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Original Article

Cost-effectiveness and budget impact analysis of a population-based screening program for colorectal cancer

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ABSTRACT

Background: Colorectal cancer (CRC) is one of the leading causes of cancer mortality in Belgium. In Flanders (Belgium), a population-based screening program with a biennial immunochemical faecal occult blood test (iFOBT) in women and men aged 56–74 has been organised since 2013. This study assessed the cost-effectiveness and budget impact of the colorectal population-based screening program in Flanders (Belgium).
Methods: A health economic model was conducted, consisting of a decision tree simulating the screening process and a Markov model, with a time horizon of 20 years, simulating natural progression. Predicted mortality and incidence, total costs, and quality-adjusted life-years (QALYs) with and without the screening program were calculated in order to determine the incremental cost-effectiveness ratio of CRC screening. Deterministic and probabilistic sensitivity analyses were conducted, taking into account uncertainty of the model parameters.
Results: Mortality and incidence were predicted to decrease over 20 years. The colorectal screening program in Flanders is found to be cost-effective with an ICER of 1681/QALY (95% CI −1317 to 6601) in males and €4,484/QALY (95% CI −3254 to 18,163). The probability of being cost-effective given a threshold of €35,000/QALY was 100% and 97.3%, respectively. The budget impact analysis showed the extra cost for the health care payer to be limited.
Conclusion: This health economic analysis has shown that despite the possible adverse effects of screening and the extra costs for the health care payer and the patient, the population-based screening program for CRC in Flanders is cost-effective and should therefore be maintained.

1. Introduction

Colorectal cancer (CRC) is the fifth leading cause of death in Europe. From a national perspective, it is the third most prevalent cancer in Belgian men and the second most prevalent cancer in Belgian women [1]. Annually, 8500 people in Belgium are diagnosed with CRC [2] and about 1800 persons die from the disease. In light of this burden, program-based cancer screening has been recommended by various international organisations [3–5]. However, in times of limited budgets, policymakers require clinical and health-economic evidence in order to spend the available resources in the most optimal way. Several studies have illustrated that detection of pre-cancerous lesions (adenomas) and early-stage cancers results in significant health benefits, although observational studies provide inconsistent results on the magnitude of these benefits [6–10]. The CRC screening policy recommended by the European Commission is the Faecal Occult Blood test for men and women aged 50–74 with a screening interval of maximum 2 years [3]. Since 2013, a biennial CRC population-based screening program has been organised in Flanders, the northern region of Belgium, inviting men and women between 56 and 74 years old to be screened by means of the Immunochemical Faecal Occult Blood test (FIT). The FIT seems to be a cost-effective alternative to the older and low-sensitivity Gaiac Faecal Occult Blood test [11,12]. However, up to now, the value for money of the recent Flemish CRC screening program has not yet been evaluated. Therefore, the purpose of this study was to analyze the cost-effectiveness as well as the budget impact of the population-based CRC screening program in Flanders. The result of this analysis is an important source of information for policy decision makers in order to make evidence-based choices concerning the screening policy for CRC.

2. Methods

2.1. Screening strategy

The health economic model assessed the costs and effects of the Flemish CRC screening program and compared these costs and effects to those expected in the absence of an organized screening program.

