RESEARCH ARTICLE

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Economic Evaluation of Fecal Occult Blood Test and Colonoscopy for Colorectal Cancer Screening in Indonesia: A Cost-Effectiveness Analysis

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Abstract

Objective: to evaluate the cost-effectiveness of Fecal Occult Blood Test (FOBT) and colonoscopy as Colorectal Cancer (CRC) screening methods in Indonesia. It is hoped that the results will serve as a reference for developing an efficient and targeted early CRC screening policy. **Methods:** A cost-effectiveness analysis comparing FOBT and colonoscopy for CRC screening in Indonesia was performed using a Markov model with a 40-year horizon. The analysis, from a healthcare payer perspective, included direct medical costs and QALYs. Parameters were sourced from literature and national data. Outcomes were lifetime costs, QALYs, and ICERs, with a willingness-to-pay threshold of three times GDP per capita. Costs and outcomes were discounted at 3%. Sensitivity analyses tested model uncertainty. Analyses were done using Microsoft® Excel. **Result:** CRC screening reduced both the incidence of colorectal cancer and CRC-related mortality compared to no screening. In terms of costs and outcomes, colonoscopy every 10 years produced the highest QALYs (2,114,459) and was the only strategy considered cost-effective compared to no screening, with an ICER of US$2,909.675/QALY, well below the willingness-to-pay threshold. While screening strategies incurred higher costs than no screening, colonoscopy was dominant when compared to both annual and biennial FOBT (ICERs: US$ -33,063.979/QALY and US$ -14,338.339/QALY, respectively). One-way sensitivity analysis identified cancer utility as key drivers of ICER variability. Probabilistic sensitivity analysis confirmed the robustness of the results, with the majority of simulations favoring colonoscopy as the most cost-effective option. **Conclusion:** Colonoscopy every 10 years is the most cost-effective strategy for colorectal cancer screening in Indonesia. It is cost-effective compared to no screening and dominant compared to annual or biennial FOBT.

Keywords: Colorectal cancer- screening- Colonoscopy- FOBT- Cost-effectiveness

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Introduction

Colorectal cancer (CRC) is one of the three most commonly diagnosed cancers worldwide and is the second leading cause of cancer-related death, after lung cancer [1]. According to the WHO in 2020, there were 1.9 million new cases and more than 930,000 deaths caused by colorectal cancer. By 2040, the number of CRC cases is projected to increase to 3.2 million per year, with 1.6 million deaths [2]. This increase is in line with the economic burden, with estimated costs reaching up to USD 2.8 trillion globally and 191 billion euros per year in the European region [3].

The success of CRC therapy highly depends on early detection of adenomas, so that curative surgery can be performed immediately. However, in Indonesia, most patients present at an advanced stage, resulting in poor prognosis and low life expectancy [4]. Consequently, early screening will be key to decreasing mortality and improving patients' quality of life [5-7]. CRC screening is important to be implemented as a government program because the disease has a long asymptomatic period of about 10-15 years.

Some screening methods are already available, such as fecal occult blood test (FOBT), sigmoidoscopy, colonoscopy, and DNA stool test [8]. In Indonesia, the most commonly used methods for CRC screening are colonoscopy and FOBT. Although colonoscopy has high sensitivity, this method is invasive, can cause bleeding, and has a low participation rate [9, 10]. Because of this, non-invasive methods like FOBT are considered as alternatives

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[9]. In the Indonesian context, both guaiac-based fecal occult blood test (gFOBT) and immunochemical fecal occult blood test (iFOBT or FIT) are utilized for colorectal cancer screening.

In Indonesia, CRC screening is not implemented or systematically integrated into the National Health Insurance (Jaminan Kesehatan Nasional / JKN) program. The absence of this scheme results in limited access to early detection. Moreover, there is no pharmacoeconomic study to support CRC screening policy relevant to the Indonesian context [11]. Based on the context above, the aim of this study was to evaluate the cost-effectiveness of FOBT and colonoscopy as CRC screening methods in Indonesia. It is hoped that the results will serve as a reference for developing an efficient and targeted early CRC screening policy.

