Modelling future capacity needs and spending on colonoscopy in the English bowel cancer screening programme

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ABSTRACT

Background: Bowel cancer screening using faecal occult blood testing and colonoscopy is currently being rolled out across England. Guidelines recommend that people identified by colonoscopy as having intermediate- or high-risk bowel polyps be offered periodic surveillance colonoscopy because of their elevated risk of bowel cancer. We make projections of the likely year-on-year increase in volumes and spending on colonoscopy due to the screening and surveillance programmes.

Methods: We constructed a model based on current bowel cancer screening and surveillance guidelines using screening outcome measures taken from the second round of the English bowel screening pilot. This was then used to predict colonoscopy volumes and cost for a hypothetical population.

Results: For a hypothetical population of 500 000 people, with average deprivation and 66 956 subjects aged 60–74 years, the initial screening and surveillance round would be expected to detect 34 cancers at a cost of £394 157. In the first 8 years, colonoscopy numbers will grow at a rate of 23 per year, most of which will be surveillance colonoscopies. Colonoscopy costs may grow by £11 808 yearly in the same period, representing a cost per eligible person of £2.86 initially, increasing by £0.13 every year. Sensitivity analyses suggest significant changes in these predictions if screening uptake changes by 20%.

Conclusion: The model has been used to make projections for five primary care trusts within the South Central Strategic Health Authority. Results from the volume and cost projections can inform service planning and resource allocation at local levels for the implementation of the current and future bowel cancer screening programme.

Colorectal cancer is the third most prevalent cancer in the United Kingdom after lung and breast cancer. Around 100 new cases are diagnosed in the country daily, representing an age-standardised rate of 44.3 per 100 000 population in all persons.[1] Its incidence has increased in recent decades although attributable mortality has slowly declined in both men and women.[2] Although average 5 year survival with colorectal cancer is about 40%, most people in whom cancer is detected before bowel wall penetration has occurred have an approximately 83% chance of surviving 5 years.[3]

The English national screening programme for bowel cancer aims to use a faecal occult blood test (FOBt) and colonoscopy to achieve early detection of colorectal cancers in order to improve cancer survival. The intention is that by December 2009 the programme will be fully implemented across England for people aged 60–69 years, and extended to people up to 75 years by 2010.

Seventy to ninety per cent of colorectal cancers arise from adenomatous polyps that develop in the bowel lining over a period of 10–15 years. Most of these polyps are completely removable during endoscopy.[4] Both colorectal carcinomas and bowel polyps have a tendency to bleed as faeces pass along the bowel. These microscopic bleeds are detectable by the FOBt, which when implemented as a screening test has been shown to reduce colorectal cancer mortality.[5–6]

Adenomatous bowel polyps may be described according to their risk of progression to bowel cancer as low, intermediate or high and some patients who have undergone colonoscopy and removal of polyps are at increased risk of developing bowel cancer in the future.[7] Following removal of polyps, widely adopted national guidelines recommend placing individuals with intermediate and high-risk polyps on colonoscopic surveillance at different periodicities.[7] The National Bowel Cancer Screening Programme (BCSP) will be responsible for this surveillance and so local screening centres, who provide colonoscopies, and primary care trusts (PCTs), who commission the service, will have to plan funding and capacity for the initial screening colonoscopies, of people with a positive test, and surveillance colonoscopies of those who need follow up monitoring.[8]

While some economic modelling studies have examined the cost-effectiveness of colonoscopy as part of a bowel cancer screening programme,[9] we are not aware of any studies that have modelled the cost and volume implications of the additional screening and surveillance colonoscopies for local programmes. This paper uses screening outcome measures from the second round of the English Bowel Cancer Screening Pilot in the West Midlands[10] to make projections of the likely activity and cost implications over the next 16 years of implementing colorectal cancer screening for a hypothetical population in accordance with the national guidelines. The intention is that this model will be used by local programmes using their own data to plan for the additional capacity and funding required for implementing the screening programme.

