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Diagnostic performance of CT colonography in a nonscreening population at an academic centre in British Columbia

The excellent diagnostic performance of CT colonography found in a recent study suggests that this safe and minimally invasive imaging modality may have a greater role to play in the screening of colorectal cancer in BC.

ABSTRACT

Background: **An estimated 3000 new cases of colorectal cancer and 1210 deaths from this common malignancy occurred in British Columbia in 2014. Given the excellent diagnostic performance and superior safety record of CT colonography (CTC) compared with colonoscopy, CTC is currently underutilized as both a diagnostic test and a screening tool.**

Methods: **To evaluate the diagnostic performance, safety, and costs of the CTC service at UBC Hospital, we conducted a retrospective review of all CTC studies completed at the hospital between 1 June 2012 and 30 June 2013 at UBC hospital. Data were collected on patient demographics, study indication, study quality, and clinically significant colonic or extracolonic findings. Medical records were reviewed for follow-up colonoscopy/surgery and extracolonic imaging.**

Results: **A total of 220 CTC studies were reviewed. Patients had a mean age of 65.3 (SD 11.1) years. A history of failed colonoscopy was noted for 131 patients (59.5%). CTC detected 74 polyps (6 mm or greater in diameter) in 52 patients. Follow-up colonoscopy/surgery in 39 patients identified 29 colonic polyps/masses. The per-polyp sensitivity was 71.4% for intermediate polyps (6 to 9 mm) and 100% for large polyps (10 mm or greater), while the per-polyp positive predictive value was 66.7% for intermediate polyps and 83.3% for large polyps. The overall per-patient positive predictive value was 77.8%. Extracolonic findings on CTC resulted in 26 follow-up imaging investigations, amounting to an additional cost of $37.93 per CTC study. There were no cases of colonic perforation or major complication in this study.**

Conclusions: **The CTC service at UBC Hospital demonstrates good diagnostic performance, a low rate of complication, and has the potential to play a greater role in diagnosis and screening of colorectal cancer in BC. Although the current consensus is that CTC is less accurate than colonoscopy in the diagnosis of colorectal cancer, and thus less cost-effective, advancements in imaging protocol and institution experience will continue to increase both diagnostic accuracy and cost-effectiveness.**

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Background

Colorectal cancer is the third most common malignancy and second leading cause of cancer death in Canada, with British Columbia alone accounting for an estimated 3000 new cases and 1210 deaths in 2014.[1] The majority of cases arise from precancerous adenomatous polyps and are highly preventable and treatable with effective early screening.[2] Current BC guidelines recommend average-risk patients undergo fecal immunochemical testing (FIT) every 1 to 2 years or a screening colonoscopy every 10 years. A positive FIT is to be followed up with diagnostic colonoscopy within 8 weeks. In BC, population screening with FIT has placed increased demand on colonoscopy, with wait times occasionally exceeding 1 year.

CT colonography (CTC), also known as virtual colonoscopy, is a minimally invasive imaging modality used in the detection of colonic lesions. Patients undergo a standard bowel preparation protocol before the colon is insufflated with carbon dioxide gas and imaged with a multidetector CT scan. Antispasmodic and oral contrast agents for stool and fluid tagging are often used to improve visualization. The resulting images are read by radiologists in 2D slices and 3D reconstructions to detect colonic polyps or masses. Patients with positive colonic findings are then referred for colonoscopy or surgical intervention.

In BC, public access to CTC requires specialist referral and is reserved for patients who have previously failed or are unlikely to tolerate colonoscopy. Given its excellent diagnostic performance and superior safety record compared with colonoscopy,[3] CT colonography is currently underutilized as both a diagnostic test and screening tool. Increasing the use of CTC for colorectal cancer screening could shorten wait lists for colonoscopy and supplement FIT to improve detection rates.

Methods

We conducted a retrospective review of diagnostic performance, safety, and associated costs of CTC performed at UBC Hospital. The study population included all patients who underwent CTC at the hospital between 1 June 2012 and 30 June 2013. Incomplete and suboptimal studies were included, and no exclusion criteria were applied. All patient data were anonymized. This study was approved by the UBC Clinical Research Ethics Board.

We reviewed the radiologist reports of all the CTC studies completed and collected data on patient demographics, study indication, study quality, and colonic and extracolonic findings. The reporting threshold for a colonic polyp was at least 6 mm in maximal diameter. Colonic and extracolonic findings (**Table 1** and **Table 2**) were categorized according to the CT Colonography Reporting and Data System (C-RADS).[4]

Table 1. Classification of colonic findings from CT colonography studies performed at UBC Hospital.

