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Cost-effectiveness Analysis of Increasing Access to Colorectal Cancer Diagnostic Approaches: an Example from Thailand

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Data availability statement: Colo-Sim model used in this analysis is publicly available at https://github.com/zhasgul/colosim. Additional materials for this analysis are reported in the supplementary document.

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Abstract

Objectives: Low and middle-income countries (LMICs) face constraints of low access to colorectal cancer (CRC) diagnosis and limited colonoscopy capacity. We aim to conduct an economic evaluation of increasing access to diagnostic approaches and colonoscopy capacity building in Thailand.

Methods: We conducted a population-based cost-effectiveness analysis through healthcare and societal perspectives using Colo-Sim, a system dynamics model of CRC care in Thailand. We analyzed improvement in access to the fecal immunochemical test (FIT) screening (strategy-I), symptom evaluation (strategy-II), and both (strategy-III). We analyzed these strategies in combination with the 8-point risk score (RS) and under current versus increasing colonoscopy capacity to a sufficient level (SC). We estimated the quality-adjusted life years (QALYs) gained and costs from each strategy over 25 years. We also performed probabilistic sensitivity analyses to study their uncertainty.

Results: Under the current willingness-to-pay (WTP) in Thailand (160,000 THB), strategy-III+RS+SC results in the highest QALY gained (2.6M) and an additional cost of 158B THB with 95% chance of being cost-effective compared to the status quo. Each strategy combined with RS or SC results in a more cost-effective approach than strategies without RS or SC. When WTP is lower than 75,000, the status quo has the highest probability of being the most cost-effective strategy. However, as WTP increases, strategy-III+RS+SC achieves the highest probability with an 80% chance of being the most cost-effective strategy at the current WTP.

Conclusions: Our study analyzed the cost-effectiveness of strategies for CRC screening and care under limited colonoscopy capacity. A combination of strategies, including increasing access to FIT screening and symptom evaluation, using the 8-point risk score, and building more colonoscopy capacity, has the potential to be the most cost-effective strategy.

Introduction

Colorectal cancer (CRC) is one of the most common cancers and a major cause of global cancer deaths [1]. Moreover, CRC is projected to have the second highest global cost in 2020-2050 among all cancers, with a burden of $2.8 trillion [2]. Early detection efforts such as screening and symptom evaluation can effectively prevent CRC [1]. However, in low and middle-income countries (LMICs), there are constraints in access to early CRC detection, and colonoscopy capacity is limited, resulting in the growth of CRC incidence and mortality rates [3].

Colonoscopy is considered the gold standard in diagnosing CRC, and it is used as a screening tool in the USA [4]. Unlike developed countries, LMICs have been recommended to use colonoscopy as a secondary test after a positive fecal immunochemical test (FIT) due to limitations in colonoscopy capacity [5]. Despite its benefit in decreasing CRC-related deaths, FIT is insufficient in CRC prevention due to low sensitivity in precancerous detection [1st article[1]]. Thus, risk-stratification scores were developed to improve test performance, such as the 8-point risk score for CRC screening validated in the Asia-Pacific population [6]. Before receiving FIT screening, the 8-point risk score is used to classify individuals based on their demographic data, and only high-risk individuals should directly receive a colonoscopy. The 8-point risk score can further increase the sensitivity of FIT, which is found to be more cost-effective in countries such as Japan [7]. However, using this risk score in addition to FIT decreases specificity, resulting in more false positive cases and greater colonoscopy capacity than what is required [6].

Thailand has recommended FIT as a main primary screening method since 2017 [8]. Meanwhile, individuals experiencing symptoms are able to undergo colonoscopy for symptom evaluation directly. However, in Thailand, low access to CRC diagnosis (i.e., FIT screening and symptom evaluation) has resulted in more than half of CRC cases being diagnosed in the late stage [1st article]. Moreover, improving access to CRC diagnosis is insufficient in both CRC prevention and death reduction due to poor FIT test performance and limited colonoscopy capacity [9]. Prior research suggests that Thailand

[1] See the GitHub page for the link to our first article that reports Colo-Sim: https://github.com/zhasgul/colosim

should build more colonoscopy capacity and improve test performance by combining FIT with risk-stratification scores [9]. However, the economic requirements of building colonoscopy capacity are still unclear, and the effects of the risk score in countries with limited colonoscopy capacity are underexplored.

In this study, we perform an economic evaluation of increasing access to CRC detection in the context of limited colonoscopy capacity. We analyzed different CRC detection approaches, including FIT screening (with and without the 8-point risk score) and symptom evaluation. We also aim to quantify the economic burdens of building colonoscopy capacity in Thailand.

Material and Methods

Overview of Colo-Sim

We used Colo-Sim to conduct this economic evaluation. Colo-Sim is a population-based compartmental dynamic model representing colorectal cancer screening and care with constraints in low access to diagnosis and limited colonoscopy capacity [1st article]. The model was calibrated to Thai historical data from 2004-2021 and validated with expert interviews. In Colo-Sim, we focused on patients aged 50 years or older in Thailand. The model simulated the progression of CRC development based on the adenoma-carcinoma sequence (see Fig. S1).

