A Decision Analytic Approach for Optimal Surgical Treatment in Early-Stage Breast Cancer

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Background

- Women with early-stage breast cancer are faced with several surgical options.
- Studies have reported statistically equivalent survival for breast-conserving therapy (BCT) and mastectomy, but small differences in survival outcomes may influence patient decision making depending on how patients value survival-related objectives relative to quality of life objectives.

Objective

- Use a decision analytic approach to determine how different surgical treatments best achieve patient objectives related to survival and quality of life, with an explicit evaluation of tradeoffs.

Methods

- Patient Cohort: 180,913 patients from the National Cancer Database: women 40-70 years old, T0-T2 (≤5cm), N0-N1, M0, zero comorbidities, income ≥$48k, private insurance, comprehensive, academic, or integrated cancer program.
- Surgery types: BCT (n = 113,405), mastectomy (n = 29,794), and mastectomy with reconstruction (n = 37,714).
- Kaplan-Meier estimator to calculate overall survival (5 and 10 yr) by surgery type.

Simulation
- Generate overall survival rate and 4 quality of life values for 16,000 patients, drawing values from the mean and uncertainty bounds for each objective.

Patient Preferences
- All permutations of rank order of objectives using rank order centroid to apply patient weights (preferences) on each objective. e.g., 4 quality of life + 1 survival objective; 120 permutations of rank order on 5 objectives; 16,000 patients x 120 weight combinations = 1,920,000 decisions.

Decision
- Multi-criteria decision analysis to calculate optimal surgical decision for survival only, quality of life only, and quality of life + survival objectives.

Results: Survival Only Objective

Table 1. Kaplan-Meier survival rates.

ER/PR Status	Stage	Surgical Treatment	5-year	SD	10-year	SD
			Overall Survival Rate (%)			
ER-PR-	I	BCT	95.20	0.25	92.04	0.38
ER-PR-	I	Mastectomy	94.20	0.55	90.20	0.81
ER-PR-	I	Mast+Recon	94.55	0.50	89.46	0.96
ER-PR-	II	BCT	89.81	0.40	85.43	0.53
ER-PR-	II	Mastectomy	83.93	0.67	78.06	0.86
ER-PR-	II	Mast+Recon	88.05	0.66	82.12	0.95
ER-PR+	I	BCT	99.10	0.04	96.90	0.12
ER-PR+	I	Mastectomy	98.43	0.15	95.22	0.36
ER-PR+	I	Mast+Recon	99.00	0.10	96.64	0.30
ER-PR+	II	BCT	97.62	0.12	92.30	0.27
ER-PR+	II	Mastectomy	96.09	0.22	88.96	0.46
ER-PR+	II	Mast+Recon	97.57	0.17	91.82	0.47
ER+PR-	I	BCT	98.34	0.18	95.23	0.39
ER+PR-	I	Mastectomy	96.26	0.60	93.10	1.03
ER+PR-	I	Mast+Recon	97.08	0.46	93.00	0.94
ER+PR-	II	BCT	93.88	0.49	88.48	0.79
ER+PR-	II	Mastectomy	91.54	0.77	82.18	1.27
ER+PR-	II	Mast+Recon	92.54	0.79	84.39	1.49
ER+PR+	I	BCT	95.79	0.88	94.27	1.10
ER+PR+	I	Mastectomy	94.18	2.02	88.77	3.71
ER+PR+	I	Mast+Recon	94.63	2.15	92.38	3.06
ER+PR+	II	BCT	90.62	1.57	86.94	2.00
ER+PR+	II	Mastectomy	88.90	2.29	83.05	3.21
ER+PR+	II	Mast+Recon	87.94	3.07	86.69	3.27

Table 2. Percentage of 16,000 simulations that each surgical treatment option scored highest in decision analysis.

ER/PR Status	Stage	yr Survival	BCT	Mastectomy	Mastectomy +Recon
ER-PR-	I	5	99.5%	0%	0.5%
ER-PR-	II	5	100%	0%	0%
ER-PR-	I	10	100%	0%	0%
ER-PR-	II	10	100%	0%	0%
ER-PR+	I	5	81.9%	0%	18.1%
ER-PR+	II	5	96.4%	0%	3.6%
ER-PR+	I	10	83.1%	0%	16.9%
ER-PR+	II	10	57.6%	0%	42.4%
ER+PR-	I	5	100%	0%	0%
ER+PR-	II	5	100%	0%	0%
ER+PR-	I	10	100%	0%	0%
ER+PR-	II	10	100%	0%	0%
ER+PR+	I	5	95.3%	0%	4.7%
ER+PR+	II	5	84.1%	0%	15.9%
ER+PR+	I	10	92.6%	0%	7.4%
ER+PR+	II	10	99.2%	0%	0.8%

Breast-conserving therapy (BCT) is optimal decision for all cancer subtypes/stages for patients who value overall survival as their only objective.

