An observational study to compare the utilisation of computed tomography colonography with optical colonoscopy as the first diagnostic imaging tool in patients with suspected colorectal cancer

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AIM: To evaluate the clinical and cost implications of using computed tomography colonography (CTC) compared to optical colonoscopy (OC) as the initial colonic investigation in patients with low-to-intermediate risk of colorectal cancer (CRC).

MATERIALS AND METHODS: A non-randomised, prospective single-centre study recruited 180 participants to compare the cost implications of two clinical pathways used in the diagnosis of low-to-intermediate risk of CRC that differ in the initial diagnostic test, either CTC or OC. Costs were compared using generalised linear models (GLM) and combined with quality-adjusted life years (QALYs, based on the EQ-5D-5L) to estimate cost-effectiveness at 6 months post-recruitment. Secondary outcomes assessed access to care and patient satisfaction.

RESULTS: Mean (SD, n) cost at 6 months post-recruitment per participant was £991 (£316, n=105) for the OC group and £645 (£607, n=68) for the CTC group, leading to an estimated cost difference of £370 (95% CI: £554, £185, p<0.001). Assuming a £20,000 willingness-to-pay per QALY threshold, there was a 91.4% probability of CTC being cost-effective at month 6. The utilisation of CTC led to improved access to care, with a shorter mean time from referral from primary care to results (6.3 days difference, p=0.005). No differences in patient satisfaction were detected between both groups.

CONCLUSION: The utilisation of CTC as the first-line investigation for patients with low-to-intermediate risk of CRC has the potential to release OC capacity, of pivotal importance for patients more likely to benefit from an invasive diagnostic approach.

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Introduction

Colorectal cancer (CRC) is one of the leading causes of mortality and morbidity worldwide, with the highest incidence rates in Australia, New Zealand, Europe, and North America. It is the third most common cancer in the UK, with an annual incidence of over 40,000 new cases. Survival rates are stage dependent with 5-year survival rates in men being 95% at stage 1 and <10% at Stage 4.

There has been a steady decrease in bowel cancer mortality rates in most economically developed countries since the early 1970s, despite the relative stability in overall incidence rates. This trend can be partly attributed to better detection and removal of colonic polyps, improved detection of CRC at an earlier stage, and the development of more effective primary and adjuvant treatments. However, 5-year CRC survival rates in the UK are significantly lower compared to other countries, partly due to the fact that only approximately 40% of all CRCs in the UK are diagnosed at an early stage.

The NHS Long-Term Plan was published in the UK in January 2019, setting out commitments to improve cancer outcomes and services in England over the next 10 years. One of its key ambitions is by 2028 the proportion of cancers diagnosed at stages 1 and 2 should rise from around 40% to 75% of cancer patients. Cancer alliances across the country have been developed to implement the cancer strategy at a local level, with the introduction of faster, more intensive. The Department of Health predicts an annual increase of 10% in the demand for endoscopies, putting a considerable waiting time burden on an already stretched OC capacity.

Optical colonoscopy (OC) is the diagnostic reference test for CRC but remains technically difficult and resource intensive. The Department of Health predicts an annual increase of 10%–15% in the demand for endoscopies, putting an additional burden on an already stretched OC capacity. Linked to capacity constraints, there are considerable waiting times for an OC test in the NHS. In 2012, >25% of NHS providers presented with waiting times in excess of 4 weeks in 25% of OC tests. In 2018, it was estimated that about half of NHS hospitals did not meet the 2-week target for urgent colonoscopy.

Backed by evidence of non-inferiority of computed tomography colonography (CTC) in the diagnosis of median to large polyps and CRC, the use of non-invasive CTC as a direct alternative to the reference standard OC has been introduced in routine clinical practice. A potential drawback of CTC is that, in the event of positive findings, the patient then needs to undergo a subsequent invasive technique for polyp removal and/or tissue biopsy. This means that these patients would in effect undergo two diagnostic procedures. Atkin et al. (2013) estimated that 30% of patients had additional colonic investigations following CTC, compared with only 8% after OC. However, it has been shown that <10% of symptomatic patients referred to NHS outpatient clinics due to suspected CRC are actually diagnosed with the disease. This means that CTC can potentially reduce the need for an unnecessarily invasive test in the majority of patients, minimising the risk of perforation (reported between 0.005–0.03% with CTC compared to 0.06–0.19% with OC). The aim of the present study was to build on the existing evidence and evaluate the clinical and cost implications of using CTC as a substitute test for patients referred from primary care with low-to-intermediate risk of CRC.

