

PD63-08 Multi-Institutional Study: Automated performance metrics to predict continence recovery after robotic radical prostatectomy utilizing machine learning

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Center of Robotic Simulation and Education

1. Keck Medicine of USC, Los Angeles, CA 2. St. Antonius-Hospital, Gronau, Germany 3. Houston Methodist Hospital, Houston, Texas







Study supported in part an Intuitive Surgical Clinical Research Grant Mimic Technologies, Inc. (consultant).

Andrew J. Hung has financial disclosures with Quantgene, Inc. (consultant) and

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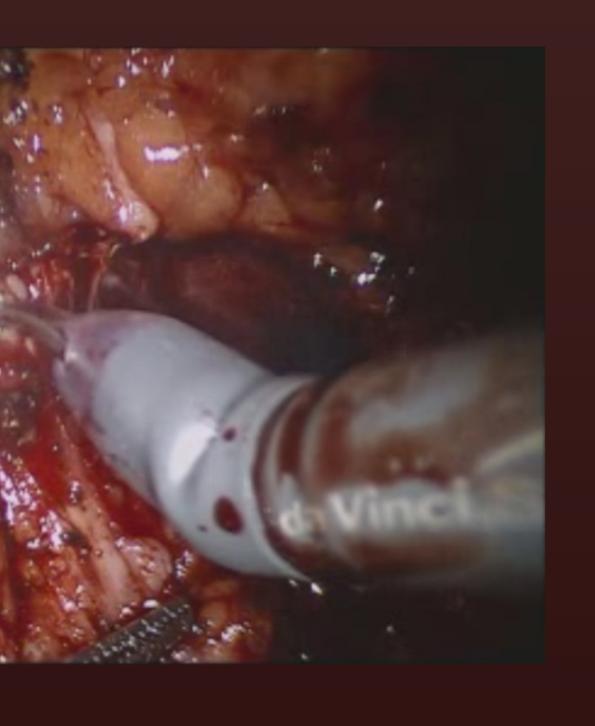


Surgical video



Automated Performance Metrics

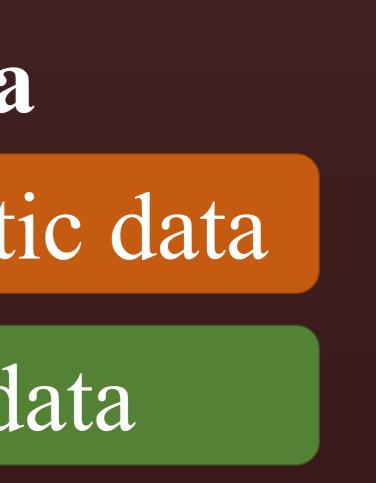




Systems data Instrument kinematic data

Systems event data





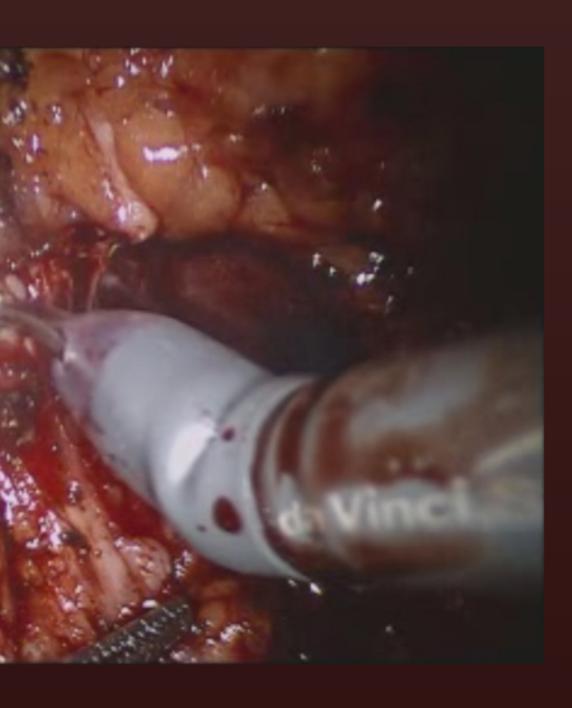


Surgical video



Automated Performance Metrics







Systems data

Systems event data

Instrument kinematic data

Automated performance metrics (APMs)









New Technology and Techniques

Development and Validation of Objective Performance Metrics for Robot-Assisted Radical Prostatectomy: A Pilot Study

Andrew J. Hung a 은 쩝, Jian Chen a, Anthony Jarc ^{b, †}, David Hatcher a, Hooman Djaladat a, Inderbir S. Gill ^a

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Automated Performance Metrics

The Journal of Urology

Volume 199, Issue 1, January 2018, Pages 296-304



American Urological American Urological Association

Volume 199

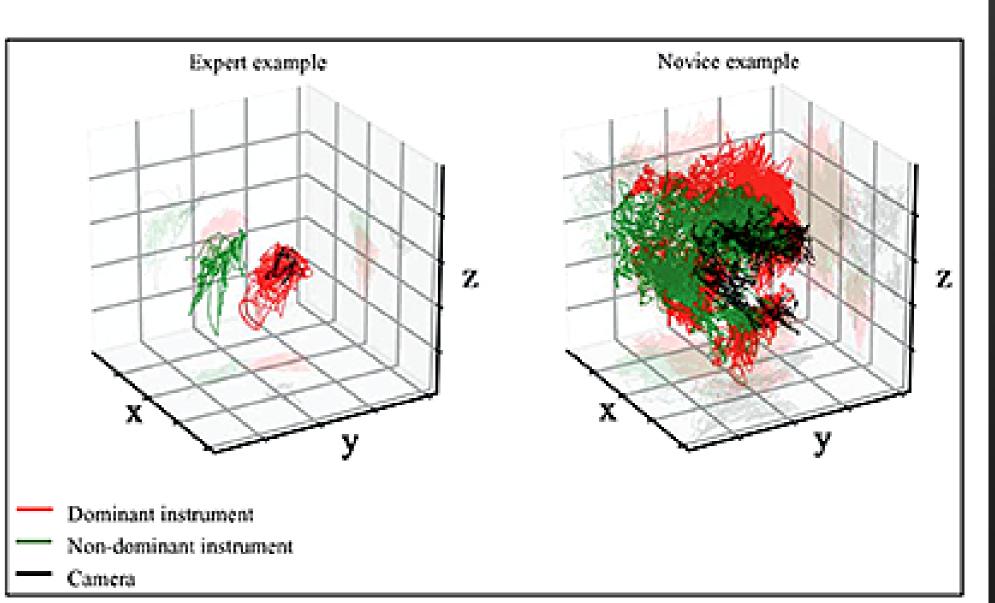
Number 1

January 2018





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Validation of robot-assisted radical prostatectomy (page 296)

- Prostate Specific Antigen Testing after Radical Prostatectomy—Can We Stop at 20 Years?
- Predictors of Infectious Complications after Targeted Prophylaxis for Prostate Needle Biopsy
- Five-Year Followup Results of Prospective, Multicenter Study of Patients with Overactive Bladder Treated with Sacral Neuromodulation







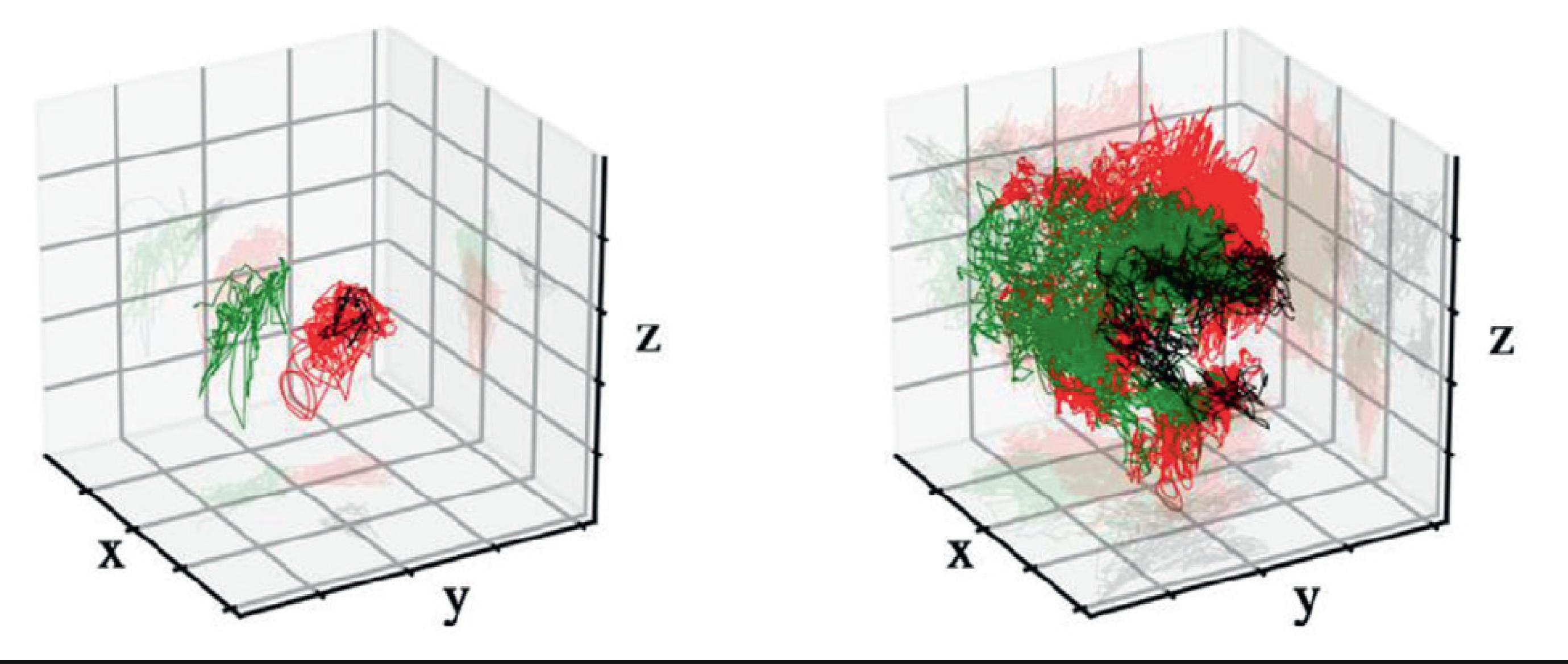
Bladder mobilization (BM)



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Automated Performance Metrics

Expert example

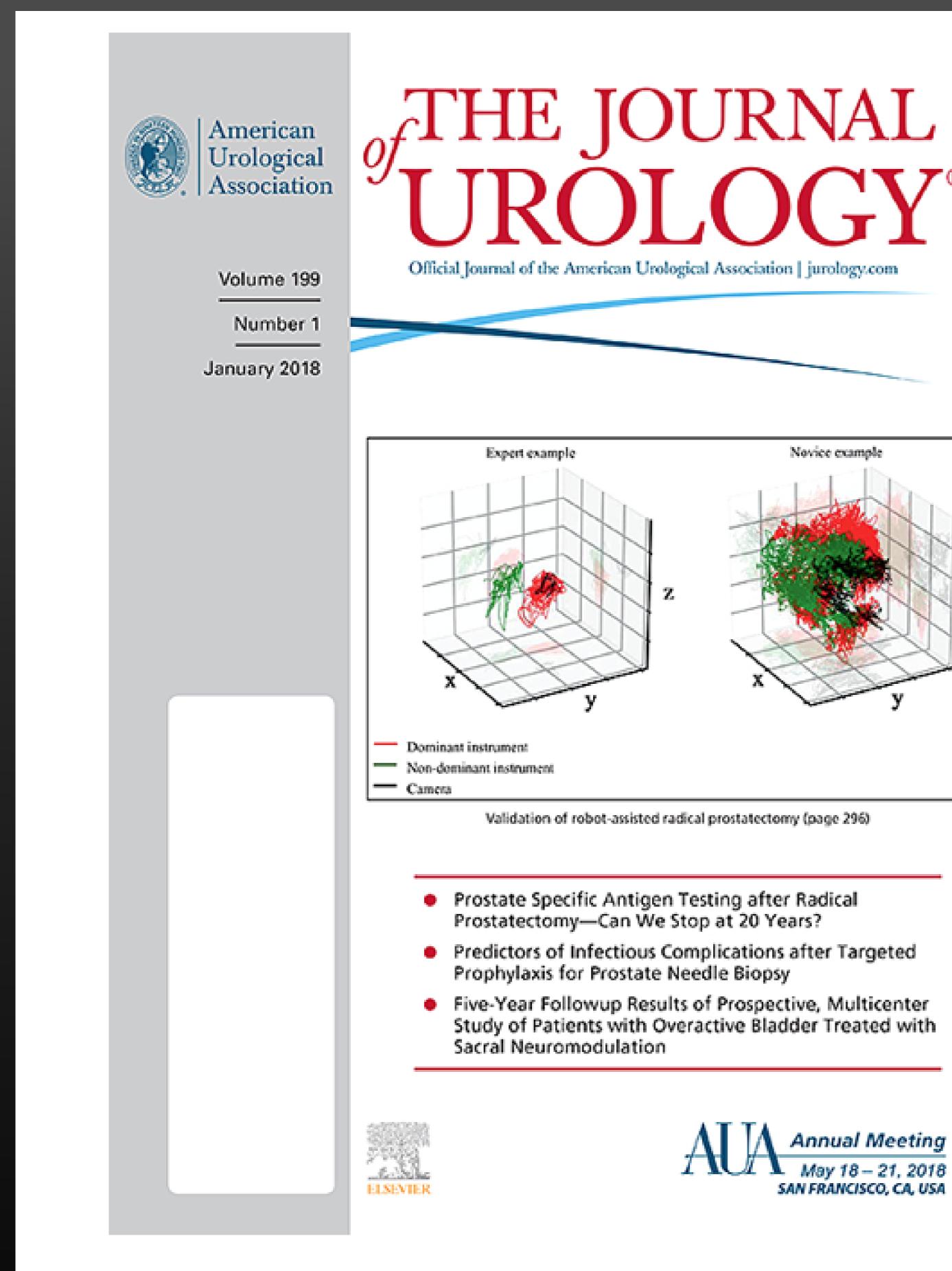


Non-dominant Instrument

Novice example







January 2018 Cover

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APMs on the cover of JU







American Urological Association

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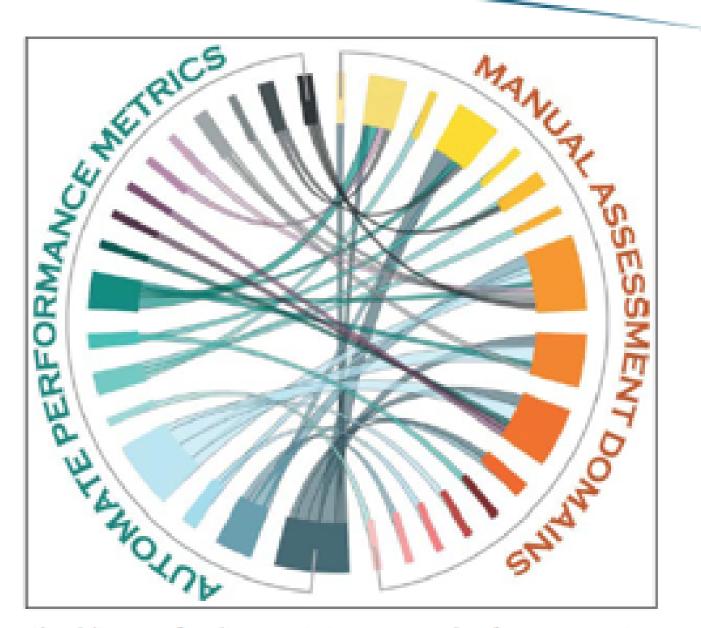
Number

March 2019



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Chord diagram of studies associating automated performance metrics and manual assessment domains in systematic review (page 465).

