Computed tomography colonography performs poorly in detection of sessile serrated lesions

Shiristi Kumar, Andrew McCombie, Simon Richards, Tamara Glyn, Emma Bone, Tim Eglinton

ABSTRACT

BACKGROUND: Computed tomography colonography (CTC) is an alternative to colonoscopy for the detection of polyps and colorectal cancer (CRC). One-third of CRCs arise via the sessile serrated pathway. Evidence supports using CTC to detect adenomas and CRC; however, its accuracy for sessile serrated lesions (SSLs) remains uncertain. This study aimed to determine the accuracy of CTC in detecting SSLs compared with colonoscopy.

METHOD: Electronic records identified all colonoscopy procedures where a histologically validated SSL was excised over a 11-month period. In those patients who had a CTC within 1 year prior to colonoscopy, the presence, size and location of SSLs were compared to determine the accuracy of CTC in SSL identification.

RESULTS: A total of 4,346 procedures were performed (2,548 people, 2,082 [47.9%] male, mean age 59.6). A total of 2,204 SSLs were removed, representing 24% of all polypectomies. SSLs were predominantly located in the right colon (65.1%) and were typically (85%) <10mm in size. A total of 110 SSLs were obtained from 39 procedures with a prior CTC. Of these procedures, 12 (30.8%) had lesions identified on CTC; however, CTC only accurately identified 14.5% of the total SSLs. Five of 16 (32%) SSLs ≥10mm were correctly identified compared with 11 of 94 (11%) SSLs 1–9mm, (odds ratio 3.42, p=0.0495).

CONCLUSION: This study demonstrated that CTC has poor efficacy in detecting SSLs, irrespective of polyp size and location. Based on these findings, CTC as a substitute for colonoscopy is not advisable in patients at risk of SSLs.

Globally, colorectal cancer (CRC) is the third most common cancer and is the second leading cause of cancer-related mortality. The incidence of CRC is higher in developed countries and is increasing in middle- and low-income countries.[1] Aotearoa New Zealand is no exception: CRC is the second most commonly diagnosed cancer and the second most common cause of cancer-related death, with over 1,200 deaths annually.[2] Its prevalence increases with age, with most cases occurring in individuals ≥50 years.[1,3] It is widely recognised that the CRC-associated health burden can be significantly reduced by early detection and timely management.

CRC develops within pre-cursor lesions, justifying screening and polyp resection in at-risk individuals.[4] The majority of current screening and detection guidelines focus on detection of conventional adenomas, which progress via the chromosomal instability pathway (CIN).[5] Contemporary CRC research suggests that at least one-third of CRCs arise from the progression of serrated lesions via the serrated pathways.[6–8]

Sessile serrated lesions (SSLs), previously referred to as sessile serrated adenomas,[9] gained pathological recognition in 1990 after identification of polyps that shared features of both hyperplastic and adenomatous polyps.[10] Despite this, global recognition and reporting of SSLs did not begin until the early 2000s, at which time SSLs were described as their own entity[11] and, importantly, differentiated from their low malignant potential counterpart, the hyperplastic polyp.

Computed tomography colonography (CTC) utilises low-dose radiation and pneumatic colonic insufflation to obtain views of the colon. Its advantages lie in it being non-sedative, non-invasive and minimising the risk of bleeding and colonic perforation.[12] CTC has demonstrated high sensitivity for large polyps in both asymptomatic[13] and symptomatic populations.[14] As such, meta-analysis data illustrate the sensitivity of CTC for polyps 6mm or larger and 10mm or larger as 85.3% and 90.8% respectively.[15]

Previous work from this institution[16] questioned whether CTC is a viable screening tool for SSL, in particular for smaller polyps, given over 85% of SSLs in this study were <10mm. Flat colonic lesions are a known source of false-negative CTCs;[17] this in turn raises questions regarding its utility for the detection of SSLs, given their flat morphology. To date, there have been mixed results with respect to the adequacy of CTC in identifying SSLs,[12,18–22] with many studies predating the recent histological classification of SSLs and technical improvements in both colonoscopy and CTC. Few studies have specifically looked at the efficacy of CTCs in detecting flat SSLs in direct comparison with colonoscopy. A recent study[18] of 79 patients, evaluating the efficacy of CTC in detecting polyps, identified a high false-negative rate with almost one-third of large SSLs (>1cm) being missed by CTC, and, overall, CTC identified less than half of all SSLs seen on subsequent colonoscopy.