Results: Quality of Life Only Objectives

Table 3. Quality of life objectives and their mean values for each surgery type.

Quality of Life Objectives	Direction	BCT	Mastectomy	Mastectomy + Recon
1. Surgical Concerns				
a. Need for Additional Surgery[a]	Minimize	22.8	2.87	7.78
b. Complicaitons[b]	Minimize	4.09	7.97	11.28
c. Recovery[c]	Minimize	3	6	8
d. Post-Operative Physical Well-being[d]	Maximize	63.9	70.89	75.08
e. Number additional surgeries[e]	Minimize	1.11	1.06	2.10
2. Radiotherapy Concern[f]	Minimize	100	24.37	17.7
3. Satisfaction with breasts[g]	Maximize	69.3	51.3	64.1
4. Need for future testing/Surveillance[h]	Minimize	1	0	0

[a] Percent of patients needing at least 1 additional operation (re-excision rate for BCT, re-operation rate for mastectomy and mastectomy with reconstruction)
[b] Any complication ≤90 days
[c] Recovery time after surgery (weeks)
[d] Breast-Q: Physical well-being/breasts (pain/tightness in upper limb, shoulder, girdle, chest area)
[e] Number of additional surgeries
[f] Percent of patients receiving radiotherapy
[g] Breast-Q: Satisfaction with breasts (breast size, symmetry, softness, appearance, feeling in and out of clothes)
[h] Frequency of future surveillance/screening/monitoring/imaging (number of times in a year)
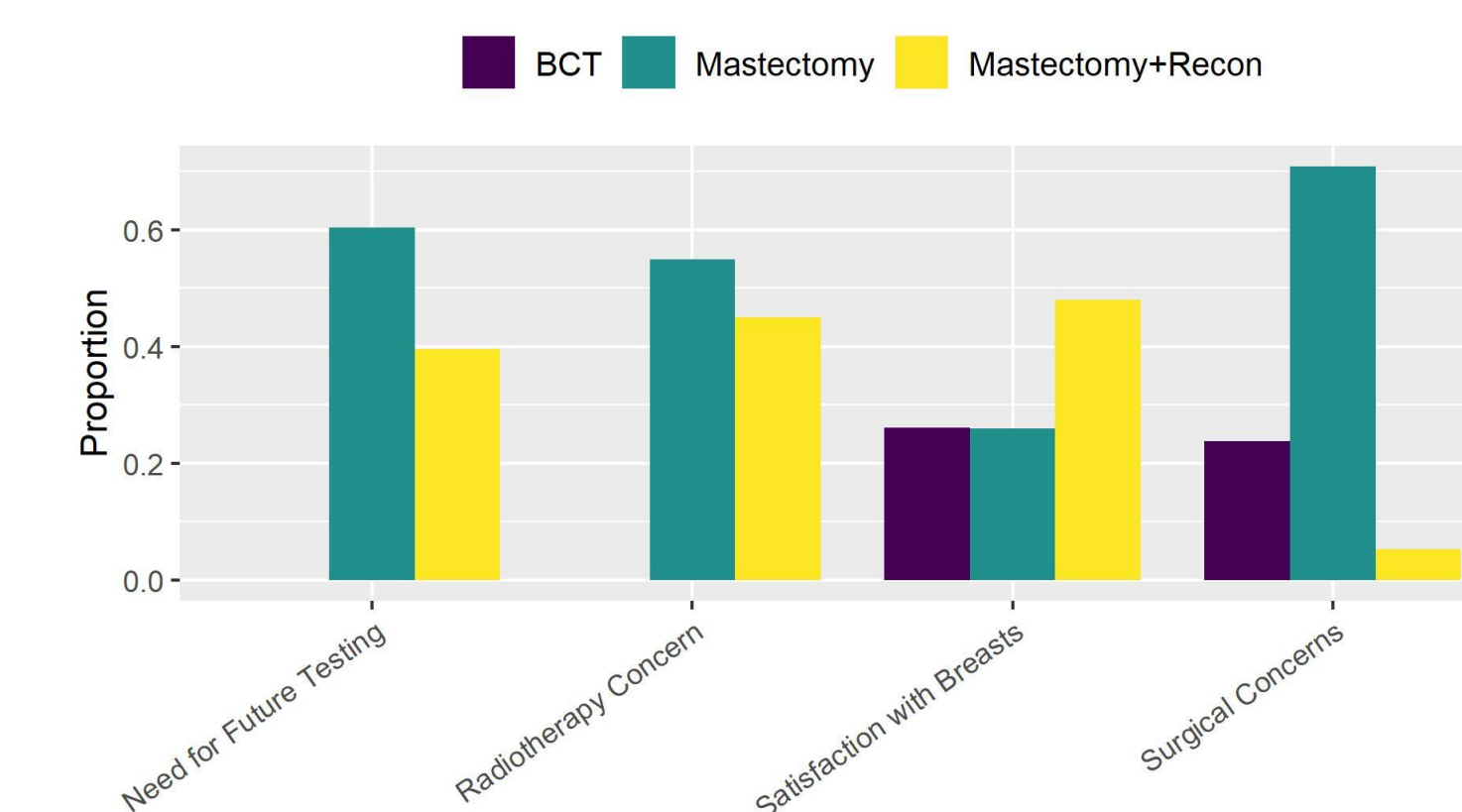

