Expert knowledge and data-driven Bayesian Networks to predict post-RT dyspnea and 2-year survival

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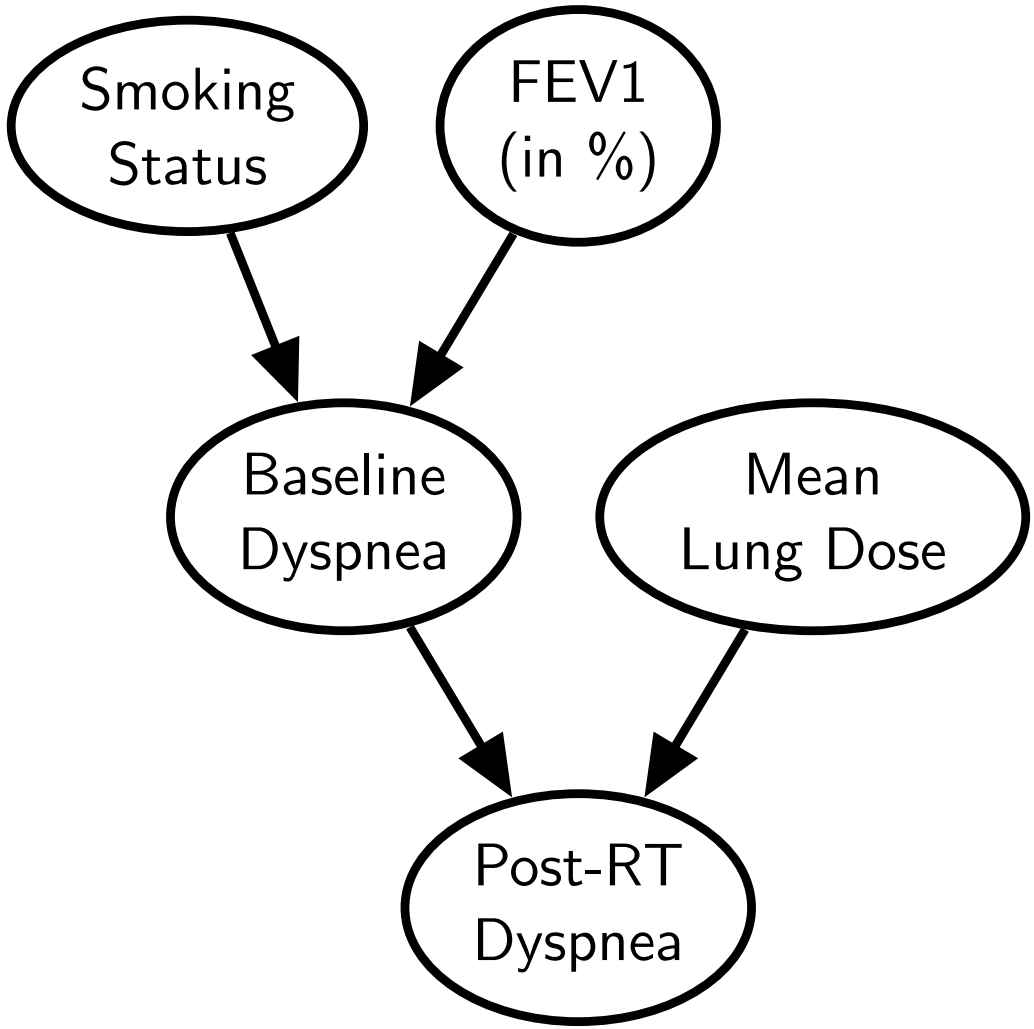
