A Monte-Carlo Simulation of Benefits After Bariatric Surgery on Obese Patients with Type-2 Diabetes –A Reanalysis

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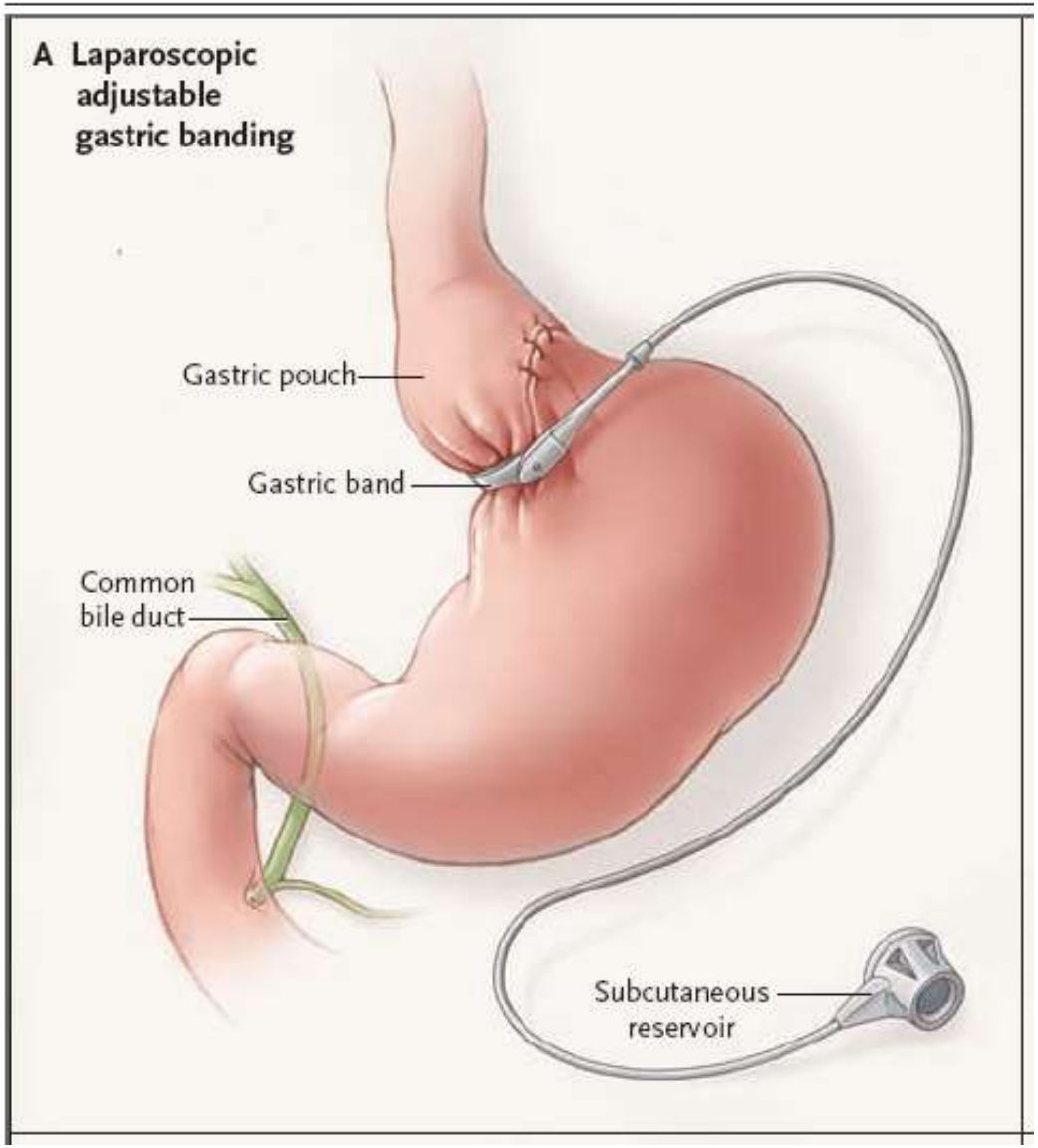
Monte Carlo simulation

Monte Carlo simulation lets you see different possible outcomes of your decisions and the probabilities of their occurrences. This lets you quantitatively assess the risks of forecasted outcomes and, enables, better decision-making under uncertainty.