Fig 1. Proportion of 16,000 simulations that each surgical treatment option scored highest in multi-criteria decision analysis when each objective is ranked as #1 and includes all permutations of rank order of the other 3 objectives.

Mastectomy is most frequently selected as the best surgical decision when either surgical concerns (71%), need for future testing (60%), or radiotherapy concerns (55%) are the top ranked objectives. Mastectomy with reconstruction is most frequently (48%) the best surgical decision when satisfaction with breasts is ranked highest. BCT is chosen as best decision 26% when satisfaction with breasts is ranked #1 and 24% of the simulated decisions when surgical concerns is ranked #1.

Results: Quality of Life + Survival Objectives

Table 4. Optimal surgical decision based on highest average normalized weighted scores from multi-criteria decision analysis when each objective is ranked highest and includes all permutations of rank order for the other 4 objectives.

ER/PR Status	Stage	5 or 10 yr Survival	Need for Future Testing	Radiotherapy Concerns	Satisfaction with Breasts	Surgical Concerns	Survival
ER-PR-	I	5	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	BCT
ER-PR-	II	5	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	Mast+Recon
ER-PR-	I	10	Mastectomy	Mastectomy	BCT	Mastectomy	BCT
ER-PR-	II	10	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	BCT
ER-PR+	I	5	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	BCT
ER-PR+	II	5	Mastectomy	Mastectomy	BCT	Mastectomy	BCT
ER-PR+	I	10	Mast+Recon	Mastectomy	Mastectomy	Mastectomy	Mast+Recon
ER-PR+	II	10	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	Mast+Recon
ER+PR-	I	5	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	BCT
ER+PR-	II	5	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	BCT
ER+PR-	I	10	Mast+Recon	Mastectomy	BCT	Mastectomy	BCT
ER+PR-	II	10	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	BCT
ER+PR+	I	5	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	Mast+Recon
ER+PR+	II	5	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	BCT
ER+PR+	I	10	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	Mast+Recon
ER+PR+	II	10	Mast+Recon	Mast+Recon	Mast+Recon	Mastectomy	Mast+Recon

Mastectomy with reconstruction is optimal decision for most cancer sub-types/stages when quality of life and survival are both important objectives to a patient because need for future testing and radiotherapy concerns contribute positively. However, when survival is the most important objective for a patient, BCT is the optimal decision for 9 of 16 cancer sub-types/stages/5 or 10 yr survival.

