

PD63-08 Multi-Institutional Study:

Automated performance metrics to predict continence recovery after robotic radical prostatectomy utilizing machine learning

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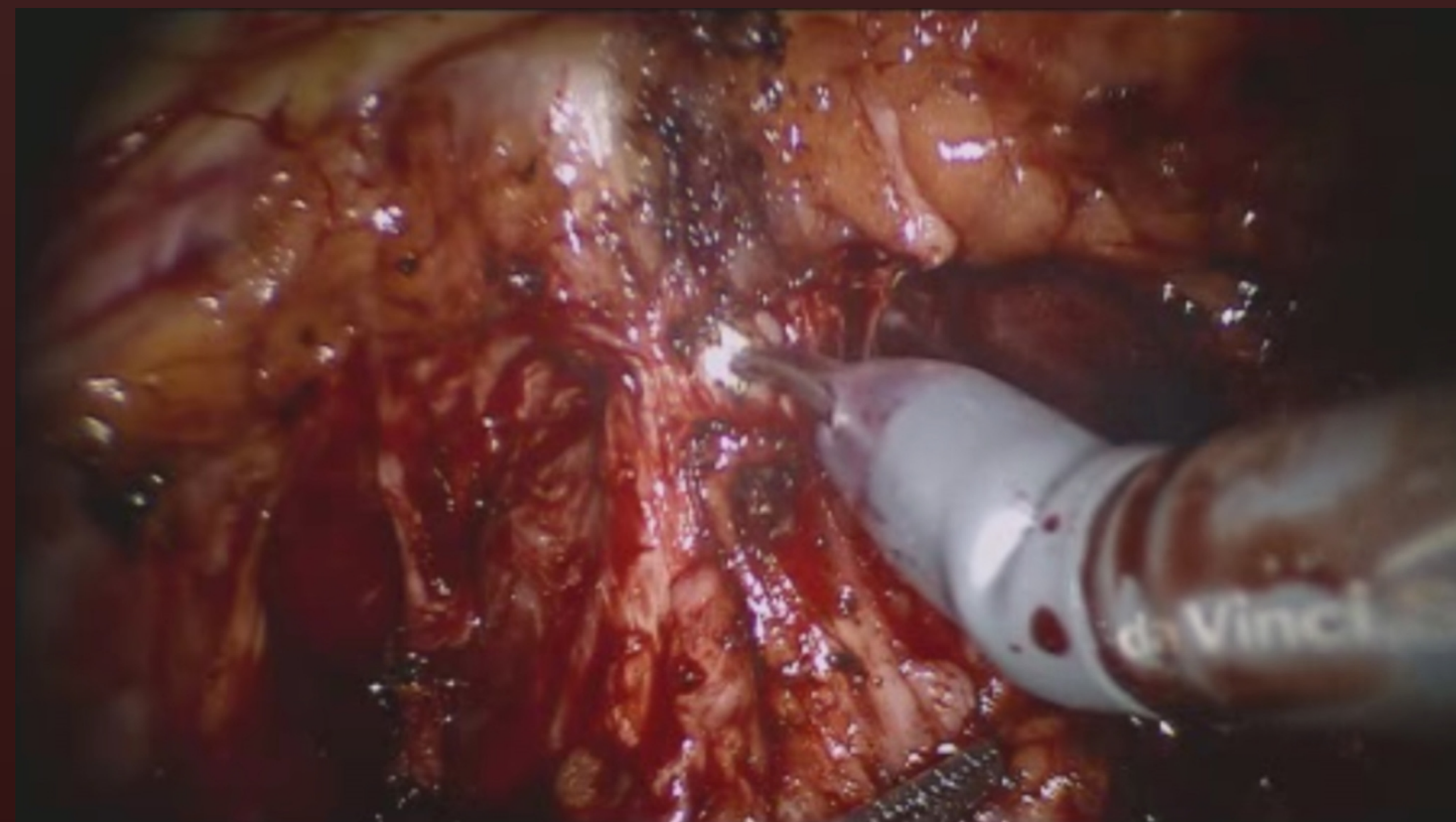
Study supported in part an Intuitive Surgical Clinical Research Grant

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

Automated Performance Metrics



Surgical video

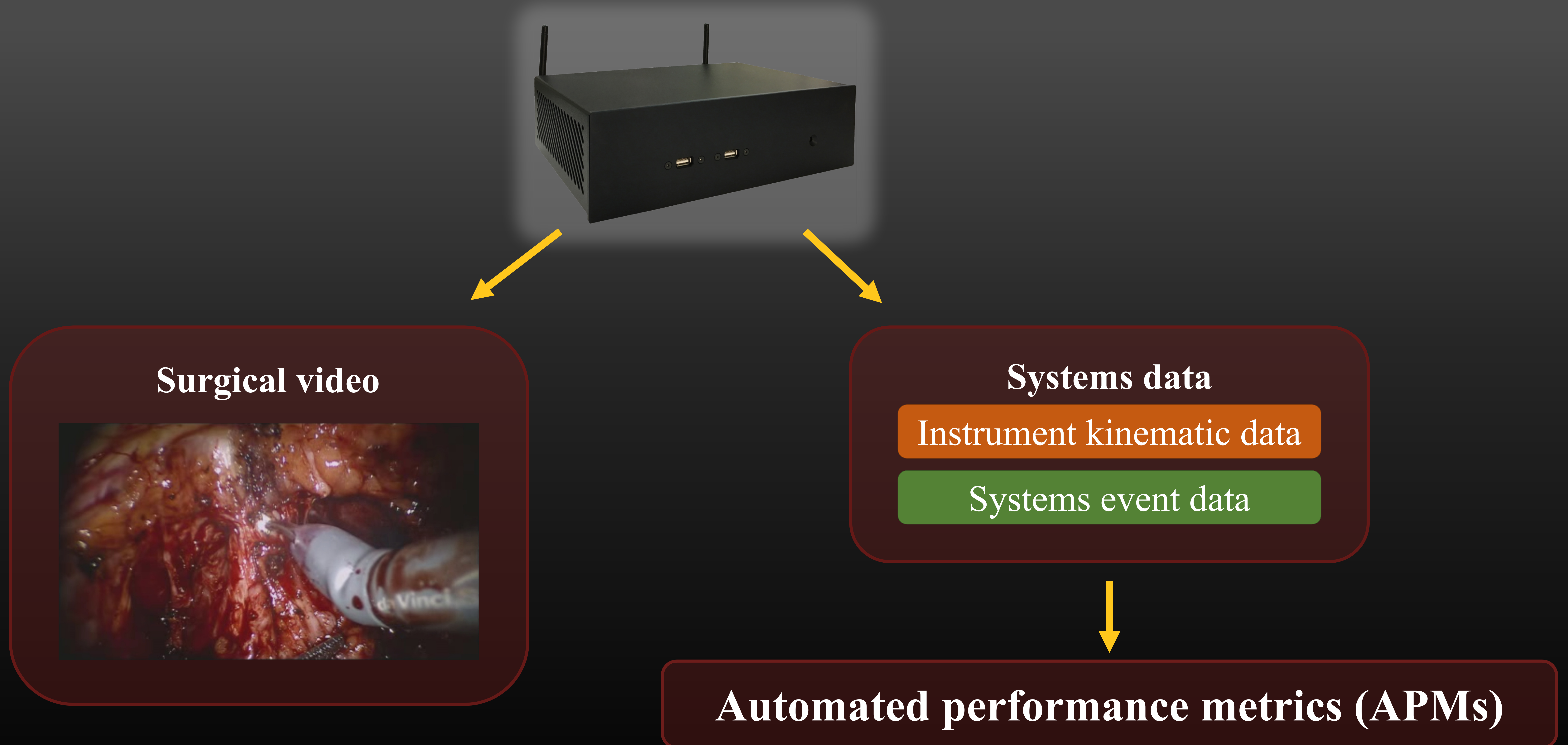


Systems data

Instrument kinematic data

Systems event data

Automated Performance Metrics





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New Technology and Techniques

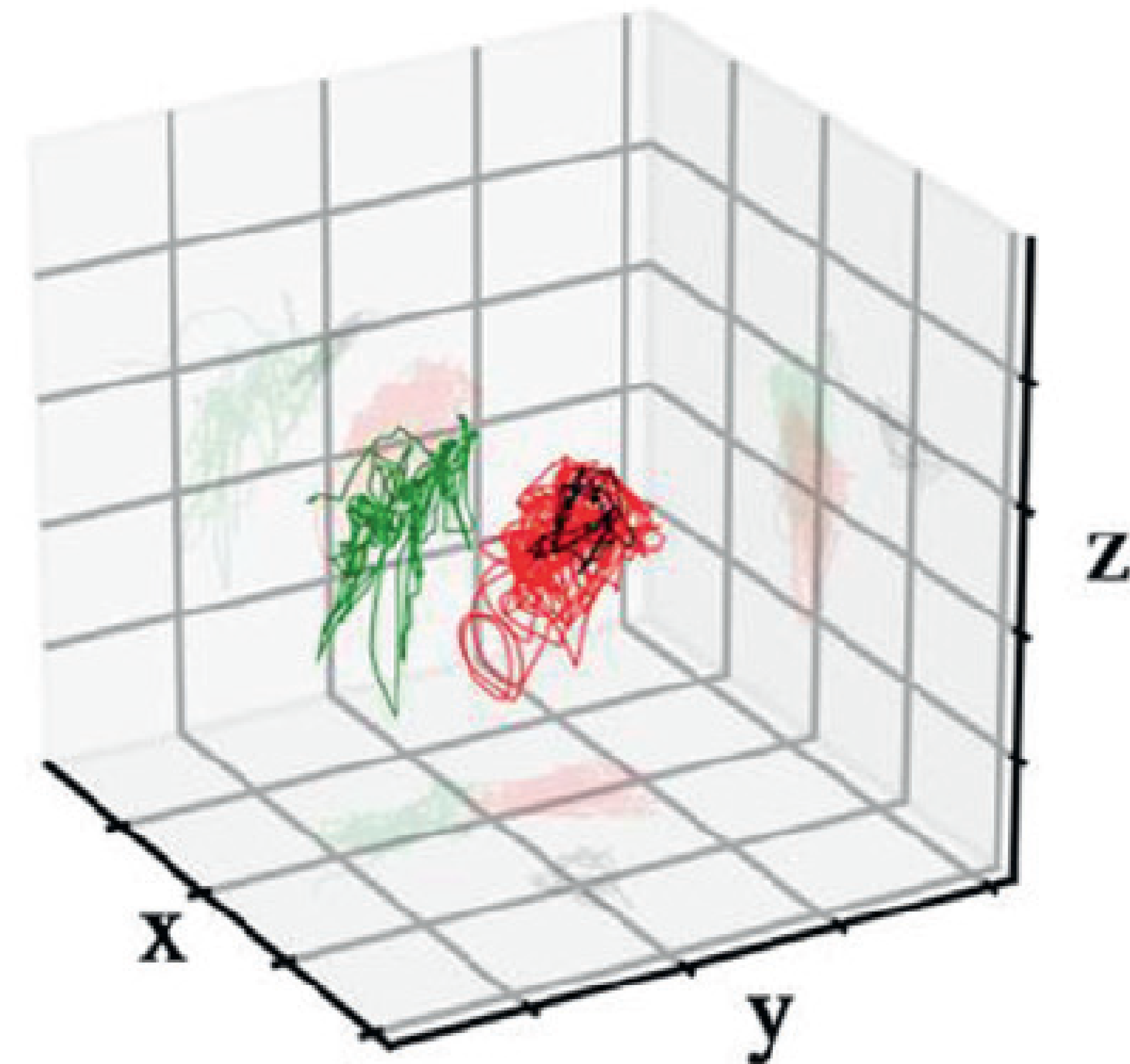
Development and Validation of Objective Performance Metrics for Robot-Assisted Radical Prostatectomy: A Pilot Study