METHODS

The English bowel cancer screening pilot

Evaluation of the second round of the pilot was funded by the UK Department of Health and

Table 1 Screening uptake in the first year taking into account age, gender, ethnicity and deprivation

Parameter (a)		Eligible population (b)	Uptake from pilot (c)	Numbers taking up screening (b×c)	OR from pilot	Distance of OR from unity	Weight derived from OR	Weighted average uptake
Sex	Male	16181	0.477	7718	1	0.42	0.354	6106
	Female	16965	0.562	9534	1.42			
Age	60–64	13870	0.555	7698	1.47	0.507	0.427	7683
	65–69	10304	0.585	6028	1.82			
	70–74	8894	0.480	4269	1.23			
Ethnicity		33146	0.54	17898	1.00	0	0.000	0
Deprivation		33067	0.54	17856	0.74	0.26	0.219	3912
								17701

OR, odds ratio.

provided detailed estimates of outcomes for population-based bowel cancer screening.[10] In this round of the pilot, 127 746 invitees aged between 50 and 69 years were offered screening by FOBt at an interval of 2 years after the first round. Data from the pilot site was used to study uptake of FOBt and colonoscopy by demographic characteristics and screening experience in the first round.[10] Outcome measures from the second round pilot report were more applicable to this study as it tested the feasibility of a continuous screening programme.

Patient pathway through the bowel cancer screening process

Currently, people aged 60–69 years (60–74 years by 2010) are invited by post to participate in the screening programme by one of five regional centres (hubs) in England. Those who want to be screened are sent an FOB test kit by the hub to be returned within 4 weeks. Returned kits are read and normal results notified to general practitioners (GPs) and responders. Those with unsatisfactory or weak positive results are repeated. When a strongly positive result is found, the hub will book an appointment for the person at their local screening centre for a consultation with a specialist screening nurse practitioner (SSP). At the clinic, those who are suitable and consent to a colonoscopy are scheduled for the procedure. People who have normal results or low-risk polyps are returned to the screening pool. Those with medium- or high-risk polyps are suspended from the screening programme and enter a surveillance programme where they are invited to attend periodically for further colonoscopies. Where cancer has been detected, a referral is made to each patient's local colorectal cancer unit for treatment. Patients are offered a second consultation with the SSP to discuss abnormal colonoscopy results.

The hypothetical population

This study models colonoscopy volumes and cost over 16 years from 2008 to 2023 for a hypothetical PCT with a starting (2008) population of 500 000 people and 66 956 (13.4%) people in the reference age group (60–74 years). Ethnically, 3.6% of this population comes from the Indian subcontinent and the population falls into the middle quintile for deprivation. The year-on-year change in the size of the eligible population from 2008 to 2023 was modelled after the corresponding annual changes for England taken from the 2004-based Subnational Population Projections for English Counties and Unitary Authorities.[11] As the national projections take account of the impact of mortality amongst other things, our model reflects the impact of mortality on the hypothetical population over the years. It was assumed that the eligible population would be invited over the course of the 2 year screening round, ie, half invited in the first year and half in the second year.

Screening uptake

In the English pilot, eligible adults were invited for screening biennially.[10] Screening uptake was defined in the evaluation as the proportion of the eligible population returning adequate kits. Uptake was influenced by ethnicity, age and sex distribution, and deprivation (measured by the Index of Multiple Deprivation 2004). In the pilot report, participating populations were categorised into five quintiles for ethnicity according to the proportion of their populations from the Indian subcontinent. They were also categorised into five quintiles from "most deprived" to "least deprived" according to their minimum and maximum cut-off values for deprivation.[10] Our model took account of the fact that screening uptake in subsequent (incident) rounds in the pilot was influenced by uptake and outcome of FOBt in the first (prevalent) round.

Table 1 shows the screening uptake determined using outcome measures from the pilot, adjusted for age and sex distribution, ethnicity and deprivation in the hypothetical population.

Table 2 Faecal occult blood test (FOBt) positivity in the first year taking into account age, gender, ethnicity and deprivation

Parameter (a)		Eligible population	Number returning adequate kits (b)	FOBt positivity rate from pilot (c)	FOBt positive results (b×c)	OR from pilot	Distance of OR from unity	Weight derived from OR	Weighted average for FOBt positivity
Sex	Male	16181	7919	0.0217	172	1	0.35	0.288	90
	Female	16965	9782	0.0142	139	0.65			
Age	60–64	13870	7572	0.0206	156	1.49	0.673	0.555	226
	65–69	10304	5930	0.0226	134	1.62			
	70–74	8894	4199	0.0280	118	1.91			
Ethnicity		33146	17701	0.0163	289	1.00	0.00	0.000	0
Deprivation		33067	17701	0.0178	315	1.19	0.19	0.157	49
									365

OR, odds ratio.