Materials and Methods

Model

An economic evaluation was performed to assess the cost-effectiveness of FOBT and colonoscopy for colorectal cancer (CRC) screening in Indonesia. A Markov model was constructed with three health states: 1) healthy, 2) colorectal cancer, and 3) death, using a one-year cycle length and adopted from previous studies (see Figure 1) [12, 13]. The model does not explicitly incorporate population participation rates in screening due to the lack of representative data on screening adherence in Indonesia. This approach aligns with the study's objective to provide a foundational or baseline assessment of the intervention's effectiveness.

In this model, the "Healthy" state represents individuals who are currently healthy but have risk factors for developing colorectal cancer (i.e., starting at age 45 years). During each annual cycle, individuals may transition to the "Colorectal Cancer" or "Death" states. We simulated a cohort of 100,000 adults aged 45 years and older. Three screening strategies were evaluated in the model: colonoscopy every 10 years, fecal occult blood test (FOBT) annually (every 1 year), and FOBT biennially (every 2 years). The model's time horizon was set to 40 years, representing a lifetime, and the analysis was conducted from the perspective of the healthcare payer.

Parameter Input

The baseline characteristics of the hypothetical cohort are presented below. The cohort consisted of individuals starting at age 45. In the base-case analysis, annual transition probabilities were derived from Carr et al (2020) and these probabilities vary every five years (as shown in Table 1) [14]. The treatment effect was assumed to remain constant over the lifetime horizon.

The effectiveness of screening methods, in terms of sensitivity and specificity, was based on Ramdzan et al. for FOBT and Zhang et al. for colonoscopy [15-18]. The modeling process incorporated colorectal cancer specificity to account for false positives. Due to the absence of CRC-specific utility data for Indonesia, utility values were estimated using a combination of breast, colorectal, and lung cancer data from the study by Perwitasari et al. [19]. Only direct medical costs were considered, as the analysis was conducted from a healthcare payer's perspective. These included both screening and treatment

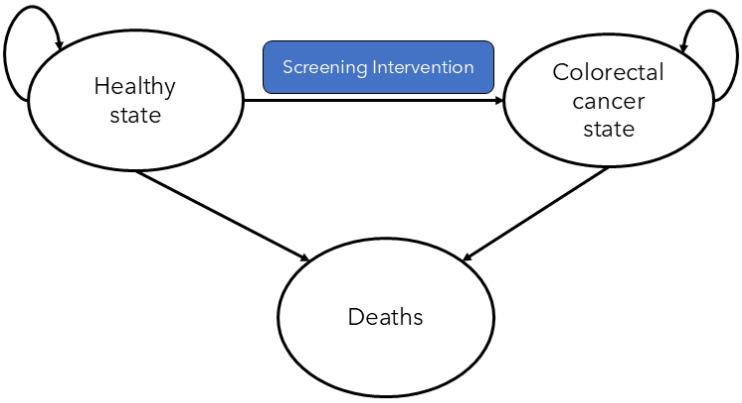

Figure 1. Three-State Markov Model

Table 1. Age-Specific Transition Probabilities at 5-Year Intervals

Transition Probability	Age								
	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85 older
TP_H2H	0.999763	0.9995345	0.999161	0.9986685	0.9980785	0.997427	0.9966595	0.9958305	0.99535
TP_H2CRC	0.000237	0.0004655	0.000839	0.0013315	0.0019215	0.002573	0.0033405	0.0041695	0.00465
TP_H2D	0.0023235	0.0038525	0.005849	0.009049	0.013446	0.020591	0.039381	0.0673965	0.149337
TP_CRC2D	0.00006	0.0001245	0.000235	0.0004055	0.0006395	0.000951	0.0014355	0.002153	0.0032385
TP_CRC2CRC	0.99994	0.9998755	0.999765	0.9995945	0.9993605	0.999049	0.9985645	0.997847	0.9967615

TP_H2H, Transition probability health to health; TP_H2CRC, Transition probability health to colorectal cancer; TP_H2D, Transition probability health to deaths; TP_CRC2D, Transition probability colorectal cancer to deaths; TP_CRC2CRC, Transition probability colorectal cancer to colorectal cancer