- Perioperative Oral Nutrition Supplementation Reduces Prevalence of Sarcopenia following Radical Cystectomy: Results of Prospective Randomized Controlled Trial
- Active Surveillance for Localized Prostate Cancer: Nationwide Observational Study
- Hypofractionated Radiation Therapy for Localized Prostate Cancer: Executive Summary of ASTRO, ASCO and AUA Evidence-Based Guideline

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🔄 Wolters Kluwer

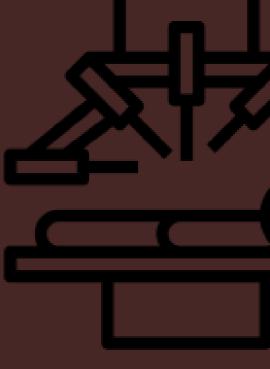
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Surgeon factors



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Robot-assisted radical prostatectomy

Clinicopathological

Surgical skill and performance

Disease recurrence



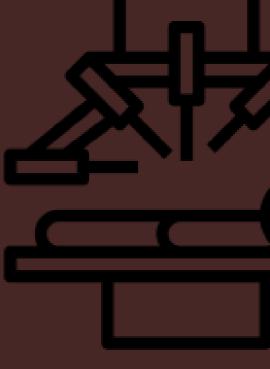
Urinary continence

Erectile function





Surgeon factors



Center of Robotic Simulation and Education

Robot-assisted radical prostatectomy

Clinicopathological

Surgical skill and performance

Disease recurrence



Urinary continence

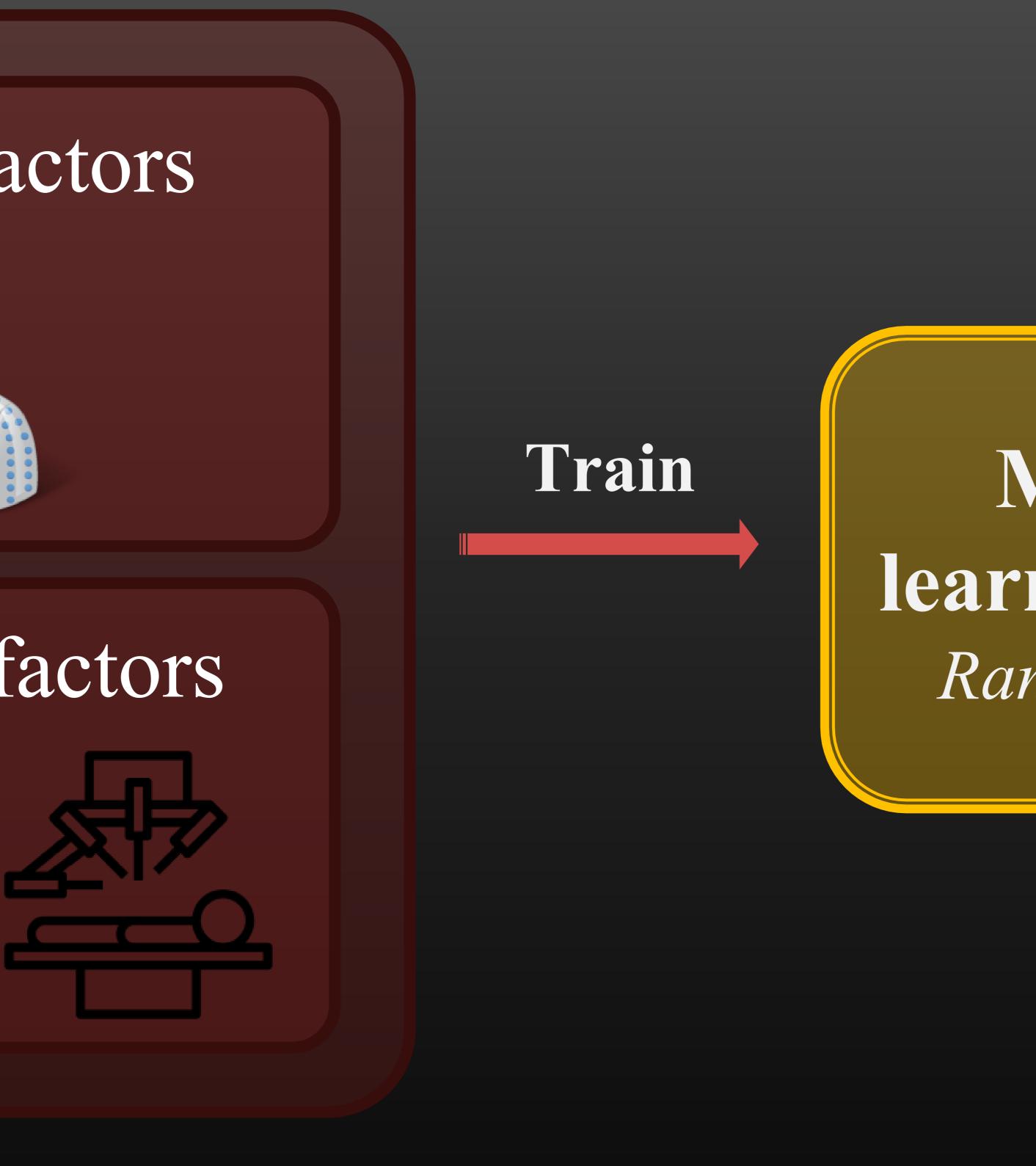
Erectile function





Surgeon factors





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Method

Machine learning model Random Forest

Predict

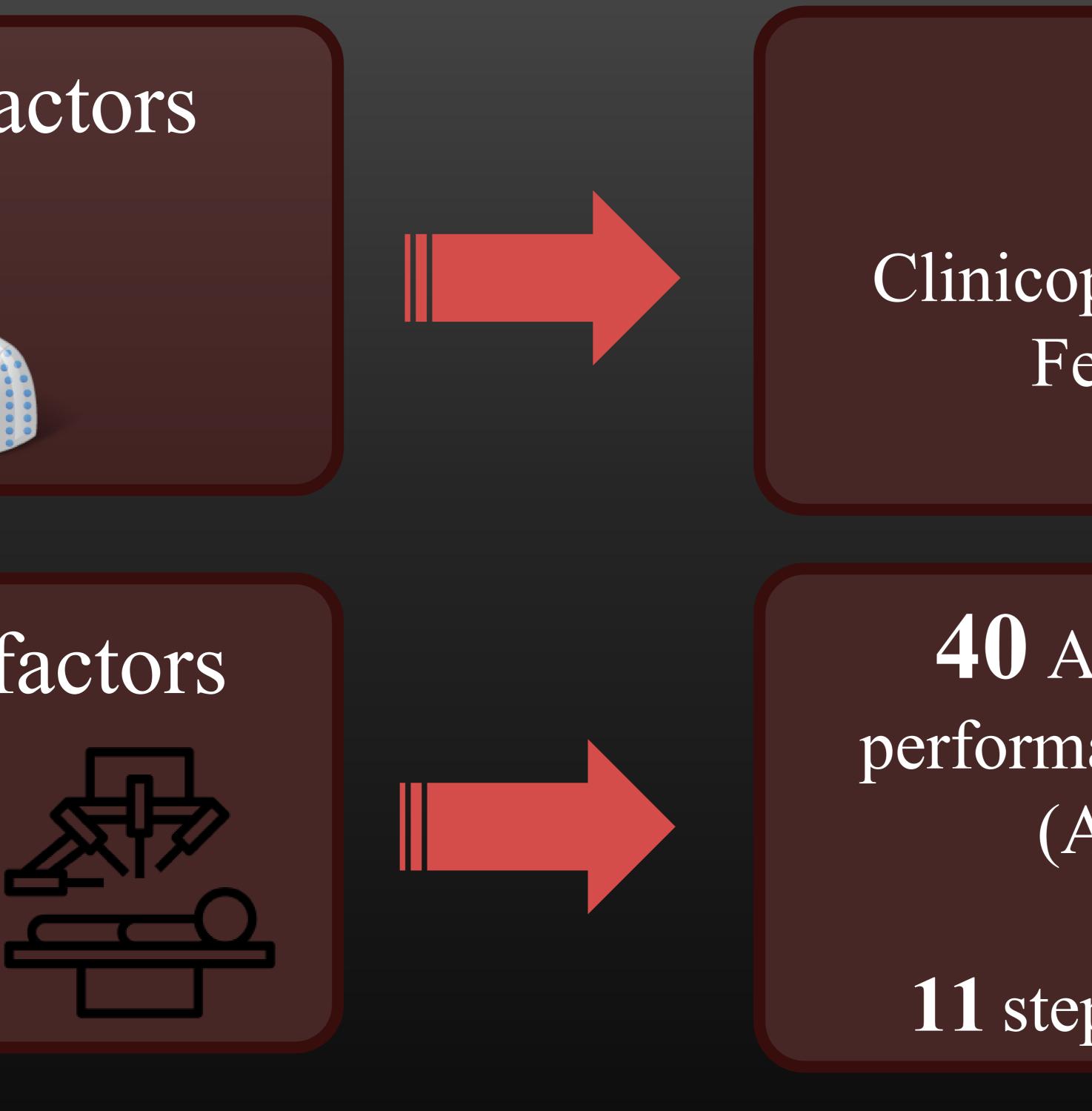


Urinary continence recovery





Surgeon factors



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Robot-assisted radical prostatectomy