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

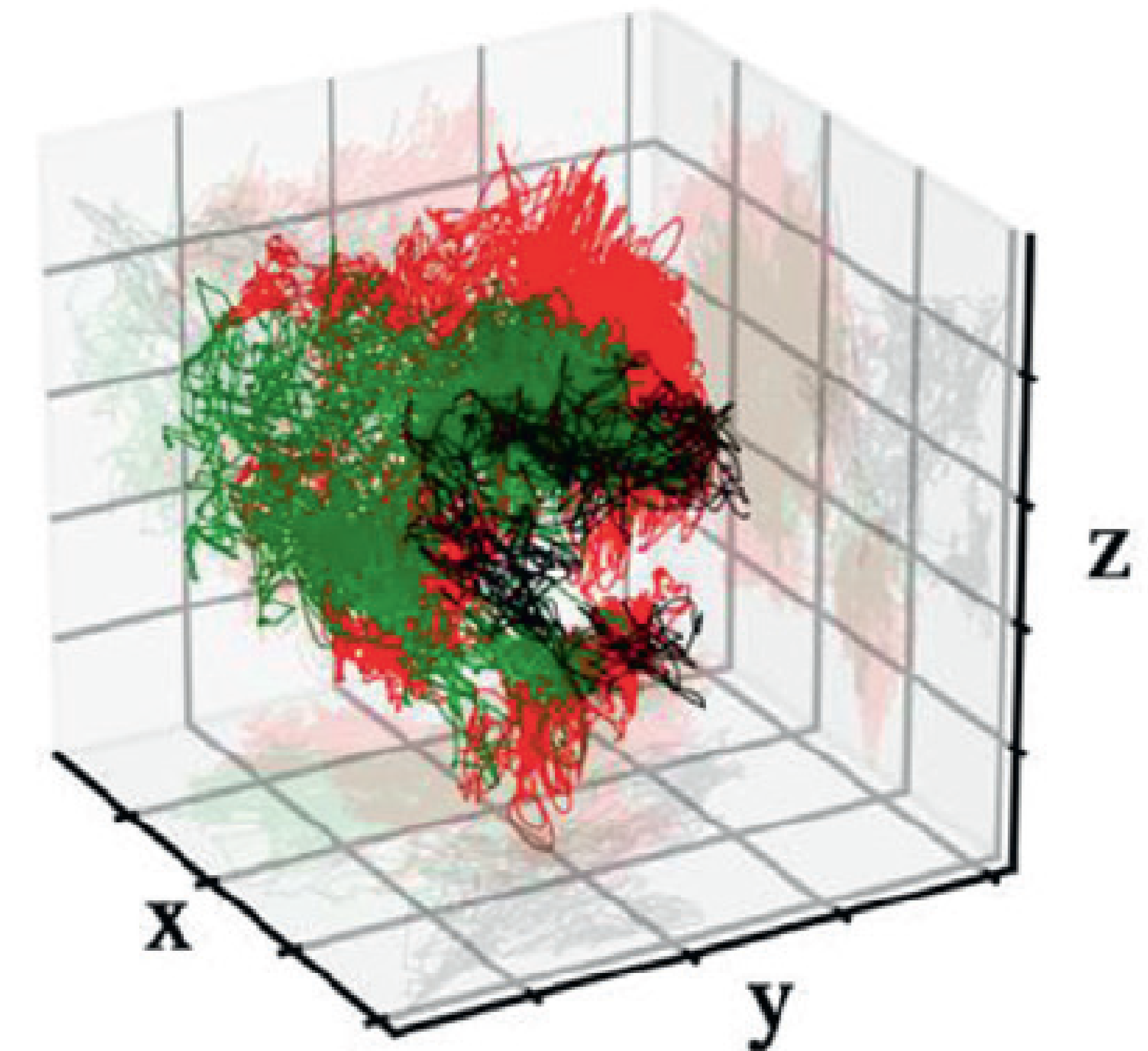


Bladder mobilization
(BM)

Expert example



Novice example



- Dominant Instrument
- Non-dominant Instrument
- Camera



January 2018 Cover



October 2018 Cover



March 2019 Cover

Robot-assisted radical prostatectomy

Patient factors

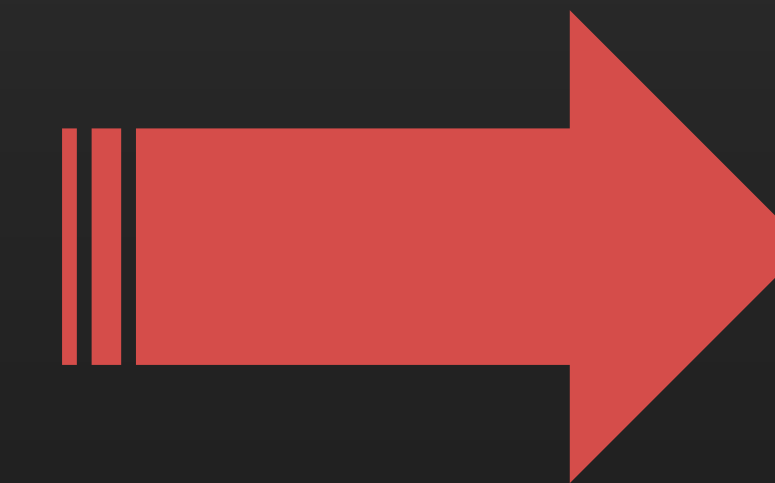


Clinicopathological

Surgeon factors



Surgical skill and performance



**Urinary
continence**

**Disease
recurrence**

**Erectile
function**

Robot-assisted radical prostatectomy

Patient factors

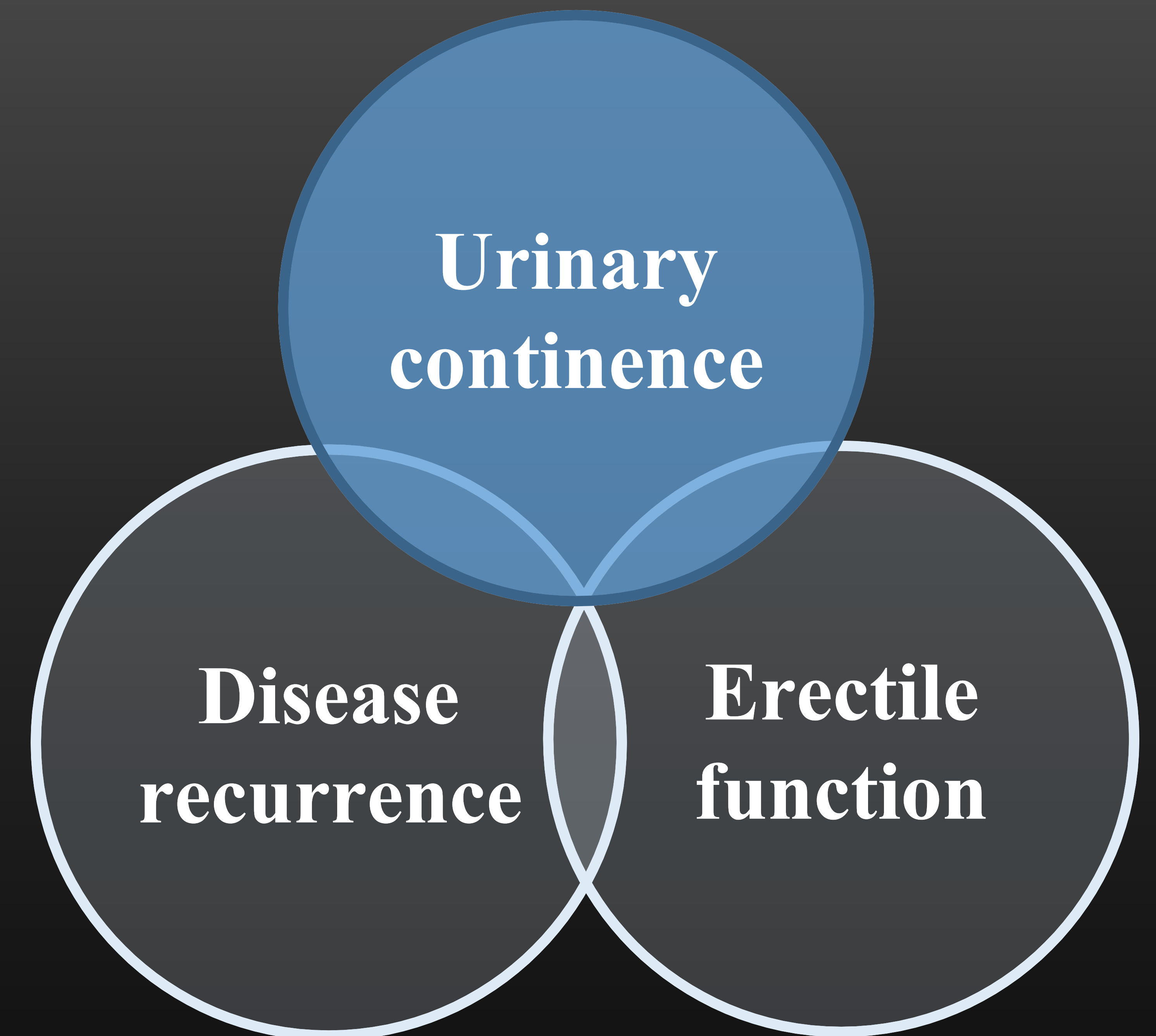
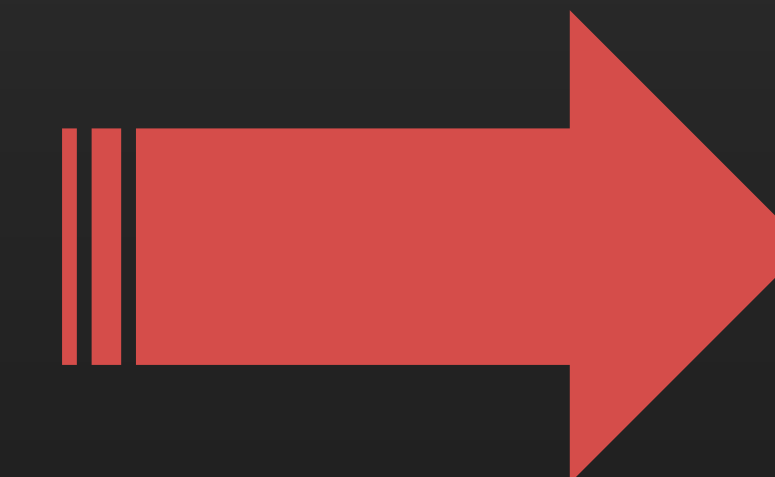