C-RADS* colonic category	Number of studies (% total)	Description
C0	13 (5.9%)	Inadequate study • Excess fluid/feces or inadequate insufflation • Cannot exclude lesions ≥ 10 mm
C1	146 (66.4%)	Normal colon or benign lesions • No polyps ≥ 6 mm • e.g., lipoma, diverticula, non-neoplastic findings
C2	38 (17.3%)	Intermediate polyps • < 3 intermediate polyps (6–9 mm) • Indeterminate findings cannot exclude polyps ≥ 6 mm
C3	14 (6.4%)	Large polyps or advanced adenoma • ≥ 3 intermediate polyps (6–9 mm) • Large polyps (≥ 10 mm)
C4	9 (4.1%)	Likely malignant colonic mass • Mass compromising bowel lumen or with extracolonic spread

* CT Colonography Reporting and Data System[4]

Table 2. Classification of extracolonic findings from CT colonography studies performed at UBC Hospital.

C-RADS* extracolonic category	Number of studies (% total)	Description
E0	2 (0.9%)	Inadequate or limited study • Cannot evaluate extracolonic structures
E1	56 (25.5%)	Normal study • Normal anatomy or anatomic variant • No extracolonic abnormalities
E2	99 (45.0%)	Clinically unimportant findings • e.g., simple liver cysts, osteoarthritis, nonobstructing renal stones
E3	46 (20.9%)	Incompletely characterized finding, workup may be indicated • e.g., benign lung nodules, indeterminate renal cysts, hepatic lesions
E4	17 (7.7%)	Potentially important finding, likely requiring further workup • e.g., suspect lung nodules, bony lesions, obstructing renal masses

* CT Colonography Reporting and Data System[4]

Reports of patients with potentially significant colonic findings, defined as C-RADS C0, C2, C3, and C4, were reviewed further for one or more of the following: follow-up colonoscopy, flexible sigmoidoscopy, surgery, or pathology using province-wide electronic health records. The size, location, and histology of each polyp was recorded and compared with CTC findings to evaluate concordance. Polyps were deemed concordant if they were located in the same anatomical region of the large colon and were of equal diameter, plus or minus 2 mm. Patients with extracolonic findings likely to require follow-up, specifically studies categorized as C-RADS E3 and E4, were reviewed for any additional extracolonic imaging performed.

Table 3. Primary indications for 220 CT colonographies performed at UBC Hospital.

Indication	Number of studies (% total)
History of failed colonoscopy	131 (59.5%)
Unknown history of colonoscopy	89 (40.5%)
Rectal bleed	15 (6.8%)
Change in bowel habits	15 (6.8%)
Anatomical contraindication	14 (6.4%)
Abdominal pain	12 (5.5%)
Anemia	11 (5.0%)
History of colonic polyps	9 (4.1%)
Family history of CRC	7 (3.2%)
Refusal of colonoscopy	2 (0.9%)
Weight loss	1 (0.5%)
Not specified	3 (1.4%)

Table 4. Histology of polyps following positive findings on CT colonography.

Histologic type	Intermediate polyps (6–9 mm)	Large polyps (≥ 10 mm)
Hyperplastic	2	0
Inflammatory	0	1
Lipoma	0	1
Serrated adenoma	1	0
Tubular adenoma	9	5
Tubulovillous adenoma	1	1
High-grade dysplasia	0	0
Adeno-carcinoma	1	6
Metastasis	0	1
Totals	14	15

Results

The study population consisted of 220 patients with a mean age of 65.3 (SD 11.1) years. The population included 90 males (40.9%) and 130 females (59.1%). A history of failed colonoscopy was noted in reports for 131 patients (59.5%). The remaining 89 patients (40.5%) had an unknown history of colonoscopy, with 54 patients (24.5%) presenting with symptoms (e.g., rectal bleed, change in bowel habits, abdominal pain, weight loss), 16 (7.3%) with a family or past history of colorectal cancer or polyps, 14 (6.4%) with anatomical contraindications to colonoscopy (e.g., diverticular strictures), and 2 (0.9%) who refused colonoscopy (**Table 3**).

CTC study quality

There were 185 CTC studies (84.1%) of excellent quality that allowed for accurate detection of all polyps 6 mm or greater in diameter. The remaining 35 studies (15.9%) were suboptimal due to poor bowel distention (19 studies), poor bowel preparation (15 studies), and metallic artifact (1 study). Of the suboptimal studies, only 13 studies (5.9%) were deemed inadequate (C-RADS C0) and could not determine if large polyps (10 mm or greater in diameter) were present.

No major complications from CTC resulting in further hospitalization or long-term morbidity were seen in our study population. There were two studies featuring minor complications, including a vasovagal response and abdominal discomfort from elevated intraluminal pressures during colonic insufflation.