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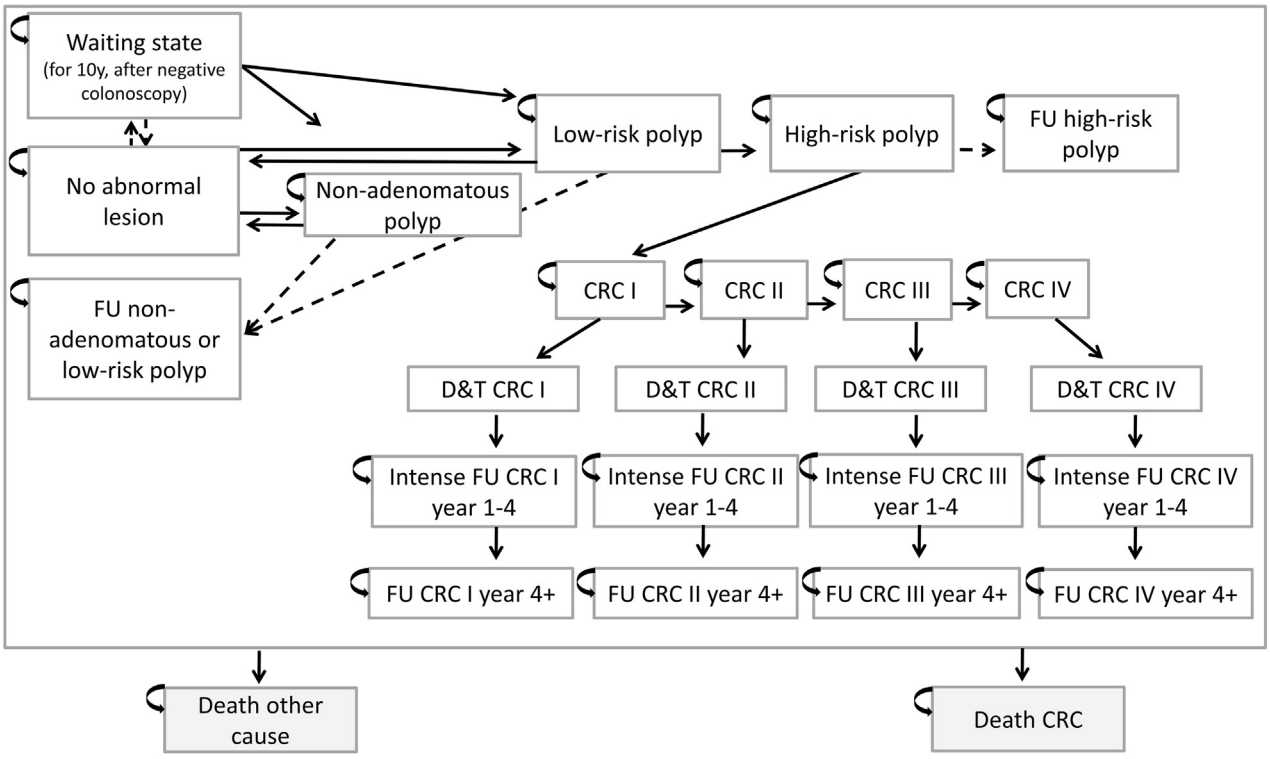

Fig. 1. Markov model depicting the natural progression of CRC and the possible transitions. CRC = colorectal cancer; D&T = diagnosis and treatment; FU = Follow-up. From the state of treatment or follow-up regional metastasis (stage III) or distant metastasis (stage IV) can occur, after which one transitions to the treatment phase of this stage. Death from CRC is only possible for a person with CRC stage III or stage IV. Dotted lines correspond to transitions which are only possible in case of systematic or opportunistic screening.

In the Flemish CRC screening program an FIT is mailed to the target population as a self-test with simple instructions. The stool needs to be pierced with a small included stick and mailed back for testing. The stool is then analyzed by means of the one-sample OC-sensor test, using a hemoglobine cut-off value of 75 nanogram/milliliter. At each FIT-screening round, men and women attending the screening may have either a (false) negative result or a (false) positive result which will lead to further examination with colonoscopy. After a negative colonoscopy, one will not be invited to the screening program for the next 10 years. After a positive colonoscopy, the patient will be treated accordingly.