Materials and methods

Study design and patient selection

This was a single-centre site, prospective, observational study. The study compared two existing clinical pathways used in the management of patients with low-to-intermediate risk of CRC following referral from primary care that differed in the initial diagnostic test with either CTC or OC. The allocation was decided during an initial triage telephone appointment based on clinical judgment (e.g., clinical symptoms, overall health, and previous colonic investigations) as well as patient choice. Subsequent care was guided by the diagnostic findings in both tests and consistent with standard of care. The high-level description of both clinical pathways is depicted in Fig. 1. In both groups, there was no change to routine clinical practice as the study focussed on evaluating two established clinical pathways in the management of patients with suspected CRC.

Patients considered suitable for the study included patients >40-years old, presenting with constipation or change in bowel habit with a differential diagnosis of CRC. Participants were excluded if at least one of the exclusion criteria was present: anaemia, diarrhoea for >6 weeks, rectal bleeding, previous whole-colon examination in the past 6 months, known CRC, lacking capacity to give consent or participate in the study, already taking part in any clinical trial of an investigational medicinal product, or not fluent in English. The study was given ethical approval by the Health Research Authority and Research Ethics Committee.

Study outcomes

The primary outcome was the 6-month healthcare costs associated with both groups in the management of suspected CRC from a healthcare payer perspective. Secondary outcomes comprised a 6-month cost-effectiveness analysis and the assessment of incidence of extra-colonic findings, time taken to reach a definitive diagnosis, and participant satisfaction associated with both clinical pathways. Fig. 2 summarises the structure of the CRC study.

Service use costs

The estimate of the total costs was based on the multiplication of any colon-related healthcare events by
the unit cost of each event. These included, among others, visits to general practitioners (GPs) or practice nurse, inpatient care, gastroenterologist or other outpatient visits, visits to the emergency department, and imaging examinations. Costs associated with the management of incidental findings in the CTC group were included in the baseline analysis. Cancer treatment costs were not considered part of the baseline analysis so as not to skew the analysis due to potential imbalances in cancer detection rates between both groups. Resource use data were retrieved from multiple hospital and primary care databases as well as self-reported data from participants (via a resource use diary). For the primary outcome, the valuation of unit costs was, whenever possible, based on NHS Reference Costs 2016–2017. Table 1 lists the unit costs used in the calculations. Participants were followed-up for a period of 12 months using the Hospital Episode Statistics (HES) database to confirm that no cancer (CRC or other type of cancer) was diagnosed.

Cost-effectiveness analysis

The incremental analysis of effectiveness considered quality-adjusted life years (QALYs) as the measure of effect. QALYs were estimated from utility scores derived from the use of EQ-5D-5L questionnaire at three points in time: baseline and 3 and 6 months post-recruitment using area under the curve methods assuming linear movement between adjacent points. A multiple regression analysis was used to address the potential imbalance between utilities at baseline likely to be correlated with the QALYs over the follow-up period. The cost—utility analysis, which is the preferred method of economic evaluation of NHS interventions, was performed according to NICE recommendations.

Statistical analyses

This study was observational but all analyses were based on the “intention-to-treat” so that all participants...
recruited were included in the analysis as per the group they were recruited to, regardless of whether they actually received the intended intervention or not. Given the study’s time horizon of 6 months, no discounting of costs nor effects was considered. Baseline sociodemographic and clinical characteristics were compared in the two intervention groups, i.e., gender, age, number of bowel-related complaints, number of active health problems/co-morbidities, number of months with change in bowel habits and self-perceived quality of life (EQ-5D-5L). For continuous data following a normal distribution, t-tests were used, the Mann–Whitney U-test was used for non-normal quantitative data, and categorical data were compared using chi-squared tests. Given the skewness associated with the cost distribution, all cost differences between groups were assessed using generalised linear models (GLM) with an identity-link and gamma distribution. An identity-link function instead of a log link was used to give estimates as means to avoid potential analytical biases. An unadjusted GLM cost analysis with the study group (OC versus CTC group) as the only covariate was performed as the first step. Given the study’s observational design and potential selection biases during the initial telephone clinic appointment, the groups being compared could have potentially been different due to the lack of randomisation with subsequent impact on healthcare costs. For this reason, an adjusted analysis was performed including all baseline variables with \( p < 0.10 \). For all GLM analyses, group difference estimates and associated confidence intervals were reported, together with \( p \)-values. One thousand replicate bootstrap analyses showing difference in costs and outcomes were presented on cost-effectiveness planes. All analyses were conducted using Stata version 15 for Windows (StataCorp, Lakeway Drive, TX, USA).