Screening and symptom evaluation

The model includes two ways to diagnose CRC, including screening and symptom evaluation. We used FIT as the primary screening modality. Based on the USPSTF2016, all asymptomatic individuals aged 50-75 are recommended to get a FIT screening annually [8]. All FIT-positive individuals are recommended to get a colonoscopy to confirm the diagnosis, whereas the symptomatic population should get an urgent evaluation with a colonoscopy [8,10].

In addition, we analyzed the impact of combining the 8-point risk score with FIT. First, the 8-point risk score should be calculated by physicians based on age, sex, CRC family history, body mass index, and smoking history (see Table S5). Individuals with five scores and more are considered high risk. Those with a high-risk score are recommended to receive colonoscopies, while individuals with a low-risk score (four scores or less) are directed toward FIT screening [6].

Colonoscopy capacity

A recent study noted the current colonoscopy capacity of about 200K people per year [9]—this estimate is subject to sensitivity analysis, as we discuss below. However, information on resources required to build colonoscopy capacity is limited. From Thai databases and interviews with four experts in gastroenterology, colorectal surgery, and CRC modeling in Thailand, we collected information on these resources, including medical devices, colonoscopy units, and healthcare workforces [11]. We estimated and reported the colonoscopy demand for each strategy in Table S3. Based on the colonoscopy demand and currently available resources, experts believe that the available devices and colonoscopy units in Thailand are sufficient to meet the demand for colonoscopy under all strategies (see Table S4). However, there is a shortage of healthcare workforces, including physicians and nurses, to perform the procedure. Thus, we assumed that expanding colonoscopy capacity in Thailand for the strategies required only training more physicians and nurses.

Strategies

In the status quo (baseline), we assumed no improvement in access to diagnosis (i.e., screening and symptom evaluation) or colonoscopy capacity. To estimate the values of access to screening and symptom evaluation, we conducted model calibration based on available data. Then we used their values in 2022 to project quality-adjusted life year (QALY) and cost for 2023-2047.

We projected QALY and the cost of twelve strategies over the next 25 years compared to the status quo. The strategies included a combination of two different screening modalities (FIT with and without the 8-point risk score (RS)); increasing access to screening (strategy-I), symptom evaluation (strategy-II), and both (strategy-III); and increasing colonoscopy capacity to a sufficient level (SC). We estimated a sufficient level of colonoscopy capacity based on the maximum colonoscopy demand for each strategy over 25 years. We calculated the cost of expanding resources for colonoscopy capacity building for each strategy based on inputs from experts and the Thai database. See more details of each strategy in Table S2.

Data input

We used costs from both healthcare and societal perspectives reported in Thai Baht (THB) (1 USD (March 2023)=34.19 THB). We gathered all cost and utility data from published literature in Thailand. Estimates on the cost of increasing colonoscopy capacity are limited; hence, we collected and combined information from literature, the Thai database, and expert interviews (see Table S1). Sources of other parameters were mainly described in our recent study [1st article].

Budget impact and strategy analyses

We estimated cost and QALY for the status quo and each strategy over 25 years. We performed a budget impact analysis to compare the cost of each strategy with the status quo. We also estimated an incremental cost-effectiveness ratio (ICER) per QALY gained compared to the status quo for each strategy. We used 1.5-time per capita GDP (160,000 THB) as the common wiliness-to-pay (WTP) threshold in Thailand [13].

Sensitivity analysis

We conducted three sensitivity analyses. First, we conducted a probabilistic sensitivity analysis (PSA) on all model parameters, using 1,000 simulation runs with Latin hypercube sampling. We assigned distribution to parameters based on prior research, as shown in Table S1. We used a uniform distribution with a range of ±20% for parameters without a confidence interval.

Second, as noted earlier, a recent study reported a colonoscopy capacity of 200K people per year; however, the methodology used to estimate this capacity was not provided [9]. We therefore performed a sensitivity analysis to explore the effects of different current colonoscopy capacities on the results.

Finally, we analyzed uncertainty on both QALY gained and budget impact from each strategy compared to the status quo, as well as various willingness-to-pay (WTP) thresholds from 0 to 3 times per capita GDP in Thailand. We analyzed the probability of each strategy being the most cost-effective choice at each WTP.

Results

Budget impact and strategy analyses

The key results from our budget impact and strategy analyses are presented in Table S6. In the status quo, we project that annual costs for CRC care will increase due to rising CRC incidence rates, resulting in a cumulative cost of 443B THB over 25 years. Each strategy we analyze requires an additional budget but offers greater QALY gained than compared to the status quo.

Compared with the status quo under the current WTP threshold, strategy-I and I+RS are not cost-effective, while others are. Strategy I+RS+SC results in the lowest ICER of 59K THB compared to the status quo. Among all strategies, strategy-III+RS+SC is the most cost-effective strategy with the highest QALY gained.

