A COMPARATIVE STUDY OF PARAMETRIC AND AI-ENHANCED NONPARAMETRIC RELIABILITY ESTIMATORS IN ONCOLOGY SURVIVAL MODELS

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Outline

Introduction

Reliability in Medical Context

- R = P(Strength > Stress) $R = P(X > Y)$
- X = strength (patient survival time) Y = stress (risk / treatment burden)
- Classical in Engineering, Evolving in Medicine
- AI-enhanced survival modeling = better decisions

- **Applications of R:** • Engineering: material strength, mechanical failure
  - Medicine: comparing survival time vs treatment burden

Measurement Requirement

X and Y must be in the same unit

Examples:

Time vs Time

Dose vs Dose

Pressure vs Pressure

Motivation & Research Gap

1. Classical methods assume specific distributions

2. Real survival data violates assumptions

3. AI methods add flexibility

4. Need a combined hybrid approach

Practical Limitation (Middle East Servers)

- DeepSurv and several survival AI models cannot run on most Middle Eastern servers
- They require U.S./European GPU-based cloud infrastructure
- Therefore, we used methods that can run locally : RSF (ranger)— GBM–Cox

Methods Overview (Merged)

Empirical (Classical)

ECDF(X) + Kernel PDF(Y)

RSF (AI, ranger)

Survival trees

Handles nonlinear patterns

GBM–Cox (AI)