This study aimed to determine the accuracy of detection of SSLs in patients undergoing CTC within a year prior to colonoscopy, in an Aotearoa New Zealand tertiary centre. Additionally, acknowledging the previously reported right-sided abundance of SSLs and greater sensitivity of CTCs for large polyps, it secondarily aimed to determine whether the location and/or size of SSLs affects their detection rate on CTC.

Method

Population

The methodology used to collect this dataset has been previously described.[16] All adult patients undergoing either a colonoscopy or flexible sigmoidoscopy within the Canterbury District Health Board (DHB) between 1 January 2022 and 1 December 2022 were identified retrospectively through the local prospectively maintained endoscopic database, Provation® (Provation Software Inc, Minneapolis, United States of America). Procedures were excluded if there was inadequate clinical, demographic or pathological information. This study was approved by the New Zealand Health and Disability Ethics Committee as an out-of-scope review. Locality approval was obtained from Te Whatu Ora – Health New Zealand Waitaha Canterbury (RO#22215). This study included patients from our previously published paper known to have had both (at least) one SSL and undergone a CTC. All CTCs were subject to standard bowel preparation and were exempt from polyp detection aids like oral barium contrast and/or faecal tagging. The centre at which this study was conducted has a 97% caecal intubation rate and 94.6% ≥6-minute withdrawal time.

The inclusion criteria for this study comprised adult patients who underwent colonoscopy within the Canterbury DHB between 1 January 2022 and 1 December 2022. Eligible participants were patients who had at least one SSL diagnosed using the latest World Health Organization (WHO) classification system during the study period and undergone a CTC within 1 year prior to the SSL resection. A 1-year cutoff period was chosen, given that a short follow-up period would identify lesions that were "missed" rather than SSLs that were interval growths. Additionally, only records with complete demographic and clinicopathological data, including age, gender, ethnicity, indication for examination, polyp location and polyp size, were considered for inclusion.

Exclusion criteria for this study included procedures with incomplete or inadequate clinical, demographic or pathological information, as well as any CTCs performed more than 1 year prior to the assessment. Suboptimal CTCs (e.g., through inadequate insufflation) were excluded.

Data extraction

Demographic and clinicopathological data were extracted from patient medical records and anonymised. Collected variables included age, gender, ethnicity and examination indication. Procedure and pathology reports provided data on polyp location (categorised as right colon, left colon, and rectum) and size (small [<10mm] or large [≥10mm]). The latest WHO classification system for SSLs was employed. This determines that the presence of one unequivocally distorted crypt is diagnostic of an SSL, and crypt distortion was defined by the presence of any of: horizontal crypts, dilated basal third of the crypt and/or serrations extending into the crypt base.[23]

When patients with an SSL were identified their record was searched, and all those who had a CTC within 1 year prior to the colonoscopy were included in this analysis. The CTC reports were reviewed and the presence, size and location of any lesions recorded. The endoscopic data were compared with the CTC findings on both a per-polyp and per-procedure basis to determine the accuracy of CTC in identifying SSLs.

Statistical analysis

RStudio[24] was used for statistical analysis. For the per-procedure analysis, percentages of each gender and ethnicity were calculated and it was cross-tabulated whether there was at least one large polyp (≥10mm) versus whether at least one small polyp (<10mm) was detected on CTC. For the per-polyp analysis, whether or not the polyp was seen on CTC was cross-tabulated against the size (≥10mm versus <10mm) and location (left colon or rectum versus right colon). All cross-tabulations were calculated using binary logistic models and odds ratios (ORs) and p-values reported.