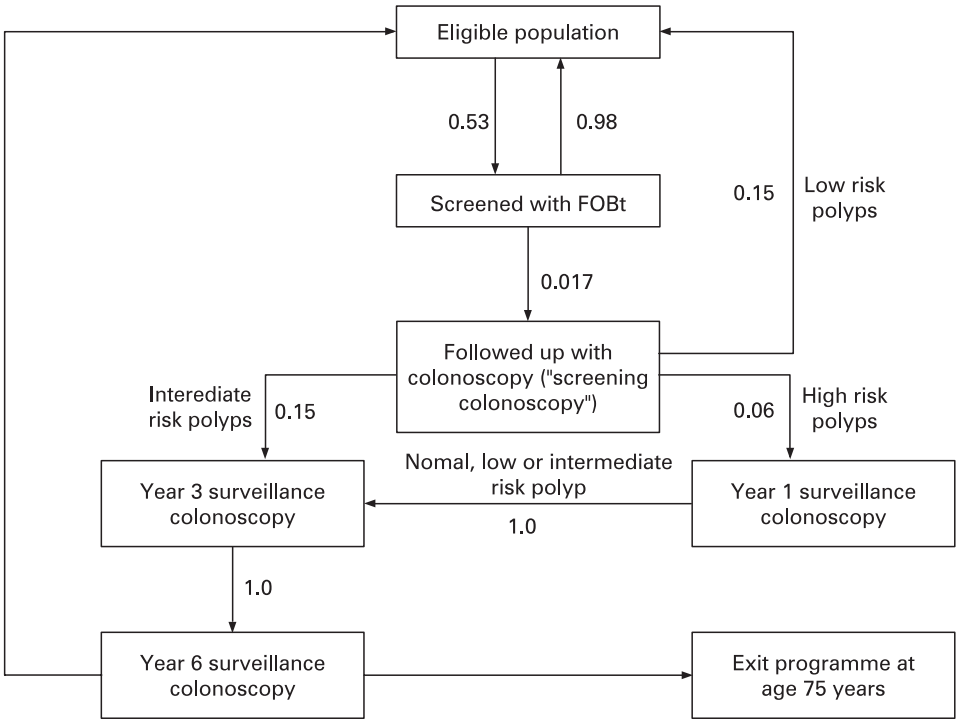

Figure 1 A state transition diagram with relevant transition probabilities. FOBt, faecal occult blood test.

FOBt positivity and colonoscopy uptake

FOBt positivity rate was defined in the pilot report as the proportion of total returned adequate kits testing positive. This rate was influenced by age and sex distribution, ethnicity and deprivation. Table 2 shows the derivation of FOBt positivity using outcome measures taken from the pilot but adjusted for age and sex distribution, ethnicity and deprivation in the hypothetical population. As people over 70 years of age were not invited in the pilot, FOBt positivity rate for the 70–74 years age group was taken from the Nottingham trial,[12] which reported uptake rates comparable to those reported for other age groups in the English pilot.[10]

Colonoscopy uptake in the second round of the pilot was about 83% and did not vary with age, sex, ethnicity or deprivation.[10] This uptake rate was applied to the predicted yearly FOBt positive results to derive likely numbers of screening colonoscopies each year.

Compliance with surveillance colonoscopy will ostensibly determine future colonoscopy burden but could vary as widely as from 11% to 91%.[13] Modelling an event as imprecise as compliance would not add value to our predictions, so it was not included in the model. However, we analysed the likely outcome of a very low compliance rate.

Adenoma detection by risk type

In the pilot report, adenoma detection was expressed per 1000 adequate kits returned. Using values for returned adequate kits derived in earlier steps of the modelling, we obtained numbers of adenomas by risk type and entered these into the algorithm.

Generating a modelling algorithm

To generate an accurate model, assumptions taken from the nationally adopted guidelines for surveillance colonoscopies after removal of colorectal polyps were made.[7] These assumptions were that:

- people with low-risk adenomas are returned to the screening pool and do not contribute to numbers of surveillance colonoscopies;
- people with intermediate risk adenomas are scheduled for 3-yearly surveillance (all of them returning two consecutive negative examinations after the initial screening and then exiting surveillance);
- people with high risk adenomas are scheduled for an initial surveillance colonoscopy at 12 months, and return a "normal" result (negative, low or intermediate risk adenomas). Thereafter they are maintained on the surveillance programme on 3-yearly examinations until they exit the surveillance programme at 75 years.

