

Precision Screening for Prostate Cancer : Toward an AI-Empowered Nationwide Program in Taiwan



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Outline

Universal PrCa Screening

Precision PrCa Screening

AI-empowered PrCa Precision Screening

Taiwan's Precision PrCa Screening Initiative

Evidence from RCTs of prostate cancer screening

PLCO The Prostate, Lung, Colorectal and Ovarian (PLCO) Cancer Screening Trial

ERSPC European Randomized Study of Screening for Prostate Cancer



The NEW ENGLAND
JOURNAL of MEDICINE

2009;360:1310-9.

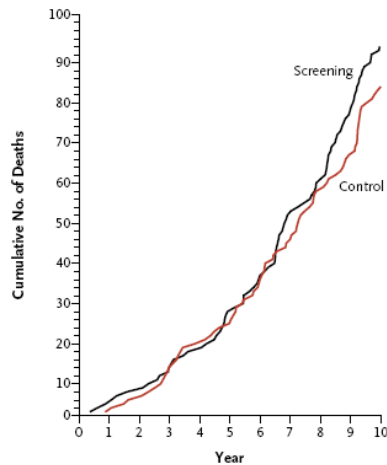


Figure 1. Number of Diagnoses of All Prostate Cancers (Panel A) and Number of Prostate-Cancer Deaths (Panel B).

2009;360:1320-8.

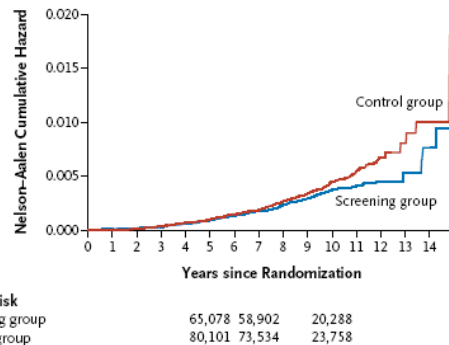


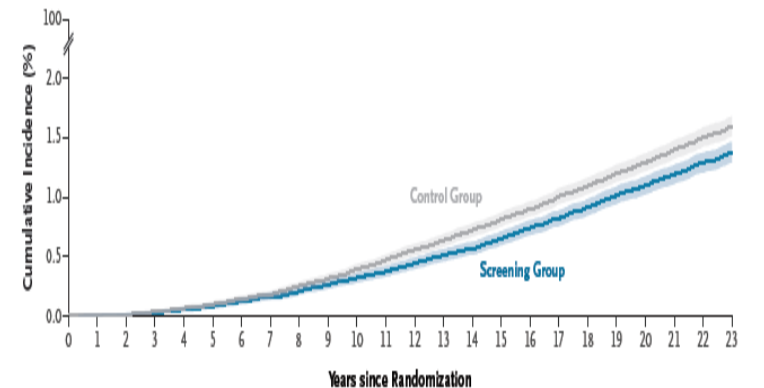
Figure 2. Cumulative Risk of Death from Prostate Cancer.

As of December 31, 2006, with an average follow-up time of 8.8 years, there were 214 prostate-cancer deaths in the screening group and 326 in the control group. Deaths that were associated with interventions were categorized as being due to prostate cancer. The adjusted rate ratio for death from prostate cancer in the screening group was 0.80 (95% CI, 0.65 to 0.98; $P=0.04$). The Nelson-Aalen method was used for the calculation of cumulative hazard.

PLCO, 7-yr follow-up
RR=1.13 (0.75-1.70)

ERSPC, 8-yr follow-up
RR=0.80 (0.65-0.98)

2025; 393:1669-1680



ERSPC, 23-yr follow-up
RR=0.87 (0.80-0.95)

Modeling the overdetection of screen-identified cancers in population-based cancer screening with the Coxian phase-type Markov process

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Funding information

Ministry of Science and Technology,

Modeling overdetection resulting from screening often uses the conventional competing risk model. This model assigns screen-detected cases dying from other causes as overdetection modeled by a one-jump process, which may not be true for the censored overdetected cases. To relax this restrictive assumption, accommodate a finite Markov process for overdetection, and dispense with long-term follow-up until death, we propose a generalized Coxian phase-type Markov process to distinguish the progressive latent multistate pathway from the nonprogressive (overdetected) latent multistate pathway. Various new likelihood functions were developed to estimate the transition parameters with the available data accrued at the time of diagnosis. The proportion of overdetected cancers by the cured model was further estimated by using parameters with and without distinguishing between the two latent pathways. While perturbation analyses were conducted by changing their parameters to assess their effects on

Estimated results of Markov model ($m = 2$) for natural history of prostate cancer with and without consideration of overdetetection

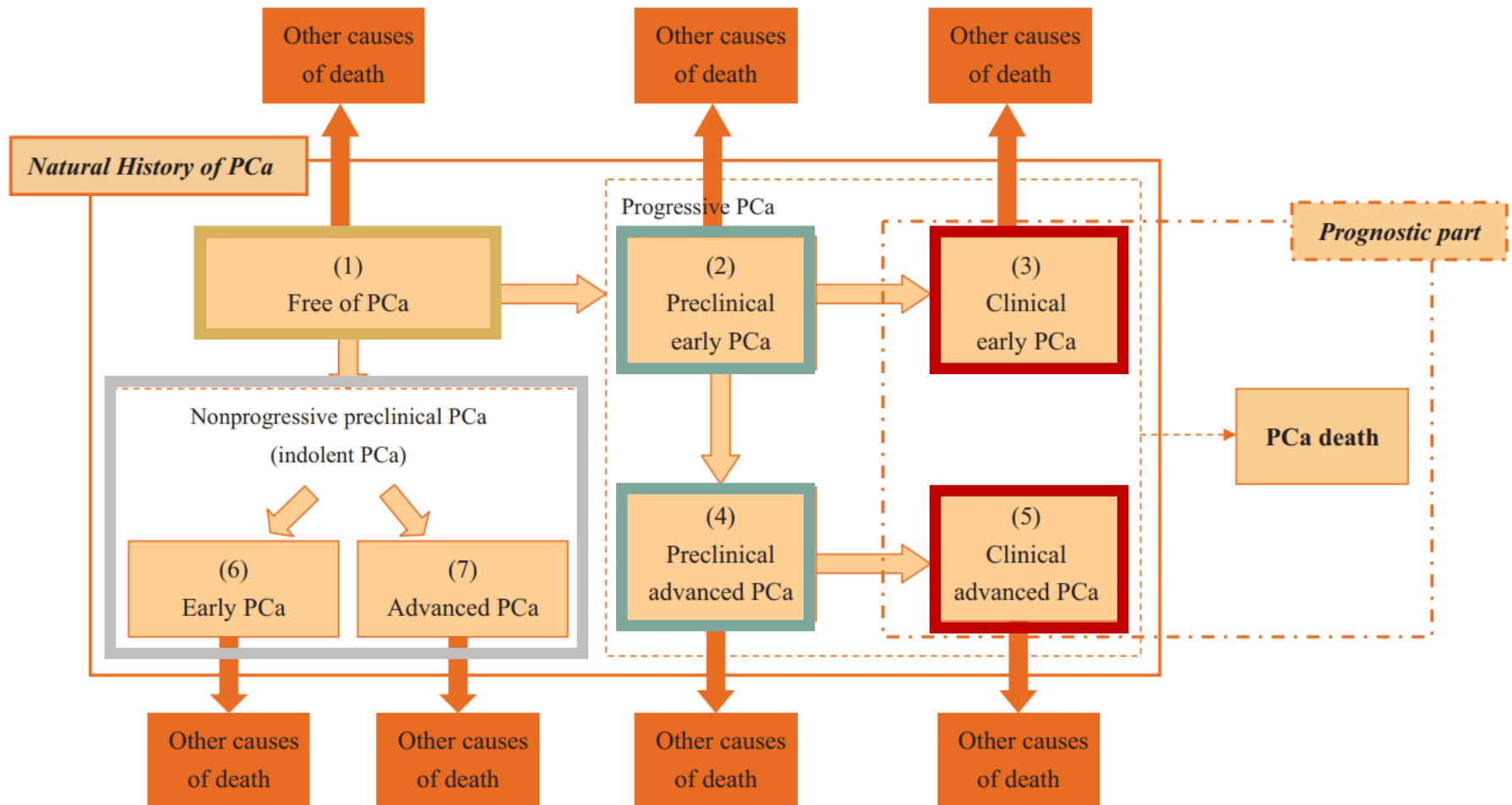


Table 2. Estimated results of preclinical incidence of progressive and nonprogressive prostate cancer, transition rates and sensitivity

