

Redesigning the diagnostic screening process for colorectal cancer

August 30 2024, by Alistair Jones



Credit: Anna Tarazevich from Pexels

During recent decades, the incidence of colorectal cancer (CRC) has been rising globally and its prevalence in Singapore is no exception.

Research from the National Institutes of Health has shown that among Southeast Asian countries, Singapore has the highest age-standardized incidence rates, more than twice that of the next country.

If detected early, [colorectal cancer](#) is treatable. Diagnostic screening is commonly a two-stage process, beginning with a simple fecal immunochemical test (FIT) before moving on to a colonoscopy if the FIT detects elevated traces of non-visible blood in a stool sample.

"Unfortunately, the uptake rate for the FIT is low, and there are a significant number of individuals who, after receiving positive FIT results, do not follow up with doctors for a colonoscopy to confirm whether they have cancer," says Yini Gao, an Assistant Professor of Operations Management at Singapore Management University (SMU).

"This seemingly irrational behavior motivated us to study the reasons behind it and explore ways to redesign the [screening process](#) to encourage more people to adhere and achieve early detection," adds Professor Gao, whose research partner is Daniel Zheng, an Associate Professor of Operations Management at SMU.

The primary data source for the study was a nationwide survey conducted in Singapore with 3920 respondents.

"The survey asked questions about their awareness and attitudes toward CRC and screening programs, their willingness to participate in these programs, and the reasons behind any barriers to participation," Professor Gao says.

Altering beliefs

The key issue in the study is the sensitivity of the FIT when measuring hemoglobin concentration. If the cut-off value is set too low, this creates

higher sensitivity and hence more positive readings, but many of these may be false positives.

"While we aim to encourage all individuals to adhere to the screening guidelines and follow up with a colonoscopy after receiving a positive FIT result, we need to be mindful of the risks and drawbacks and we do not want the people that are actually healthy to go through colonoscopy," Professor Gao says.

"Colonoscopy is a scarce health care resource. In Singapore, the median waiting time for a colonoscopy in public hospitals was 38 days in 2021, indicating potential resource constraints. Improving cancer detection while considering these limited resources is essential."

The study was able to model cut-off selection in a medical test while accounting for patient behavior. Of the participants in the survey, more than 28% did not follow up for further diagnosis, via a colonoscopy, after a positive FIT result.

"When an individual receives a FIT result, they interpret their actual risk of having cancer, which we call the individual's belief," Professor Gao says.

"Different cut-off values lead to different probabilities of false positives and false negatives, directly affecting an individual's beliefs about their risk of having cancer. When making adherence decisions, individuals choose the option that provides the highest utility, calculated based on these beliefs. Thus, cut-off values influence adherence decisions by altering beliefs.

"[Our] model explicitly specifies individual utility, which depends not only on the actual risk of having cancer but also on their subjective beliefs and the perceived benefits and drawbacks of undergoing a

colonoscopy. This approach captures all the behavioral factors identified in our survey," Professor Gao says.

Among surveyed participants' concerns about undergoing a colonoscopy were embarrassment, lack of support, distrust in doctors and FIT results, and feeling too old to undergo cancer treatment.

A higher cut-off

The researchers believe the present FIT cut-off in Singapore is too low.

"The current qualitative FIT cut-off of 20 $\mu\text{g/g}$ used in Singapore is considered too low because it leads to excessive [false positives](#) and poor adherence compared to the optimal cut-off we found, which is 39 $\mu\text{g/g}$," Professor Gao says.

"Although this cut-off is higher than current practices and results in fewer FIT positive outcomes for cancer and polyps cases, the increased follow-up/adherence rates ultimately lead to the detection of more cancer and polyps cases, which is the most desired outcome."

It seems counterintuitive that a higher, less sensitive cut-off could detect more cancers, an improvement the researchers estimate at 20.83%.

"Although sensitivity decreases, the false positive rate also decreases substantially," Professor Gao says.

"This leads to individuals being more likely to follow up after receiving a positive outcome. High sensitivity generates more FIT positives, but if fewer people follow up with a colonoscopy to confirm their cancer status, the actual number of detected cases may be lower.

"Therefore, raising the cut-off to a certain extent can balance adherence

and cancer detection, resulting in a higher overall detection rate. Moreover, with fewer cases being recommended for colonoscopy, the waiting time can be substantially reduced, leading to more timely detection of early-stage cancers. This, in turn, can improve adherence to the recommendations. "

The research model was able to analyze the potential of using different cut-off levels for different groups.

"Age and gender turned out to be the two most critical features, while ethnicity was not," Professor Gao says.

Personalized risk

"We also explored the possibility of using multiple cut-offs to provide more stratified risk alerts to the public. In one extreme, we considered directly reporting the biomarker concentration values to individuals instead of risk levels," Professor Gao says.

"Interestingly, we find that it might be advantageous to provide the exact [fecal-hemoglobin] concentration reading to individuals rather than concealing it behind binary signals. This approach could be optimal for maximizing detection by allowing individuals to interpret their personalized risk more precisely.

"This is particularly true when individuals are more sensitive to the worst test outcomes. By giving individuals access to the precise risk of having CRC/polyps, those with higher risk (with higher biomarker concentrations) are more likely to follow up than if they received a less stratified risk alert, such as just a positive outcome."

Policy impact

The study has been well received by the Ministry of Health, the Health Promotion Board and doctors in Singapore.

"Other countries and regions have implemented or are discussing similar changes," Professor Gao says. "For instance, the Netherlands raised their FIT cut-off from 15 $\mu\text{g/g}$ to 47 $\mu\text{g/g}$ due to insufficient colonoscopy capacity. Spain uses a cut-off of 20 $\mu\text{g/g}$ and faces strained [colonoscopy](#) resources as screening extends to the entire country."

The research has further to run.

"We are currently pursuing a follow-up project in collaboration with the Ministry of Health that involves Singapore's Healthier SG initiative, and we hope the results of our study can have a real impact on Singapore's health care system," Professor Gao says.

More information: Gao, Y. Optimizing Initial Screen for Colorectal Cancer Detection with Adherence Behavior. Accepted in *Management Science*.

Provided by Singapore Management University

Citation: Redesigning the diagnostic screening process for colorectal cancer (2024, August 30) retrieved 31 August 2024 from <https://medicalxpress.com/news/2024-08-redesigning-diagnostic-screening-colorectal-cancer.html>

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