

# Intuitionistic Fuzzy Nomograms for Prostate Cancer Patients

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# Problem Statement

- Prostate cancer complications:
  - second most frequent solid cancer, fourth leading cause of cancer-related death in men worldwide
  - approximately 1.5 million cases per year, over 400 000 deaths in 2024
  - projection for 2050, to reach 2.9 million cases per year, annual mortality of 0.92 million.
- Clinical course varies considerably:
  - making the interpretation of long-term outcomes an important part of care after treatment
  - radical prostatectomy is a treatment option for selected patients with localized or locally advanced disease, other treatment options available
  - examination of the surgical specimen provides information on tumour grade, pathological stage,  
lymph-node involvement, and surgical margins can inform postoperative assessment
  - overall survival vs. cancer-related survival



# Our Research Goals

- Instrumentalize the theory of IFSs for better modelling of the inherent uncertainty involved in medical decision making
- Create an IF variant of the nomograms, more specifically, create prostate cancer nomograms, thus giving a prognostic model estimating the 5- and 10-year life expectancy in prostate cancer patients with radical prostatectomy (RP)
- Develop a software tool supporting medical specialists to build prognostic models estimating the 5- and 10-year life expectancy in prostate cancer patients after definitive surgical treatment (RP)



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# Patient Dataset and Observed Outcomes

- The case study in this paper is based on postoperative patient records from University Hospital “Tsaritsa Yoanna – ISUL”, Sofia, Bulgaria.
- The clinical material includes patient characteristics and separately documented survival and follow-up information after radical prostatectomy.
- We use 58 records for which the variables required by the present demonstration and a recorded follow-up duration are available.
- For all 58 patients, the reported survival years are clinical observations as of April 2026.
- Several preoperative and postoperative variables are recorded for all 58 patients.

# Patient data and observed outcomes

- The following available pre- and postoperative variables are recorded:

| Indicator              | Recorded values or groups (number of patients)    |
|------------------------|---------------------------------------------------|
| Age (years)            | $< 60$ : 12; $60-69$ : 36; $\geq 70$ : 10         |
| Preoperative PSA       | $\leq 10$ : 20; $> 10-20$ : 24; $> 20$ : 14       |
| Gleason score          | 2: 1; 3: 2; 4: 3; 5: 10; 6: 15; 7: 15; 8: 7; 9: 5 |
| pT category            | T2a: 15; T2b: 15; T2c: 3; T3a: 8; T3b: 13; T4: 4  |
| pN                     | 0: 0; 1: 14                                       |
| Surgical margin R      | 0: 47; 1: 11                                      |
| SEER extent of disease | 1, local (S1): 31; 2, regional (S2): 27           |

# Software

The developed software tool connects three graphical views:

- an intuitionistic fuzzy nomogram of recorded subgroup outcome ranges,
- their corresponding exploratory Kaplan–Meier curves, and
- an interactive classical point nomogram, featuring a second layer uncertainty recording.