15 Clinicopathological Features

40 Automated performance metrics (APMs)

11 steps per case

X



Total of 455 features per case



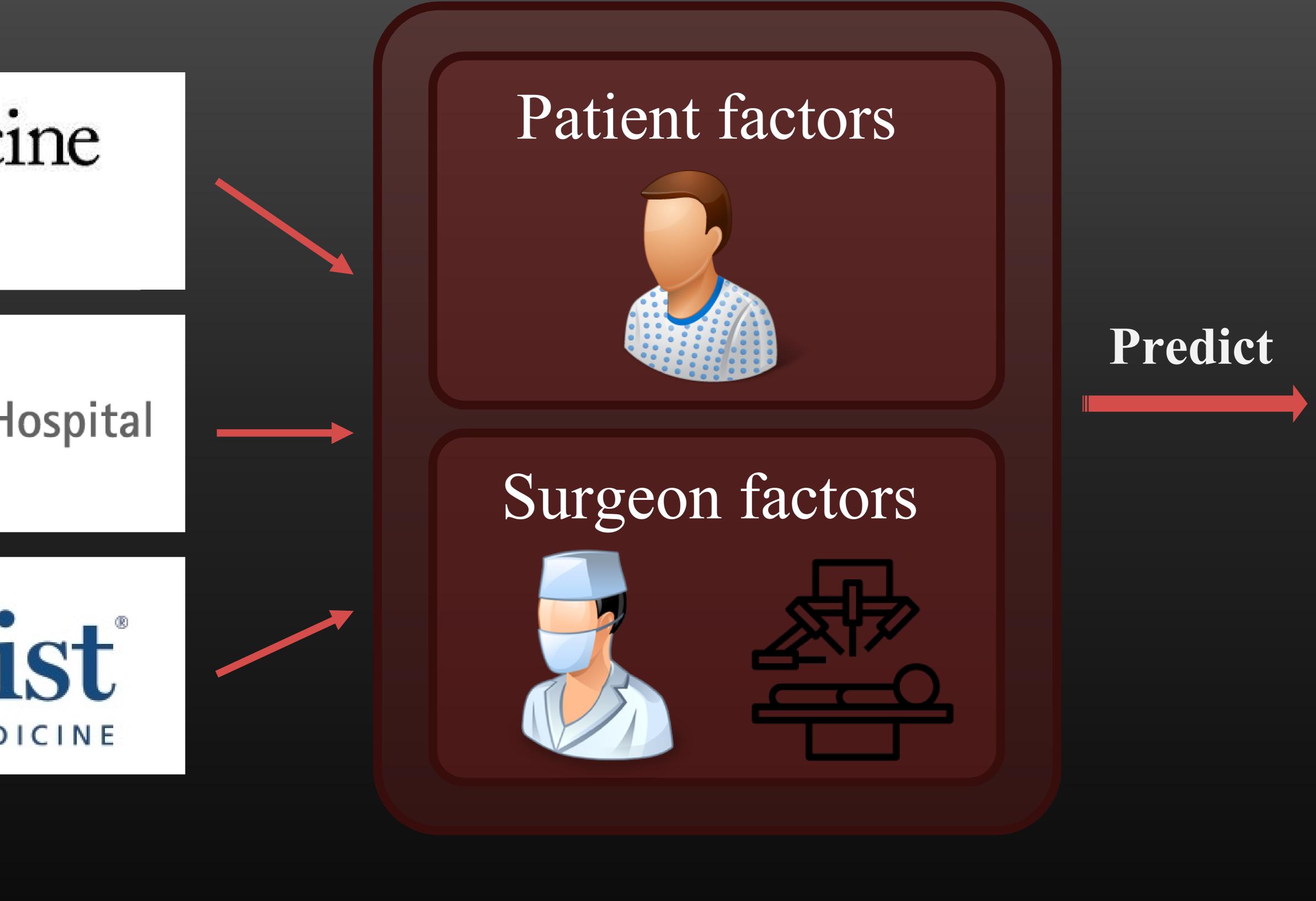
Keck Medicine of USC

St. Antonius-Hospital Gronau GmbH

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Multi-Institutional Study

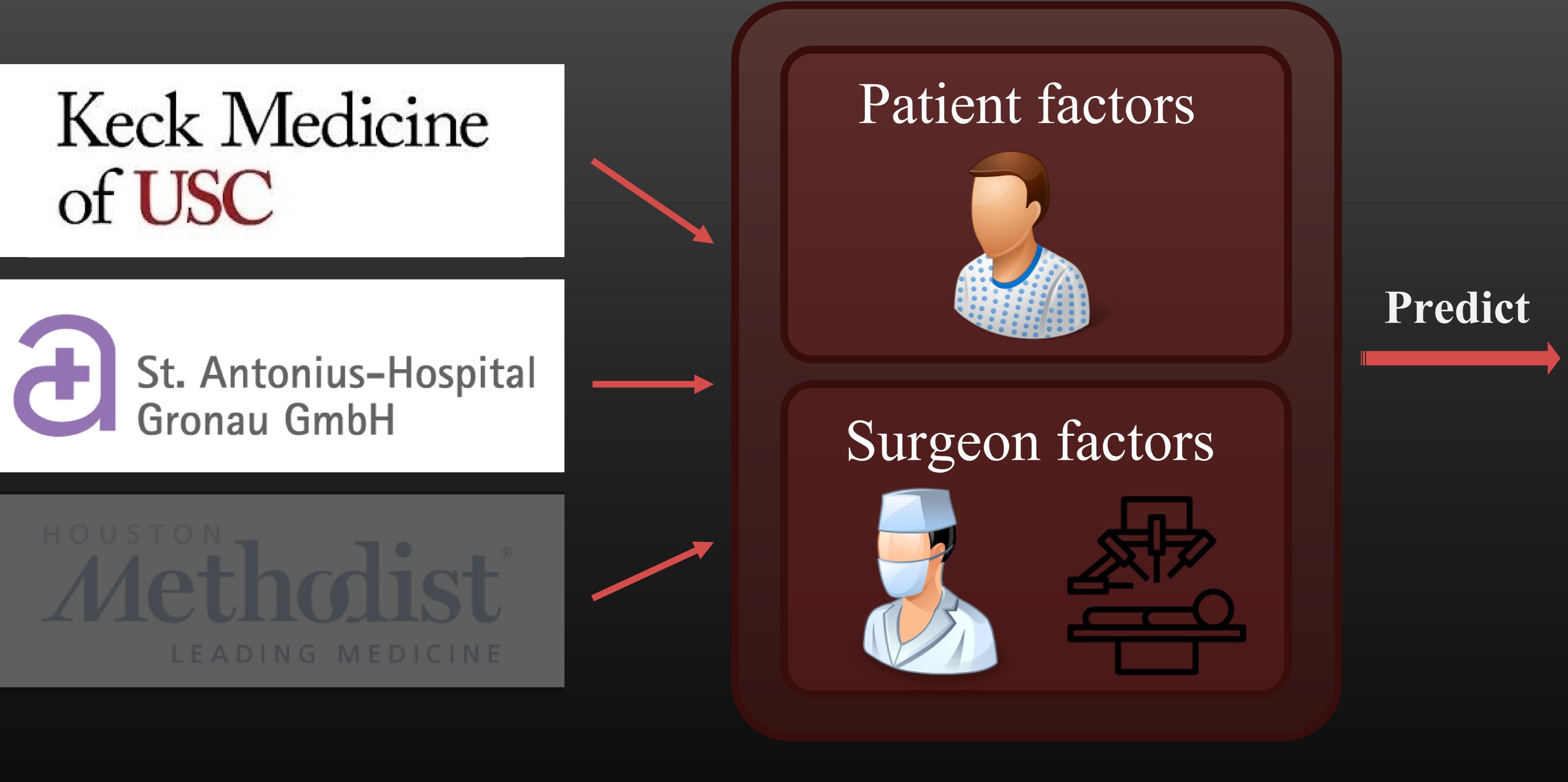


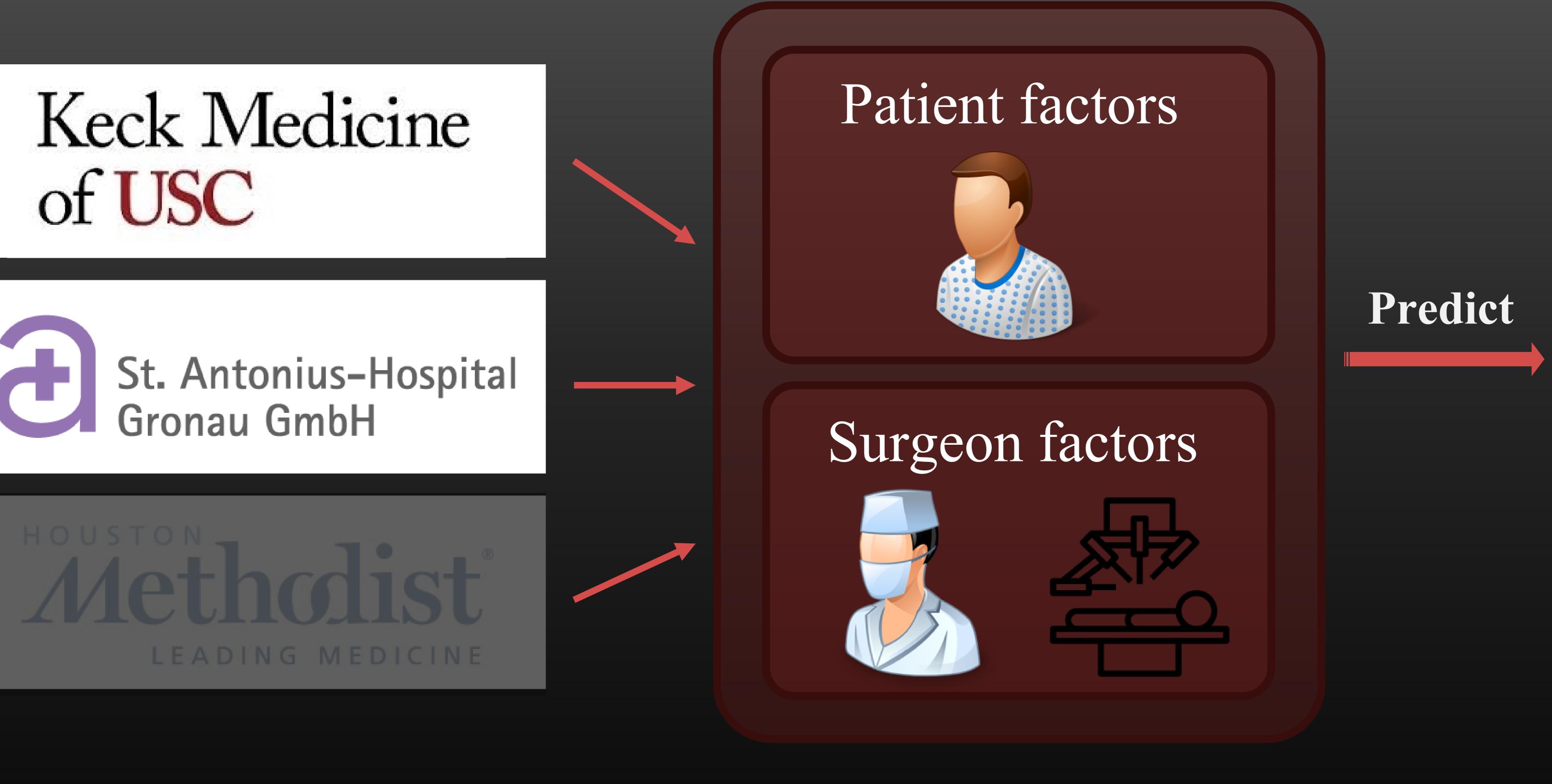


Urinary continence recovery



of USC





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Multi-Institutional Study



Urinary continence recovery



Site 1 # Patients 116 # Surgeons

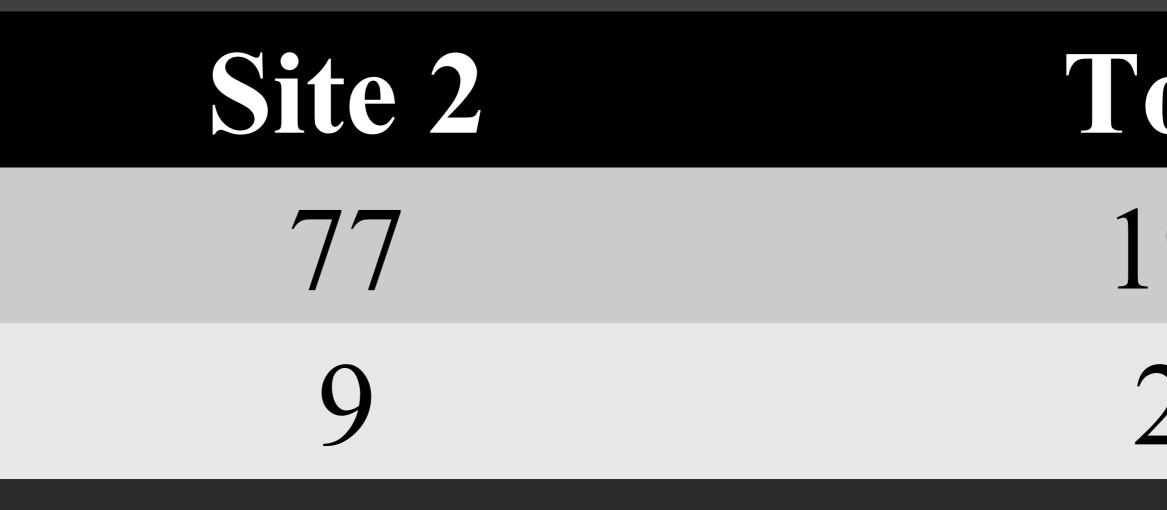
• 3 month: 56.7% of patients achieved urinary continence after surgery

• 6 month: 73.3% of patients achieved urinary continence after surgery

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Participants





USC Institute of Urology

Total 193 20





Pre-op features

Age year BMI kg/m2 ASA PSA ng/mL pre-op Gleason score

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Incontinent vs Continent at 3 month

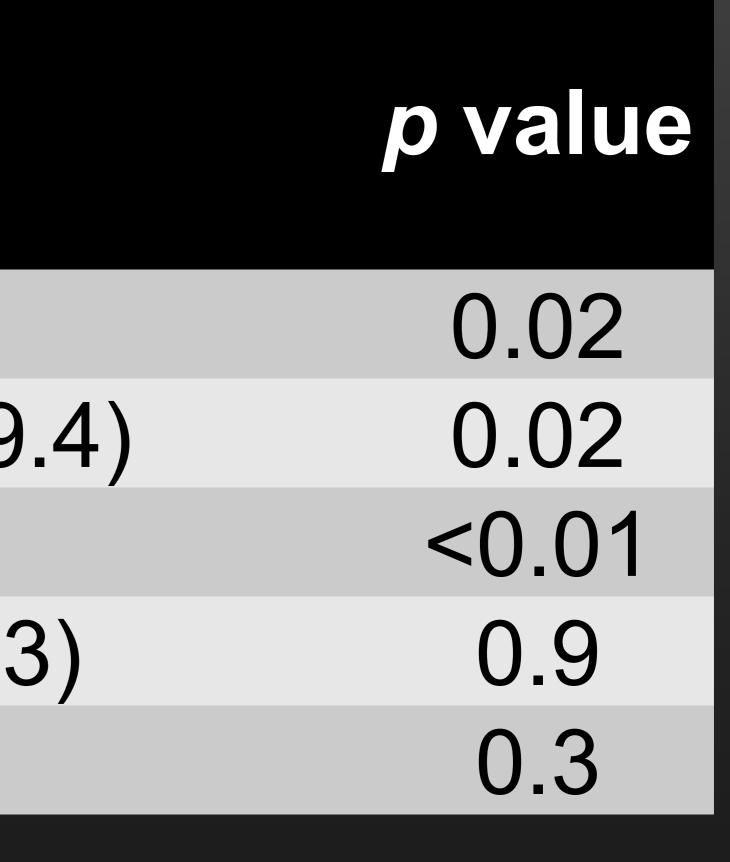
Incontinent (N = 78)

66.6±7.1 28.9 (25.6 - 31.4) 3 (2 - 3) 7.3 (5.4 - 10.6) 7 (7 - 7)

Continent (N = 102)

64.2±6.7 26.9 (25.4 - 29.4) 2 (2 - 3) 7.5 (5.9 - 10.3) 7 (7 - 7)







Pre-op features

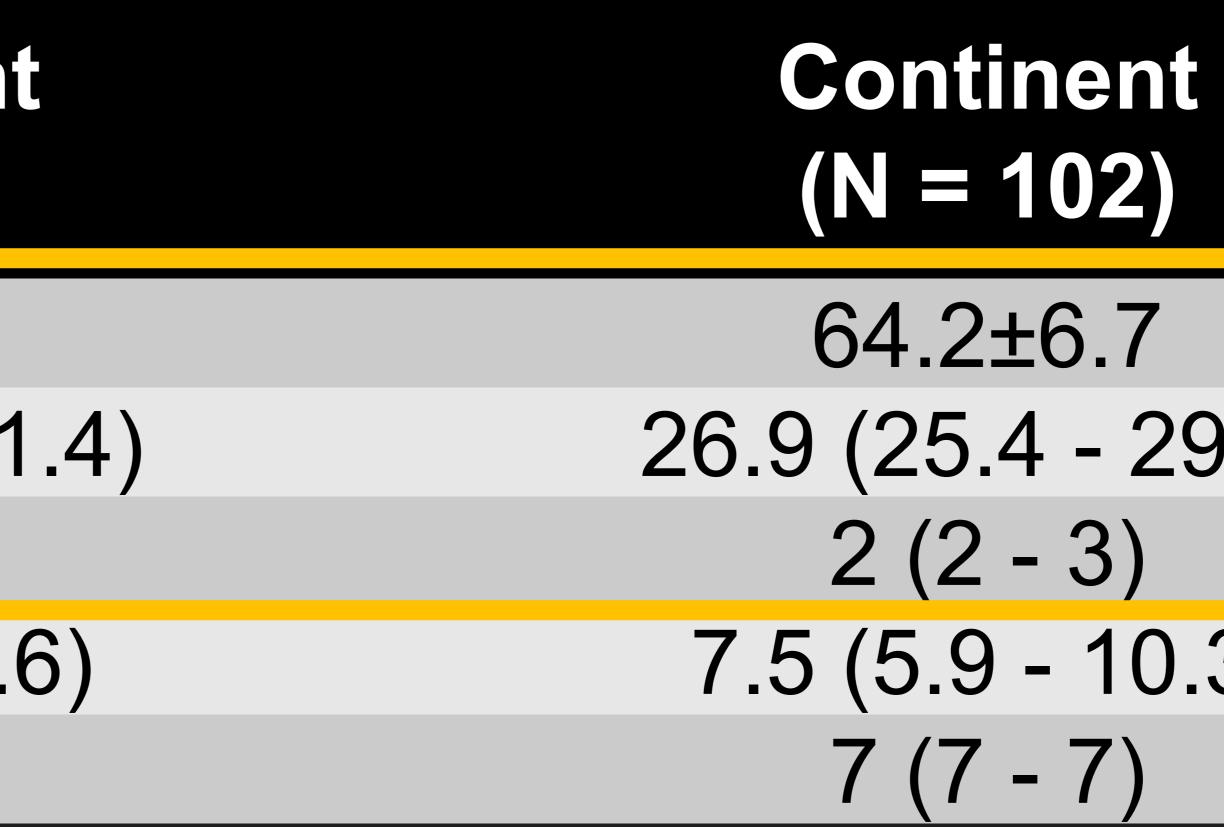
Age year BMI kg/m2 ASA PSA ng/mL pre-op Gleason score

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Incontinent vs Continent at 3 month

Incontinent (N = 78)

66.6±7.1 28.9 (25.6 - 31.4) 3 (2 - 3) 7.3 (5.4 - 10.6) / (7 - 7)





pvalue

	0.02	
9.4)	0.02	
	< 0.01	
.3)	0.9	
	0.3	



Pathologic features

Pathological tumor stage pT2 ≥pT3 **Post-op Gleason score** Prostate volume (g) **Positive surgical margin**

no

yes

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Incontinent vs Continent at 3 month

Incontinent (N = 78)

27 (32.93%) 49 (52.69%) 7 (7 - 7) 51 (40 - 67

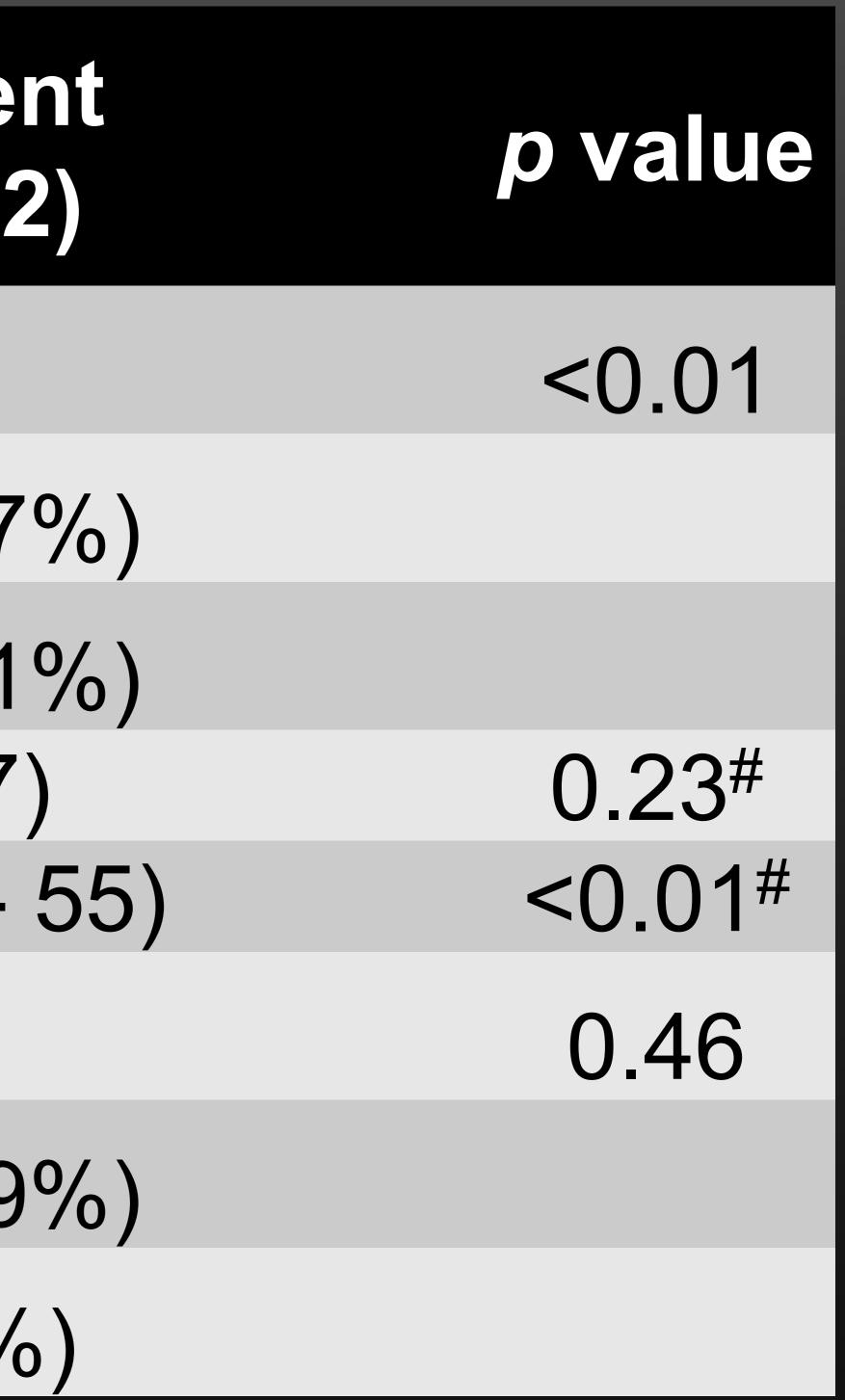
65 (42.21%) 13 (50%)

