ARCHIMEDES
MOVING MEDICINE THROUGH MATHEMATICS

Cost Effectiveness Analysis of Colorectal Cancer Screening Cessation in a Population of Patients with Chronic Illnesses

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The optimal stop age for colon cancer depends on many factors

- Some colorectal cancer (CRC) screening guidelines recommend a fixed age to stop screening, while others recommend assessment of health status to determine if continuing screening would be beneficial.

- Ideally, the stop age for screening would be based on careful consideration of multiple factors: an individual's risk of CRC morbidity and mortality, life expectancy, likelihood of adverse events from screening, and past screening results.
  - This is especially difficult for patients with chronic conditions such as diabetes and cardiovascular disease.

Cost-effectiveness analysis can be used to determine optimal colorectal cancer screening strategies in populations with chronic illnesses.

Relationships between colorectal cancer and chronic illnesses are complex

- Chronic illnesses and CRC share many common risk factors
  - Including age, gender, race/ethnicity, obesity, diet, smoking, and others.
- Diabetic patients are at increased risk of developing colorectal adenoma (Elwing *et al.*, 2006) and being diagnosed with colorectal cancer (Coughlin *et al.*, 2004; Larsson *et al.*, 2005; Will *et al.*, 1998).
- A person who has diabetes and/or cardiovascular disease may not only have a shorter life expectancy but may also have a higher risk of colorectal cancer.
- Advanced age and the presence of chronic illnesses increase the risk of adverse events related to screening by colonoscopy (Gatto *et al.*, 2003; Warren *et al.*, 2009).

Therefore, a screening recommendation using life expectancy and cancer risk estimates for the general population is not accurate.