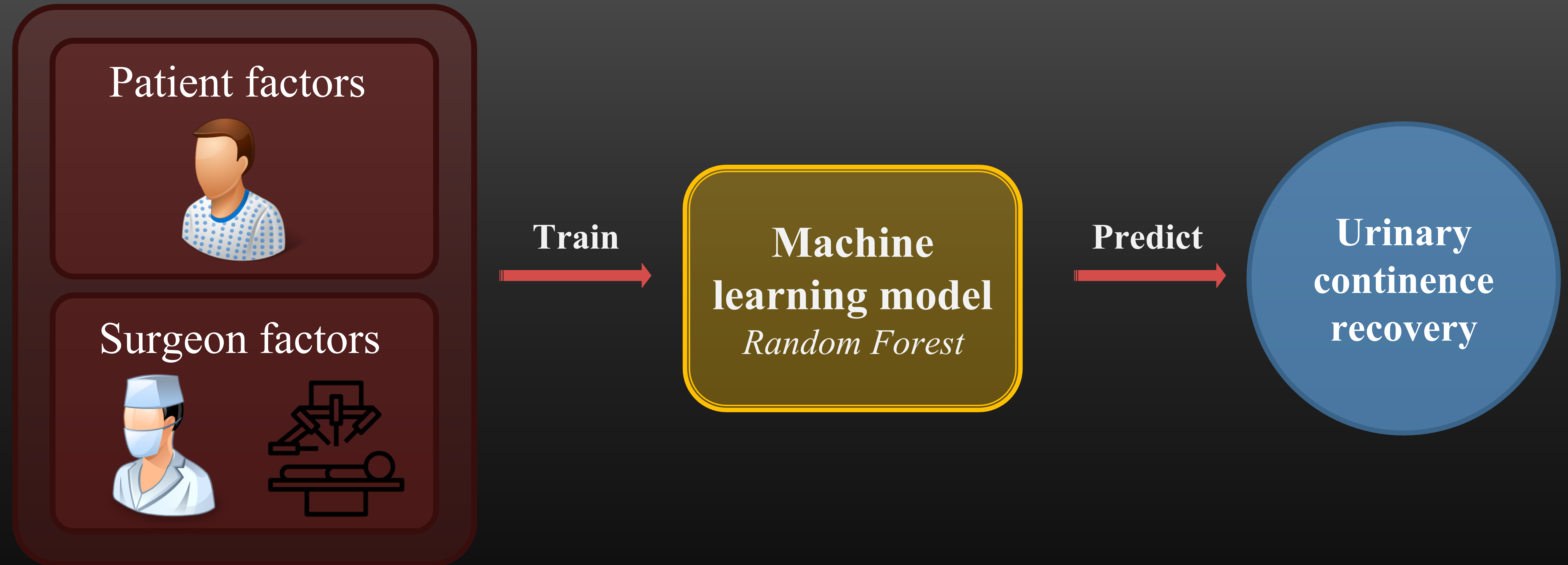
Clinicopathological

Surgeon factors

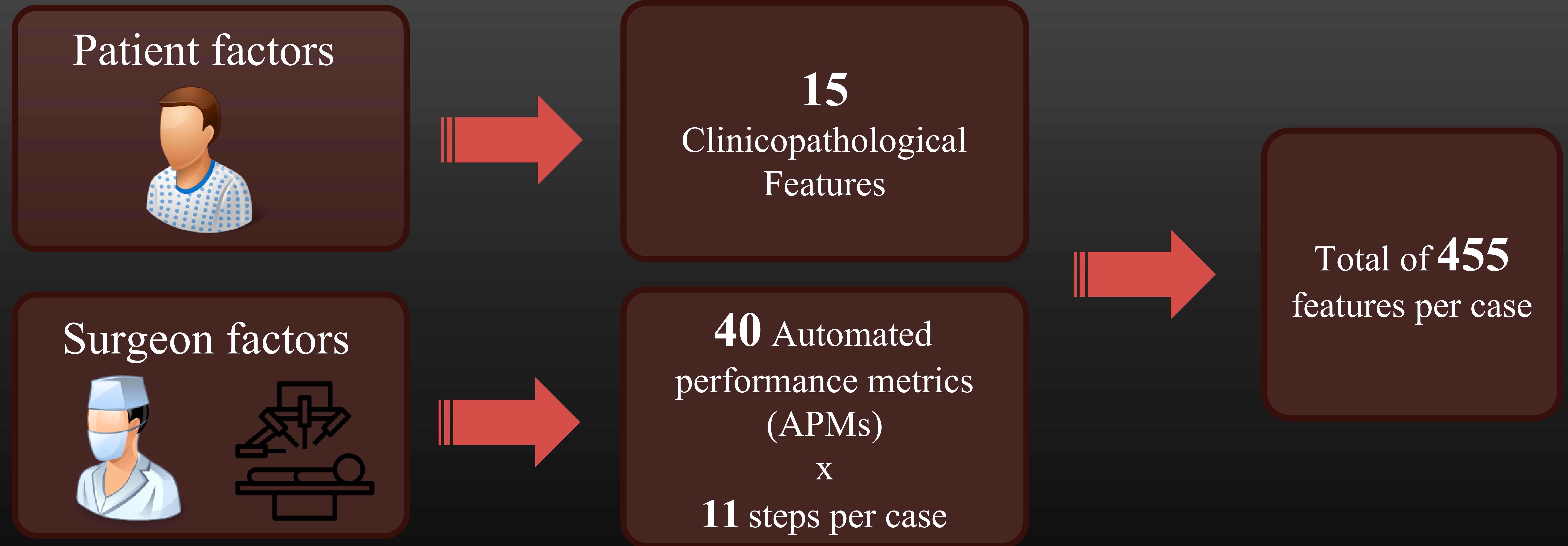


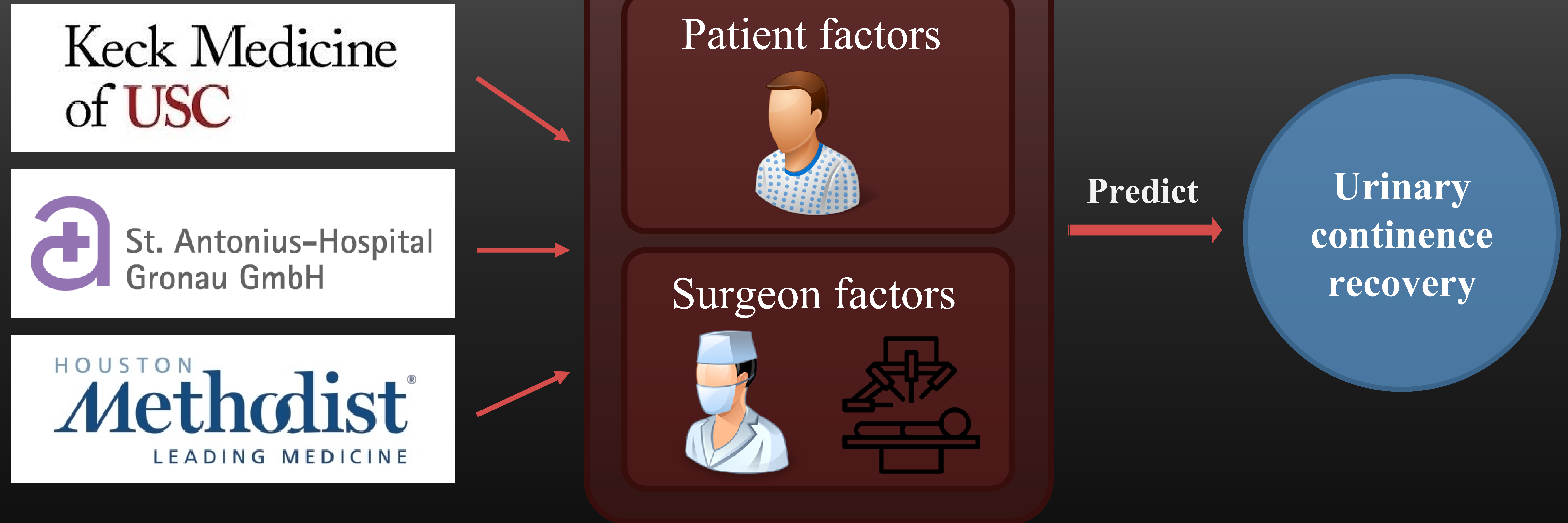
Surgical skill and performance

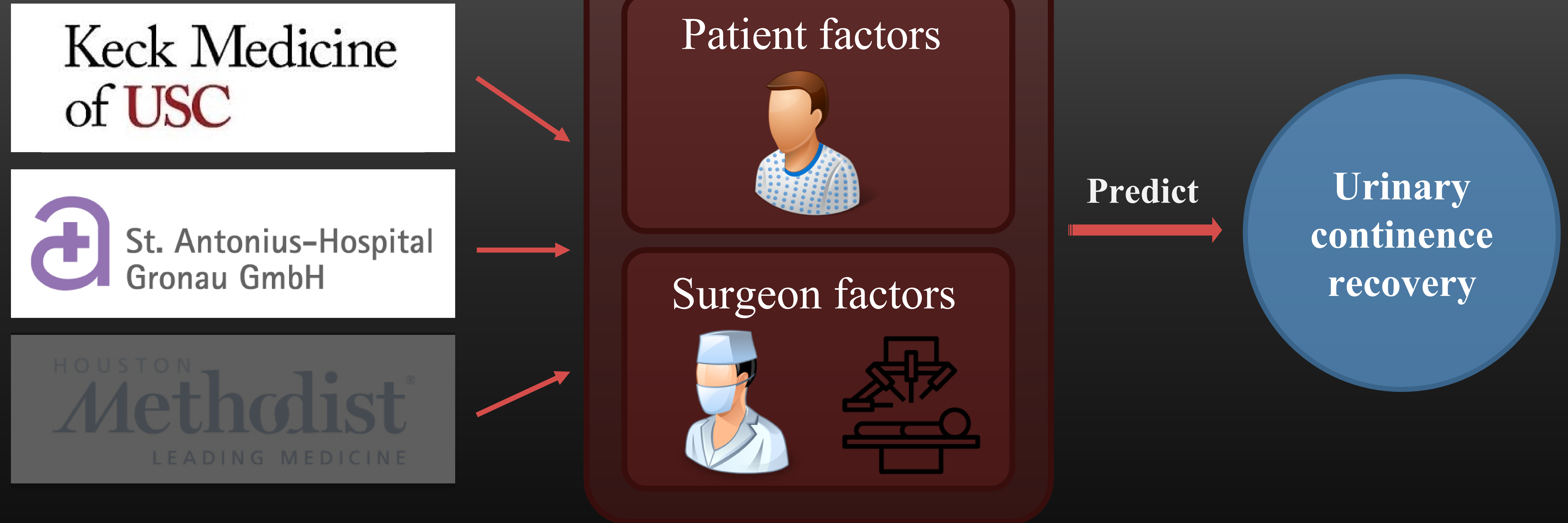




Robot-assisted radical prostatectomy









	Site 1	Site 2	Total
# Patients	116	77	193
# Surgeons	11	9	20

- **3 month: 56.7%** of patients achieved urinary continence after surgery
- **6 month: 73.3%** of patients achieved urinary continence after surgery



Pre-op features	Incontinent (N = 78)	Continent (N = 102)	<i>p</i> value
Age year	66.6±7.1	64.2±6.7	0.02
BMI kg/m2	28.9 (25.6 - 31.4)	26.9 (25.4 - 29.4)	0.02
ASA	3 (2 - 3)	2 (2 - 3)	<0.01
PSA ng/mL	7.3 (5.4 - 10.6)	7.5 (5.9 - 10.3)	0.9
pre-op Gleason score	7 (7 - 7)	7 (7 - 7)	0.3