Continent (N = 102)

55 (67.07
44 (47.31
7 (7 - 7
43.5 (36 -

89 (57.79%) 13 (50%)







Pathologic features

Pathological tumor stage pT2 ≥pT3 **Post-op Gleason score** Prostate volume (g) **Positive surgical margin** no yes

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Incontinent vs Continent at 3 month

Incontinent (N = 78)

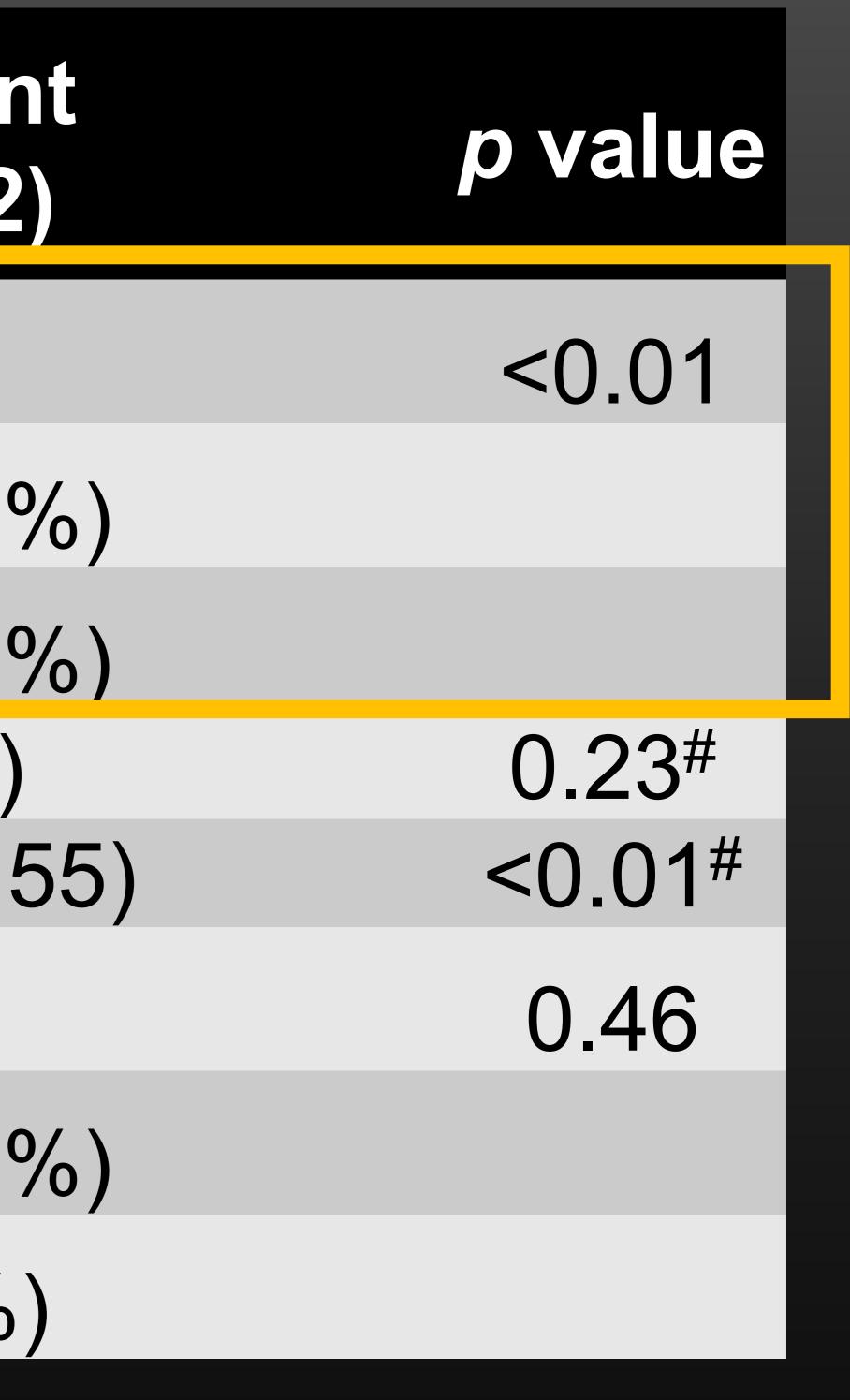
27 (32.93%) 49 (52.69%) 7 (7 - 7) 51 (40 - 67)

65 (42.21%) 13 (50%)

Continent (N = 102)

- 55 (67.07%) 44 (47.31%) 7 (7 - 7) 43.5 (36 - 55)
 - 89 (57.79%) 13 (50%)







Pathologic features Pathological tumor stage pT2 ≥pT3 Post-op Gleason score Prostate volume (g) **Positive surgical margin** no yes

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Incontinent vs Continent at 3 month

Incontinent (N = 78)

27 (32.93% 49 (52.69% 7 (7 - 7) 51 (40 - 67

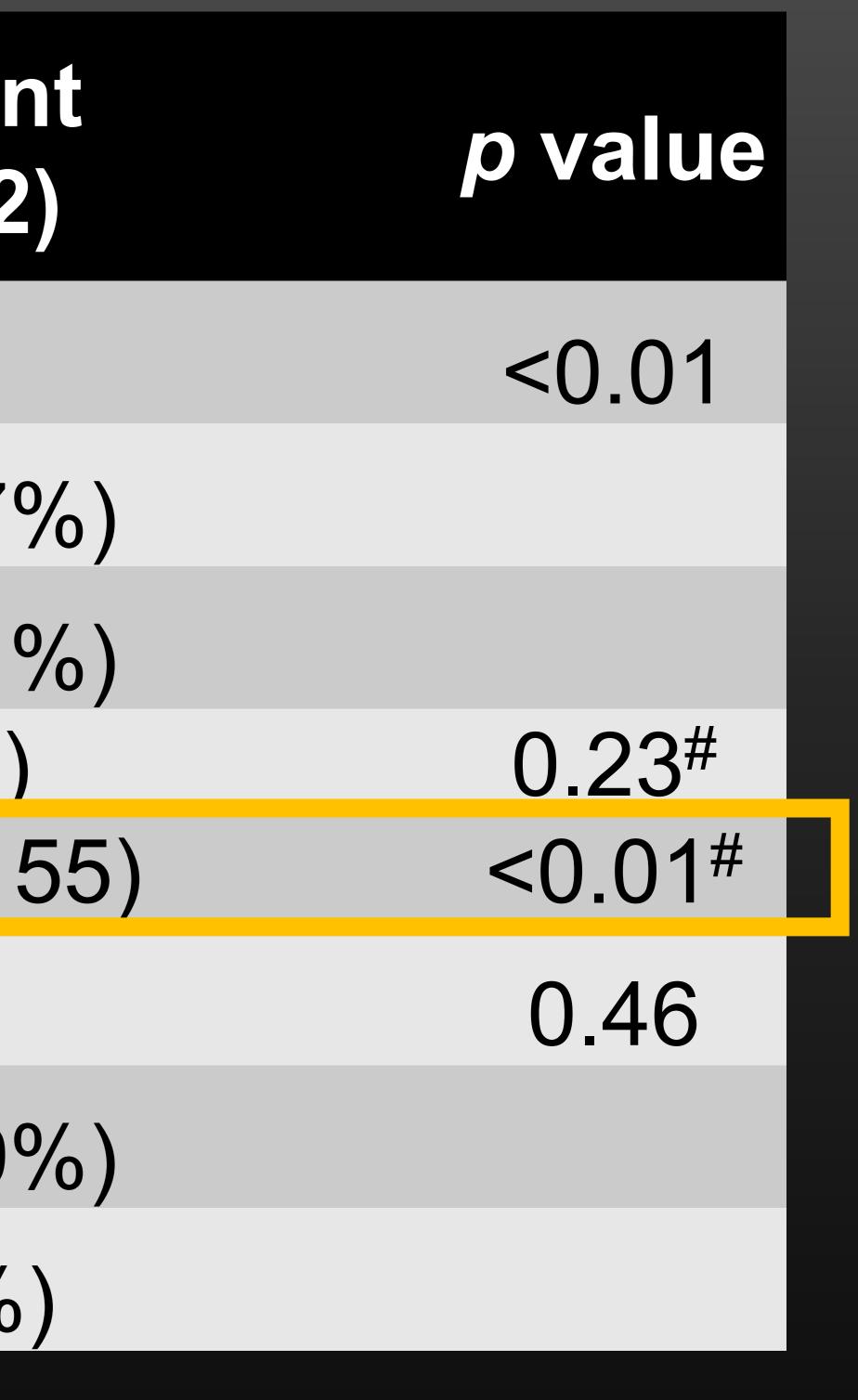
65 (42.21%) 13 (50%)

Continent (N = 102)

6)	55 (67.07
6)	44 (47.31
	7 (7 - 7)
7)	43.5 (36 -

89 (57.79%) 13 (50%)







Pre-op features

Age year BMI kg/m2 ASA PSA ng/mL pre-op Gleason score

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Incontinent vs Continent at 6 month

Continent Incontinent (N = 129)(N = 47)67.5±6.8 64.6±6.7 28.7 (27 - 33.1) 27.2 (25.4 - 30 2 (2 - 3) 2 (2 - 3) 7.4 (5.8 - 10. 7.8 (5.9 - 11.1)

- /



	pvalue
	0.01
0.1)	0.01
	0.01
.2)	0.30
	0.43

-



Pre-op features

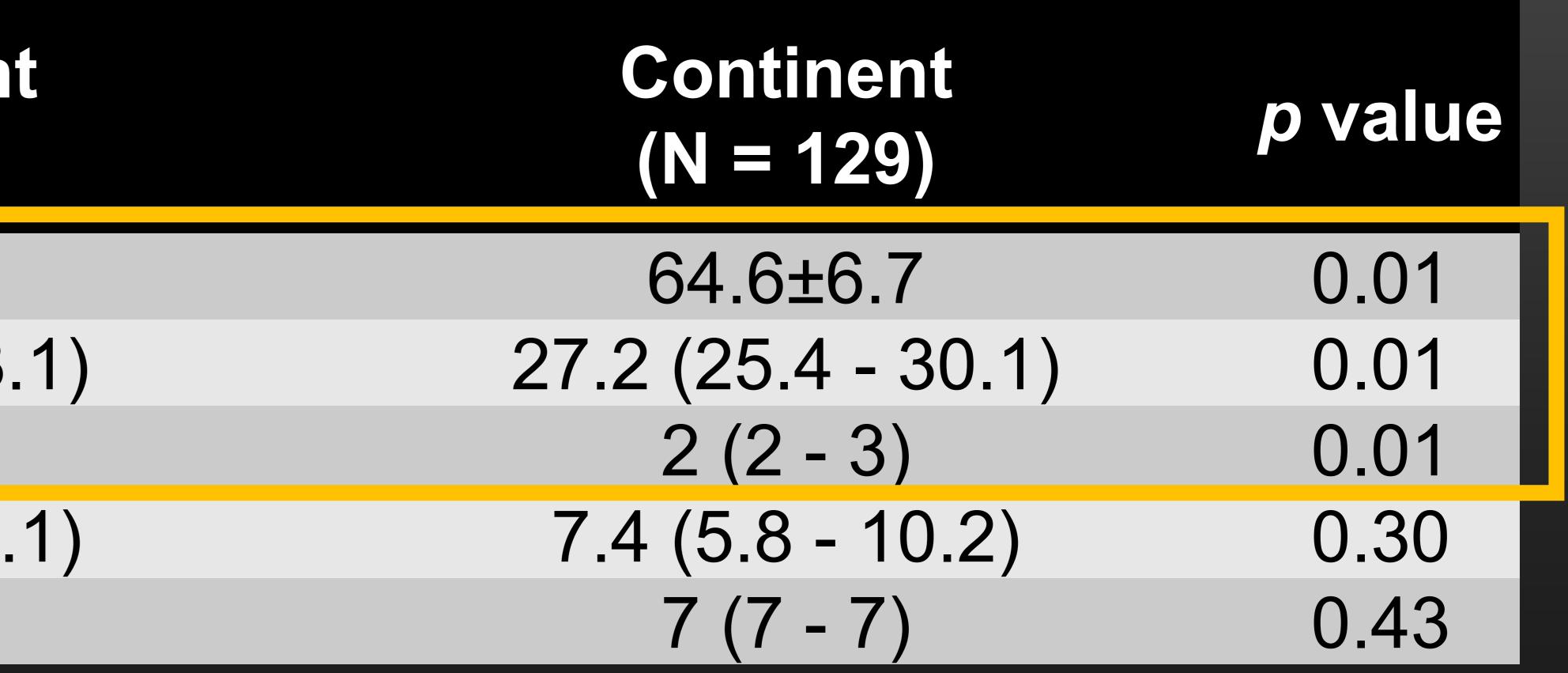
Age year BMI kg/m2 ASA PSA ng/mL pre-op Gleason score

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Incontinent vs Continent at 6 month

Incontinent (N = 47)

67.5±6.8 28.7 (27 - 33.1) 2 (2 - 3) 7.8 (5.9 - 11.1) - /







Pathologic features

Pathological tumor stage pT2 ≥pT3 **Post-op Gleason score Prostate volume (g) Positive surgical margin** no yes

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Incontinent vs Continent at 6 month

Incontinent (N = 47)

16 (19.51%) 30 (33.33%) 7 (7 - 7) 50.5 (40 - 64)

37 (24.34%) 10 (41.67%)

Contine (N = 129)

66 (80.49 60 (66.67 7 (7 - 7 45 (37 - 5

115 (75.66 14 (58.33%)



nt))	pvalue
	0.04
%)	
%)	
	0.13
58)	0.06
	0.07
5%)	



Pathologic features

Pathological tumor stage

pT2

≥pT3

Post-op Gleason score Prostate volume (g) Positive surgical margin

no

yes

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Incontinent vs Continent at 6 month

Incontinent (N = 47)