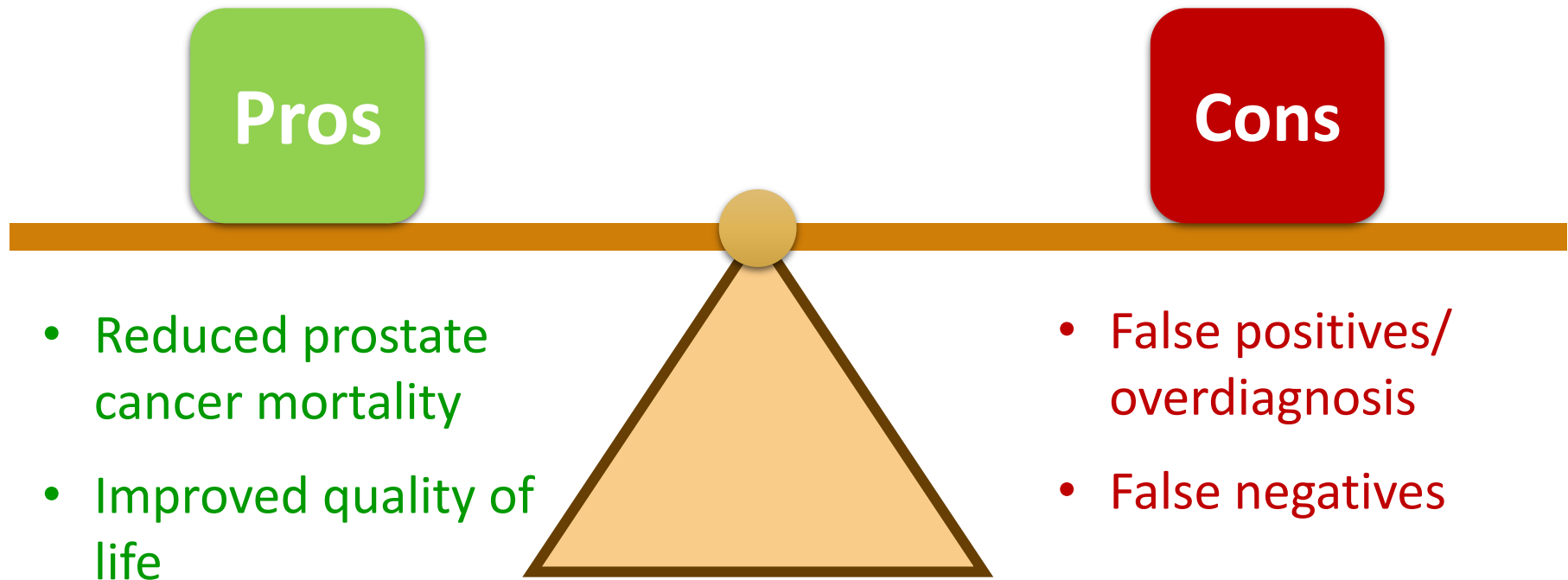
Parameters	Estimates
Preclinical incidence of progressive prostate cancer (I_P)¹	
Aged 55–58	0.00128 (0.00099–0.00156)
Aged 59–62	0.00326 (0.00278–0.00375)
Aged 63–66	0.00505 (0.00439–0.00570)
Aged 67–71	0.00774 (0.00689–0.00859)
Preclinical incidence of nonprogressive prostate cancer (I_{NP})	
Aged 55–58	0.00040 (0.00027–0.00054)
Aged 59–62	0.00061 (0.00042–0.00081)
Aged 63–66	0.00074 (0.00049–0.00098)
Aged 67–71	0.00066 (0.00040–0.00093)
Transition of progressive prostate cancer from PCDP to CP	
Transition rate (λ_2)	0.1295 (0.0931–0.1660)
Mean sojourn time ($1/\lambda_2$)	7.72 (6.03–10.74)
Sensitivity	
Prevalent screen	42.8% (35.1%–50.6%)
Subsequent screen	59.8% (47.5%–72.0%)

Overdiagnosis

60%

Prostate cancer screening: Pros & Cons

Population-wide PSA screening



Outline

Universal PrCa Screening

Precision PrCa Screening

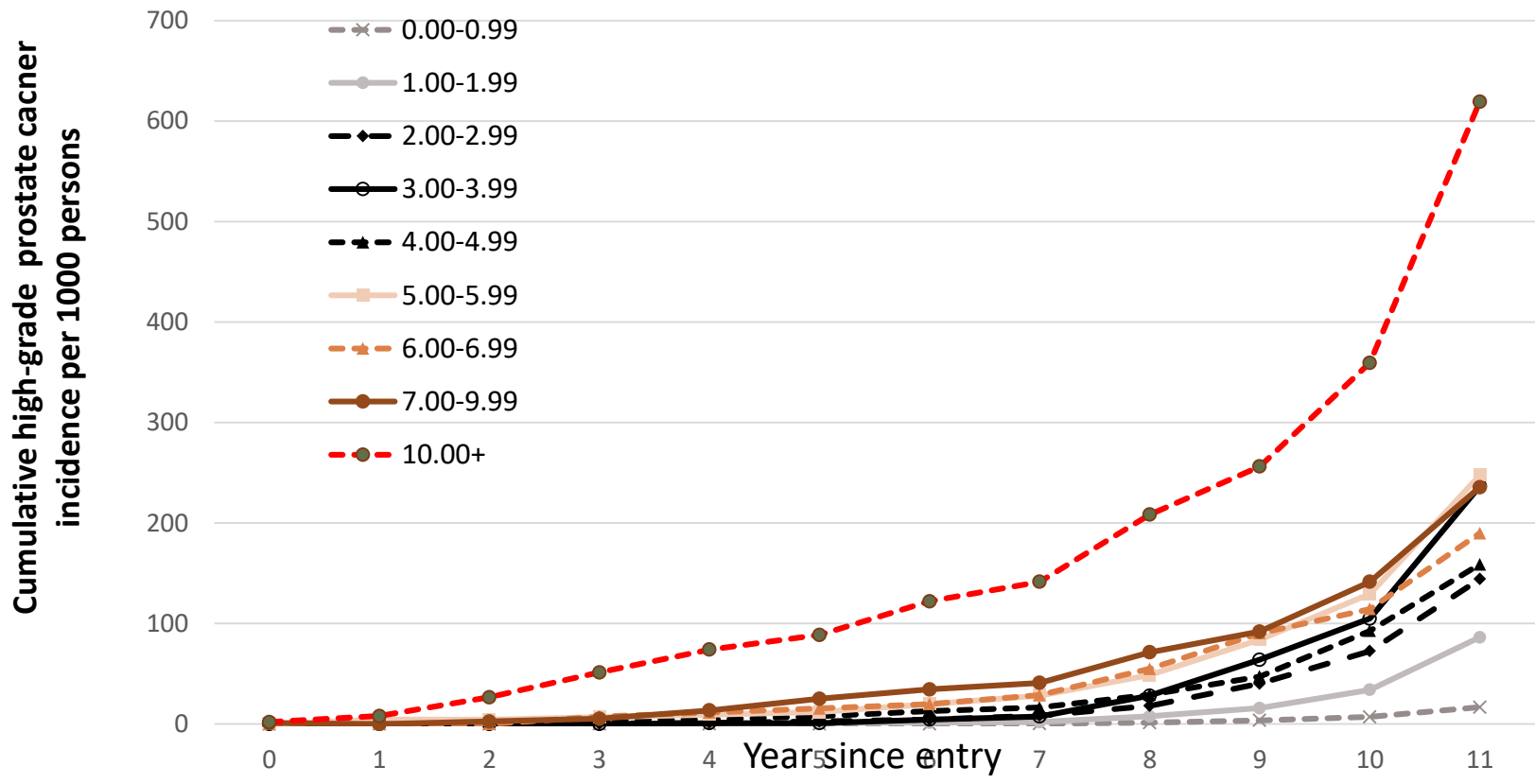
AI-empowered PrCa Precision Screening

Taiwan's Precision PrCa Screening Initiative



Incidence of high-grade prostate cancer by PSA concentration

Data from Finnish Trial



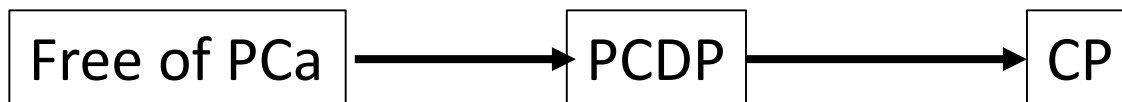
PSA concentration associated with prostate cancer risk



Year since entry	0.00-0.99	1.00-1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-5.99	6.00-6.99	7.00-9.99	10.00+
0	0.5	0.5	1.5	1.5	1.5	0.5	0.5	1.5	1.5
1	0.5	0.5	3.0	0.5	3.0	0.5	0.5	0.5	0.5
2	0.5	0.5	4.5	0.5	4.5	0.5	0.5	0.5	2.5
3	0.5	0.5	4.5	0.5	4.5	0.5	0.5	2.5	11.0
4	0.5	0.5	4.5	0.5	4.5	0.5	3.5	8.0	23.0
5	0.5	0.5	4.5	0.5	6.0	5.0	8.0	14.0	26.0
6	0.5	0.5	4.5	0.5	6.0	8.0	8.0	17.0	36.0
7	0.5	0.5	4.5	2.0	6.0	8.0	17.0	20.5	43.0
8	0.5	0.5	4.5	3.0	8.0	8.0	17.0	24.5	56.0
9	0.5	0.5	4.5	3.5	8.0	8.0	17.0	24.5	62.0
10	0.5	0.5	4.5	3.5	8.0	8.0	17.0	24.5	62.0
11	0.5	0.5	4.5	3.5	8.0	8.0	17.0	24.5	62.0

Multi-state Model incorporating PSA as a covariate

$$\lambda_1 = \lambda_{10} \times \exp(\beta_1 \cdot PSA) \quad \lambda_2 = \lambda_{20} \times \exp(\beta_2 \cdot PSA)$$

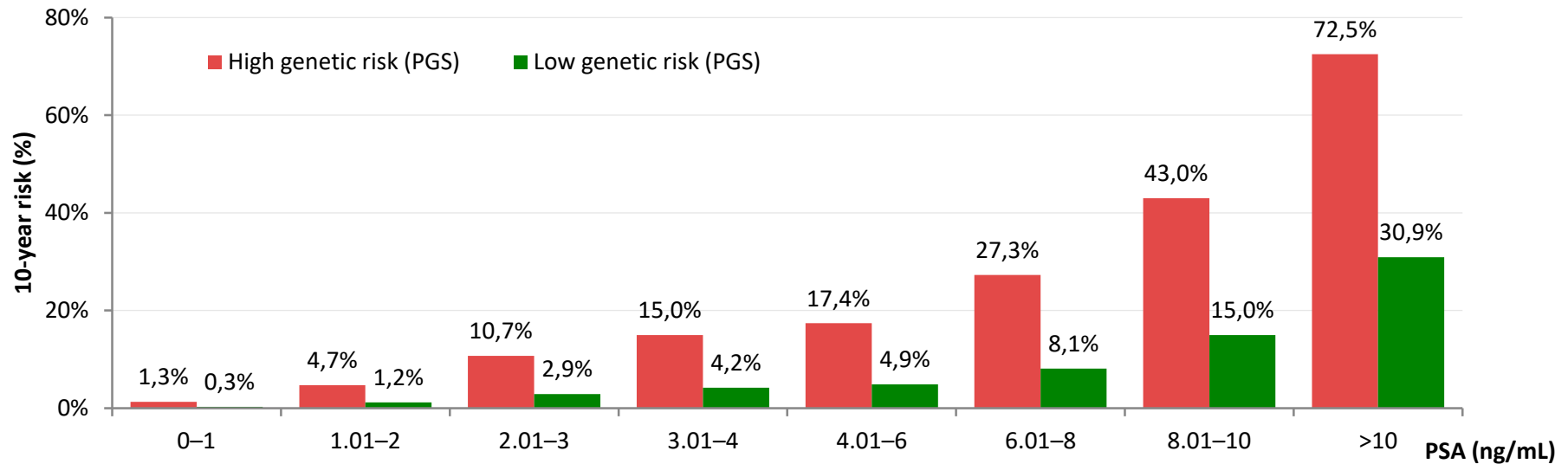


Data on PSA at diagnosis
for interval cancers

Parameters	Estimate	95% CI
Incidence of preclinical Pca (per 1000)		
Intercept	0.0002	0.0002, 0.0003
Regression coefficient for PSA	0.7724	0.7117, 0.8331 RR=2.16, 95% CI: 2.11-2.23
Transition from the PCDP to the CP		
Intercept	0.0223	0.0165, 0.0281
Regression coefficient for PSA	0.1	RR=1.13, 95% CI: 1.10-1.16

10y risk of PCa by PSA levels and genetic risk groups

Higher polygenic risk (PGS) raises 10-year risk at every PSA threshold, and the gap widens sharply above 8 ng/mL.