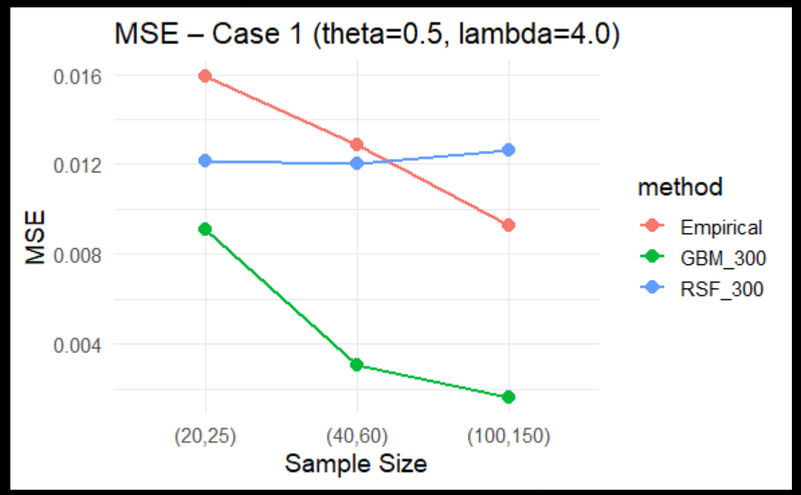
Boosted Cox

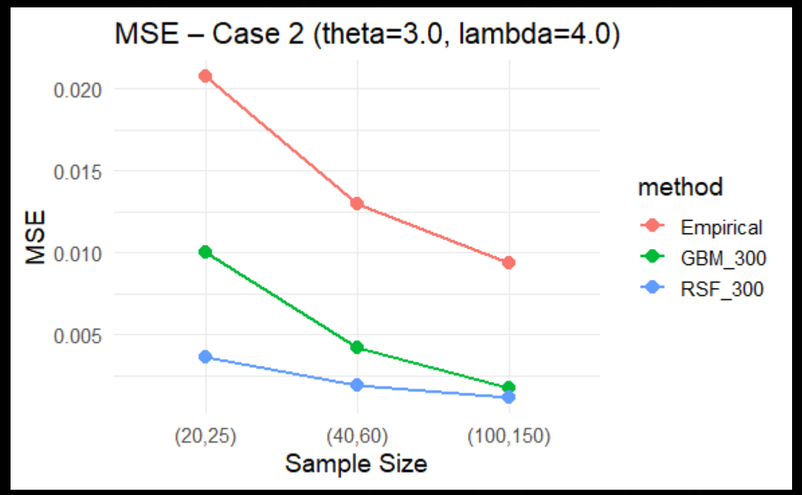
Strong predictive performance

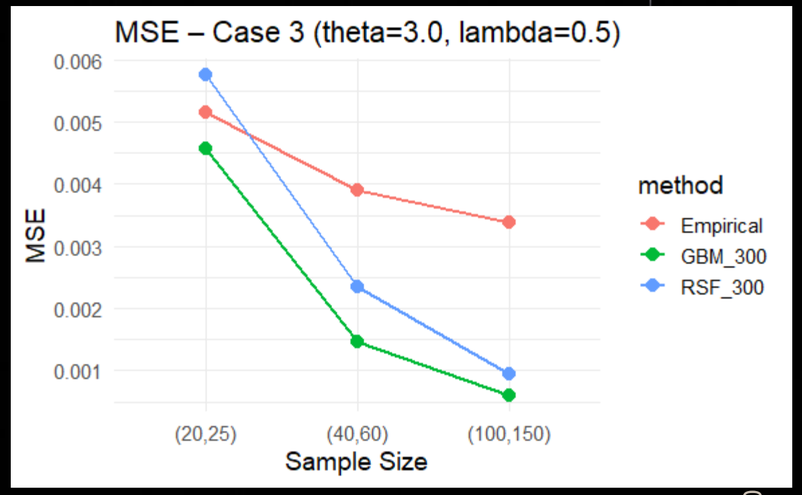
Simulation Setup

- Distributions: Exponential & Weibull
- Three sample sizes
- Replications: N simulations per case
- AI models use 300 trees
- Evaluation metric: MSE only

Exponential Results (MSE)

