Image-Guided Prostate Brachytherapy: A US/MR-Based HDR Workflow

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University of Nebraska Medical Center

Conflict of Interest

- Nothing to disclose
- I do not endorse any products, manufacturers, vendors, or suppliers mentioned in this talk.

Objectives

- Overview of our center's experience performing intraoperative prostate HDR brachytherapy using US and MR image guidance

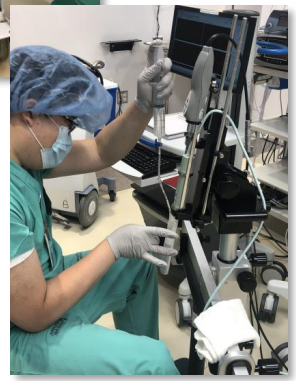
- Describe of the prostate HDR treatment workflow including:
  - Image acquisition
  - Contouring
  - Pre-planning
  - Needle insertion
  - Needle reconstruction
  - Dose optimization and evaluation
  - Treatment preparation and treatment

- Discuss challenges encountered as well as practical tips and tricks for ensuring a smooth procedure

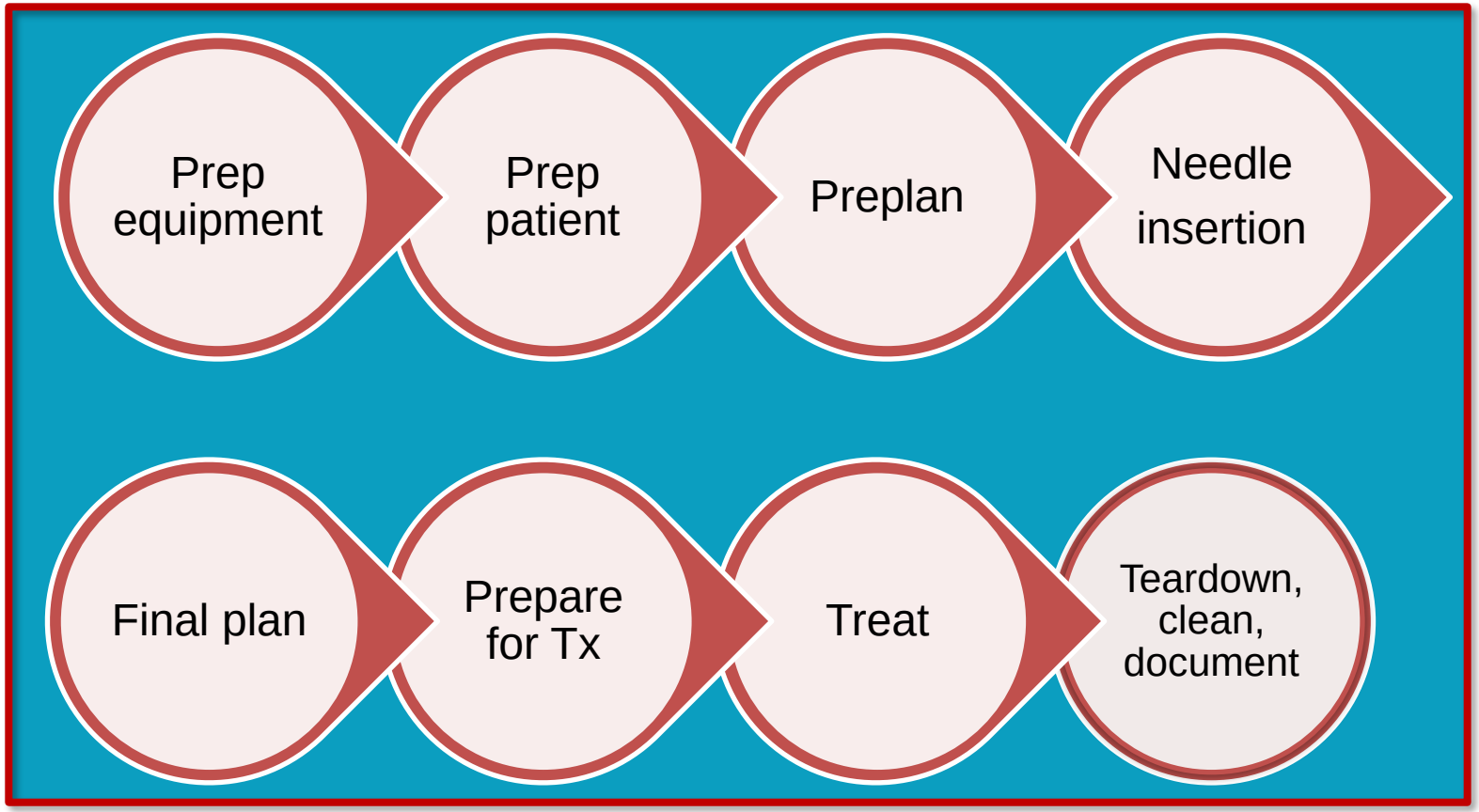
UNMC HDR Prostate Brachytherapy Program

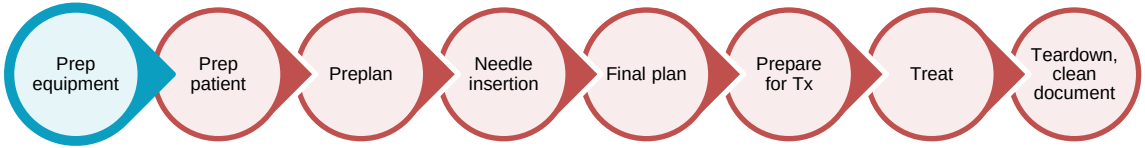
UNMC HDR Prostate Brachytherapy Program

- **Treatment types:**
  - Boost
    - 110+ patients
    - Primarily US guided (with some MR guidance)
    - 1 x 15 Gy HDR followed by 25 x 1.8 Gy EBRT
    - SpaceOAR and fiducials implanted after HDR
  - Focal Salvage
    - 5 patients
    - US/MR guided
    - 2 x 13 Gy, 2 wks apart
- **Logistics:**
  - Treat ~1-2 patients per week
  - Sometimes treat 2 patients per day

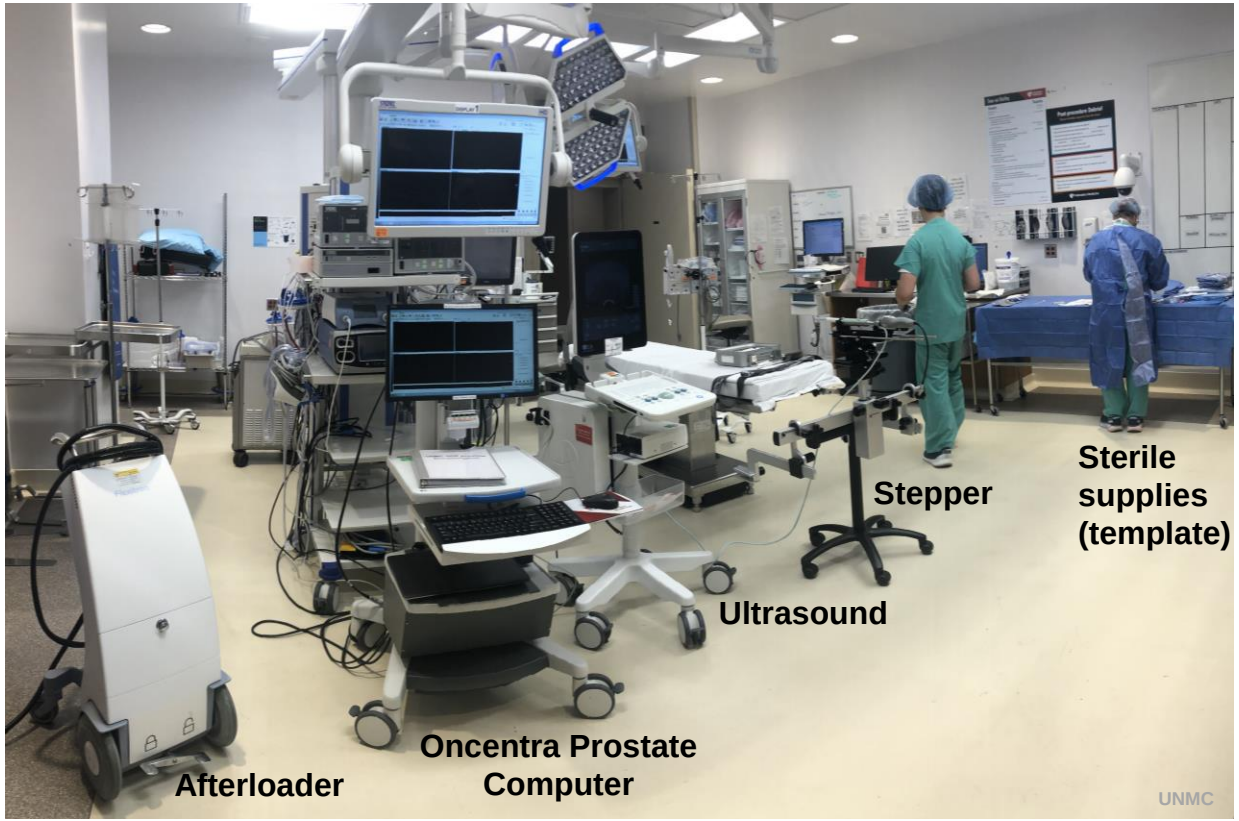


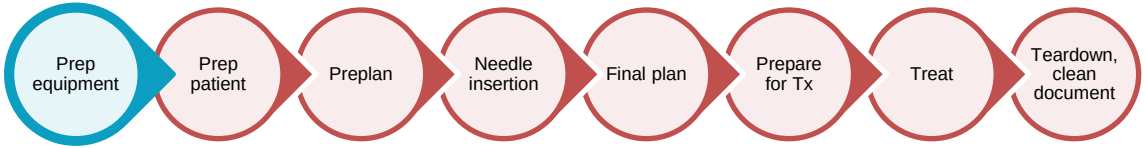
HDR Boost Treatment Workflow





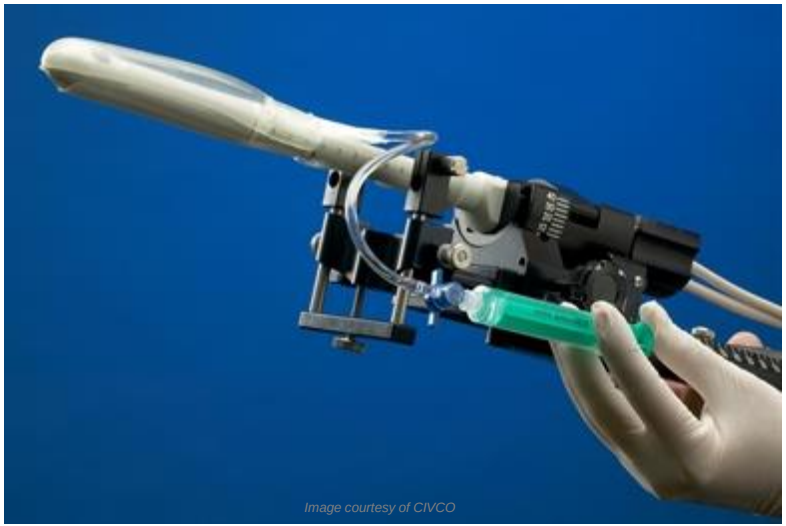
Prep equipment in treatment room:

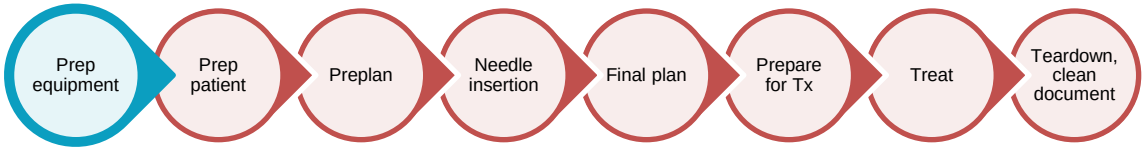




Prep equipment in treatment room:

- Prepare US brachy balloon:
  - Fill inside with US gel
  - Slide balloon to US probe and tape end down to secure in place
  - Fill with saline using syringe
  - Remove all air bubbles!