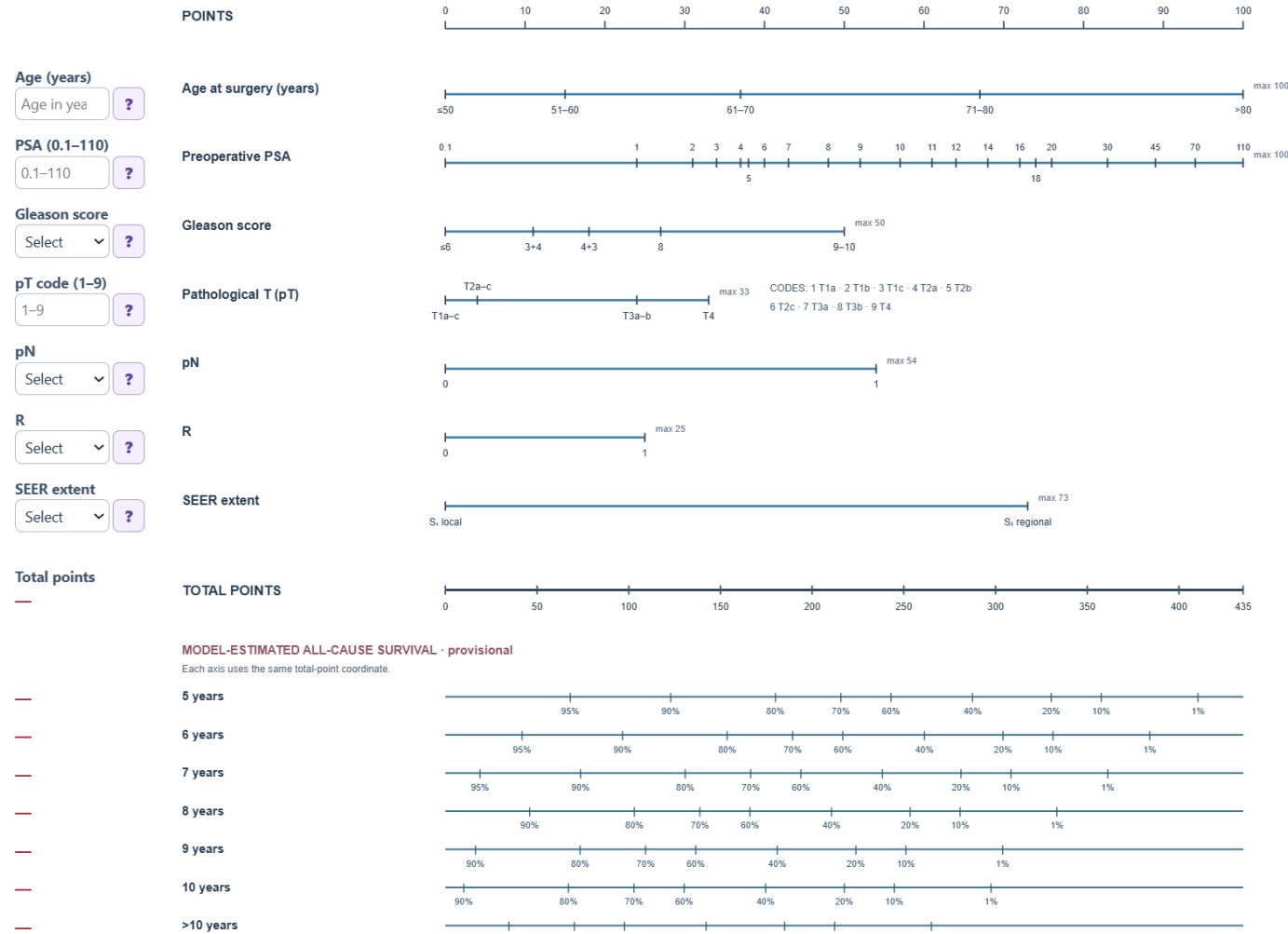


<https://biomed.bas.bg/en/projects/kp-06-n43-7/software/>

# Classical Point Nomogram

## CLASSICAL POINT NOMOGRAM · EXPLORATORY

Seven indicators · original score knots retained · illustrative overall survival calibration