Colonic findings

There were 146 studies (66.4%) with unremarkable colonic findings requiring no further workup (C-RADS C1) and 74 studies (33.6%) with indeterminate or potentially important findings (C-RADS C0, C2, C3, C4). A total of 74 polyps were identified in 52 patients on CTC, including 50 intermediate polyps (6 to 9 mm in diameter) and 24 large polyps or masses (10 mm or greater in diameter).

Subsequent colonoscopy or surgery was performed in 39 patients (17.7%), with reports available for 36 of these. Pathology reports identified 29 colonic lesions, including 6 advanced adenomas, 7 adenocarcinomas, and 1 peritoneal metastasis from a primary breast cancer (**Table 4**). Notably, colonoscopy was avoided in 181 patients (82.2%) evaluated with CTC.

The per-polyp positive predictive value (PPV) is the percentage of polyps detected on CTC and confirmed subsequently on colonoscopy or surgery. The per-patient PPV represents the percentage of positive CTC studies concordant with colonoscopy or surgery for the presence of a polyp, mass, or non-neoplastic finding. In this study, the per-polyp PPV was 66.7% for intermediate polyps and 83.3% for large polyps, while the per-patient PPV was 77.8%. Among patients receiving both CTC and colonoscopy, four intermediate polyps were missed on CTC, resulting in a per-polyp sensitivity of 71.4% for intermediate polyps and an overall

Table 5. Diagnostic performance of CT colonography for the detection of colonic polyps.

Polyp size	True positive	False positive	False negative	PPV* % (95% CI)	Sensitivity % (95% CI)
Intermediate (6–9 mm)	10	5	4	66.7% (38.7%-87.0%)	71.4% (42.0%-90.4%)
Large (≥ 10 mm)	15	3	0	83.3% (57.7%-95.6%)	100% (74.7%-100%)
Totals	25	8	4	75.8% (57.4-88.3%)	86.2% (67.4%-95.5%)

* per-polyp predictive value

per-polyp sensitivity of 86.2%. No large polyps or colonic neoplasms were missed on CTC (Table 5).

Extracolonic findings

There were 157 CTC studies (71.4%) with unremarkable extracolonic findings (C-RADS E0, E1, E2), demonstrating normal anatomy or clinically unimportant findings. Conversely, 63 studies (28.6%) revealed potentially important extracolonic findings (C-RADS E3, E4), possibly requiring further workup or ongoing surveillance (Table 2).

Overall, 26 additional imaging studies were performed in 26 patients (11.8%) for investigation of extracolonic findings, averaging 0.12 additional imaging studies per CTC study (Table 6). Using the BC Medical Services Plan payment schedule, the estimated cost of follow-up extracolonic imaging was $37.93 per CTC study performed.[5] However, the Medical Services Plan payment schedule does not account for significant overhead costs and is likely an underestimation.

Conclusions

In BC, CTC is used predominantly as a diagnostic test in patients not suitable for colonoscopy and has not been adopted for population screening. The topic remains controversial: several US guidelines currently recommend CTC every 5 years for population screening,[6,7] while other organizations, including the Canadian Association of Gastroenterology, have yet to support it.[8,9] Factors preventing adoption of CTC for screening include uncertainty about its diagnostic performance and safety, and concerns about exposure to ionizing radiation and overall cost-effectiveness.

Diagnostic performance

Greater utilization of CTC has been hampered somewhat by the variable performance of this modality reported in the literature. Some large prospective studies have demonstrated excellent sensitivity of 84.0% to 93.7% for detection of large polyps and 70% to 88.7% for detection of intermediate polyps, with overall performance comparable to colonoscopy.[10,11] Other studies have reported sensitivities of only 55% to 59% for large polyps and 39% to 51% for intermediate polyps.[12,13] Differences in CT scanning protocols, CTC workstations, and institution experience all affect diagnostic performance, and each institution should be appraised individually.

In this retrospective study, diagnostic performance at our CTC service compared favorably with current literature standards. Our institution's overall per-polyp sensitivity (86.2%) aligned with reporting values from other centres of 86% to 89%.[14-16] Similarly, both our per-patient PPV (77.8%) and per-polyp PPV (75.8%) agreed with literature values, typically cited between 70% and 79%.[14-16]

It remains unclear whether extracolonic evaluation with CTC is beneficial overall. While extracolonic investigation may detect a subclinical disease process or reassure the

Table 6. Follow-up imaging for 26 extracolonic findings following CT colonography.