Results

A total of 4,346 colonoscopy procedures (2,548 people, 2,082 [47.9%] male, mean age 59.6) were performed between 1 January 2022 and 1 December 2022 (inclusive), of which 2,786 (64.1%) underwent polypectomy. As reported previously,[16] data on 10,026 individual polyps were collected. After excluding "normal tissue", "adenocarcinoma" and "other" non-polypoid histology, of the 9,166 polyps there were 2,204 SSLs (24%), of which 3.6% were dysplastic. SSLs were typically (85%) less than <10mm and predominantly (65%) located within the right colon (versus 33% in the left colon and 2% in the rectum). Table 1 describes the patient and SSL characteristics.

A CTC was performed within a year prior to 39 endoscopic procedures where a total of 110 SSLs were removed with polypectomy and were histologically confirmed (Table 1). All of the CTCs were of excellent quality. The maximum time to polypectomy was 5 months, with most (>97%) of SSLs resected within 3 months of the CTC. Of the 39 procedures, 20 (51.3%) were males versus 19 (48.7%) in females, and 36 (92.3%) were in patients of European descent. Median age was 62 years (interquartile range 62–79 years). In only 12 of the CTCs performed prior to these 39 procedures (30.8%), at least one SSL was detected and CTC only correctly identified 16 (14.5%) of all 110 SSLs.

SSL detection rate based on size and location

Size of polyps

CTC had a poor detection rate for both small and large SSL. Five of 16 (32.25%) large polyps (≥10mm) versus 11 of 94 (11.7%) small polyps (<10mm) were detected (OR 3.42, p=0.0495). Four of eight (50%) procedures that contained at least one large polyp (≥10mm) had at least one detected on CTC versus eight of 31 (25.8%) that did not have at least one large polyp (≥10mm) (OR 2.88, p=0.20).

Locations of polyps

Despite the well-known right-sided distribution predominance of SSLs, also evident in our study, CTC failed to detect the majority of right-sided SSLs. Fourteen of 75 (18.7%) polyps were detected in the right colon compared with two of 35 polyps (5.7%) in the left colon/rectum (OR 3.79, p=0.09). Breaking down the left-sided lesions, detection rates within the left colon itself were two of 32 (6.3%) and zero of three in the rectum (0%).

Discussion

This study found that CTC has poor efficacy in detecting SSLs, irrespective of size and/or location and, overall, correctly identified only 14.5% of all SSLs, resulting in a high miss rate. This finding aligns with emerging literature showing poor efficacy of CTC in detecting SSLs.[18,19,22]

Deiss-Yehiely et al.[22] compared multitarget stool DNA with CTC in the detection of SSLs; the authors identified a CTC detection rate of 14.4% at 6mm and 25.9% at 10mm thresholds. Of note, however, they used low-density oral barium to aid polyp detection.[22] Singla et al.[18] directly compared the efficacy of CTC and colonoscopy in detecting SSLs and concluded that 51.3% of SSLs were missed by CTC. In keeping with the current study, they had a poor detection rate regardless of size, with nearly one-third of large (>10mm) SSLs being missed on CTC.

This finding of a high miss rate is of particular concern given the recent recognition that SSLs are premalignant lesions[25] that may progress to CRC at higher and more rapid rates than previously reported.[26–28] As a result, timely detection and treatment of SSLs is of significant clinical importance. Having previously been predominantly used in those patients with contraindication to colonoscopy or in resource-constrained environments, more recently CTC has been increasingly used as a screening tool due to its non-invasive nature, faster procedure time, better safety profile and ability to avoid sedation.[19,29,30] Recent publications from Australasia[19] and Asia[29] promote the use of CTC in both the screening and non-resource-constrained environment.[29] These recommendations are likely a result of previous studies identifying high accuracy for polyp detection, even those polyps <10mm[12,31,32] and not differentiating polyp subtype. It is likely that many studies also predate the modern histological classification of SSLs.[23] As a result, we recommend caution in the use of CTC for CRC screening due to this high miss rate and thereby recommend high-quality colonoscopy as our preferred screening modality due to its ability to detect and remove all types of colonic polyps.

SSLs are infrequently detected by faecal immunochemical tests (FIT), with meta-analysed pooled detection rates of only 4.1%.[33] However, SSLs frequently coexist with conventional adenomas,[34] making it more likely that patients undergo follow-up colonoscopy after a positive FIT triggered by an advanced adenoma rather than the SSL itself. While diagnostic colonoscopy is usually performed following a positive FIT result, in our study the main indication for colonoscopy leading to SSL resection was abnormal polyp detection on CTC imaging.