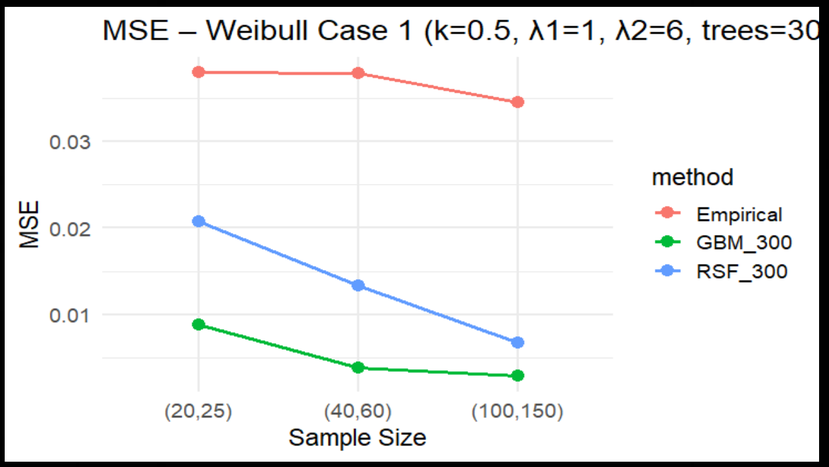


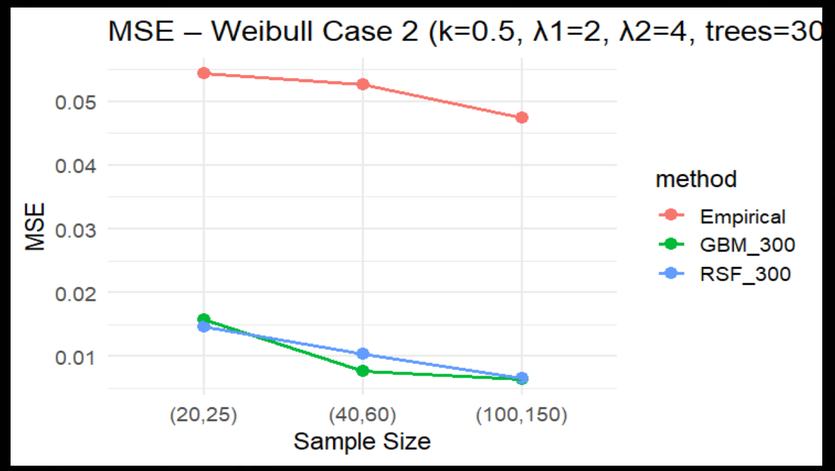


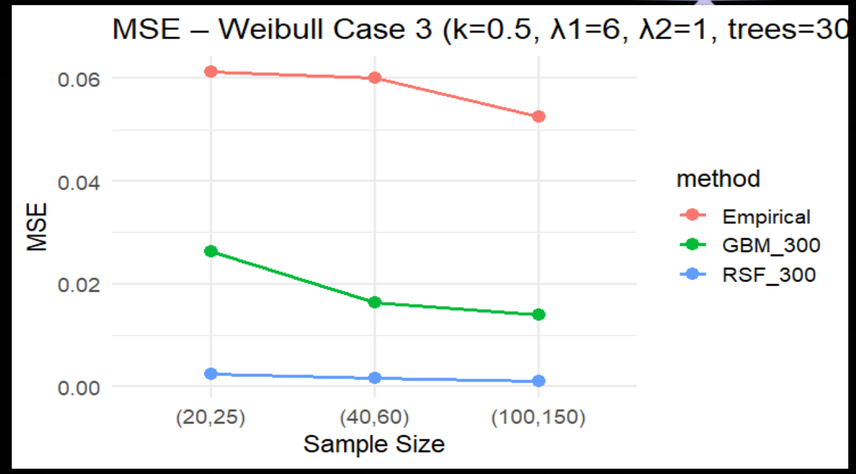


- Empirical = highest MSE
- GBM best in Cases (1 & 3)
- RSF best in Case 2
- MSE ↓ with larger samples

Weibull Results (MSE)







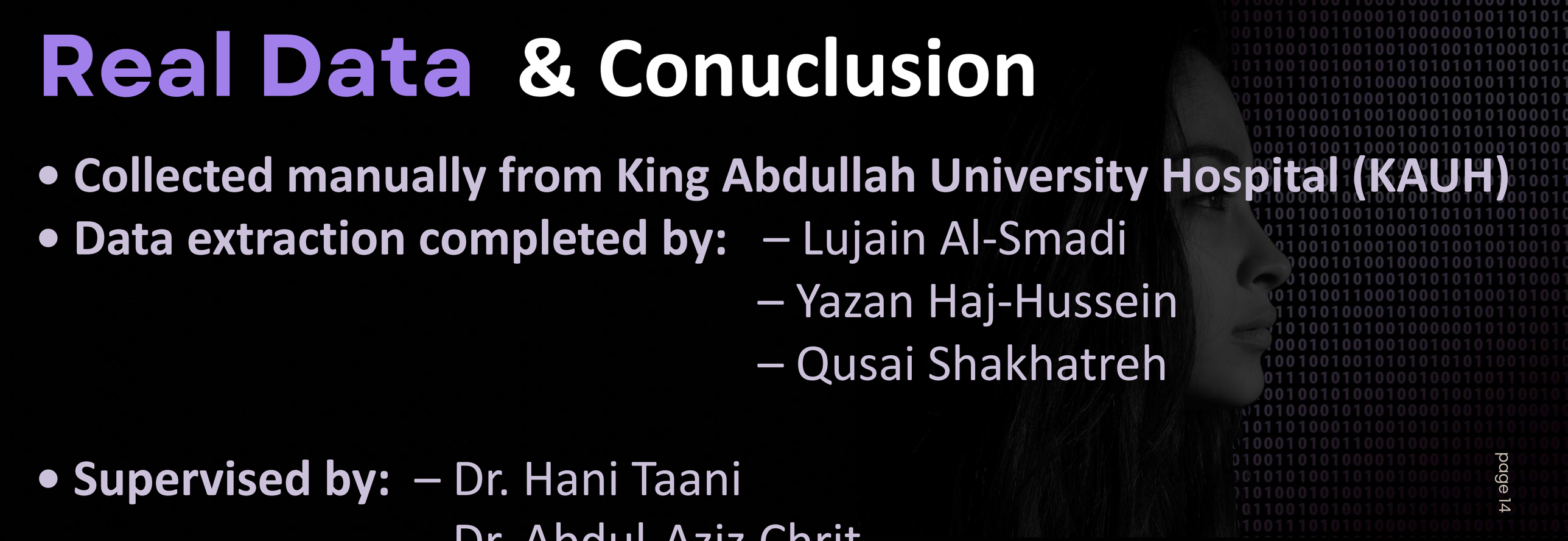
- Empirical = worst
- GBM best in Cases 1 & 2
- RSF best in Case 3