2.2. General model description

The health economic model consisted of a decision tree, simulating the screening process, and a state-transitional Markov model simulating the natural progression of the disease, over a period of 20 years for the Flemish population aged 50 and older. The population was distributed in age-categories of five years and simulated until they reached the age of 100 or until death. Several disease states were comprised in the model, categorized as unidentified lesions (i.e. not yet detected and diagnosed by a physician) and identified lesions (i.e. detected and diagnosed) (Fig. 1). At the start of the model, according to observed 2011 prevalence figures, the total population was distributed over the state of 'free of any abnormal lesion', 'unidentified polyp' (defined as non-adenomatous polyp, low-risk adenomatous polyp[1] or high-risk adenomatous polyp), or 'unidentified invasive CRC', assuming that all existing lesions were unidentified by start. Furthermore, the model presumed all cancers to arise from pre-existing adenomas. Adenomas could only be detected by means of organised or spontaneous screening since it was assumed that these lesions are not associated with symptoms. Non-adenomatous and low-risk adenomatous polyps could naturally regress every year. However, all polyps detected by screening were removed by polypectomy (resection). CRC stages were determined according to the 7th edition of the tumour-nodes-metastases-classification for malignant tumours [13]. The population transitioned through the states on an annual basis, based on age- and gender-specific transition probabilities estimated from national epidemiologic data and published literature. From the stages treatment or follow-up, one could develop regional metastases (stage III) or distant metastases (stage IV) and go back into treatment. From stage III and stage IV, one could die from CRC and from all stages one could die from other causes than CRC. CRC could be detected by means of the screening program, spontaneous opportunistic screening in case one was not invited or did not participate in the screening program, or it could be clinically detected (based on symptoms). In case of detection, in either way, it was assumed that the tumour was treated in the same year of detection. In the year following treatment, the patient progressed to the follow-up state which was separated into a temporary intense follow-up state (first 4 years) and a long-term follow-up state (next years), because of more intense follow-up and higher risk of recurrence and death in the first years after treatment.

2.3. Epidemiological and clinical inputs

Epidemiologic input data were collected from the Belgian Cancer Registry. The prevalence of unidentified CRC at start of the model was defined as the total prevalence of CRC, namely, the prevalence of registered CRC diagnoses (most recent available data, but before the screening program was implemented) [14] supplemented with the yield of the screening program (2014). Since at the moment of the analysis, test characteristics of the screening were not yet systematically measured, we relied on published literature to estimate the sensitivity and specificity of the FIT and colonoscopy. The incidence of polyps was derived from the study of Brenner et al. [15], as diagnosis of polyps is not registered in

[1] 1 or 2 small tubular adenomatous polyps with low-grade dysplasia; serrated polyps < 10mm or without dysplasia

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Belgium. However, a correction factor to the Belgian situation was applied, based on CRC incidence of both countries [16]. Prevalence at start of the model and transition probabilities between the disease states are depicted in Table A1–A4 (Appendix). All screening-related data were obtained from the Flemish government [17] (Table 1). Annual constant screening uptake rates were applied over the years, meaning that participation was not linked to disease incidence or progression.

2.4. Health-economic inputs

Health effects of the screening program are represented as the impact on CRC mortality and on the quality of life of patients. The combination of these effects is expressed as quality-adjusted life-years (QALY), calculated by means of utilities during the lifespan of the model population. Utilities express the quality of life with a value between 0 (death) and 1 (perfect health). The utilities used in the model are age and gender specific and were derived from Flemish as well as international published data (Table A5 Appendix). A false-positive FIT result was assumed to be associated with a 3-month utility loss of 10% in reference to the general population, because of the related psychological stress [21]. The utility for patients in follow-up was calculated as the average of the utility for patients with a detected tumour and patients with an undetected tumour.

The cost-effectiveness analysis was conducted from a societal perspective, including direct medical as well as indirect costs due to productivity loss because of morbidity, or premature death. All costs in the model were calculated in EURO with 2014 as reference year. Medical costs were separated into costs for detection and diagnosis, costs for treatment, and costs for follow-up. The medical costs for detection and diagnosis were calculated per stage based on official Belgian costs of medical procedures. The medical costs for treatment and for follow-up were derived from the Belgian report of Pacolet et al. [22] and made stage-specific based on the ratios of the study of Tilson et al. [23]. For the treatment cost of stage IV, a correction was applied to take into account the new and more expensive therapies (panitumumab, cetuximab) that emerged in the last few years.