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Pathologic features	Incontinent (N = 78)	Continent (N = 102)	<i>p</i> value
Pathological tumor stage			<0.01
pT2	27 (32.93%)	55 (67.07%)	
≥pT3	49 (52.69%)	44 (47.31%)	
Post-op Gleason score	7 (7 - 7)	7 (7 - 7)	0.23 [#]
Prostate volume (g)	51 (40 - 67)	43.5 (36 - 55)	<0.01 [#]
Positive surgical margin			0.46
no	65 (42.21%)	89 (57.79%)	
yes	13 (50%)	13 (50%)	

Incontinent vs Continent at 3 month

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Pre-op features	Incontinent (N = 47)	Continent (N = 129)	<i>p</i> value
Age year	67.5±6.8	64.6±6.7	0.01
BMI kg/m2	28.7 (27 - 33.1)	27.2 (25.4 - 30.1)	0.01
ASA	2 (2 - 3)	2 (2 - 3)	0.01
PSA ng/mL	7.8 (5.9 - 11.1)	7.4 (5.8 - 10.2)	0.30
pre-op Gleason score	7 (7 - 7)	7 (7 - 7)	0.43



Pre-op features	Incontinent (N = 47)	Continent (N = 129)	<i>p</i> value
Age year	67.5±6.8	64.6±6.7	0.01
BMI kg/m2	28.7 (27 - 33.1)	27.2 (25.4 - 30.1)	0.01
ASA	2 (2 - 3)	2 (2 - 3)	0.01
PSA ng/mL	7.8 (5.9 - 11.1)	7.4 (5.8 - 10.2)	0.30
pre-op Gleason score	7 (7 - 7)	7 (7 - 7)	0.43



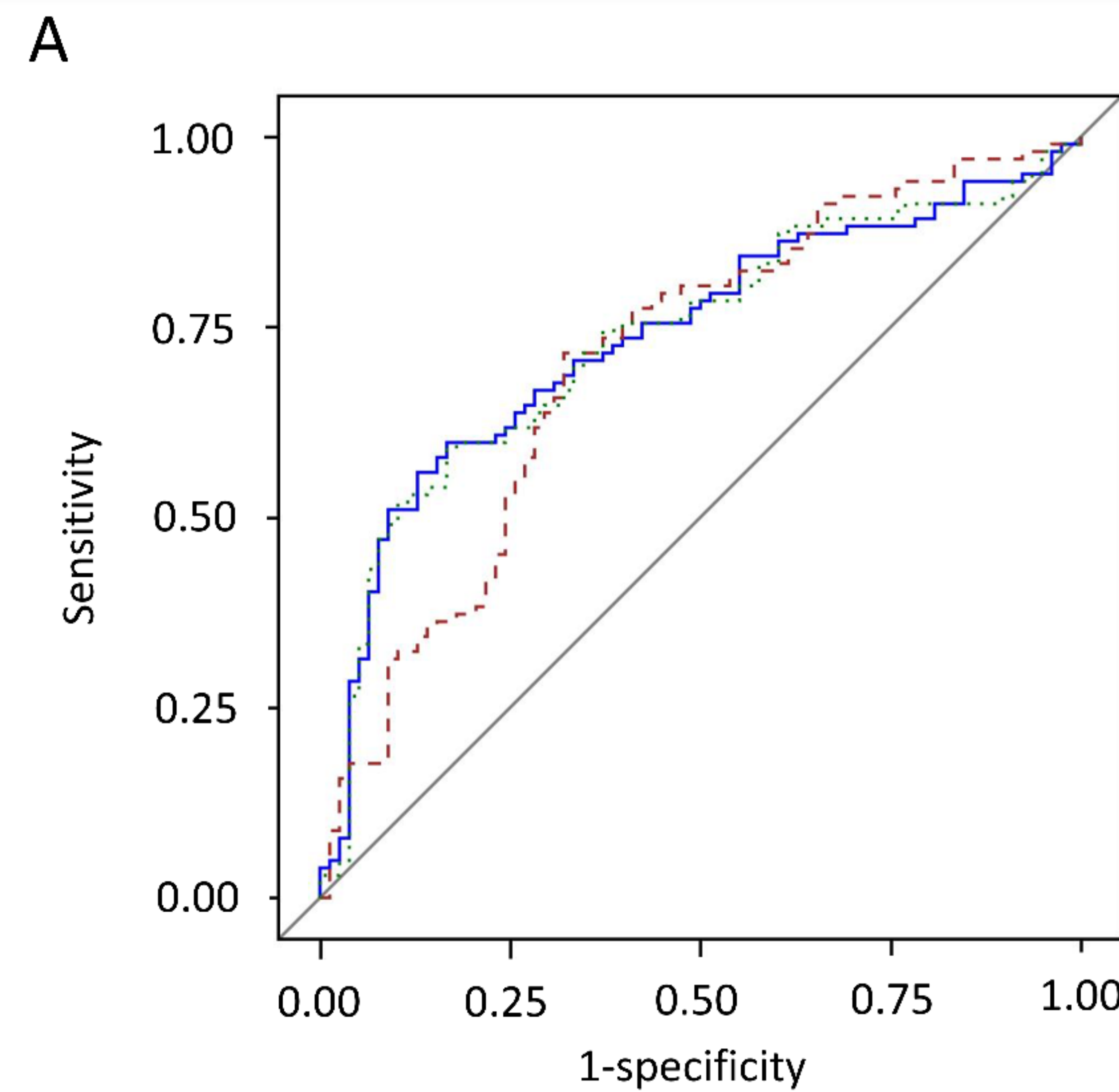
Pathologic features	Incontinent (N = 47)	Continent (N = 129)	<i>p</i> value
Pathological tumor stage			0.04
pT2	16 (19.51%)	66 (80.49%)	
≥pT3	30 (33.33%)	60 (66.67%)	
Post-op Gleason score	7 (7 - 7)	7 (7 - 7)	0.13
Prostate volume (g)	50.5 (40 - 64)	45 (37 - 58)	0.06
Positive surgical margin			0.07
no	37 (24.34%)	115 (75.66%)	
yes	10 (41.67%)	14 (58.33%)	



Pathologic features	Incontinent (N = 47)	Continent (N = 129)	<i>p</i> value
Pathological tumor stage			0.04
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Positive surgical margin			0.07
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yes	10 (41.67%)	14 (58.33%)	

