PILOT EXPERIMENTAL ANALYSIS OF MEATUS CONFORMATION AND DEVELOPMENT OF NOVEL MEASUREMENTS FOR ABERRANT URINARY STREAM IN 3D PRINTED URETHRAS DERIVED FROM CADAVERIC MODEL

Andrew J Cohen[1], German Patino[2], Seyed Mirramezani[3], Sudarshan Srirangapatanam[4], Anas Tresh[4],Bhagat Cheema[4], Jenny Tai[5], Dylan Romero[5], Anthony Enriquez[4], Shawn Shadden[3], Benjamin N Breyer[4,6]

1: Brady Urological Institute, Johns Hopkins Bayview Medical Center 2: Hospital Universitario San Ignacio, Bogota 3: University of California, Berkeley, Department of Mechanical Engineering 4: Department of Urology, University of California San Francisco 5: Makers Lab Library, University of California San Francisco 6: Department of Biostatistics and Epidemiology, University of California San Francisco

Background

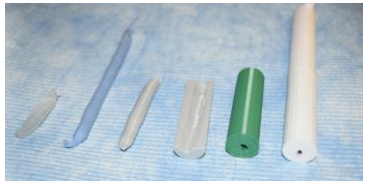
- 10% of male adults have split, sprayed or dribbled stream
- Spray is an underappreciated QOL outcome for urethral surgery
- No current method to evaluate urinary stream deviation
- What is 'normal' urine spray?
- Remains unknown how urethral surgeries affect stream attributes

Objective

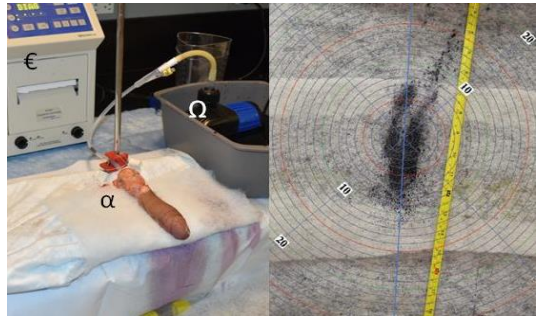
- Develop and test method to measure spray
- Experimentally recreate normal and abnormal anatomical conformations w/ 3D printing & cadaveric surgery

Methods

- cadaveric tissues → 3D-printed models
- penile tissue & 3D printed models were affixed to a fluid pump simulating micturition
- dye captured on fabric
- spray pattern area, deviation from normal location, & flowrates recorded
- additional experiments performed with altered urethral meatus
- computation modelling occurred concurrently



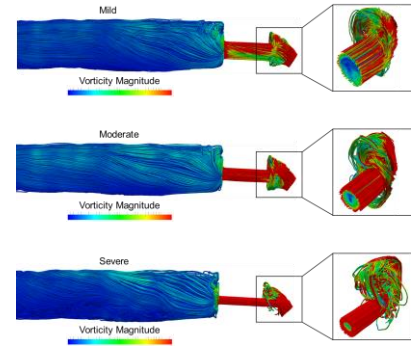
Evolution of urethral casts to 3D printed model



Left: Experimental set up for flow experiments; α: modified 18 Fr silicone tube affixed to cadaveric penis, €: MedAmicus 4114UF Lumax Cystometry System, Ω: Uniclife Controllable DC Water Pump
Right: Example urinary spray pattern result of cadaveric model with radial measurement schema overlay

Cadaveric vs. 3D Printed Models Flow & Spray Dynamics

Specimen[α] (#)	Cadaver Qmax (ml/s)	Matched Model Qmax (ml/s)	P-value	Cadaver Spray Area (cm²)	Matched Model Spray Area (cm²)	P-value
1	21.7	19.0	0.04	38.5	70	0.02
2	21.0	16.3	0.03	48	31.3	0.02
3	23.3	4.6	0.04	48	70	0.03
4	22.9	6.3	0.05	20	42.5	0.03
Average	22.2	11.6	<0.01	38.6	53.4	0.11



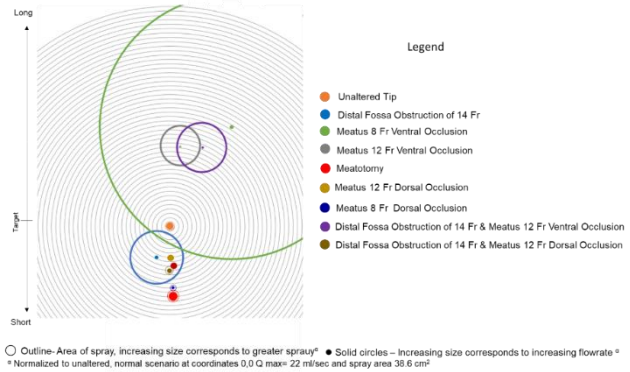
Computational modeling demonstrating increased vorticity with 83%, 90% and 96% reduction in lumen area for mild, moderate, and severe obstruction, respectively

Summary of Tip Alterations and Relative Spray Effects

Tip Alteration	Relative Flow Rate, %	Relative Spray, %	Relative Distance*, cm
Unaltered	Ref	Ref	Ref
Distal Fossa Obstruction of 14 Fr	52	748	-11
Meatus 8 Fr Ventral Occlusion	6	3740	38
Meatus 12 Fr Ventral Occlusion	28	571	23
Meatotomy	120	203	-18
Distal Fossa Obstruction of 14 Fr & Meatus 12 Fr Ventral	29	706	27
Distal Fossa Obstruction of 14 Fr & Meatus 12 Fr Dorsal	60	117	-10
Meatus 12 Fr Dorsal Occlusion	72	29	-11
Meatus 8 Fr Dorsal Occlusion	48	82	-15

* Negative Distances assigned for y axis (short/long)

Visualization of Voiding Strength and Spray Stratified by Cadaveric Tip Alternations



○ Outline- Area of spray, increasing size corresponds to greater sprayα ● Solid circles – Increasing size corresponds to increasing flowrate α
α Normalized to unaltered, normal scenario at coordinates 0,0 Q max= 22 ml/sec and spray area 38.6 cm²

Conclusions

- Successful development of tool to experimentally measure urine spray
- 3D printed models underperform relative to cadaveric tissues
- yet: cheap, safe, & reproducible manner to study urine flow if improved
- Increasing obstruction increases spray area and reduces flow rates in cadaveric model
- Computational models highlight potential role of vorticity in spray

We developed a novel ***urinary spray detector*** and created 3D-printed urethral models suitable for ***dynamic flow experiments***
Urine spray worsens with distal urethral obstruction
These methods have ***paradigm shifting potential*** in the future study of urethral surgery

Twitter: @brady_urology @AJCuro
Facebook: Brady Urology at Johns Hopkins