The state transition diagram in fig 1 shows different states and transition probabilities in the screening and surveillance process, fully reflecting the assumptions we made in the model. The modelling algorithm was generated on a Microsoft Office Excel 2003 spreadsheet.

Outcomes

Modelling algorithm

The algorithm reflects predicted screening colonoscopy uptake, adenoma detection by risk type and progression along the screening pathway. By incorporating up-to-date guidance on referral into the surveillance programme, it generates the pattern of annual changes in the volumes of screening and surveillance colonoscopies.

Predicted cost of colonoscopy

The cost analysis reflects expected spending on screening and surveillance colonoscopies by the National Health Service (NHS) BCSP. It does not include costs outside the NHS (social or patient costs) or resulting savings or costs in other parts of the NHS (such as an initial increase in activity in the oncology departments).

Table 3 Outcome measures from the model in the first round of screening

	Number or per cent
Population of hypothetical primary care trust	500000
Number eligible	66956
Number returning adequate kit	35569
Number FOBt positive	734
Number who underwent colonoscopy	600
Cancers detected	34
Polyps detected	243
Screening uptake	53.1%
FOBt positivity rate	2.06%
Cancer detection rate (per 1000 persons screened)	0.96
Adenoma detection rate (per 1000 persons screened)	6.8

FOBt, faecal occult blood test.

According to the 2007/08 Payment by Results national tariff for elective procedures, a colonoscopy costs £488.[14] A nurse-led pre-colonoscopy counselling clinic will precede each screening colonoscopy appointment and will cost about £155.[14] These costs were factored into the modelling but different costs can be entered in to refresh the outputs in the future.

Year-on-year growth in colonoscopy cost and volume was expressed as the cumulative annual rate of increase (CARI), derived as the n-th root of the total growth rate, where n is the number of years considered in the modelling (16 years). This is expressed mathematically as

$$\text{CARI} = (\text{end value}/\text{starting value})^{(1/15)} - 1.$$

The CARI is similar to the Compound Annual Growth Rate used similarly in financial circles. It is limited by its assumption of a uniform annual increase. Therefore, as the trends during the analysis showed an apparent difference in the rate of growth between years 0–7 and 8–15, the annual growth rates for these periods were calculated separately.

Per capita cost of colonoscopy

The predicted cost of colonoscopy per eligible person invited for screening was derived from the yearly cost of colonoscopy and the yearly eligible population over the modelled years. The estimated annual rate of increase in the per capita cost of colonoscopy was also derived separately for the first and next 8 years of screening using the method for deriving cumulative annual rate of increase.

Sensitivity analyses

Population estimates from the UK Office for National Statistics (ONS) were used to determine annual populations but these may not accurately reflect changes in the eligible population size for some actual populations. Additionally, local health promotion initiatives may increase uptake whilst in some areas significant numbers of people may opt for a private colonoscopy. We thus subjected our estimates to sensitivity analyses to determine changes in our results when key assumptions or variables are altered. We tested the impact on colonoscopy volumes of changing screening uptake by 20%. We also tested the impact of assuming that 25% of high-risk adenomas recur in the first year. As compliance with surveillance colonoscopy reportedly varies between 11 and 91%[13] we tested the assumption that only 11% of people attended for this procedure.

RESULTS

A summary of the predicted screening outcome measures for the hypothetical population in the first round of screening is presented in table 3. These values represent average outcome measures in the first round of screening.

The predicted screening uptake rate for the population is 53% (CI, 52.7% to 53.5%). Of every 100 adequate kits returned and tested, 2.1 (CI, 1.9 to 2.2) will be positive on the FOB test and of every 1000 persons screened by the FOB test, 1 (CI, 0.7 to 1.3) will have a bowel cancer and 6.9 (CI, 6.0 to 7.7) will have adenomatous polyps.

The modelling algorithm showing the individual steps in the generation of annual colonoscopy figures is displayed in table 4.

For any particular year, the modelled activity includes a predicted number of screening colonoscopies carried out within the year plus surveillance colonoscopies required for people who entered the surveillance programme in previous years. For example, in year 4, the total activity includes people with a positive FOBt who need a screening colonoscopy plus those in the surveillance programme who were diagnosed with high risk adenomas in year 3 and those diagnosed with intermediate risk adenomas in year 1.

