Evaluating Screening Policies for Diabetic Retinopathy: A Simulation Approach

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Background

Diabetic retinopathy (DR) is the leading cause of blindness in American Adults and the most common diabetic eye disease. More than 60% of patients with type 2 diabetes and more than 90% of patients with type 1 diabetes will develop DR within 20 years of diagnosis [1]. Regular and timely screening examinations are crucial as early treatment can prevent up to 98% of DR-related vision loss [2]. Unfortunately, only 30% to 60% of the patients are screened on a yearly basis [3]. The current clinical screening exams are time-consuming, inconvenient, and costly, leading to such low compliance rates.

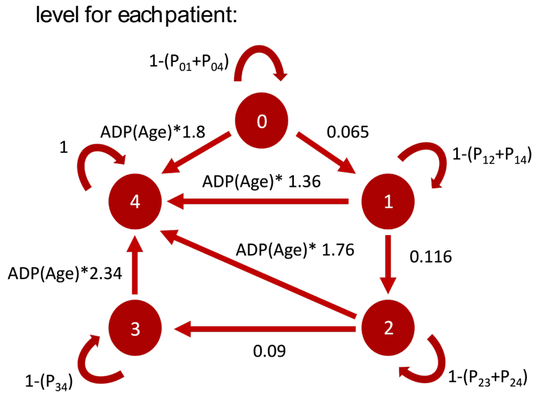
In the last decade, teleretinal screening has received increasing attention as an inexpensive and convenient screening technique. Telescreening facilities use cameras with simple functions to obtain retinal images, which are then electronically sent to specialists. Due to its accessibility, telescreening is considered a viable supplementary exam. However, there is a lack of quantitative understanding about the right balance between teleretinal and in-clinic exams and how this knowledge can help determine an optimal DR screening policy for diabetic patients.

Research Objectives

- Develop a simulation model that mimics the progression of DR and captures the impact of both in-clinic and teleretinal screening on patients' health benefit and spending
- Conduct cost-effectiveness analysis for different screening policies utilizing teleretinal and in-clinic screening technologies to find the optimal screening policy for patients

Methodology

- The primary method used for our analysis was discrete event simulation
- Two different types of measures were used to evaluate screening policies:
  (1) Quality-adjusted life years (QALYs)
  (2) Cost
- Screening accuracy data from the Harris Health teleretinal screening program was collected
- Clinical literature was used to define a base patient: African American, 40-year old male
- A Markov Chain was modeled where each state represents a different disease level for each patient:



0 = NoDR (No DR)
1 = NPDR (Non-Proliferative DR)
2 = PDR (Proliferative DR)
3 = Blindness
4 = Death
$P_{00} = 1-(P_{01}+P_{04})$
$P_{01} = 0.065$
$P_{04} = ADP(Age)*1.8$
$P_{11} = 1-(P_{12}+P_{14})$
$P_{12} = 0.116$
$P_{14} = ADP(Age)*1.36$
$P_{22} = 1-(P_{23}+P_{24})$
$P_{23} = 0.09$
$P_{24} = ADP(Age)*1.76$
$P_{33} = 1-(P_{34})$
$P_{34} = ADP(Age)*2.34$
$P_{44} = 1$
ADP=Annual death probability

- A simulation model was developed based on the Markov chain, where five different screening policies were simulated for further evaluation:

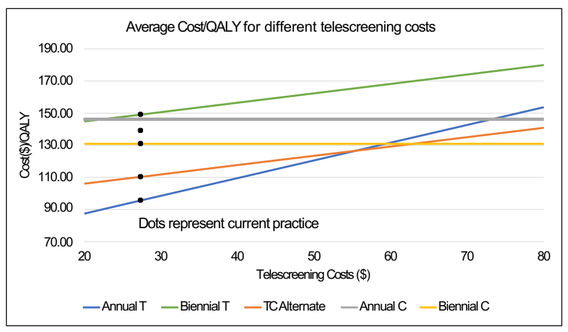
1. Annual teleretinal screening (Annual T)
2. Biennial teleretinal screening (Biennial T)
3. Teleretinal/In-clinic alternate screening (TCAlternate)
4. Annual in-clinic screening (Annual C)
5. Biennial in-clinic screening (Biennial C)

- Sensitivity analysis was conducted to compare the screening policies based on various factors, including screening costs, accuracy, and initial patient probabilities