Table 2. Input Parameters for the Markov Model

Input Parameter	Baseline	Minimum Value	Maximum Value	Sources
Utility				
Healthy	1	-	-	Assumption
Cancer	0.68	0.36	1	Perwitasari et al., 2023
Deaths	0	-	-	Assumption
Risk Ratio, Sensitivity, and Specificity				
RR reduced CRC (Colonoscopy-10 years)	0.49	0.45	0.53	Zhang et al., 2020
RR reduced mortality (Colonoscopy-10 years)	0.38	0.36	0.4	Zhang et al., 2020
RR reduced CRC incidence (FOBT-Annually)	0.86	0.72	1	Jodan et al., 2019
RR reduced mortality (FOBT-Annually)	0.69	0.56	0.86	Jodan et al., 2019
RR reduced CRC incidence (FOBT-Biennially)	0.95	0.87	1	Jodan et al., 2019
RR reduced mortality (FOBT-Biennially)	0.88	0.82	0.93	Jodan et al., 2019
Sensitivity Colonoscopy	0.89	0.82	0.93	Hassan et al., 2011
Specificity Colonoscopy	0.26	0.21	0.31	Hassan et al., 2011
Sensitivity FOBT	0.31	0.25	0.38	Ramdzan et al., 2019
Specificity FOBT	0.87	0.86	0.89	Ramdzan et al., 2019
Discount rate				
Cost	0.03	0.01	0.05	Kristin et al., 2021
Utility	0.03	0.01	0.05	Kristin et al., 2021
Cost (USD)				
Colonoscopy	168.10	126,075	210,125	Permenkes No. 3 Tahun 2023
FOBT	60.61	45.46	75.76	Permenkes No. 3 Tahun 2023
CRC Treatment	1,092.16	1,365.2	819.12	Permenkes No. 3 Tahun 2023

Abbreviation: RR, Relative risk; Cls, Colonoscopy; FOBT, Fecal occult blood test; CRC, Colorectal cancer; Table note: All cost data were converted to US Dollar (currency based on 2025).

costs. Treatment costs were calculated from preoperative staging through to advanced stages, in accordance with colorectal cancer treatment guidelines in Indonesia [4].

The treatment cost data were sourced from national tariffs of primary and secondary healthcare services as outlined in the Ministry of Health Regulation of the Republic of Indonesia No. 3 of 2023 [20]. The total treatment costs, including chemotherapy agents, hospital bills, and doctor visits, were weighted according to treatment patterns specific to each cancer stage (1–4). The costs were adjusted based on proportions reported by Toes-Sountendijk et al. [21]. We assumed that patients diagnosed with cancer would automatically receive treatment. The estimated costs in the cohort are expressed as per-cycle (1-year) costs and are projected over the patient's lifetime. The Gross Domestic Product (GDP) deflator was used to adjust for inflation, and all costs were converted to 2025 US dollars. An overview of the model input parameters used in the analysis is provided in Table 2.

Model outcomes

Total lifetime costs and quality-adjusted life years (QALYs) were estimated for each strategy. The incremental cost-effectiveness ratio (ICER) was calculated by dividing the additional costs by the additional QALYs gained between the intervention and comparator across various scenarios (e.g., screening vs. no screening or between different screening methods). An intervention was deemed cost-effective if the ICER was below the willingness-to-pay (WTP) threshold, set at three times the GDP per capita, as recommended for Indonesia [22, 23]. In 2024, Indonesia's GDP per capita was reported at US$4,960.3 [24]. Both costs and health outcomes were discounted at an annual rate of 3%, in line with national health economic evaluation guidelines. All analyses were performed using Microsoft® Excel.

Sensitivity Analysis

To assess the robustness of the model outcomes, both one-way sensitivity analysis (OSA) and probabilistic sensitivity analysis (PSA) were conducted. In the OSA, individual parameters were varied independently across their respective 95% confidence intervals (CIs) or standard deviations (SDs). When neither 95% CI nor SD was available, a ±25% variation from the base-case value was applied. For the discount rate, a range between 1% and 5% was used. The findings from the OSA were illustrated using a tornado diagram.