Figure 2 shows how the numbers of colonoscopies may change annually over the first 16 years of the screening programme. The highest yearly increase in total numbers of colonoscopies is expected in the third and sixth years. Most of the year-on-year increase is due to people entering the surveillance programme, with only small increases in screening colonoscopies. Overall, we would expect an increase of 23 new colonoscopies (of which five are likely to be screening colonoscopies) yearly in the first 8 years and nine new colonoscopies (three of which are likely to be a screening colonoscopy) yearly in the following 8 years.

Table 5 shows the predicted cost of screening colonoscopies (with and without nurse-led clinics), and the total cost of all colonoscopies. As with the activity, surveillance colonoscopies account for the majority of the increase in costs each year. When the cost of nurse-led clinics is excluded, total colonoscopy costs will probably increase by about £11 002 yearly in the first 8 years and by £4500 yearly in the following 8 years. When the cost of nurse-led clinics are included, total colonoscopy costs for the hypothetical population will increase by £11 808 yearly in the first 8 years and by £5007 yearly in the following 8 years.

These costs represent a colonoscopy cost per eligible person of £2.86 in year zero, increasing by £0.13 yearly in the first 8 years and by £0.028 yearly in the next.

The sensitivity analysis shows that with a 20% variation in screening uptake, there will be important changes in colonoscopy volume and costs (table 6 and fig 3). For example in year 16, a 20% increase in uptake would lead to 10% more colonoscopies and costs. However, as the similar gradients of the three curves in fig 3 suggest, the yearly rates of increase in both volume and cost of colonoscopy will remain approximately unchanged with varied uptake.

We earlier stated our assumption that all high risk adenoma patients returned negative results during the twelfth month (surveillance) colonoscopy, and are thus placed on 3-yearly surveillance examination until age-determined exit. When we changed this assumption to reflect the possibility that 25% of high risk adenomas recur in the first year,[15] this resulted in an increase of only one to three colonoscopies per year. When we changed the proportion of people attending surveillance colonoscopy to 11%, there was a 3–28% reduction in the total annual number of colonoscopies.