Decision for ER-PR-, Stage I, 10-yr Survival

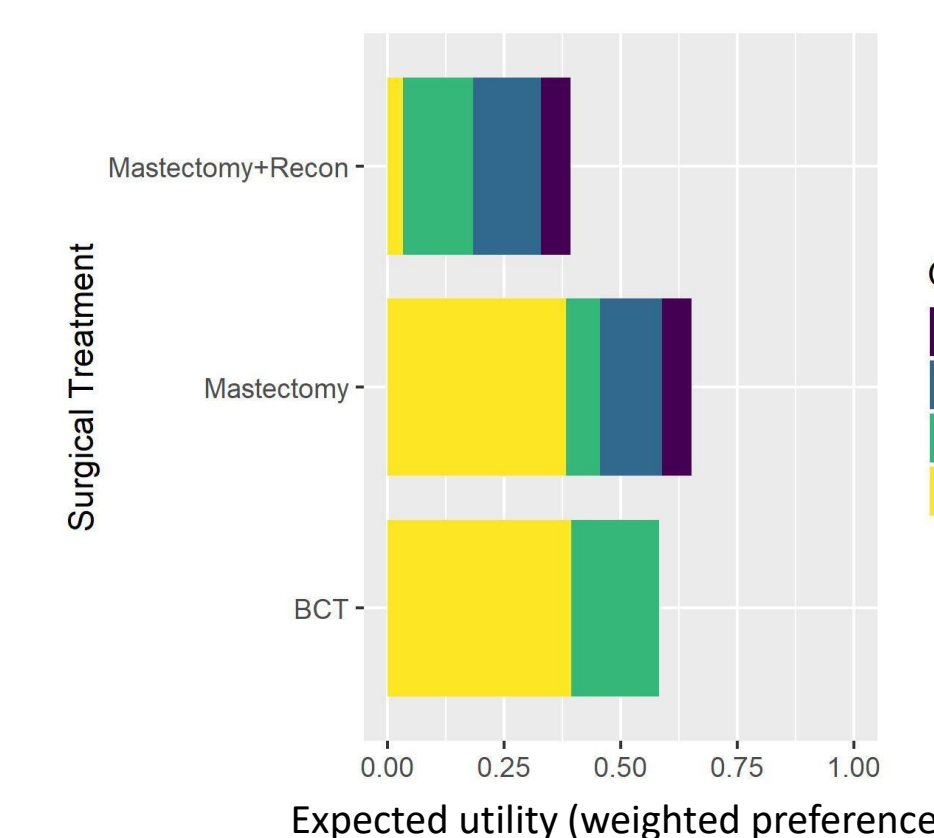Fig. 2. Optimal decision based on survival-only objective is BCT.