Under the current WTP threshold, all strategies with RS are more cost-effective than those without. RS results in less QALY gained with less additional cost combined with strategies-I and III, but had minimal effect on strategy-II and strategy-II+SC. However, RS results in more QALY gained with lower cost when combined with strategy-I+SC and strategy-III+SC. Therefore, strategy-I+RS+SC and strategy-III+RS+SC dominate strategy-I+SC and strategy-III+SC across all WTP thresholds, respectively.

Combining SC with each strategy results in more QALY gained with additional cost. Based on the current WTP, all strategies with SC are more cost-effective than those without SC (see Table S6).

Probabilistic sensitivity analysis

Fig. 1 shows uncertainty in QALY gained and budget impact for each strategy under 160,000 THB WTP threshold compared to the status quo. Strategy-II, II+RS, II+SC, and II+RS+SC have the highest probability of being cost-effective among 12 strategies at 100%. Strategy-I has the lowest chance of being cost-effective at 30% (See Table S7).

Both RS and SC increased or maintained the probability of being cost-effective for each strategy under the current WTP (see Table S7). SC has a greater impact on increasing QALY gained for each strategy compared to RS. However, both had minimal effect on strategy-II.

Figure 2 shows the probability of each strategy being the most cost-effective at different WTP thresholds. At WTP thresholds of 74,000 THB or less, the status quo has the highest probability of being the most cost-effective strategy. Strategy-III+RS+SC has the highest probability at 75,000 THB or more WTP. At the current WTP (1.5 times per capita GDP), strategy-III+RS+SC has the highest probability of 82% of being most cost-effective, followed by strategy-II+RS, strategy-II, and strategy-III+SC (8%, 6%, and 4%, respectively). At WTP of 320,000 THB (3 times per capita GDP), strategy-III+RS+SC has the highest probability of 89%, followed by strategy-III+SC, strategy-II+RS, and strategy-II (6%, 3%, and 2%, respectively) (see Table S7).