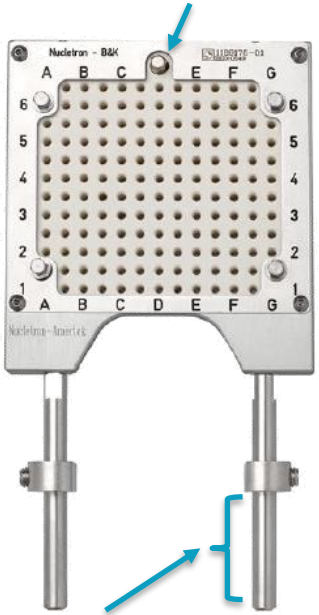




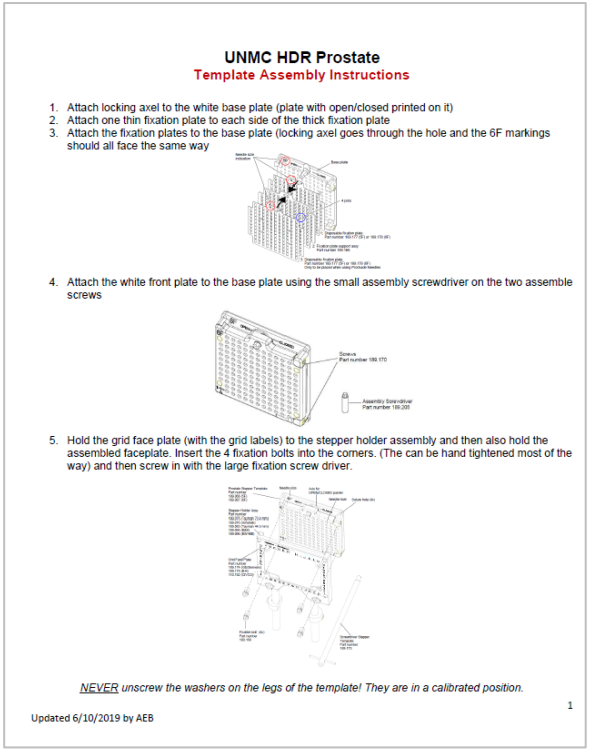
Prep equipment in treatment room:

- Sterile OR nurse/tech will assemble template & prep all sterile items

Insert needle and test locking mechanism



measure distance to ensure template height has not changed



UNMC HDR Prostate

Template Assembly Instructions

1. Attach locking axel to the white base plate (plate with open/closed printed on it)
2. Attach one thin fixation plate to each side of the thick fixation plate
3. Attach the fixation plates to the base plate (locking axel goes through the hole and the 6F markings should all face the same way

4. Attach the white front plate to the base plate using the small assembly screwdriver on the two assemble screws

5. Hold the grid face plate (with the grid labels) to the stepper holder assembly and then also hold the assembled faceplate. Insert the 4 fixation bolts into the corners. (The can be hand tightened most of the way) and then screw in with the large fixation screw driver.

NEVER unscrew the washers on the legs of the template! They are in a calibrated position.

Updated 6/10/2019 by AEB

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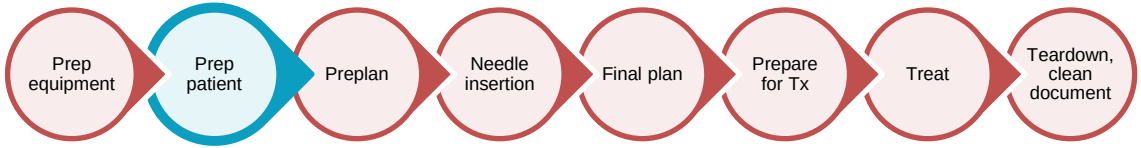
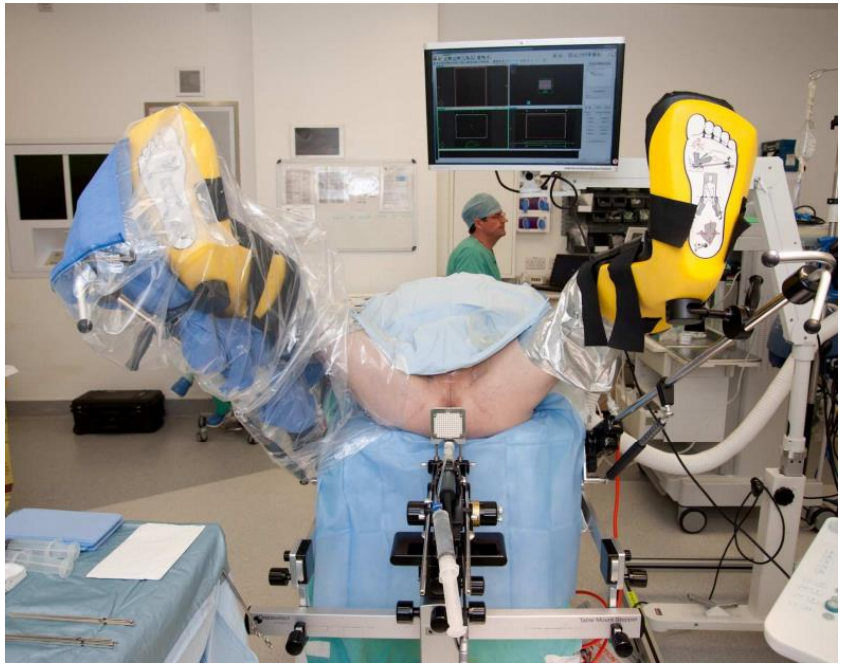
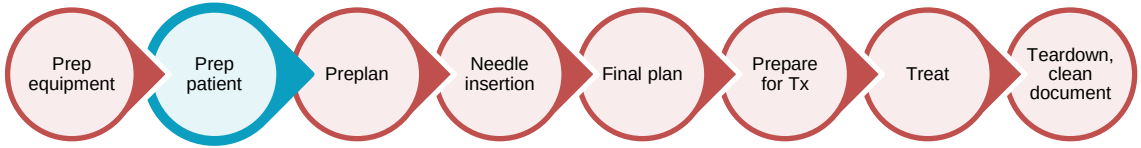


Prep Patient:

- Patient put under general anesthesia
- Anesthesia administers paralytic (Rocuronium)
- Patient placed in dorsal lithotomy position (ensure legs are level)
- Foley catheter placed
- Suction rectum (if needed)
- Use Ioban to tape genitals away from perineum
- Prep perineum with Iodine
- Time out
- Attach stepper and US to couch, insert probe
- Insert template into stepper holder arm
- Place sterile drapes

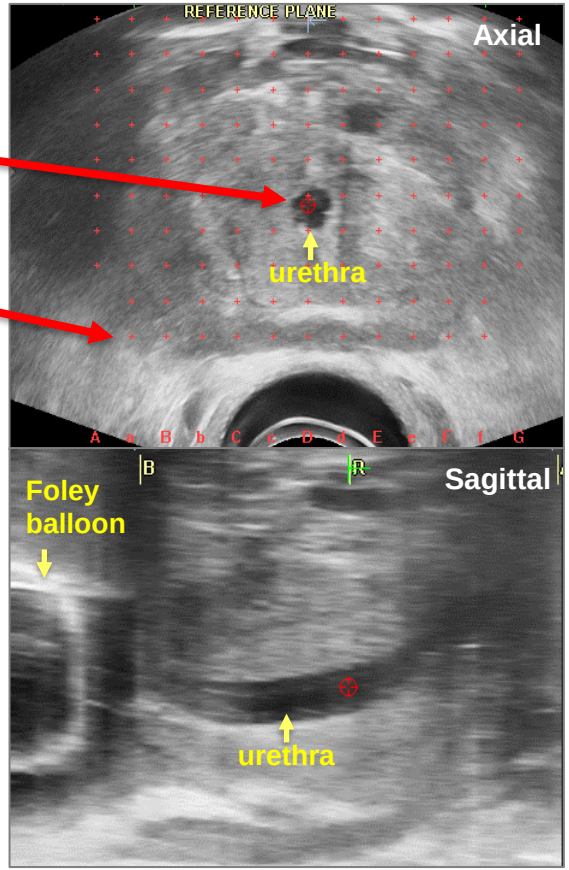


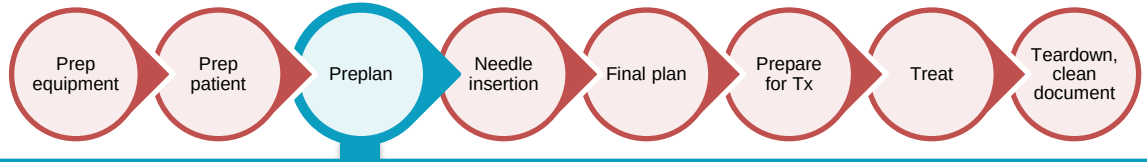
"Real Time Image Guided HDR Brachytherapy for Prostate Cancer" presentation by Bashar Al-Qaisieh, Leeds Cancer Centre



Optimize US placement and image quality:

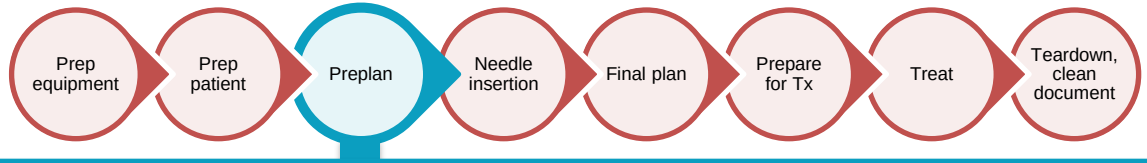
- Center the prostate laterally in the template/grid (urethra aligned with column “D”)
- Adjust the probe height or inflate the brachy balloon so that the bottom template/grid row is a few mm above to the posterior edge of the prostate
  - Don’t overdo it though! Else, the rectum may be squashed against the prostate and/or the prostate will be pushed anteriorly into the pubic arch
- Ensure there are no ultrasound artifacts
- Ensure the whole prostate from base to apex (plus some margin) is well visualized





Pre-plan: Acquire 3D US image → Contour → Insert virtual needles → Optimize plan

"Real Time Image Guided HDR Brachytherapy for Prostate Cancer" HDR Prostate Brachytherapy Workshop Presentation by Josh Mason Leeds Cancer Centre



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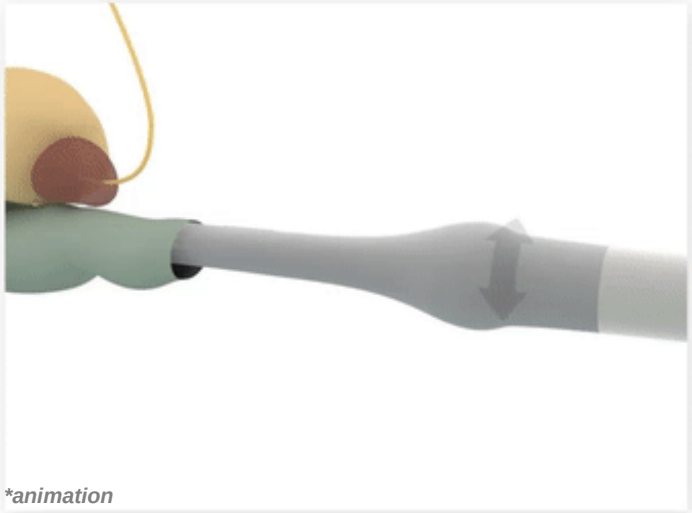
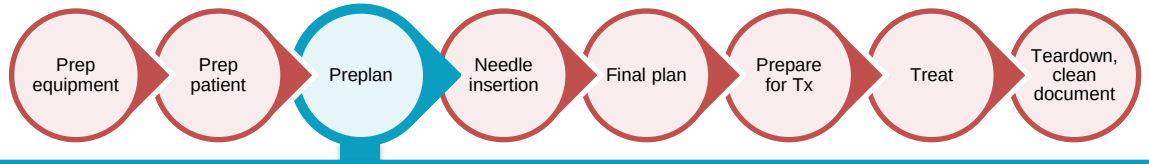
- Acquire 3D US image:



**animation*

Video courtesy of Elekta https://www.youtube.com/watch?v=zSuWCw2Z3c4



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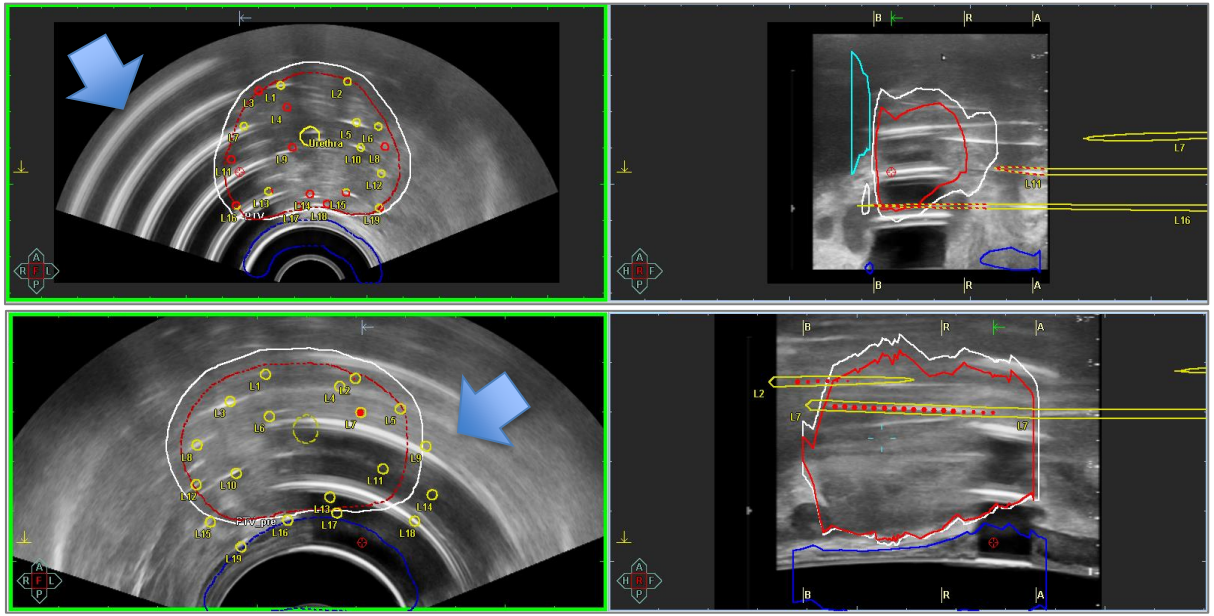
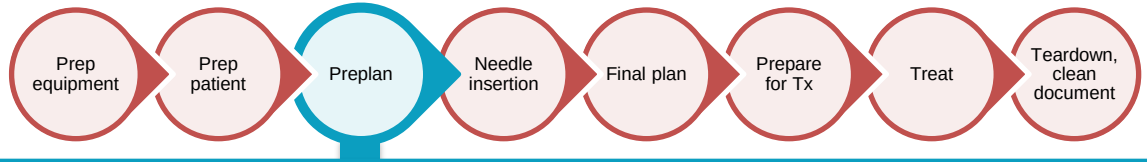
Challenge: Artifacts

- Air bubble in brachy balloon
- Gas/stool in rectum
- Bad contact between the probe and rectum

Recommendation:

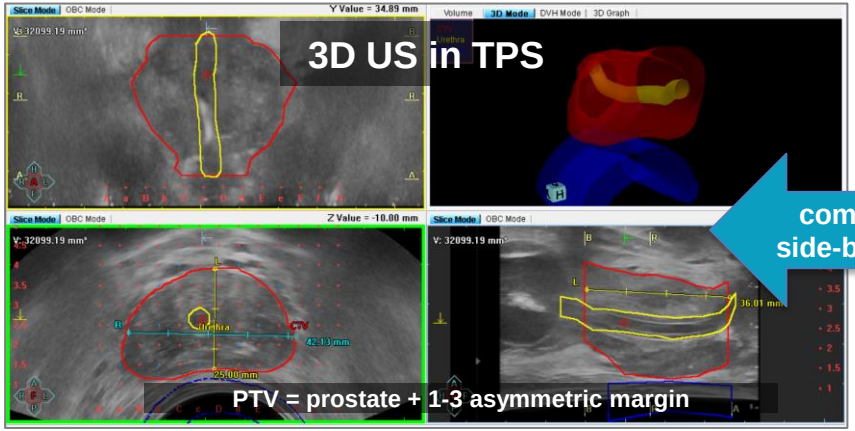
- Fix the issue and re-image to ensure accurate visualization

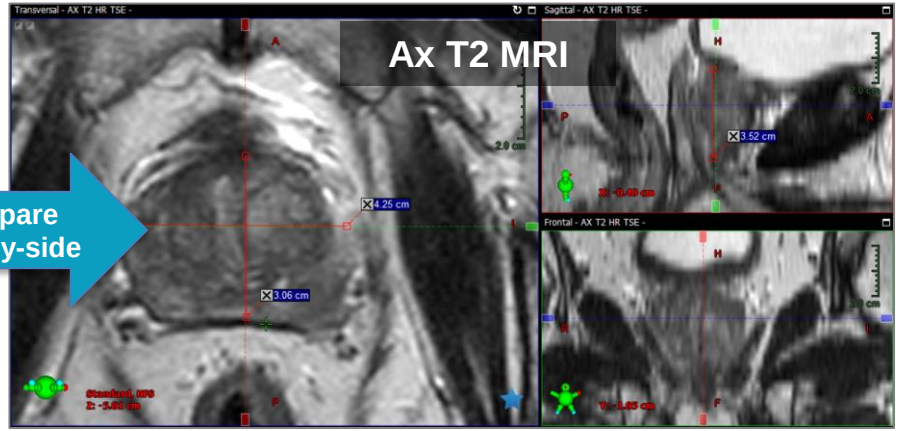


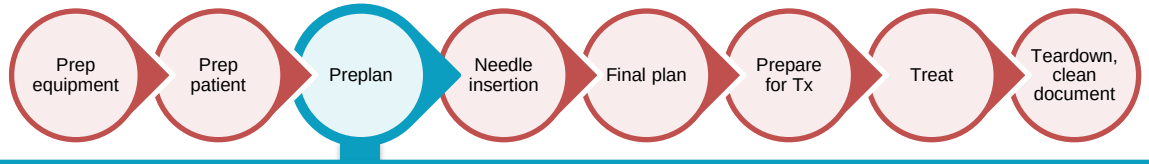


Pre-plan: Acquire 3D US image → **Contour** → Insert virtual needles → Optimize plan

- CTV = whole prostate on US, seminal vesicle(s) include if disease is present
- PTV = prostate + 0-3 mm asymmetric margin
- No formal US/MR image registration, but pull up diagnostic Ax T2 MR side-by-side → compare length/width/height and volume
- Rad Onc relays areas of disease seen on MR to physics team to ensure full coverage in those regions



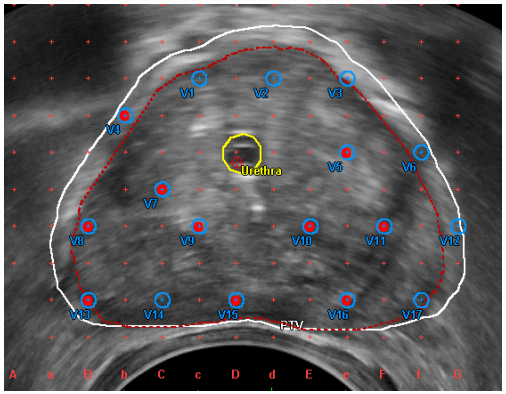


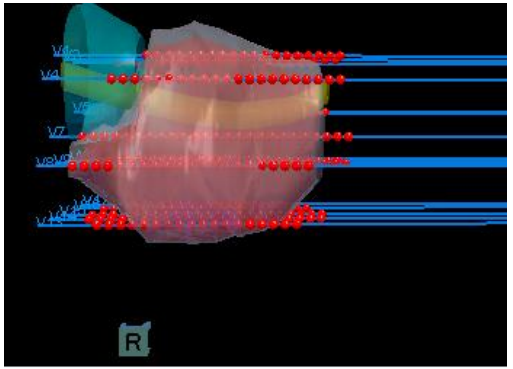


Pre-plan: Acquire 3D US image → Contour → **Insert virtual needles** → Optimize plan

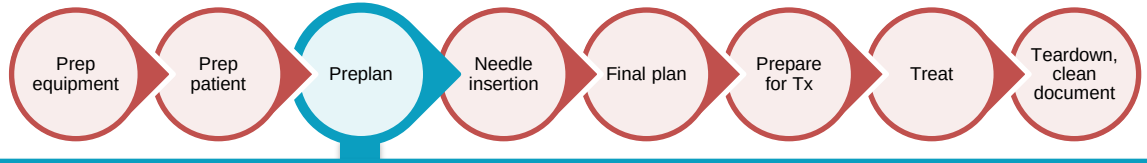
Needle placement guidelines:

1. Use ~10-20 needles, “less is more”
2. Follow approximate peripheral loading
3. Try to space out needles from each other
4. Avoid radially overlapping needles if possible (prevents shadowing of anterior needles by artifacts of posterior needles)





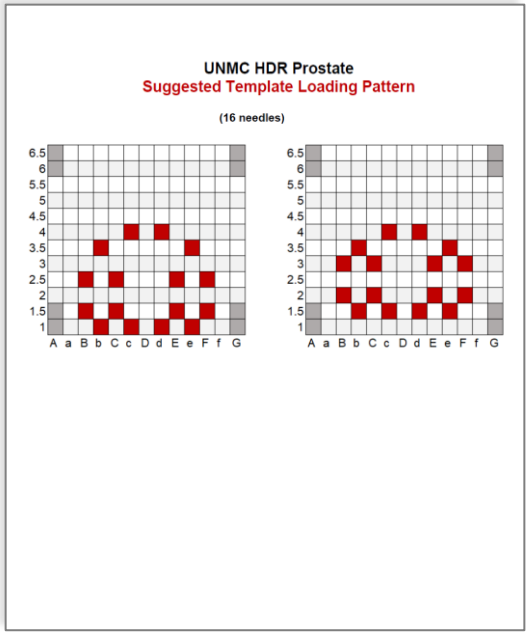
Ref: Nicolae, A., et al (2018). Dosimetric impact of inter-observer catheter reconstruction variability in ultrasound-based high-dose-rate prostate brachytherapy. Brachytherapy, 17(2), 306-312

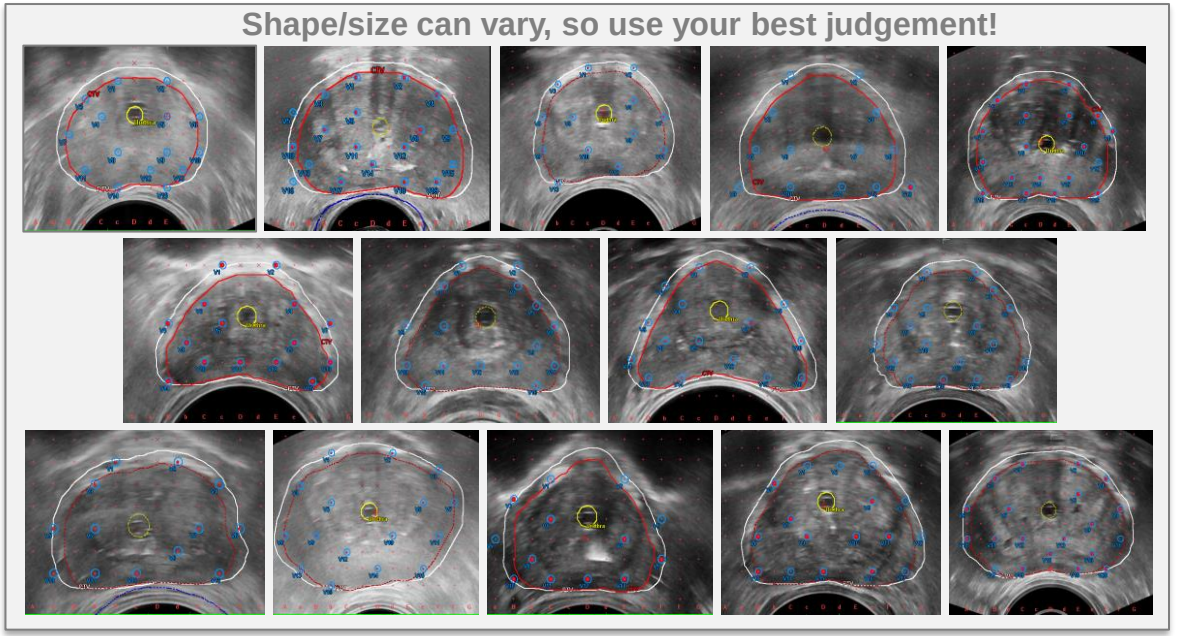


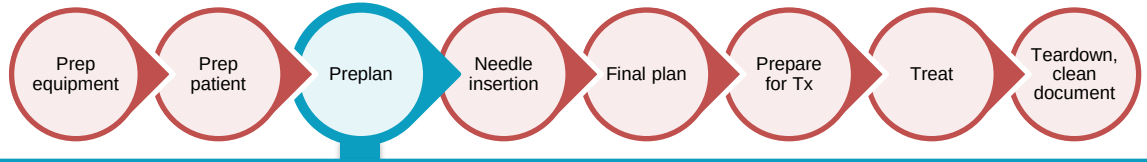
Pre-plan: Acquire 3D US image → Contour → **Insert virtual needles** → Optimize plan