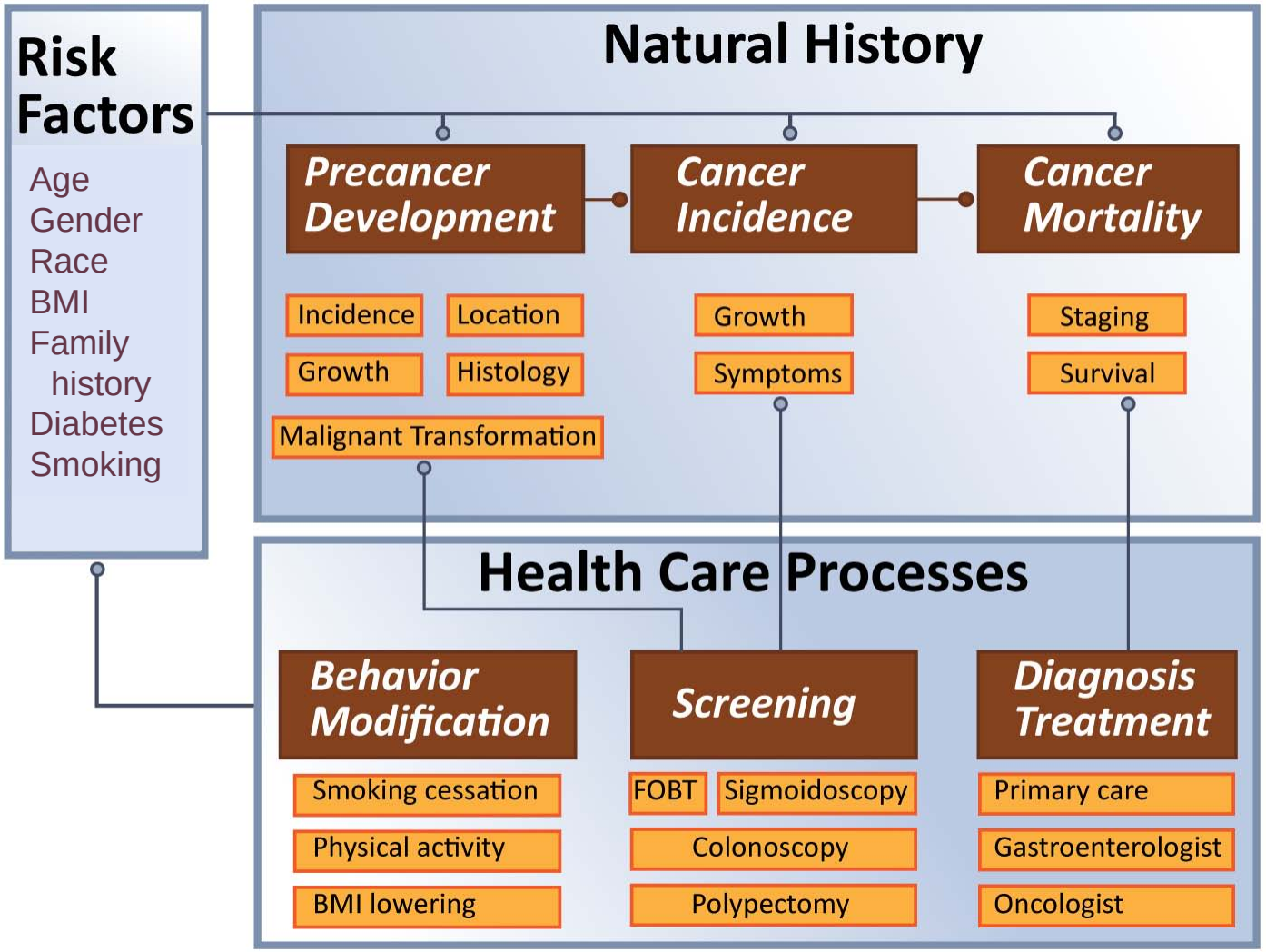
Methods

- We used the Archimedes Model to analyze the cost-effectiveness of different stop ages for CRC screening in people with and without diabetes or cardiovascular diseases.

- The Archimedes Model is a large-scale simulation of human physiology, diseases, interventions, and health care systems. The Model includes descriptions of diabetes, congestive heart failure, coronary artery disease, stroke, hypertension, obesity, in addition to breast, lung, and colorectal cancers.

- The colorectal cancer component of the Archimedes Model was developed in collaboration with the American Cancer Society and was built from large scale databases such as CORI and SEER, as well as meta-analyses of the literature. The model has been validated against a large number of studies including Cancer Prevention Study II.

Structure of Colorectal Cancer Model



Population in the study

- A cross-section of the US population, aged 50 years old at the start of the simulation.

- Subpopulations (at the start of the simulation):
  1. Individuals without diabetes
  2. Individuals with diabetes, without hypertension
  3. Individuals with diabetes and hypertension

Screening strategies

1. **No screening**
2. **Stop age 50:** screened by colonoscopy once, at age 50
3. **Stop age 60:** screened by colonoscopy twice, at ages 50 and 60
4. **Stop age 70:** screened by colonoscopy at 10-year intervals, starting at age 50, and stopping after age 70
5. **Stop age 80:** screened by colonoscopy at 10-year intervals, starting at age 50, and stopping after age 80
6. **No stop age:** screened by colonoscopy starting at age 50, at 10-year intervals, until death

In this study, we only considered screening by colonoscopy.

Outcomes measured

Category	Outcome variable
Disease-specific measures	Colorectal cancer incidence
	Colorectal cancer death
	Number of colonoscopies
Global outcome measures	Deaths
	Life years
	Quality-adjusted life years (QALYs)
	Costs of CRC screening and surveillance
	Costs of CRC treatment
	Costs related to CRC (screening, surveillance, and treatment)
	Other costs (e.g. diabetes, CVD)
	Total medical costs
	Cost per QALY saved

All costs and QALYs are discounted 3% annually

Colonoscopy screening reduces the incidence of CRC and increases life expectancy in diabetics

Patients diagnosed with diabetes at age 50 and without hypertension

Screening Strategy	Reduction in CRC compared to no screening (%)	Life years saved compared to no screening
No Screening	0	0
Stop at age 50	51	0.145
60	67	0.178
70	76	0.192
80	79	0.195
No stop age	80	0.196