Fig 3. Optimal decision is mastectomy for patients who value quality of life objectives with surgical concerns ranked highest, satisfaction with breasts ranked second, radiotherapy concerns ranked third, and need for future testing ranked fourth.
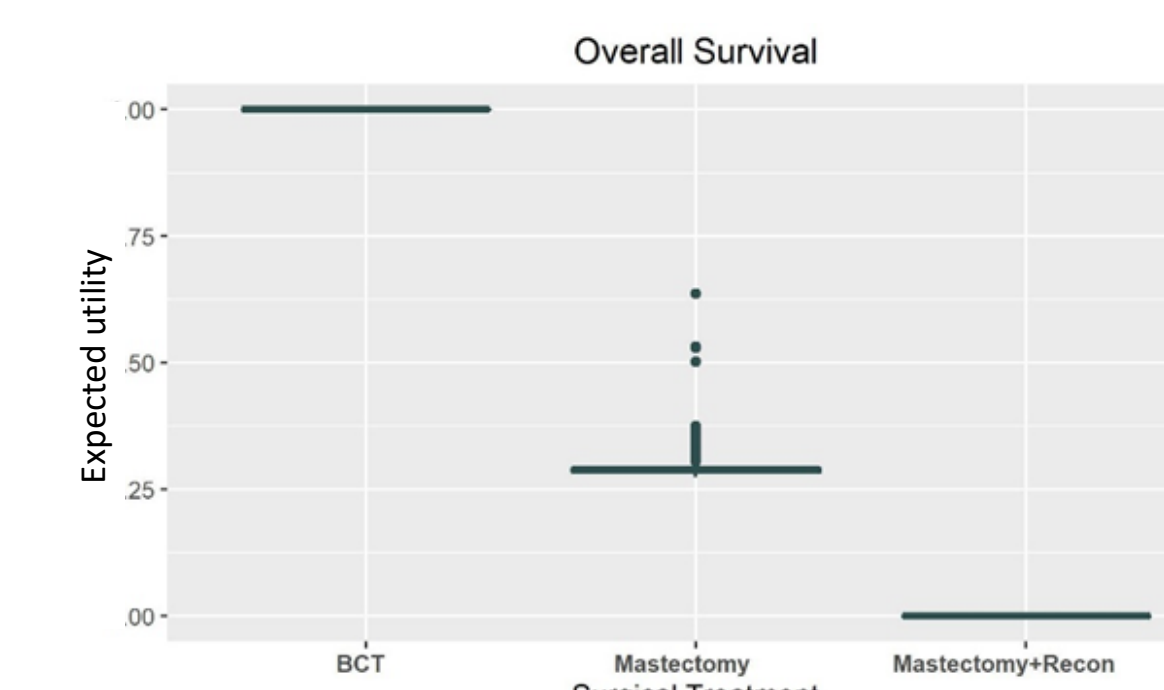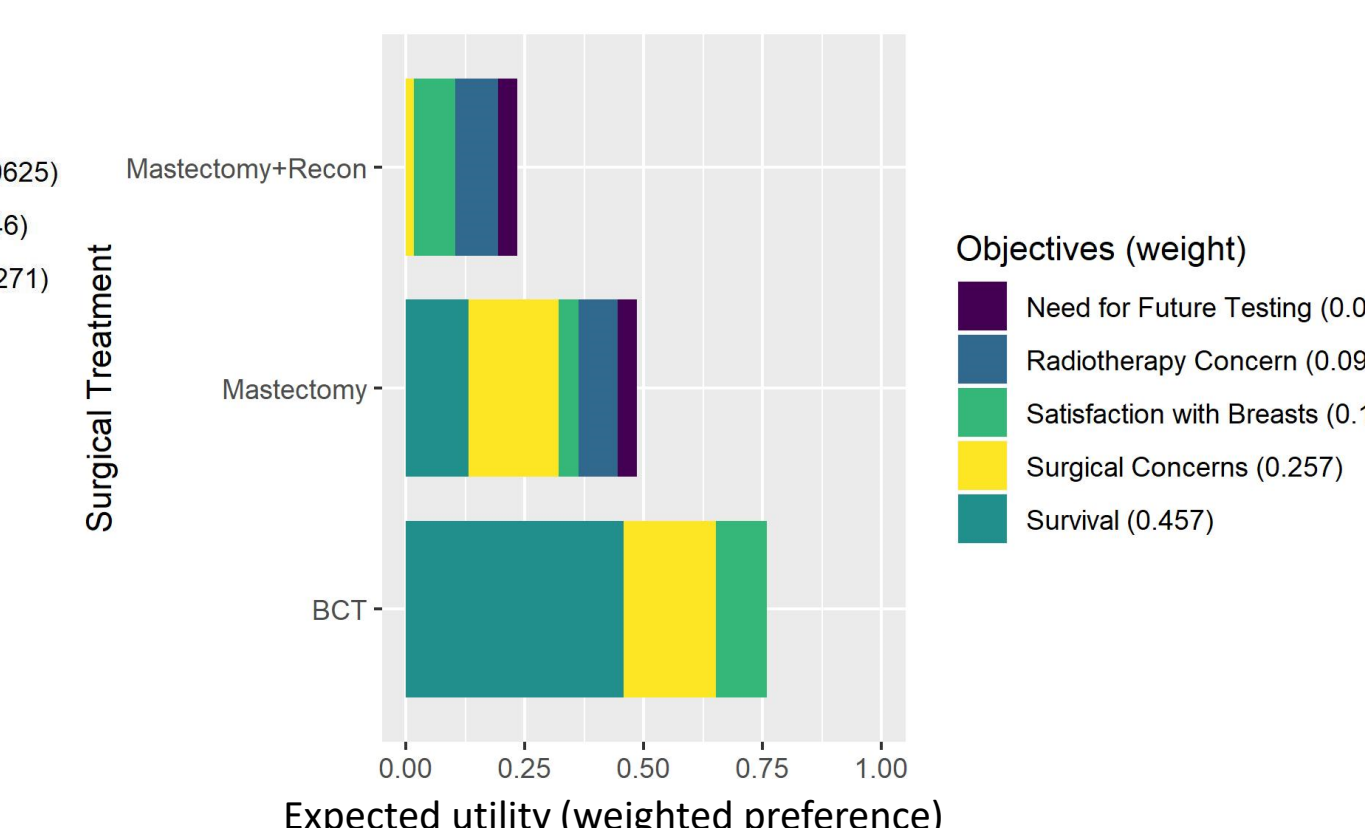