Needle placement guidelines:

5. Use template loading pattern for guidelines



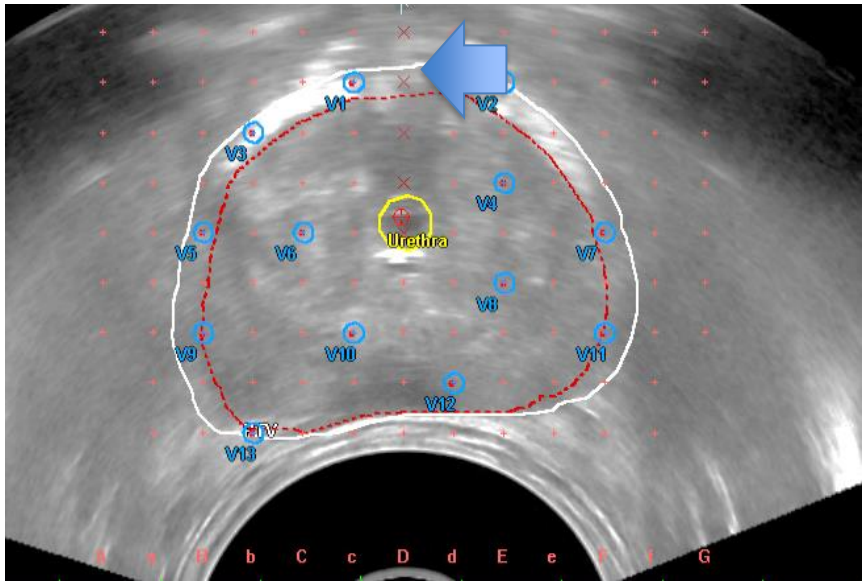




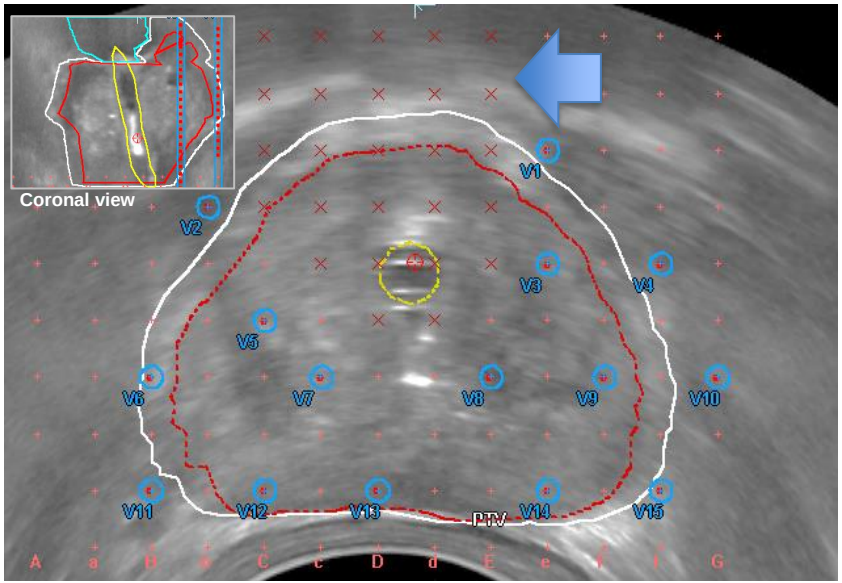
Pre-plan: Acquire 3D US image → Contour → **Insert virtual needles** → Optimize plan

Needle placement guidelines:

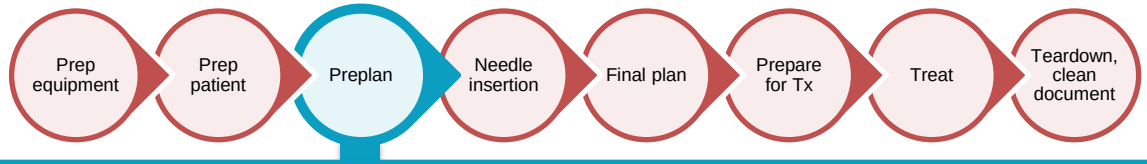
6. Do not place needles through urethra (blocked in Oncentra)



Only 1 row blocked due to urethra being narrow and straight



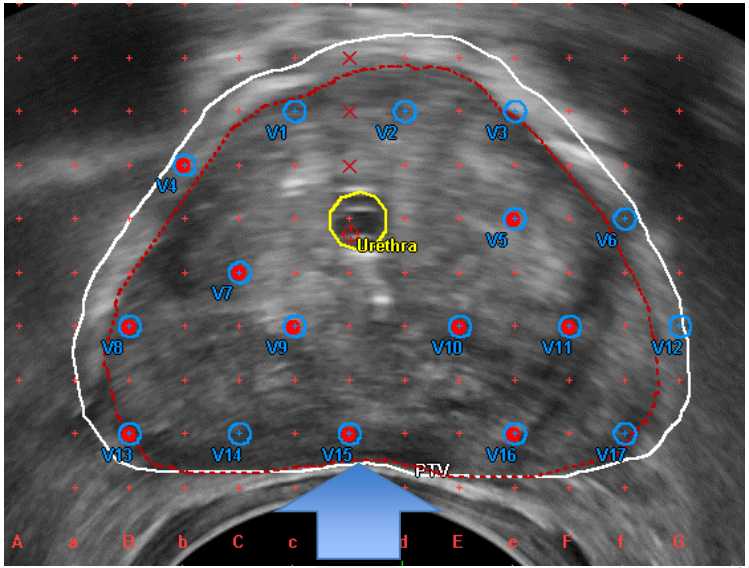
5 rows blocked due to urethra bending laterally! (may have to disable blocking)



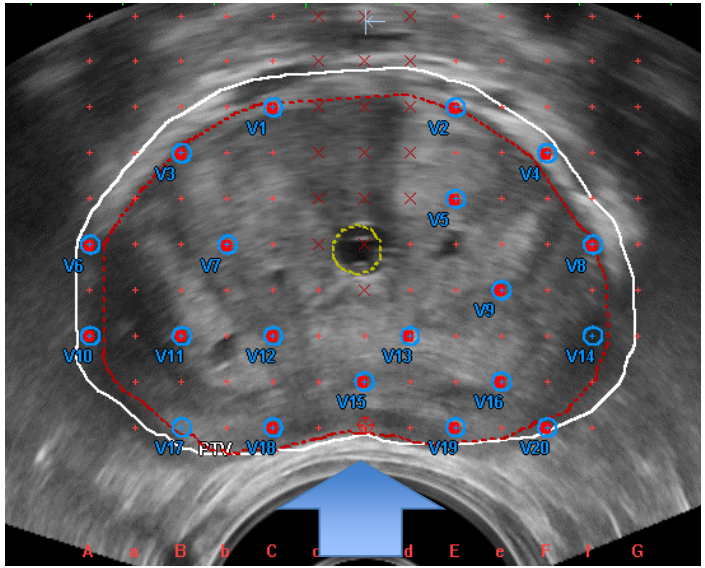
Pre-plan: Acquire 3D US image → Contour → **Insert virtual needles** → Optimize plan

Needle placement guidelines:

7. Ensure the lowest template row in the prostate is a few mm above the posterior edge



Template bottom row positioned well ✓

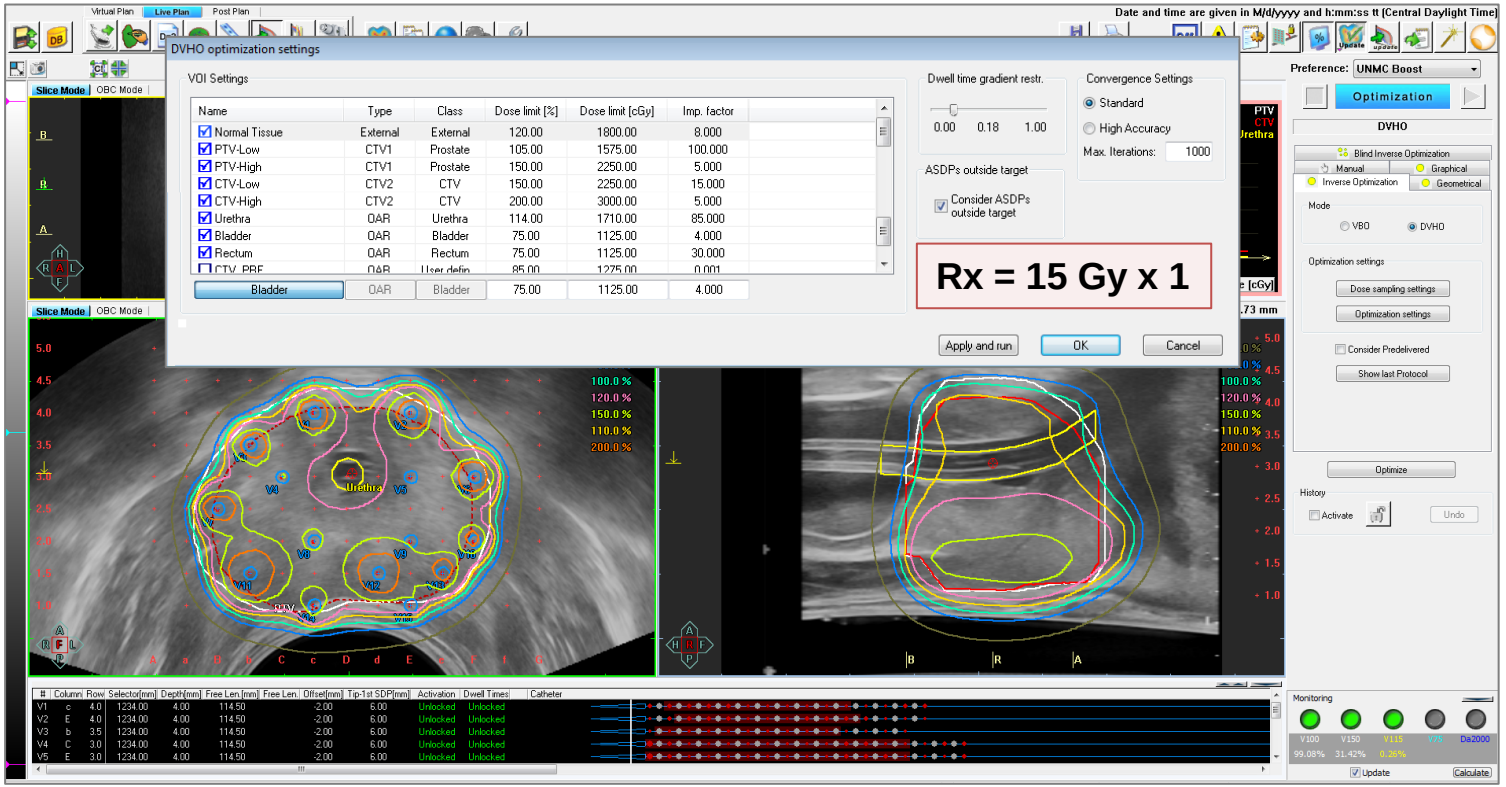


Template bottom row too low ✗

needles placed there → high rectal dose

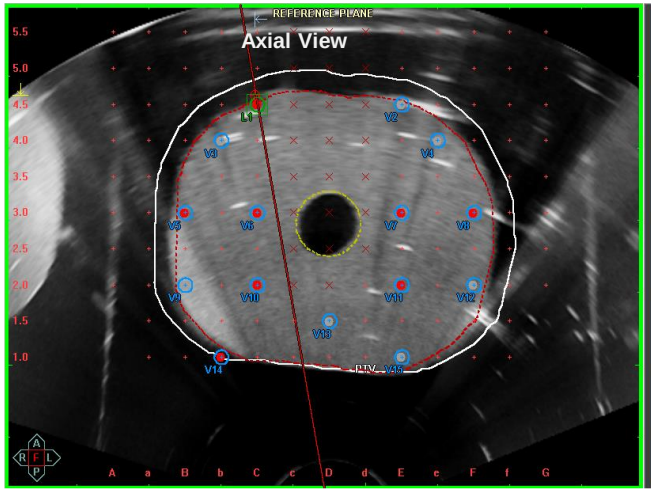
Prep equipment → Prep patient → Preplan → Needle insertion → Final plan → Prepare for Tx → Treat → Teardown, clean document