Cost due to productivity loss were estimated according to the friction cost method [24]. The number of days off work were multiplied by the cost for one day absenteeism estimated previously by the Belgian Health Care Knowledge Centre [25]. A productivity loss of 160 days was assigned to deceased people [24]. These costs due to productivity loss were only applied to the productive age-categories of 50–65 years, taking into account the employment rate. Future costs were discounted with 3%, health effects with 1.5%, according to the Belgian guidelines for health economic analyses [25]. Table A6 (Appendix) shows the costs for diagnosis, treatment, and follow-up.

2.5. Outcome parameters

Over a period of 20 years, the difference in total costs was divided by the difference in total effects resulting in an incremental cost-effectiveness ratio expressed as a cost per QALY gained. The budget impact analysis measured the net cumulative cost of the screening program (including the cost of consequent examinations, treatment, and follow-up) over a period of 20 years for Flemish males and females older than 50 years. To calculate the budget impact, an annual inflow of new 50-year-old persons was assumed. As shown by previous studies, CRC screening is expected to result in a decrease in the incidence and mortality of CRC. Both were calculated as the difference between the invited and non-invited cohort.

2.6. Scenario and sensitivity analyses

Several additional scenarios were tested. First, costs due to productivity loss were excluded. Second, 50- to 55-year olds were included in the screening program as recommended by the European guidelines [3]. In the third scenario, we included an annual inflow of new 50-year olds and in the final scenario we extended the time horizon of the model to 50 years. In the scenario with a time horizon of 50 years, an annual inflow of new 50-year olds was included, as after 20 years the original cohort is not eligible for screening anymore. Both one-way and probabilistic sensitivity analyses were conducted to take into account uncertainty in the input parameters and to test the robustness of the results. The one-way sensitivity analysis included the cost of the screening program, medical costs, days off work, utilities, test characteristics of the FIT and colonoscopy, participation rate per age-category, percentage performed colonoscopies after referral, prevalence of non-identified polyps, incidence of low-risk adenomatous polyps, positivity rate of the screening program, natural progression rates and the discount rate. These parameters were varied based on standard error estimates derived from the literature (if not available, ±30% ranges were used). In order to perform the probabilistic sensitivity analysis (PSA), probability distributions were defined for the costs (gamma distribution), utilities (beta distribution), test characteristics of the FIT and colonoscopy (beta distribution), incidence of low-risk adenomatous polyps (beta distribution), participation rate per age-category (beta distribution), and days off work (normal distribution). A cost-effectiveness plane was plotted to visualise the values of the 5000 2nd-order Monte Carlo simulations. As to provide information on the proportion of

Table 1
Screening-related parameters.
BC: breast cancer; DCIS: ductal carcinoma in situ.

Model parameter	Input value					
	56–60 y		61–70 y		71–74 y	
	Males	Females	Males	Females	Males	Females
Participation rate screening[a]	43.90%	43.10%	51.20%	50.20%	45.30%	44.50%
Adherence to colonoscopy (after positive FIT)[a]	82.20%	82.20%	95.80%	95.80%	84.80%	84.80%
% of screening population with spontaneous opportunistic screening[a]	6.17%	7.21%	6.34%	6.93%	5.53%	5.94%
Sensitivity FIT for polyps and low-risk adenomas[b]	5.70%	5.70%	5.70%	5.70%	5.70%	5.70%
Sensitivity FIT for polyps and high-risk adenomas[b]	34.20%	34.20%	34.20%	34.20%	34.20%	34.20%
Sensitivity FIT for CRC[b]	73.00%	73.00%	73.00%	73.00%	73.00%	73.00%
Specificity FIT[b]	97.00%	97.00%	97.00%	97.00%	97.00%	97.00%

[a] Source: Annual report Flemish cancer screening, 2013 [17].
[b] Source: [18–20].