LR+	1.30	1.55	2.40	2.83	2.69	5.45	4.7	7.71	5.3	10.6	10.1	18.1	25.6	39.2	-	69.2
LR-	0.18	-	0.31	0.08	0.51	0.24	0.6	0.28	0.75	0.48	0.82	0.5	0.89	0.74	0.93	0.87

Smart Precision Prostate Cancer Screening

Condition

Risk

Smart Precision screening

PSA

PGS

10-yr risk

Start age

Inter-screening
interval

>10

H

L

17%

7%

50

1

2

50

8-10

H

L

12%

5%

50

1

2

50

6-8

H

L

6%

2%

50

2

4

60

4-6

H

L

3%

1%

55

3

4

60

3-4

H

L

3%

1%

55

3

4

60

2-3

H

L

2%

0.8%

55

3

4

60

1-2

H

L

1%

0.3%

60

4

6

60

<1

H

L

0.2%

0.1%

60

6

6

60

available at www.sciencedirect.com

journal homepage: www.europeanurology.com



European Association of Urology

Prostate Cancer

The Impact of Interscreening In Screening With Prostate-Specific

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^aTampere School of Public Health, University of Tampere, Tampere, Finland; ^bHealth, National Taiwan University, Taipei, Taiwan; ^cSchool of Oral Hygiene, Finland; ^dDepartment of Urology, Tampere University Hospital, University Central Hospital, Helsinki, Finland; ^eDepartment of Pathology, ^fDepartment of Urology, Helsinki University Central Hospital, Helsinki, Finland

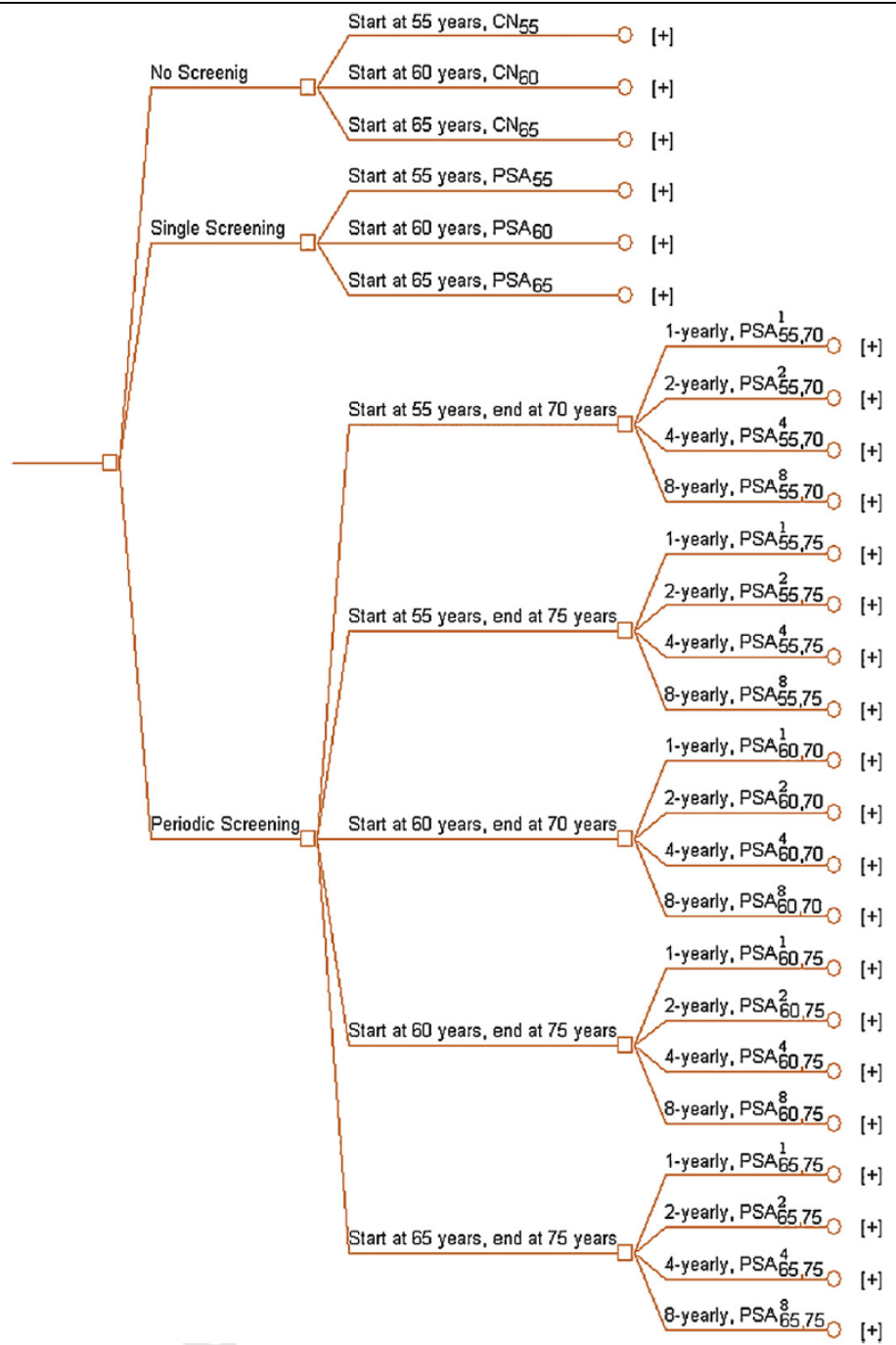
Article info

Article history:

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print on January 14, 2012

Abstract

Background: Population prostate-specific antigen (PSA) affected by screening the control group in **Objective:** Assess the impact of the above-mentioned factors on screening efficacy.



Cost-Effectiveness Analysis of Prostate Cancer Screening

Screening strategy	Incremental cost (USD)	Incremental life-year gained	Incremental cost effectiveness ratio (USD/LYG)
No screening			-
Universal 4-y screening	133,837,735	2,564.75	52,184
Precision screening	129,589,498	2,908.65	44,553

Willing to Pay: 1 GDP

1 GDP (Finland, 2024): USD, 53,189

Yang et al, 2021

Emerging tools for early detection using PSA-related markers

PHI

Prostate Health Index

$$\frac{-2\text{proPSA}}{f\text{PSA}} \times \sqrt{t\text{PSA}}$$

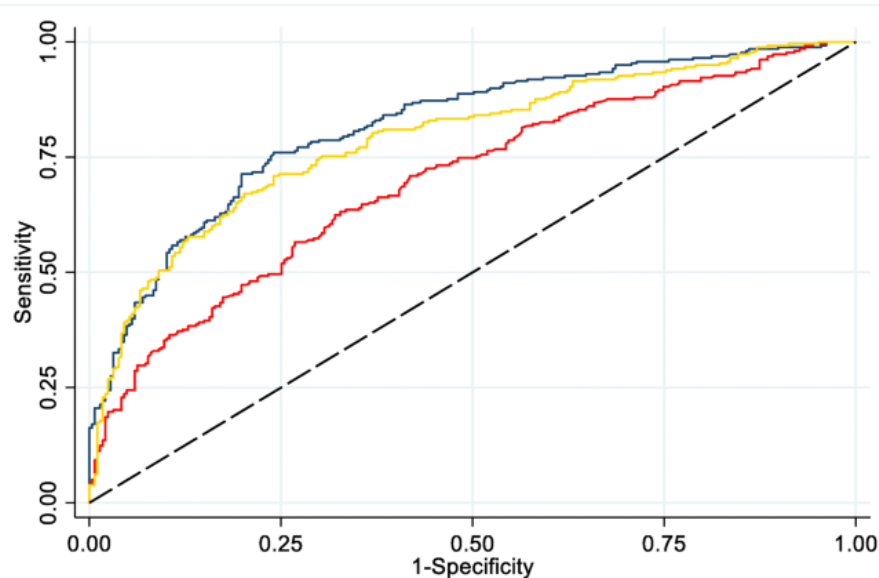
4K Score

1. *tPSA*
2. *fPSA*
3. *intact PSA*
4. *human kallikrein – related peptidase – 2, hK2*

- *tPSA, total PSA*
- *fPSA, free PSA*

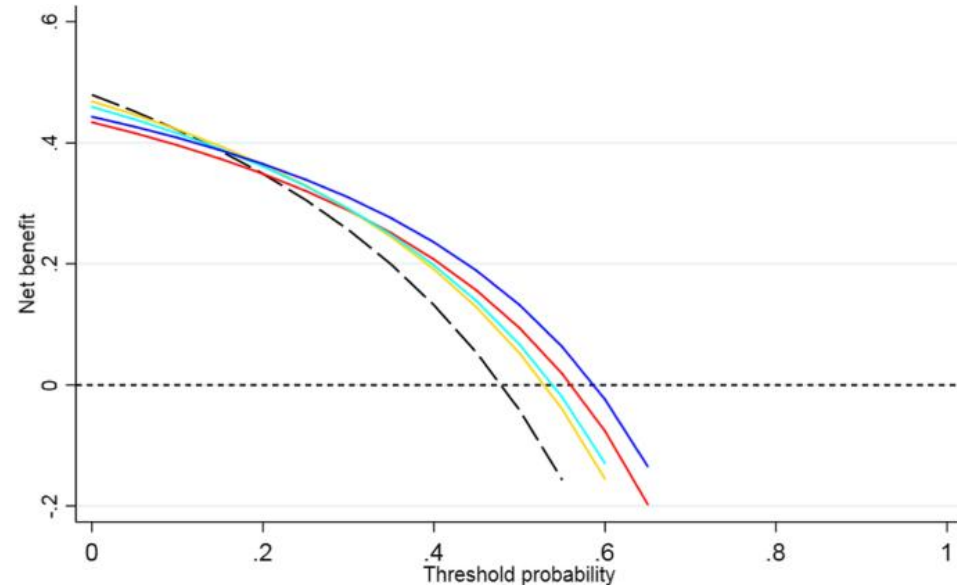
Emerging prostate cancer tumor markers enable better patient triage