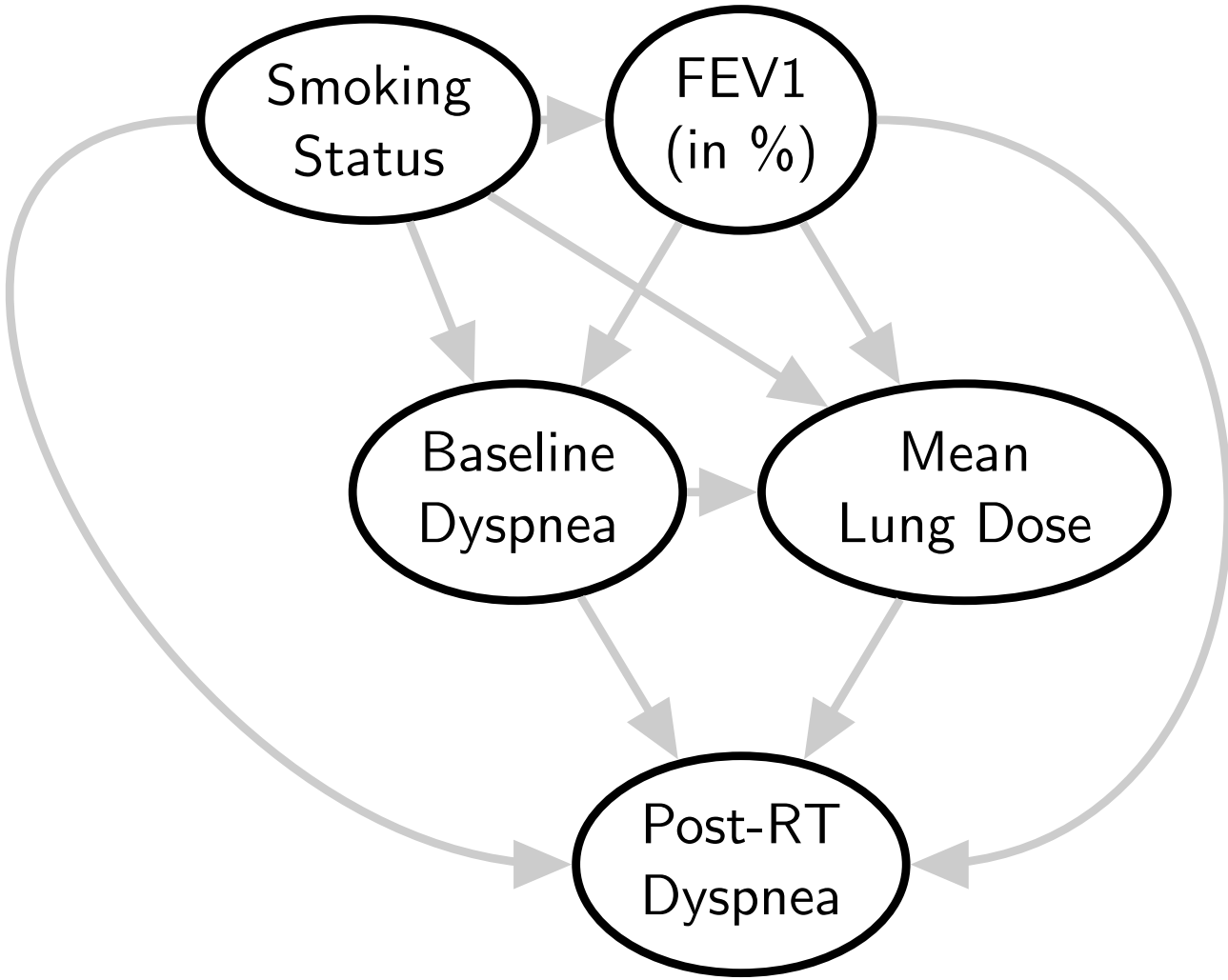
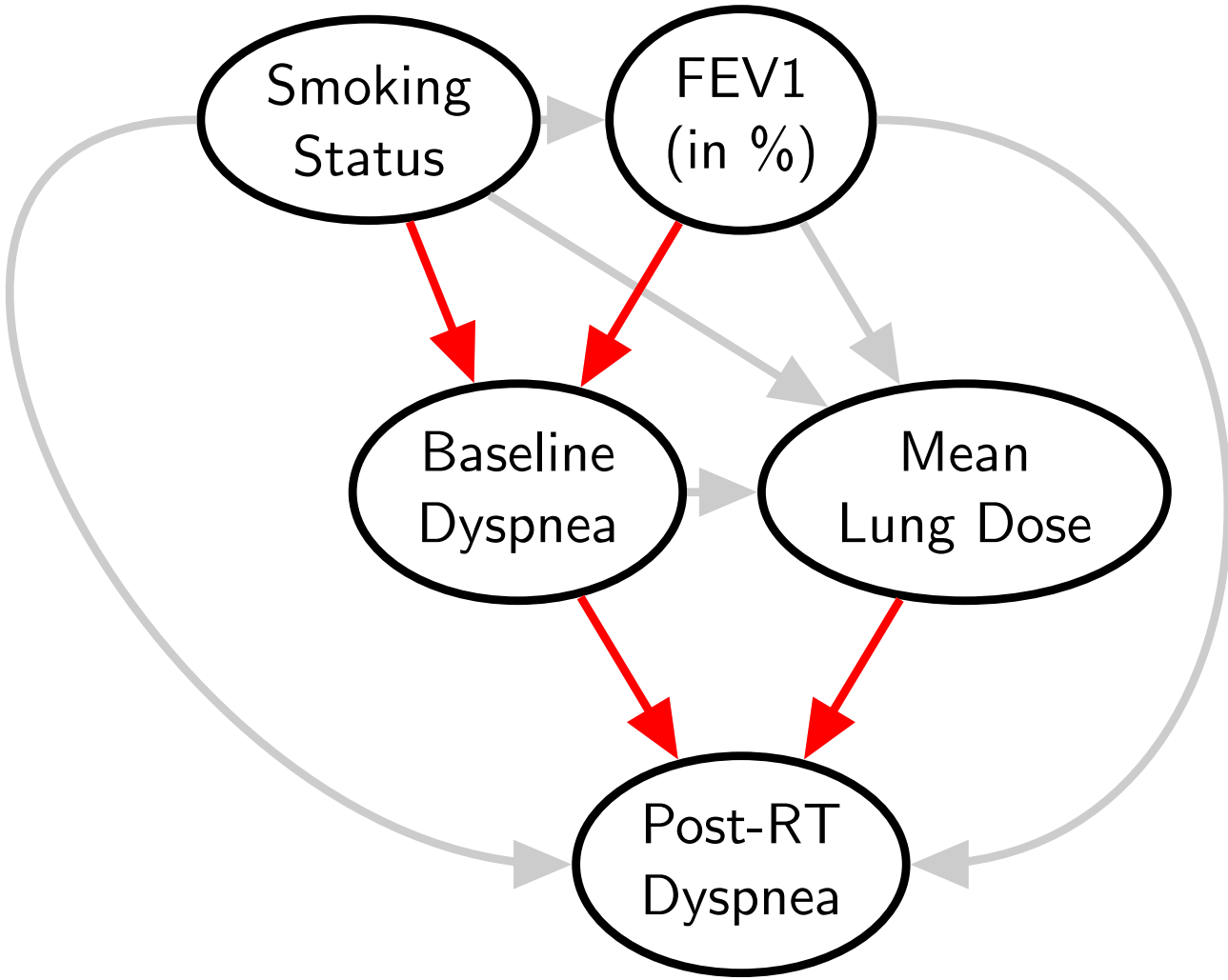
Example: Bayesian Network