Surgery to Control Obesity

- Laparoscopic gastric banding is **surgery to help with weight loss**. The surgeon places a band around the upper part of your stomach to create a small pouch to hold food. The band limits the amount of food you can eat by making you feel full after eating small amounts of food.


A Laparoscopic adjustable gastric banding
Gastric pouch
Gastric band
Common bile duct
Subcutaneous reservoir

NEJM 2007

Simulation analysis of the study below

- An Australian study (Monash University) looked at the efficacy of Gastric By-Pass Surgery in weight management of Type-2 diabetes[1].
- The study was a Randomized Control Trial[2] over a 2-year period and evaluated the
  - Costs of Gastric By-Pass Surgery
    - Surgery Costs, Post-Surgery monitoring etc.
  - Benefits of Gastric By-Pass Surgery
    - Higher remission rates

Using Simulation For Lifetime Analysis

- **Objective**: Using a simulation approach to extrapolate results of the Australian 2-year trail, to a lifetime analysis, i.e. *until simulated death or ninety-nine years of age, whichever is earlier.*

Now	Year1	Year2	Year3	Year4	Year5	Year6	Year7	.	.	.	EndOfSimulationPeriod
0	Trial	Trial	simulation	simulation	simulation	simulation	simulation	simulation	simulation	simulation	simulation

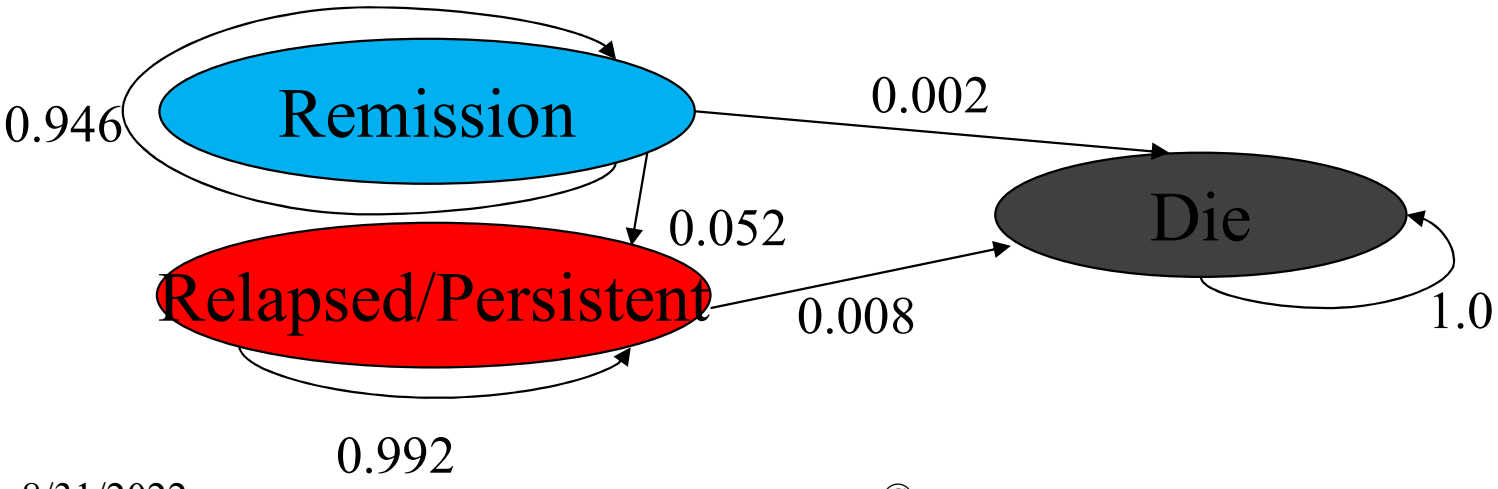
- **Why Simulate**:
  - If properly done, can help model very long term costs and benefits, with some degree of confidence.
  - Sometimes, it may be difficult to get ethical consent for certain sample control approaches –simulation is one way to continue to do analysis.