Table 4 Modelling algorithm based on widely adopted guidance

Year	Screening colonoscopies	Numbers of intermediate- and high-risk patients entering surveillance			Pathway	Total colonoscopies*
YR0	294	IR0		48	IR0 – go to yr 3; HR0 – go to yr 1	294
		HR0	HR-N0	17		
YR1	306	IR1		49	IR1 – go to yr 4; HR1 – go to yr 2; HR-N0 - go to yr 4	323
		HR1	HR-N1	17		
YR2	312	IR2		50	IR2 – go to yr 5; HR2 – go to yr 3; HR-N1- go to yr 5	333
		HR2	HR-N2	18		
YR3	317	IR3		50	IR3 – go to yr 6; HR3 – go to yr 4; HR-N2 - go to yr 6; IR0 – go to yr 6	387
		HR3	HR-N3	18		
YR4	321	IR4		51	IR4 – go to yr 7; HR4 – go to yr 5; HR-N3 - go to yr 7; HR-N0 – go to yr 7; IR1 – go to yr 7	405
		HR4	HR-N4	18		
YR5	325	IR5		52	IR5 – go to yr 8; HR5 – go to yr 6; HR-N4 - go to yr 8; HR-N1 – go to yr 8; IR2 – go to yr 8	415
		HR5	HR-N5	18		
YR6	330	IR6		52	IR6 – go to yr 9; HR6 – go to yr 7; HR-N5 - go to yr 9; HR-N2 – go to yr 9; IR3 – go to yr 9; IR0 – leave programme	468
		HR6	HR-N6	19		
YR7	333	IR7		53	IR7 – go to yr 10; HR7 – go to yr 8; HR-N6 - go to yr 10; HR-N3 – go to yr 10; HR-N0 – go to yr 10; IR4 – go to yr 10; IR1 - leave programme	487
		HR7	HR-N7	19		
YR8	338	IR8		53	IR8 – go to yr 11; HR8 – go to yr 9; HR-N7 - go to yr 11; HR-N4 – go to yr 11; HR-N1 – go to yr 11; IR5 – go to yr 11; IR2 - leave programme	499
		HR8	HR-N8	19		
YR9	344	IR9		54	IR9 – go to yr 12; HR9 – go to yr 10; HR-N8 - go to yr 12; HR-N5 – go to yr 12; HR-N2 – go to yr 12; IR6 – go to yr 12; IR3 – leave programme	505
		HR9	HR-N9	19		
YR10	348	IR10		55	IR10 – go to yr 13; HR10 – go to yr 11; HR-N9 - go to yr 13; HR-N6 – go to yr 13; HR-N3 – go to yr 13; HR-N0 – go to yr 13; IR7 – go to yr 13; IR4 – leave programme	525
		HR10	HR-N10	19		
YR11	351	IR11		55	IR11 – go to yr 14; HR11 – go to yr 12; HR-N10 - go to yr 14; HR-N7 – go to yr 14; HR-N4 – go to yr 14; HR-N1 – go to yr 14; IR8 - go to yr 14; IR5 – leave programme	534
		HR11	HR-N11	20		
YR12	355	IR12		56	IR12 - go to yr 15; HR12 – go to yr 13; HR-N11 - go to yr 15; HR-N8 – go to yr 15; HR-N5 – go to yr 15; HR-N2 – go to yr 15; IR9 - go to yr 15; IR6 – leave programme	541
		HR12	HR-N12	20		
YR13	359	IR13		57	IR13 – go to yr 16; HR13 – go to yr 14; HR-N12 - go to yr 16; HR-N9 – go to yr 16; HR-N6 – go to yr 16; HR-N3 – go to yr 16; IR10 - go to yr 16; IR7 – leave programme; HR-N0 – go to yr 16	561
		HR13	HR-N13	20		
YR14	360	IR14		57	IR14 – go to yr 17; HR14 – go to yr 15; HR-N13 - go to yr 17; HR-N10 – go to yr 17; HR-N7 – go to yr 17; HR-N4 – go to yr 17; IR11 - go to yr 17; IR8 – leave programme; HR-N1 – go to yr 17	566
		HR14	HR-N14	20		
YR15	363	IR15		57	IR15 – go to yr 18; HR15 – go to yr 16; HR-N14 - go to yr 18; HR-N11 – go to yr 18; HR-N8 – go to yr 18; HR-N5 – go to yr 18; IR12 - go to yr 18; IR9 – leave programme; HR-N2 – go to yr 18	572
		HR15	HR-N15	20		
YR16	367	IR16		58	IR16 – go to yr 19; HR16 – go to yr 17; HR-N15 - go to yr 19; HR-N12 – go to yr 19; HR-N9 – go to yr 19; HR-N6 – go to yr 19; IR13 - go to yr 19; IR10– leave programme; HR-N3 – go to 19; HR-N0 would have left surveillance programme at yr 15	575
		HR16	HR-N16	21		
YR17	372	IR17		59	IR17 – go to yr 20; HR17 – go to yr 18; HR-N16 - go to yr 20; HR-N13 – go to yr 20; HR-N10 – go to yr 20; HR-N7 – go to yr 20; IR14 - go to yr 20; IR11 – leave programme; HR-N4 – go to 20; HR-N1 would have left surveillance programme at yr 16	581
		HR17	HR-N17	21		

IRx, Intermediate risk patients in year x; HRx, high risk patients in year x; HR-Nx, high risk patients in year x who undergo colonoscopy in year (x + 1) and found to be negative.
*Screening + surveillance.

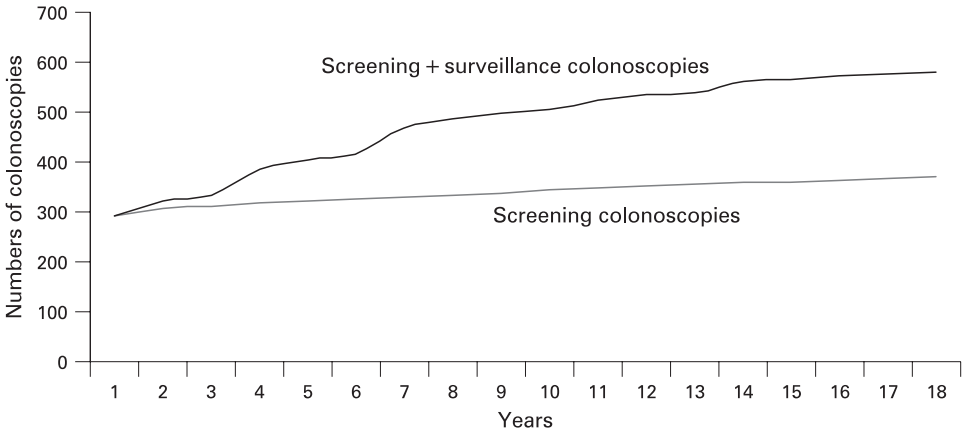

Figure 2 Sixteen year pattern of increase in volume of colonoscopies for a hypothetical population.