**Sample size**

The sample size estimate was calculated based on the primary endpoint, total 6-months healthcare costs. A total of 110 participants were recruited in the OC group and 70 participants in the CTC group to achieve a detection of a cost difference of £200 assuming standard deviations of £400 and £300, respectively, with 90% power at the 5% two-sided significance level. A 20% increase in sample size due to unknown cost distribution and attrition rate was considered.

**Results**

Participant flow associated with the CRC study is illustrated in Fig. 3. A total of 180 participants were recruited, 110 to the OC group and 70 to the CTC group. During the follow-up duration, 4.5% (\( n=5 \)) and 2.9% (\( n=2 \)) of participants withdrew the informed consent in the OC and CTC group, respectively, and therefore, were considered lost to follow-up. All participants that did not withdraw informed
consent ($n=173$) were included in the analysis, 105 and 68 participants in the OC and CTC group, respectively.

Data regarding baseline sociodemographic, clinical, and resource use in the past 6 months are detailed in Table 2. A similar proportion of females were recruited to both groups but participants in the CTC group were older, with a mean age of 69.2 years compared to 61.3 in the OC group ($p<0.001$). In terms of clinical characteristics, participants in the CTC group reported greater disease burden levels with: (i) higher mean number of comorbidities/active health problems (4.0 versus 2.9 in OC group, $p=0.002$); and (i) lower mean utility values at baseline (0.793 in the CTC group versus 0.832 in the OC group, $p=0.023$). With regards to NHS resource use in the 6 months prior to recruitment to the study, no statistically significant difference between the two groups was found.

![Figure 3](image-url) Figure 3 Participant flow chart for the CRC study.

Table 1
Unit costs for all primary and secondary care events considered in the colorectal cancer study.

<table>
<thead>
<tr>
<th>Category</th>
<th>Unit type</th>
<th>Unit cost (£)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary care</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GP appointment (face-to-face)</td>
<td>Per appointment</td>
<td>£36.5</td>
<td>Unit costs of health and social care 2016(^1) and inflated to 2017 using the Hospital And Community Health Services (HCHS) index</td>
</tr>
<tr>
<td>GP phone appointment</td>
<td>Per appointment</td>
<td>£14.8</td>
<td></td>
</tr>
<tr>
<td><strong>Secondary care</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telephone clinic appointment</td>
<td>Per episode</td>
<td>£82</td>
<td></td>
</tr>
<tr>
<td>MRI (1 zone)</td>
<td>Per scan</td>
<td>£146</td>
<td></td>
</tr>
<tr>
<td>CT (1/2 zones/with contrast)</td>
<td>Per scan</td>
<td>£100/£153/£250</td>
<td></td>
</tr>
<tr>
<td>Ultrasound</td>
<td>Per scan</td>
<td>£51</td>
<td></td>
</tr>
<tr>
<td>CTC</td>
<td>Per scan</td>
<td>£262</td>
<td></td>
</tr>
<tr>
<td>OC (dependent on procedure, e.g., sedation)</td>
<td>Per scan</td>
<td>£515 to £760</td>
<td></td>
</tr>
<tr>
<td>Flexible sigmoidoscopy</td>
<td>Per scan</td>
<td>£475 to £633</td>
<td></td>
</tr>
<tr>
<td>ED visit (variable as per number of tests and procedures performed)</td>
<td>Per episode</td>
<td>£150 to £244</td>
<td></td>
</tr>
<tr>
<td>Initial outpatient appointment</td>
<td>Per appointment</td>
<td>£186 to £374</td>
<td></td>
</tr>
<tr>
<td>(variable as per specialty)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow-up outpatient appointment</td>
<td>Per appointment</td>
<td>£82 to £92</td>
<td></td>
</tr>
<tr>
<td>(variable as per specialty)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DNA cost</td>
<td>Per appointment</td>
<td>25%</td>
<td>Of the actual cost of the respective event (assumption).</td>
</tr>
<tr>
<td>Scan not performed due to poor bowel preparation</td>
<td>Per appointment</td>
<td>25%</td>
<td></td>
</tr>
</tbody>
</table>