Markov Transitional Probabilities for a "Typical" patient

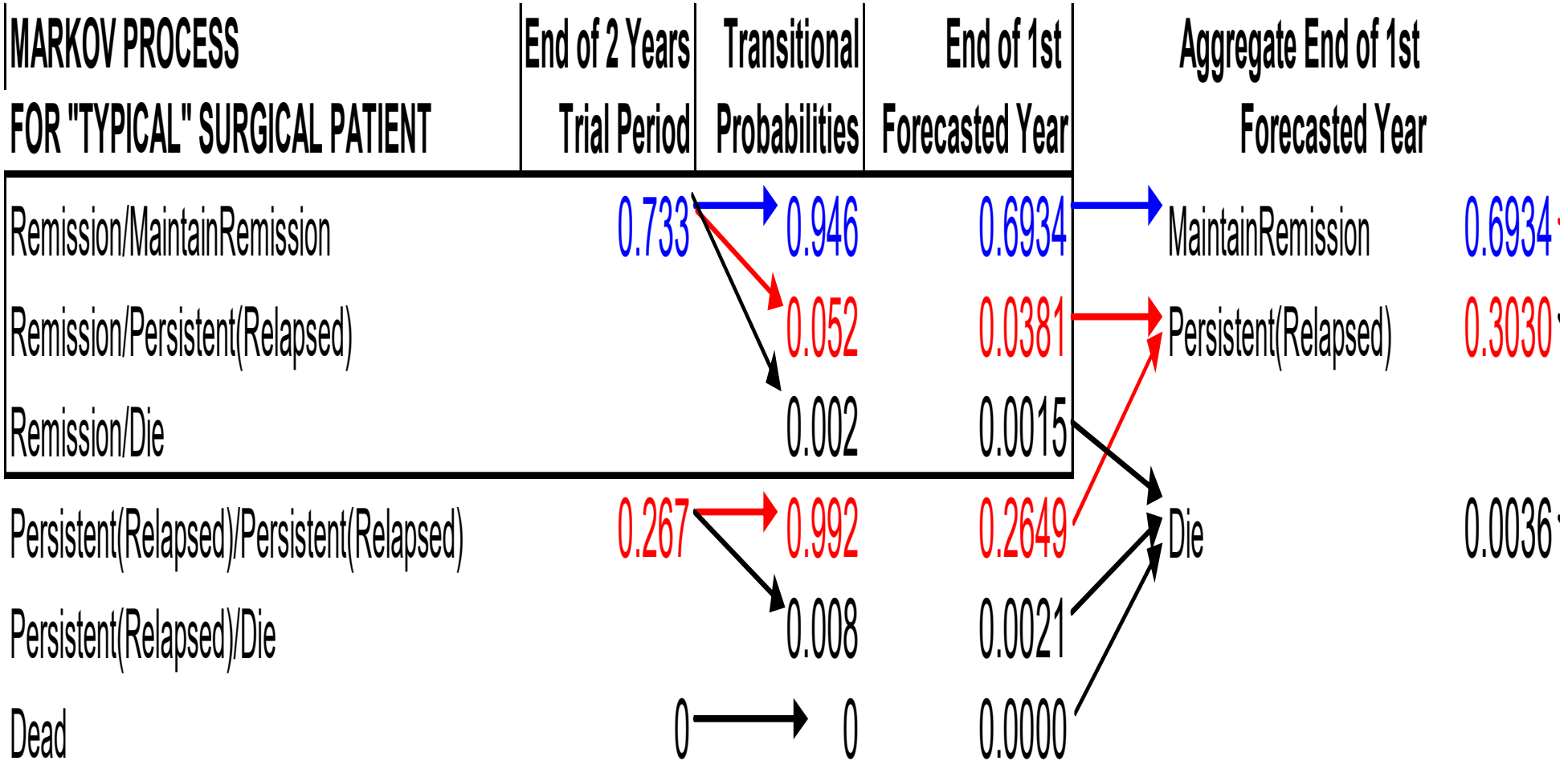
Presently, an obese patient may not have Type-2 diabetes. It's also possible that he may have had Type-2 diabetes in the past but is presently not diabetic. Presently, not having Type-2 diabetes is depicted as the "Remission" state and is shown in blue.