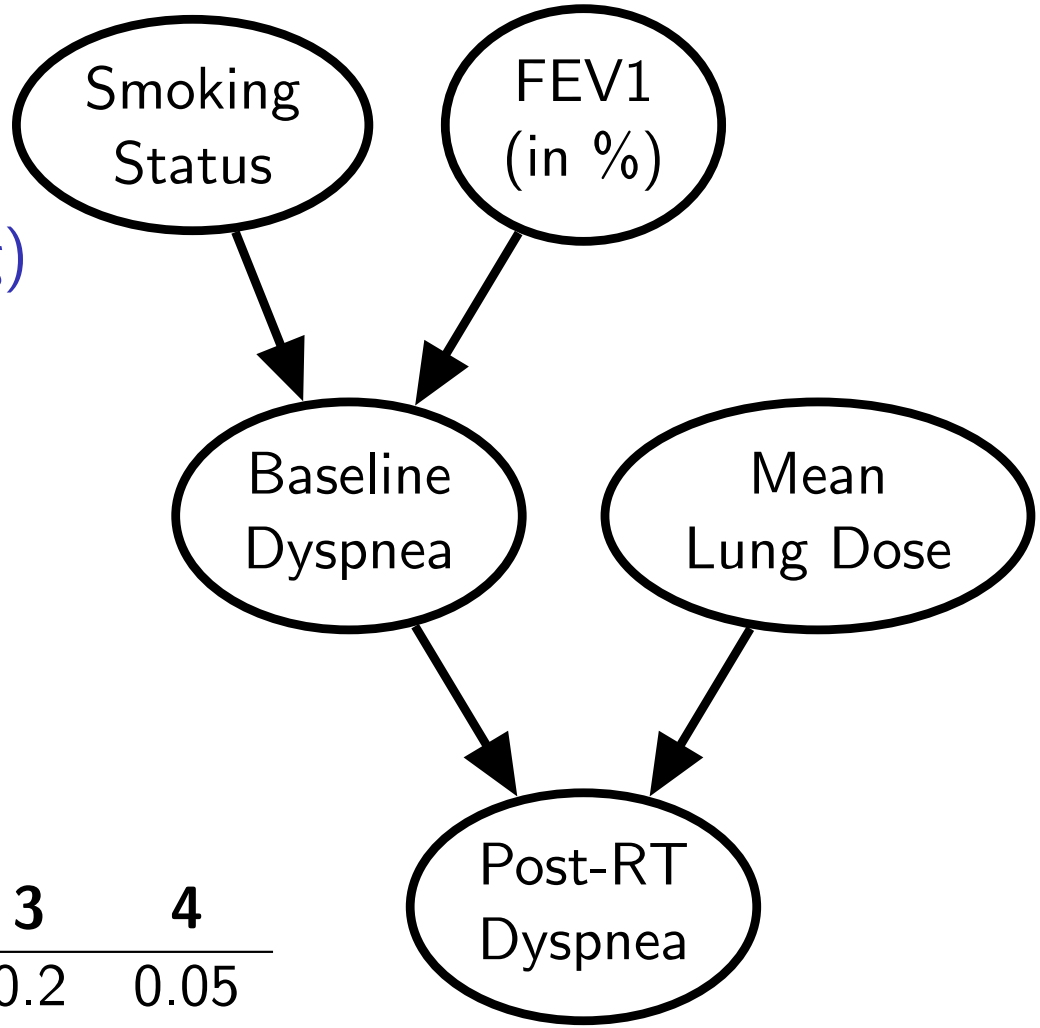
Step 1: Structure Learning



Step 1: Structure Learning



