Modeling the cost-effectiveness of risk-stratified screening for esophageal cancer in China

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Background

Esophageal squamous cell carcinoma (ESCC) is a major cause of cancer mortality across Asia, with China bearing the largest share of cases and deaths.

Early screening can reduce mortality, but nationwide implementation has been limited by high costs and resource constraints, underscoring the need for more efficient screening strategies.

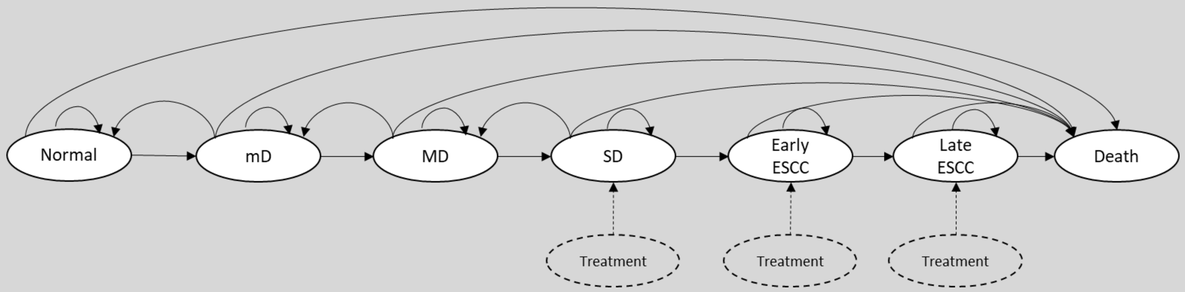
We aim to evaluate the cost-effectiveness of population-based, risk-tailored ESCC screening strategies in China, with the goal of informing national policy and providing insights for similar high-burden settings across Asia.

Methods

- We conducted a model-based cost-effectiveness analysis of ESCC screening strategies in Chinese adults aged 30-79 years.
- A cohort Markov model simulated disease progression across health states over a lifetime horizon from a healthcare perspective.
- The model evaluated risk-stratified strategies incorporating age, sex, geographic area, ALDH2 genotype, and alcohol consumption.
- Inputs were drawn from published sources, with uncertainty addressed through probabilistic sensitivity analysis.
- Outcomes included incremental costs, quality-adjusted life years (QALYs), and incremental cost-effectiveness ratios (ICERs) for population segments.

Methods

Figure 1. Model structure



ESCC: esophageal squamous cell carcinoma; mD: mild dysplasia; MD: moderate dysplasia; SD: severe dysplasia.

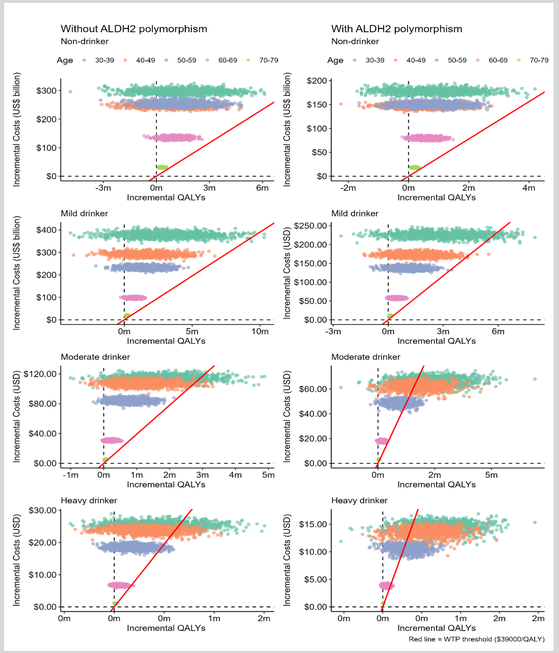
Results

Table 1. Incremental Costs, QALYs, and ICERs for ESCC Screening Using Uniform Screening (Strategy 1) and Single-Risk Stratified Strategies (Strategy 2) among Chinese Adults