Colonoscopy screening potentially reduces costs related to CRC

Patients diagnosed with diabetes at age 50 and without hypertension

Screening Strategy	Cost of CRC Treatment	Cost of CRC Screening	Total Cost associated with CRC	Difference in total cost associated with CRC, compared to no screening
No Screening	$ 2437	0	$ 2437	**0**
Stop age: 50 ***(once at age 50)***	$ 1170	$ 1167	$ 2337	**$ -99**
Stop age: 80	$ 715	$ 2076	$ 2791	**$ 354**

Patients without diabetes at age 50

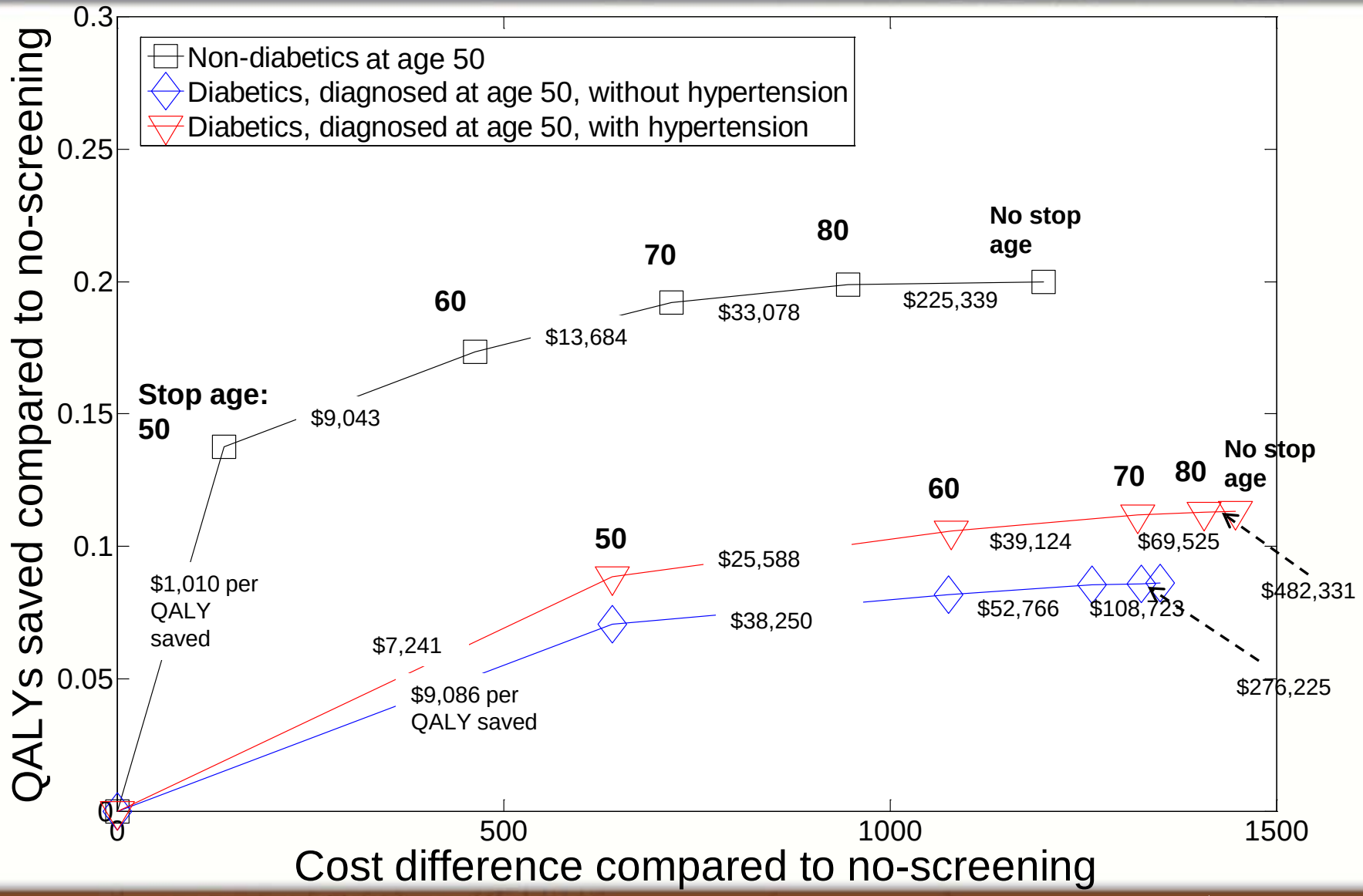
Screening Strategy	Difference in total cost associated with CRC, compared to no screening
Stop age: 50 ***(once at age 50)***	**$ -511**
Stop age: 80	**$ -93**