Step 2: Prediction Learning



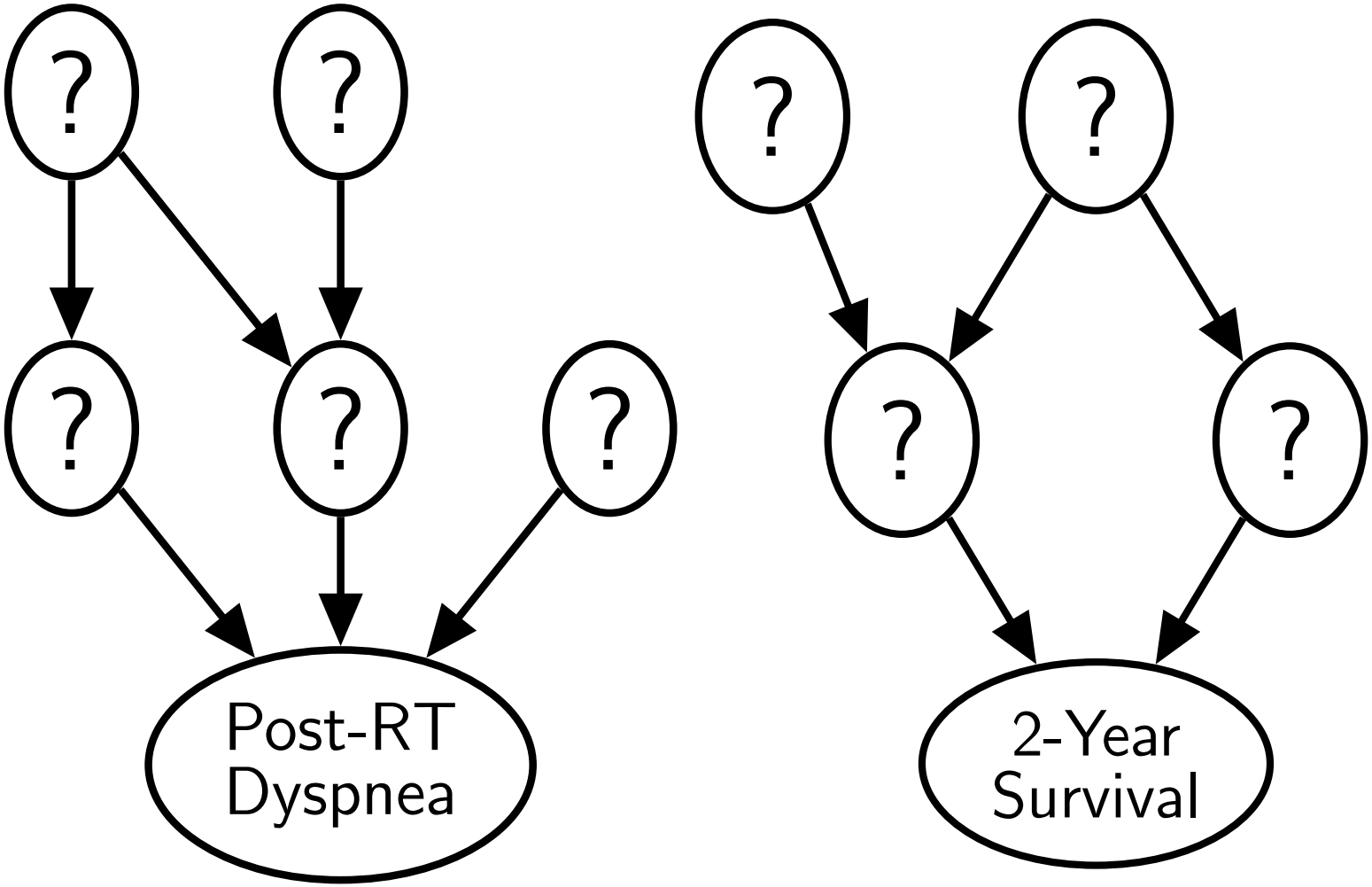
Prob(B. Dysp.|Smoking)