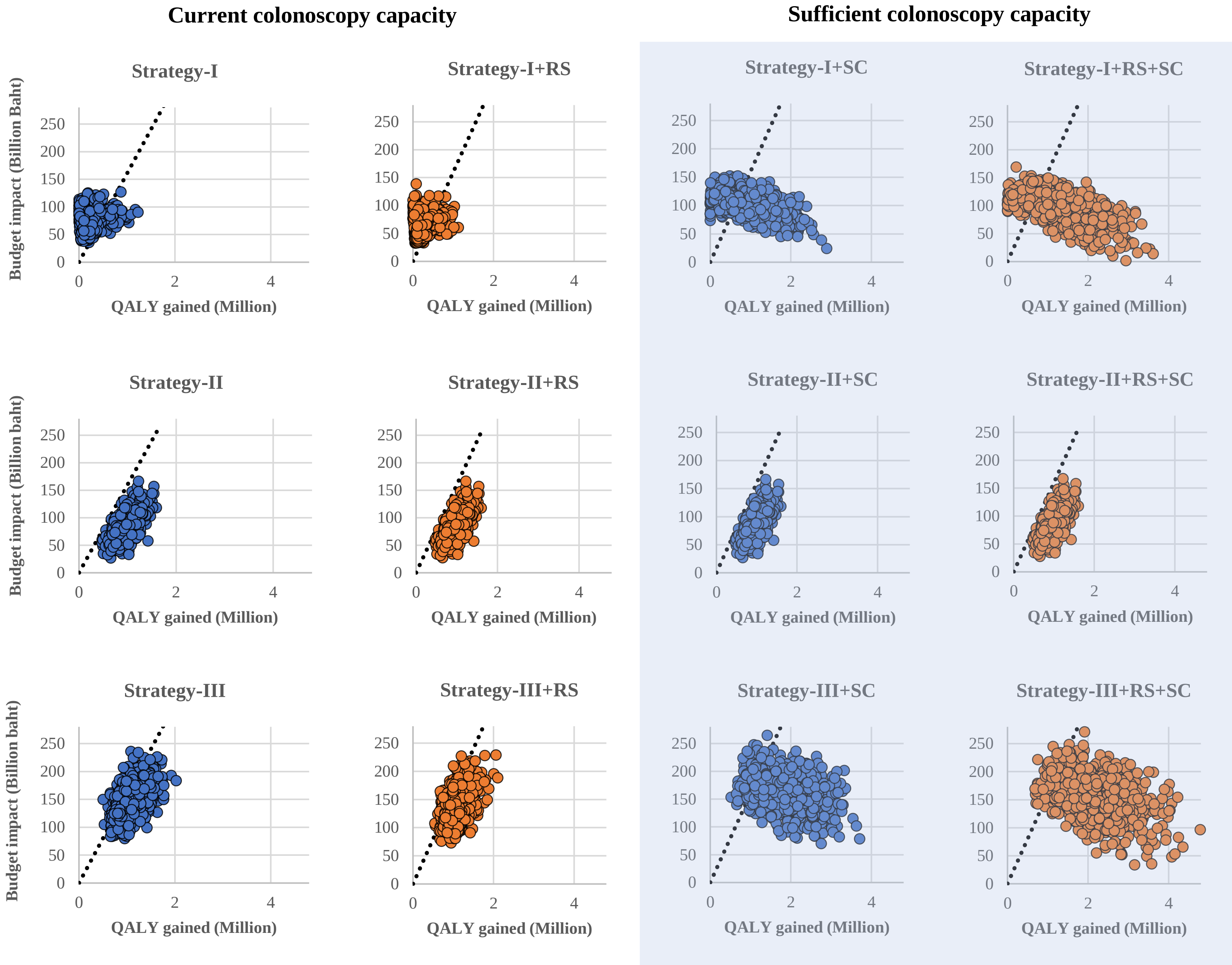

Fig. 1: Probabilistic sensitivity analysis on uncertainty parameters in QALY gained (x-axis) and budget impact (y-axis) from twelve strategies compared to the status quo. Given RS: 8-point risk score, SC: increasing to sufficient colonoscopy capacity.

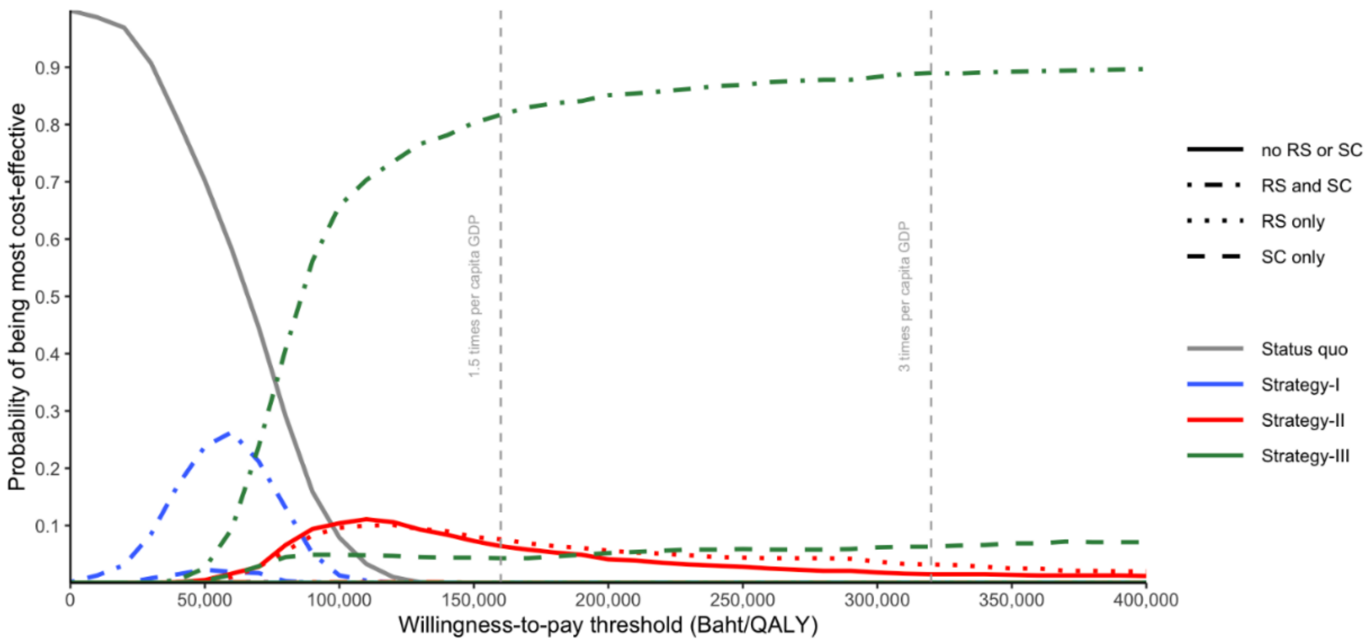

Fig. 2: Cost-effective acceptability curve for strategies across various level of WTP thresholds

Discussion

This study presents the QALY and budget impact over 25 years of CRC care in Thailand. We analyzed the status quo and twelves strategies, a combination of increased access to CRC diagnosis (i.e., screening, symptom evaluation), using the 8-point risk score, and increasing colonoscopy capacity. This is the first study that a) evaluates the cost-effectiveness of increasing access to CRC diagnosis with and without combining the 8-point risk score in limited colonoscopy capacity, and b) estimates the cost-effectiveness of increasing colonoscopy capacity.

Each strategy increases early detection and treatment, resulting in better overall prognosis and greater QALY than the status quo. However, each requires an additional budget due to higher coverage of CRC diagnosis, treatment, and surveillance. We found that a combination of strategies, including increasing access to screening and symptom evaluation, using the 8-point risk score, and increasing the colonoscopy capacity was the most cost-effective at a current general WTP (1.5 times per capita GDP). In sensitivity analysis, this strategy also has the highest probability of being the most cost-effective if WTP is more than 75,000 THB (0.7 times per capita GDP).