Extracolonic follow-up imaging modality	Extracolonic finding(s) investigated	Number of studies
Abdominal ultrasound	Hepatic lesion	7
CT chest (without contrast)	Lung nodule, bronchiectasis	5
CT abdomen and pelvis (with contrast)	Hepatic lesion, renal cyst, pancreatic mass	4
CT abdomen and pelvis (without contrast)	Adrenal incidentaloma, mesenteric panniculitis	2
Renal ultrasound	Renal cyst	2
Bone scan	Bony lesion	2
MRI lumbar spine	Perineural cyst	2
MRI adrenals	Adrenal incidentaloma	1
Laparoscopy	Peritoneal mass	1

patient with a normal exam, the majority of extracolonic findings are benign, and additional imaging for clinically unimportant findings results in unnecessary costs, patient anxiety, and radiation exposure. A considerable percentage of our patients (11.8%) received further extracolonic imaging, which may be explained in part by the advanced age and the comorbidities seen in our study population. We did not assess the clinical significance of each follow-up imaging study, but Pickhardt and colleagues showed new clinically important extracolonic findings, including undiagnosed malignancies, were found in 2.5% of patients undergoing CTC.[17]

Safety

The most prominent concern of colonoscopy is colonic perforation, with a cited risk between 0.05% and 0.20%.[3,18,19] This poses a small risk to an individual but is of greater consequence in the setting of population screening. In comparison, the perforation rate of CTC is 0.04% or less, including asymptomatic cases detected only on imaging.[20,21] This study featured no cases of colonic perforation or other serious complication from CTC, an important outcome given that our patients would have been technically difficult colonoscopies with a higher risk of endoscopic perforation.

Unlike colonoscopy, CTC does not require conscious sedation and thus eliminates the inherent health risks of sedation (e.g., respiratory depression, hypotension). As well, postprocedure driving restrictions (with the associated risks if the patient is nonadherent) and postprocedure nursing supervision are not needed. A recent BC study showed 77% of patients preferred colonoscopy over CTC for repeat screening, as they felt less pain, discomfort, and anxiety with colonoscopy.[22] However, this may be attributable to the sedation offered rather than the nature of the procedures themselves. A larger study where only half of patients were given conscious sedation during colonoscopy reported no significant difference in comfort between CTC and colonoscopy and that CTC was preferred for future screening.[23]

Exposure to ionizing radiation

Exposure to ionizing radiation with CTC presents a risk of radiation-induced cancer. Brenner and Georgsson estimated the lifetime risk of radiation-related cancer from a single CTC exam was 0.14% at age 50 and fell to 0.07% at age 70.[24] However, this small risk of iatrogenic malignancy appears to be mitigated by a favorable risk-benefit ratio. Berrington de Gonzalez and colleagues used risk projection models to estimate that a screening CTC every 5 years in patients aged 50 to 80 years (effective dose of 7 to 8 mSv) would prevent 24 to 35 cases of colorectal cancer for every radiation-related cancer caused.[25] Continual optimization has lowered the interinstitution median effective dose for a screening CTC to 4.4 mSv and for a nonscreening CTC 7.6 mSv,[26] which represents less radiation than a standard CT of the abdomen and pelvis. The median effective dose of approximately 8.1 mSv for a diagnostic CTC at UBC is comparable to other centres, and ranges from 4.2 to 13.8 mSv depending on patient body habitus. Ongoing research into implementing lower tube current, tube voltage, and utilization of iterative reconstruction algorithms promises to further reduce radiation risks and improve the risk-benefit ratio.[27]

Cost-effectiveness

The current consensus is that CTC is less cost-effective than colonoscopy for colorectal cancer screening.[28] A 2005 Canadian study by Heitman and colleagues found that although CTC would eliminate the costs related to complications requiring hospitalization and postsedation supervision seen with colonoscopy, CTC would still be more costly than colonoscopy because of poorer prevention of colorectal cancer due to inferior diagnostic performance.[29] The costs associated with early detection and additional workup of extracolonic findings were not included in these studies, however, and are seldom satisfactorily considered in the literature.

Heitman and colleagues state that CTC will not be cost-effective in Canada until the unit cost per study is reduced below $422.[29] With the current cost estimated to be in the $400 to $500 range.[14] CTC is not too far from being cost-effective, and ongoing improvements in diagnostic accuracy could eventually make CTC a reasonable option for colorectal cancer screening. This is especially true in BC, where there is unlikely to be a significant increase in colonoscopy resources to meet the demand generated by FIT screening. CTC is an attractive alternative to screening colonoscopy and would be relatively inexpensive to implement with much of the infrastructure already available in many centres.

In summary, this study suggests that CTC, with its low complication rate and good diagnostic performance relative to literature standards, may have a greater role to play as a minimally invasive diagnostic and screening test in BC that could help shorten colonoscopy wait times and allow patients to avoid unnecessary colonoscopies. Advancements in imaging protocol and institution experience will continue to increase diagnostic accuracy, minimize radiation exposure, and improve cost-effectiveness.

Competing interests
None declared.

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