For the PSA, probability distributions were assigned to all model inputs, and random values were simultaneously sampled across parameters. The model was then recalculated through 1,000 Monte Carlo simulations. Beta distributions were applied to probabilities, utilities, and effectiveness values, while gamma distributions were used for cost parameters. The PSA results were displayed using cost-effectiveness planes and cost-effectiveness acceptability curves (CEACs).

Table3. Results for the Cost-effectiveness Analysis Using a Payer Perspective

Screening methods	Lifetime cost (USD)	Lifetime QALYs	Incremental Cost (USD)	Incremental QALYS	ICERs (USD/QALY)	Decision
Without screening	37,818,280	2,109,554	Ref	Ref	Ref	-
Colonoscopy every 10 year	52,091,659	2,114,459	14,273,379	4.905	2,909.675	Cost-Effective
FOBT Annually	158,042,580	2,111,255	120,224,300	1.701	70,675.753	Not cost-effective
FOBT Biennially	98,037,741	2,111,255	60,219,461	1.701	35,400.961	Not cost-effective
Colonoscopy every 10 year	52,091,659	2,114,459	Ref	Ref	Ref	-
FOBT Annually	158,042,580	2,111,255	105,950,921	-3.204	-33,063.979	Dominated by colonoscopy
FOBT Biennially	98,037,741	2,111,255	45,946,082	-3.204	-14,338.339	Dominated by colonoscopy

Table note: Blue table=without screening as comparator (reference); Orange table=Colonoscopy every 10 year as comparator (reference)

Results

Clinical outcomes

Colorectal cancer (CRC) screening has been shown to be effective in reducing both the incidence of CRC and CRC-related mortality compared to no screening. Colonoscopy every 10 years demonstrated the greatest reduction in CRC incidence over time, followed by annual FOBT, biennial FOBT, and no screening. A similar pattern was observed in preventing CRC-related deaths, with colonoscopy every 10 years providing the most significant benefit in reducing mortality. The predicted annual decreases are presented in detail in Figure 2.

Cost-effectiveness analysis

The discounted costs and QALYs for each strategy are presented in the Table 3. The discounted costs for all screening methods are higher than for no screening: US$52,091,659 for colonoscopy every 10 years, US$158,042,580 for annual FOBT, US$98,037,741 for biennial FOBT, and US$37,818,280 for no screening.

Colonoscopy every 10 years yields the highest discounted QALYs, followed by annual FOBT, biennial FOBT, and no screening. The ICER results, when compared to no screening, show that only colonoscopy every 10 years is cost-effective (ICER: US$8,577/QALY). Furthermore, when compared to the other screening methods, colonoscopy was dominant (vs. annual FOBT: US$ -33,063.979/QALY; vs. biennial FOBT: US$ -14,338.339/QALY).

Sensitivity Analysis

In the one-way sensitivity analysis, we examined the impact of changes in each parameter on the ICER value. Based on the tornado diagram in Figure 3, the most influential parameter on the ICER for each strategy is the utility value of cancer, followed by the cost of colonoscopy, and discount utility. Other parameters, such as cost, discount rate, and the effectiveness of colonoscopy, did not significantly affect the ICER values.

We conducted a probability sensitivity analysis using a Monte Carlo simulation, running it 1000 times to iterate the calculation process for new cost and QALY values. The outcomes, represented by the distribution of 1,000 new ICERs are visualized on a cost-effectiveness plane or scatter plot (detailed on figure 4) and will be illustrated with cost-effectiveness acceptability curve (detailed on Figure 5). At a threshold 3xGDP per capita Indonesia (USD 14,880/QALY), colonoscopy every 10 years vs without screening, cost-effective in 88%. Performing