The 8-point risk score has pros and cons to CRC care, especially in settings with limited colonoscopy capacities. It increases the sensitivity to detect polyps and CRC, resulting in more early treatment, more CRC prevention, and overall better CRC prognosis. However, the risk score also decreases the specificity, resulting in more false positives primary screening [6]. Thus, combining the 8-point risk score might allocate the limited colonoscopy capacity into false positive individuals, resulting in delayed treatment in true positive and less QALY gained (e.g., increasing access to FIT screening strategy with versus without the risk score). With the common WTP of 160,000 THB in Thailand, each strategy combined with the 8-point risk score is more cost-effective than the strategy alone. However, studies in other countries with limited colonoscopy capacity might have different results due to varying WTP and costs of interventions. For example, in our study, increasing access to FIT screening strategy without the risk score is more cost-effective than the strategy with the risk score if WTP is more than 207,000 THB (1.9 times per capita GDP).

LMICs face the constraint of limited colonoscopy capacity. However, economic evaluations in LMICs, including Thailand, analyzed strategies for increasing screening access without considering this constraint [5,10,14–16]. A study suggested that increasing access to FIT screening is cost-effective [8], consistent with studies in other countries. However, in our study, increasing access to FIT screening has only a 30% probability of being cost-effective. Without increasing colonoscopy capacity, a combination of strategies, including increasing access to only symptom evaluation and using the 8-point risk score was the most cost-effective among the twelve strategies, with the highest probability of being cost-effective (100%) compared to the status quo.

In our previous study, colonoscopy capacity building prevents CRC deaths and cases [1st article]. However, the cost of building more capacity is unknown. Thus, we tried to estimate the cost and cost-effectiveness of colonoscopy capacity building. Thailand has a strong CRC care infrastructure, such as sufficient colonoscopy devices and units (where the procedure is performed) to satisfy increased demands from each strategy. Thus, based on expert interviews, we assumed that the cost of building colonoscopy capacity only comes from increasing healthcare workforce to perform colonoscopies.

There are several ways to expand the number of physicians, such as training more gastroenterologists and surgeons—gastroenterologists and surgeons are the only subspecialties qualifying to perform the procedure in Thailand [17]. We suggest training internal medicine doctors and general practitioners in a short course on performing colonoscopy, which is relatively low-cost and has a short training duration [18,19]. Based on expert interviews, we estimated that each doctor trained in the short course could perform colonoscopies 4 patients per week, and training each doctor required one more assisted nurse. In other words, training one doctor and one nurse can increase the colonoscopy capacity by 208 (4*52 weeks) people per year. In this way, colonoscopy capacity building results in a great increase in QALY gained while it slightly increases the total budget. Thus, each strategy combining colonoscopy capacity building is more cost-effective than the strategy with the current capacity. However, other countries with different infrastructures might have different results and should conduct the research based on their contexts.

Our study has several limitations. First, all limitations of the Colo-Sim [1st article] are limitations to this study. Second, several inputs were missing to calculate the cost of colonoscopy capacity building. We estimated them using assumptions made by the experts interviewed. Third, our analysis is at the national level. We did not consider area differences in the colonoscopy devices and units, workforce, and access to CRC diagnosis. Fourth, our study assumed that access to CRC diagnosis remains constant after strategy implementations. However, the level of access may decline over time after the implementation, which may require strategies and a budget to maintain the access. Lastly, we did not include opportunity costs from delayed treatment in other benign diseases, such as hernia, osteoarthritis of the knee, and chronic gastritis. All strategies we analyzed increase CRC burdens because of higher coverage in CRC diagnosis, treatment, and surveillance. Healthcare workers will spend more time on CRC care, resulting in less time to take care of these diseases. Moreover, operating rooms will be used for CRC screening, treatment, and surveillance, which might delay the treatment of these diseases.

Despite these limitations, this study provides insights by evaluating the cost-effectiveness of increasing access to CRC diagnostic approaches. These approaches include a combination of FIT screening, symptom evaluation, and using the 8-point risk score. The combination of increased access to FIT screening, symptom evaluation, the 8-point risk score, and building more colonoscopy capacity has the potential to be the most cost-effective strategy over 25 years in Thailand.

Conflict of Interest: None.

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Online Supplementary materials for

Cost-effectiveness Analysis of Increasing Access to Colorectal Cancer Diagnostic Approaches: an Example from Thailand