MRI, magnetic resonance imaging; CT, computed tomography; CTC, computed tomography colonography; OC, optical colonoscopy; ED, emergency department; DNA, did not attend.

Data regarding baseline sociodemographic, clinical, and resource use in the past 6 months are detailed in Table 2. A similar proportion of females were recruited to both groups but participants in the CTC group were older, with a mean age of 69.2 years compared to 61.3 in the OC group ($p<0.001$). In terms of clinical characteristics, participants in the CTC group reported greater disease burden levels with: (i) higher mean number of comorbidities/active health problems (4.0 versus 2.9 in OC group, $p=0.002$); and (i) lower mean utility values at baseline (0.793 in the CTC group versus 0.832 in the OC group, $p=0.023$). With regards to NHS resource use in the 6 months prior to recruitment to the study, no statistically significant difference between the two groups was found.

Table 2
Baseline characteristics of the population analysed.

<table>
<thead>
<tr>
<th>Variable</th>
<th>OC group ($n=105$)</th>
<th>CTC group ($n=68$)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years, mean (SD)(^a)</td>
<td>61.3 (10.4)</td>
<td>69.2 (11.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gender female, n (%)</td>
<td>54 (51)</td>
<td>36 (53)</td>
<td>0.846</td>
</tr>
<tr>
<td>Number of comorbidities/active health problems, mean (SD)(^a)</td>
<td>2.9 (2.1)</td>
<td>4.0 (2.2)</td>
<td>0.002</td>
</tr>
<tr>
<td>Number of months with change in bowel habits, mean (SD)(^a)</td>
<td>3.7 (3.9)</td>
<td>4.1 (3.7)</td>
<td>0.465</td>
</tr>
<tr>
<td>Self-reported questionnaires</td>
<td>EQ-5D-5L</td>
<td>EQ-5D-5L</td>
<td></td>
</tr>
<tr>
<td>Mean utility at baseline (SD)(^a)</td>
<td>0.832 (0.197)</td>
<td>0.793 (0.173)</td>
<td>0.023</td>
</tr>
<tr>
<td>Total NHS costs in the 6 months prior to recruitment, mean (SD)(^a)</td>
<td>£187 (£165)</td>
<td>£206 (£155)</td>
<td>0.242</td>
</tr>
</tbody>
</table>

CTC, computed tomography colonography; OC, optical colonoscopy; SD, standard deviation; EQ-5D-5L, five-level EQ-5D.

\(^a\) Statistically significant difference between groups.
Service use costs

The NHS resource use of primary care and hospital base services over a period of 6 months following recruitment is summarised in Table 3. Participants in the CTC group presented more often to primary care compared to the OC group. Out of the 105 participants in the OC group, 12 (11%) had subsequent investigations, with five being repeated OC, one flexible sigmoidoscopy, and six CTCs. In the CTC group, 22 (32%) participants underwent additional invasive testing, equally split between 11 OC and 11 flexible sigmoidoscopies.

The mean cost management per participant (mean [SD]) was lower in the CTC group compared to the OC group (£645 [£607] versus £991 [£316]), leading to an unadjusted mean cost difference between groups of £345 per participant (p<0.001; Table 4). Hence, at 6 months, there was a statistically significant difference between the two groups. This cost difference was mainly driven by the higher proportion of participants in the CTC group in the £0 to £500 range compared to the OC group (41 [60%] versus 0 participants; Fig. 4). On the opposite end, a marginally higher proportion of participants in the CTC group (five participants [7.4%] versus six [5.7%]) presented very large costs (>£1,500). The latter was mainly due to participants that required more than one diagnostic examination and the costs associated with the management of extra-colonic incidental findings. As an example, one participant was found to have a mass in the omentum, a situation that led to its surgical excision with laparotomy.