	0	**1**
0	0.6	0.3
1	0.2	0.3
2	0.1	0.2
3	0.1	0.2

Prob(Dysp.|B. Dysp.)

	0	**1**	**2**	**3**	**4**
$< \mathbf{2}$	0.9	0.8	0.3	0.2	0.05
$\geq \mathbf{2}$	0.1	0.2	0.7	0.8	0.95

Target Nodes



Patient Data

2-Year Survival (452 patients)	Dyspnea ≥ 2 (994 patients)
(Chemo-)radiotherapy	(Chemo-)radiotherapy
Curative treatment	Curative treatment
Primary tumor	Primary tumor
NSCLC	NSCLC & SCLC
No surgery	With & without surgery
	Baseline Dyspnea < 2

Missing data is commonplace!

Stratified data split

80% training
20% validation

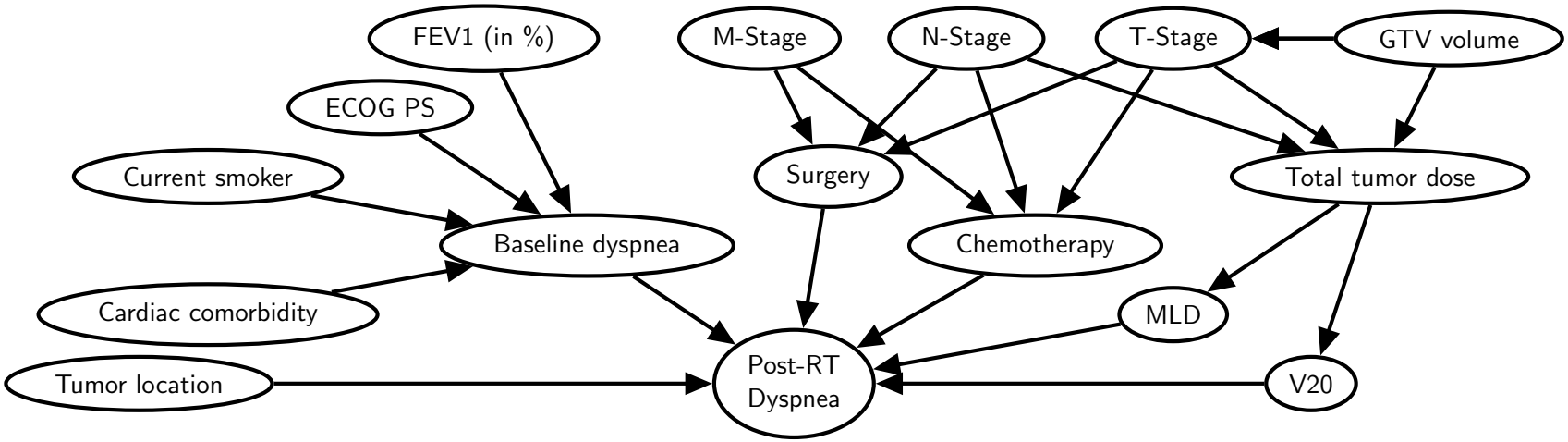
Patient Data

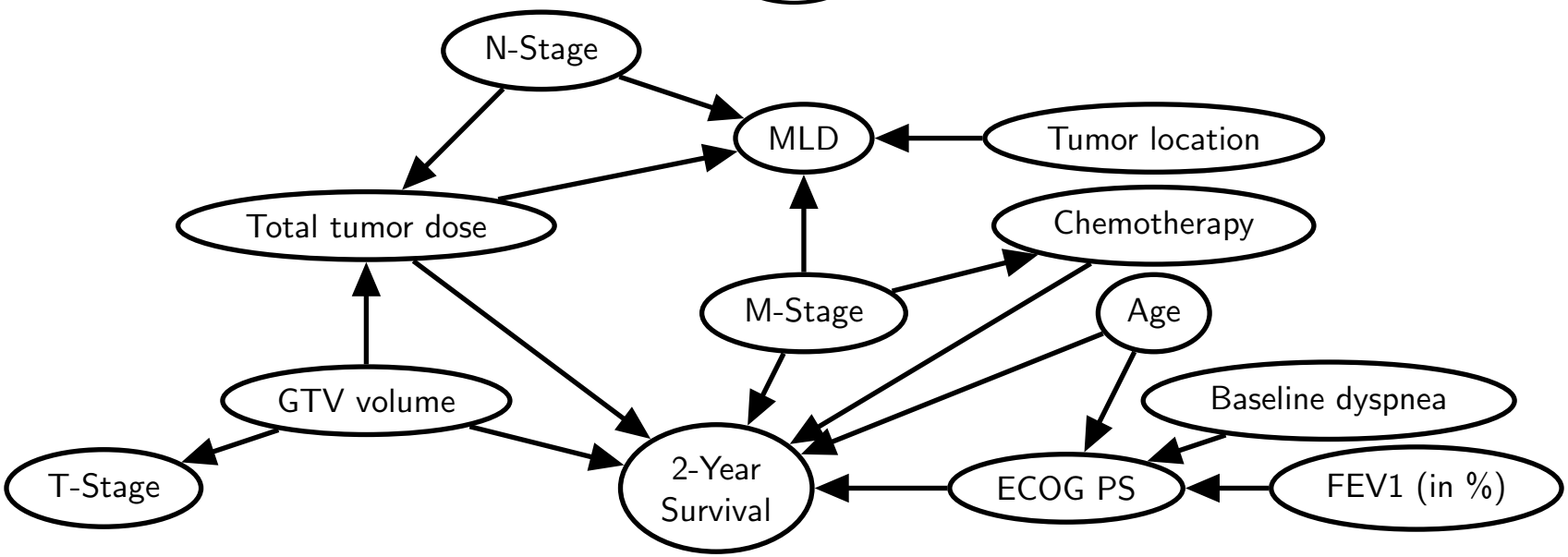
Demographics	Clinical Variables	Disease Variables	Treatment Variables
Age	ECOG PS	Histology	Surgery
Gender	FEV1 (in %)	Tumor Location	Chemotherapy
Smoking Status	Baseline Dyspnea	T-Stage	Modality
		N-Stage	Treatment Time
		M-Stage	Mean Lung Dose
		GTV Volume	$V_{20\%}$
			Tumor Dose

"How do you model dependencies between clinical variables?"