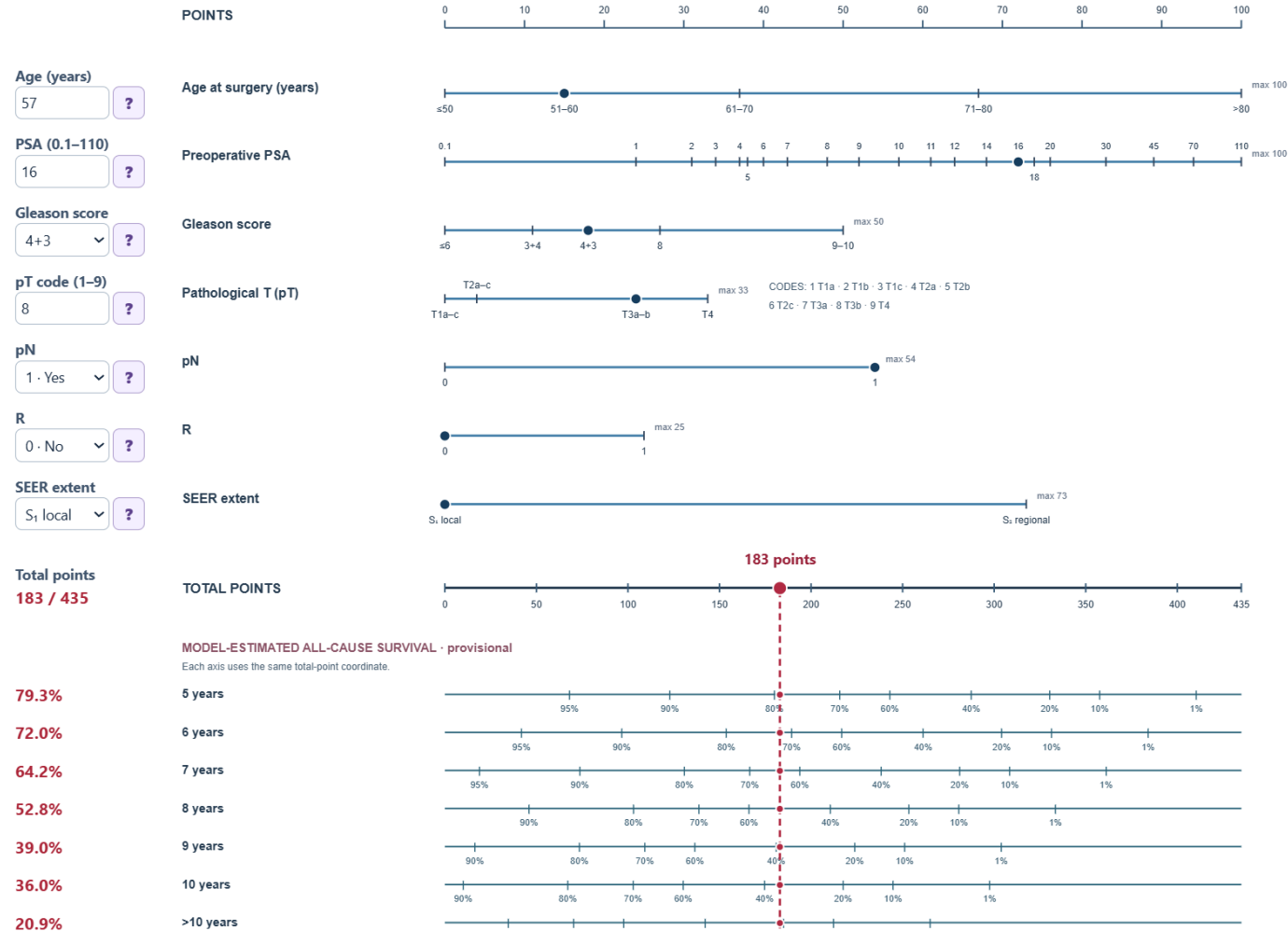
Variable weights draw on published nomograms and clinicians' expertise.

Total-score-to-survival mapping is estimated from the 58 real patient records using ridge-penalized Cox regression and the Breslow baseline hazard estimator.

# Classical Point Nomogram

## CLASSICAL POINT NOMOGRAM · EXPLORATORY

Seven indicators · original score knots retained · illustrative overall survival calibration