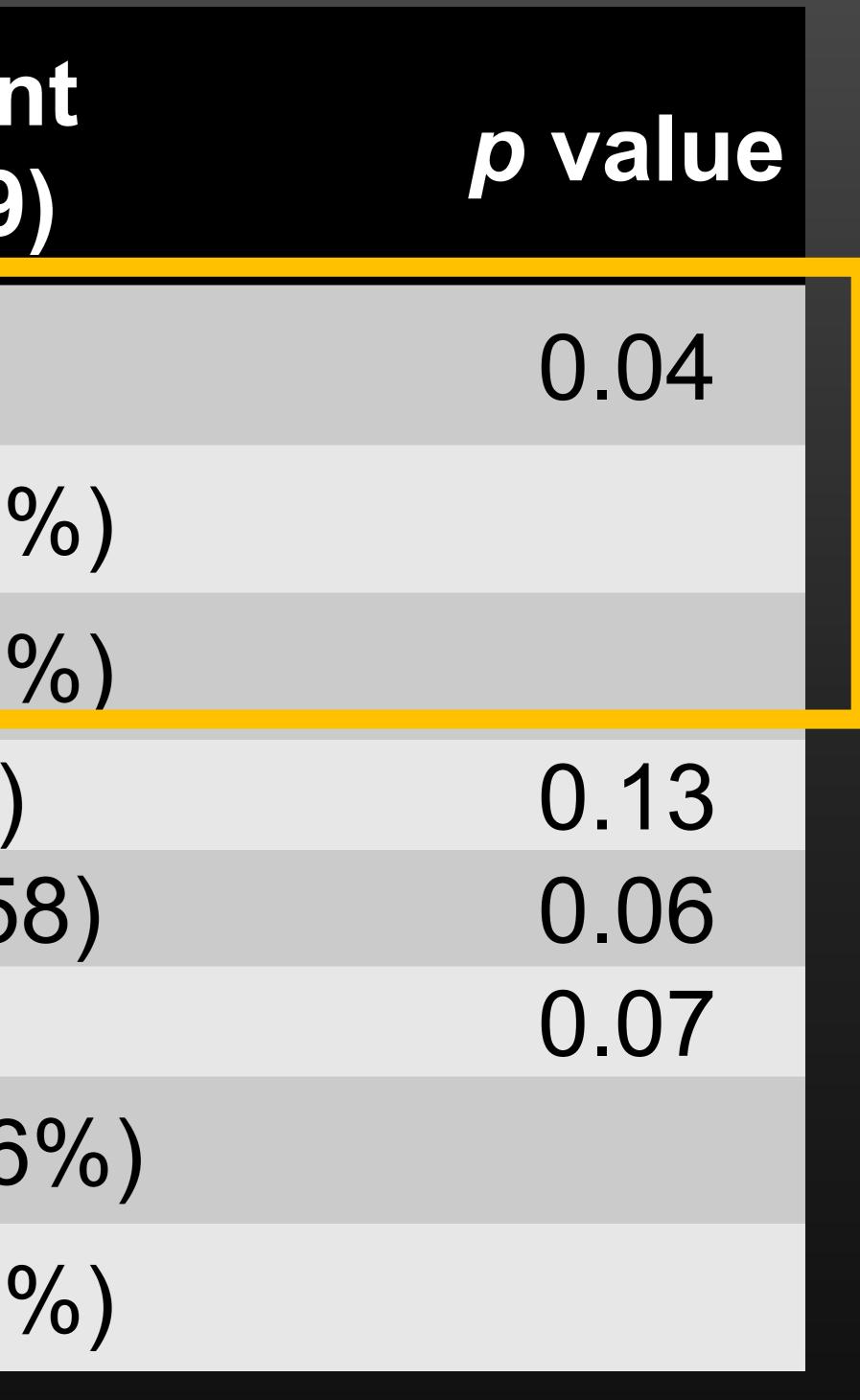
16 (19.51%) 30 (33.33%) 7 (7 - 7) 50.5 (40 - 64)

37 (24.34%) 10 (41.67%)

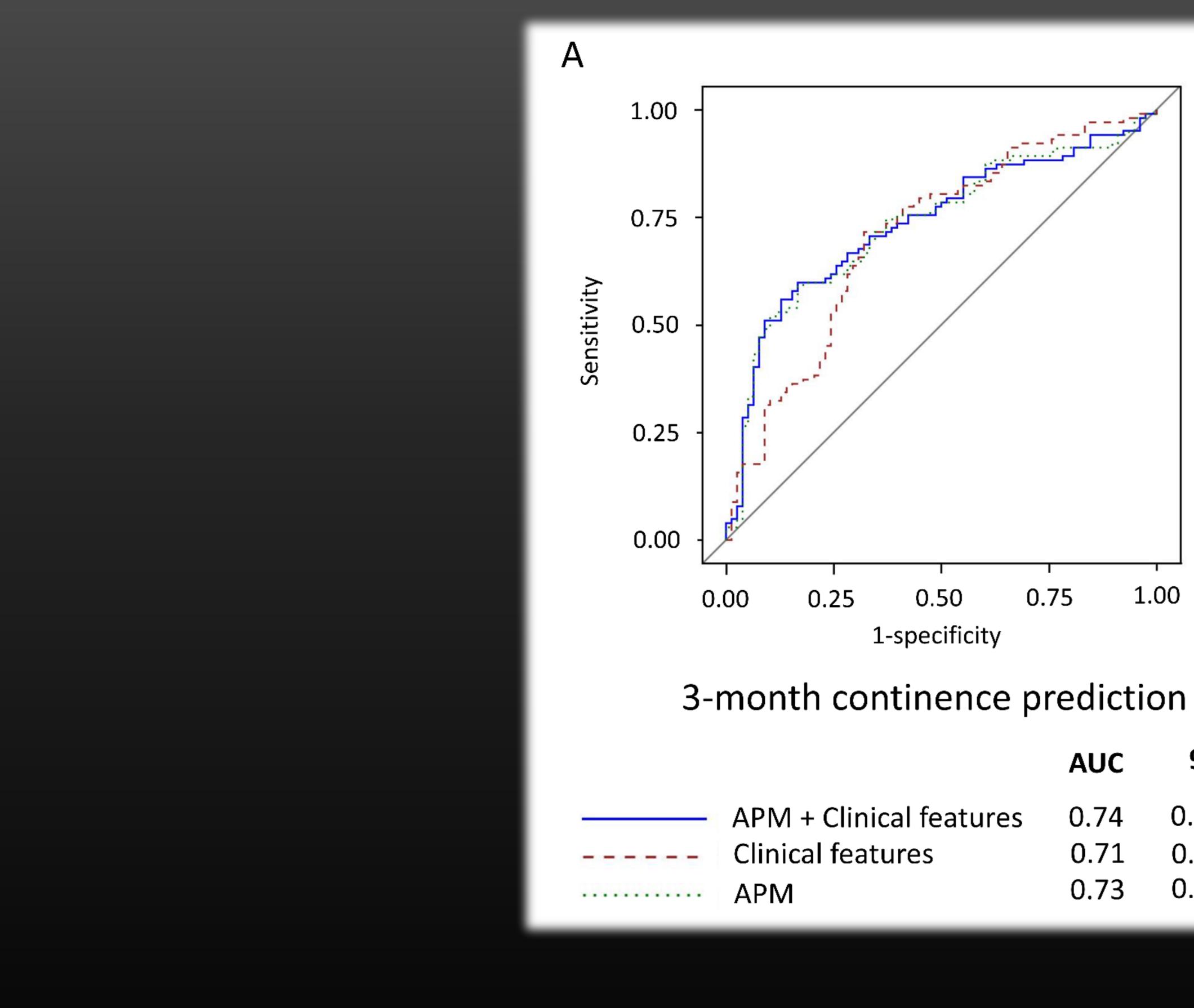
Continent (N = 129)

- 66 (80.49%) 60 (66.67%) 7 (7 - 7) 45 (37 - 58)
 - 115 (75.66%) 14 (58.33%)







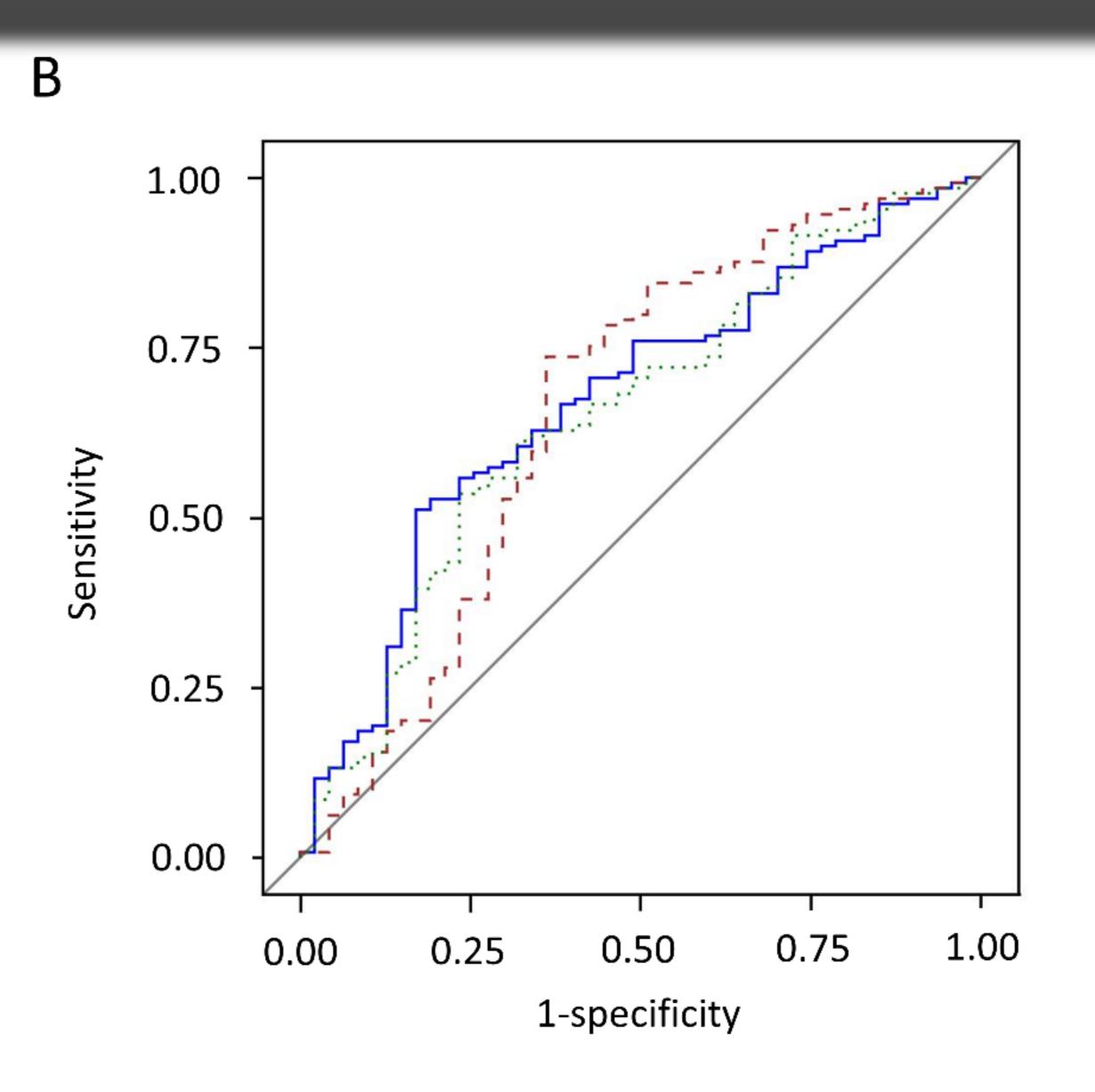


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Prediction Accuracy

Random Forest 10-fold cross validation

	AUC	95% CI
 APM + Clinical features	0.74	0.66-0.81
Clinical features	0.71	0.63-0.78
 APM	0.73	0.66-0.81