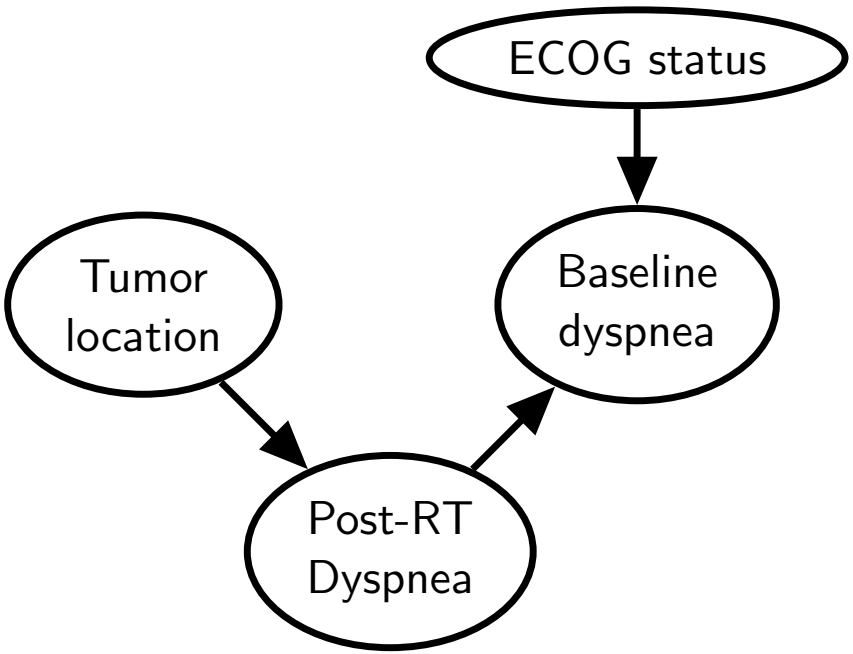
- 10 experts from 5 countries
  - 7 radiation oncologists
  - 3 researchers

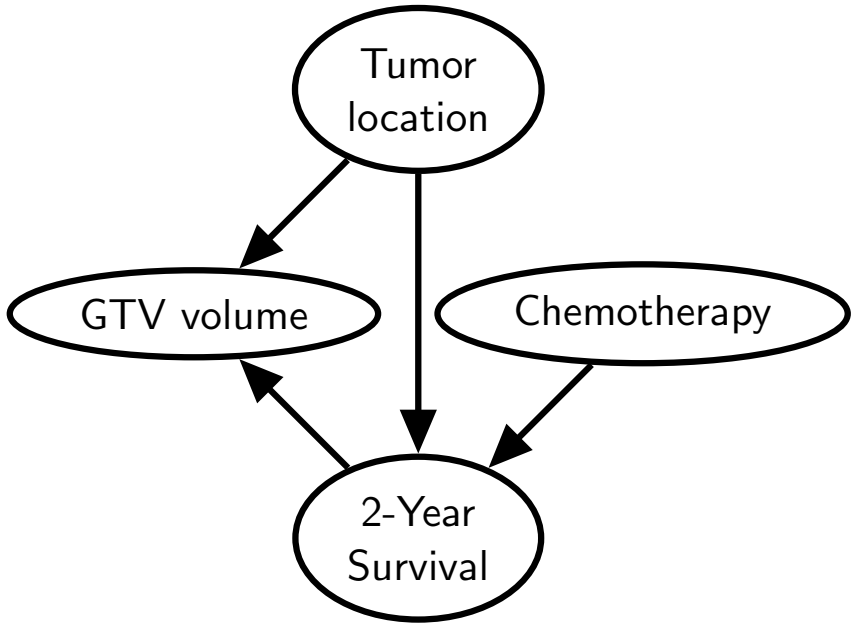
Expert Answers





Algorithm Output





Post-RT Dyspnea ≥ 2

		AUC
Expert	1	0.58
	2	0.61
	3	0.49
	4	0.59
	5	0.65
	6	0.69
	7	0.57
Alg		0.52

[1] Confidence intervals based on 1000 bootstraps

Post-RT Dyspnea ≥ 2

		AUC	AUC 95% CI[1]
Expert	1	0.58	[0.42,0.73]
	2	0.61	[0.43,0.77]
	3	0.49	[0.32,0.65]
	4	0.59	[0.45,0.73]
	5	0.65	[0.5,0.8]
	6	0.69	[0.56,0.83]
	7	0.57	[0.43,0.7]
Alg		0.52	[0.38,0.66]