Given the non-randomised study design, a second GLM analysis was performed to adjust for baseline characteristics statistically different between groups using a conservative threshold (p<0.05). The initial unadjusted 6-month cost difference between groups (−£345) was robust and hardly affected due to the observational nature of the study (−£370; Table 4). In all analyses, the utilisation of CTC as the initial investigation for these cohort of participants was associated with statistically significant cost-savings for the NHS.

Cost-effectiveness analysis

At baseline, participants in the OC group presented a higher utility value (mean utility of 0.832 versus 0.793, p=0.023) using the EQ-5D-5L questionnaire. Two additional collection points, at 3 and 6 months post-recruitment, were also registered (Table 5). No statistical significant difference (p>0.05) between the groups occurred at either 3 or 6 months in relation to the utility scores.

The cost-effectiveness analysis was based on incremental costs divided by incremental effects, in this case measured in QALYs. In order to adjust for imbalance in mean baseline utilities, a multiple regression analysis was considered. The mean cost per QALY at month 6 was estimated at −£69,080 (i.e. the intervention dominates, producing marginally more QALYs at a lower cost) as follows:

\[
\text{ICER} = \frac{\text{Cost CTC} - \text{Cost OC}}{\text{QALY CTC} - \text{QALY OC}} = \frac{-£345.3}{0.005} = -£69,080
\]

Fig. 5 illustrates the bootstrap analysis with 1,000 replicates, considering the 6-month cost per QALY. At month 6, the use of CTC as the initial investigation had a probability of 56% of being dominant and 0% of being dominated by the control group. The remaining 44% of bootstraps were in the cost-effectiveness analysis quadrants, i.e., the probability of being cost-effective depends on the overall system willingness-to-pay for each QALY. Assuming a £20,000 and £30,000 willingness-to-pay per QALY (thresholds typically considered by NICE), there was a 91.4% and 83.6% of CTC being cost-effective compared to OC at 6 months, respectively.

Clinical findings

Out of the 105 participants in the OC group, five cancers (4.8%) were diagnosed during the 12-month follow-up period. Three of these cancers were CRCs and were diagnosed as part of the initial OC test (sigmoid colon T3 N2; descending colon T4a N1b; anal canal T3 N0). Out of the 68 participants in the CTC group, a total of six cancers (8.8%) were diagnosed, with four being CRCs (two polyp adenocarcinomas extracted; rectal cancer T3 N1, and colon cancer T4b N1c M1) diagnosed during the initial CTC. With regards to medium to large polyps, a higher proportion of participants in the OC group had one or more polyps diagnosed (40% compared to 13% in the CTC group). Out of the 68 participants in the CTC group, 17 (25%) presented extra-colonic findings, 3 (4.4%) of which warranted further

<table>
<thead>
<tr>
<th>Type of NHS appointment</th>
<th>OC group (n=105)</th>
<th>CTC group (n=68)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total of episodes</td>
<td>Mean</td>
</tr>
<tr>
<td>Primary care services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GP face-to-face appointment</td>
<td>42</td>
<td>0.40</td>
</tr>
<tr>
<td>GP phone appointment</td>
<td>14</td>
<td>0.13</td>
</tr>
<tr>
<td>Hospital-based services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ED visit</td>
<td>3</td>
<td>0.03</td>
</tr>
<tr>
<td>Outpatient appointments</td>
<td>22</td>
<td>0.21</td>
</tr>
<tr>
<td>CTC</td>
<td>6</td>
<td>0.06</td>
</tr>
<tr>
<td>OC</td>
<td>109</td>
<td>1.04</td>
</tr>
<tr>
<td>Flexible sigmoidoscopy</td>
<td>1</td>
<td>0.01</td>
</tr>
</tbody>
</table>

CTC, computed tomography colonography; OC, optical colonoscopy; GP, general practitioner; ED, emergency department.

Table 3
Breakdown of key number of NHS appointments per type of activity organised per group.