Complete information provided

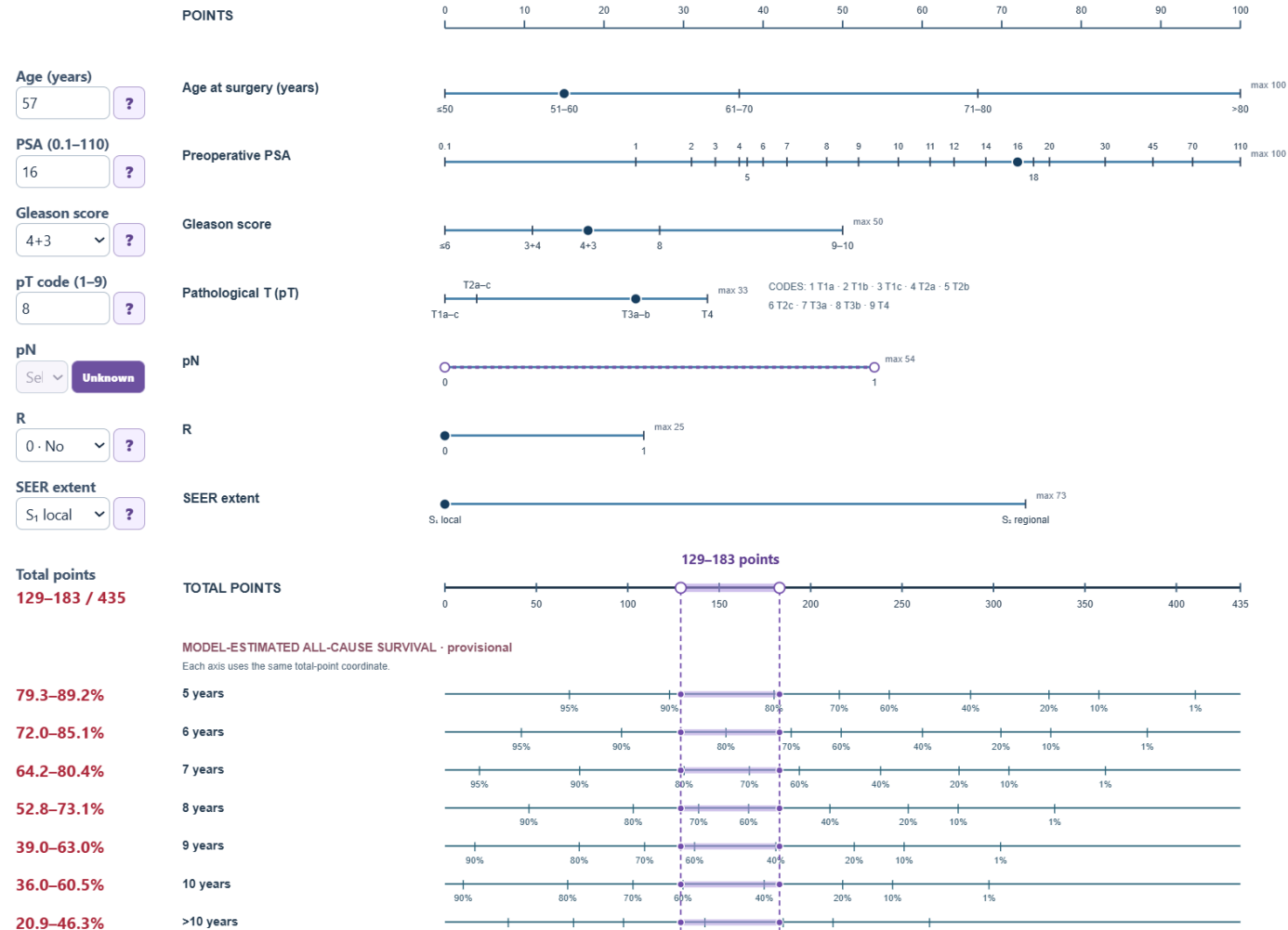
Precise total points score

Numerical life expectancy

# Classical Point Nomogram

## CLASSICAL POINT NOMOGRAM · EXPLORATORY

Seven indicators · original score knots retained · illustrative overall survival calibration



Incomplete information provided

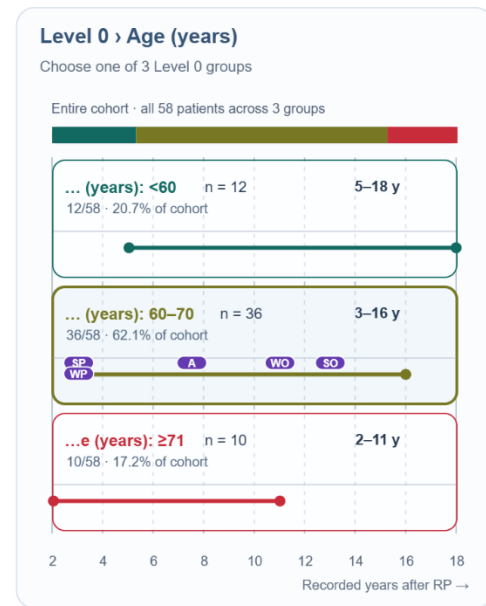
Intervalized total points score

Intervalized life expectancy

# Intuitionistic Fuzzy Nomogram

## IF Nomogram

Recorded years after surgery, up to death or last observation; shared axis, 2–18 years.