DISCUSSION

Our study uses empirical screening outcome measures to predict future capacity and finance needs for a population bowel cancer screening programme using biennial FOBt and colonoscopy, for people aged 60–74 years. Similar issues have been investigated in high-risk individuals undergoing colonoscopic surveillance but with other screening tools.[16] In one model of a hypothetical North American population of 100 000 people aged 50 years, the cost-effectiveness of annual FOBt was assessed using a Markov process.[17] Although the authors assumed that positive FOB tests were worked up with 3-yearly colonoscopy, the study differed from ours in the target age group, frequency of FOBt and the dependence of surveillance periodicity on the risk category of polyps in our estimations.

Our model makes spatial predictions of uptake rates and cost of a screening programme serving a hypothetical population of 500 000 people, modelled to reflect an average English population's deprivation and ethnicity indices. It estimates that the population would have a screening uptake of 53%. Although uptake rates as low as 22.3% have been reported, upper limits are more difficult to define.[18] FOBt uptake is influenced by ethnicity and deprivation profiles,[19 20] and our population was modelled to reflect an average English population with respect to deprivation and ethnicity. Consequently, actual populations with more deprivation and a higher proportion of people from the Indian subcontinent may expect lesser uptake rates. In addition, a health promotion drive, such as one that has a combination of mass media and personal communicative elements, can increase FOBt uptake.[21] If, for example, uptake in our population increased by 20% (new uptake of 64%), sensitivity analysis suggests that a 10% increase in the volume and cost of colonoscopy would be seen. Indeed, the cost-effectiveness of screening with FOBt is known to be more sensitive to changes in uptake rates than to assumptions about screening frequency and polyp incidence.[17]

A key assumption of the model was that all patients with high-risk adenomas are free of adenomas both at the 1 year and 3-yearly examinations, but are maintained on the surveillance programme until age-determined exit. When this assumption was changed to reflect a 25% risk of recurrence of high risk adenomas in the first year,[15] there was no important difference in the model output in terms of the volumes of surveillance colonoscopies.

The predicted drop in the annual rate of increase in colonoscopy volume and cost after the eighth year is probably related to the assumption that people with intermediate risk adenomas will be found to be negative at two consecutive 3-yearly examinations, and will therefore return to the population screening pool. The risk of recurrence of intermediate risk adenomas is around 5% after the first year.[15] Most of these recurrent adenomas will be low risk, suggesting that, in practice,

Table 5 Predicted cost of colonoscopy

	Cost		
Year	Screening colonoscopies (£)	Screening + surveillance colonoscopies (£)	Screening + surveillance colonoscopies + nurse-led clinics (£)
0	143387	143387	188929
1	149460	157756	205228
2	152295	162665	211037
3	154725	189007	238152
4	156750	197864	247652
5	158776	202452	252882
6	160801	228267	279341
7	162421	237695	289284
8	164851	243297	295658
9	167687	246499	299760
10	169712	256210	310114
11	171332	260514	314933
12	173357	263881	318943
13	175382	273714	329420
14	175787	276315	332149
15	177002	279238	335459

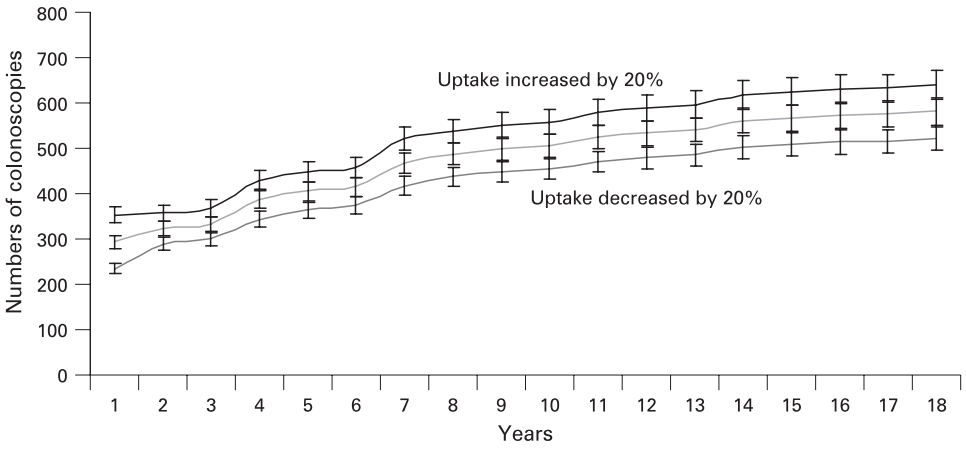

Figure 3 Sensitivity analysis with 20% variation in uptake.