A recent Australian report[19] suggested that with the growing demand for endoscopies, increased utilisation of CTC could reduce waiting times for colonoscopy, thereby broadening access to timely and effective CRC screening. However, the need to subject patients to a follow-up colonoscopy after a positive CTC can negatively affect the cost–benefit ratio of this approach.

Due to concerns regarding waiting times and resource limitations, stool-based tests, such as quantitative FIT or faecal DNA testing, can serve as non-invasive alternatives for initial screening, prompting follow-up colonoscopy if abnormalities are detected. Additionally, given the challenge of detecting SSLs with CTCs, a risk-stratified approach to screening, prioritising colonoscopy for individuals at higher risk of SSLs—such as those with a family history of CRC or prior polyps—can help optimise resource allocation and improve overall screening to ensure accurate diagnosis and prevention of CRC.

In those patients where colonoscopy is contraindicated and/or timely access to colonoscopy may be limited, the use of adherent contrast material may aid in SSL detection.[35–37] In a retrospective study of flat polyps, Kim et al. demonstrated that oral contrast in conjunction with CTC improved sessile serrated polyps and traditional serrated polyp detection rates with an OR of 40.4 (95% confidence interval 10.1–161.4).[36] Our centre does not routinely employ oral barium or contrast agents to facilitate polyp detection; however, this remains an area of interest for future research.

The strengths of this study include a large sample size from a tertiary healthcare institution with expert endoscopists and reporting radiologists, with synoptic reporting allowing for complete data capture and more robust results. While many radiology centres across Aotearoa New Zealand do not routinely report on polyps <5mm visible on CTCs, our centre did, hence small polyps were included in the present study. Given SSLs drive an accelerated pathway to CRC, with rapid development of microsatellite instability, BRAF mutations and CpG island methylator phenotype, resulting in faster progression compared with conventional adenoma,[38] and our initial work illustrated the majority of SSLs were <10mm, focussing on smaller SSLs was thought to be clinically significant. The main limitation is the retrospective design allows for only a snapshot of SSL incidence within a local population. Furthermore, the high incidence and miss rate of SSLs with CTC observed in an Aotearoa New Zealand population may not be directly generalisable to other populations. This study did not specifically investigate post-imaging CRC as key performance indicator (KPI). Future research could look at the post-CTC and colonoscopy CRC rate as a KPI as this information was not available for the present study. Nonetheless, this notable increase in miss rates highlights the need for consideration of contemporary SSL data in other regions and necessitates a re-evaluation of CTC efficacy in CRC surveillance on a global scale.

Conclusion

This study demonstrated a high prevalence of SSLs at colonoscopy and that CTC has poor efficacy for detecting SSLs, irrespective of size and location. In light of these findings, CTC cannot be considered as equivalent to colonoscopy for detecting SSLs and is not recommended by the authors. With CRC rates continuing to rise across Western populations, the detection and removal of precursor lesions remains the cornerstone of combatting CRC pathogenesis. Advanced techniques including contrast tagging offer potential improvement in detection rates, and further research is required to examine these.

Table 1: Patient and sessile serrated lesion (SSL) characteristics.

Patient characteristics	
Patients (n)	39
Procedures (CTC)	39
Males	20 (51.3%)
Females	19 (48.7%)
Median age	62 (interquartile range 62–79)
SSL characteristics	
Total SSL	110
Dysplastic SSLs	0
SSL <10mm	94
SSL >10mm	16
At least one SSL detection per CTC	30.8% (12 procedures)
% SSLs correctly identified by CTC	14.5% (16/100)

SSL = sessile serrated lesion; CTC = computed tomography colonography.

COMPETING INTERESTS

None declared.

This research was conducted as part of an interest-driven research initiative in the corresponding author's internship year. This research was conducted as part of a summer studentship project funded by the Maurice and Phyllis Paykel Trust.

DATA AVAILABILITY STATEMENT

Can be made available on request.