(A)From "Remission" it's possible to go to a Type-2 diabetic stage. That state is called "Relapsed" and is shown in red. The probability of doing so, within a year, is 0.052. It's also possible to go to a "Die" state with a probability of 0.002, in a year, the "Die" state is shown in dark grey. Finally it's possible to persist in "Remission".

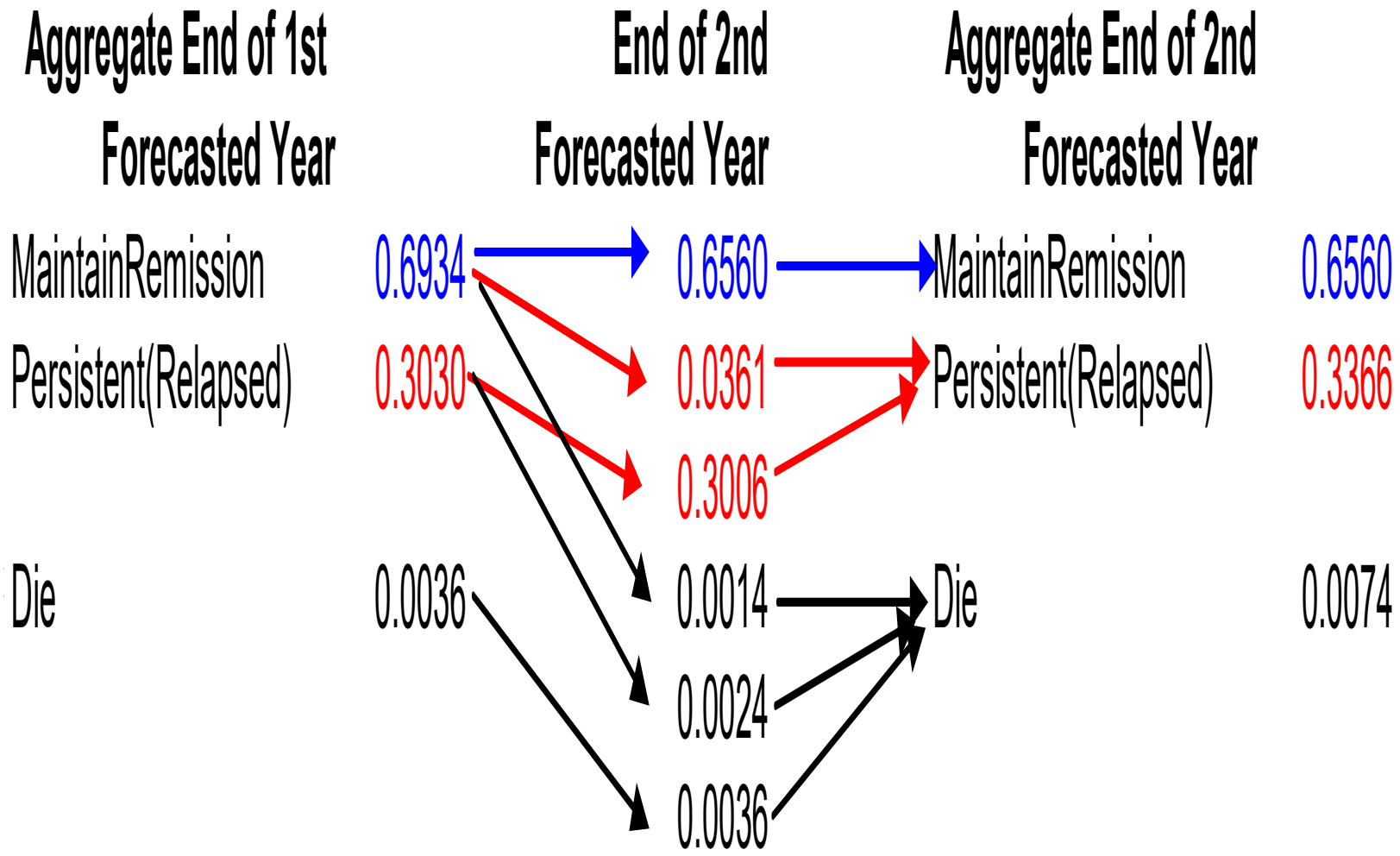
(B)From "Relapsed" state, it's possible to either persist in that state, with probability 0.992 or go to the "Die" state with probability 0.008, in a year.