Performance of the various tumor markers



— PHI — PSA — PSA density

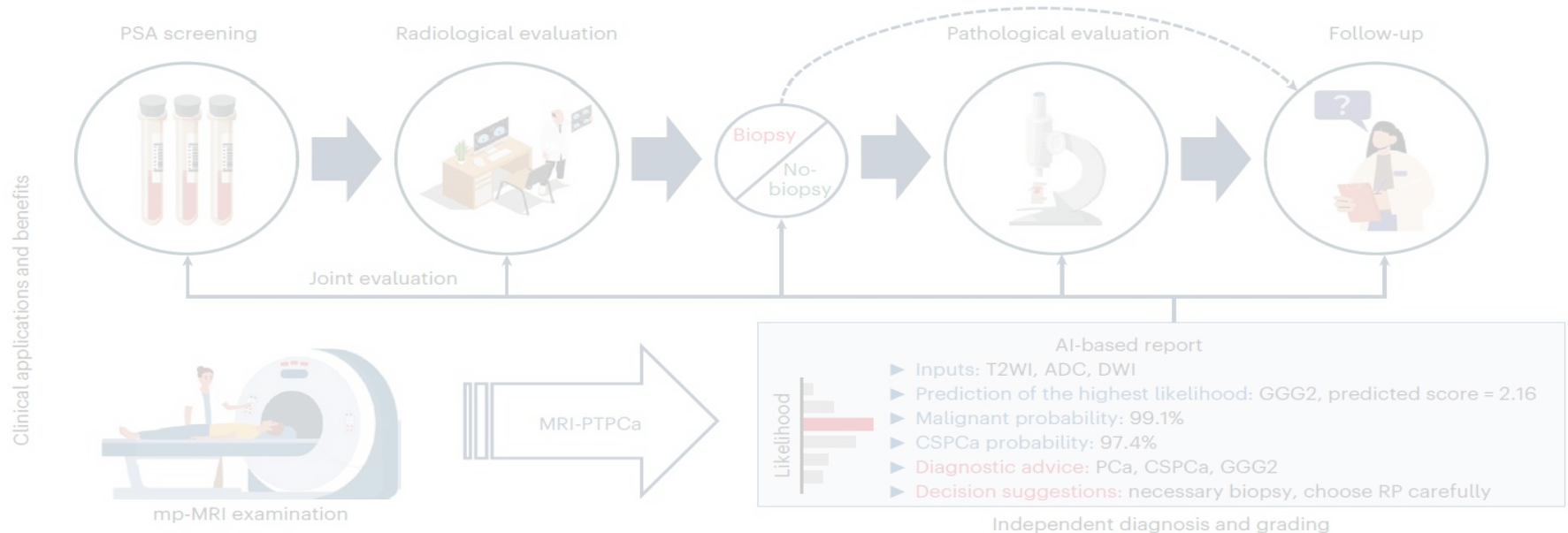
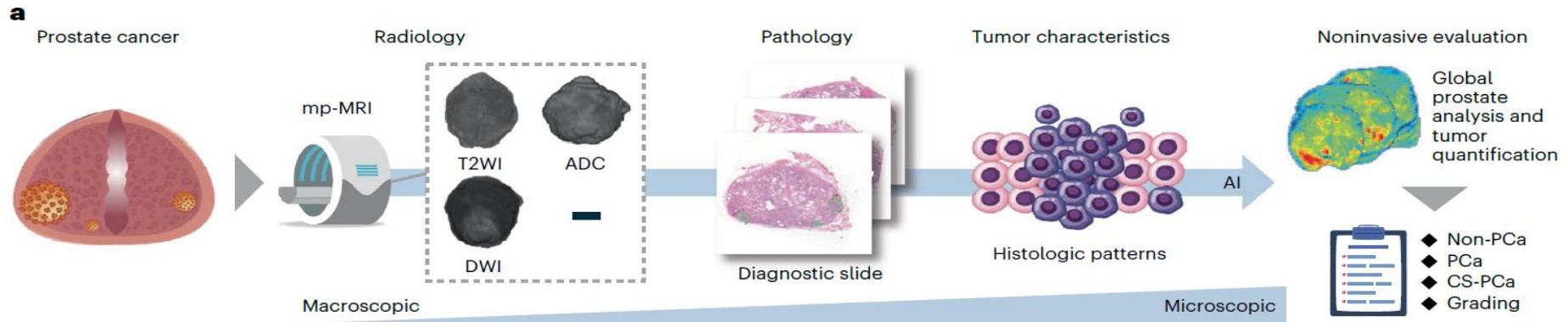
Appropriate patient triage/management selection improves net benefit



— treat all — MRI — MRI-PSAd — PHI25 — PHI30

Non-invasive imaging-based diagnosis and grading of PCa

Shao et al, 2025 *Nature Cancer*



A Randomized Trial of Precision Prostate Cancer Screening



Anssi Auvinen
Tampere Univ.



50-63 y/o, male

Random allocation 1:3



Invitation 15,299

Control 45,544

PSA < 1.5 ·
6-yr later inv

PSA 1.5~3 ·
4-yr later inv

PSA ≥ 3 ng/ml $\rightarrow$ 4KScore

4KScore positive ($\geq 7.5\%$)

4KScore negative

4KScore

1. Total PSA
2. free PSA
3. intact PSA
4. human kallikrein-related peptidase-2 (hK2)

mpMRI

Follow-up

PI-RADS, 3+
Positive,
biopsy

Negative

JAMA | Preliminary Communication

Prostate Cancer Screening With PSA, Kallikrein Panel, and MRI
The ProScreen Randomized Trial

Non PrCa, reinv 2-yr later

Auvinen et al, 2024 JAMA

A Randomized Trial of Precision Prostate Cancer Screening



50-63 y/o, male

Random allocation 1:3



Invitation 15,299

Control 45,544

PSA < 1.5
6-yr later inv

Goals of precision screening:

- Reduce overdiagnosis of low-grade prostate cancer;
- Increase detection of clinically significant (high-grade) prostate cancer

mpMRI

- 4KScore
1. Total PSA
 2. free PSA
 3. intact PSA
 4. human kallikrein-related peptidase-2