## IF PAIRS FOR THE ORIGINAL LINES

Bulgarian cohort ·  $\tau_0 = 0$  y ·  $\sigma_0 = 20$  y · selected: Age (years): 60–70

Original-line limits use all recorded follow-up, including censored observations.

### S1 – local · original line

n = 31;  $\tau = 4$  y;  $\sigma = 18$  y

mu = 0.200 nu = 0.100 pi = 0.700

### S2 – regional · original line

n = 27;  $\tau = 2$  y;  $\sigma = 16$  y

mu = 0.100 nu = 0.200 pi = 0.700

### Selected: Age (years): 60–70

n = 36;  $\tau = 3$  y;  $\sigma = 16$  y

mu = 0.150 nu = 0.200 pi = 0.650

## IF PROGNOSTIC EVALUATIONS · SELECTED BRANCH

Completed durations (deaths): n = 28; 8 censored excluded.

$\tau = 3$ , first/last mode = 3/11, median = 7.5,  $\sigma = 13$  years.

Five evaluations · median lies between the first and last modal times (equality allowed).

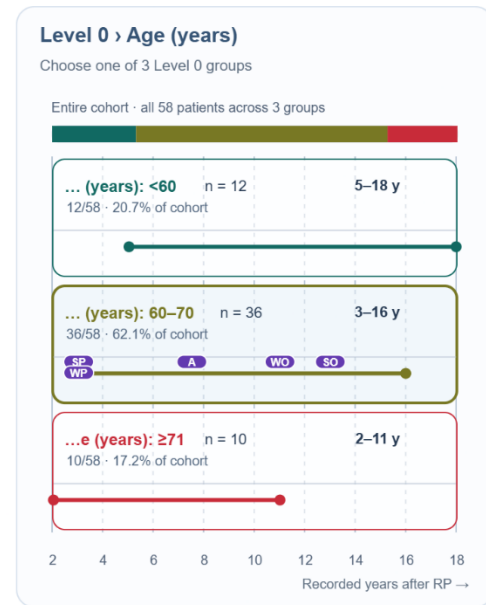
| Evaluation         | Time  | mu, nu                | pi    |
|--------------------|-------|-----------------------|-------|
| Strong pessimistic | 3 y   | mu = 0.000 nu = 0.850 | 0.150 |
| Weak pessimistic   | 3 y   | mu = 0.150 nu = 0.850 | 0.000 |
| Average            | 7.5 y | mu = 0.150 nu = 0.450 | 0.400 |
| Weak optimistic    | 11 y  | mu = 0.550 nu = 0.350 | 0.100 |
| Strong optimistic  | 13 y  | mu = 0.650 nu = 0.000 | 0.350 |

IF membership, non-membership and indeterminacy are not overall survival probabilities.

# Intuitionistic Fuzzy Nomogram

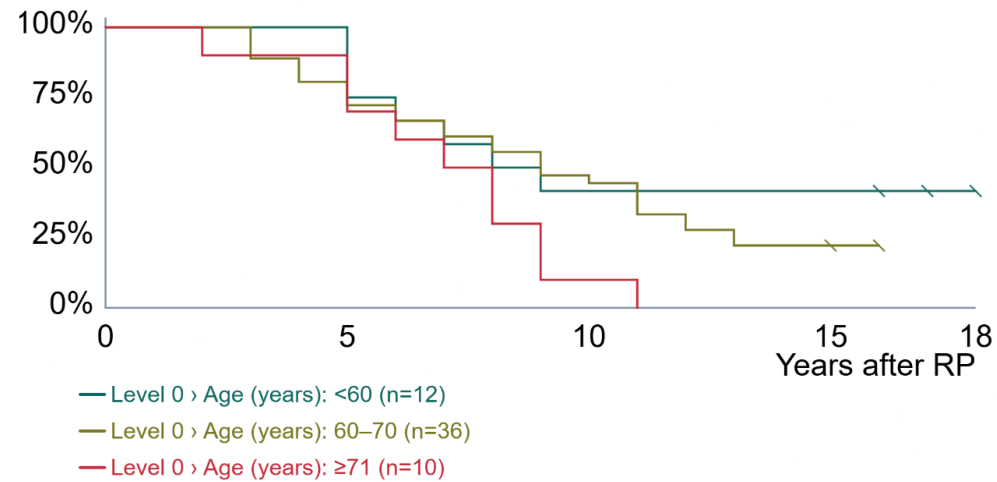
## IF Nomogram

Recorded years after surgery, up to death or last observation; shared axis, 2–18 years.