MSE Summary (Exponential + Weibull)

Model	Case	Empirical MSE	GBM-300 MSE	RSF-300 MSE	Best
Exponential	Case 1 (θ=0.5, λ=4.0)	0.0159 → 0.0093	0.0091 → 0.0016	0.0121 → 0.0126	⭐ GBM-300
Exponential	Case 2 (θ=3.0, λ=4.0)	0.0207 → 0.0093	0.0100 → 0.0017	0.0036 → 0.0011	⭐ RSF-300
Exponential	Case 3 (θ=3.0, λ=0.5)	0.00514 → 0.00337	0.00456 → 0.00059	0.00575 → 0.00095	⭐ GBM-300
Weibull (k=0.5)	Case 1 (λ_1=1, λ_2=6)	0.035–0.038	0.0029–0.0089	0.0067–0.0207	⭐ GBM-300
Weibull (k=0.5)	Case 2 (λ_1=2, λ_2=4)	0.047–0.054	0.0063–0.0157	0.0065–0.0147	⭐ GBM-300
Weibull (k=0.5)	Case 3 (λ_1=6, λ_2=1)	0.052–0.061	0.0139–0.0263	0.00098–0.00248	⭐ RSF-300

As sample size increases, RSF and GBM-Cox outperform the Empirical method

Real Data & Conuclusion



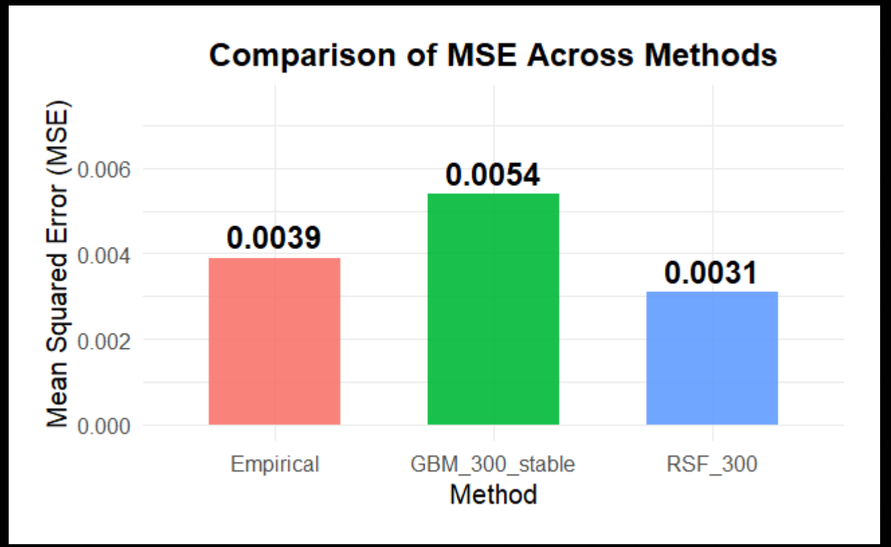
- **Collected manually from King Abdullah University Hospital (KAUH)**
- **Data extraction completed by:** – Lujain Al-Smadi
  – Yazan Haj-Hussein
  – Qusai Shakhatreh