6-month continence prediction

	AUC
 APM + Clinical features	0.67
 Clinical features	0.66
 APM	0.65



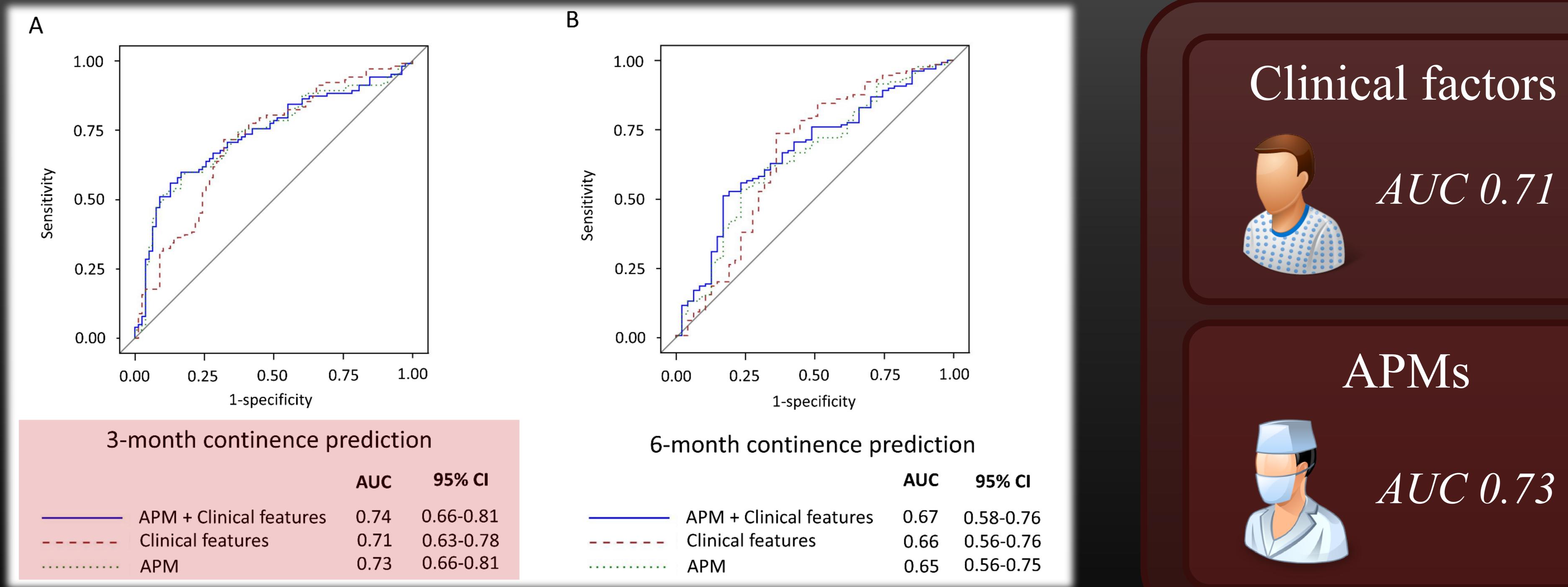
95% CI

0.58-0.76 0.56-0.76

0.56-0.75



Random Forest 10-fold cross validation



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Prediction Accuracy



3-month continence prediction



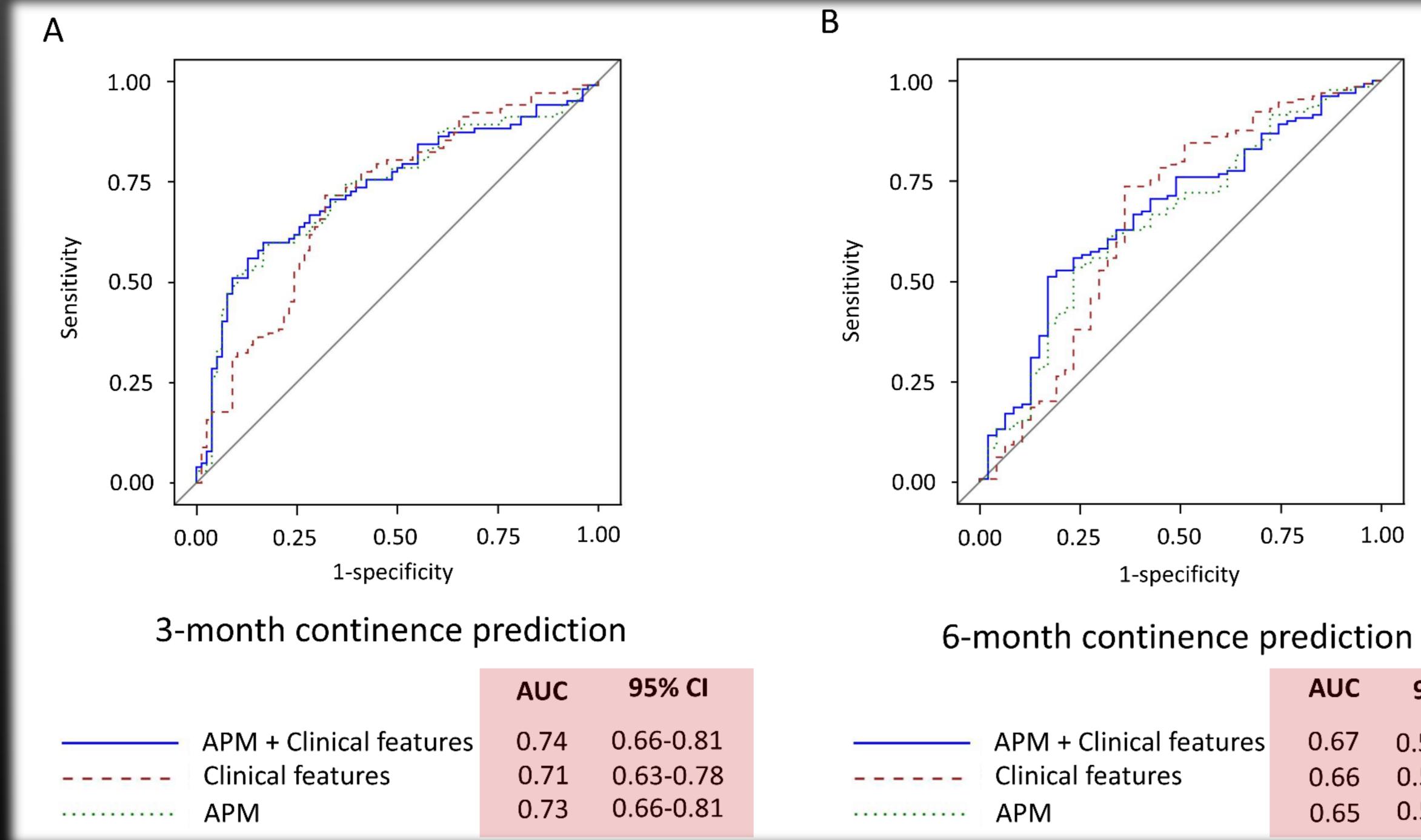
AUC 0.71

AUC 0.74

AUC 0.73



Random Forest 10-fold cross validation



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Prediction Accuracy



3-month

Combined AUC 0.74

Clinical AUC 0.71

1.00

2	95% CI
7	0.58-0.76
5	0.56-0.76
5	0.56-0.75

APMs AUC 0.73



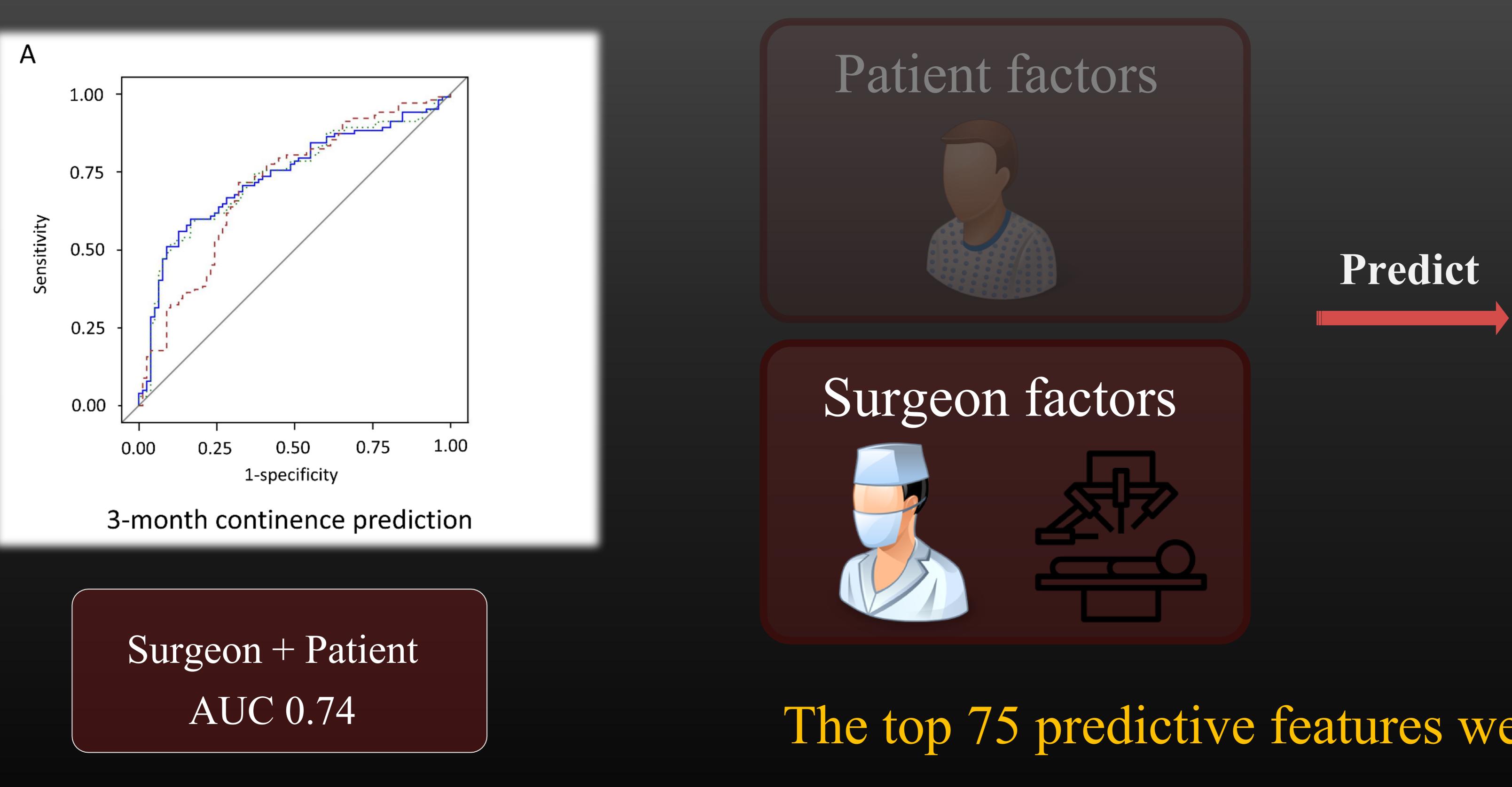
6-month

Combined AUC 0.67

Clinical AUC 0.66

APMs AUC 0.65





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Predictive Features -3 mo continence

The top 75 predictive features were surgeon factors!



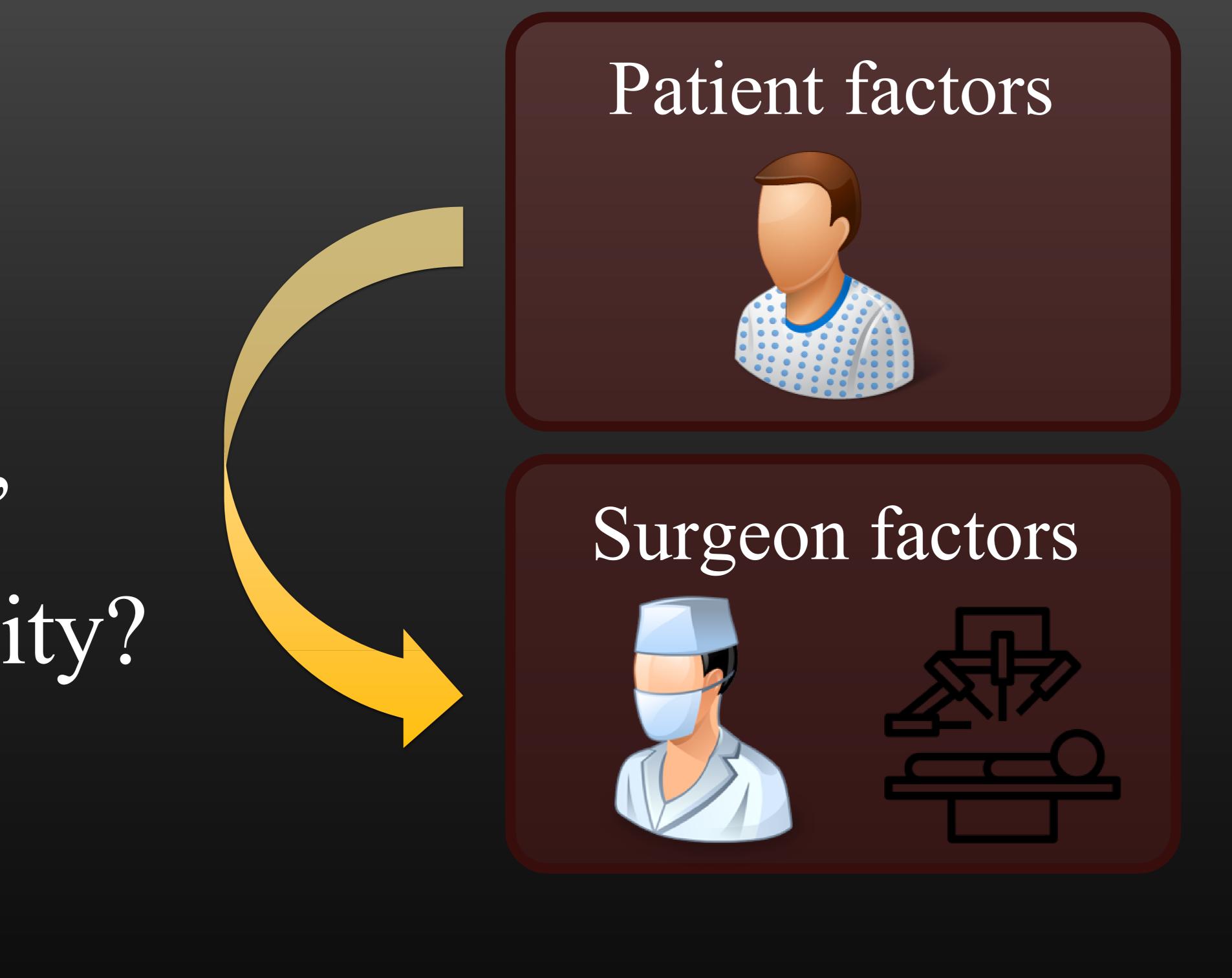
Urinary continence recovery



How do patient factors impact APMs' predictive ability?

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Impact of Patient Factors



Predict



Urinary continence recovery

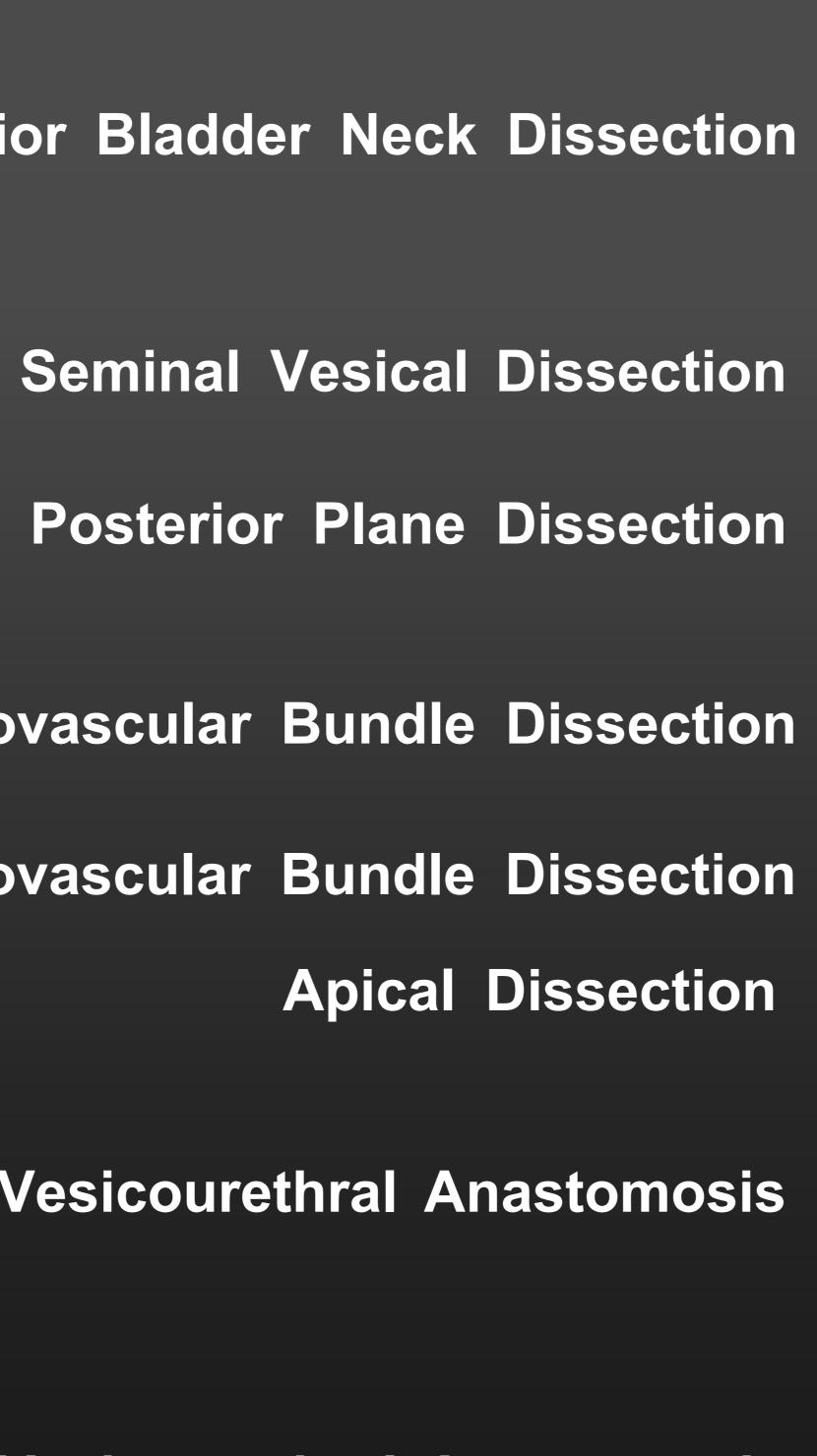


Automated performance metrics (APMs)