Exploratory overall survival › provisional

Kaplan—Meier curves



Number at risk, just before each year

Level 0 › Age (years): <60

Level 0 › Age (years): 60–70

Level 0 › Age (years): ≥71

| 5 y | 6 y | 7 y | 8 y | 9 y | 10 y | >10 y |
|-----|-----|-----|-----|-----|------|-------|
| 12  | 9   | 8   | 7   | 6   | 5    | 5     |
| 29  | 26  | 24  | 22  | 20  | 17   | 16    |
| 9   | 7   | 6   | 5   | 3   | 1    | 1     |

# Intuitionistic Fuzzy Nomogram

## IF Nomogram

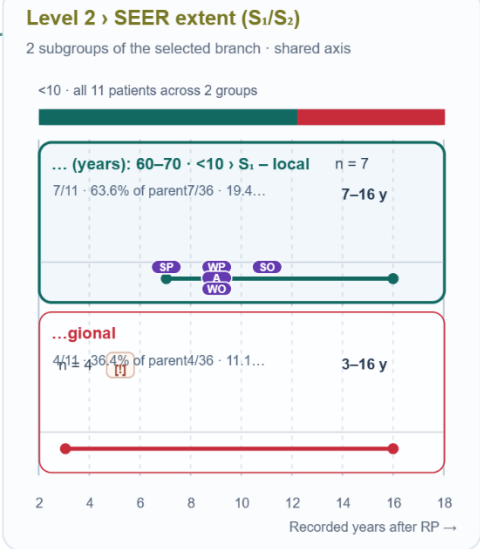
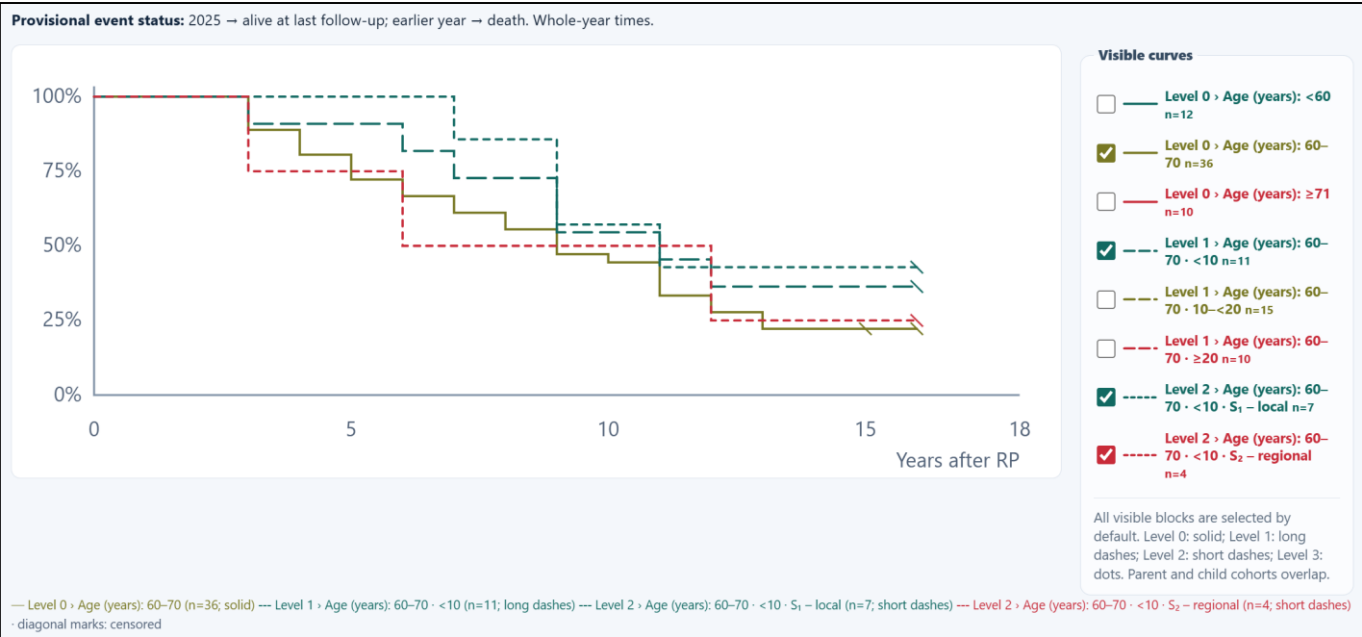
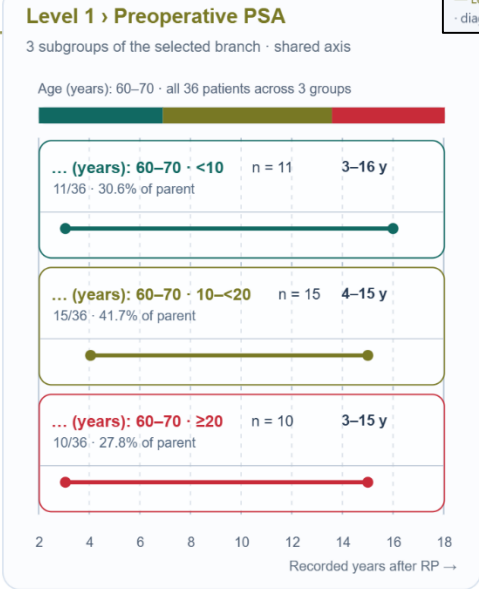
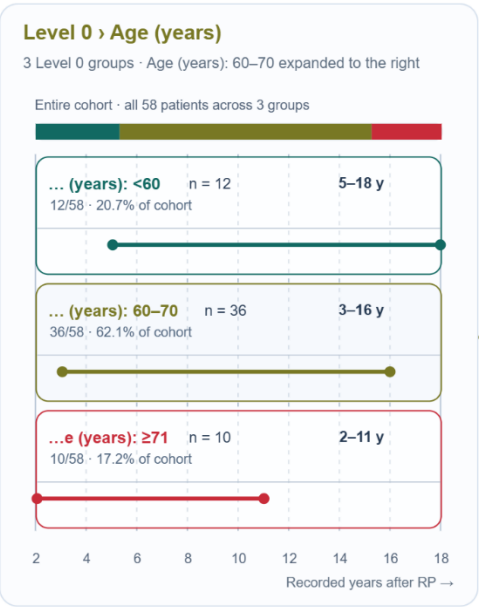
Recorded years after surgery, up to death or last observation; shared axis, 2–18 years.