Pre-plan: Acquire 3D US image → Contour → Insert virtual needles → **Optimize plan**

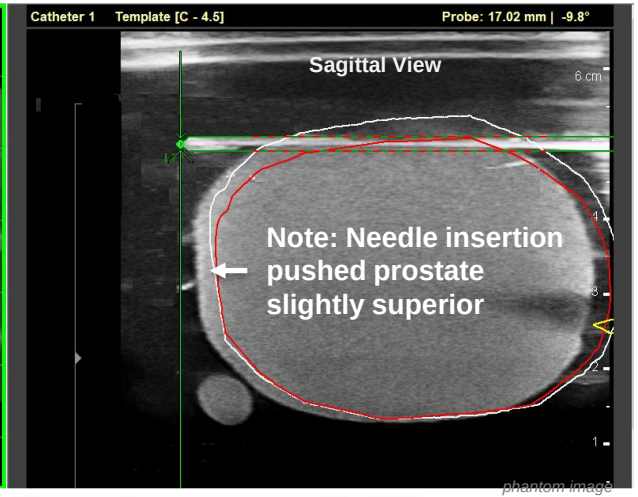


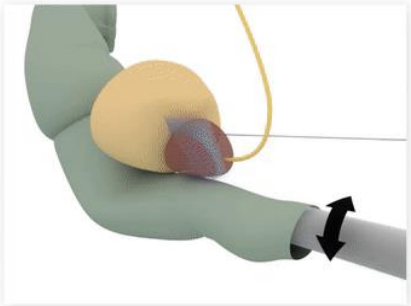
Prep equipment → Prep patient → Preplan → **Needle insertion** → Final plan → Prepare for Tx → Treat → Teardown, clean document

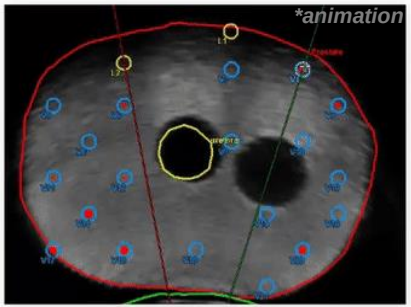
3D Pre-plan Ultrasound Image



Live Ultrasound Image







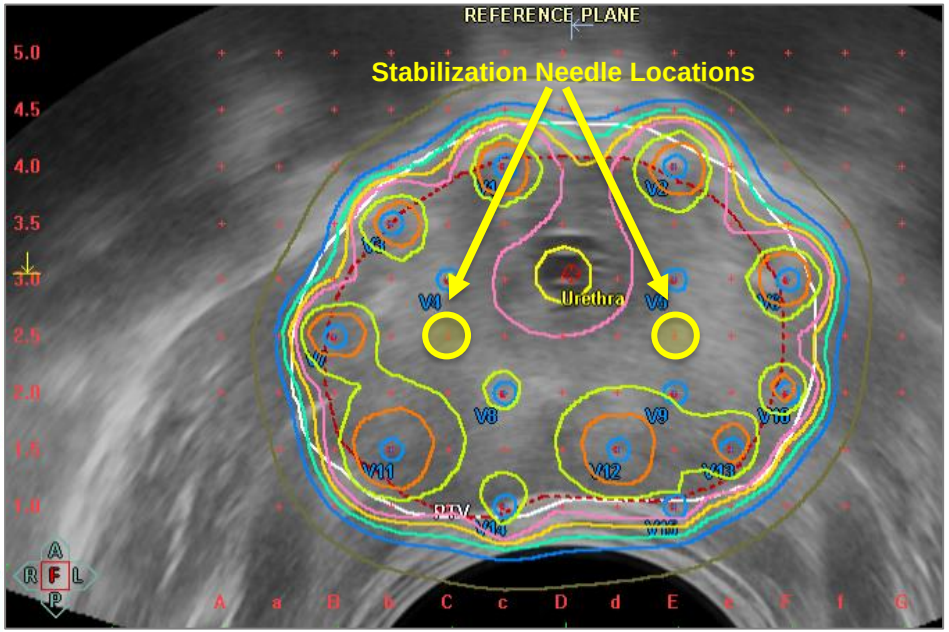
Video courtesy of Elekta https://www.youtube.com/watch?v=zSuWCw2Z3c4

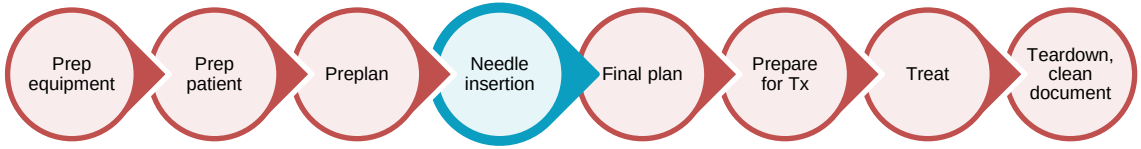
Prep equipment → Prep patient → Preplan → **Needle insertion** → Final plan → Prepare for Tx → Treat → Teardown, clean document

Insert Stabilization Needles:

- Stabilization needles help keep the prostate from being pushed superiorly as the treatment needles are inserted
- Choose 2 unused grid locations near middle of prostate

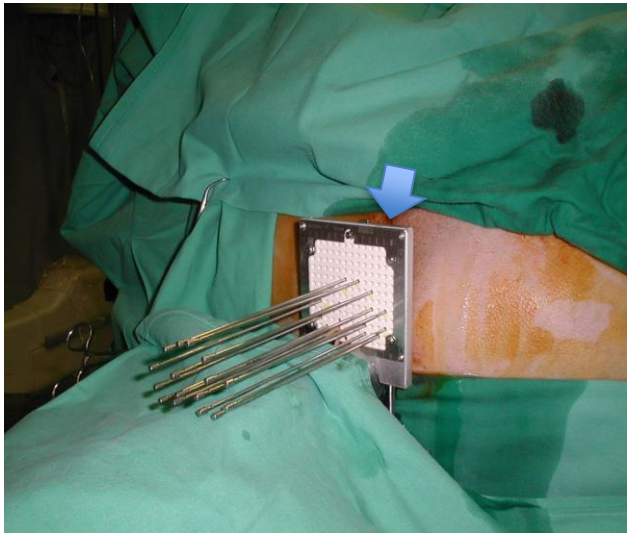
Image courtesy of Argon Medical Devices





<u>Challenge</u>: Needles aren't going in the desired direction

<u>Possible solution</u>: Use diddler (similar to crochet needle) between template and patient to bend needles



Prada, Pedro J. "High-dose-rate interstitial brachytherapy as monotherapy in one fraction for the treatment of favorable stage prostate cancer." Advances in prostate cancer. InTech (2013): 145-154.

Image courtesy of Mick Radio Nuclear Instruments, Inc

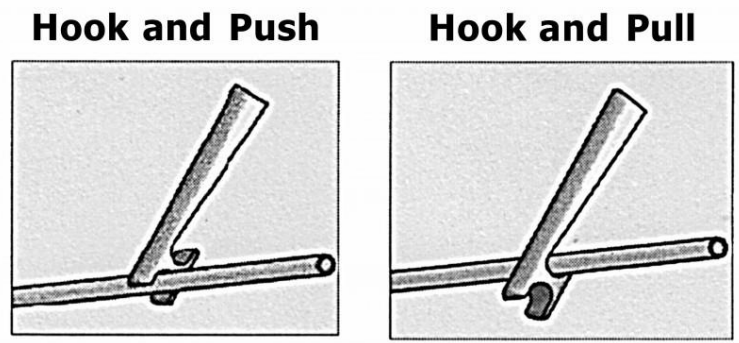
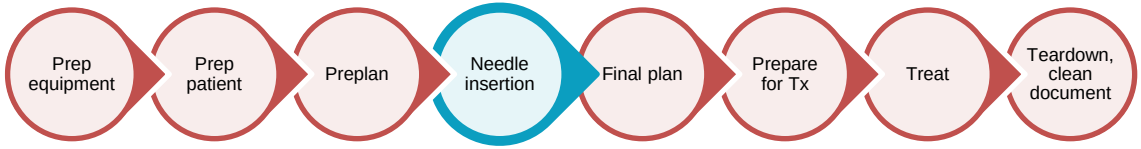


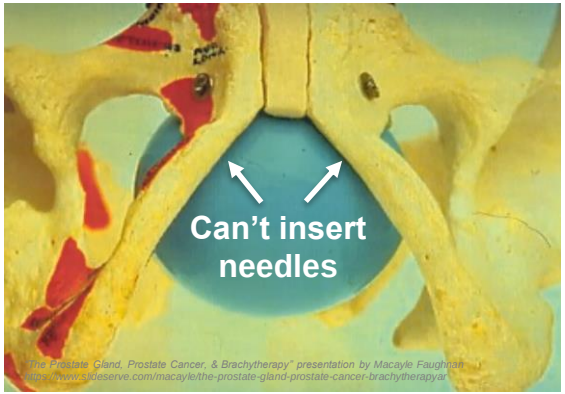
Image courtesy of RPD, Inc

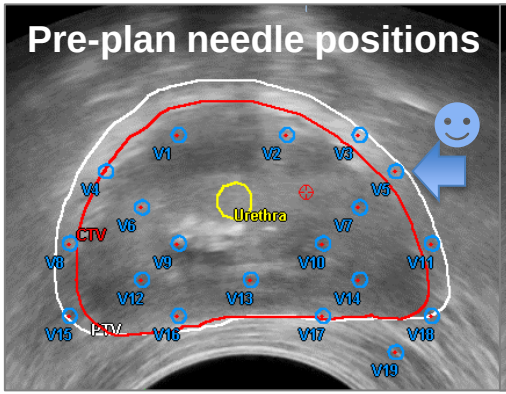


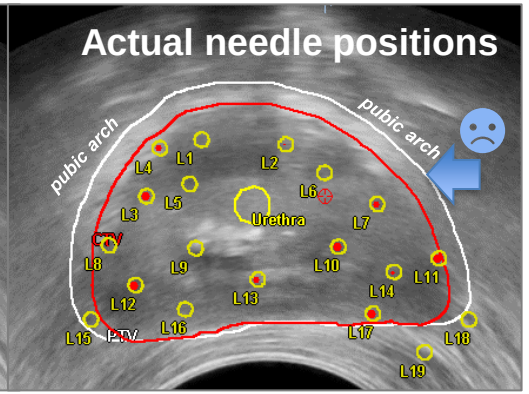
Challenge: Pubic Arch Interference

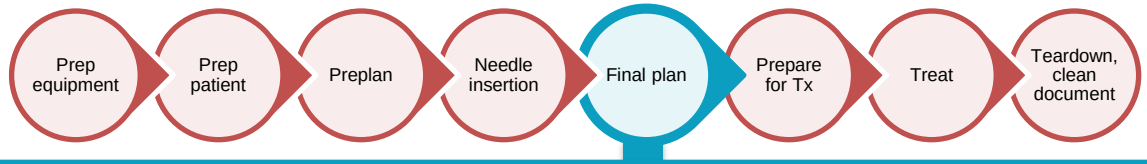
Possible solutions:

- Angle patient's legs farther back towards chest (>90°)
- Change angle of US probe/template
- Reduce filling of the brachy balloon
- Use diddler to try to bend needle underneath pubic arch
- Adapt plan and choose new needle locations