<table>
<thead>
<tr>
<th>Mean total cost (SD)</th>
<th>CTC group (n=68)</th>
<th>OC group (n=105)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unadjusted cost difference (95% CI, p-value)</td>
<td>£645 ($±$607)</td>
<td>£991 ($±$316)</td>
</tr>
<tr>
<td>Adjusted cost difference (95% CI, p-value)</td>
<td>£-345 ($±$501 to $-370 ($±$594 to $-190))</td>
<td>£-185 ($±$0.001 to $-185 ($±$0.001 to $-185))</td>
</tr>
</tbody>
</table>

Table 4
Unadjusted and adjusted GLM analyses at months 6 post-recruitment.

6 months £991 ($±$316) £645 ($±$607) £-345 ($±$501 to $-370 ($±$594 to $-190) $<0.001 $>0.05 $<0.05 $>0.05 $<0.05 $>0.05 $>0.05

C., computed tomography colonography; OC, optical colonoscopy.
assessment. The first participant had a mass in the omentum that led to laparotomy with surgical excision, the second presented an inguinal hernia that led to follow-up CT and an initial outpatient appointment at which no further action was deemed necessary, and the third participant was diagnosed with a Bosniak type 2F left renal lesion that after a follow-up CT warranted no further action.

CTC and OC had similar rates of incomplete or suboptimal bowel visualisation, with nine (8.6%) and six (8.8%) scans deemed not suitable, and thus, requiring a second test, as detailed in the following section on service use costs.

**Time to reach a definitive diagnosis**

The time taken to reach a definitive diagnosis was estimated as the number of days elapsed from the referral from primary care to the results being available back to the referrer. The mean (SD) time was 34.2 (18) and 27.9 (16.6) days for the OC and CTC group, respectively. The time difference of 6.3 days was statistically significant ($p=0.005$).

**Patient satisfaction**

Patient satisfaction was assessed the morning following the diagnostic scan and evaluated the participant’s opinion regarding: (i) the bowel preparation (pre-test); (ii) the bowel test (test), and (iii) the morning after the test (post-test). Electronic Supplementary Material Appendix I summarises the responses from participants in the OC group ($n=69$) and the CTC group ($n=45$). No statistical differences were detected between the two groups before, during, or after the initial test (OC or CTC).

**Discussion**

Previous clinical studies have compared the accuracy levels of CTC and OC and established a non-inferiority of CTC compared to OC in the diagnosis of medium to large polyps ($\geq 5$ mm) and CRC. This finding was corroborated by the present study as all positive findings in the CTC were confirmed (i.e., true positives) based on a subsequent invasive test (either OC or flexible sigmoidoscopy). No CRC was diagnosed up to 12 months post-recruitment in the participants with negative findings in the CRC. Although reassuring, this was a study limitation as patients with negative findings in the CTC did not undergo an invasive test as per routine clinical practice. CTC enables the visualisation of extracolonic findings that may not relate to the presenting clinical condition but may be of clinical significance, e.g., an abdominal aortic aneurysm that is potentially life threatening if untreated. Out of the 68 participants in the CTC group, 17 (25%) had an incidental finding. Out of these 17 participants, 14 (82%) did not warrant any follow-up, with the remaining three (18%) requiring follow-up with diagnostic CT follow-up and, in one case, even led to the surgical excision of a mass.

The study showed that the use of CTC produced cost-savings to the NHS at 6 months post-recruitment, with mean cost difference per participant of £345 (95% CI: £501 to £190, $p<0.001$). When adjusting for baseline imbalances between both groups, the mean cost difference per participant increased to £370 (95% CI: £554 to £185, $p<0.001$). The cost differences may have been due to the fact that participants in the CTC group were, on average, 8 years older and presented a higher disease burden (both measured as the number of comorbidities and self-reported quality of life). These cost differences were multifactorial, primarily driven by two factors: (i)
low incidence of colon findings and (ii) the lower unit cost (£262) of CTC compared to OC (£515 to £760). The study’s underlying hypothesis was that the use of CTC as the initial investigation for patients with low-to-intermediate risk of CRC would avoid the need for invasive diagnostic examinations (such as OC) that are more expensive to the overall healthcare system. Atkin et al. (2013) reported that 30% of patients had additional colonic investigations following CTC, compared with only 8% after OC. These findings were corroborated by the present study, with 11.4% and 32.4% participants having a subsequent colonic investigation in the OC and CTC group, respectively. These conversion rates were pivotal in the assessment of resource use and drivers of overall cost for the healthcare system as the unit cost of each CTC (£262) is less than half of the cost of each OC procedure; however, in contrast to OC, positive findings found in CTC routinely lead to a follow-up invasive colonic test and subsequent increase in overall costs. In essence, more than the tests’ accuracy, that are considered to be equivalent, the presence of positive or negative findings is determined by the incidence of medium to large polyps or CRC in the population included in the study (overall 4% CRC incidence rate). For this reason, the inclusion criteria were deliberately aimed at patients with low-to-intermediate risk of CRC. These patients are less likely to require a biopsy during an invasive colonic procedure, thus maximising the utility of CTC to rule-out any major colonic finding. Out of 68 participants in the CTC, 46 (68%) were discharged based on the CTC results alone. In other words, the use of CTC released 46 OC slots that are more likely to benefit patients at higher risk of CRC. If patients with red flags (e.g., rectal bleeding, anaemia) were to be included, a higher proportion of patients would be expected to require an OC, reducing the cost-savings or even increasing total costs to the healthcare payer.