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simulations with a cost-effective result, given a certain willingness-to-pay threshold, a cost-effectiveness acceptability curve (CEAC) was drawn.

3. Results

3.1. Base case

Over a period of 20 years, the screening program is expected to reduce CRC mortality by 23% in males and 19% in females and the incidence of invasive CRC by 26.6% in males and 21.5% in females. In the first years of the model, more tumours were found in persons invited for screening than controls, while in later years, more tumours were found in the control cohort (Figure A1). Additionally, 0.012 QALY were gained per male aged 50+ and 0.005 QALY per female aged 50+, against an incremental cost of €19 and €18, respectively. The cost-effectiveness ratio of the CRC screening program, in reference to no screening program, was €1582/QALY in males and €3327/QALY in females (Table 2). Without including the cost of productivity loss, the cost-effectiveness worsened marginally to €2498/QALY and €4357/QALY, respectively. Assuming a cost-effectiveness threshold of €35,000/QALY (i.e. Belgian GDP), these ratios show the CRC screening program to be very cost-effective. Results of the budget impact analysis showed that, on the long term, the screening program does not save money for the health care payer, but instead induces extra costs (Table 3). Over a period of 20 years, the screening program resulted in a net cumulative cost of €63,084,518 in males (N = 2,073,770, inclusive of people who died in those 20 years) and €54,528,777 in females (n = 2,187,983 inclusive of people who died in those 20 years), totalling the extra cost over 20 years to €117,613,295.

3.2. Scenario and sensitivity analyses

Results of the different scenarios are shown in Table 2. Excluding costs due to productivity loss worsened the result to a small extent. When opting to invite 50- to 55-year olds to the screening program (in line with the European guidelines but not currently implemented), slightly more QALYs were gained than in base case, namely, 0.013 per male aged 50+ and 0.006 per female aged 50+. The cost-effectiveness ameliorated somewhat, showing the CRC screening program to be slightly more cost-effective if 50 to 55-year olds would be invited. An annual inflow of 50-year-old males and females increased and thus deteriorated the result to €6073/QALY in males and €10,884/QALY in females aged 50+. Extending the time horizon to 50 years instead of 20 years -including annual inflow- altered the outcome markedly as the result became cost-saving. All scenarios were still in favour of the CRC screening program.

Results of the one-way sensitivity analysis present the influence of the parameters on the cost-effectiveness result. The parameters with the highest impact were the sensitivity of the FIT for high-risk polyps, the natural progression of CRC, the specificity of the FIT, the prevalence of unidentified high-risk polyps, the adherence to colonoscopy after referral, and the sensitivity of colonoscopy for high-risk polyps. When the value of these parameters was varied to the maximum, then the incremental cost-effectiveness ratio ameliorated. Consequently, the opposite was true when the value of these parameters was varied to the minimum. Importantly, in all simulations, the result remained cost-effective, demonstrating the robustness of the resultin the base case scenario. A change in the participation rate—one of the main features of a screening program—did not considerably influence the result. Tornado diagrams are shown in Figure A2 (Appendix).

A PSA with 5000 Monte Carlo simulations was performed, generating credible intervals (CI) around the point estimate of the ICER. Over a period of 20 years, the PSA resulted in an incremental cost-effectiveness ratio of €1681/QALY (95% CI −1317 to 6601) in males and €4484/QALY (95% CI −3254 to 18,163) in females (Table 2). The cost-effectiveness planes display the result of the simulations (Fig. 2). Most of the simulations were situated in the north-east quadrant of the graph, meaning that the screening program resulted in health benefits but against an extra cost, as shown by the cost-effectiveness results. In some of the simulations, the screening program was expected to result in health benefits and cost-savings (south-east quadrant). However, in females, some simulations also resulted in a loss of health benefits due to the screening program (north-west quadrant). The CEAC (Fig. 3) depicts the probability for the biennial FIT to be cost-effective in case of a willingness-to-pay threshold ranging from €5000 to €55,000/QALY. The Flemish CRC population-based screening program has a probability of 100% and 97.3% to be cost-effective in males and females, respectively, given a threshold of €35,000/QALY.