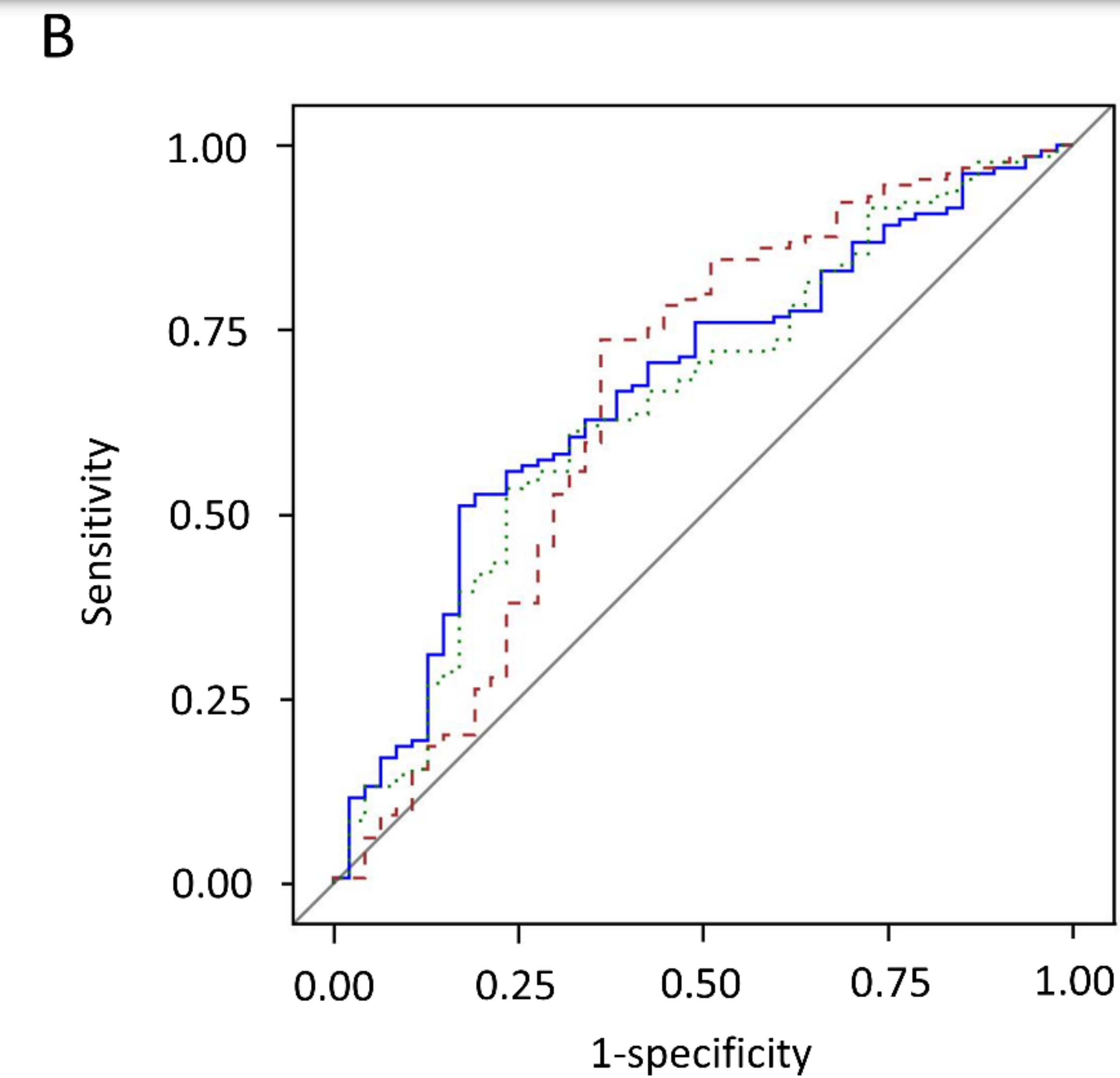
Prediction Accuracy

Random Forest 10-fold cross validation



3-month continence prediction

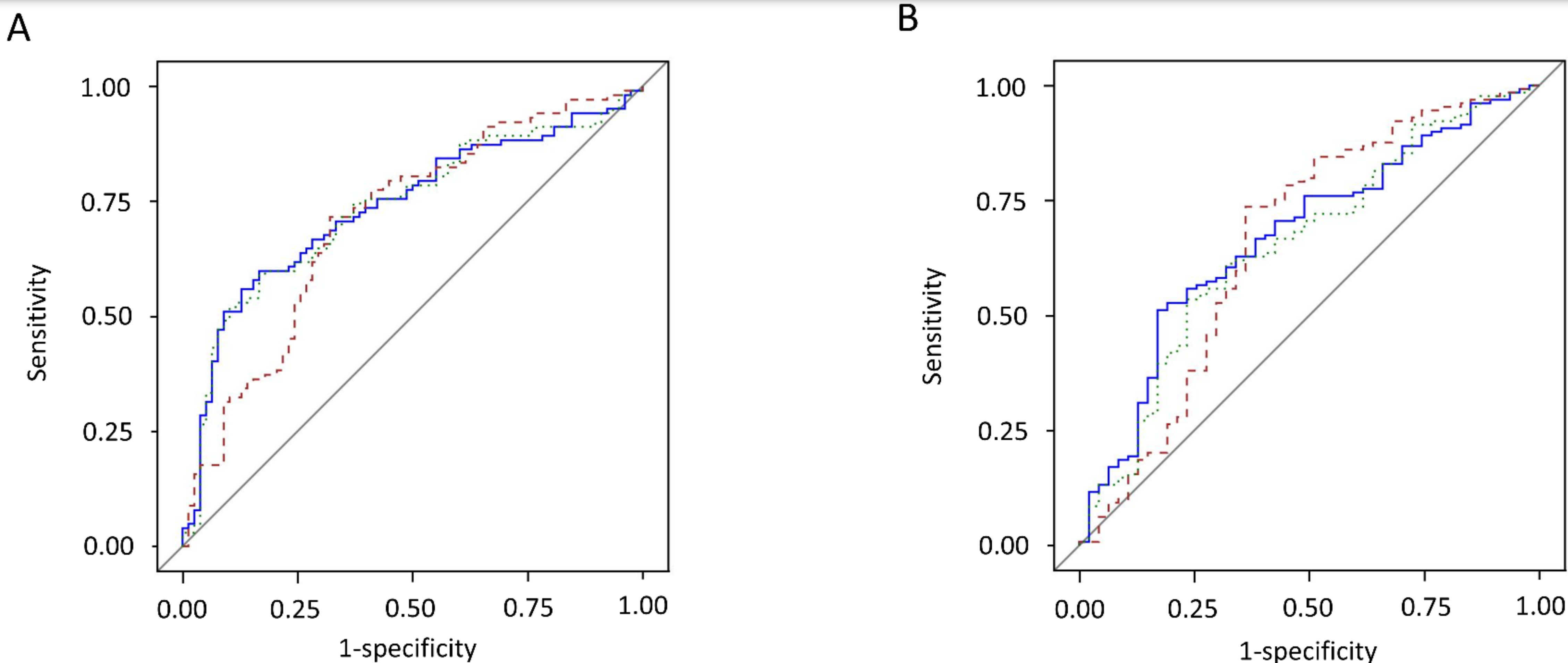
	AUC	95% CI
— APM + Clinical features	0.74	0.66-0.81
- - - Clinical features	0.71	0.63-0.78
... APM	0.73	0.66-0.81



6-month continence prediction

	AUC	95% CI
— APM + Clinical features	0.67	0.58-0.76
- - - Clinical features	0.66	0.56-0.76
... APM	0.65	0.56-0.75

Random Forest 10-fold cross validation



3-month continence prediction		
	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	95% CI
APM + Clinical features	0.67	0.58-0.76
Clinical features	0.66	0.56-0.76
APM	0.65	0.56-0.75