Markov Model for a Surgical patient simulating a 1-year forecast



Markov Model for Surgical patient simulating a 2-year forecast



Markov model for conventional treatment (diet control). Simulating 1-year forecast.

MARKOV PROCESS	End of 2 Years	Transitional	End of 1st		Aggregate End of 1st	
FOR "TYPICAL" CONVENTIONAL PATIENT	Trial Period	Probabilities	Forecasted Year		Forecasted Year	
Remission/MaintainRemission	0.133	0.946	0.1258	→	MaintainRemission	0.1258
Remission/Persistent(Relapsed)		0.052	0.0069	→	Persistent(Relapsed)	0.8670
Remission/Die		0.002	0.0003			
Persistent(Relapsed)/Persistent(Relapsed)	0.867	0.992	0.8601		Die	0.0072
Persistent/Die		0.008	0.0069			
Die	0	0	0.0000			

Surgical versus Conventional

1st SIMULATION RUN	End of 2-year Trial	End of 1st Forecasted Year	End of 2nd Forecasted Year	..... End of 48th Forecasted Year
SURGICAL				
Remisson	0.7330	0.6934	0.6560	...
Persistent(Relapsed)	0.2670	0.3030	0.3366	...
Die	0.0000	0.0036	0.0074	...
CONVENTIONAL				
Remission	0.1330	0.1258	0.1190	...
Persistent(Relapsed)	0.8670	0.8670	0.8666	...
Die	0.0000	0.0072	0.0144	...
Relative Risk=.733/.133	5.5			

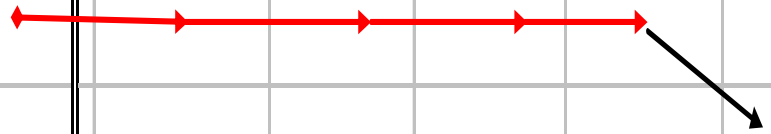
Monte Carlo Simulation

1st SIMULATION RUN	End of 2-year Trial	End of 1st Forecasted Year	End of 2nd Forecasted Year
SURGICAL			
Remisson	0.7330	0.6934	0.6560
Persistent(Relapsed)	0.2670	0.3030	0.3366
Die	0.0000	0.0036	0.0074
CONVENTIONAL			
Remission	0.1330	0.1258	0.1190
Persistent(Relapsed)	0.8670	0.8670	0.8666
Die	0.0000	0.0072	0.0144
Relative Risk=.733/.133	5.5		

2nd SIMULATION RUN			
Simulated Relative Risk	6.1		
SURGICAL			
Remisson	0.7330	0.6934	0.6560
Persistent(Relapsed)	0.2670	0.3030	0.3366
Die	0.0000	0.0036	0.0074
CONVENTIONAL			
Remission	0.1206	0.1141	0.1079
Persistent(Relapsed)	0.8794	0.8786	0.8775
Die	0.0000	0.0073	0.0145