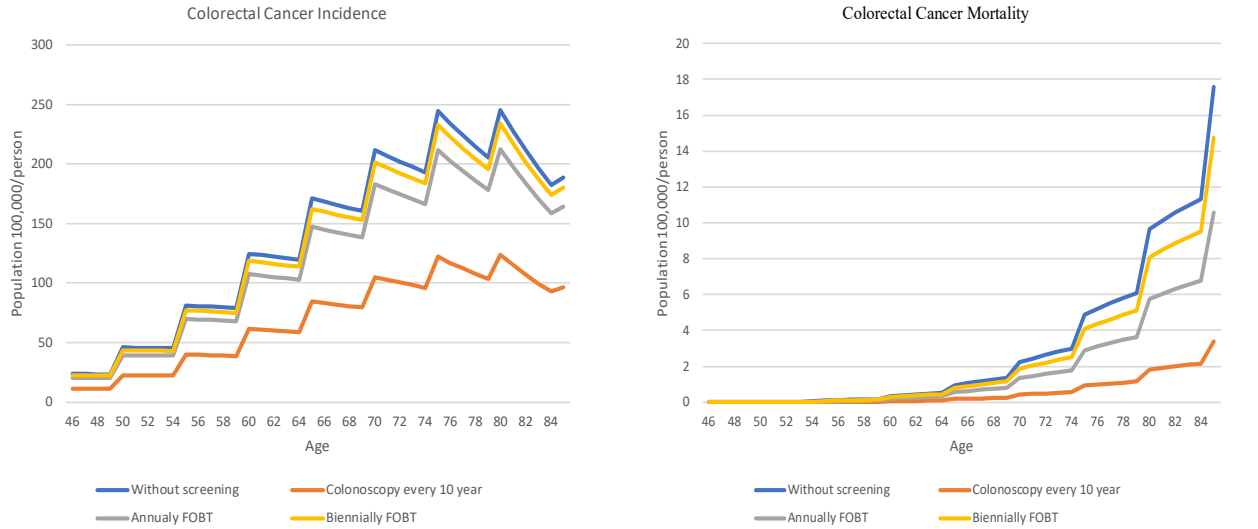

Figure 2. CRC Incidence Curve (Left) and Mortality Curve (Right)