S1. Model overview

Fig. S1. Visualization

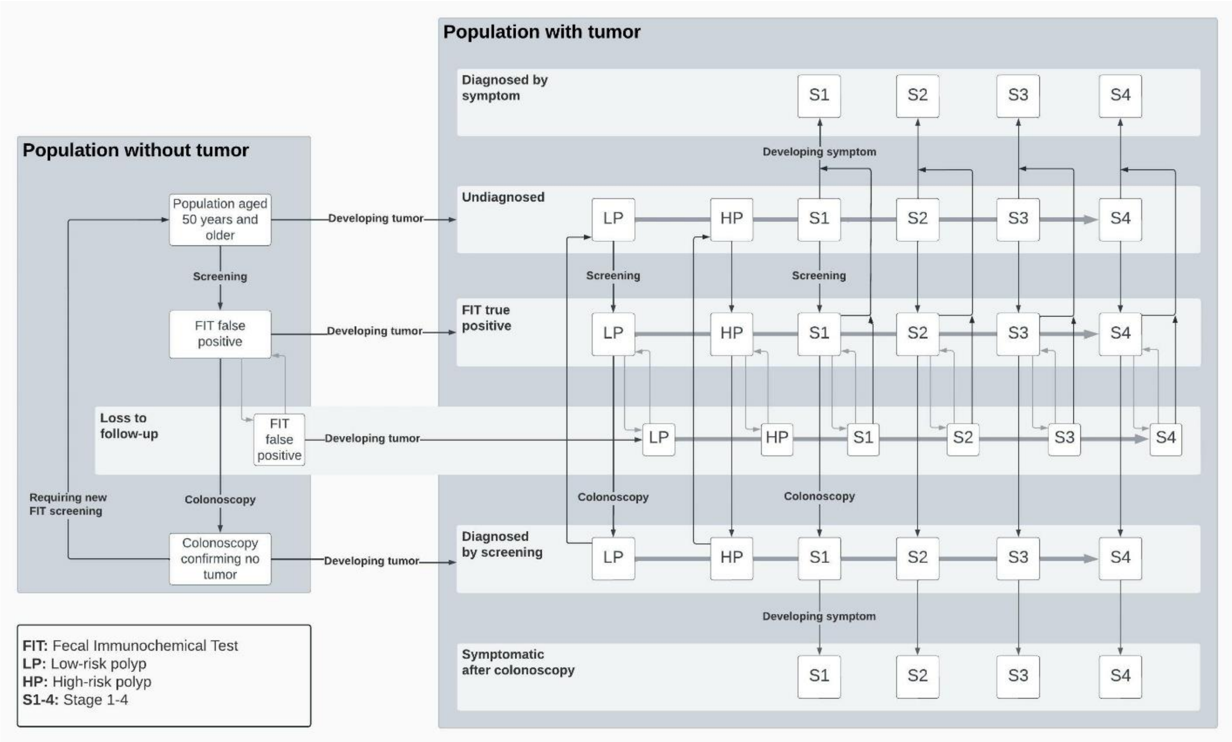

Table S1. Data inputs

Parameter	Value	Unit	Reference
Accessibility to diagnostic colonoscopy from screening policy	0.72	Dmnl	[20]
Accessibility to FIT from screening policy	0.62	Dmnl	[20]
Accessibility to FIT ratio in population without tumors	1.17	Dmnl	1st article*
Accessibility to symptom evaluation relative to the baseline from symptom evaluation policy	3.43	Dmnl	1st article
Average time in FIT positive waiting for a colonoscopy	1	Year	Assumption
Colonoscopy capacity	200,000	People/year	[9]
Crude death rate of HRP	0.017	Per year	1st article
Crude death rate of LRP	0.017	Per year	1st article
Crude death rate of population without tumors	0.017	Per year	1st article
Crude death rate of symptomatic diagnosed CRC stage 1	0.05	Per year	[21]
Crude death rate of symptomatic diagnosed CRC stage 2	0.08	Per year	[21]

Parameter	Value	Unit	Reference
Crude death rate of symptomatic diagnosed CRC stage 3	0.18	Per year	[21]
Crude death rate of symptomatic diagnosed CRC stage 4	0.4	Per year	[21]
Crude death rate ratio in undiagnosed and asymptomatic diagnosed CRC	0.47	Dmnl	1st article
DMC 1st year treatment CRC stage 1	50,955	Baht/people	[22]
DMC 1st year treatment CRC stage 2	98,947	Baht/people	[22]
DMC 1st year treatment CRC stage 3	113,444	Baht/people	[22]
DMC 1st year treatment CRC stage 4	121,084	Baht/people	[22]
DMC bleeding complication	16,004	Baht/people	[22]
DMC colonoscopy with biopsy	4,115	Baht/people	[22]
DMC colonoscopy without biopsy	3,264	Baht/people	[22]
DMC FIT screening	42	Baht/people	[22]
DMC other years treatment CRC stage 1	5,337	Baht/people /year	[22]
DMC other years treatment CRC stage 2	22,485	Baht/people /year	[22]
DMC other years treatment CRC stage 3	27,078	Baht/people /year	[22]
DMC other years treatment CRC stage 4	121,084	Baht/people /year	[22]
DMC perforation complication	37,420	Baht/people	[22]
DMC short course training per one doctor and nurse	50,000	Baht/people	[18,19]
DNMC 1st year treatment CRC stage 1	21,170	Baht/people	[22]
DNMC 1st year treatment CRC stage 2	53,937	Baht/people	[22]
DNMC 1st year treatment CRC stage 3	64,679	Baht/people	[22]
DNMC 1st year treatment CRC stage 4	103,361	Baht/people	[22]
DNMC bleeding complication	2,339	Baht/people	[22]
DNMC colonoscopy	1,085	Baht/people	[22]
DNMC diagnosis	1,430	Baht/people	[22]
DNMC FIT negative	267	Baht/people	[22]
DNMC FIT positive	283	Baht/people	[22]
DNMC other years treatment CRC stage 1	5,168	Baht/people /year	[22]
DNMC other years treatment CRC stage 2	15,313	Baht/people /year	[22]