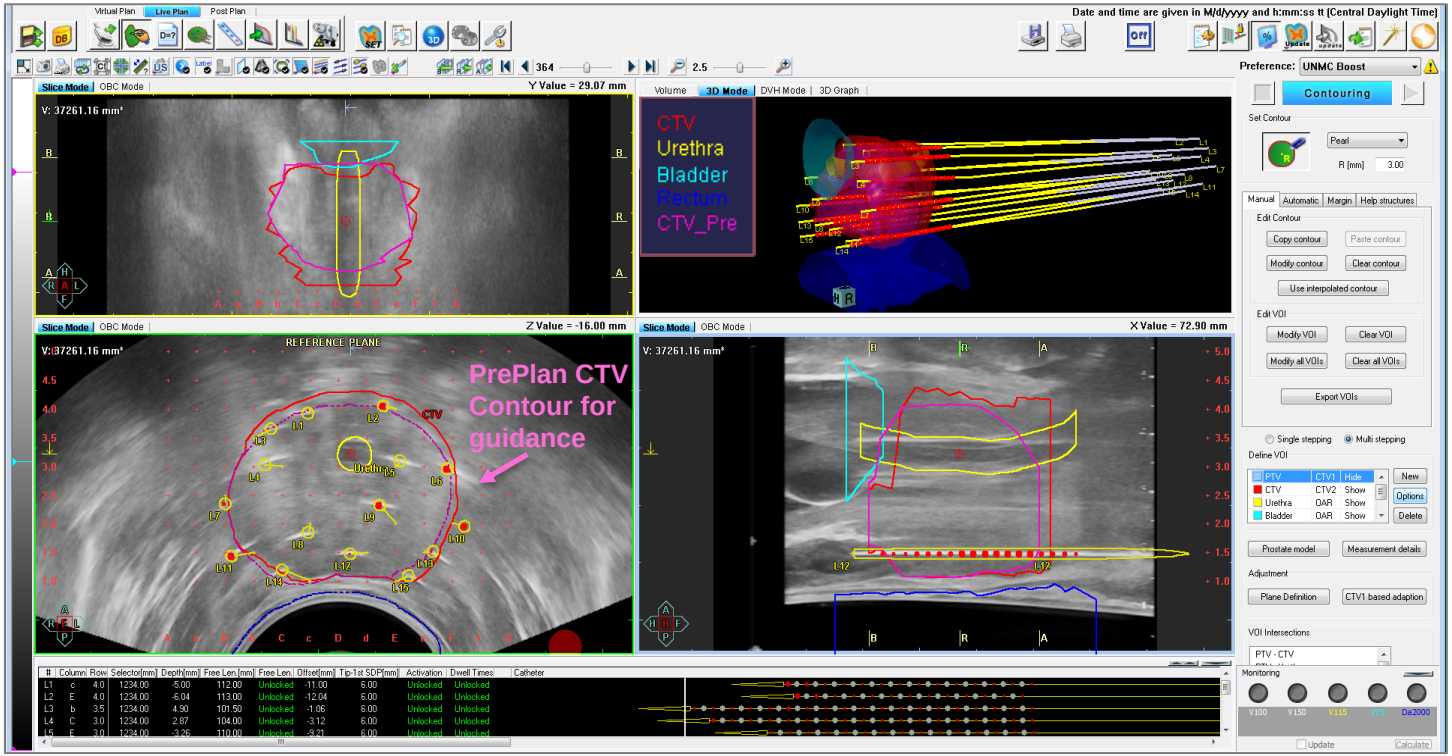


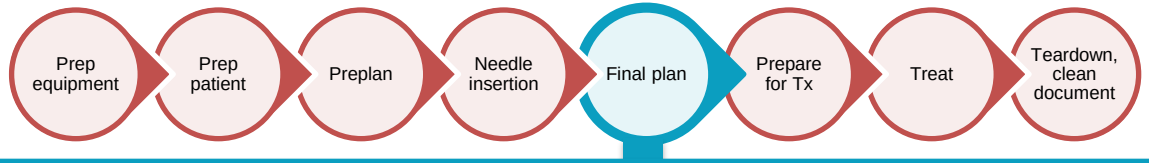


Final-plan: Acquire 3D US image → Contour → Recontruct needles → Optimize plan

Prep equipment → Prep patient → Preplan → Needle insertion → **Final plan** → Prepare for Tx → Treat → Teardown, clean document

Final-plan: Acquire 3D US image → **Contour** → Recontruct needles → Optimize plan





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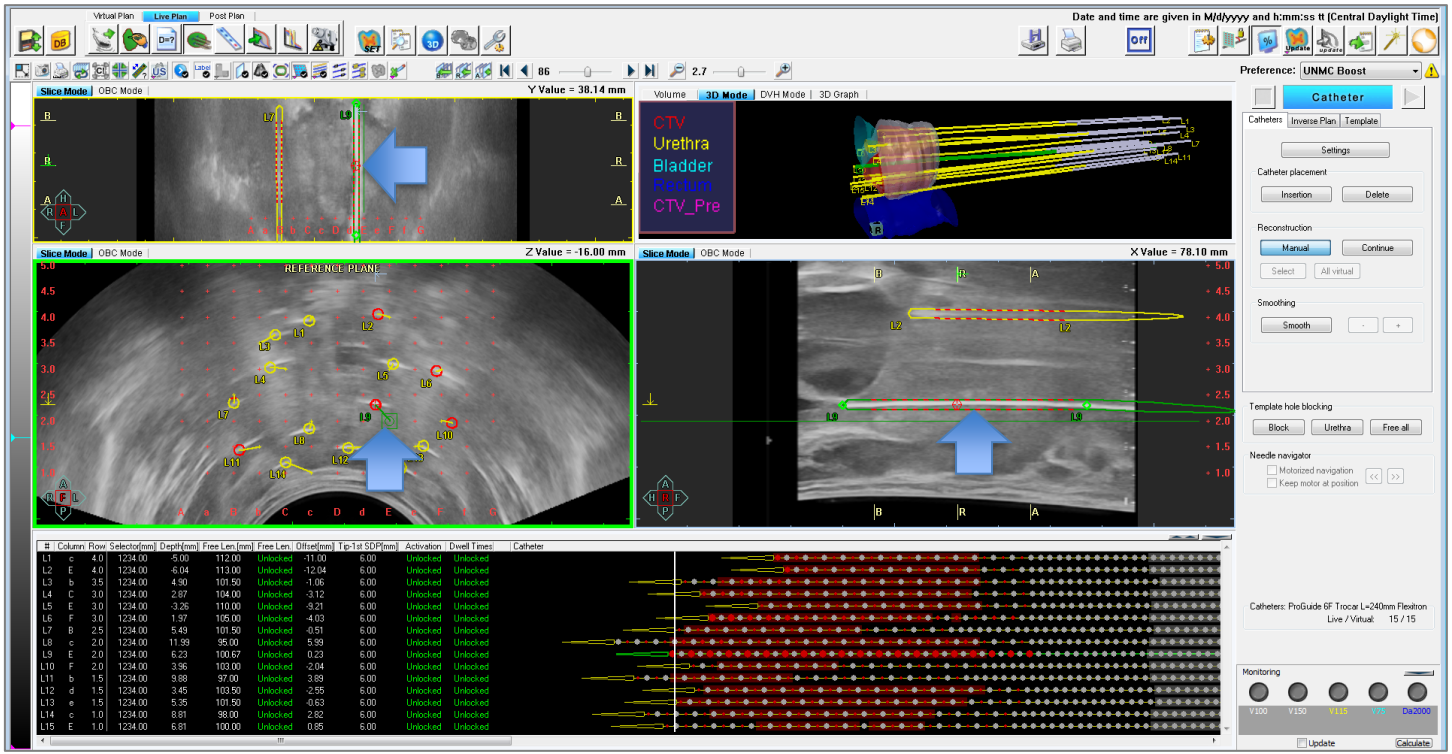
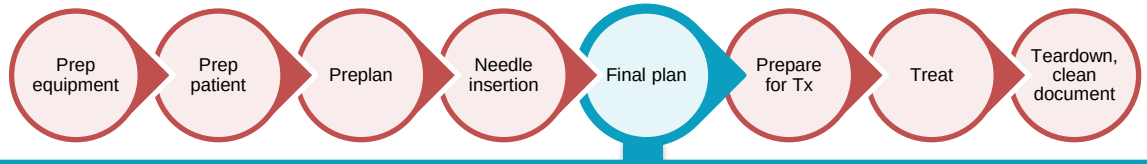
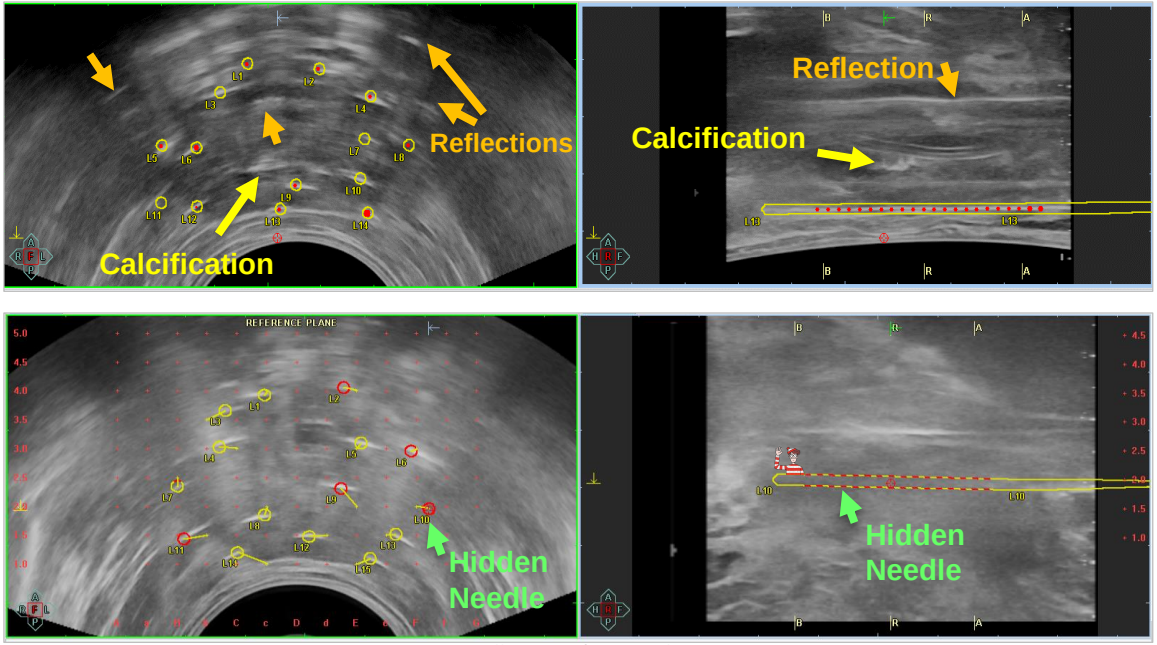




Final-plan: Acquire 3D US image → Contour → **Recontruct needles** → Optimize plan

Challenge:
Artifacts or US image quality makes reconstructing needles difficult. Sometimes needles can be ne nearly invisible.



Waldo image courtesy of Entertainment Rights PLC

Solution:
Go back to live imaging, re-insert obturator, & wiggle it until you can see it. Use live reconstruction.

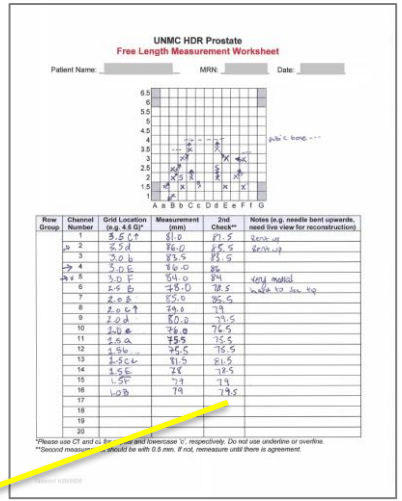
Ref: Nicolae, A., et al (2018). Dosimetric impact of inter-observer catheter reconstruction variability in ultrasound-based high-dose-rate prostate brachytherapy. Brachytherapy, 17(2), 306-312

Prep equipment → Prep patient → Preplan → Needle insertion → **Final plan** → Prepare for Tx → Treat → Teardown, clean document

Final-plan: Acquire 3D US image → Contour → **Recontruct needles** → Optimize plan

Measure Freelength:

- Measure needle freelength with ruler
- Enter measured freelength into TPS
- Ensure measured value is relatively close to the tracked freelength
- Tip: We perform the measurement in parallel with the final planning (contouring and needle reconstruction) to save time.