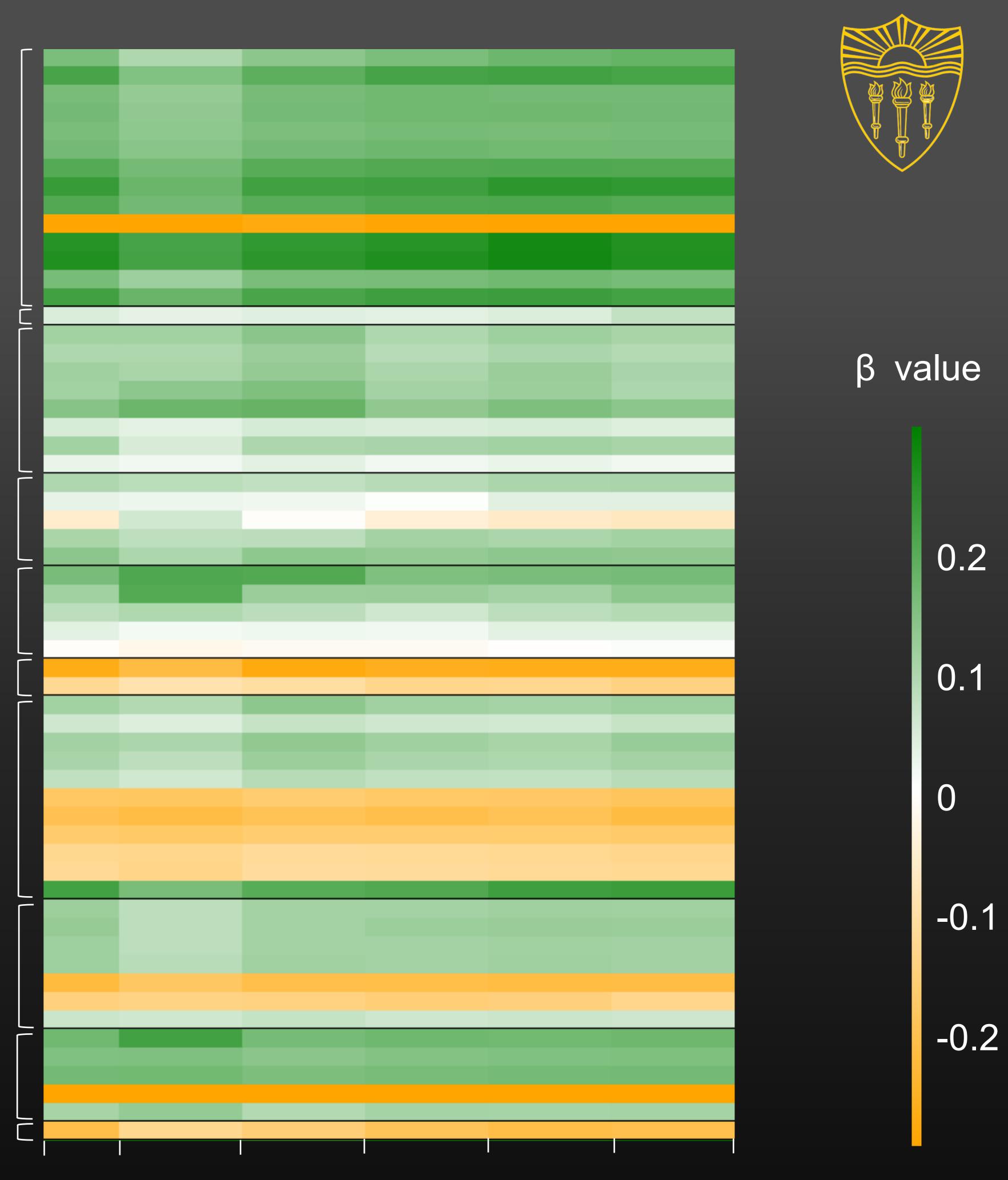
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Anterior Bladder Neck Dissection

- Left Neurovascular Bundle Dissection
- **Right Neurovascular Bundle Dissection**
- **Posterior Vesicourethral Anastomosis**
- Anterior Vesicourethral Anastomosis
 - Left Lymph Node Dissection



Right Lymph Node Dissection



Patient factors



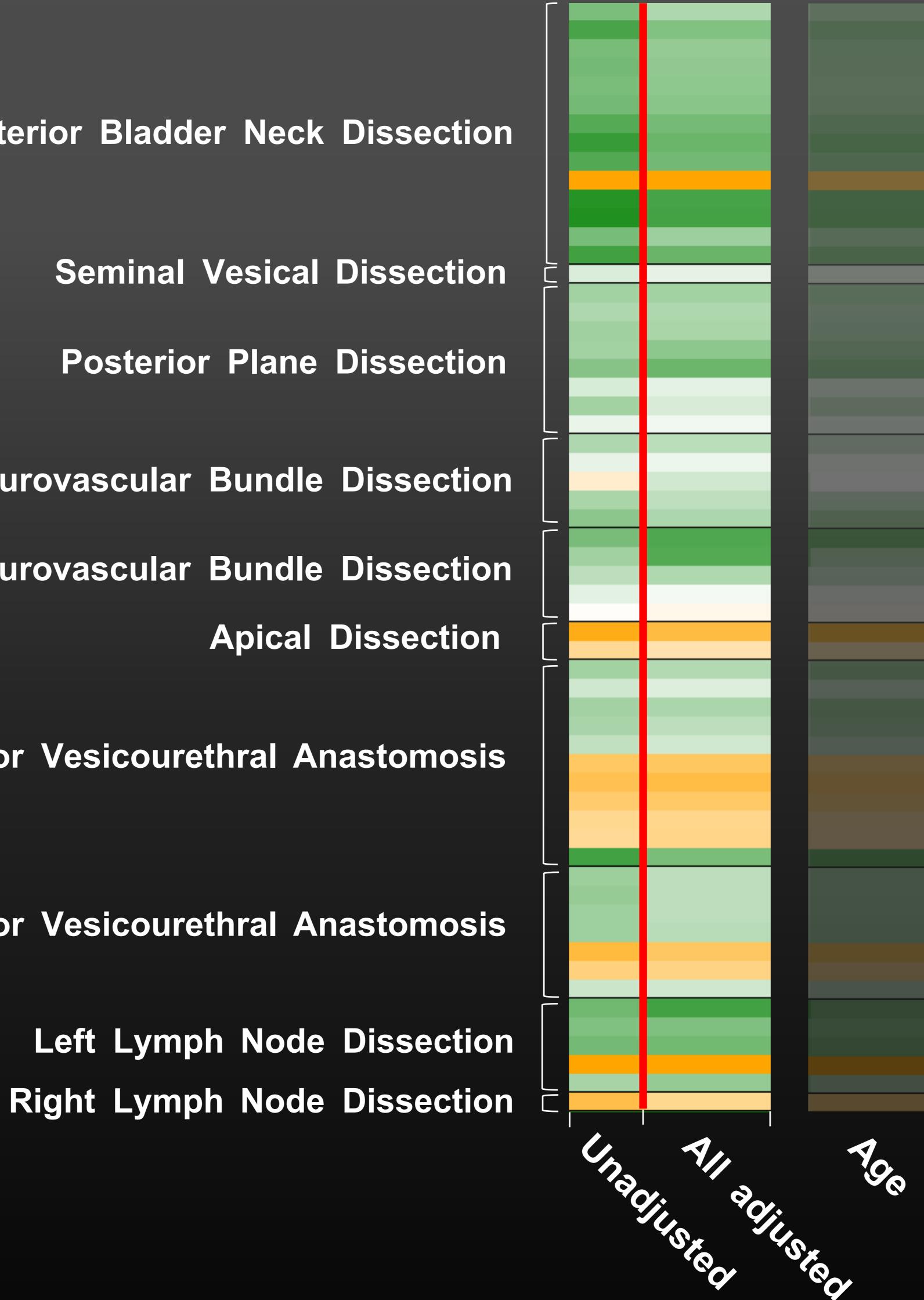
1st and 2nd column:

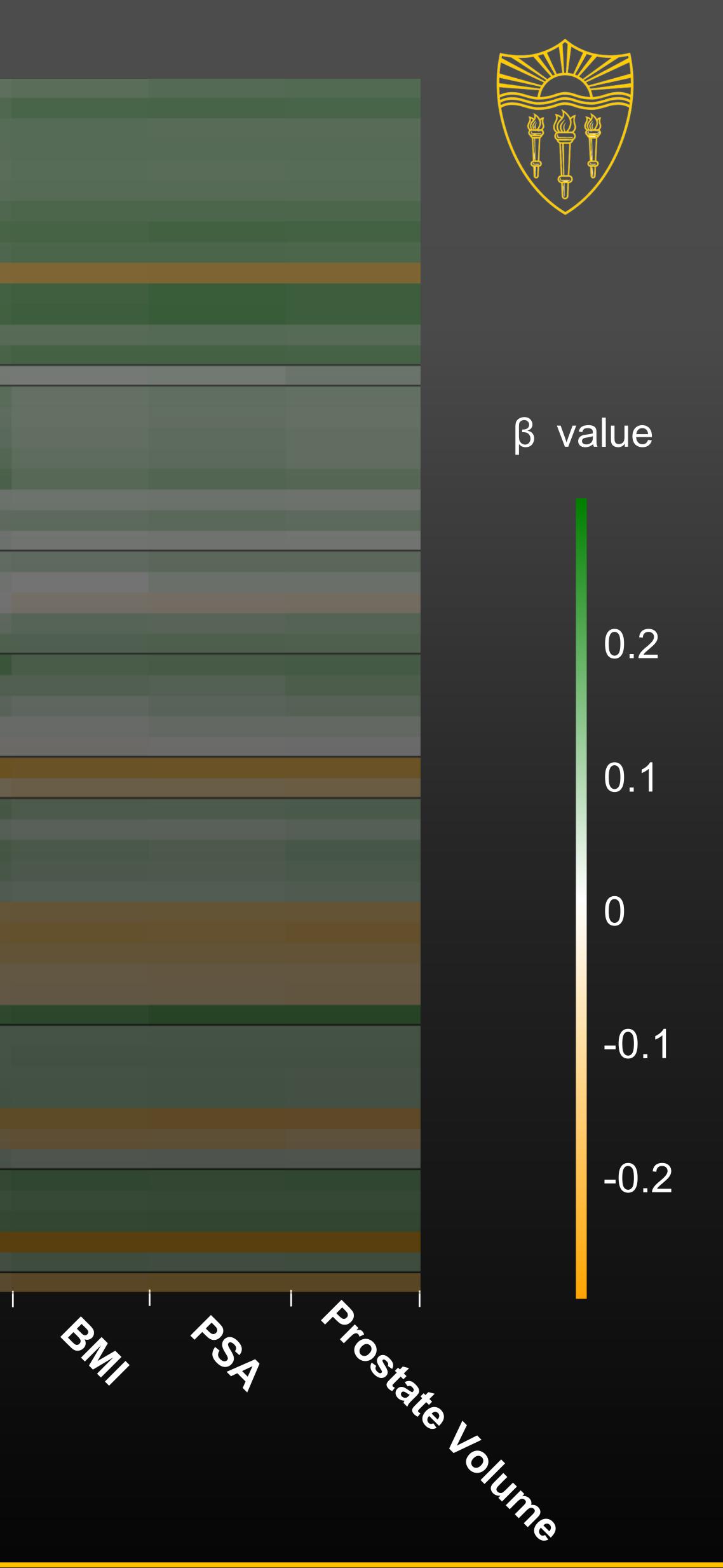
APMs' predictive ability unadjusted and adjusted by all patient factors

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Anterior Bladder Neck Dissection

- Left Neurovascular Bundle Dissection
- **Right Neurovascular Bundle Dissection**
- **Posterior Vesicourethral Anastomosis**
- Anterior Vesicourethral Anastomosis







The predictive ability of most APMs remained stable after adjusting important patient factors

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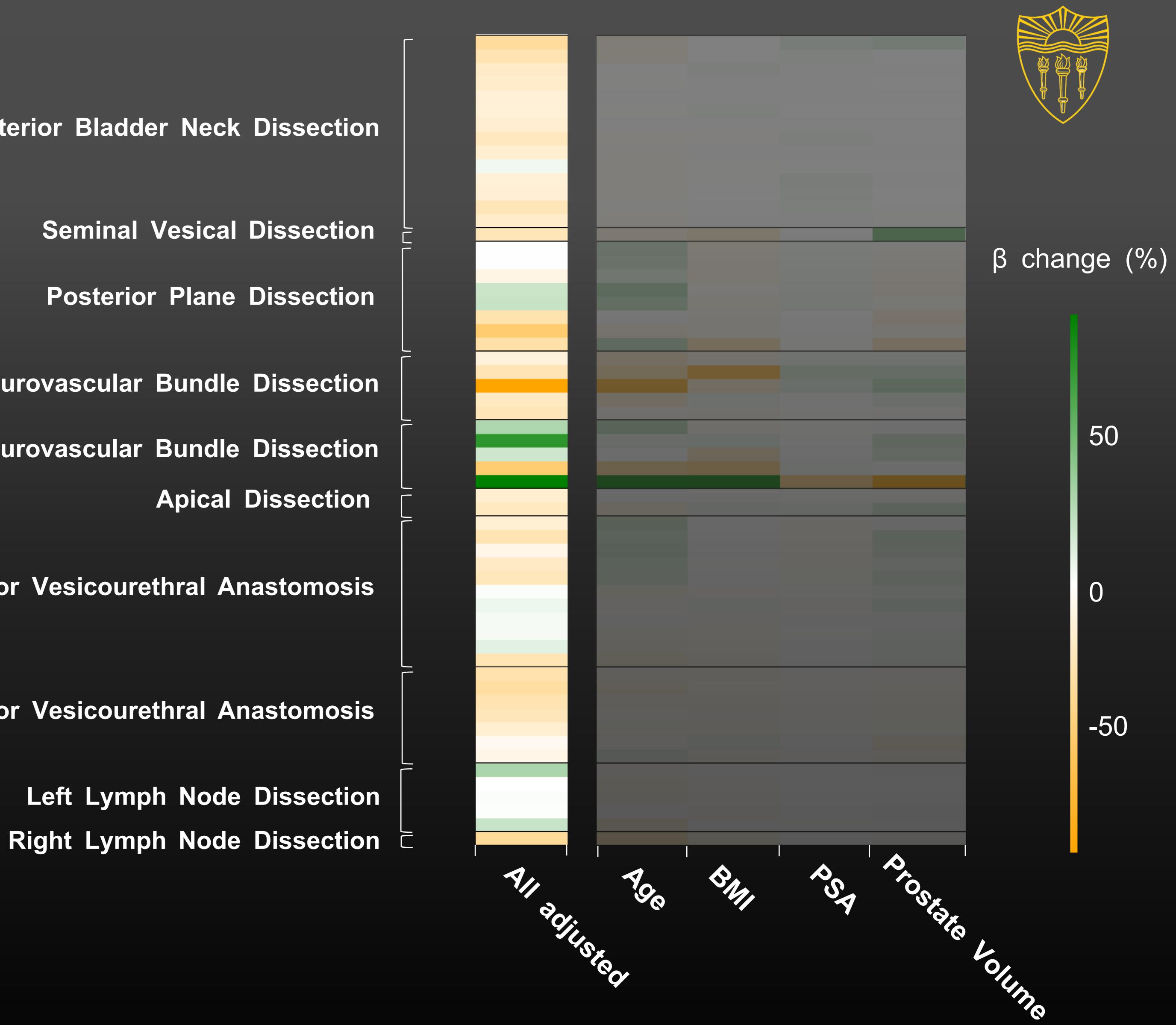
Anterior Bladder Neck Dissection