Simulation Runs

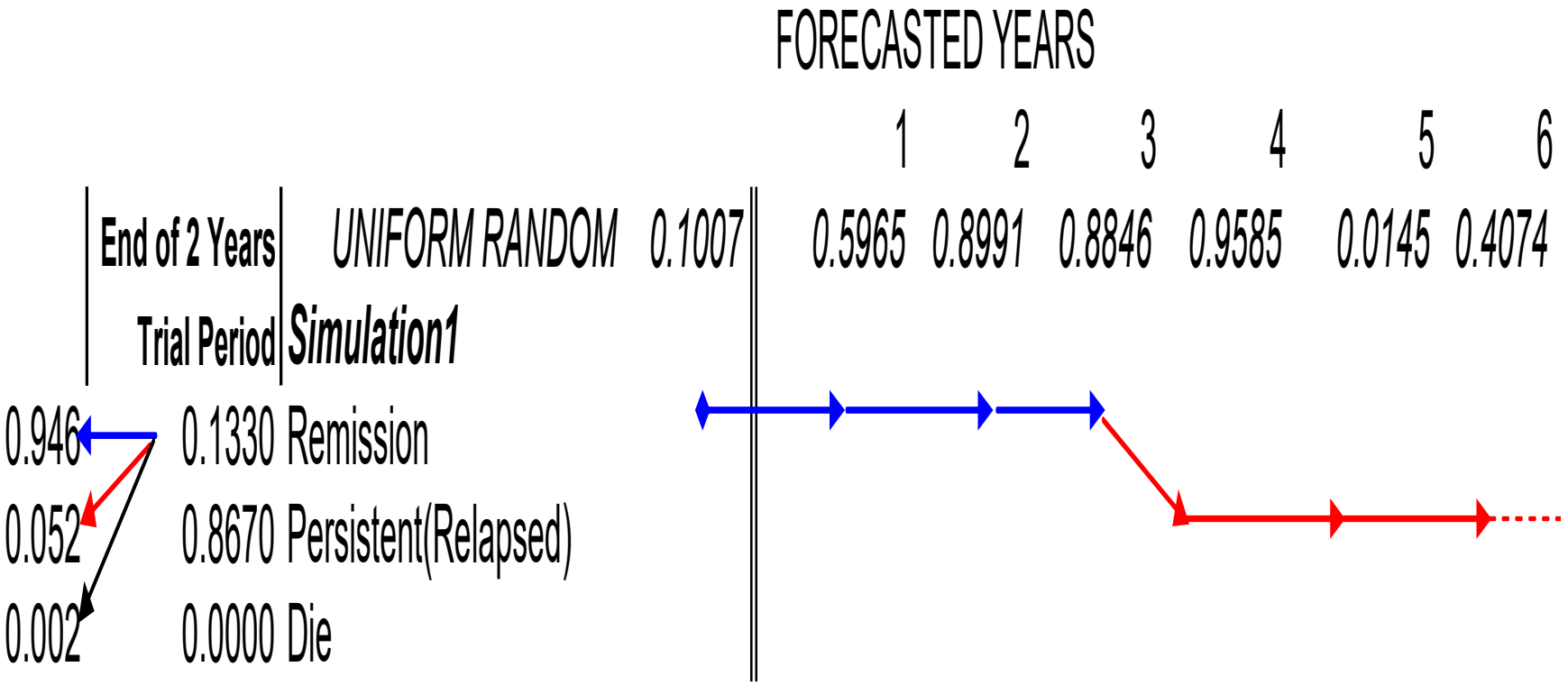
				FORECASTED YEARS				
				1	2	3	4	5
		UNIFORM RANDOM	*0.1282*	*0.0301*	*0.2047*	*0.6820*	*0.8206*	*0.993*
		Simulation2						
	0.1206	Remission						
0.992	0.8794	Persistent(Relapsed)						
0.008	0.0000	Die						



Shows, based on a uniform random draws, how the patient evolves over different years into different health states. In the simulation run above, the patient starts of in persistent diabetes, at end of 2-year trial period and for 4-years after that stays in that state before dying

This provides data on costs incurred in each year, diabetes state and mortality for that patient in that simulation run.