3-month continence prediction

Clinical factors



AUC 0.71

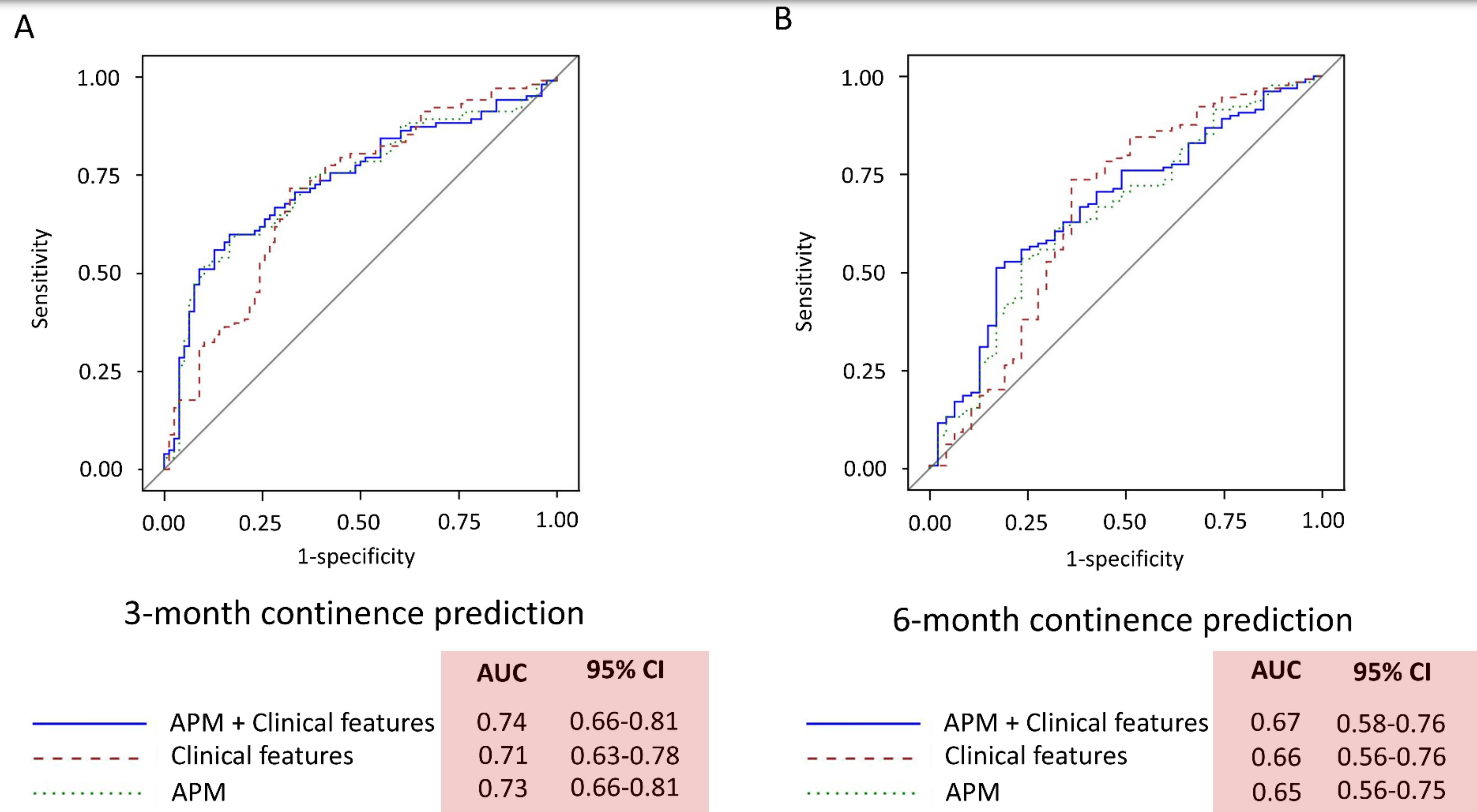
APMs



AUC 0.73

AUC 0.74

Random Forest 10-fold cross validation



3-month

Combined
AUC 0.74

Clinical
AUC 0.71

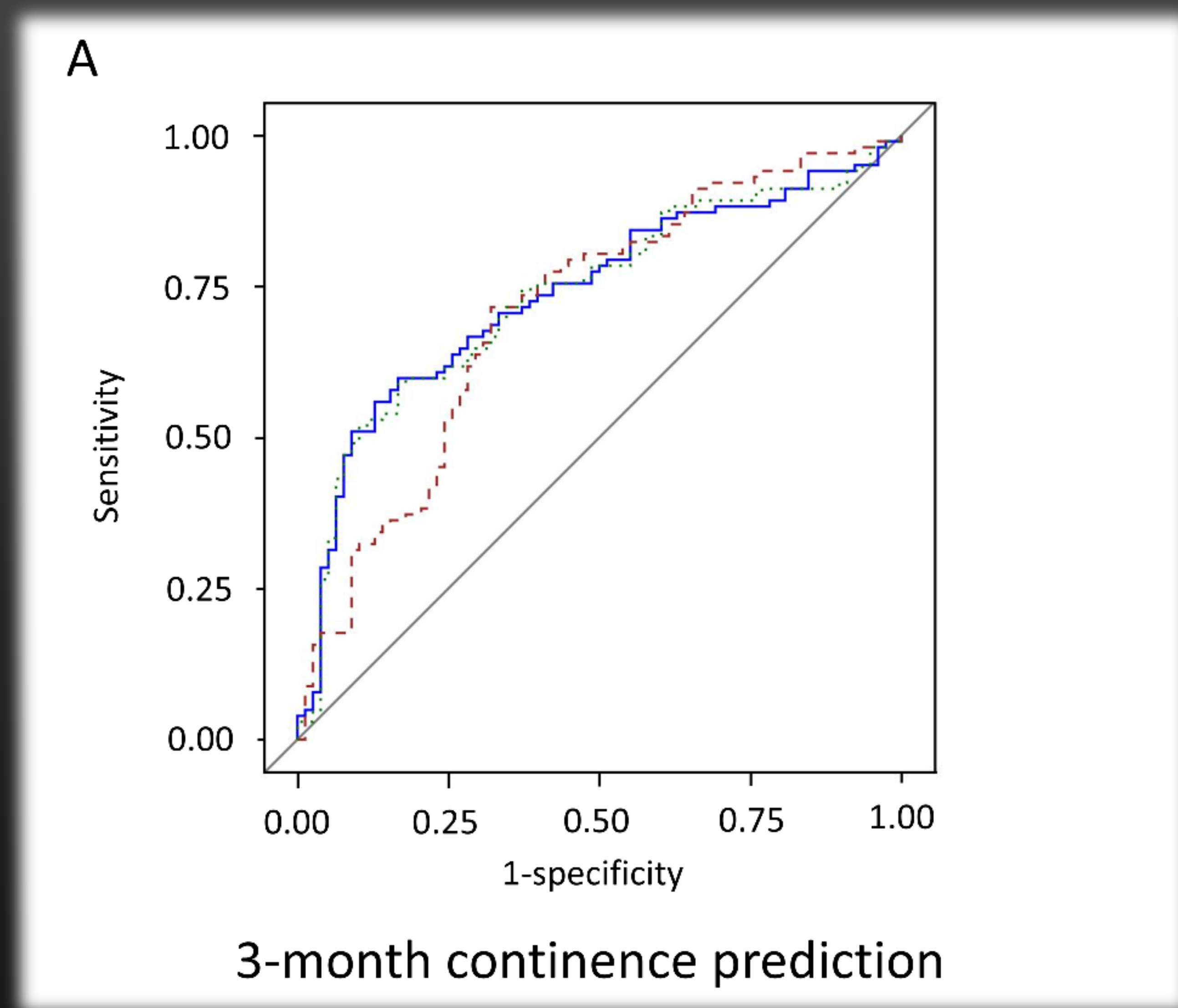
APMs
AUC 0.73

6-month

Combined
AUC 0.67

Clinical
AUC 0.66

APMs
AUC 0.65



Surgeon + Patient
AUC 0.74

Patient factors



Surgeon factors



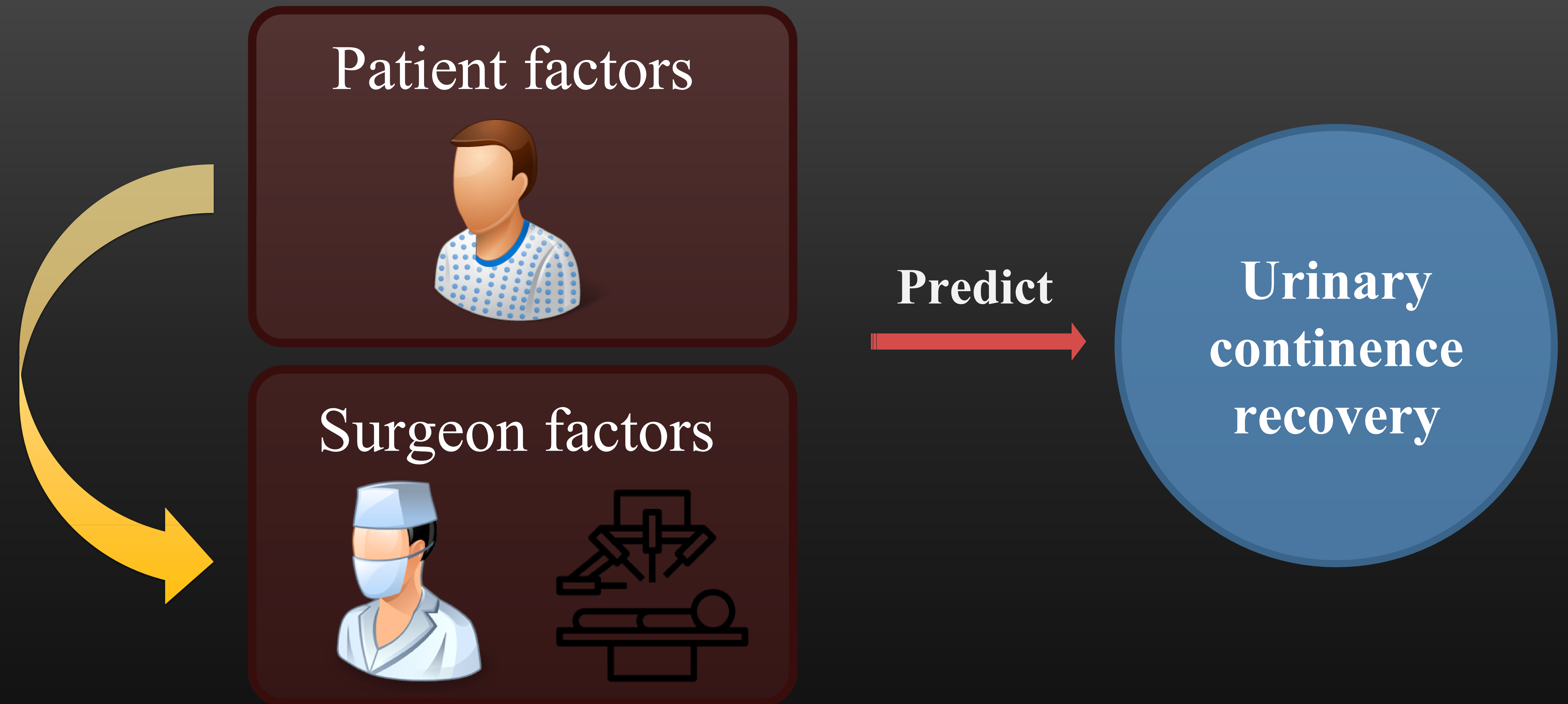
Predict



Urinary
continence
recovery

The top 75 predictive features were **surgeon factors**!

How do
patient factors
impact APMs'
predictive ability?



Automated performance metrics (APMs)