1000 Participated

97 PSA ≥ 3.0 ng/mL

68 Kallikrein panel
score $\geq 7.5\%$

26 PI-RADS ≥ 3 ,
8 PSAD > 0.15 ng/L²

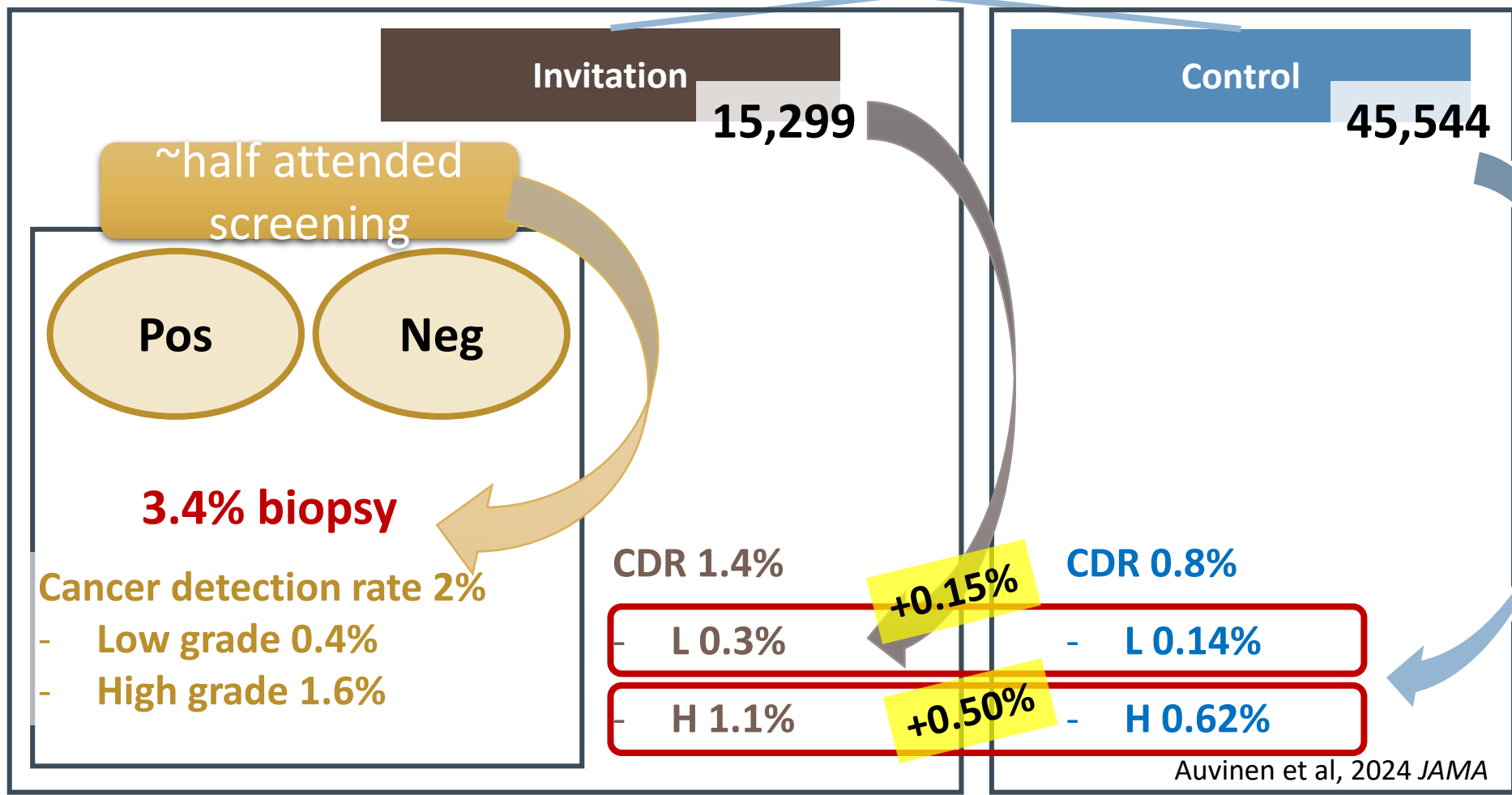
34 Biopsied

17 High-grade
prostate cancers
4 Low-grade
prostate cancers

ProScreen: Empirical Results



50-63 y/o, male 60,843
Random allocation 1:3



Outline

Universal PrCa Screening

Precision PrCa Screening

AI-empowered PrCa Precision Screening

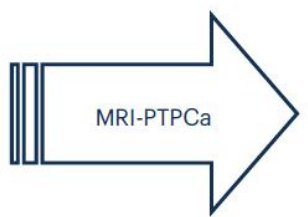
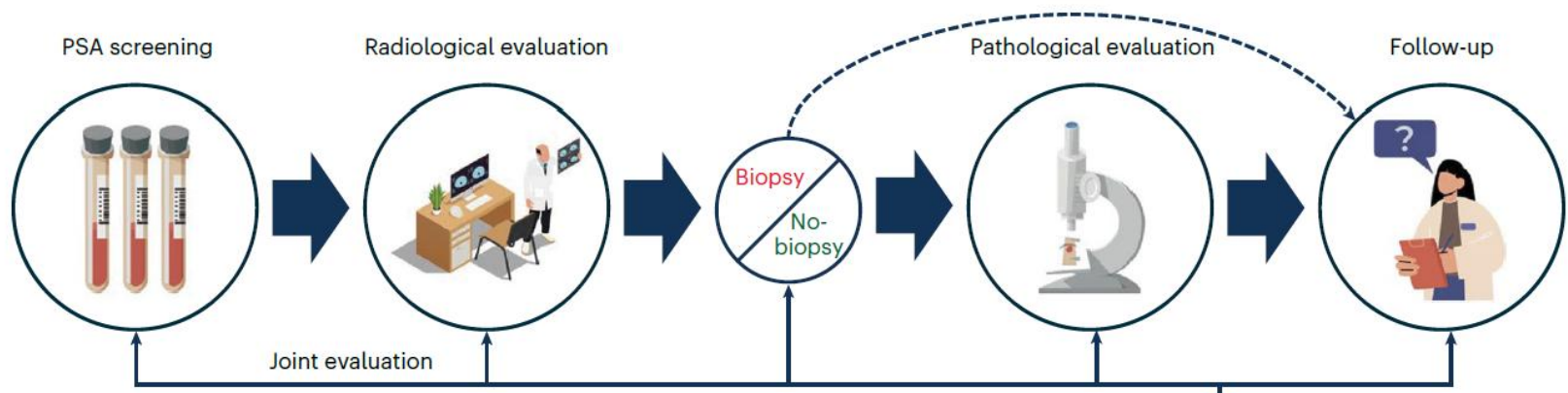
Taiwan's Precision PrCa Screening Initiative

AI-based non-invasive precision diagnosis and grading of PCa

Shao et al, 2025 *Nature Cancer*



Clinical applications and benefits



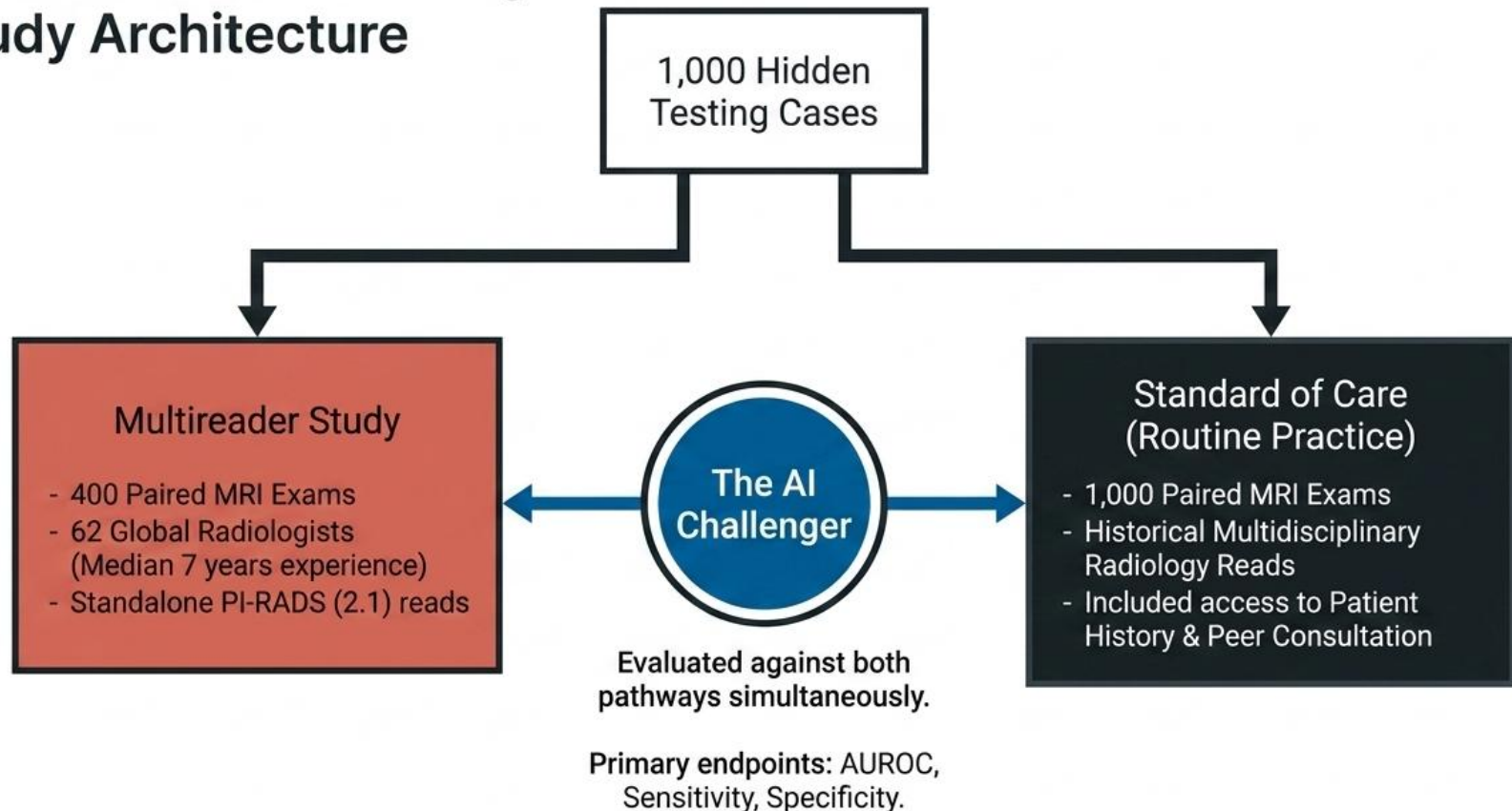
AI-based report

- ▶ Inputs: T2WI, ADC, DWI
- ▶ Prediction of the highest likelihood: GGG2, predicted score = 2.16
- ▶ Malignant probability: 99.1%
- ▶ CSPCa probability: 97.4%
- ▶ **Diagnostic advice:** PCa, CSPCa, GGG2
- ▶ **Decision suggestions:** necessary biopsy, choose RP carefully

Independent diagnosis and grading

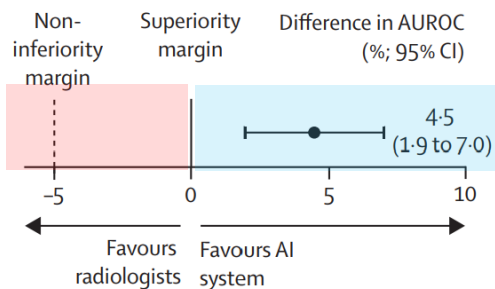
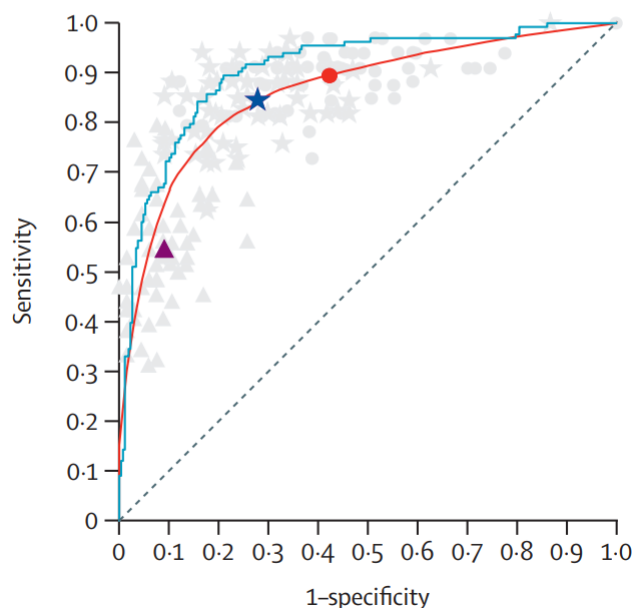
AI and radiologists in Pca detection on MRI (PI-CAI): an international, paired, **noninferiority**, confirmatory study

Dual-Path Confirmatory Study Architecture



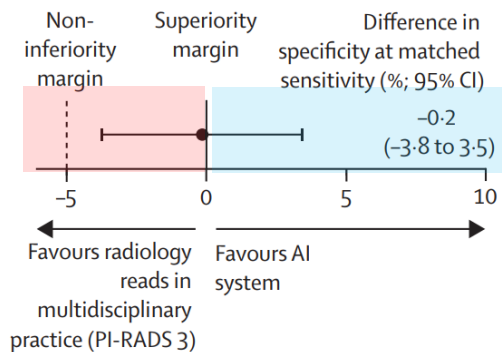
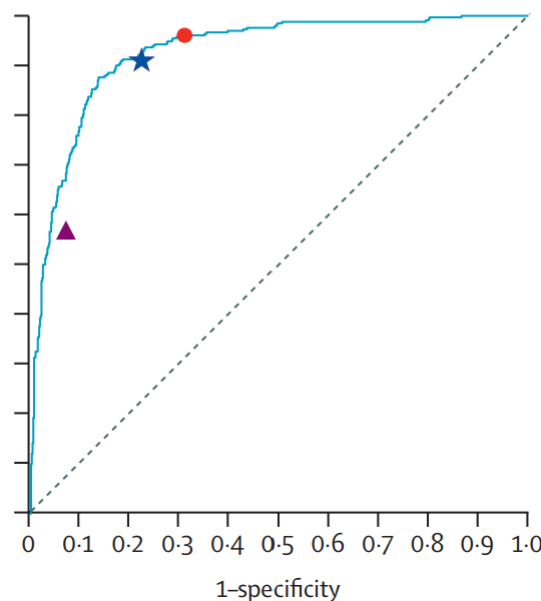
AI and radiologists in Pca detection on MRI (PI-CAI): an international, paired, **noninferiority**, confirmatory study