3.3. Model validation

Results of the health economic analysis were validated with respect to the observed results from the actual screening program. Estimated

Table 3
Results of the budget impact analysis.

	Cost health care payer	Cost for organization of screening	Total extra cost
Males			
With screening program	€1,046,716,220	€28,901,310	€63,084,518
Without screening program	€1,012,533,012	€0	
Females			
With screening program	€787,561,407	€29,235,862	€54,528,777
Without screening program	€762,268,492	€0	

Table 2
Results of the cost-effectiveness analysis, with several scenarios.

Scenario	Δ cost (€)		Δ QALY		ICER (€/QALY)		Mortality reduction	
	Males	Females	Males	Females	Males	Females	Males	Females
Base case det.	19	18	0.012	0.005	1582	3327	23%	19%
Excl. productivity loss	30	23	0.012	0.005	2498	4357	23%	19%
Incl. 50–55 year olds	16	18	0.013	0.006	1211	3169	25%	20%
Incl. new inflow	52	37	0.011	0.003	4922	10,884	22%	19%
Time horizon 50 years (incl. new inflow)	−1596	−70	0.070	0.033	Cost-saving		25%	20%
Base case prob. (95% CI)	17 (−15–57)	16 (−5–48)	0.011 (0.007–0.014)	0.005 (0.001–0.007)	1681 (−1317–6601)	4484 (−3254–18,163)	20% (16%–23%)	19% (15%–22%)

Δ cost: total cost with screening program minus total cost without screening program.
Δ QALY: total QALY with screening program minus total QALY without screening program.
ICER: Incremental cost-effectiveness ratio.
Mortality reduction: mortality due to CRC without screening program (i.e. non-invited) minus with screening program (i.e. invited).
det.: deterministic prob.: probabilistic.

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Fig. 2. Cost-effectiveness plan for males (left) and females (right).

average positivity rates derived by the model were lower than field results (5% versus 10%). Three arguments can be proposed. First, since only the first field screening round has been evaluated, it can be expected that future screening rounds will result in a lower yield. Moreover, the first screening round only included people aged over 66 years, while in the model, people aged 56–66 years were also invited. Second, the prevalence and incidence of polyps is uncertain. These input figures could be underestimated in the model, leading to lower estimated positivity rates. Third, the test-characteristics of the FIT were not derived from the Flemish screening program as they are not available yet. It could be that the test-characteristics used in the model, differ from the ones in the screening program. To compare, the pilot screening study in one Flemish province in 2009 had a positivity rate of 5.3%, and also the study of Hol et al. [26]—using the same FIT and hemoglobin cut-off value—showed a positivity rate of 5.7% in the Dutch trial, which are both closer to our estimations. The false-positive rate in the actual screening program was not determined yet at the time of this analysis. We calculated a false-positive rate of the FIT of on average 2.2%.