Simulation Runs –Another Path



In this run, a patient starts of in remission and stays there till year 4 when, based on the random number of that year, he migrates to persistent and continues there till she dies (mortality year not shown above).

Costs[1].

- All costs and benefits are discounted. E.g. costs and benefits, at end of 1st year, are multiplied by 1/1.03. At end of 2nd year, they are multiplied by (1/1.03^2) and so on.
- Treatment Costs[2] -Sources
  - Type 2 Diabetes are provided by diabetes duration and age. Their mean is $5000 AUD p.a.
  - Type 2 Diabetes remission was at 43% of the cost of a Type 2 Diabetes, i.e., $2150 AUD p.a.
- Data was gathered from
  - Surgical Therapy Maintenance Costs-Monash University database.
  - Surgical Therapy Complications Costs (O'Brien PE and Dixon JB *Am J Surg 2002*)
  - Diabetes Remission-Monitoring Costs (Trial Study extrapolation, Australian Medicare Benefits Schedule).

[1] *Keating et al. Diabetes Care, April 2009- Surgical therapy appears to be a cost effective option for managing Type- 2 diabetes in Class I and II obese patients over the 2-year trial period*

[2] *Costs are in Australian Dollars AUD*

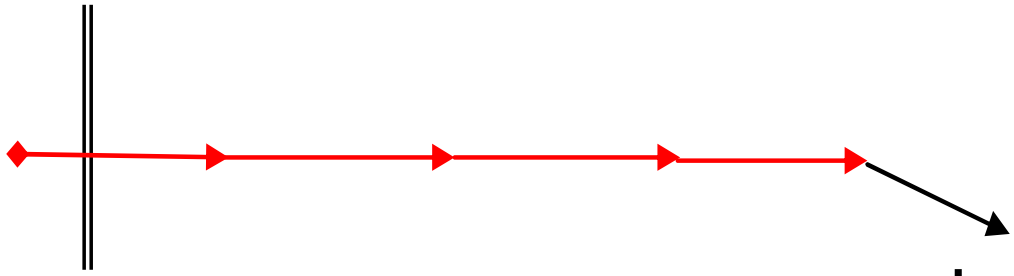
Costs, Mortality and QALY Benefits for the Simulation Run

Simulation2

Remission

Persistent(Relapsed)

Die



FORECASTED YEARS	**1**	**2**	**3**	**4**	TOTAL
COSTS(AUD)	3800	3900	4000	4100	
Discount Factors	0.971	0.943	0.915	0.888	
Discounted COSTS (AUD)	3689	3676	3661	3643	14669
Discounted Years				3.55	3.55
Quality of Life Years(QALY)				0.8	2.84

In the previous run, the patient lived for 4 years after the trial and died after that. The costs, the discounting factors and the discounted costs are shown. They total AUD 14669. The total life years are 4, discounted to 3.55 and quality adjusted to 2.84. Years in remission is 0.

Benefits (used from the Australian 2-year RCT.)

- Quality–adjusted life-years (QALYs) utility weight 0.67 to 0.81 for patient with diabetes and 0.84 for patients in remission
- Surgical patients gained additional 9.4 years in remission and 1.6 additional life years. The discounted QALY was 1.2 years.
- **Surgical therapy was the dominant treatment as it was both cheaper and provided more QALYs.**
- Worst case scenarios for intervention effect and cost of treatment of Type 2 diabetes shifted the economic status of the surgical therapy from dominant to cost effective. A similar result was obtained by combining the intervention effect and duration of diabetes remission in worst-case scenarios