- AI system (AUROC=0.91, 95% CI 0.87–0.94)
- Radiologists (AUROC=0.86, 95% CI 0.83–0.89)
- Radiologists (PI-RADS ≥ 3)
- ★ Radiologists (PI-RADS ≥ 4)
- ▲ Radiologists (PI-RADS ≥ 5)



significant

- AI system (AUROC=0.93, 95% CI 0.91–0.94)
- Radiology reads in multidisciplinary practice (PI-RADS ≥ 3)
- ★ Radiology reads in multidisciplinary practice (PI-RADS ≥ 4)
- ▲ Radiology reads in multidisciplinary practice (PI-RADS ≥ 5)

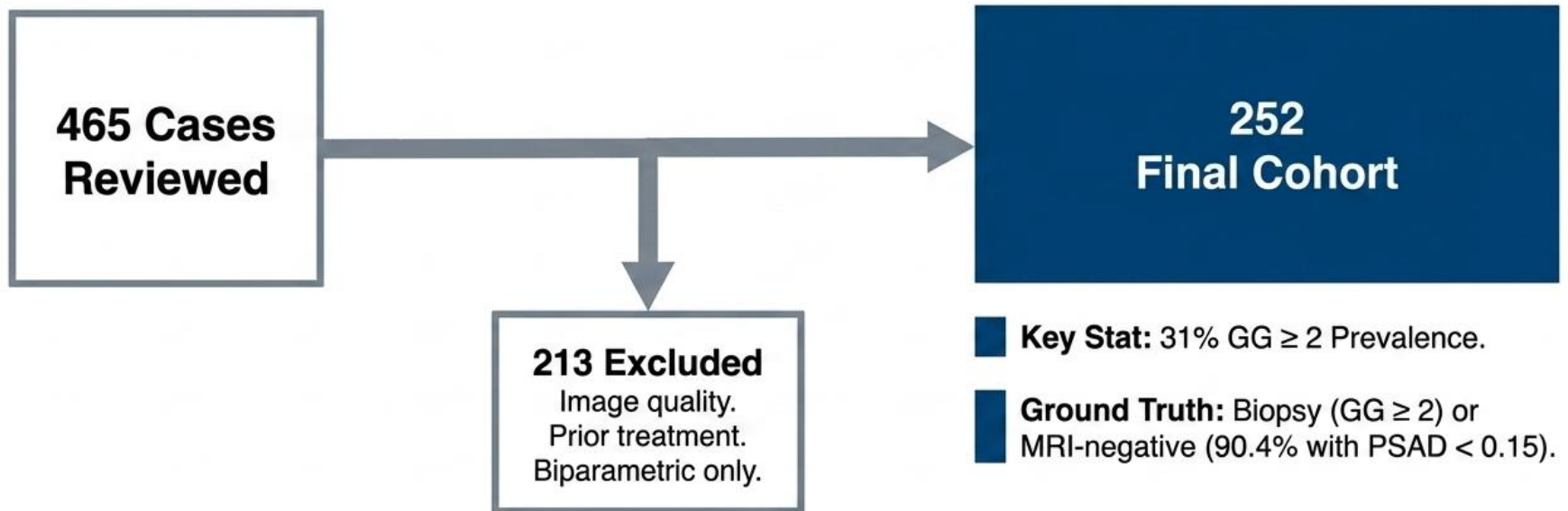


insignificant

AI-powered prostate cancer detection

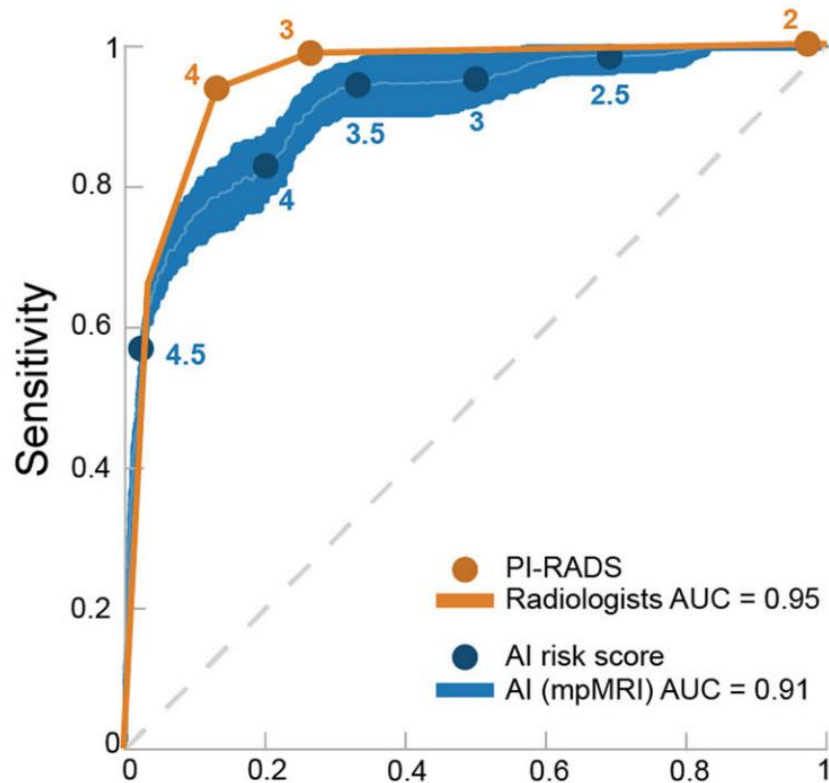
a multi-centre, multi-scanner validation study

The Validation Cohort

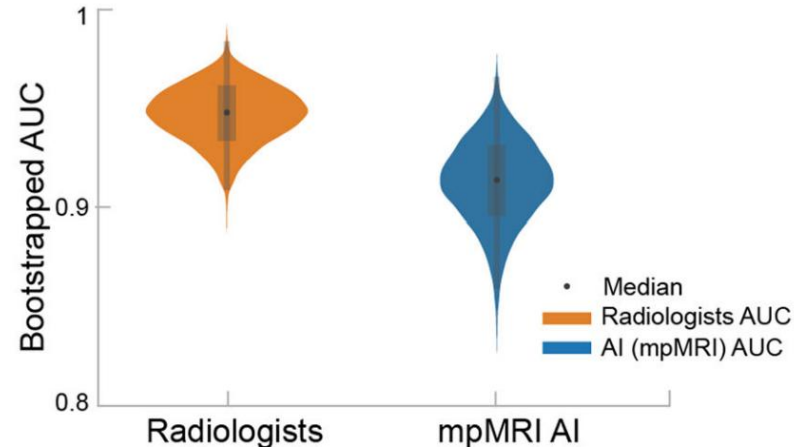


AI-powered prostate cancer detection a multi-centre, multi-scanner validation study

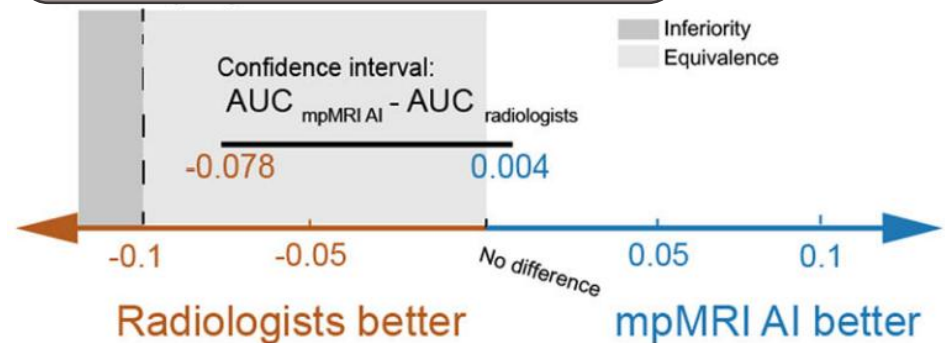
ROC Curve



AUC

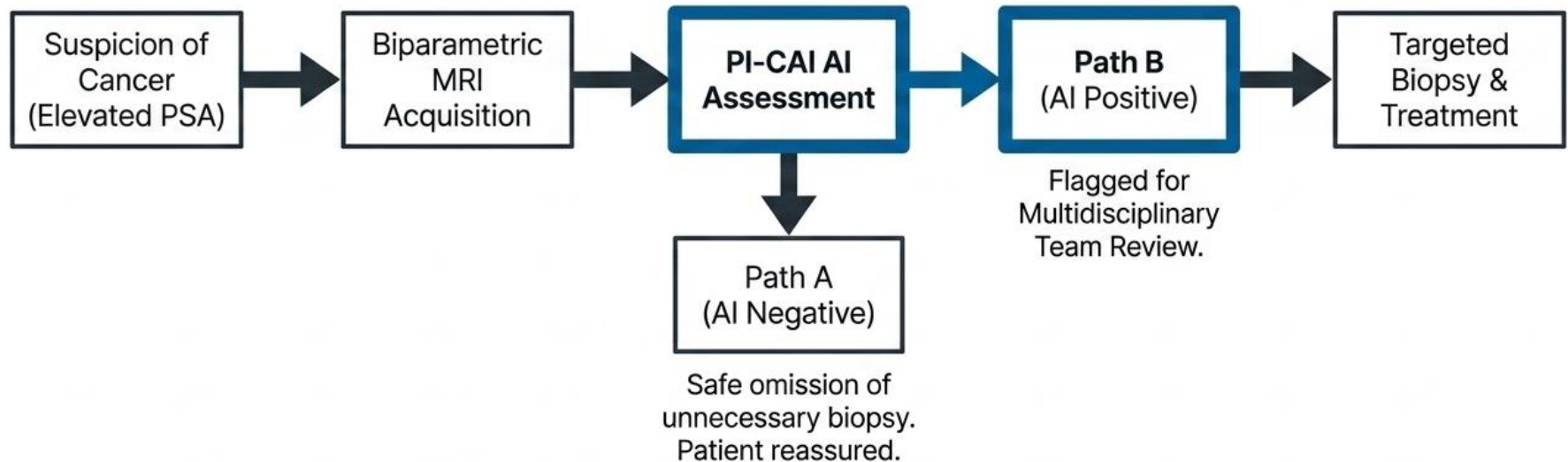


Non-inferiority design



A dedicated AI medical tool matches the performance of multidisciplinary team-supported radiologists in prostate cancer detection and generalises to multiple sites and scanners.