Strategy	Incremental cost (US$ Billion)	Incremental QALYs (Million)	ICER (US$ Thousand)
Strategy 1 Uniform screening			
Uniform screening	3815.1 (3549.4 - 4081.7)	33.2 (-38.2 - 106.4)	114.8 (99.8 - 131)
Strategy 2 Single-Risk Stratified Strategies			
Area			
Rural	2194.4 (2043 - 2347.1)	18.5 (-24 - 62.2)	118.6 (97.7 - 142.6)
Urban	1620.7 (1506.4 - 1734.6)	14.7 (-14.2 - 44.3)	109.9 (86.8 - 138.8)
Age			
30-39 years	1298 (1205 - 1391)	13.6 (-15.7 - 43.7)	95.1 (70.8 - 127.6)
40-49 years	1064.3 (989 - 1138.7)	8.4 (-12.2 - 29.7)	127.4 (92.6 - 174.3)
50-59 years	934.5 (870.5 - 998.7)	7 (-8.6 - 23)	133.6 (110.5 - 153.6)
60-69 years	428 (401.3 - 456.3)	3.3 (-2 - 8.5)	130 (125.7 - 132.9)
≥70 years	90.3 (83.7 - 97)	1 (0.3 - 1.6)	94.9 (94.2 - 95.8)
Gender			
Female	1907.2 (1794.6 - 2027.9)	7.9 (-20.6 - 36.8)	241.8 (211.4 - 277)
Male	1907.9 (1754.8 - 2053.8)	25.4 (-17.6 - 69.6)	75.2 (67.4 - 84)
Alcohol Pattern			
Non-drinker	1535.7 (1441.8 - 1634.4)	7.7 (-16.2 - 31.8)	200.1 (165.8 - 237.8)
Mild	1621.2 (1510.5 - 1734.8)	13.4 (-17.2 - 44.7)	121.4 (101.6 - 150.2)
Moderate	539.6 (490.8 - 583.4)	9.5 (-4 - 23.6)	56.9 (48.4 - 66.8)
Heavy	118.6 (106.3 - 129.1)	2.7 (-0.9 - 6.3)	43.6 (33 - 59.3)
ALDH2 polymorphism			
Active ALDH2	2397.7 (2239 - 2561.3)	17.2 (-25.1 - 60.4)	139.4 (118.5 - 163.7)
Inactive ALDH2 variant carrier	1417.4 (1310.5 - 1520.4)	16 (-13.1 - 46)	88.4 (70.3 - 110.4)

Notes: ALDH2: Aldehyde Dehydrogenase 2. ESCC: Esophageal Squamous Cell Carcinoma. ICER: Incremental Cost-Effectiveness Ratio. PSA, Probabilistic Sensitivity Analysis. QALY: Quality-Adjusted Life Year. UI: Uncertainty Interval

Figure 2. Cost-Effectiveness Plane from Probabilistic Sensitivity Analysis (PSA) for Multiple-Risk Stratified Strategies by Age, Alcohol Consumption, and ALDH2 Genotype.



Notes: ALDH2: Aldehyde Dehydrogenase 2. ICER: Incremental Cost-Effectiveness Ratio. PSA, Probabilistic Sensitivity Analysis. QALY: Quality-Adjusted Life Year. WTP: Willingness-to-Pay.

Results

- Results Uniform screening every five years for all adults aged 30–79 yielded an ICER of $92,595 (95% CI: $82,565–$104,705), exceeding the willingness-to-pay threshold of $39,000, indicating it is not cost-effective.
- Stratified analysis revealed substantial heterogeneity. Screening was more cost-effective in males (ICER $71,600) than females ($137,200) and in 60-69 age groups (ICER $ 80,900.
- Alcohol intake and genetic factors were strong modifiers. Heavy drinkers with ALDH2 deficiency had ICERs well below the WTP threshold, particularly at younger ages.
- Moderate drinkers with ALDH2 deficiency aged 30–49 also met cost-effectiveness criteria, with ICERs ranging from $27,900 to $32,800.

Discussion & Conclusion

- Risk-tailored strategies that incorporate ALDH2 genotype and alcohol consumption substantially improve efficiency compared to uniform approaches.
- It supports transitioning from rigid age-based eligibility to precision screening approaches that integrate genetic and behavioral risk factors, informing policy development in China and other high-burden Asian settings.

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