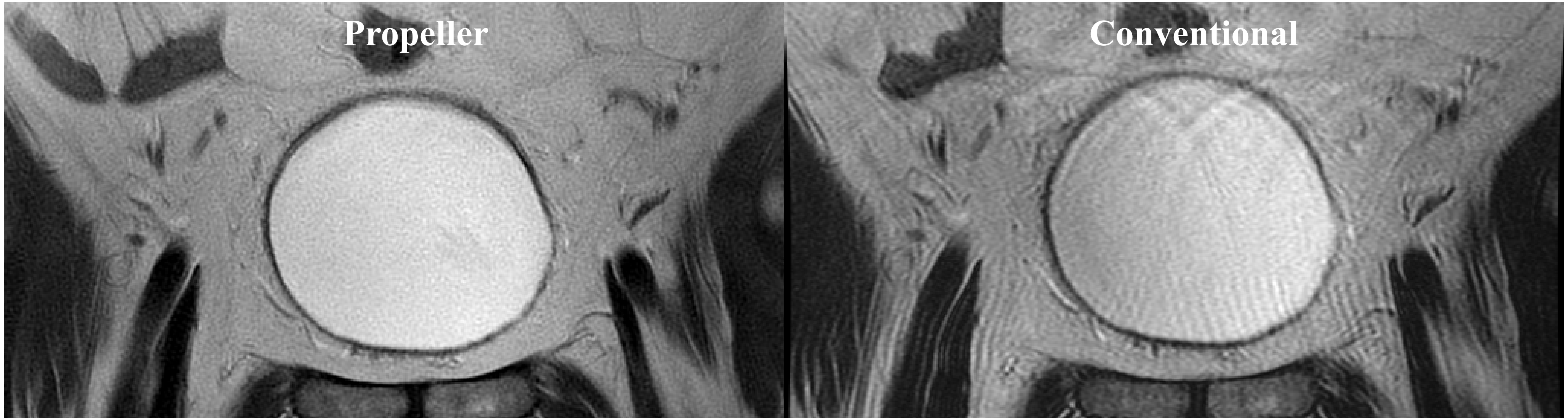


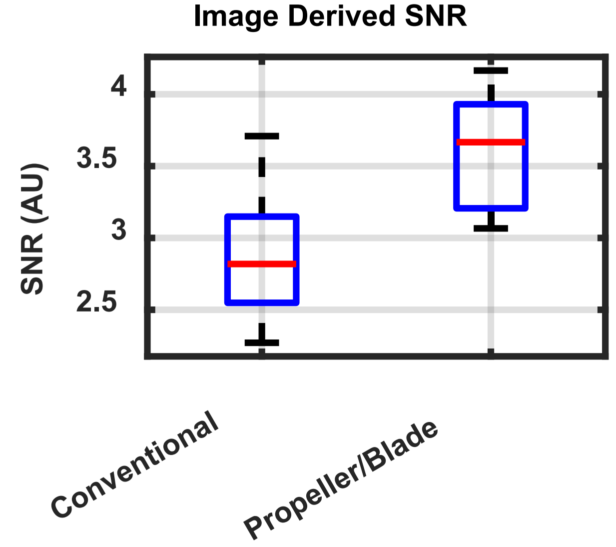
Final



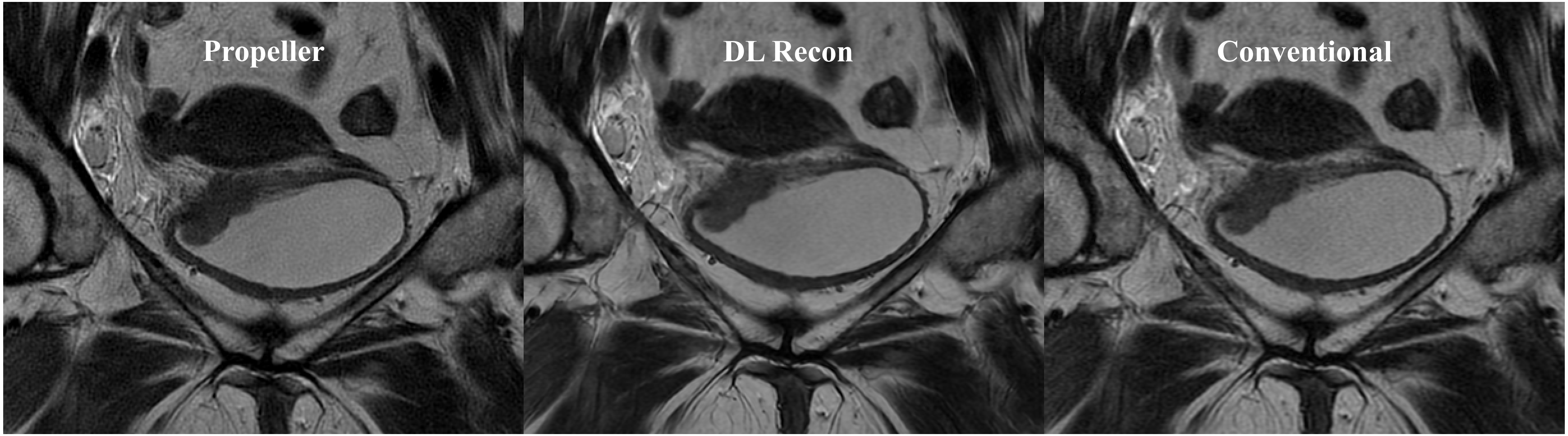
Benefits of Non-Cartesian Acquisitions



- **T2 sequences sensitive to bowel motion**
- **Acquisition reduces motion artifacts**
- **18% slower but increased SNR**
- **Optimized by:**
  - maximizing receive BW
  - using 2 NEX with 2-fold acceleration



Impact of Deep Learning-Based Image Reconstruction



- **DL recon evaluated on Cartesian T2 Datasets**
  - Improved apparent SNR
  - Suffered from motion artifacts
- **Non-Cartesian DL Recons an avenue for future development**
  - Potential to reduce scan time and/or increase resolution