4. Discussion

The health economic evaluation showed that the Flemish population-based CRC screening program with a biennial FIT is highly cost-effective. These results are in concordance with studies from other countries [11,19,27–29], although these studies may have included different values for the screening parameters such as for participation rate or other parameters. Consequently, the use of different methodologic approaches and different model designs to assess the cost-effectiveness ratios, makes study results difficult to compare. In our analysis, the population-based CRC screening program yielded 0.012 and 0.005 QALYs per male or female aged over 50 years. This amount of QALYs gained seems rather small, but when interpreted on the population level, it leads to a considerable benefit for the Flemish population aged over 50 years of 20,451QALYs (or with inflow: 26,047 QALYs). This health benefit is higher than in the Flemish breast cancer screening program [30]. Beside the gain in QALYs, other health benefits as predicted by the model were the decrease in incidence and mortality of CRC. This argues for the early detection and treatment of polyps (and tumours) leading to aversion of new and more advanced CRC tumours. However, it must be taken into account that these findings were not yet proven by randomized controlled trials (RCTs) or observational studies, as the screening program is only been running from 2013. Hewitson et al. [31] evaluated in their meta-analysis the combined results from three RCTs that used biennial screening and showed a 15% mortality reduction (RR 0.85, CI: 0.78–0.92) with an average follow-up of 17 years and an average participation rate of 61%. As the sensitivity of the FIT is shown to be better compared to the Gaiac Faecal Occult Blood test [32,33], it is expected that the reduction in CRC incidence and mortality due to FIT will be higher. Few observational studies up to now have evaluated this FIT health benefits though. Ventura et al. [10] showed a mortality reduction of 41% over a period of 11 years (with 40% participation). However, these results are calculated for invited participants versus invited non-participants, while we compared an invited cohort (with an average participation rate of 44%) versus a non-invited cohort, which makes comparison more difficult. Comparing screened persons versus non-screened persons should indeed show better results, as in Ventura et al. Another recent Italian study showed a mortality reduction of 24% over 16 years (with participation of about 50%) [9]. This result is better than the expectations based on our model. However, based on the few available observational studies evaluating FIT today, it is difficult to validate the predictions of our model yet. More real-life evidence is necessary. However, the CRC population-based screening program was predicted not only to result in a health gain but also to induce a net cost. The result of the budget impact analysis showed that over 20 years, the screening program would lead to a net cumulative cost of €118 million for the government. It can be deducted that the screening program induces more examinations, treatment, and follow-up, leading to higher costs for the health care payer. However, the cost-effectiveness result showed that this invested budget offers value for money. Besides, compared to the total extra cost due to the breast cancer screening program (€452 million), the budget impact can be assessed as limited [30]. The cost-effectiveness result in our analysis was better for males than for females, which can be explained by the higher incidence of polyps and the higher prevalence of non-identified CRC tumours at start of the model in males than in females. Hence, screening can attain a greater benefit in males in terms of earlier detection and treatment and mortality reduction. The more favourable result by introducing the age-category 50–55 in the screening program could be explained by the fact that when a tumour is detected early in these persons, more healthy life-years could be gained since persons in this age-category have a higher average quality of life than older persons. When including an annual inflow of 50-year olds, the result deteriorated, probably because the effect of screening is underestimated in case of new inflow. For these inflowing people, the simulation runs between 1 and 19 years (dependent on the year they enter the model) instead of 20 years, decreasing the potential benefit of screening in these persons. Extending the time horizon to 50 years instead of 20 years altered the cost-effectiveness result quite markedly. Over a period of 50 years the CRC screening program would be cost-saving. It should be kept in mind that a different time horizon can have a great impact on the

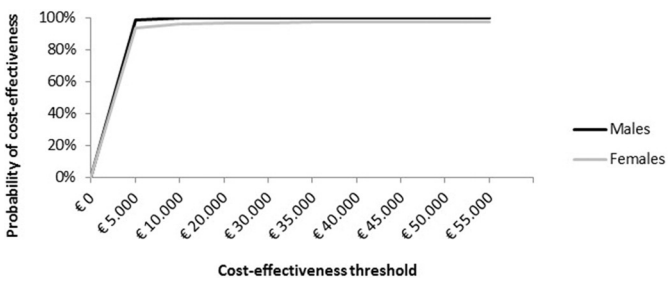

Fig. 3. Cost-effectiveness acceptability curve.

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results. The one-way- and probabilistic sensitivity analyses demonstrated the test-characteristics of the FIT, the natural progression of CRC, the prevalence of high-risk polyps and patient adherence to be the most influencing parameters, although the conclusion based on the cost-effectiveness result remains the same. The Flemish CRC population-based screening program has a probability of 100% and 97.3% to be cost-effective in males and females respectively.