In addition to the 6-month cost analysis, a cost-utility analysis was conducted, comparing the incremental costs and QALYs as the measure of effect, as per NICE guidance. CTC was found to be more cost effective than OC achieving more QALYs at a lower cost. The CTC group was found to dominate the OC group in 54% of the bootstrap replicates (i.e., generating more QALYs at a lower cost), with the remaining 46% replicates showing that CTC led to a decrease in overall costs and QALYs. Considering NICE’s traditional willingness-to-pay thresholds of £20,000 to £30,000 per QALY, CTC was found to have a probability of 91% and 84% of being cost-effective, respectively.

Access to care was also evaluated as part of the study. The use of CTC as the initial investigation led to the results being available to the referrer, on mean, 6.3 days earlier compared to the OC group (p=0.005). The longer waiting time in the OC group was mainly due to the diagnostic workload associated with biopsies taken during the OC test. As part of the OC procedure, biopsies of potential lesions (polyps or CRC) were often taken. The time it took to complete the pathological assessment of biopsies seemed to be the major contributing factor for the difference in access to care between the two groups.

Patient satisfaction in both groups was compared using a non-standard questionnaire to be completed the morning after the diagnostic scan (CTC or OC). No statistically significant experience was found between the two groups.

The estimate of NHS resource use data was primarily based on comprehensive and complete data retrieved from hospital-based databases that captured both the acute and elective elements of the pathway associated with the management of patients with low to intermediate risk of CRC. These data were supplemented by both primary care utilisation data, collected from each participant’s GP, and...
self-reported participant data. The aim was to guarantee that any colon-related NHS event was costed regardless of the healthcare provider and its location. The prospective collection of healthcare utilisation and self-perceived quality of life data, the conduction of economic evaluation analyses (rather than cost analyses only) and the evaluation of the impact of the interventions using different dimensions of analysis (efficiency, quality of care, access to care and patient satisfaction) were other key factors that contributed to the overall strength of the study.

There were however some limitations to this study. First, this was a single-centre study with participants recruited from one central hospital in London. A multi-centre study would be necessary to explore the generalisability of the results. Second, as with any observational study, no randomisation between groups was performed. An adjusted GLM was performed to mitigate the potential impact of the study observational design on the primary outcome. Third, specific inclusion and exclusion criteria means the study sample might not be representative of all patients with low to intermediate risk of CRC. Fourth, participants with negative CTC findings could not be definitively ruled-out as potential false negatives as they did not undergo an OC as per routine clinical practice. Lastly, for the purpose of secondary outcomes, most data were self-reported and hence prone to recall bias.

This study found that the use of CTC, instead of OC, as the initial investigation scan for patients referred from primary care with low-to-intermediate risk led to significantly lower costs to the NHS at 6 months post-recruitment. Furthermore, the use of CTC compared to OC presented, respectively, a probability of 84%–91% of being cost-effective at month 6 using NICE’s willingness-to-pay thresholds. The use of CTC also improved access to care and no difference in patient satisfaction was noted. In summary, the use of CTC for patients with low-to-intermediate risk of CRC led to savings for the NHS whilst enabling the release of vital OC capacity to enhance access to care for patients more likely to benefit from an invasive procedure.

Conflict of interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crad.2020.04.014.

References