Older stop ages increase total medical costs

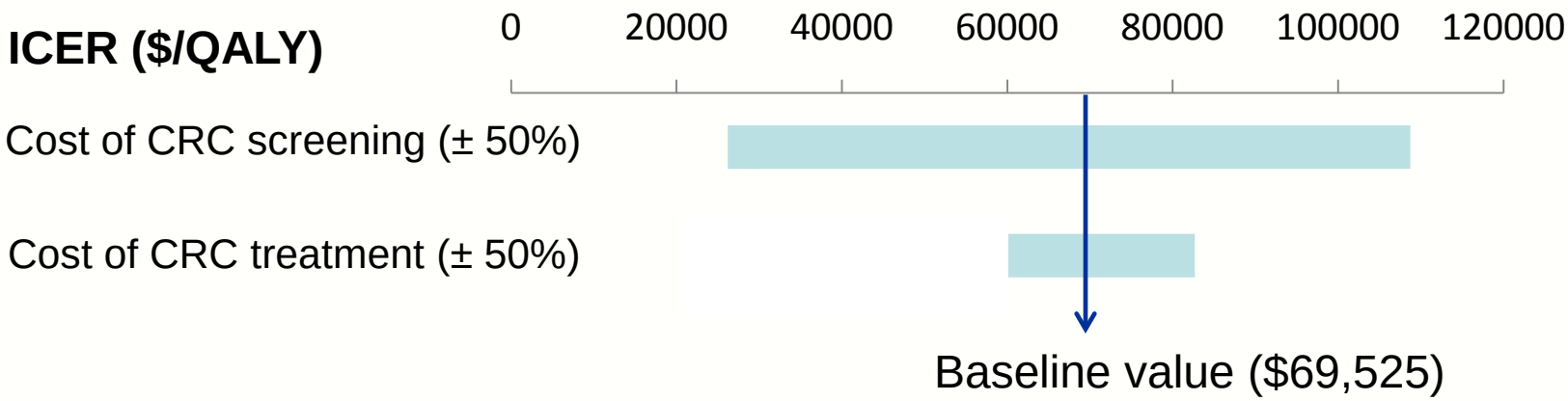
Patients diagnosed with diabetes at age 50 and without hypertension

Screening Strategy	Total cost associated with CRC	Total cost associated with other diseases (mostly CVD and diabetes)	Total medical cost	Difference in total medical cost compared to no screening
No Screening	$ 2437	$ 130410	$ 132847	**0**
Stop age: 50 ***(screened once at age 50)***	$ 2337	$ 131151	$ 133488	**$ 641**
Stop age : 80	$ 2791	$ 131462	$ 134253	**$ 1406**

QALY *vs.* Cost


Non-diabetics at age 50
Diabetics, diagnosed at age 50, without hypertension
Diabetics, diagnosed at age 50, with hypertension
QALYs saved compared to no-screening
Cost difference compared to no-screening
0.3
0.25
0.2
0.15
0.1
0.05
0
500
1000
1500
Stop age:
50
60
70
80
No stop age
$9,043
$13,684
$33,078
$225,339
$1,010 per QALY saved
50
60
70
80
No stop age
$25,588
$39,124
$69,525
$482,331
$7,241
$38,250
$52,766
$108,723
$9,086 per QALY saved
$276,225