Parameter	Value	Unit	Reference
DNMC other years treatment CRC stage 3	19,415	Baht/people /year	[22]
DNMC other years treatment CRC stage 4	103,361	Baht/people /year	[22]
DNMC perforation complication	11,949	Baht/people	[22]
Incidence rate of bleeding from colonoscopy	0.0026	Per year	[23]
Incidence rate of perforation from colonoscopy	0.0005	Per year	[23]
Initial fraction undiagnosed CRC stage 1	0.003	Dmnl	1st article
Initial fraction undiagnosed CRC stage 2	0.0004	Dmnl	1st article
Initial fraction undiagnosed CRC stage 3	0.0007	Dmnl	1st article
Initial fraction undiagnosed CRC stage 4	0.0003	Dmnl	1st article
Initial fraction undiagnosed HRP	0.0137	Dmnl	1st article
Initial fraction undiagnosed LRP	0.1419	Dmnl	1st article
Progression rate from CRC stage 1 to CRC stage 2	0.3	Per year	[24]
Progression rate from CRC stage 2 to CRC stage 3	0.45	Per year	[24]
Progression rate from CRC stage 3 to CRC stage 4	0.5	Per year	[24]
Progression rate from HRP to CRC stage 1	0.05	Per year	[24]
Progression rate from LRP to HRP	0.015	Per year	[24]
Progression rate from population without tumor to LRP	0.015	Per year	1st article
Rate of coming back to observed FIT positive	0.01	Per year	Assumption
Sensitivity of colonoscopy in CRC	0.95	Dmnl	[25]
Sensitivity of colonoscopy in HRP	0.85	Dmnl	[25]
Sensitivity of colonoscopy in LRP	0.75	Dmnl	[25]
Sensitivity of FIT in CRC	0.67	Dmnl	[26]
Sensitivity of FIT in HRP	0.24	Dmnl	[27]
Sensitivity of FIT in LRP	0.076	Dmnl	[27]
Sensitivity of FIT+RS in CRC	0.7	Dmnl	[6]
Sensitivity of FIT+RS in HRP	0.464	Dmnl	[6]
Sensitivity of FIT+RS in LRP	0.076	Dmnl	[6]
Specificity of FIT	0.95	Dmnl	[26]
Specificity of FIT+RS	0.864	Dmnl	[6]
Symptomatic detected rate CRC stage 1	0.006	Per year	1st article
Symptomatic detected rate CRC stage 2	0.088	Per year	1st article
Symptomatic detected rate CRC stage 3	0.344	Per year	1st article
Symptomatic detected rate CRC stage 4	0.657	Per year	1st article
Utilities CRC stage 1**	0.74	Dmnl/people	[8]
Utilities CRC stage 2**	0.67	Dmnl/people	[8]

Parameter	Value	Unit	Reference
Utilities CRC stage 3**	0.61	Dmnl/people	[8]
Utilities CRC stage 4**	0.25	Dmnl/people	[8]
Utilities population without tumor/polyp**	0.83	Dmnl/people	[8]

FIT: Fecal immunochemical test, HRP: High-risk polyp, LRP: Low-risk polyp, CRC: Colorectal cancer, DMC: Direct medical cost, DNMC: Direct non-medical cost, RS: using the 8-point risk score

* We refer to another submission to ISDC 2023 for full details about the model (including model description, formulation, and calibration): submission #1164 titled "Dynamics of Colorectal Cancer Screening in Low and Middle-Income Countries: A Modeling Analysis from Thailand."

** These parameters have a Beta distribution. All other parameters have a uniform distribution.

S2. Strategy details

Table S2. Descriptions for each strategy

Strategy	Definition	Parameter names	Baseline value	Strategy value	References
Strategy-I	Improving access to screening at achievable rates, estimated in a previous study in Thailand	Accessibility to FIT	3%	62%	[20]
		Accessibility to diagnostic colonscopy	10%	72%	[20]
Strategy-II	Improving access to symptom evaluation in each stage, projected to result in mean sojourn time of five years in 2032 (assuming to reach the USA level; reported to be five years in 1997-2010). All undiagnosed CRC cases have no symptoms and a mortality rate equal to the population without a tumor.	Accessibility to symptom evaluation relative to the baseline	1	3.43	1st article
Strategy-III	Combination of strategy-I and II				
SC	Increasing colonoscopy capacities to a sufficient level for the strategies	Colonoscopy capacity	200,000	See Table S3	[9]
RS	Combining FIT screening with risk stratification using the 8-point risk score	Specificity of primary screening	95%	86%	[6]
		Sensitivity of primary screening in high-risk polyp detection	22%	46%	[6]
		Sensitivity of primary screening in CRC detection	63%	70%	[6]