The AI-Assisted Diagnostic Pathway



AI acts as a **high-throughput, high-specificity supportive tool**, augmenting radiologists and drastically **reducing resource strain** at the top of the funnel.

Outline

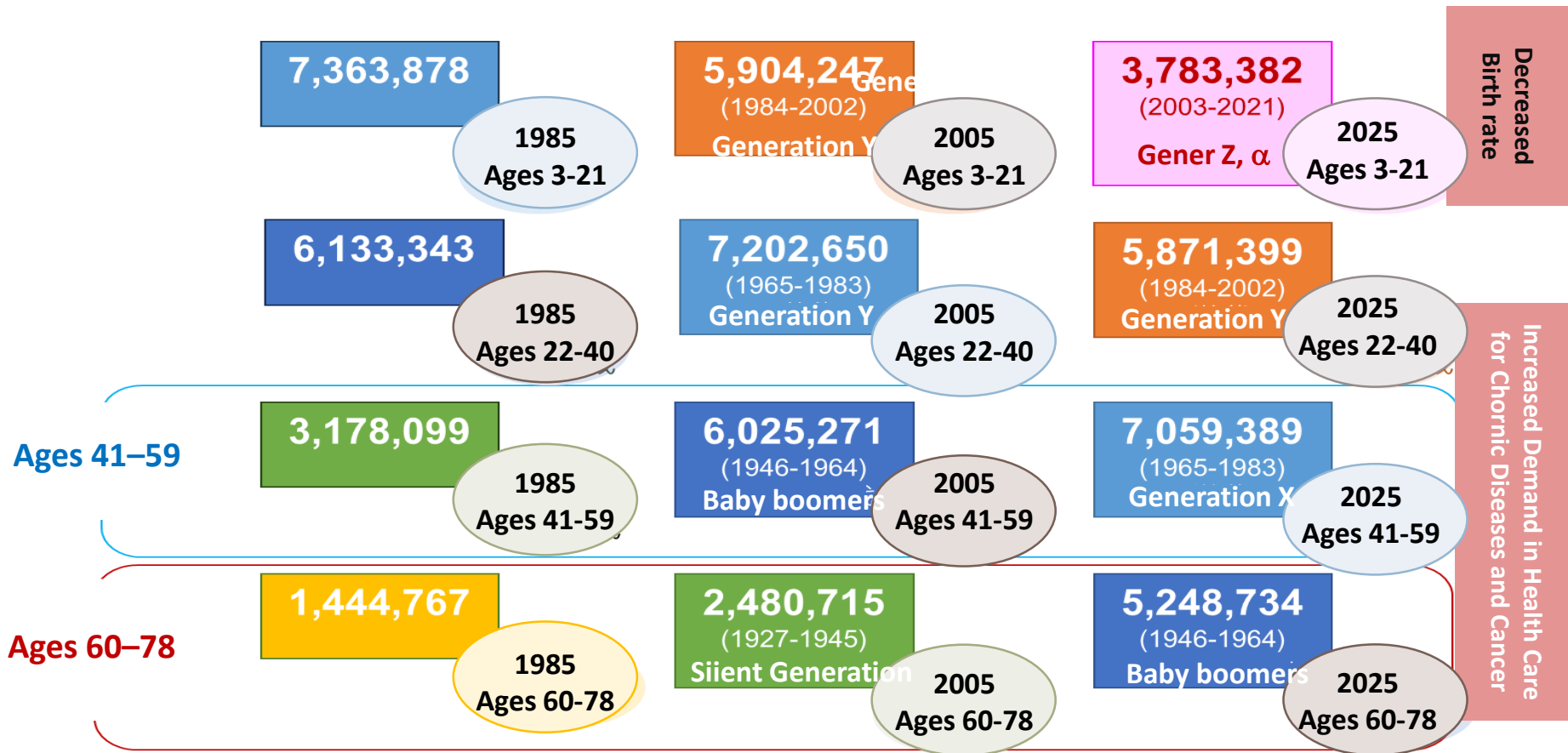
Universal PrCa Screening

Precision PrCa Screening

AI-empowered PrCa Precision Screening

Taiwan's Precision PrCa Screening Initiative

Demographic changes in Taiwan





One-Size-Fits-All vs. Precision Screening: Healthcare Utilization and Cancer Detection

Taiwan Data

PSA	50+
0~0.99	43.5%
1~1.99	27.2%
2~2.99	10.2%
3~3.99	5.5%
4~4.99	3.5%
5~5.99	2.4%
6~6.99	1.6%
7~7.99	1.2%
8~8.99	0.9%
9~9.99	0.7%
10+	3.4%

12-yr period

N ~ 4M male

50-75 y/o

One-Size-Fits-All
(Four-yearly)

➔ 16M screens

Precision interval

➔ 13.6 M screens

↓ 15% PSA screens

PSA	Interval
0~0.99	6-yr based age-aware selective screening
1~1.99	
2~2.99	
3~3.99	4
4~4.99	4
5~5.99	3
6~6.99	3
7~7.99	2
8~8.99	1
9~9.99	1
10+	Intensive Surveillance

One-Size-Fits-All vs. Precision Screening

Healthcare Utilization and Detection of Clinically Significant Cancer

16M PSA screens

12-yr period

13.6M PSA screens

PSA	%	Interval
-----	---	----------

0~0.99	43.5%	6-yr based & age-aware selective screening
1~1.99	27.2%	
2~2.99	10.2%	
3~3.99	5.5%	
4~4.99	3.5%	4
5~5.99	2.4%	3
6~6.99	1.6%	3
7~7.99	1.2%	2
8~8.99	0.9%	1
9~9.99	0.7%	1
10+	3.4%	Intensive Surveillance