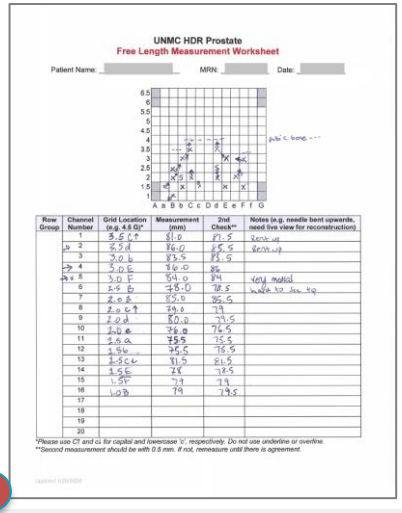


#	Column	Row	Selector[mm]	Depth[mm]	Free Len.[mm]	Free Len	Offset[mm]	Tip-1st SDP[mm]	Activation	Dwell Times	Catheter
L1	c	4.0	1234.00	-5.00	81.50	Unlocked	-11.00	6.00	Unlocked	Unlocked	
L2	E	4.0	1234.00	-6.04	85.50	Unlocked	-12.04	6.00	Unlocked	Unlocked	
L3	b	3.5	1234.00	4.90	83.50	Unlocked	-1.06	6.00	Unlocked	Unlocked	
L4	C	3.0	1234.00	2.87	86.00	Unlocked	-3.12	6.00	Unlocked	Unlocked	
L5	E	3.0	1234.00	-3.26	84.00	Unlocked	-9.21	6.00	Unlocked	Unlocked	
L6	F	3.0	1234.00	1.97	78.50	Unlocked	-4.03	6.00	Unlocked	Unlocked	
L7	B	2.5	1234.00	5.49	85.50	Unlocked	-0.51	6.00	Unlocked	Unlocked	
L8	c	2.0	1234.00	11.99	79.00	Unlocked	5.99	6.00	Unlocked	Unlocked	
L9	E	2.0	1234.00	6.23	79.50	Unlocked	0.23	6.00	Unlocked	Unlocked	
L10	F	2.0	1234.00	3.96	76.50	Unlocked	-2.04	6.00	Unlocked	Unlocked	
L11	b	1.5	1234.00	9.88	75.50	Unlocked	3.89	6.00	Unlocked	Unlocked	
L12	d	1.5	1234.00	3.45	75.50	Unlocked	-2.55	6.00	Unlocked	Unlocked	
L13	e	1.5	1234.00	5.35	81.50	Unlocked	-0.63	6.00	Unlocked	Unlocked	
L14	c	1.0	1234.00	8.81	78.50	Unlocked	2.82	6.00	Unlocked	Unlocked	
L15	E	1.0	1234.00	6.81	79.00	Unlocked	0.85	6.00	Unlocked	Unlocked	
					79.50						

Final-plan: Acquire 3D US image → Contour → **Recontruct needles** → Optimize plan

Information needed to accurately localize the dwell positions:

1. Measured needle freelength
2. Location of the needle tip
3. Distance from the needle tip to the first dwell position
4. Catheter index length



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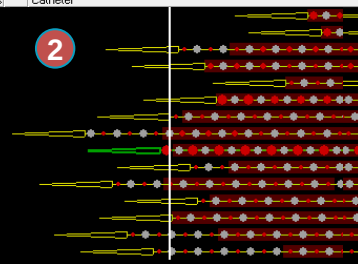
L8	c	2.0	1234.00	11.99	79.00	Unlocked	5.99	6.00	Unlocked	Unlocked
L9	E	2.0	1234.00	6.23	79.50	Unlocked	0.23	6.00	Unlocked	Unlocked
L10	F	2.0	1234.00	3.96	76.50	Unlocked	-2.04	6.00	Unlocked	Unlocked
L11	b	1.5	1234.00	9.88	75.50	Unlocked	3.89	6.00	Unlocked	Unlocked
L12	d	1.5	1234.00	3.45	75.50	Unlocked	-2.55	6.00	Unlocked	Unlocked
L13	e	1.5	1234.00	5.35	81.50	Unlocked	-0.63	6.00	Unlocked	Unlocked
L14	c	1.0	1234.00	8.81	78.50	Unlocked	2.82	6.00	Unlocked	Unlocked
L15	E	1.0	1234.00	6.81	79.00	Unlocked	0.85	6.00	Unlocked	Unlocked

Catheter



Ref: Nicolae, Smith, B. R., Strand, S. A., Dunkerley, D., Flynn, R. T., Besemer, A. E., Kos, J. D., ... & Kim, Y. (2021). Implementation of a real-time, ultrasound-guided prostate HDR brachytherapy program. Journal of applied clinical medical physics, 22(9), 189-214.

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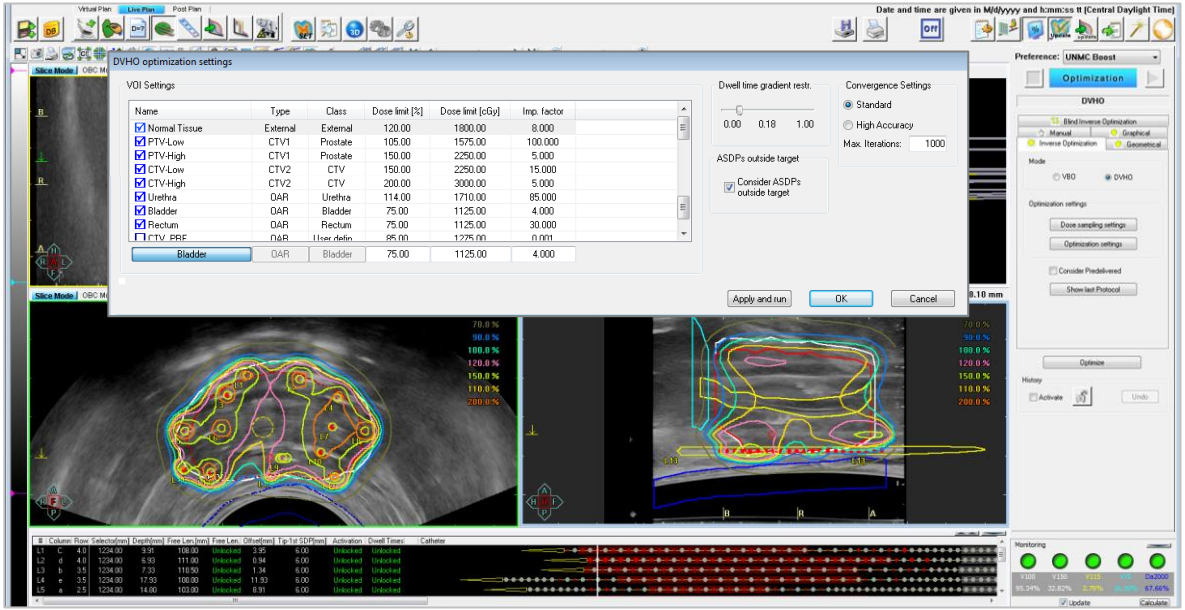


UNMC HDR Prostate - DVH Evaluation Sheet

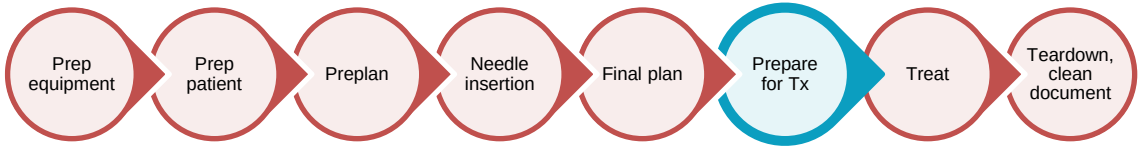
Patient	
MRN	
Treatment Date	
Treatment Type	Boost
Fraction	1 of 1
Prescription Dose	15 Gy
Physcian	Baine

Structure	Dose Objective	Plan Value	MD Approved?
PTV	V100% ≥ 90-95%	96.1%	√
	D90% ~ 105%-115%	106.5%	√
	V150% ≤ 35%	33.0%	√
	V200% ≤ 11%	12.8%	ok
CTV	V100% ≥ 90-95%	96.4%	√
	D90% ~ 105%-115%	107.0%	√
	V150% ≤ 35%	36.4%	ok
	V200% ≤ 11%	15.6%	ok
Urethra	V115% ≤ 5%	2.1%	√
	V125% ≤ 1 cc	0.0	√
	V150% = 0 cc	0.0	√
	D10% ≤ 120%	114%	√
	D0.01 cc ≤ 125%	116%	√
Bladder	V75% ≤ 1 cc	0.32	√
	D0.01 cc ≤ 90-100%	84.4%	√
Rectum	V75% ≤ 1 cc	0.07	√
	V80% ≤ 0.5 cc	0.00	√
	V100% = 0 cc	0.0	√
	D2cc ≤ 70%	0.0%	√

ROI Voume (cc)	PTV	37.39
	CTV	28.78
	Urethra	0.59

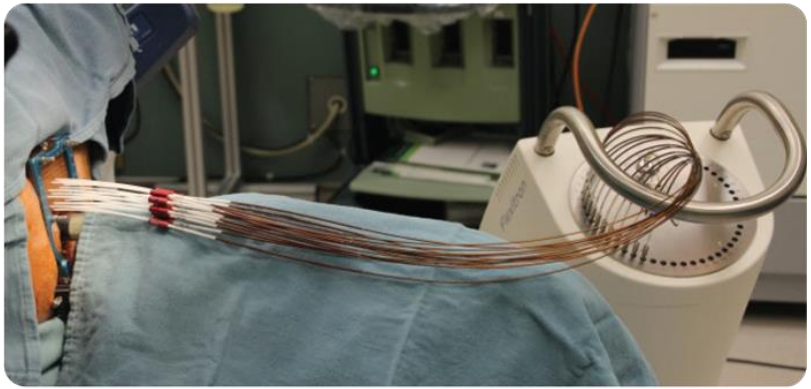
Dose Objective Guidelines: ABS, RTOG 0321, RTOG 0924, & other institutions

[1] Hsu, I. C., et al. (2008). ABS Prostate High-Dose Rate Task Group. American Brachytherapy Society Guidelines. [2] Hsu, I. J., et al. "Prostate HDR dosimetric parameters and treatment related toxicity in the Radiation Therapy Oncology Group (RTOG) 0321." International Journal of Radiation Oncology, Biology, Physics 81.2 (2011): S13-S14. [3] Roach III, Mack, et al. "Radiation Therapy Oncology Group RTOG 0924. Androgen deprivation therapy and high dose radiotherapy with or without whole-pelvic radiotherapy in unfavorable intermediate or favorable high risk prostate cancer: a phase III randomized trial." [4] Hoskin, Peter J., et al. "GEC/ESTRO recommendations on high dose rate afterloading brachytherapy for localised prostate cancer: an update." *Radiotherapy and Oncology* 107.3 (2013): 325-332.