Table S3. Colonoscopy demands from strategies

Strategy	Maximum colonoscopy demand during 2023-2047 (people/year)
Status quo	156,000
Strategy-I	667,000
Strategy-I + RS	1,230,000
Strategy-II	258,000
Strategy-II + RS	264,000
Strategy-III	728,000
Strategy-III + RS	1,250,000

Note: Each strategy with SC has equal colonoscopy demand to the strategy without SC

Table S4. The current level of resources required for colonoscopy capacity building in public hospital, Thailand (extracted on 20th March, 2023)

Category	Resource	Value	Unit	References
Medical devices				
	Colonoscopy	500	Piece	Assumption
	CT scan	160	Pieces	[11]
Colonoscopy units				
	Operating room	1,955	Room	[11]
	Tertiary care	96	Place	[11]
	Quaternary care	29	Place	[11]
Healthcare workforces				
	Gastroenterologist	227	People	[11]
	General surgeon	1,402	People	[11]
	Colorectal surgeon	44	People	[11]
	Internal medicine doctor	1,768	People	[11]
	General practitioner	5,194	People	[11]
	Nurse	138,252	People	[11]

Experts believed that the current colonoscopy capacity is more than 200K people per year, which is reported in the literature. Thus, we estimated the range of possible colonoscopy capacity and we used this range in to perform sensitivity analysis. We calculate the upper bound of the range by using an assumption from interviews—gastroenterologists and surgeons (general and colorectal) can handle at most 10 and 4 patients per week, resulting in colonoscopy capacity of 419K patients per year. We used 200K people per year as the lower bound of the range.

Table S5. Description of the 8-point risk score [6]

The 8-point risk score		
Sex		
	Male	1
	Female	0
Age		
	≥ 70 years	3.5
	60-69 years	3
	50-59 years	2
	40-49 years	0
CRC family history		
	Presence of ≥ 2 first-degree relatives with CRC	2
	Others	0
Body mass index		
	> 22.5 Kg/M^2	0.5
	≤ 22.5 Kg/M^2	0
Smoking history		
	> 18.5 pack-years	1
	≤ 18.5 pack-years	0

S3. Results

Table S6. Key results of the budget impact and strategy analyses, 2023-2047

Strategy	**QALY**	**QALY gained**	**Cost (THB)**	**Additional cost compared to the status quo**	**ICER (THB)**
Status quo	669,751,658	0	442,697,979,634	0	-
Strategy-I	670,084,149	332,492	525,925,098,081	83,227,118,447	250,313
Strategy-I+RS	669,972,089	220,432	502,776,941,930	60,078,962,296	272,552
Strategy-I+SC	671,080,637	1,328,979	549,685,963,439	106,987,983,805	80,504
Strategy-I+RS + SC	671,431,020	1,679,362	541,677,340,468	98,979,360,834	58,939
Strategy-II	670,856,713	1,105,056	531,289,884,298	88,591,904,664	80,170
Strategy-II + RS	670,860,978	1,109,320	531,280,206,571	88,582,226,937	79,853
Strategy-II + SC	670,857,421	1,105,763	531,491,792,870	88,793,813,236	80,301
Strategy-II + RS + SC	670,862,049	1,110,392	531,654,214,190	88,956,234,556	80,112
Strategy-III	671,063,941	1,312,283	607,787,162,972	165,089,183,338	125,803
Strategy-III + RS	670,987,458	1,235,800	586,123,396,772	143,425,417,138	116,059
Strategy-III + SC	672,068,216	2,316,559	611,295,555,868	168,597,576,234	72,779

Strategy-III + RS +SC	672,367,089	2,615,431	601,084,957,846	158,386,978,212	60,559

QALY = quality-adjusted life year; ICER = incremental cost-effectiveness ratio; RS = risk-stratification (8-point risk score); SC = sufficient colonoscopy capacity

Table S7. Key results of the probabilistic sensitivity analyses, 2023-2047

Strategy	**Probability to be cost-effective compared to the status quo**	**Probability to be the most cost-effective strategy**		
		WTP of 110**K THB** (1-**time per captia GDP**)	**Current WTP of** 160**K THB** (1.5 **time per capita GDP**)	**WTP of** 320**K THB** (3-**time per capita GDP**)
Status quo	-	0.08	0.00	0.00
Strategy-I	0.30	0.00	0.00	0.00
Strategy-I + RS	0.41	0.00	0.00	0.00
Strategy-I + SC	0.68	0.00	0.00	0.00
Strategy-I + RS + SC	0.85	0.01	0.00	0.00
Strategy-II	1	0.10	0.07	0.02
Strategy-II + RS	1	0.10	0.08	0.03
Strategy-II + SC	1	0.00	0.00	0.00
Strategy-II + RS + SC	1	0.00	0.00	0.00
Strategy-III	0.89	0.00	0.00	0.00
Strategy-III + RS	0.94	0.00	0.00	0.00
Strategy-III + SC	0.91	0.05	0.04	0.06
Strategy-III + RS +SC	0.95	0.66	0.80	0.89

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