most people with initial intermediate-risk adenomas will exit the programme after two consecutive examinations. Therefore the model's prediction that the annual rate of increase in volume and cost of colonoscopy will markedly reduce after the eighth year seems a reasonable estimation.

The English Bowel Cancer Screening Programme will have significant capacity and financial implications. Currently, most local programmes are funded centrally by the national screening office but this will stop and PCTs will have to pick up ongoing costs. As these costs are likely to be in the form of a tariff for each unit of activity, it is essential that PCTs have some understanding as to how this will change year on year. For example, our model indicates that in the first year, surveillance colonoscopies will account for 6% of all colonoscopies but in year 7 this will have risen to 46%. A similar forecasting model in the USA suggested there might be adequate national capacity for screening using FOBt and diagnostic colonoscopy.[22] However, in England, the bowel cancer screening programme also has an important component of periodic surveillance following diagnostic colonoscopy. For this additional component, capacity issues should receive careful thought. Furthermore, cost estimates from our model may be conservative. Current English guidelines describe two types of nurse clinics: one preceding screening colonoscopy and the other around abnormal colonoscopy results that patients may wish to discuss. Our model only accounts for the former.

Introduction of the screening programme will entail substantial initial costs but these may be offset in the future by fewer individuals presenting symptomatically with advanced cancer. Currently, only 7% of paients aged 60–69 years with bowel cancer present symptomatically at the earliest stage (Dukes' stage A) whereas it has been predicted that 45% of screen-detected cancers in the same age group are diagnosed at this stage.[9] The estimated lifetime cost per patient of treating Dukes' stage A cancer is £7250, compared to £19 076 for Dukes' stage C disease.[9] The difference in cost is primarily due to the additional chemotherapy and radiotherapy treatment; all other costs are similar (ie, for surgery, diagnosis, follow-up appointments).[9] Further work will be required, however, to model how the costs to PCTs of the screening programme are offset by the reduction in advanced bowel cancer incidence.

The population used in this study was hypothetical; however, the model has been tested against five PCT populations in the South Central Strategic Health Authority area prior to screening being implemented. Local population data were used in the model to predict the uptake and activity over a 15 year period. When local programmes begin screening, it will be possible to refresh the model with up-to-date data about uptake and positivity rates. Changes in the future to the surveillance programme guidelines can also be incorporated.

Variation between local bowel cancer screening programmes and the pilot sites are already being noted. It has been reported

Table 6 Sensitivity analysis of 20% variation in uptake

	Numbers of *all* colonoscopies			Cost of all colonoscopies (with nurse-led clinics) in £		
Years	−20%	Baseline	+20%	−20%	Baseline	+20%
0	235	294	353	151144	188929	226715
1	289	323	358	183483	205228	226926
2	300	333	368	189903	211037	232782
3	344	387	430	211848	238152	264044
4	363	405	448	222080	247652	273468
5	373	415	458	227677	252882	279110
6	416	468	522	249087	279341	310860
7	437	487	537	259762	289284	319095
8	448	499	550	265481	295658	326247
9	454	505	558	269415	299760	330837
10	470	525	579	278061	310114	342091
11	479	534	589	282712	314933	347520
12	486	541	596	286555	318943	351530
13	502	561	618	294835	329420	362906
14	510	566	625	298907	332149	366734
15	514	572	630	301072	335459	369555

that positivity rates vary between 1 and 3% across the country[23] and that many people who have a positive test are symptomatic. This has resulted in higher rates of pathology than might be expected.[23] Whether this will result in a reduction in the number of people referred to symptomatic clinics or whether the high profile of bowel cancer screening in the media encourages people to visit their GP are questions that remain to be answered. The model outlined here should be robust and sensitive enough to incorporate these differences when predicting future activity for any particular population.

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