Incremental cost-effectiveness ratio is sensitive to costs of CRC screening and costs of CRC treatment



ICER for stop age 80

Population: patients diagnosed with diabetes at age 50, without hypertension

Conclusion

- Using $50,000 per QALY as the threshold for cost-effectiveness
  - It is cost-effective to screen patients without **diabetes at age 50** for colorectal cancer using colonoscopy, starting at age 50 at 10-year intervals **up to age 80**.
  - It is cost-effective to screen patients **diagnosed with diabetes at age 50, without hypertension, up to age 70**.
  - It is borderline cost-effective to screen patients **diagnosed with diabetes at age 50, and with hypertension up to age 70**.

Implications: In the future, colorectal cancer screening recommendations can be individualized

- Consider patient A
  - age 78, male, no family history of CRC
  - BMI = 25, normal blood pressure, no diabetes
  - at ages 52 and 67, he had two colonoscopies which found no adenoma

Screening Option	Reduction in risk of developing CRC compared to do nothing	Life years saved compared to do nothing	Risk of adverse events due to screening	ICER ($ per QALY saved) compared with no screening
Do nothing (no more screening)	0	0	0	**0**
Screened once more at age 78	49%	0.0681	0.0028	**$ 7,319**

Implications: In the future, colorectal cancer screening recommendations can be individualized

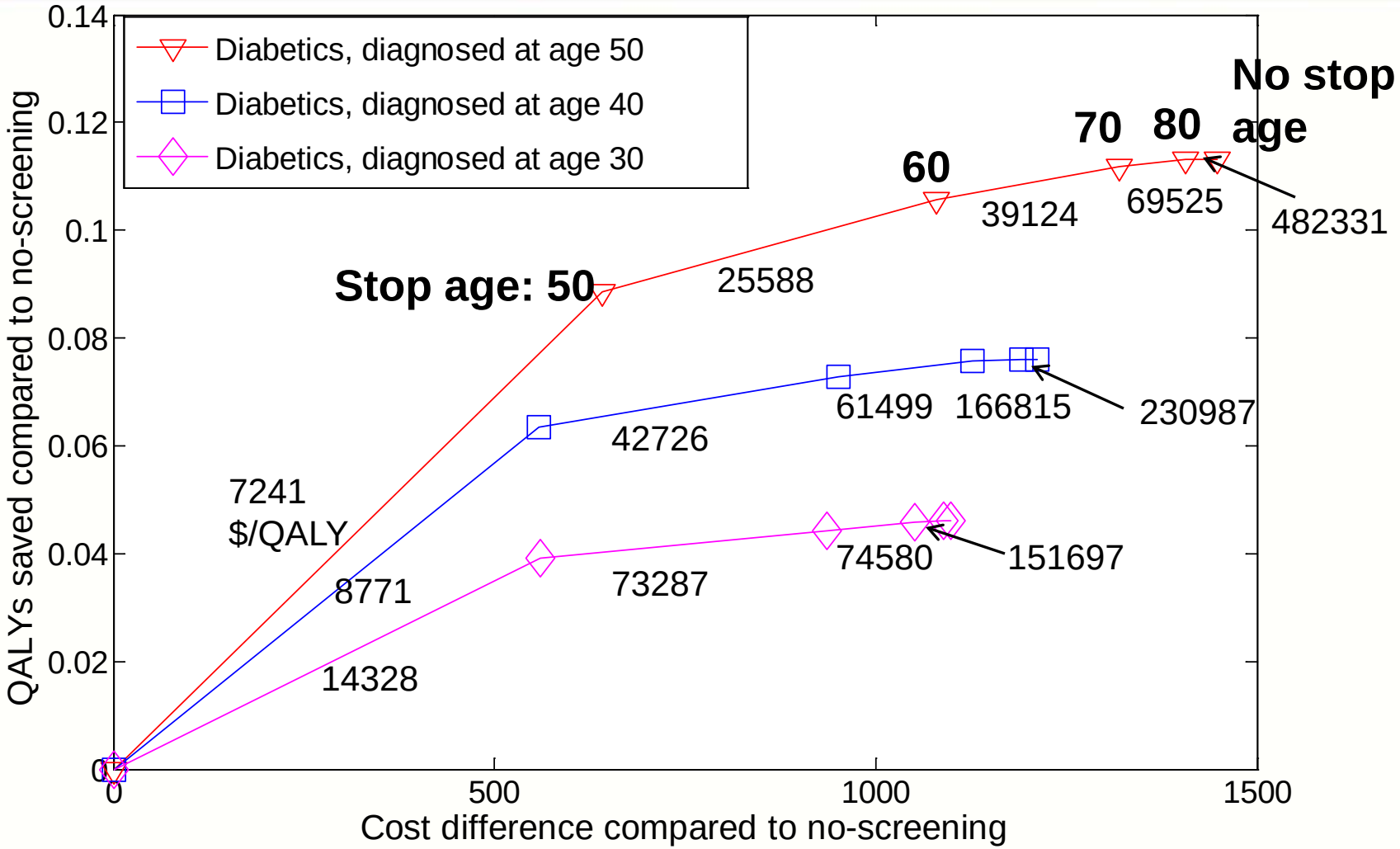
- Consider patient B
  - age 70, male, no family history of CRC
  - BMI = 34, diagnosed with diabetes at age 42, with hypertension
  - at 59, he had a colonoscopy which found no adenoma.