It is the first time that both costs and benefits of the CRC screening program in Flanders have been analyzed thoroughly. Not only the benefits of screening were captured in the model but—since there has been a lot of debate concerning the negative aspects of population-based screening—we have tried to include the impact of a false-positive screening result on quality of life in terms of psychological harms as well. However, anxiety that could possibly be induced by receiving the mailing kit and by participating in the screening, regardless of the test result, was not included since we are not able to estimate this parameter (because of the lack of scientific evidence). The risk of overtreatment was implicitly included in the model. Polyps that are detected are removed at the same time, by means of polypectomy, regardless of whether this polyp would have caused any harm. These costs are included in the model. Direct costs related to colorectal cancer used in our model, were derived from the study of Pacolet et al. [22], and were based on the 'All Patient Refined-Diagnostic Related Groups'-classification. The basis for this classification consists of the main diagnosis in combination with surgery procedures, the age and sex of the patient, and occurrence of complications. This means that the cost associated with the risk of bowel perforation or bleeding as a consequence of colonoscopy, is implied in the cost estimates.

Nonetheless, some limitations of our analysis should be addressed. First, the incidence and prevalence of adenoma is uncertain, since these data are not registered in the Belgian cancer registry. For the adenoma incidence we had to rely on German data of the publication of Brenner et al. [15]. However, we applied a correction in reference to the ratio between CRC incidence in Germany and in Belgium. The prevalence of adenoma identified in the opportunistic circuit is unknown so we could only rely on the number of adenoma identified in the screening program (2014). This possibly resulted in an underestimation of the prevalence of adenoma and thus an underestimation of the yield of the screening program. Consequently, the result of our analysis is rather a conservative estimate of the cost-effectiveness ratio. On the other hand, the one-way sensitivity analysis showed that this parameter did not have a major impact on the cost-effectiveness result. Second, evidence about the test-characteristics of the FIT and colonoscopy in the Flemish population is not available yet as the screening program has only been implemented since October 2013. Therefore, we used numbers from published literature. One-way sensitivity analysis showed the test-characteristics of the FIT to have the highest influence on the cost-effectiveness result. This should be kept in mind when interpreting the results. We used published test-characteristics, but information on the test-characteristics of the screening program should be available, soon. Third, due to a lack of information on the natural progression of CRC, we had to derive these progression rates from U.S. studies who estimated them based on calibration to observed data [35,36]. Fourth, we assumed that all CRC arise from a prior adenoma. In reality, although negligible, there is a small percentage of CRC tumours that do not arise from a pre-existing adenoma. Fourth, we did not perform separate analyses for low-SES subgroups. In these subgroups, CRC mortality is expected to be higher, although CRC incidence might be lower [37]. This difference in epidemiology, together with a predicted lower screening uptake, can influence the cost-effectiveness of CRC screening in these groups. Lastly, it should be noted that screening parameters such as participation rate as well as unit costs of detection, treatment, and follow-up are context-specific limiting the transferability of the results across different countries. However, we believe that this positive health economic evaluation can inspire decision makers internationally and stimulate them to make similar evaluations.

5. Conclusion

In this health economic analysis, we evaluated the cost-effectiveness and budget impact of the population-based CRC screening program in Flanders. Results of the analysis show that, despite the possible adverse effects of screening, and the induced costs for the health care payer and patient, the population-based screening program for CRC in Flanders is very cost-effective and should be maintained. Policymakers could decide to also include 50- to 55-year-old males and females in order to be in line with the European guidelines. Although there is currently few long-term real-life evidence on the effectiveness of FIT, modelling should be used to estimate the cost-effectiveness of a screening program and the potential impact of changes in policy [38]. Additionally, we should be aware that the techniques for screening and treatment of cancer are evolving continuously, emphasizing the need to frequently evaluate the population-based screening programs.

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Conflict of interest statement

The authors declare there is no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ejim.2016.03.031.

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