Results

Model results-lifetime means per patient	**Surgical**	**Conventional**	**Difference**
Discounted at 3% for both costs and benefits (Costs AUD)			
2-year RCT intervention	13,383	3,397	9,987
Surgical intervention maintenance	6,477		6,477
Surgical intervention complications	1,768		1,768
Type 2 diabetes remission—monitoring costs	16,479	2,874	13,605
Health care costs to treat type 2 diabetes	60,824	95,105	-34,281
Total cost	98,931	101,376	-2,444
Effectiveness			
Total life-years	20	19.2	0.7
QALYs	15.7	14.5	1.2

Results

Model results-lifetime means per patient	**Surgical**	**Conventional**	**Difference**
Undiscounted			
Years in diabetes remission	11.4	2.1	9.4
Total life-years	32.1	30.5	1.6
QALYs	24.9	22.6	2.3
Discounted at 3% for both costs and benefits (Costs AUD)			
2-year RCT intervention	13,383	3,397	9,987
Surgical intervention maintenance	6,477		6,477
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Conclusion

- From a cost perspective, disregarding quality of life and life expectancy benefits of diabetes remission, this analysis suggests that after 10 years the return on investment of surgical therapy is fully recovered through saving in health care costs to treat type 2 diabetes.

Appendix I

Definition of terms

1. *Mortality rate indicates the probability of dying by age of the person and health state. Usually mortality rates increase by age. Mortality rates also tend to be higher for a Type-2 diabetic person as compared to the average healthy adult who is currently not Type-2 diabetic.*
2. *Relapse indicates going into a Type-2 diabetic stage –which is a health deterioration.*
3. *Relative Risk is the ratio of Remission rate of Surgically Treated (Experimental) to the Remission rate of Conventionally Treated (Control).*
4. *Remission indicates not being in a Type-2 diabetic stage –which is a desirable health stage, in this study.*
5. *Randomized Control Trial: Patients are randomly to two groups: an "experimental" group of those who had bariatric surgery for weight management and a "control" group, who did not use bariatric surgery, but had conventional treatments for weight management, e.g. restricted diet.*
6. *QLY is a generally recognized indicator of quality-of-life. E.g. being alive but being bed-bound is different than being alive and being active and mobile as an average healthy adult. The Australian study used a European Quality Of Life measure. The EuroQol 3-level (EQ5D) is a versatile quality of life (QOL) instrument with five dimensions (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression) and a visual analog scale. It can be used to calculate quality-adjusted life years.*

Appendix II

Acknowledgements

- Dr. Mohammad Maruf helped with step-wise mentoring and detailed explanation of medical concepts, terms and practices.
- Journal Articles
  - Karlsson J, Taft C, Ryden A, Sjostrom L, Sullivan M: Ten-year trends in health-related quality of life after surgical and conventional treatment for severe obesity: the SOS intervention study. Int J Obesity (Lond) 31:1248–1261, 2007
  - Dixon et. al. JAMA, 2008- Surgical therapy induced weight loss results in better glycemic control and less need for diabetes medications
  - Keating et al. Diabetes Care, Cost-efficacy of surgically induced weight loss for the management of type 2 diabetes: a randomized controlled trial https://pubmed.ncbi.nlm.nih.gov/19171726/
  - Keating et al. Diabetes Care, April 2009. Cost-effectiveness of surgically induced weight loss for the management of type 2 diabetes: modeled lifetime analysis
  - Brianna N. Lauren, BS; Francesca Lim, MS; Abraham Krikhely, MD; Elsie M. Taveras, MD, MPH; Jennifer A. Woo Baidal, MD, MPH; Brandon K. Bellows, PharmD, MS; Chin Hur, MD, https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2789003 Estimated Cost-effectiveness of Medical Therapy, Sleeve Gastrectomy, and Gastric Bypass in Patients With Severe Obesity and Type 2 Diabetes.
- Mr. Mike Miller for being a superb teacher of Simulation and other Computer Science techniques in my AP Computer Science classes.