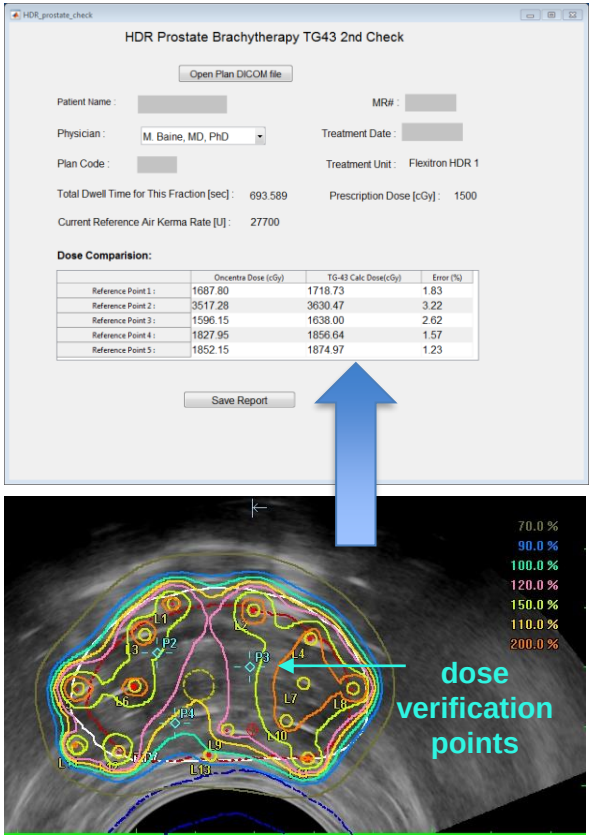
Prepare for treatment:

- Perform 2nd check calculation
- Prepare documentation
- Send plan to afterloader control computer
- Physics 2nd check
- Connect needles & transfer tubes to afterloader
- Check cable run
- Pre-tx survey, safety checks, post signs, etc



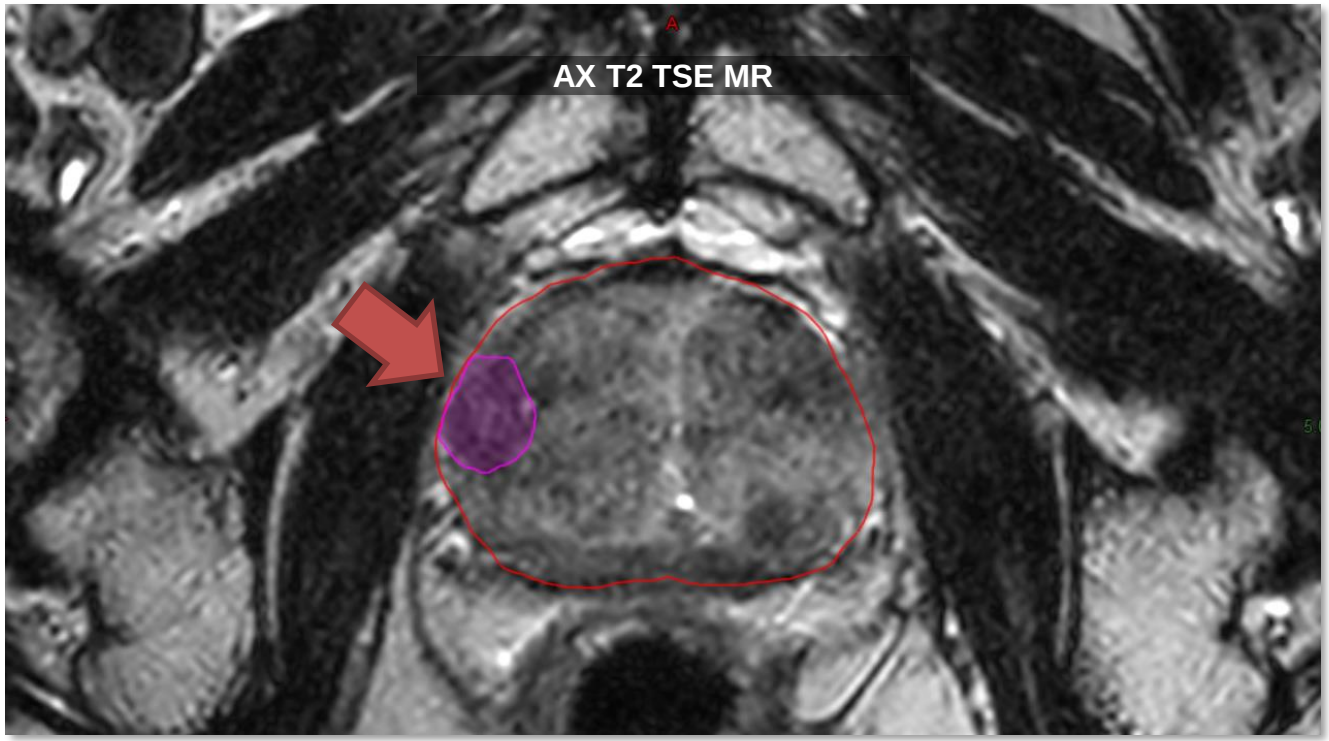
Images courtesy of Sunnybrook Health Science Centre https://sunnybrook.ca/content/?page=60442

In-house 2nd check calculation software



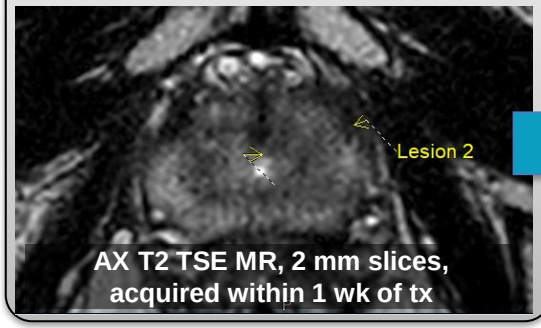
HDR Focal Salvage Workflow

- Patients with locally recurrent prostate cancer after previous radiation treatments
- Focal HDR brachytherapy to the PI-RADS lesion

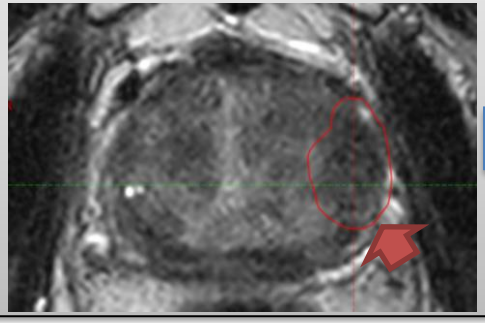


HDR Focal Salvage Workflow

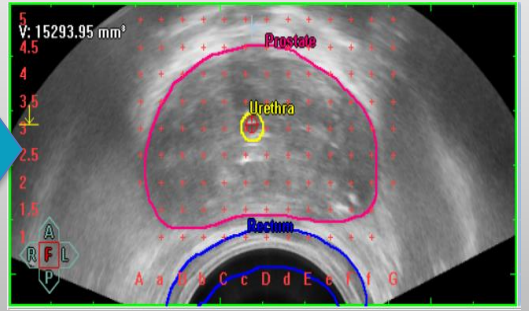
Radiologist marks PI-RADS lesion



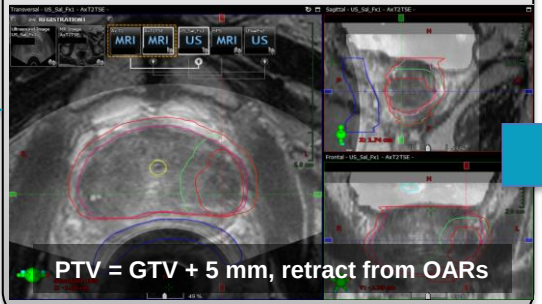
Rad Onc contours focal GTV



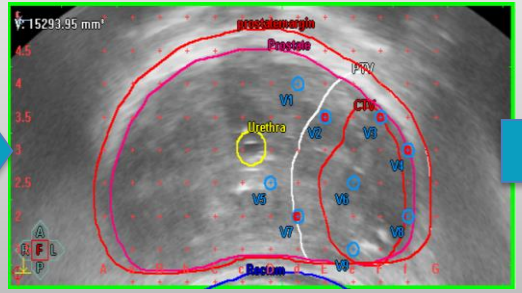
Acquire 3D ultrasound



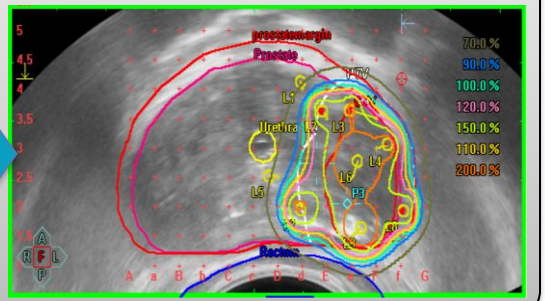
Register MR/US & contour



Needle insertion: ~5-12 needles



Rx = 2 x 13 Gy (2 wks apart)
Use salvage dose objectives



[1] Murgic, Jure, et al. International Journal of Radiation Oncology Biology* Physics 102.3 (2018): 561-567.[2] Maenhout, Metha, et al. Technology in cancer research & treatment 16.6 (2017): 1194-1201. [3] Zamboglou, Constantinos, et al. Journal of contemporary brachytherapy 8.3 (2016): 241. [4] Wojcieszek, Piotr, et al. Radiotherapy and Oncology 119.3 (2016): 405-410. [5] van Son, Marieke Juliet, et alInternational Journal of Radiation Oncology* Biology* Physics 107.1 (2020): 126-135.*

Summary

- Overviewed of our center’s experience performing intraoperative prostate HDR brachytherapy using US and MR image guidance

- Described of the prostate HDR treatment workflow including:
  - Image acquisition
  - Contouring
  - Pre-planning
  - Needle insertion
  - Needle reconstruction
  - Dose optimization and evaluation
  - Treatment preparation and treatment

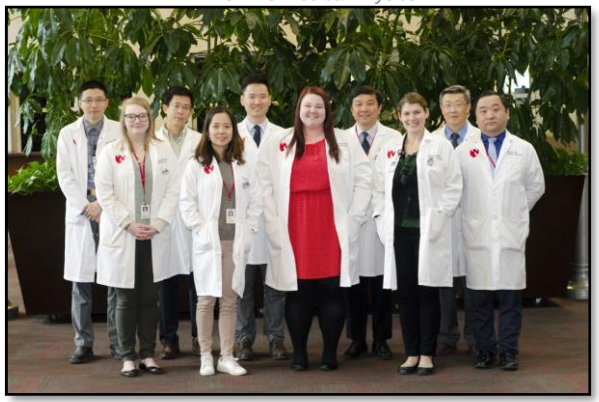
- Discussed challenges encountered as well as practical tips and tricks for ensuring a smooth procedure

Acknowledgements

- UNMC medical physics team (past and present)
- UNMC HDR prostate physicians:
  - Dr. Charles Enke
  - Dr. Michael Baine
- Jane Stopak, RN - prostate HDR nursing coordinator extraordinaire
- All other involved UNMC radiation oncology, urology, anesthesiology, & OR faculty and staff
- Elekta Oncentra Prostate and BK Ultrasound service, training, & support team. Especially:
  - Don Larsen
  - Scott Campbell
  - Jacob Matl

Thank You

UNMC Medical Physics



Dr. Enke

Dr. Baine

References

1. Smith, B. R., Strand, S. A., Dunkerley, D., Flynn, R. T., Besemer, A. E., Kos, J. D., ... & Kim, Y. (2021). Implementation of a real-time, ultrasound-guided prostate HDR brachytherapy program. Journal of applied clinical medical physics, 22(9), 189-214.
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6. Batchelar, Deidre L., et al. "Intraoperative ultrasound-based planning can effectively replace postoperative CT-based planning for high-dose-rate brachytherapy for prostate cancer." *Brachytherapy* 15.4 (2016): 399-405.
7. Poulin, Eric, et al. "Validation of MRI to TRUS registration for high-dose-rate prostate brachytherapy." *Brachytherapy* 17.2 (2018): 283-290.
8. Murgic, Jure, et al. "Focal salvage high dose-rate brachytherapy for locally recurrent prostate cancer after primary radiation therapy failure: results from a prospective clinical trial." *International Journal of Radiation Oncology* Biology* Physics* 102.3 (2018): 561-567.
9. Maenhout, Metha, et al. "Focal MRI-guided salvage high-dose-rate brachytherapy in patients with radiorecurrent prostate cancer." *Technology in cancer research & treatment* 16.6 (2017): 1194-1201.
10. Zamboglou, Constantinos, et al. "Single fraction multimodal image guided focal salvage high-dose-rate brachytherapy for recurrent prostate cancer." *Journal of contemporary brachytherapy* 8.3 (2016): 241.
11. Wojcieszek, Piotr, et al. "Salvage high-dose-rate brachytherapy for locally recurrent prostate cancer after primary radiotherapy failure." *Radiotherapy and Oncology* 119.3 (2016): 405-410.
12. van Son, Marieke Juliet, et al. "MRI-guided ultrafocal salvage high-dose-rate brachytherapy for localized radiorecurrent prostate cancer: Updated results of 50 patients." *International Journal of Radiation Oncology* Biology* Physics* 107.1 (2020): 126-135.

Images cited throughout

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