# Intuitionistic Fuzzy

## IF Nomogram

Recorded years after surgery, up to death or last observation; shared axis, 2–18 years.



Five evaluations · median lies between the first and last modal times .

| IF evaluation      | Time | $\langle \mu, \nu \rangle$     | $\pi$ |
|--------------------|------|--------------------------------|-------|
| Strong pessimistic | 7 y  | $\langle 0.000, 0.650 \rangle$ | 0.350 |
| Weak pessimistic   | 9 y  | $\langle 0.350, 0.550 \rangle$ | 0.100 |
| Average            | 9 y  | $\langle 0.450, 0.550 \rangle$ | 0.000 |
| Weak optimistic    | 9 y  | $\langle 0.450, 0.450 \rangle$ | 0.100 |
| Strong optimistic  | 11 y | $\langle 0.550, 0.000 \rangle$ | 0.450 |

# Interactive Demo



Intuitionistic Fuzzy Nomogram Explorer  
(Research prototype • version 3.1.1)

[https://biomed.bas.bg/en/projects/  
kp-06-n43-7/software/](https://biomed.bas.bg/en/projects/kp-06-n43-7/software/)

The background of the slide is a complex, artistic composition. On the left side, there is a stylized, semi-transparent illustration of a prostate gland in shades of orange and red. Overlaid on this and extending across the entire slide are numerous thin, curved lines in blue and red, which connect various small, semi-transparent circular nodes of the same colors. These lines and nodes create a network-like or molecular structure, suggesting themes of biology, medicine, or complex systems. The overall color palette is dominated by deep blues and purples, with the orange/red of the prostate providing a focal point.

Thank you for your attention!

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