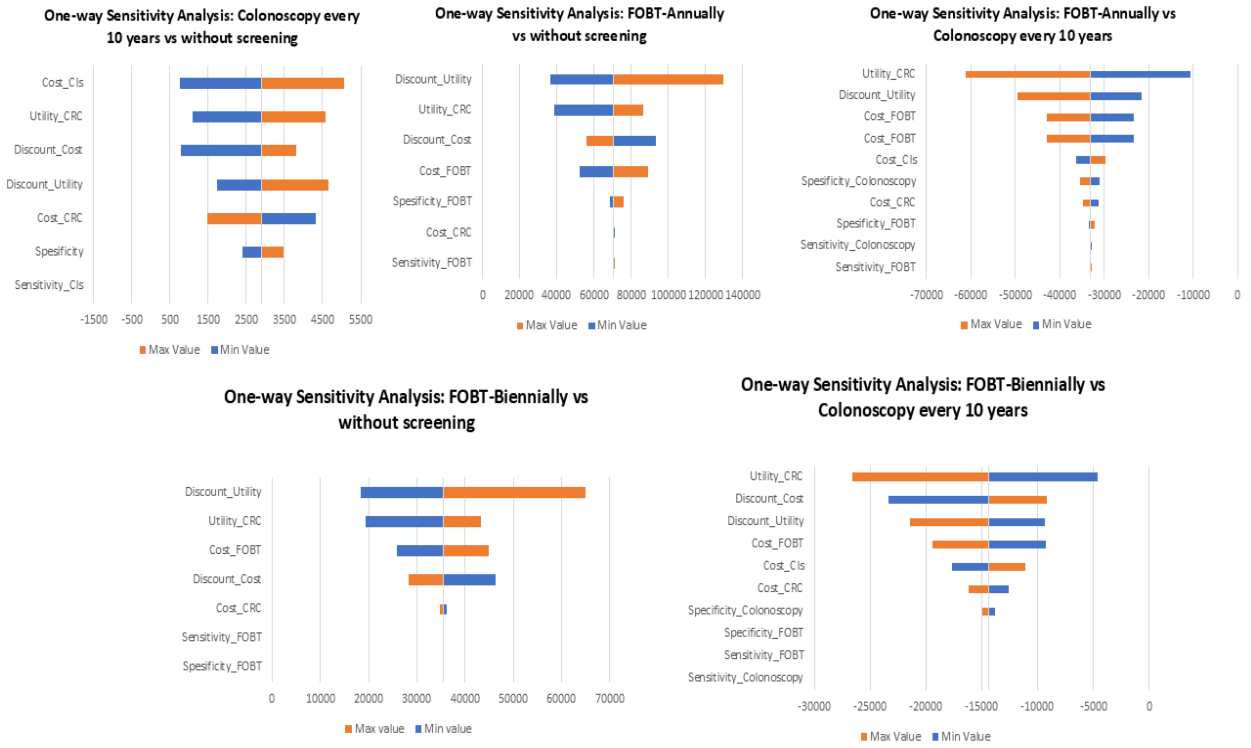

Figure 3. One-way sensitivity analysis. Figure Note: Cost_CRC = Cost of colorectal cancer treatment; Cost_Cls = Cost of colonoscopy screening; Cost_FOBT = Cost of FOBT early detection; Discount_Utility = Utility discount rate; Discount_Cost = Cost discount rate; Sensitivity_Cls = Sensitivity of Colonoscopy; Specificity_Cls = Specificity of Colonoscopy; Sensitivity_FOBT = Sensitivity of FOBT; Specificity_FOBT = Specificity of FOBT; Utility_CRC = Utility value for colorectal cancer.

the FOBT annually or biennially is not cost-effective compared with no screening.

Discussion

We developed a population-based Markov Model

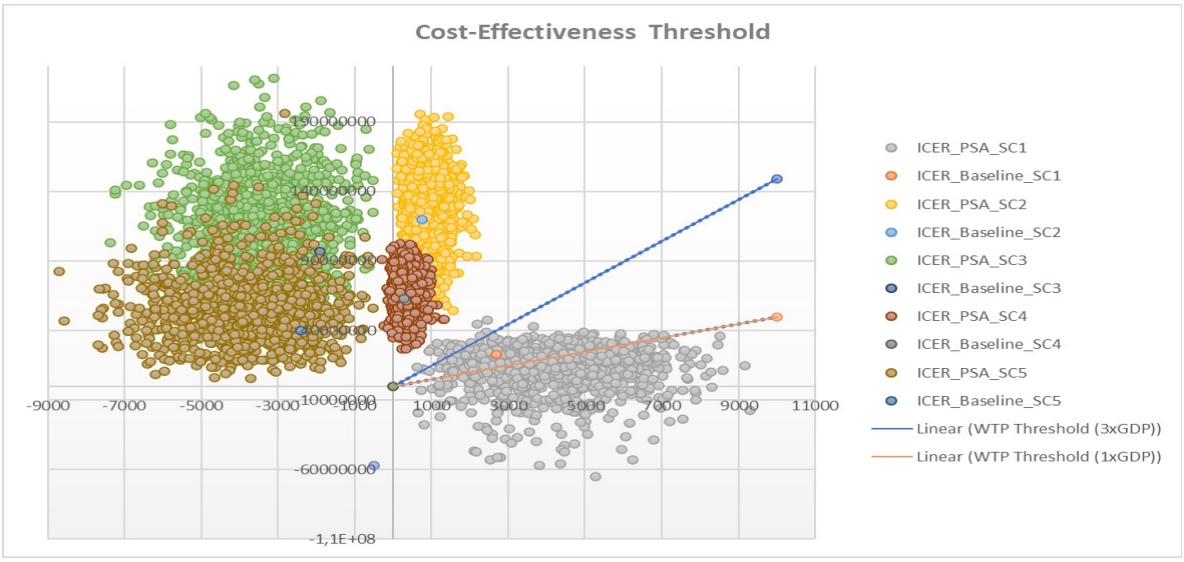

Figure 4. Cost-Effectiveness Threshold. Figure Note: ICER_PSA_SC1: ICER colonoscopy vs without screening (1,000 iterations); ICER_Baseline_SC1: ICER colonoscopy vs without screening; ICER_PSA_SC2: ICER FOBT annually vs without screening (1,000 iterations); ICER_Baseline_SC2: ICER FOBT annually vs without screening; ICER_PSA_SC3: ICER FOBT annually vs colonoscopy (1,000 iterations); ICER_Baseline_SC3: ICER FOBT annually vs colonoscopy; ICER_PSA_SC4: ICER FOBT biennially vs without screening (1,000 iterations); ICER_Baseline_SC4: ICER FOBT biennially vs without screening; ICER_PSA_SC5: ICER FOBT biennially vs colonoscopy; ICER_Baseline_SC5: ICER FOBT biennially vs colonoscopy. Abbreviation: WTP: Willingness-to-Pay; GDP: Gross domestic product