Fig 4. Optimal decision switches from mastectomy to BCT when overall survival is included and ranked highest while retaining same rank order of quality of life objectives. Absolute difference in 5-year overall survival between BCT (92.04%) and mastectomy (90.20%) was 1.8%.
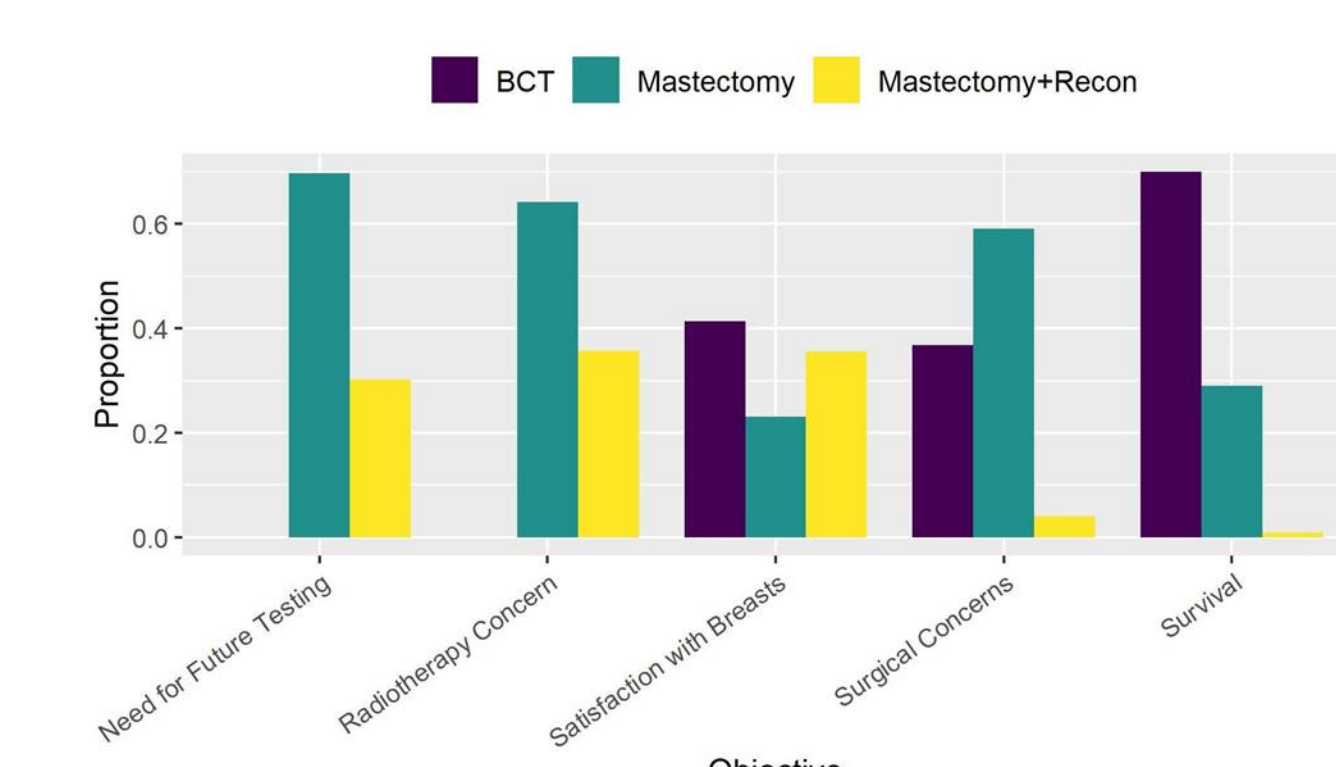

Fig 5. Proportion of simulation events where each surgical treatment is the optimal decision when each objective is ranked highest and includes all permutations of rank order of the 4 other objectives.

For ER-PR-, Stage I, 10-yr survival, when survival is ranked highest (and evaluating all permutations of rank order for the 4 quality of life objectives), the most frequently selected optimal decision is BCT (70%), followed by mastectomy (29%) and mastectomy with reconstruction (1%).

Optimal decision is BCT when patients value only survival and is mastectomy when patients value only quality of life objectives. For patients who care about both quality of life and survival objectives (and survival is ranked highest), the optimal decision is BCT.

Conclusions

- **A difference as small as 1.8% in overall survival may switch the optimal patient decision from mastectomy to BCT for patients who value survival objectives greater than quality of life objectives.**

- Information provided by surgeons may be an important determinant of surgical treatment decisions by patients, and therefore it is valuable for surgeons to understand how small differences in survival outcomes across treatments may alter optimal patient decisions for surgery type.