- **Supervised by:** – Dr. Hani Taani
  – Dr. Abdul-Aziz Chrit

- X = patient survival time
- Y = treatment burden / disease severity

Phase 1: True R (Full Dataset)

Method	True R
Empirical	0.3556
GBM_300_stable	0.3788
RSF_300	0.3754



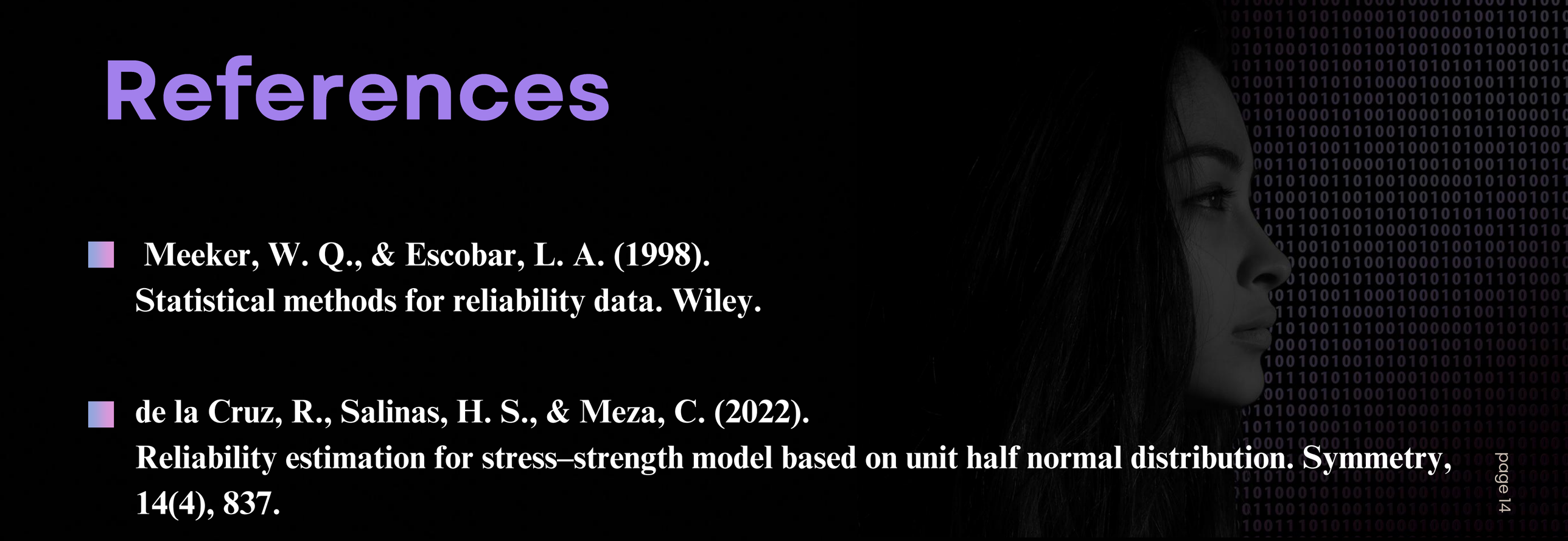
Phase 2: Sampling-Based Evaluation (Bias, MSE, Variance)

Method	R_mean	Bias	MSE	Variance
Empirical	0.3575	0.0019	0.00385	0.00385
GBM_300_stable	0.4022	0.0234	0.00536	0.00482
RSF_300	0.3908	0.0154	0.0031	0.00287

Conclusion

- AI methods outperform the classical Empirical estimator
- GBM–Cox shows the strongest overall performance
- RSF performs best when X and Y distributions differ
- MSE decreases consistently with larger samples
- AI-enhanced survival modeling improves medical decision-making

References



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THANK YOU!

Any Question ?

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