Anterior Bladder Neck Dissection

Seminal Vesical Dissection

Posterior Plane Dissection

Left Neurovascular Bundle Dissection

Right Neurovascular Bundle Dissection

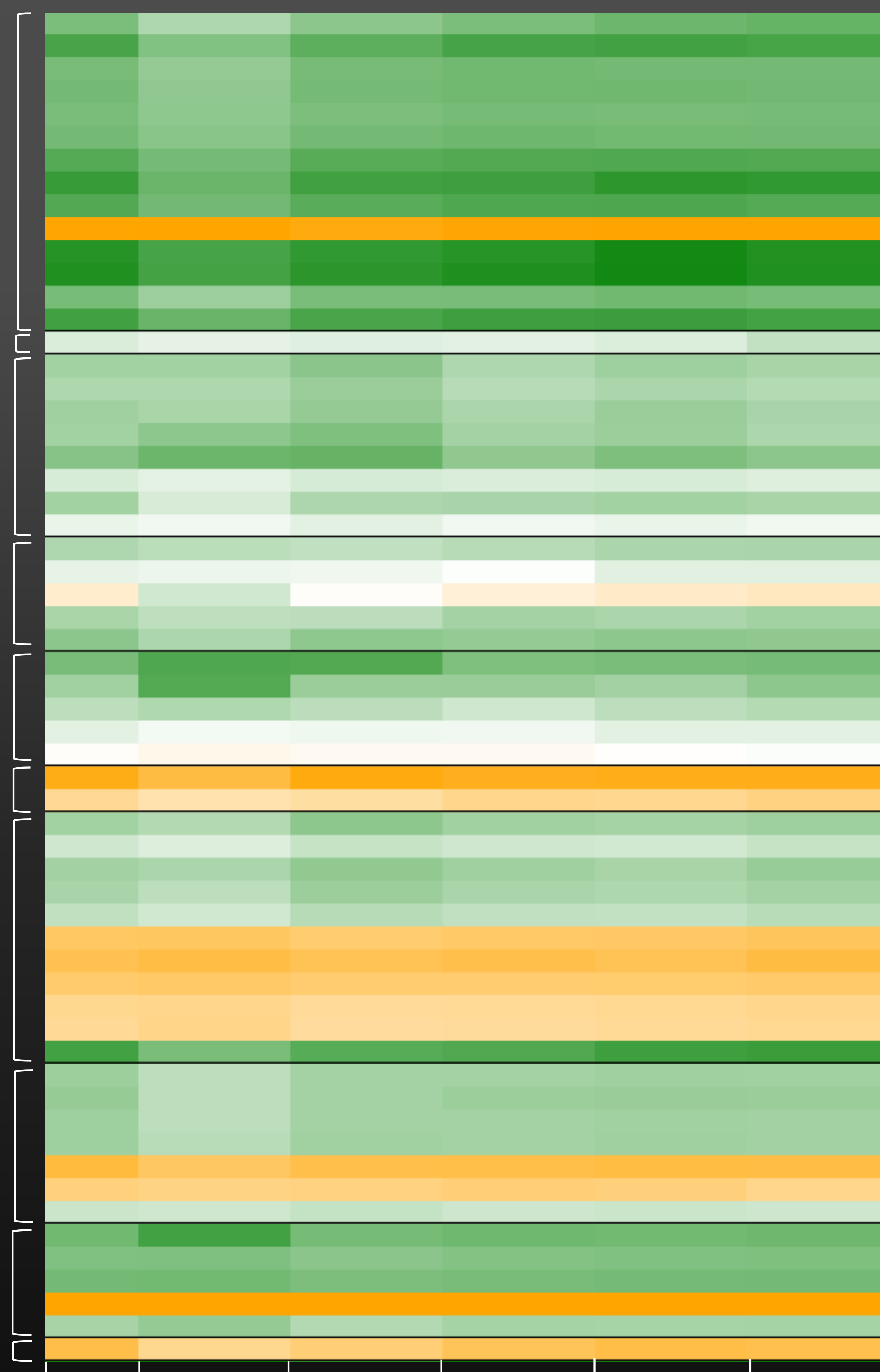
Apical Dissection

Posterior Vesicourethral Anastomosis

Anterior Vesicourethral Anastomosis

Left Lymph Node Dissection

Right Lymph Node Dissection



β value

0.2

0.1

0

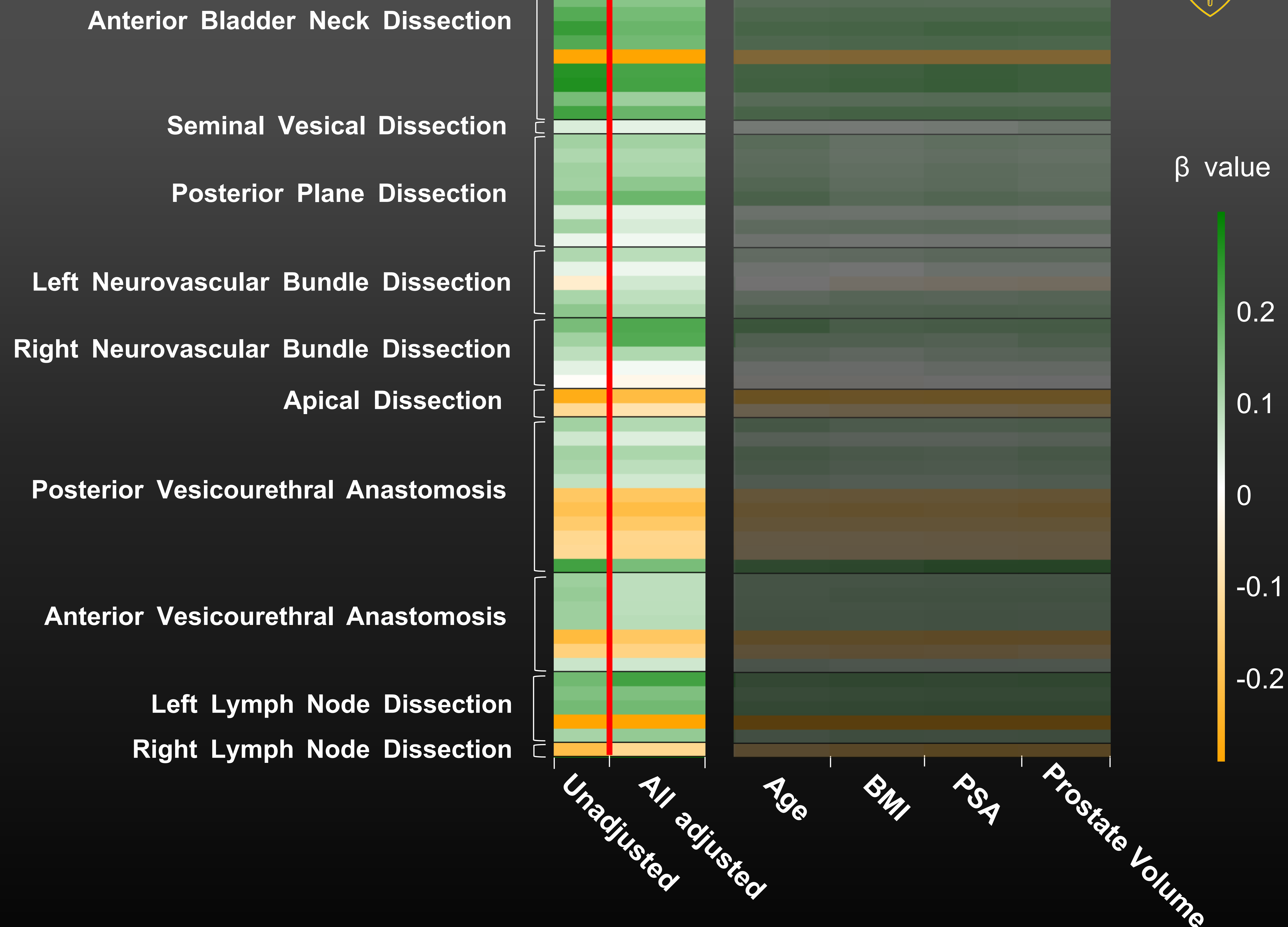
-0.1

-0.2

Patient factors

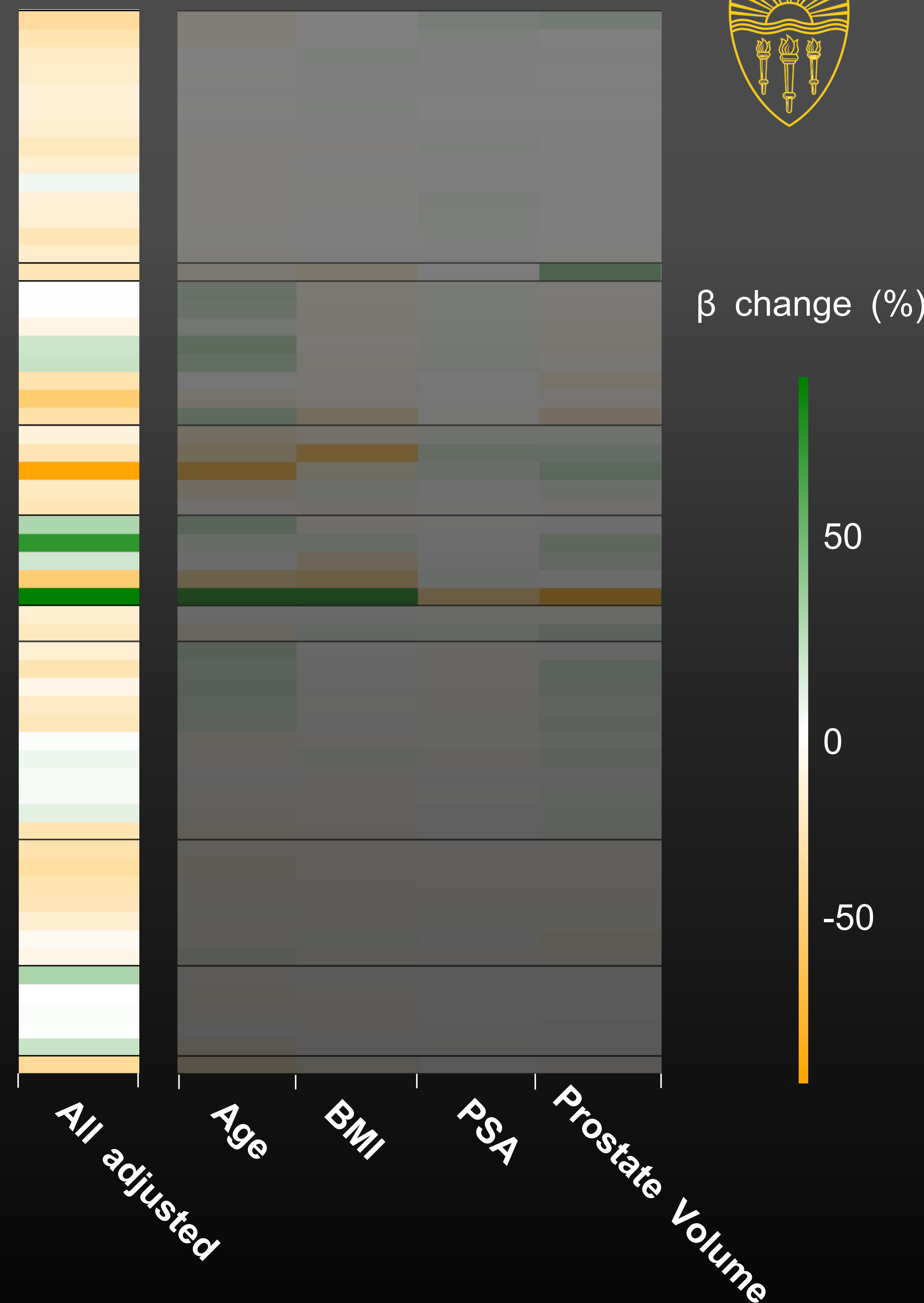
1st and 2nd column:

APMs' predictive ability
unadjusted and *adjusted* by
all patient factors



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

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



Minimal confounding *effect*

- Age
- BMI
- PSA
- Prostate Weight

Anterior Bladder Neck Dissection

Seminal Vesical Dissection

Posterior Plane Dissection

Left Neurovascular Bundle Dissection

Right Neurovascular Bundle Dissection

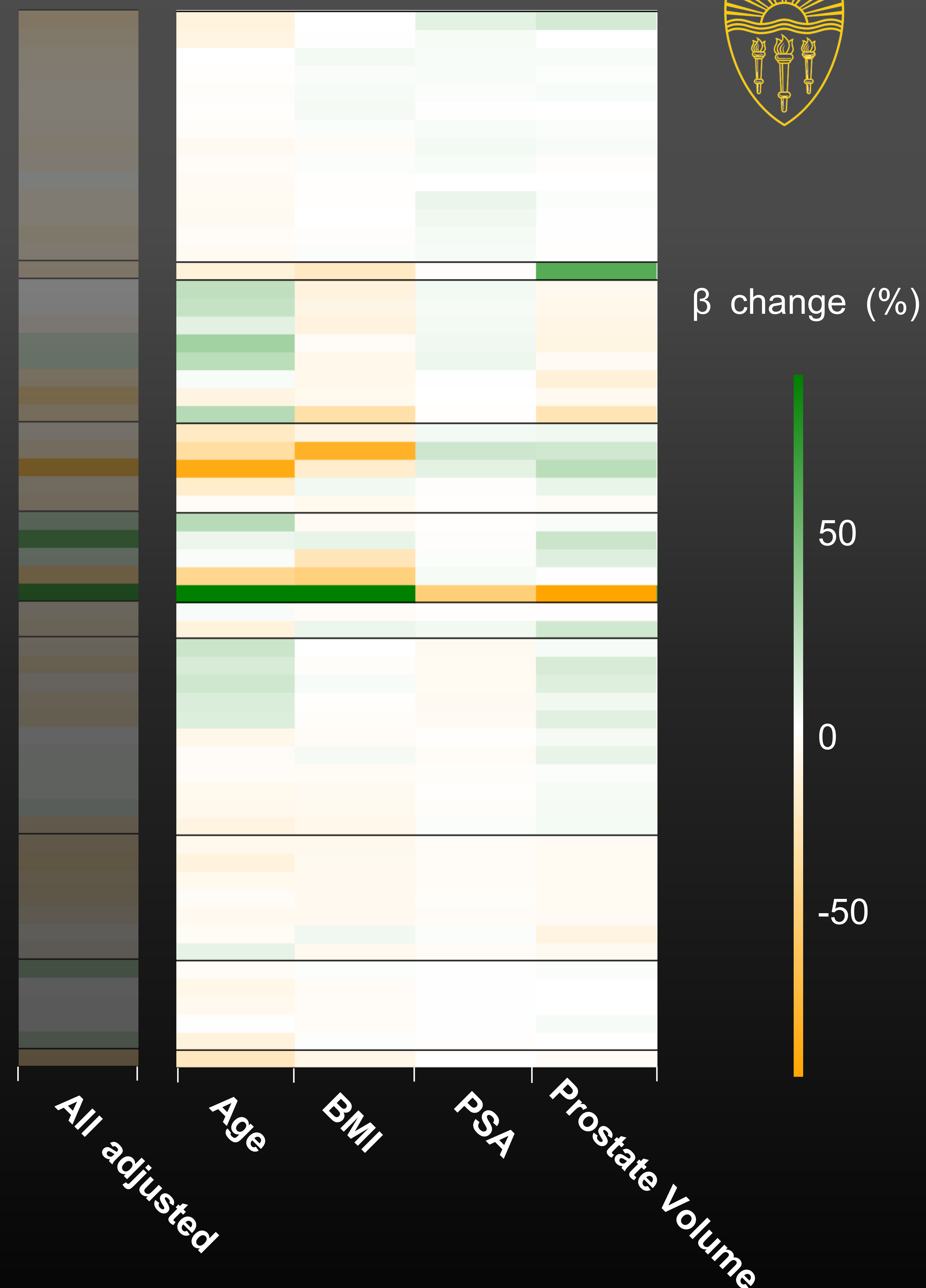
Apical Dissection

Posterior Vesicourethral Anastomosis

Anterior Vesicourethral Anastomosis

Left Lymph Node Dissection

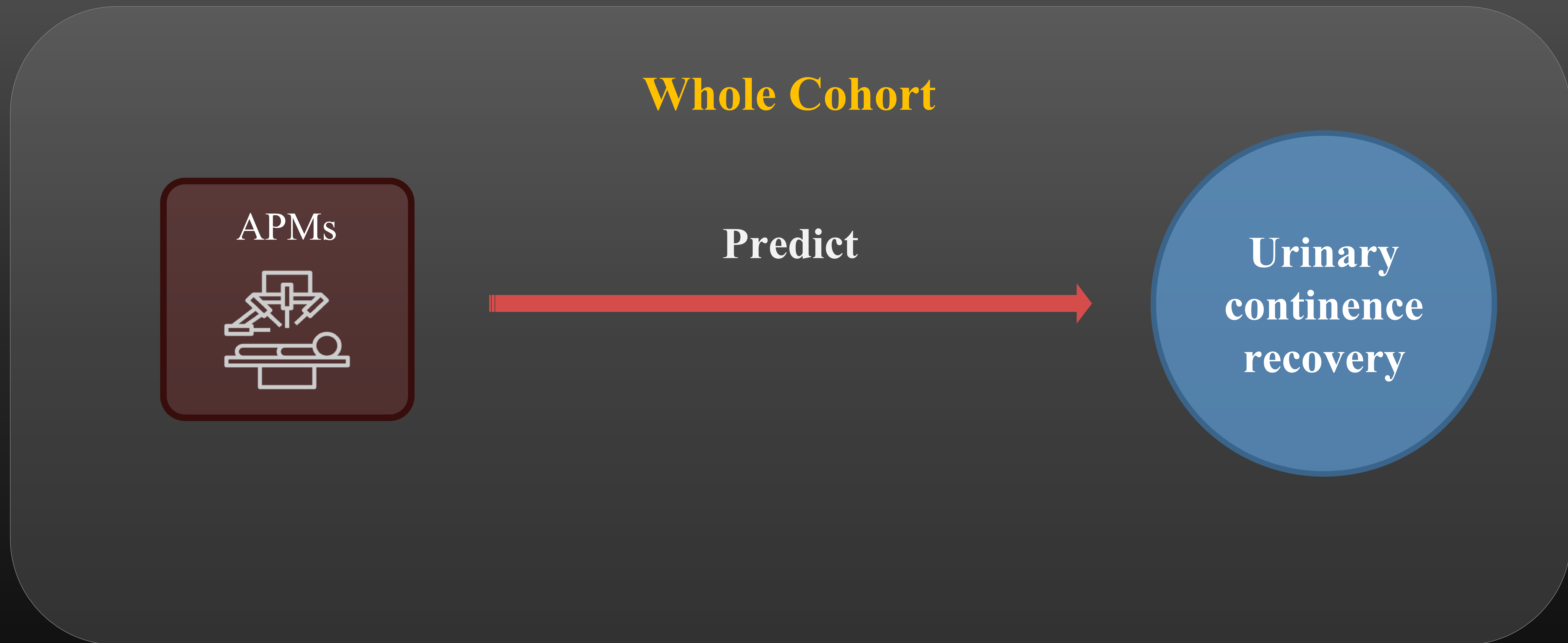
Right Lymph Node Dissection



- 33 APMs by primary surgeon were found to be **predictors of continence** recovery (univariate analysis)
- 82% (27/33) of these APMs **remained significant predictors** after adjusting for all relevant patient factors