Simulation model that incorporates different actions taken in each policy

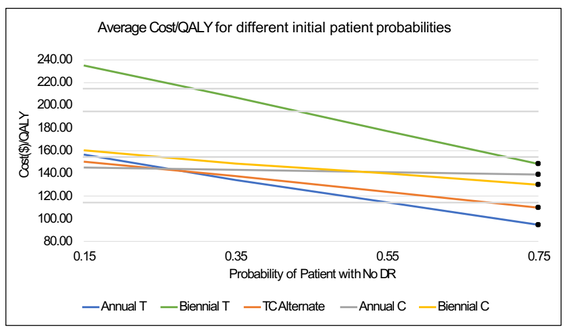
Results

Sensitivity analysis 1:
Varying cost of telescreening vs. Average Cost ($)/QALY obtained by each screening policy



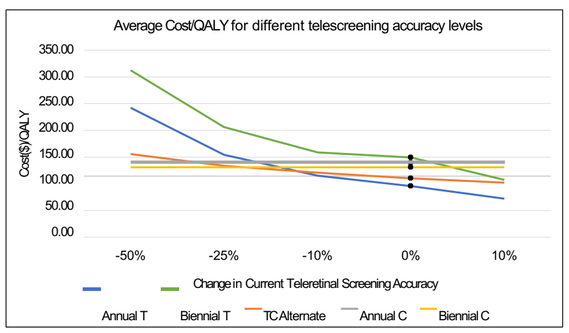
T Cost	Annual T	Biennial T	TC Alternate	Annual C	Biennial C
20	87.44	144.81	106.08	139.03	130.89
27.35	95.56	149.11	110.34	139.03	130.89
40	109.52	156.51	117.68	139.03	130.89
60	131.60	168.21	129.27	139.03	130.89
80	153.67	179.91	140.86	139.03	130.89

Sensitivity analysis 2:
Varying patients' initial probability of No DR vs. Average Cost/QALY obtained by each screening policy



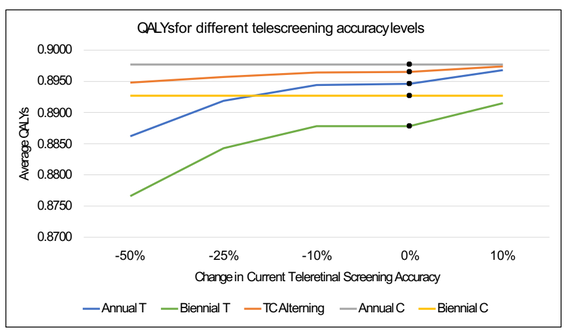
State 0 NoDR	Annual T	Biennial T	TC Alternate	Annual C	Biennial C
0.75	94.64	148.32	109.72	138.94	129.93
0.55	114.52	177.34	123.68	140.99	140.00
0.35	134.07	207.08	137.56	143.07	148.77
0.15	156.56	235.13	150.30	145.14	160.33

Sensitivity analysis 3:
Varying true positive and true negative rates of telescreening vs. Average Cost/QALY obtained by each screening policy



True Positive	True negative	Annual T	Biennial T	TC Alternate	Annual C	Biennial C
0.3744	0.4244	242.22	312.38	155.65	139.03	130.89
0.5615	0.6366	154.53	206.39	133.84	139.03	130.89
0.6738	0.7639	115.35	158.69	120.55	139.03	130.89
0.7487	0.8488	95.56	149.11	110.34	139.03	130.89
0.8236	0.9337	72.20	107.41	102.18	139.03	130.89

Sensitivity analysis 4:
Varying true positive and true negative rates of telescreening vs. Average QALYs obtained by each screening policy



True Positive	True negative	Annual T	Biennial T	TC Alterning	Annual C	Biennial C
0.3744	0.4244	0.8862	0.8766	0.8948	0.8977	0.8927
0.5615	0.6366	0.8919	0.8843	0.8957	0.8977	0.8927
0.6738	0.7639	0.8944	0.8878	0.8964	0.8977	0.8927
0.7487	0.8488	0.8946	0.8878	0.8965	0.8977	0.8927
0.8236	0.9337	0.8968	0.8915	0.8974	0.8977	0.8927

Conclusion

For the base population, annual telescreening is the most cost-effective screening policy out of the five candidate policies in terms of the average cost per QALY. Sensitivity analysis results indicate that benefits of annual telescreening can increase with improved teleretinal imaging technology and lower screening costs. However, for patients with higher probability of having DR, annual in-clinic screening is the best option due to its ability to accurately detect the disease despite the high cost. This study provides valuable insights into the design of a cost-effective DR screening program, especially for patients with low socioeconomic status and limited access to eye care.

Future Work

- Add post-treatment DR progression
- Implement optimization as a second step to find the optimal screening schedule for each patient that enters the system in order to provide personalized screening recommendations
- Incorporate patient adherence rates in the model and analyze the role of telescreening to address patient non-adherence

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