AUTHOR INFORMATION

Shiristi Kumar: Department of Surgery and Critical Care, University of Otago Christchurch, Aotearoa New Zealand; Junior Registrar, Department of General Surgery, Te Whatu Ora – Health New Zealand Waitaha Canterbury, Aotearoa New Zealand.

Andrew McCombie: Honorary Senior Research Fellow, Department of Surgery and Critical Care, University of Otago Christchurch, Aotearoa New Zealand; Research Officer and Data Analyst, Department of General Surgery, Te Whatu Ora – Health New Zealand Waitaha Canterbury, Aotearoa New Zealand.

Simon Richards: Senior Lecturer, Department of Surgery and Critical Care, University of Otago Christchurch, Aotearoa New Zealand; General Surgeon, Department of General Surgery, Te Whatu Ora – Health New Zealand Waitaha Canterbury, Aotearoa New Zealand.

Tamara Glyn: Senior Lecturer, Department of Surgery and Critical Care, University of Otago Christchurch, Aotearoa New Zealand; General Surgeon, Department of General Surgery, Te Whatu Ora – Health New Zealand Waitaha Canterbury, Aotearoa New Zealand.

Emma Bone: Trainee Intern, Department of Surgery and Critical Care, University of Otago Christchurch, Aotearoa New Zealand.

Tim Eglinton: Professor, Department of Surgery and Critical Care, University of Otago Christchurch, Aotearoa New Zealand; General Surgeon, Department of General Surgery, Te Whatu Ora – Health New Zealand Waitaha Canterbury, Aotearoa New Zealand.

CORRESPONDING AUTHOR

Andrew McCombie: Honorary Senior Research Fellow, Department of Surgery and Critical Care, University of Otago Christchurch, Aotearoa New Zealand; Research Officer and Data Analyst, Department of General Surgery, Te Whatu Ora – Health New Zealand Waitaha Canterbury, Aotearoa New Zealand.
E: Andrew.mccombie@cdhb.health.nz

URL

https://nzmj.org.nz/journal/vol-138-no-1627/computed-tomography-colonography-performs-poorly-in-detection-of-sessile-serrated-lesions

REFERENCES

1. Xi Y, Xu P. Global colorectal cancer burden in 2020 and projections to 2040. Transl Oncol. 2021 Oct;14(10):101174. doi: 10.1016/j.tranon.2021.101174.
2. Ministry of Health – Manatū Hauora. Cancer: New registrations and deaths - series [Internet]. 2023 [cited 2024 Sep 28]. Available from: https://www.health.govt.nz/nz-health-statistics/health-statistics-and-data-sets/cancer-new-registrations-and-deaths-series
3. Siegel RL, Wagle NS, Cercek A, et al. Colorectal cancer statistics, 2023. CA Cancer J Clin. 2023 May;73(3):233-254. doi: 10.3322/caac.21772.
4. Atkin W, Wooldrage K, Brenner A, et al. Adenoma surveillance and colorectal cancer incidence: a retrospective, multicentre, cohort study. Lancet Oncol. 2017 June;18(6):823-834. doi: 10.1016/S1470-2045(17)30187-0.
5. Fearon ER, Vogelstein B. A genetic model for colorectal tumorigenesis. Cell. 1990 Jun;61(5):759-767. doi: 10.1016/0092-8674(90)90186-i.
6. Crockett SD, Nagtegaal ID. Terminology, Molecular Features, Epidemiology, and Management of Serrated Colorectal Neoplasia. Gastroenterology. 2019 Oct;157(4):949-966.e4. doi: 10.1053/j.gastro.2019.06.041.
7. Goldstein NS, Bhanot P, Odish E, Hunter S. Hyperplastic-like colon polyps that preceded microsatellite-unstable adenocarcinomas. Am J Clin Pathol. 2003 Jun;119(6):778-796. doi: 10.1309/DRFQ-0WFU-F1G1-3CTK.
8. Jass JR. Classification of colorectal cancer based on correlation of clinical, morphological and molecular features. Histopathology. 2007 Jan;50(1):113-130. doi: 10.1111/j.1365-2559.2006.02549.x.
9. Aust DE, Baretton GB; Members of the Working Group GI-Pathology of the German Society of Pathology. Serrated polyps of the colon and rectum (hyperplastic polyps, sessile serrated adenomas, traditional serrated adenomas, and mixed polyps)-proposal for diagnostic criteria. Virchows Arch. 2010 Sep;457(3):291-297. doi: 10.1007/s00428-010-0945-1.
10. Longacre TA, Fenoglio-Preiser CM. Mixed hyperplastic adenomatous polyps/serrated adenomas. A distinct form of colorectal neoplasia. Am J Surg Pathol. 1990 Jun;14(6):524-537. doi: 10.1097/00000478-199006000-00003.
11. Li SC, Burgart L. Histopathology of serrated adenoma, its variants, and differentiation from conventional adenomatous and hyperplastic polyps. Arch Pathol Lab Med. 2007 Mar;131(3):440-445. doi: 10.5858/2007-131-440-HOSAIV.
12. Sha J, Chen J, Lv X, et al. Computed tomography