Effect modification

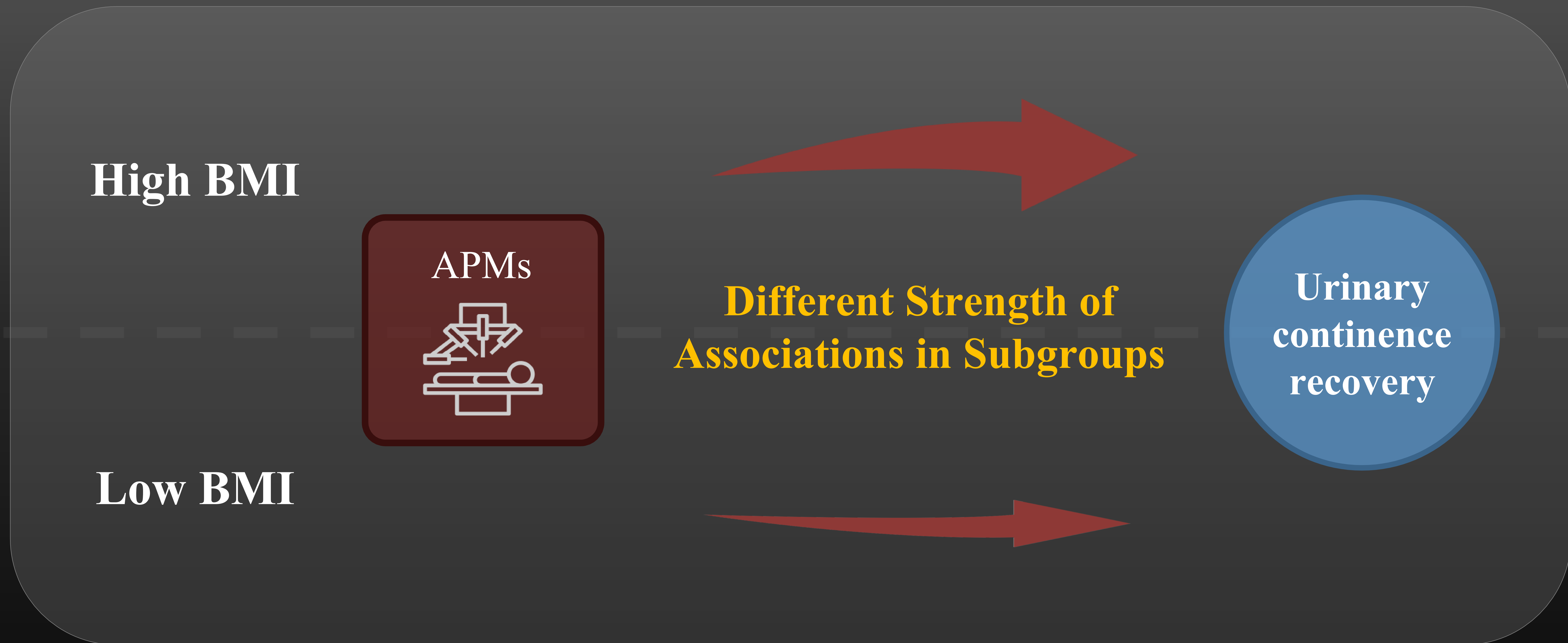


Whole Cohort

High BMI

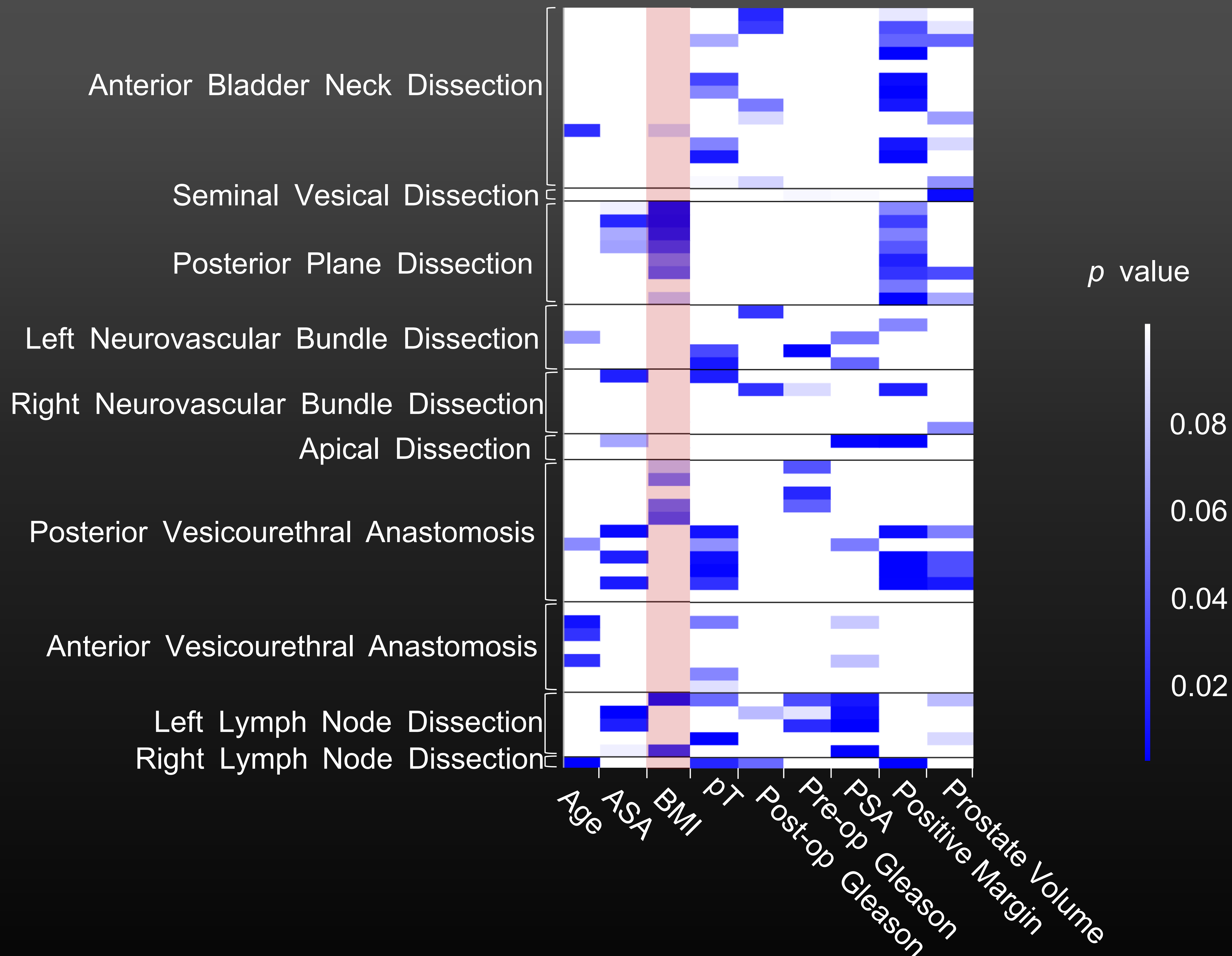
Low BMI

Effect modification



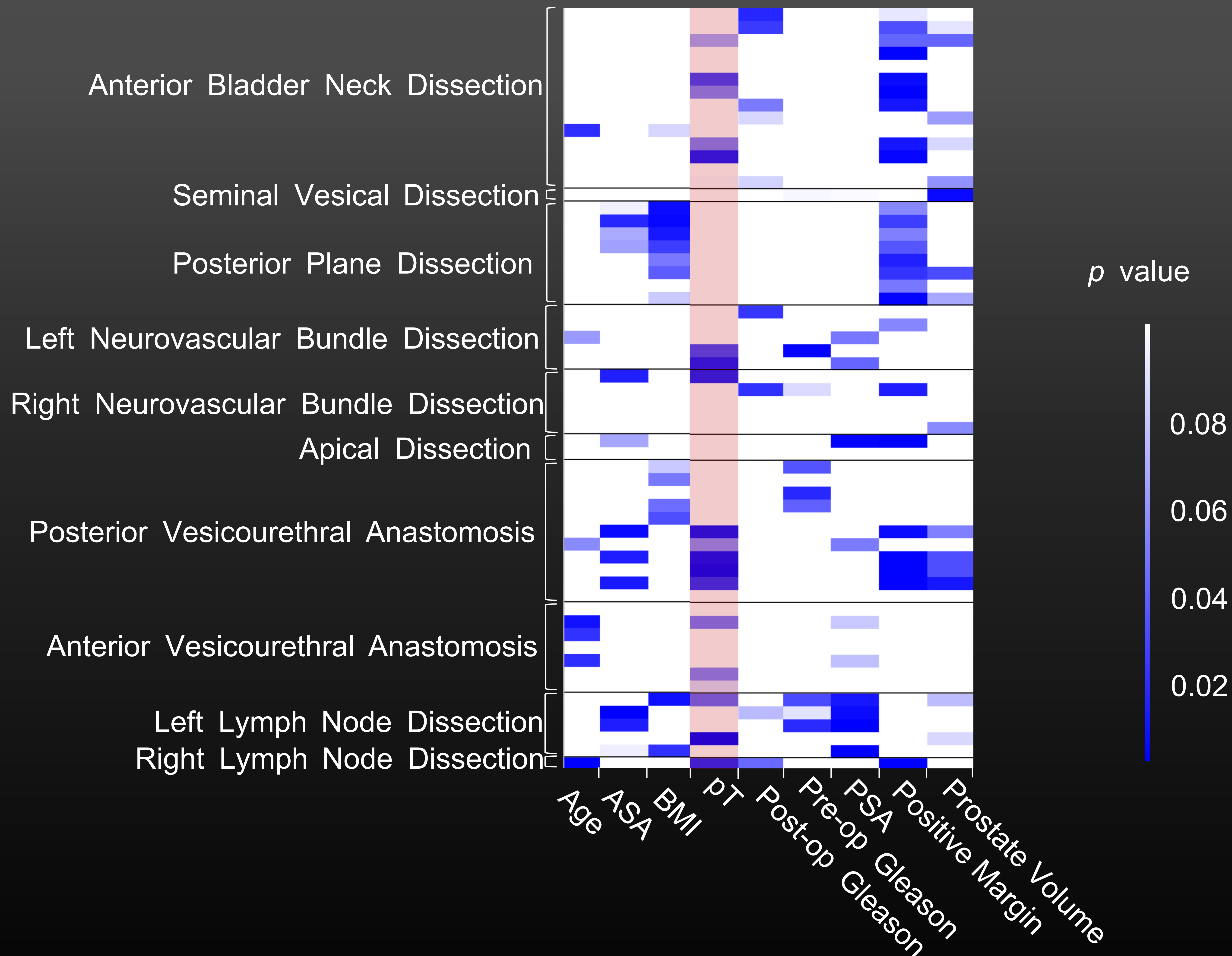
Effect modifiers

- Example:
 - BMI
 - pT stage



Effect modifiers

- Example:
 - BMI
 - pT stage





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

CRSE

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