[1] Confidence intervals based on 1000 bootstraps

Post-RT Dyspnea ≥ 2

		AUC	AUC 95% CI[1]	AUC-AUC$_{Alg}$ 95% CI[1]
Expert	1	0.58	[0.42,0.73]	[-0.07,0.22]
	2	0.61	[0.43,0.77]	[-0.14,0.32]
	3	0.49	[0.32,0.65]	[-0.19,0.15]
	4	0.59	[0.45,0.73]	[-0.06,0.22]
	5	0.65	[0.5,0.8]	[-0.05,0.32]
	6	0.69	[0.56,0.83]	[-0.03,0.39]
	7	0.57	[0.43,0.7]	[-0.08,0.2]
Alg		0.52	[0.38,0.66]	[0,0]

[1] Confidence intervals based on 1000 bootstraps

Post-RT Dyspnea ≥ 2

		AUC	AUC 95% CI[1]	AUC-AUC$_{Alg}$ 95% CI[1]	# Arcs	# Dep.
Expert	1	0.58	[0.42,0.73]	[-0.07,0.22]	30	10
	2	0.61	[0.43,0.77]	[-0.14,0.32]	9	9
	3	0.49	[0.32,0.65]	[-0.19,0.15]	23	7
	4	0.59	[0.45,0.73]	[-0.06,0.22]	22	6
	5	0.65	[0.5,0.8]	[-0.05,0.32]	20	5
	6	0.69	[0.56,0.83]	[-0.03,0.39]	14	5
	7	0.57	[0.43,0.7]	[-0.08,0.2]	7	2
Alg		0.52	[0.38,0.66]	[0,0]	6	2

[1] Confidence intervals based on 1000 bootstraps

2-Year Survival

		AUC
Expert	1	0.59
	2	0.65
	3	0.69
	4	0.56
	5	0.53
	6	0.64
	7	0.68
Alg		0.72

[1] Confidence intervals based on 1000 bootstraps

2-Year Survival

		AUC	AUC 95% CI[1]
Expert	1	0.59	[0.48,0.70]
	2	0.65	[0.54,0.76]
	3	0.69	[0.58,0.80]
	4	0.56	[0.44,0.68]
	5	0.53	[0.40,0.65]
	6	0.64	[0.53,0.75]
	7	0.68	[0.57,0.82]
Alg		0.72	[0.60,0.82]

[1] Confidence intervals based on 1000 bootstraps

2-Year Survival

		AUC	AUC 95% CI[1]	AUC-AUC$_{Alg}$ 95% CI[1]
Expert	1	0.59	[0.48,0.70]	[-0.27,0.01]
	2	0.65	[0.54,0.76]	[-0.21,0.07]
	3	0.69	[0.58,0.80]	[-0.13,0.10]
	4	0.56	[0.44,0.68]	[-0.32,-0.01]
	5	0.53	[0.40,0.65]	[-0.36,-0.01]
	6	0.64	[0.53,0.75]	[-0.21,0.05]
	7	0.68	[0.57,0.82]	[-0.19,0.12]
Alg		0.72	[0.60,0.82]	[0,0]

[1] Confidence intervals based on 1000 bootstraps

2-Year Survival

		AUC	AUC 95% CI[1]	AUC-AUC$_{Alg}$ 95% CI[1]	# Arcs	# Dep.
Expert	1	0.59	[0.48,0.70]	[-0.27,0.01]	19	10
	2	0.65	[0.54,0.76]	[-0.21,0.07]	15	7
	3	0.69	[0.58,0.80]	[-0.13,0.10]	17	6
	4	0.56	[0.44,0.68]	[-0.32,-0.01]	23	8
	5	0.53	[0.40,0.65]	[-0.36,-0.01]	13	7
	6	0.64	[0.53,0.75]	[-0.21,0.05]	16	6
	7	0.68	[0.57,0.82]	[-0.19,0.12]	20	11
Alg		0.72	[0.60,0.82]	[0,0]	4	3

[1] Confidence intervals based on 1000 bootstraps

Summary

- Experts & algorithm fail to predict dyspnea

  $\Rightarrow$ **New biomarkers needed**

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- Experts & algorithm fail to predict dyspnea

  $\Rightarrow$ **New biomarkers needed**

- Algorithm predicts survival (slightly) better

- Simpler models yield the same or better results

- Experts' complex systems not reflected in data
  - Overestimated effects?
  - Too complex for available data

  $\Rightarrow$ **Share data**

Thank you for your attention!

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