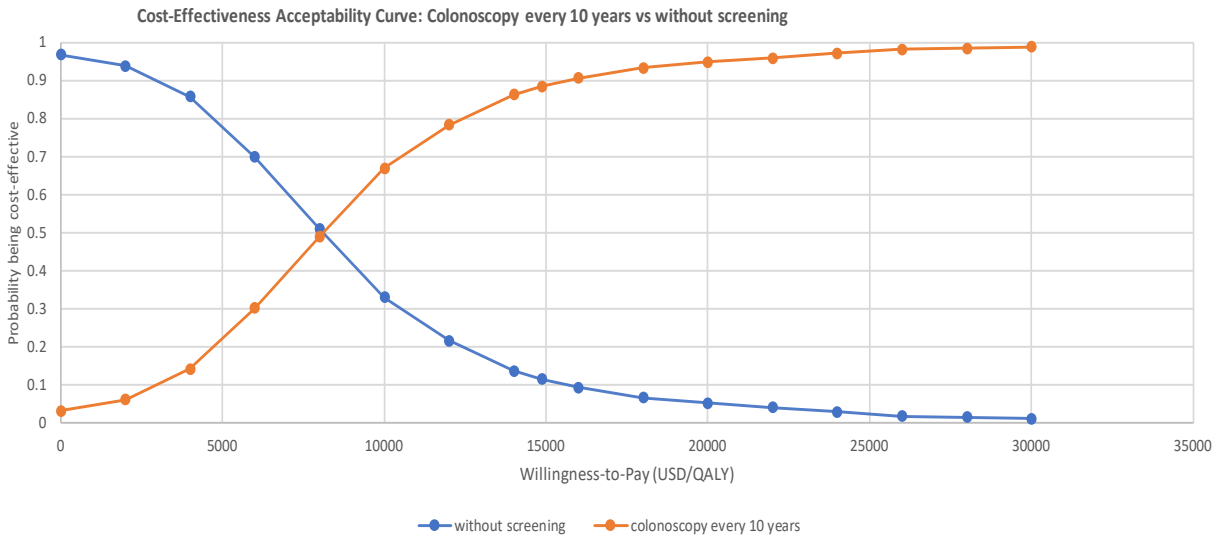

Figure 5. Cost-Effectiveness Acceptability Curve Colonoscopy Every 10-year vs without Screening

to assess the cost-effectiveness of including FOBT and colonoscopy as CRC screening methods. This intervention aimed to prevent CRC, especially in high-risk populations. Our study shows that the use of colonoscopy every 10 years compares with no screening as a cost-effective intervention, then FOBT compared to no screening. The result is in line with the PSA, which showed that the ICERs are distributed below WTP threshold (quadrant I), but when colonoscopy every 10 years compared to FOBT-annually/biennially it will be dominant based on direct medical costs (ICERs are distributed below the x-axis/quadrant II). However, this analysis does not account for direct non-medical cost and indirect costs. Prior studies have shown that colonoscopy every 10 years is the cost-effective strategy for CRC screening. However, there has not been a study in Indonesia demonstrating the cost-effectiveness of CRC screening in preventing CRC. To the best of our knowledge, this is the first study addressing this issue in Indonesia. In the clinical model results, all three early detection modalities were shown to reduce colorectal cancer incidence and mortality (compared with no screening). These findings indicate that early detection of colorectal cancer can significantly lower cancer incidence, particularly among individuals aged 50 years and older [25]. Other literature also supports that the implementation of large-scale community-based CRC screening programs can lead to reductions in both CRC incidence and mortality within a relatively short time frame [26, 27].