colonography versus colonoscopy for detection of colorectal cancer: a diagnostic performance study. BMC Med Imaging. 2020 May 18;20(1):51. doi: 10.1186/s12880-020-00446-7.
13. Pooler BD, Lubner MG, Theis JR, et al. Volumetric Textural Analysis of Colorectal Masses at CT Colonography: Differentiating Benign versus Malignant Pathology and Comparison with Human Reader Performance. Acad Radiol. 2019 Jan;26(1):30-37. doi: 10.1016/j.acra.2018.03.002.
14. Pickhardt PJ, Correale L, Delsanto S, et al. CT Colonography Performance for the Detection of Polyps and Cancer in Adults ≥ 65 Years Old: Systematic Review and Meta-Analysis. AJR Am J Roentgenol. 2018 Jul;211(1):40-51. doi: 10.2214/AJR.18.19515.
15. Cash BD, Rockey DC, Brill JV. AGA standards for gastroenterologists for performing and interpreting diagnostic computed tomography colonography: 2011 update. Gastroenterology. 2011 Dec;141(6):2240-2266. doi: 10.1053/j.gastro.2011.09.043.
16. Bone E, Kumar S, Richards S, et al. Current sessile serrated lesion incidence: implications for future clinical practice. ANZ J Surg. 2024 Oct;94(10):1806-1811. doi: 10.1111/ans.19200.
17. Fidler JL, Johnson CD, MacCarty RL, et al. Detection of flat lesions in the colon with CT colonography. Abdom Imaging. 2002 May;27(3):292-300. doi: 10.1007/s00261-001-0171-z.
18. Singla M, Kemp JD, Goldberg ME, et al. Almost One-Third of Large Sessile Serrated Polyps Are Missed on CT Colonography. Turk J Gastroenterol. 2021 Oct;32(10):837-842. doi: 10.5152/tjg.2021.20372.
19. Lee SZ, Schubert JP, Prowse SJB, Bryant RV. Are we underutilising computer tomography colonography in Australia? Intern Med J. 2022 May;52(5):864-867. doi: 10.1111/imj.15778.
20. Kim DH, Matkowskyj KA, Pickhardt PJ. Serrated polyps are detected at CT colonography: clinical observations over the past decade and results from CTC-based screening of average risk adults. Abdom Radiol (NY). 2016 Aug;41(8):1445-1447. doi: 10.1007/s00261-016-0828-2.
21. IJspeert JEG, Tutein Nolthenius CJ, Kuipers EJ, et al. CT-Colonography vs. Colonoscopy for Detection of High-Risk Sessile Serrated Polyps. Am J Gastroenterol. 2016 Apr;111(4):516-522. doi: 10.1038/ajg.2016.58.
22. Deiss-Yehiely N, Graffy PM, Weigman B, et al. Detection of High-Risk Sessile Serrated Lesions: Multitarget Stool DNA Versus CT Colonography. AJR Am J Roentgenol. 2022 Apr;218(4):670-676. doi: 10.2214/AJR.21.26719.
23. WHO Classification of Tumours Editorial Board. Digestive System Tumours: WHO Classification of Tumours, 5th Edition, Volume 1. World Health Organization; 2019.
24. RStudio. RStudio: Integrated Development Environment for R [Internet]. 2024 [cited 2024 Oct 3]. Available from: https://www.rstudio.com/
25. Hyun E, Helewa RM, Singh H, et al. Serrated polyps and polyposis of the colon: a brief review for surgeon endoscopists. Can J Surg. 2021;64(6):E561-E566. doi: 10.1503/cjs.018820.