Screening Option	Reduction in risk of developing CRC compared to do nothing	Life years saved compared to do nothing	Risk of adverse events due to screening	ICER ($ per QALY saved) compared with no screening
Do nothing (no more screening)	0	0	0	**0**
Screened once more at age 70	24%	0.0066	0.0015	**$ 115,979**

References

1. Warren JL, Klabunde CN, Mariotto AB, et al. Adverse events after outpatient colonoscopy in the Medicare population. Ann Intern Med 2009;150:849-57, W152.
2. Gatto NM, Frucht H, Sundararajan V, Jacobson JS, Grann VR, Neugut AI. Risk of perforation after colonoscopy and sigmoidoscopy: a population-based study. J Natl Cancer Inst 2003;95:230-Coughlin SS, Calle EE, Teras LR, Petrelli J, Thun MJ. Diabetes mellitus as a predictor of cancer mortality in a large cohort of US adults. Am J Epidemiol 2004;159:1160-7.
3. Larsson SC, Orsini N, Wolk A. Diabetes mellitus and risk of colorectal cancer: a meta-analysis. J Natl Cancer Inst 2005;97:1679-87.
4. Elwing JE, Gao F, Davidson NO, Early DS. Type 2 diabetes mellitus: the impact on colorectal adenoma risk in women. Am J Gastroenterol 2006;101:1866-71.
5. Will JC, Galuska DA, Vinicor F, Calle EE. Colorectal cancer: another complication of diabetes mellitus? Am J Epidemiol 1998;147:816-25.
6. Lansdorp-Vogelaar I, van Ballegooijen M, Zauber AG, Habbema JD, Kuipers EJ. Effect of rising chemotherapy costs on the cost savings of colorectal cancer screening. J Natl Cancer Inst 2009;101:1412-22.
7. Ness RM, Holmes AM, Klein R, Dittus R. Utility valuations for outcome states of colorectal cancer. Am J Gastroenterol 1999;94:1650-7.
8. Kahn R, Alperin P, Eddy D, et al. Age at initiation and frequency of screening to detect type 2 diabetes: a cost-effectiveness analysis. Lancet; 375:1365-74.

Cost *vs.* QALYs for diabetic populations of different durations of diabetes



Incremental cost effectiveness ratio (ICER) for CRC screening up to age 70 in diabetic populations is < $50,000 per QALY