A systematic review by Khalili et al. assessing the cost-effectiveness of colorectal cancer (CRC) screening reported incremental cost-effectiveness ratios (ICERs) ranging from US$3,316 to US$38,745 for colonoscopy every 10 years compared to no screening [28]. These results suggest that colonoscopy every 10 years is a cost-effective strategy relative to no screening and dominant in 74% of simulation when compared with any type of annual fecal blood testing [28, 29]. This finding is consistent with evidence from other middle-income countries such as Thailand, where colonoscopy every 10 years was also found to be a more economical option for initial CRC screening. In contrast, annual or biennial fecal occult blood testing (FOBT) did not demonstrate cost-effectiveness, which may be attributed to the cumulative costs incurred by frequent testing [30]. Colonoscopy is more sensitive and allows access to the rectum and the entire colon.

In high-income countries, both colonoscopy every 10 years and annual fecal immunochemical testing (FIT) tend to be more frequently cost-effective. This is likely due to higher healthcare spending, relatively lower costs of colonoscopy in relation to purchasing power, and higher screening adherence rates. However, in middle- and low-income countries, the implementation of early detection strategies requires careful contextual consideration, including local economic burdens, healthcare system capacity, and cost-effectiveness based on real-world local data [31]. In Markov modelling for cost-effectiveness evaluation, several factors can lead to variations in the ICER value. One such factor is the range between the starting and stopping ages of screening, the wider the range, the higher the ICER. Additionally, shorter screening intervals are associated with increased ICER values [32].

Previous studies have highlighted several contributing factors to disparities in cost-effectiveness outcomes, including regional differences, socioeconomic status, and access to healthcare services. These factors are also associated with population adherence to early detection programs [33]. Although colonoscopy demonstrates higher cost-effectiveness, its implementation depends on the availability of adequate infrastructure, skilled personnel, and patient willingness to undergo the procedure. These aspects were not addressed in detail in this analysis. Consequently, in real-world settings, non-invasive screening methods such as FOBT may be considered more feasible by policymakers due to their lower resource requirements and higher patient acceptability, despite offering lower cost-effectiveness. This has significant policy implications for early detection strategies in the country. Colonoscopy could be considered as the primary screening method and potentially integrated

into the National Health Insurance (JKN) program. In the long term, colonoscopy plays a bigger role in preventing cancer from developing in the first place. Because the long-term protective effect is strong, screening can be done less frequently without significantly reducing its benefits [34]. Efforts should also be made at the policy level to enhance public awareness and participation in CRC screening programs. Government-led health promotion campaigns, community-based outreach, and integration of screening education into primary healthcare services may help improve screening uptake.

This study has several limitations. First, the Markov model employed in the analysis only represented the natural history of CRC in a generalized manner and did not stratify the disease progression into more detailed stages. Second, the lack of Indonesia-specific utility and cost data highlights the need for future local research to better inform health economic evaluations. National efforts to collect patient-reported outcomes and real-world cost data will enhance the reliability of future decision-making. Nevertheless, these were the best available data within our setting. To address the uncertainty of these parameters, a probabilistic sensitivity analysis was conducted with 1,000 simulations. Using a willingness-to-pay (WTP) threshold of three times the GDP per capita, the ICER for colonoscopy every 10 years compared to no screening was found to be below the threshold, whereas FOBT (annual or biennial) exceeded it substantially. However, colonoscopy showed dominant based on direct medical cost potential when compared directly with FOBT at annual or biennial intervals.

This study highlights the potential cost-effectiveness of early detection strategies, suggesting that incorporating such approaches into national health programs could optimize resource allocation and improve public health outcomes. The findings provide valuable insights for policymakers to design evidence-based interventions. Future research is encouraged to use prospective data and broader population samples to strengthen the generalizability and reliability of the model outcomes. Further research is needed to utilize prospective data in the collection of input parameters, such as utility, cost data, and early detection effectiveness.

Author Contribution Statement

The authors confirm contribution to the paper as follows: study conception and design: IKS, LAKS, ANY; data collection: NKSW, NPNLD; analysis and interpretation of the results: IKS, LAKS, ANY, DE, TP; draft manuscript preparation; IKS, LAKS, ANY. All authors reviewed the results and approved the final version of the manuscript.

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Ethical Approval

The study was approved by Bali Mandara General Hospital by ethics number 088/EA/KEPK.RSBM.DISKES/2025.

Conflict of Interest

The authors have no conflicts of interest to declare; all co-authors have seen and agree with the content of manuscript.

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