26. Goldstein NS. Clinical significance of (sessile) serrated adenomas: Another piece of the puzzle. Am J Clin Pathol. 2005 Mar;123(3):329-330. doi: 10.1309/8H7M-UH9E-T9U2-1R2E.
27. Jass JR. Serrated route to colorectal cancer: back street or super highway? J Pathol. 2001 Mar;193(3):283-285. doi: 10.1002/1096-9896(200103)193:3<283::AID-PATH799>3.0.CO;2-9.
28. Lazarus R, Junttila OE, Karttunen TJ, Mäkinen MJ. The risk of metachronous neoplasia in patients with serrated adenoma. Am J Clin Pathol. 2005 Mar;123(3):349-359. doi: 10.1309/VBAG-V3BR-96N2-EQTR.
29. Kim DH. CT Colonography Is the Perfect Colorectal Screening Test That Unfortunately Few People Use Yet. Korean J Radiol. 2023 Feb;24(2):79-82. doi: 10.3348/kjr.2022.0969.
30. Ricci Z, Kobi M, Yee J. CT Colonography for Colorectal Cancer Screening. Journal of Radiology Nursing. 2020 Sep;39(3):185-193. doi: 10.1016/j.jradnu.2020.04.005.
31. Halligan S, Dadswell E, Wooldrage K, et al. Computed tomographic colonography compared with colonoscopy or barium enema for diagnosis of colorectal cancer in older symptomatic patients: two multicentre randomised trials with economic evaluation (the SIGGAR trials). Health Technol Assess. 2015 July;19(54):1-134. doi: 10.3310/hta19540.
32. Atkin W, Dadswell E, Wooldrage K, et al. Computed tomographic colonography versus colonoscopy for investigation of patients with symptoms suggestive of colorectal cancer (SIGGAR): a multicentre randomised trial. Lancet. 2013 Apr;381(9873):1194-1202. doi: 10.1016/S0140-6736(12)62186-2.
33. Garg R, Burke CA, Aggarwal M, et al. Sessile serrated polyp detection rates after fecal immunochemical test or multitarget stool DNA test: Systematic review and meta-analysis. Endosc Int Open. 2024 Apr;12(4):E474-E487. doi: 10.1055/a-2256-3411.
34. Park SK, Kim HS, Yang HJ, et al. Coexistent adenoma and serrated polyps on index

colonoscopy and the risk of metachronous advanced colorectal neoplasia. Endosc Int Open. 2019 Dec;7(12):E1748-E1754.

35. Kim DH, Matkowskyj KA, Lubner MG, et al. Serrated Polyps at CT Colonography: Prevalence and Characteristics of the Serrated Polyp Spectrum. Radiology. 2016 Aug;280(2):455-463. doi: 10.1148/radiol.2016151608.
36. Kim DH, Hinshaw JL, Lubner MG, et al. Contrast coating for the surface of flat polyps at CT colonography: a marker for detection. Eur Radiol. 2014 Apr;24(4):940-946. doi: 10.1007/s00330-014-3095-z.
37. Kim DH, Lubner MG, Cahoon AR, et al. Flat Serrated Polyps at CT Colonography: Relevance, Appearance, and Optimizing Interpretation. Radiographics. 2018;38(1):60-74. doi: 10.1148/rg.2018170110.
38. Sugai T, Uesugi N, Osakabe M, et al. Characterization of sessile serrated adenomas with dysplasia including intramucosal adenocarcinoma and colorectal carcinoma with a microsatellite instability phenotype. Hum Pathol. 2024 Mar;145:9-15. doi: 10.1016/j.humpath.2023.12.007.