Left Neurovascular Bundle Dissection

Right Neurovascular Bundle Dissection

Posterior Vesicourethral Anastomosis

Anterior Vesicourethral Anastomosis





Minimal confounding <u>effect</u> O Age • BMI PSA • Prostate Weight

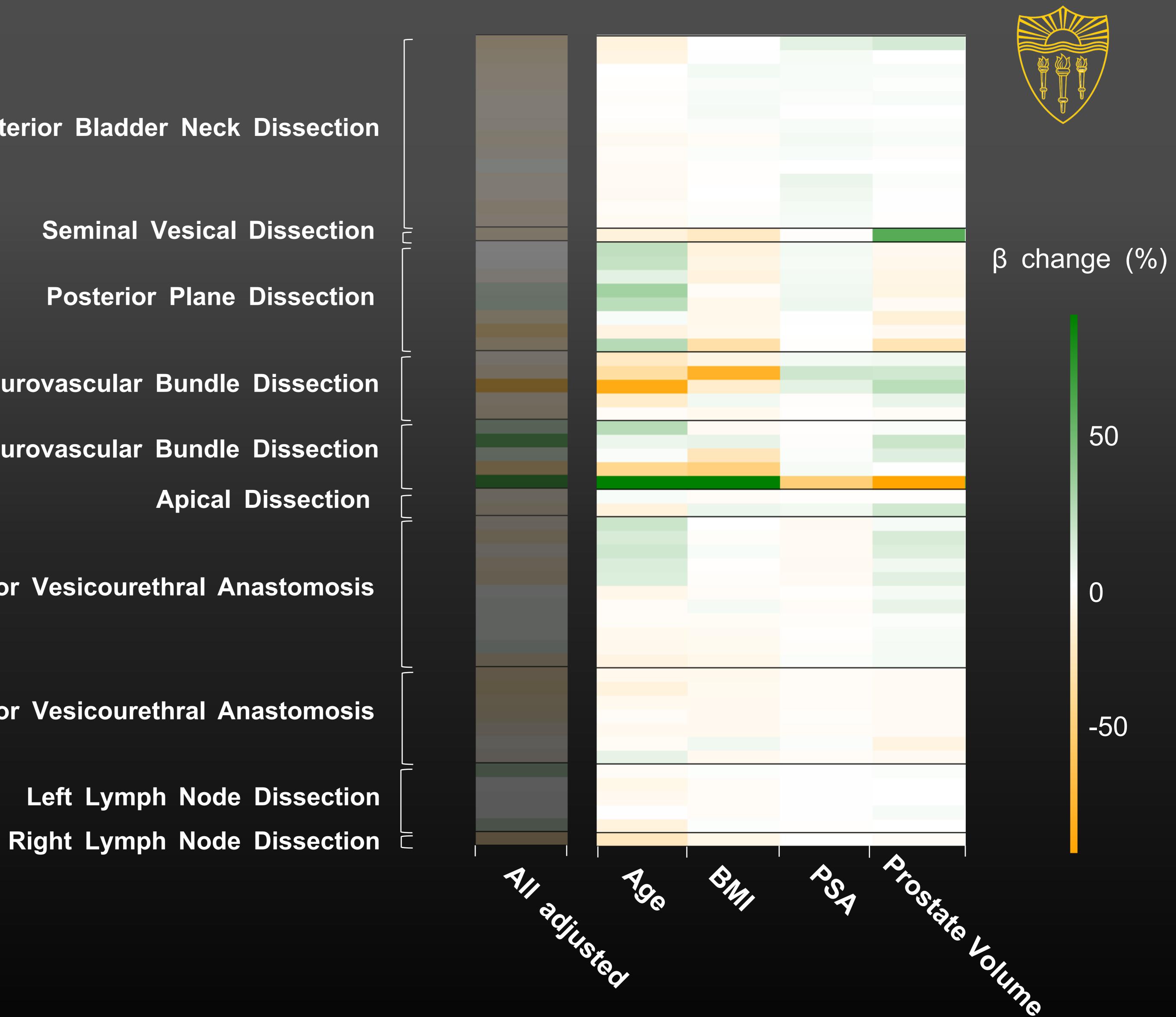
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Anterior Bladder Neck Dissection

- Left Neurovascular Bundle Dissection
- **Right Neurovascular Bundle Dissection**
- **Posterior Vesicourethral Anastomosis**

Anterior Vesicourethral Anastomosis







recovery (univariate analysis)

for all relevant patient factors

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• 33 APMs by primary surgeon were found to be predictors of continence

• 82% (27/33) of these APMs remained significant predictors after adjusting







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Predict





Urinary continence recovery





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Effect modification

Whole Cohort

Predict



Urinary continence recovery



High BMI

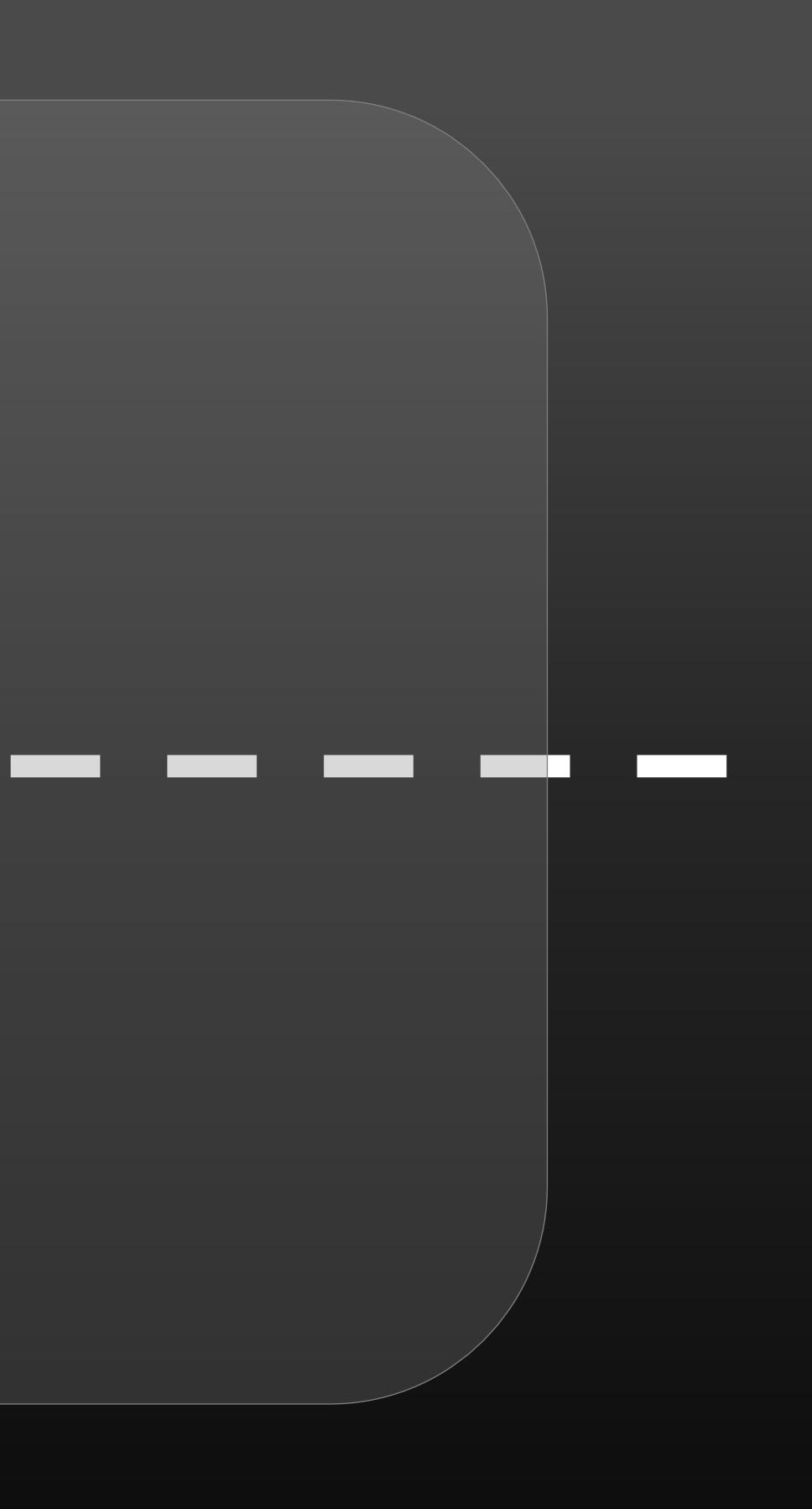
Low BMI

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Effect modification

Whole Cohort







High BMI

Low BMI

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Effect modification



Different Strength of Associations in Subgroups



Urinary continence recovery



Example: BMI pT stage

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Effect modifiers

Anterior Bladder Neck Dissection

Seminal Vesical Dissection

Posterior Plane Dissection

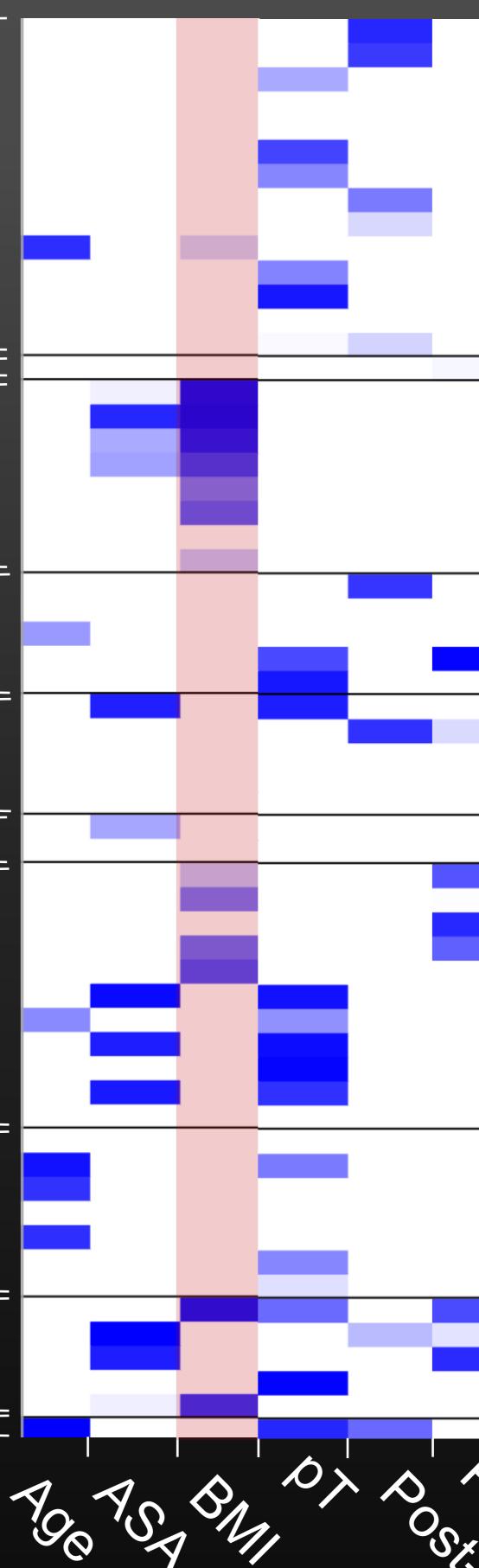
Left Neurovascular Bundle Dissection

Right Neurovascular Bundle Dissection Apical Dissection

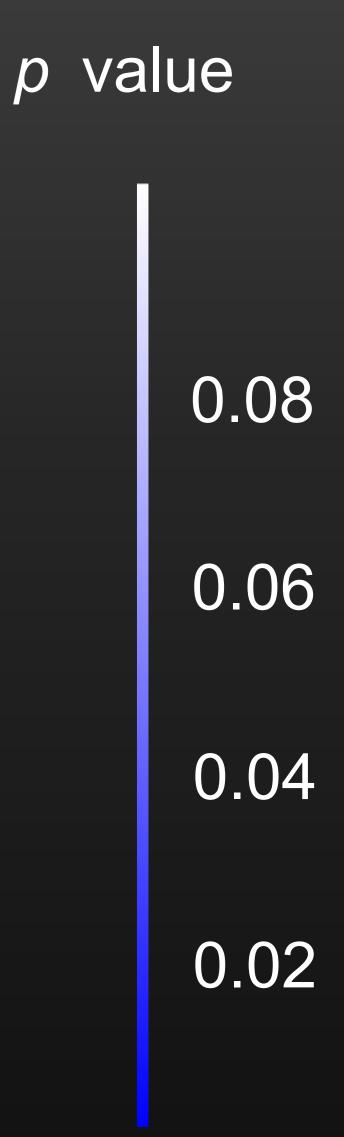
Posterior Vesicourethral Anastomosis

Anterior Vesicourethral Anastomosis

Left Lymph Node Dissection Right Lymph Node Dissection







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Example: BMI pT stage

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Effect modifiers

Anterior Bladder Neck Dissection

Seminal Vesical Dissection

Posterior Plane Dissection

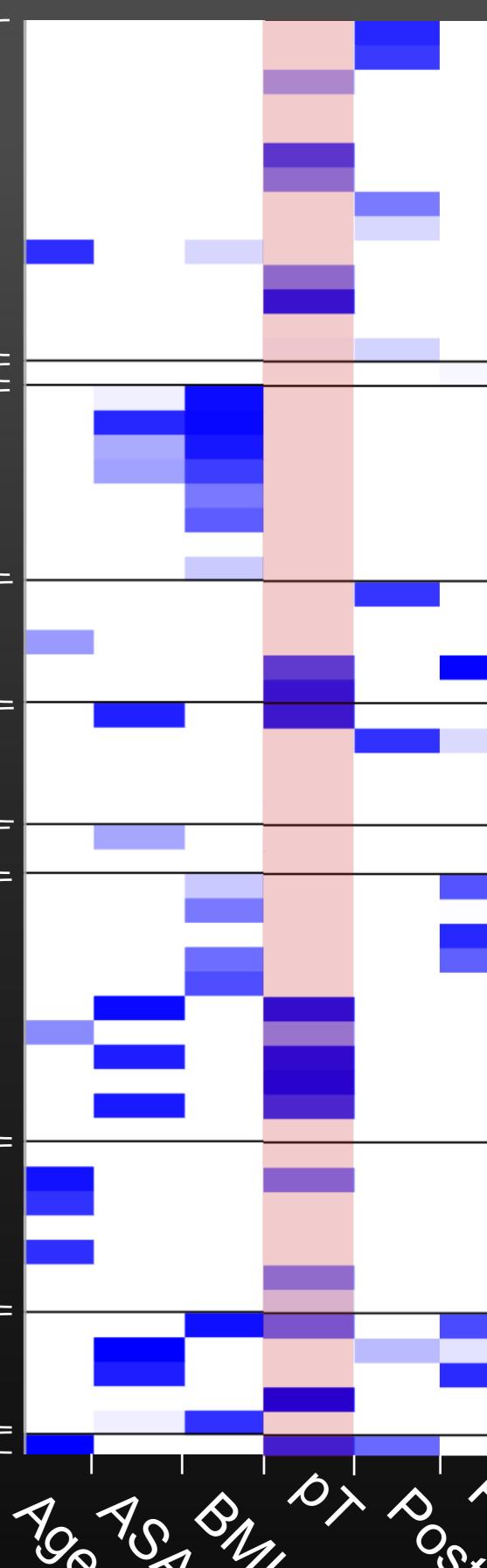
Left Neurovascular Bundle Dissection

Right Neurovascular Bundle Dissection Apical Dissection

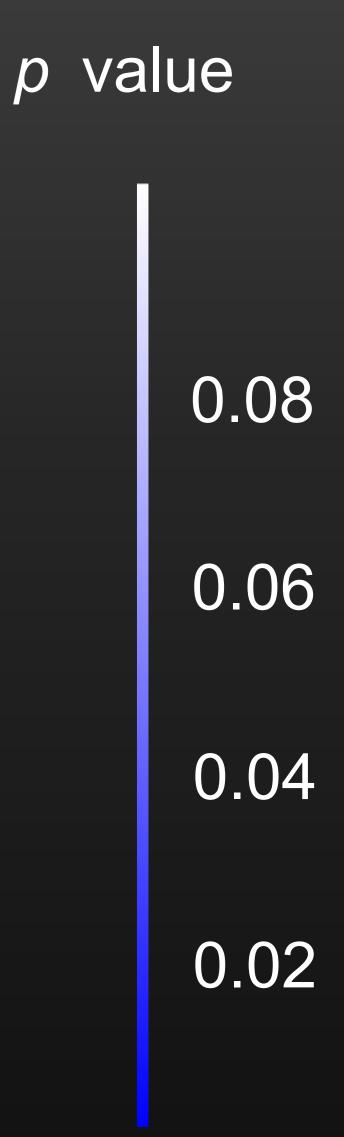
Posterior Vesicourethral Anastomosis

Anterior Vesicourethral Anastomosis

Left Lymph Node Dissection Right Lymph Node Dissection







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9;;



• While some patient factors have a confounding effect on APMs' ability to predict continence, most APMs are still independent predictors

• Select patient factors, at their high/low ends, have differing effects on APMs' ability to predict continence (effect modifiers)

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Take home points

• We can utilize surgeon factors (APMs) and patient factors to predict urinary continence recovery after RARP





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