2.6M PSA ≥ 4 ng/mL

3.06M
PSA ≥ 3 ng/mL

3-3.99 ng/mL:
DRE/free PSA
 ≥ 4 ng/mL: Biopsy

2.18M biopsy

182,800 GS ≥ 7
406,000 GS < 7

4-10 ng/mL:
PHI
 ≥ 10 ng/mL:
Biopsy

4-10 ng/mL:
AI-enabled mpMRI
 ≥ 10 ng/mL:
Biopsy

↓ 30~50% biopsy

2.5M PHI

1.37M PHI ≥ 35
1.5M biopsy

2.5M mpMRI

0.96M PI-RADS 3+
1.1M biopsy

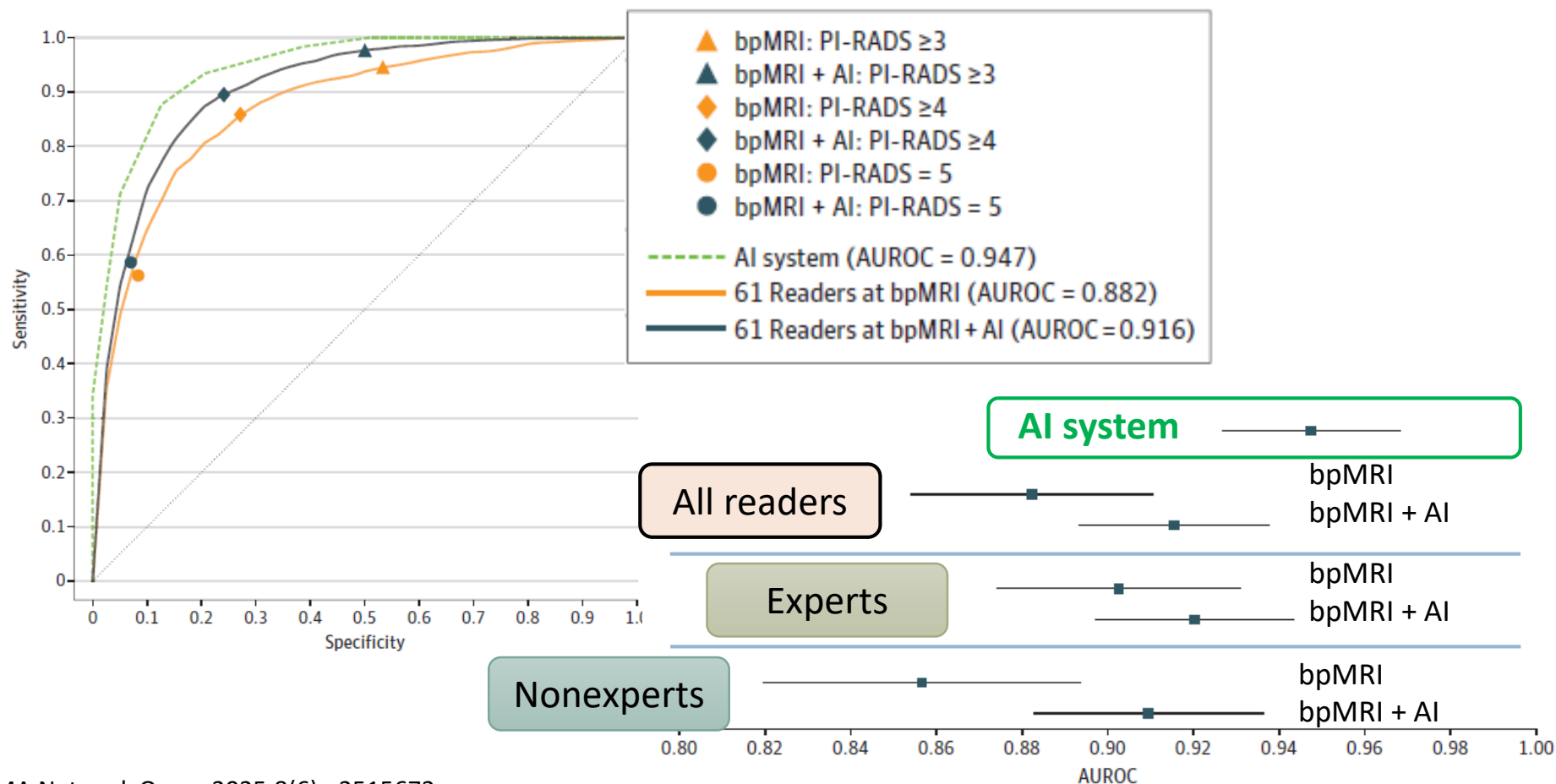
↑ 90~100% HG detection

349,200 GS ≥ 7
174,000 GS < 7

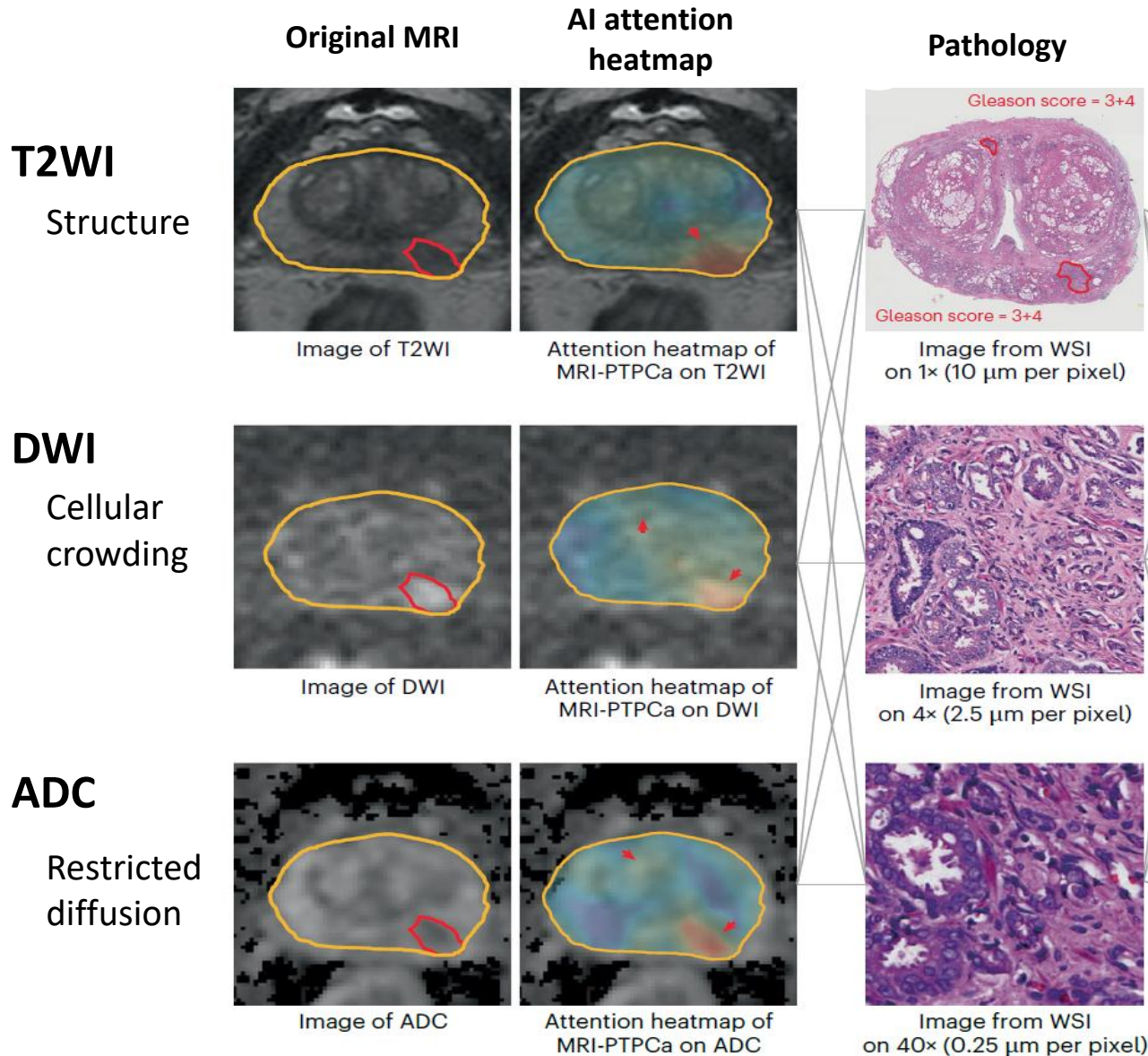
372,800 GS ≥ 7
184,400 GS < 7

AI-Assisted vs Unassisted Identification of Prostate Cancer in Magnetic Resonance Images

Jasper J. Twilt, MSc; Anindo Saha, MSc; Joeran S. Bosma, MSc; Anwar R. Padhani, MD; David Bonekamp, MD; Gianluca Giannarini, MD; Roderick van den Bergh, MD; Veeru Kasivisvanathan, MD; Nancy Obuchowski, PhD; Derya Yakar, MD; Mattijs Elschot, PhD; Jeroen Veltman, MD; Jurgen Fütterer, MD; Henkjan Huisman, PhD; Maarten de Rooij, MD; for the PI-CAI Consortium



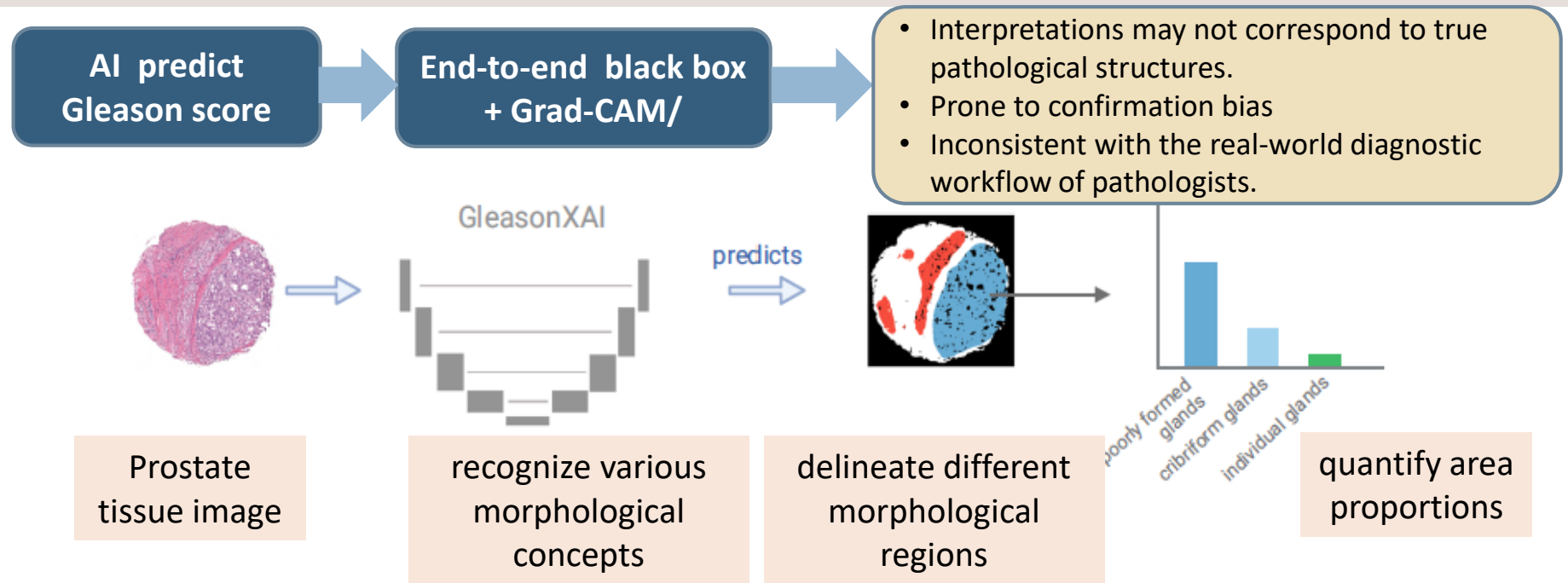
XAI-based non-invasive precision clinical decision-making for PCa



By learning and leveraging key pathology-correlated features in mpMRI, the AI model improves consistency and explainability of grading

Gleason XAI: Morphological Interpretation of PCa

- **Gleason grading:** malignancy judged by the degree of glandular architectural disorder on the slide, forming the Gleason score/ grade group.
- **Morphology:** appearance features that pathologists can name under the microscope (whether glands are fused, cribriform, or poorly formed)

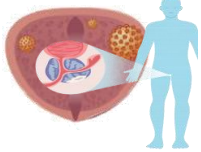


- **Conventional XAI** = end-to-end black-box model + Grad-CAM (post-hoc explanation)
- **Gleason XAI:** first predicts "morphological concepts"
- **Predicted concepts:** poorly formed glands / cribriform glands / well-formed structure

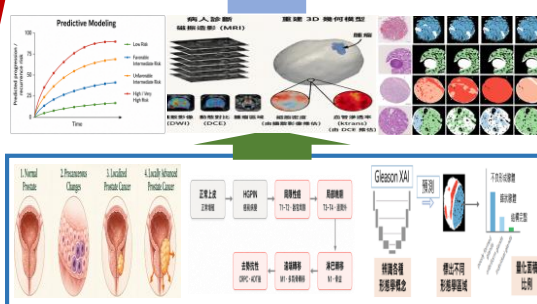
Digital Twin-enabled Adaptive Precision Screening and Surveillance

Physical World

Real Patient with delayed cancer care



Computational World



Virtual World

Virtual Patient

Primary Prevention

Chemoprevention



Environmental Hazard Prevention



Life Style and Behavior Modification

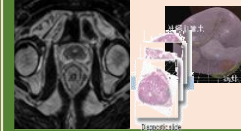


Secondary Prevention

PSA/fPSA/PHI



Image Profile: MRI/Patho



Novel Biomarkers

Molecular biomarkers

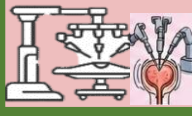


DNA-based biomarkers

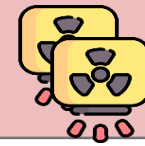


Treatment and Therapy

Surgery/Mini invasive surgery



Radiotherapy



Hormone Therapy



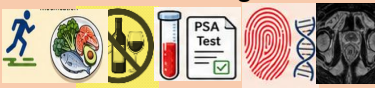
Adjuvant Chemotherapy and Target Therapy



Life Style+ Environment+ PSA Screening



Life Style+PSA+ Genetic Testing+MRI



Life style+Molecular Marker+MRI+Surgery+ Hormone Therapy



Conclusion

1

Universal screening: benefit at a cost

13% lower PCa mortality (ERSPC), but
~60% overdiagnosis

2

Precision screening does better

PSA + genetic risk tailor start age and
interval; more cost-effective

3

AI + digital twins personalize it

AI reads MRI at expert level; digital
twins evaluate screening at the person
level

Taiwan projection

4M men, 50–75 y, 12 years

↓15% PSA screens

↓30–50% biopsies

~2× high-grade
cancers found

↓55% low-grade
overdiagnosis

Take-home: find more cancers that matter, with fewer tests and less overdiagnosis



Thank you for your attention!

